Challenger Conference 2022 “Challenger 150”

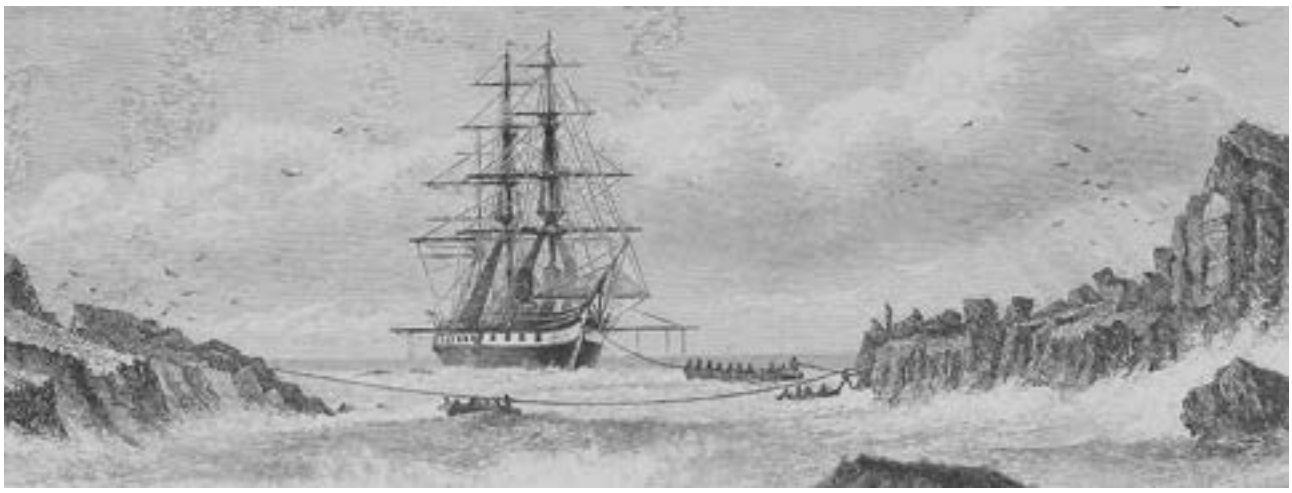
Conference Programme

The Challenger Society Conference 2022 occurs on the 150th year anniversary of the voyage of HMS Challenger

We are grateful for the support of our sponsors

Headline sponsor: The International Seabed Authority, Jamaica

The International Seabed Authority (ISA) is an autonomous international organization established under the 1982 United Nations Convention on the Law of the Sea (UNCLOS) and the 1994 Agreement, which was adopted to bring the regime of the deep seabed closer in line with political and economic realities. ISA is the organization through which States Parties to UNCLOS organize and control all activities related to mineral resources in the international seabed area (the Area). The Area effectively covers more than 50 per cent of the world’s oceans’ seabed. The Area and its resources are the common heritage of humankind, on behalf of which ISA acts. At the core of ISA’s mandate is the need to ensure the effective protection of the marine environment from harmful effects that may arise from deep-seabed related activities in the Area.



On 7th December 1872, the HMS Challenger departed Sheerness, the location of the Royal Navy Dockyard in Kent, England on a four-year global scientific expedition across the world's oceans. It was the first truly interdisciplinary grand scientific project, international in scope and involving the study of the physics, chemistry, biology and geology of the global ocean. The UK Challenger Society and the Challenger Conferences are named after this pioneering expedition and exist to bring together UK marine scientists and international colleagues to discuss the latest science and inspire new generations of ocean researchers.

The Challenger Society Conference 2022 marks the 150th anniversary of the Challenger Expedition and celebrates the birth of international, interdisciplinary oceanography. Challenger 150 will be the opportunity to take stock of where we have come in our science, in the way we do science, and will also be the opportunity to discuss, imagine and design the future of open, international, collaborative, inclusive and diverse marine science.

Local Organising Committee

Co-Chairs: Prof Richard Herrington & Dr Adrian Glover Natural History Museum, UK.
Committee: Dr Adrian Glover (NHM), Prof Jenny Collier, Dr Yves Plancherel (Imperial College), Prof Ros Rickaby (Challenger Society and University of Oxford), Katy Payne (NHM).

Science Advisory Committee

Co-Chairs: Dr Adrian Glover & Prof Richard Herrington, Natural History Museum, UK.
Committee: Prof Richard Herrington, Dr Adrian Glover, Dr Steve Stukins (NHM), Dr Yves Plancherel (Imperial College), Prof Jenny Collier (Imperial College), Prof Alessandro Tagliabue (University of Liverpool), Dr Helen Czerski (UCL), Dr Judith Wolf (NOC) Dr Heather Koldewey (ZSL), Prof Rachael James (University Southampton)

Supporting Conference Partners

We are grateful to our supporting conference partners Nortek, Admiralty Maritime Data Solutions and the Royal Society. We are also grateful to Sky News for their support to the conference.

Nortek designs, develops and produces scientific instruments that apply the Doppler principle to underwater acoustics in order to measure water in motion, such as currents and waves. These instruments are used by scientists, researchers and engineers at renowned institutions and government agencies worldwide. They are employed in demanding environments that require state-of-the-art instrumentation that is reliable and easy to use. These exploratory devices help cast light on the workings of the world's oceans, which occupy vast swathes of the planet, but are still little understood.

Admiralty Maritime Data Solutions. Supporting safe, secure and thriving oceans. In an ever-changing world, our oceans are under increasing pressure with advances in technology, busier seas and pressing environmental challenges. Our experts support safe navigation across the globe by providing hydrographic understanding to inform maritime decisions from ship to shore.

The Royal Society. The Society's fundamental purpose, reflected in its founding Charters of the 1660s, is to recognise, promote, and support excellence in science and to encourage the development and use of science for the benefit of humanity. The Society has played a part in some of the most fundamental, significant, and life-changing discoveries in scientific history and Royal Society scientists continue to make outstanding contributions to science in many research areas.

Conference Hosts

The Natural History Museum, London

The Natural History Museum is a world-class visitor attraction and leading science research centre. It uses its unique collections and unrivalled expertise to tackle the biggest challenges facing the world today. Our vision is of a future where both people and planet thrive, and to create advocates for the planet.

Imperial College, London

The vision of Imperial College is to advance world leading sustainability research and education, and to apply what Imperial excels at to the new challenges facing the world.

Conference Venue: The Royal Geographical Society

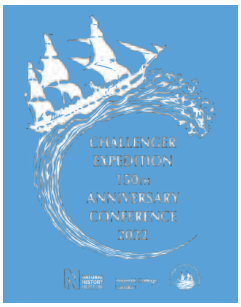
The main venue for the conference and plenary sessions is the Royal Geographical Society, which is the UK's learned society and professional body for geography, supporting geography and geographers across the world.

Additional venues used are at the Natural History Museum and Imperial College.

Conference Overview

Note that on Monday 5th September, there will be Side Events (listed in the detailed programme) and an Icebreaker for all delegates from 1830-2030 at Tamesis Dock, Albert Embankment.

MONDAY 5TH: Side Events, see schedule
Conference Icebreaker, 18:30 - 20:30 Tamesis Dock, Albert Embankment, SE1 7TY



TUESDAY 6TH

08:00

Registration, Tea & Coffee
RGS 08:00 - 09:00

09:00

Plenary 09:15 - 12:00
The Future of Global Ocean Science
RGS Ondaatje

Speakers:
H.E Michael Lodge
Prof. Angela Hatton
Prof. John Pinnegar
Prof. Nick Owens

12:00

Lunch & Poster Session
RGS 12:00 - 13:00

13:00

RGS Ondaatje	RGS Lowther	RGS Drayson	Imperial RSM G.41	Imperial RSM G.38	NHM Flett Theatre
T1: Deep-sea Mining 1	T12: Ocean Plastics	T4: Sedimentary Carbon T22: EDIA	T7: Autonomous Technology	T27: PO - Productivity	T10: Polar Ecosystems

15:15

EDIA Roundtable Discussion - RGS Ondaatje

16:00

Poster Session & Refreshments
RGS 16:00 - 18:30

18:30

ECR Mixer 1900-2030 Imperial RSM G.41

Environment, Conservation & Governance | Ocean Biogeochemistry | Physical Oceanography | Ocean Technology | Polar Oceans

WEDNESDAY 7TH

08:00 Registration

08:30

Plenary 08:30 - 10:30

Ocean Challenges, Ocean Solutions

RGS Ondaatje

Speakers: Prof. Carol Robinson
Prof. Alberto Naveira Garabato
Prof. Gary Carvalho
Dr Katherine Duncan

10:30 Tea & Coffee, Posters

11:00

RGS Ondaatje	RGS Lowther	RGS Drayson	Imperial RSM G.41	Imperial RSM G.38	NHM Flett Theatre
T2: Deep-sea Mining 2	T25: PO: Energetics	T28: PO: Coasts & Shelf	T7: Autonomous Technology	T21: Trait-Based Approaches	T10: Polar Ecosystems

13:00 Lunch RGS 13:00 - 14:00 | Lunch NHM Flett

14:00

RGS Ondaatje	RGS Lowther	Imperial RSM G.41	Imperial RSM G.38	NHM Flett Theatre
T2: Deep-sea Mining 2	T19: Satellite Oceanography	T15: Carbon Cycling	T6: Net Zero Oceanography	T13: Where Ice Meets Ocean

15:30 Tea & Coffee | Tea & Coffee

16:00

T3: Ocean Chemistry	T15: Carbon Cycling	T14: Deep Ocean Science for Sustainable Development	T24: AMOC	T13: Where Ice Meets Ocean

18:00

Conference Banquet @ NHM

19:00 - 22:30

Entrance via Darwin Centre on Queen's Gate

Environment, Conservation & Governance | Ocean Biogeochemistry | Physical Oceanography | Ocean Technology | Polar Oceans

THURSDAY 8TH

08:00 Registration

08:30 **Plenary 08:30 - 10:30**
Oceans and Climate
RGS Ondaatje

Speakers: Prof. Karen Heywood
Prof. Michael Meredith
Prof. Aradhna Tripati
Prof. Paul Wilson

10:30 Tea & Coffee, Posters

11:00

RGS Ondaatje	RGS Lowther	RGS Drayson	Imperial RSM G.41	Imperial RSM G.38	NHM Flett Theatre
T24: AMOC	T14: Deep Ocean Science for Sustainable Development	T16: Art-Science T18: Challenger Collections	T3: Ocean Chemistry	T5: Mixotrophy	T20: Ocean Policy

13:00 **Lunch**
RGS 13:00 - 14:00

14:00

RGS Ondaatje	RGS Lowther	RGS Drayson	Imperial RSM G.41
T17: Air-Sea Exchange	T3: Ocean Chemistry	T20: Ocean Policy T23: Palaeoclimates	T26: PO - Large Scale

15:30 Tea & Coffee, Posters

16:00 **Plenary 16:00 - 17:00**
Oceans Challenges, Past and Present

Speakers: Dr Erika Jones
Dr Autun Purser

Closing Ceremony and Prize Giving
17:00 - 17:45

17:45

Environment, Conservation & Governance | Ocean Biogeochemistry | Physical Oceanography | Ocean Technology | Polar Oceans

Challenger 150 Plenary Speakers

Plenary 1: The Future of Global Ocean Science

Tuesday 6th September 0915-1200; RGS Ondaatje Theatre

H.E. Mr Michael Lodge, Secretary-General, International Seabed Authority. Michael W. Lodge is a British national. He received his LLB from the University of East Anglia, and has an MSc in marine policy from the London School of Economics and Political Science. He is a barrister of Gray's Inn, London. Prior to his election as Secretary-General of the International Seabed Authority in July 2016, he had served as Deputy to the Secretary-General and Legal Counsel. Other professional experiences include serving as Legal Counsel to the ISA (1996-2003); Counsellor to the Round Table on Sustainable Development, OECD (2004-2007); Legal Counsel to the South Pacific Forum Fisheries Agency (1991-1995). He has also held appointments as a Visiting Fellow of Somerville College, Oxford (2012-2013), an Associate Fellow of Chatham House, London (2007) and a member of the World Economic Forum's Global Agenda Council on Oceans (2011-2016).

Prof Angela Hatton, Chief Scientist, National Oceanography Centre, UK. Angela joined the NOC in December 2016. Angela is a microbial biogeochemist with a specific interest in the role microorganisms play in the production and removal of environmentally significant trace gases. Angela has participated in numerous seagoing research expeditions as part of international scientific programmes including OMEX, LOIS, ESCAPE and DISCO as well as field based studies in both the Arctic and Antarctic.

Dr John Pinnegar, Principal Scientist and Lead Advisor on climate change at CEFAS, Director of the Collaborative Centre for Sustainable Use of the Seas (CCSUS), Director of the International Marine Climate Change Centre. John was a lead author of the UN Intergovernmental panel on Climate Change 6th Assessment report published in February 2022. John's role includes managing a 'Memorandum of Understanding' with the UK Department for Environment, Food & Rural Affairs to provide ad-hoc advice on marine climate change impacts, adaptation and mitigation. John's research interests include the impacts of climate change on fish and fisheries, climate change risk assessment techniques, long-term changes in marine ecosystems as well as marine food-webs. John is currently the UK representative on the ICES (International Council for the Exploration of the Sea) Science Committee, and previously co-chair of the Strategic Initiative on Climate Change in Marine Ecosystems. He was awarded the Fisheries Society of the British Isles 'FSBI Medal' in July 2009, in recognition of younger scientists who are deemed to have made exceptional advances in the study of fish biology and/or fisheries.

Prof Nicholas Owens, Director of the Scottish Association of Marine Science, UK. Dr Owens is a marine scientist with considerable experience of leadership of complex organisations engaged in research, commercial income generation and education in environmental science. He has led transformational change programmes in the public sector, including the introduction of new funding models, staff restructuring and cultural change. He is inspired by the wonders of the natural world.

Plenary 2: Ocean Challenges, Ocean Solutions

Wednesday 7th September 0830-1030; RGS Ondaatje Theatre

Professor Carol Robinson, Professor of Marine Sciences, University of East Anglia, UK. Professor Robinson leads a team which studies the role of marine bacteria, phytoplankton and zooplankton in the global cycling of carbon and oxygen, and how this varies in space and time and with changing environmental conditions such as increasing nutrient supply, temperature and carbon dioxide and decreasing dissolved oxygen. This involves laboratory and field observations, remote sensing, numerical models and the use of water mass tracers (sulphur hexafluoride), gliders and time series datasets. @carolrobinson8

Professor Alberto Naveira Garabato, Professor of Physical Oceanography, University of Southampton, UK. Professor Naveira Garabato is an oceanographer interested in the processes governing ocean circulation and its role in climate. His research focuses on unravelling the dynamics connecting all scales of oceanic flow— from small-scale turbulence to the basin-scale circulation—through the development and application of new approaches to measure the ocean. Alberto completed a PhD at the University of Liverpool, and was a postdoctoral researcher at the University of East Anglia. After being awarded two NERC Research Fellowships, he moved to the University of Southampton, where he is now a Professor of Physical Oceanography. Alberto is the founding director of the NEXUSS NERC / EPSRC Centre of Doctoral Training in the Smart and Autonomous Observation of the Environment, and is an Honorary Fellow of the British Antarctic Survey.

Professor Gary Carvalho, Emeritus Professor of Molecular Ecology, Bangor University, UK. Professor Carvalho's research has focused on employing genetic markers to address questions in ecology and evolution. Effort is placed on demonstrating the value of molecular tools and genetic diversity as core components of environmental management and conservation of biodiversity, especially among commercially exploited species in marine and freshwaters. Throughout his career, he has engaged with governance and policy making to foster awareness and inclusion of genetics in environmental science. The underpinning strategy has been to elucidate drivers of genetic change, especially at the population level, and then to apply such understanding in the conservation of genetic resources.

Dr Katherine Duncan, Senior Lecturer, University of Strathclyde Glasgow, UK. Dr Duncan's research focusses on marine natural products discovery. Her group investigates the chemical 'language' of marine microorganisms. In particular, the influence of abiotic and biotic factors on this metabolite exchange, with the goal of discovering new antibiotics to combat antimicrobial resistance. You can find out more about her research and team here: www.medicinesfromthesea.com. Prior to starting her group as a Chancellor's Fellow (2016-2020), she has completed two Postdoctoral Fellowships at Scripps Institution of Oceanography (California) in Marine Biomedicine and at The Scottish Marine Institute in Marine Biotechnology, a PhD in Biomedical Science (Canada) and a MChem (Aberdeen, Scotland) with International Placement (Florida).

Plenary 3: Oceans and Climate

Thursday 8th September 0830-1030; RGS Ondaatje Theatre

Professor Mike Meredith, Science Leader, British Antarctic Survey, UK. Professor Meredith is an oceanographer and Science Leader at the British Antarctic Survey (BAS) in Cambridge, UK. His research focusses on ocean circulation and physical processes, and their influences on climate and the Earth System. He has strong interests in the translation of science to policy, including serving as a Coordinating Leader Author with the UN's Intergovernmental Panel on Climate Change.

Professor Karen Heywood FRS, University of East Anglia, UK. Prof Heywood's research investigates physical processes in our oceans that underpin climate, such as ocean currents, eddies and turbulent mixing and she has revealed new insights into the interactions between the ocean, atmosphere and cryosphere (floating ice shelves and sea ice). She is an enthusiast for new ocean-observing technologies, especially in challenging environments.

Professor Paul Wilson, University of Southampton, UK. Prof. Paul Wilson leads the University of Southampton's Palaeoceanography and Palaeoclimate research group. He studies shifts in Earth's past climate using cores taken from deep sea sediments. In pursuit of this goal, he has spent nearly 2% of his life aboard the International Ocean Discovery Program's (IODP) drill ship, the *JOIDES Resolution*. Paul is not quite old enough to have sailed on its predecessor, *Glomar Challenger*. However, in this anniversary year, it has not escaped his attention that she was named in tribute to the heroic earlier accomplishments of *HMS Challenger*.

Professor Aradhna Tripati, University of California Los Angeles, USA. Professor Aradhna Tripati is a geoscientist at UCLA who is a Fellow of the American Geophysical Union, European Association of Geochemistry, Geochemical Society, and California Academy of Sciences, and a Royal Society Wolfson Visiting Fellow at the University of Bristol. She has worked in paleoceanography for 25 years, where her contributions include developing carbonate clumped isotope geochemistry as a temperature proxy. She founded the Center for Diverse Leadership in Science, with projects that include working with Indigenous communities on ocean and land stewardship.

Plenary 4: Ocean Challenges Past and Present

Thursday 8th September 1600-1830; RGS Ondaatje Theatre

Dr Erika Jones, Curator of Navigation and Oceanography, National Maritime Museum, UK. Dr Erika Jones is Curator of Navigation and Oceanography at the National Maritime Museum, Royal Museums Greenwich and Honorary Research Fellow at the Department of Science and Technology Studies, University College London. She is a historian of the *Challenger* Expedition (1872-1876), 19th-century science and oceanography.

Dr Autun Purser, Alfred Wegener Institute, Germany. Dr Purser is a Senior Researcher at the Alfred Wegener Helmnolz Institute for Polar and Marine Science, Germany. Dr Purser is a deep-sea ecologist and illustrator specialising in the visual documentation of new and remarkable deep-sea and polar animals.

Conference Banquet Keynote Speakers

Wednesday 7th September 1900-2230; Natural History Museum Hintze Hall

The 150th Anniversary Challenger Conference Banquet will be held in Hintze Hall, Natural History Museum.

Speakers & Panel Discussion

Dr Doug Gurr is the Director of the Natural History Museum, a world-leading scientific research centre and the UK's most-visited Museum. He was previously Country Manager of Amazon UK and was President of Amazon China. He was appointed as Chair of the Board of Trustees at The Alan Turing Institute in 2022. His previous roles include teaching mathematics and computing at the University of Aarhus in Denmark. He has also held senior roles in Government, worked as a partner at consultancy firm McKinsey, Board Director at Asda-Walmart and was founder and CEO of internet start-up Blueheath. He has two degrees in Mathematics from the University of Cambridge and a PhD in Theoretical Computer Science from the University of Edinburgh

Dr Helen Czerski is a physicist and oceanographer with a passion for science, sport, books, creativity, hot chocolate and investigating the interesting things in life. She is an Associate Professor in the Department of Mechanical Engineering at University College London, and her research focus is the physics of breaking waves and bubbles at the ocean surface. She is also a writer and broadcaster, and was awarded the Institute of Physics Gold Medal in 2018 for her work on physics communication. Her 2020 Royal Institution Christmas Lecture was on the topic of the ocean.

Prof. Alan Jamieson is Professor at the University of Western Australia and Director of the Minderoo-UWA Deep Sea Research Centre. With over 20 years of experience in deep-sea science, technology and exploration he is an authority on hadal science and has published over 110 scientific publications and the book *The Hadal Zone*. He has participated in nearly 70 deep-sea expeditions spanning every ocean. Since 2018 he has been the Chief Scientist of the DSSV *Pressure Drop*, He has completed 12 submersible dives in the DSV *Limiting Factor* including 7 to hadal depths and 2 greater than 10,000 m deep.

Panel Chair: **Dr Adrian Glover** is a Merit Researcher and Principal Investigator of the Deep-Sea Systematics and Ecology Research Group at the Natural History Museum, and Co-Chair of the Local Organising Committee of the Challenger 150 Conference. He has over 20 years experience leading deep-sea biology projects across the world with a speciality in the abyssal Pacific and Antarctic. He was the President of the Deep-Sea Biology Society from 2016-2021.

Conference Banquet: The London Sea Shanty Collective

The London Sea Shanty Collective is a community choir who sing sea shanties and songs of the sea with one eye to the tradition and the other to the future.

This will be their third *Challenger*-related event this year. On June 8th they supported the National Maritime Museum's *World Ocean Day* celebration, while in December 2021 the choir sang at the launch of choir member Philip Pearson's *A Challenger's Song*, a narrative of the voyage by his ancestor, leading stoker Charlie Collins, who sailed with the great expedition.

Music and song accompanied work and leisure aboard many a sailing ship, and the *Challenger* was no exception. The *Challenger* crew soon formed their own 12-piece band:

Sailors aboard the tall ships traditionally sang as they worked together to haul on an anchor or hoist a sail. Many shanties have origins that can be traced to the rhythmic work songs of enslaved Africans working on plantations in the Caribbean or the southern United States. When the sailors' working day was done, they would head below deck to their quarters in the forecastle for a meal, a smoke and a leisurely round of 'forebitter' songs. Their name derives from the bit of the ship where the off-duty singing usually took place: the forecastle, or 'forebit.'

They will share with us a goodly sample of work shanties and songs of longing for home, or the hardships of life on board!

'A Challenger's Song'

The book tells afresh the extraordinary story of the Challenger expedition, through the eyes of the crew and scientists, drawing on their letters and accounts. As they dredged and surveyed 'the great ocean basins,' they opened a book that was, so far, closed to mankind, reflected in a song we will perform, *The Ocean*. It includes a narrative of the life and times of one of the crew, leading stoker Charlie Collins, drawing on family history, Navy, census, other archives; for this sailor's story, like doubtless many others, has long endured in the memories of his descendants.

Side Events

Monday 5th September

NHM Flett Theatre

1000-1750 **Advances in Marine Biogeochemistry (AMBIO) Special Interest Group (SIG)** contact: A.L.Annett@soton.ac.uk

NHM Neil Chalmers Room

1300-1750 **Deep-Sea Ecosystems Special Interest Group (SIG)** contact: michelle.taylor@essex.ac.uk | kerry.howell@plymouth.ac.uk

NHM Humphrey Greenwood Room

0930-1750 **Scientific Committee for Oceanographic Research (SCOR) UK Meeting** contact: atagliab@liverpool.ac.uk

Imperial RSM G.41

1000-1700 **Wind and Waves Special Interest Group (SIG)** contact luic@noc.ac.uk

Friday 9th September

NHM Flett Theatre

1000-1750 **Ocean Modelling Special Interest Group (SIG)** contact: danday@bas.ac.uk

Imperial RSM G.41

0900-1030 ; 1600-1730 **Deep-Sea Biology Society AGM c**ontact: michelle.taylor@essex.ac.uk

At-a-Glance: All Science Sessions (excl. Plenary), Chairs, Time and Place

Theme	Session	Day/Time	Chairs	Location
Environment, Conservation & Governance	T1 - Deep Sea Mining 1 - geology, resource, legal, technical and societal aspects	Tue 1315-1530	Teagle D; Herrington R; Mills R	RGS Ondaatje
Environment, Conservation & Governance	T2 - Deep Sea Mining 2 - environmental aspects: baselines, impacts, monitoring	Wed 1100-1300; 1345-1530	Glover AG; Woulds C	RGS Ondaatje
Environment, Conservation & Governance	T12 - Interactions between plastics and marine ecosystem	Tue 1315-1545	Manno C; Cole M; Rowlands E	RGS Lowther
Environment, Conservation & Governance	T14 - A decade of deep ocean science for sustainable development	Wed 1600-1800 (Imperial G.41); Thur 1100-1300 (RGS Lowther)	Howell K; Vieira R	Imperial RSM G.41; RGS Lowther
Environment, Conservation & Governance	T16 - How Art-Science Collaborations can Inspire Societal Change	Thur 1100-1200	Mills E; Ladd-Jones H	RGS Drayson
Environment, Conservation & Governance	T18 - HMS Challenger collections as a benchmark for oceanographic studies	Thur 1200-1315	Miller G; Stukins S	RGS Drayson
Environment, Conservation & Governance	T20 - Evidence to support international oceans policy	Thur 1100-1300 (NHM Flett); Thur 1345-1500 RGS Drayson)	Whomersley P	NHM Flett; RGS Drayson
Environment, Conservation & Governance	T21 - Trait-based approaches to improve conservation, management, and restoration of our oceans	Wed 1100-1245	Campanyà-Llovet N	Imperial RSM G.38
Environment, Conservation & Governance	T22 - Strengthening Equality, Diversity, Inclusivity and Accessibility in Marine Science	Tue 1415-1500 (talks, RGS Drayson); Tue 1530-1600 (Panel Discussion RGS Ondaatje)	McGregor A; Damerell G; Woolf D; Rabe B	RGS Drayson; RGS Ondaatje
Environment, Conservation & Governance	T23 - Unlocking Climate Histories from Marine Sediments	Thur 1430-1530	Crocker A	RGS Drayson
Ocean Biogeochemistry	T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans	Wed 1600-1800 (RGS Ondaatje); Thur 1100-1300 (Imperial RSM G.41; Thur 1345-1500 RGS Lowther)	Jones R; Olivelli A; Robinson S; Annett A; Branson O et al	RGS Ondaatje; Imperial RSM G.41; RGS Lowther
Ocean Biogeochemistry	T4 - Shackleton Session: Marine Sedimentary Carbon	Tue 1315-1415	Woulds C	RGS Drayson
Ocean Biogeochemistry	T5 - The role of mixoplankton and mixotrophy in the global carbon cycle	Thur 1100-1230	Cormier M-A; Rickaby R; Whichello G	Imperial RSM G.38
Ocean Biogeochemistry	T15 - Carbon cycling in the global ocean and the role of blue carbon in climate mitigation	Wed 1400-1545 (Imperial RSM G.41); Wed 1600-1700 (RGS Lowther)	Belcher A; Cavan E; Barnes D; Rogers A	Imperial RSM G.41; RGS Lowther
Ocean Technology	T6 - Towards a Net Zero Oceanographic Capability	Wed 1400-1530	Darlington E; Hendry K; Fletcher S; Lorenzo A	Imperial RSM G.38
Ocean Technology	T7 - Pushing the limits in autonomous oceanography in a net zero carbon world	Tue 1315-1515; Wed 1100-1230	Carvalho F; Porter M; Brearley JA; Dall'Olmo G	Imperial RSM G.41
Physical Oceanography	T17 - Physical and chemical drivers of air-sea exchange processes: waves, bubbles, aerosols and surface chemistry	Thur 1345-1600	Callaghan A; Czerski H	RGS Ondaatje
Physical Oceanography	T19 - Mathematics of Satellite Oceanography	Wed 1345-1445	Holm D; Crisan D; Chapron B; Memin E	RGS Lowther
Physical Oceanography	T24 - The Atlantic Meridional Overturning Circulation: Observations, Simulations and Equations	Wedn 1600-1800 (Imperial G.38; Thur 1100-1300 (RGS Ondaatje)	Fraser N; Jones S; Sanchez-Franks A	RGS Lowther; RGS Ondaatje
Physical Oceanography	T25 - Physical Oceanography Open Session – Energetics and Mixing	Wed 1100-1300	Tedesco P; Baker LE	RGS Lowther
Physical Oceanography	T26 - Physical Oceanography Open Session – Large Scale Physical Oceanography	Thur 1345-1545	Brearley A	Imperial RSM G.41
Physical Oceanography	T27 - Physical Oceanography Open Session – Physical Drivers of Ocean Productivity	Tue 1315-1500	Fernández-Castro B	Imperial RSM G.38
Physical Oceanography	T28 - Physical Oceanography Open Session – Tides, Coasts and Shelf	Wed 1100-1300	Czerski H	RGS Drayson
Polar Oceans	T10 - Micro to macro: linking bottom-up and top-down approaches that investigate the function, resilience and conservation of polar ecosystems	Tue 1315-1515; Wed 1100-1245	Freer J; Dornan T; Liszka C; Belcher A; et al.	NHM Flett
Polar Oceans	T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers	Wed 1345-1545; Wed 1600-1815	Scott W; Davis P; White E; Maxwell J	NHM Flett

Conference Venue Overview Map

The majority of Challenger 150 events are at the Royal Geographical Society (RGS) (1 Kensington Gore). This is the location of all the Plenaries, Posters, and the majority of catering. Additional venues are at Imperial College Royal School of Mines (RSM) and the Natural History Museum Flett Theatre (NHM Flett). All these venues are easily accessible along Exhibition Road.

Conference Venue Locations & Accessibility Information

Please note that a free cloakroom is available at the RGS only. The NHM has a public cloakroom, this is available but is paid-for only. There is no cloakroom at the Royal School of Mines.

Entrance to the Royal Geographical Society, 1 Kensington Gore SW7 2AR. The entrance for conferences is on Exhibition Road. The rooms used here are **RGS Ondaatje, RGS Lowther, RGS Drayson.**

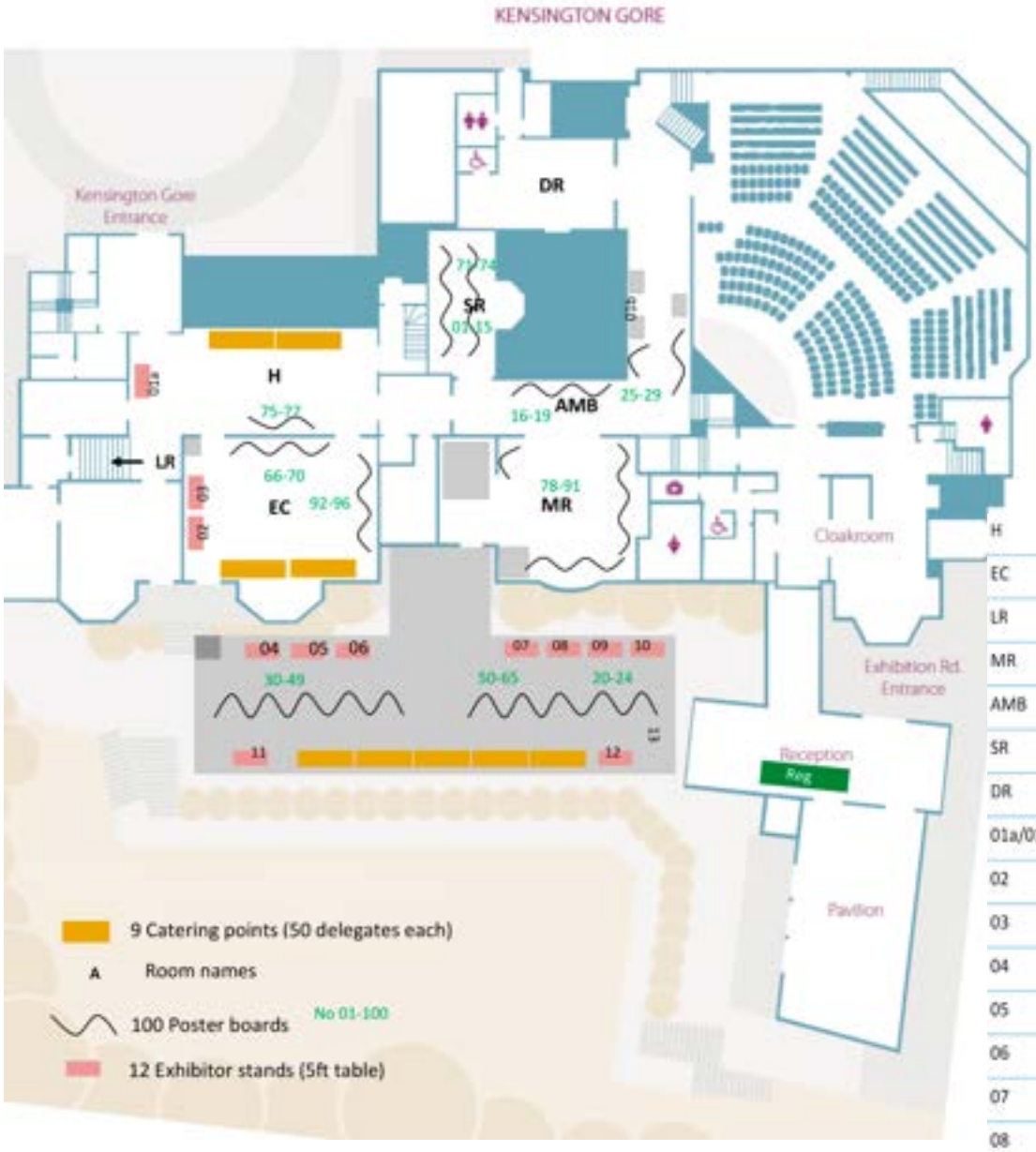
Entrance to the Royal School of Mines, Imperial College. The entrance is just off Exhibition Road on Prince Consort Road. The rooms used here are **Imperial RSM G.41 and Imperial RSM G.38.** Please follow signs.

Entrance to the Natural History Museum from Exhibition Road (Earth Galleries side). This entrance should be used to access the **NHM Flett** Theatre. To access the theatre please go up the stairs immediately on entry and follow signage.

Entrance to the Natural History Museum from Queen's Gate (Darwin Centre side). This entrance is to be used only for the **Conference Banquet.**

RGS Site Plan, Poster Map & List of Exhibitors

All posters and exhibitors are in the Royal Geographical Society (RGS). A list of Posters and all Poster numbers are provided later in this Programme. The site plan for the RGS is below – poster numbers are indicated in ***green****, exhibitor tables are indicated by* ***pink tables*** *(Exhibitors can find their table number in the key).*



H	Hall
EC	Education Centre
LR	Lowther Room
MR	Map Room
AMB	Ambulatory
SR	Sunley Room
DR	Drayson Room
01a/01b	UKHO
02	NHM Curatorial
03	NHM Consultancy
04	Chelsea Technologies
05	Hiden
06	NOC
07	RS Aqua
08	Swale Oceanographic
09	SMI
10	SEAL Analytical
11	Planet Ocean Ltd
12	Royal Society
13	UN Decade

List of Exhibitors in the RGS

Chelsea Technologies: Chelsea Technologies design and manufacture best-in-class environmental monitoring technology to make the world safer, cleaner and smarter. For over 50 years, our fluorometers, sensors & systems have been used around the world to help our customers understand the natural environment, improve water treatment processes, monitor for pollution and contaminants in all water environments, comply with ballast water and exhaust gas wash water monitoring regulations, and even support oceanographic research. For more information please contacts: sales@chelsea.co.uk https://chelsea.co.uk/

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Planet Ocean Ltd: Based in Camberley, Surrey, Planet Ocean represents gold standard suppliers of oceanographic, hydrographic and meteorological instruments from around the world, as well as designing and manufacturing bespoke instruments and systems for ocean research. Also showing ecoSUB Robotics ecoSUB Autonomous Underwater Vehicles. Contact: Planet Ocean Ltd, Unit 16 Camberley Business Centre, Bracebridge, Camberley, Surrey, GU15 3DP; Tel: (0)845 108457; email: Sales@planet-ocean.co.uk; www.planet-ocean.co.uk; www.ecoSUB.uk

RS Aqua: Empowering the world of ocean science and exploration with cutting-edge technology to enable further discovery, better understanding and the protection of our oceans. Our goals are to enable ground-breaking science, deliver long-term customer success and contribute towards the blue economy. Scientific and technical excellence, complete support and sustainability are at the heart of everything we do. The technology systems and services we supply are carefully selected for class leading performance, quality and reliability, so you can focus on successful discovery, exploration and advancement of the blue economy. https://rsaqua.co.uk/

Swale Oceanographic: Swale Technologies has been supplying quality instrumentation and equipment for over 30 years. Our wide product portfolio can be categorised as follows: i) Measuring instruments such as sensors, sonars, and sondes for monitoring the likes of underwater noise, dissolved gasses and water quality, ii) Enabling equipment to get the job done, including acoustic and inductive telemetry, profiling ARGO floats and mini AUVs, iii) Sampling equipment like Niskin bottles, rosettes, oil sheen kits and sediment grabs. We represent manufacturers with an outstanding reputation in the market for functionality, engineering and reliability. These include Evologics, General Oceanics, Mooring Systems Inc, NKE Instrumentation, Nobska, OceanAlpha, Ocean Sensor Systems, Pro-Oceanus, RJE, RTsys, SonarTech, SoundNine, Teledyne and Turo. https://swaleocean.co.uk/

SMI: The Society of Maritime Industries (SMI) promotes the interests of UK-based companies in the international market place and to governments. Our membership is inclusive of the whole supply chain from shipyards and major system providers to the manufacturers of the smallest components, as well as companies involved in marine science & technology and the growing area of autonomy https://www.maritimeindustries.org/

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Royal Society: The Royal Society is a charitable organisation that recognises, promotes, and supports excellence in science. Our journals Proceedings B, Biology Letters, Royal Society Open Science, Interface, Proceedings A and Philosophical Transactions A and B welcome submissions of research, reviews and theme issue proposals in

all areas of science. We offer authors high quality peer review by active scientists, exceptional author service, open access options and wide dissemination to an international audience. Find out more about our journals and browse recent articles by visiting royalsociety.org/journals. Visit our booth to pick up more information on publishing options.

NHM Consulting: NHM Consulting is an in-house team dedicated to help Natural History Museum scientists engage with industry - it facilitates the Museum's mission by harnessing the expertise and talent of our world-class researchers and curators. By growing long-term partnerships, we can develop innovative projects and contribute to knowledge exchange - advancing the science of nature.

NHM Curation: The NHM holds several thousand lots of specimens collected by the historic HMS Challenger Expedition spanning zoological and geological material. The display is an opportunity to see the 150 year old scientific specimens collected from the world's first Oceanographic voyage. Alongside the modest display of specimens, as a token representation of the NHM's HMS Challenger collection, will be a host of NHM Invertebrate curation team members happy to engage on questions associated with the physical collection, acquisition of material, and the ongoing history of research associated with the specimens. This is a chance to discuss old and new emerging ideas for collections-based research with the NHM.

Step-free Access Information for Venues

Royal Geographical Society. The Exhibition Road and Kensington Gore entrances are both wheelchair accessible. There are two spaces in the Ondaatje Theatre for wheelchair users, but should you require additional spaces then please do contact us in advance. A ramp can be provided for speakers to access the stage. There are a set of steps on the ground floor of the venue (connecting the Theatre to the ambulatory), but a stair lift is available for wheelchair users. The Lowther Room is located on the first floor but can be accessed by a small lift.

Imperial College (Royal School of Mines). Step-free access to the Royal School of Mines is via the main entrance to Imperial College on Exhibition Road (see map).

Natural History Museum (Flett Theatre). The Earth Galleries entrance is fully wheelchair accessible. The Flett theatre directly above the entrance can be reached by stairs or lift.

Breastfeeding / Nursing Room Access / Carers

We welcome delegates with carers who need to look after infants. Please do contact us first if you need to bring a carer or any other access issues.

At the Natural History Museum there is a space for breastfeeding but the room does not have a fridge. Please ask the NHM guides for assistance finding it. At the RGS the First Aid Room can be used for breastfeeding but also does not have a fridge. There are no breastfeeding facilities at the Royal School of Mines.

Daily Schedule of All Talks and Events

Note that only first authors are listed here. For a complete list of all authors, please see the abstract section.

Monday

Monday 5th September

Note that all Side Events are organised by the contact lead indicated below: ***separate pre-registration with them is essential to attend.***

Side Event: NHM Flett Theatre

1000-1750 **Advances in Marine Biogeochemistry (AMBIO) Special Interest Group (SIG)** contact: A.L.Annett@soton.ac.uk

Side Event: NHM Neil Chalmers Room

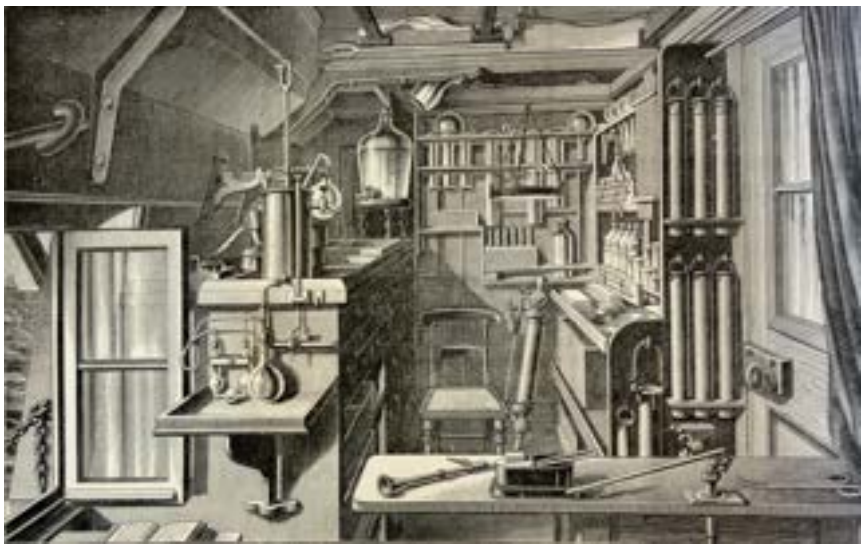
1300-1750 **Deep-Sea Ecosystems Special Interest Group (SIG)** contact: michelle.taylor@essex.ac.uk | kerry.howell@plymouth.ac.uk

Side Event: NHM Humphrey Greenwood Room

0930-1750 **Scientific Committee for Oceanographic Research (SCOR) UK Meeting** contact: atagliab@liverpool.ac.uk

1830-2030 Icebreaker Reception – Tamesis Dock, Albert Embankment, London SE1 7TY

The Tamesis Dock is a 1930s Dutch Barge, with a bar. Conference registration will be open at the Icebreaker. Pre-registration for the icebreaker is essential. Please complete the form emailed.



Tuesday 6th September

0800-0915 **Registration open at RGS**

0915-1145 Plenary 1: The Future of Global Ocean Science

Chair: Prof Richard Herrington, Natural History Museum

RGS - Ondaatje Theatre

0915 **Conference Welcome by Dr Adrian Glover, Co-Chair of the Local Organising Committee**
0920 **Opening of the Conference by Prof Mike Meredith, President-Elect of the Challenger Society**

0945 **H.E Michael Lodge, International Seabed Authority, Jamaica.** The International Seabed Authority.

The International Seabed Authority (ISA) is an autonomous international organization established under the 1982 United Nations Convention on the Law of the Sea (UNCLOS) and the 1994 Agreement, which was adopted to bring the regime of the deep seabed closer in line with political and economic realities. ISA is the organization through which States Parties to UNCLOS organize and control all activities related to mineral resources in the international seabed area (the Area). The Area effectively covers more than 50 per cent of the world's oceans' seabed. The Area and its resources are the common heritage of humankind, on behalf of which ISA acts. At the core of ISA's mandate is the need to ensure the effective protection of the marine environment from harmful effects that may arise from deep-seabed related activities in the Area.

1015 **Prof Angela Hatton**. The Future of Marine Science | Transforming Technology and Data Accessibility for a Net Zero Future.

Abstract: One of the key goals for the Decade of Ocean Science for Sustainable Development is to ensure we have 'an accessible ocean with open and equitable access to data, information, and technology and innovation'. If we are to fulfil this and ensure that marine science is fit for the future, we will need to develop and utilise new technologies to transform the way we generate data and make it accessible. This change not only requires new ways of working but also, new approaches to how we work (cultural change in the marine science community). It is already clear that there is a move from ship-based measurements, where ownership of analytical equipment was associated with initial ownership of the data generated, to a world where observational data is generated collectively and belongs to all.

In the future we will need to consider the environmental impact of our research, including how we reduce the carbon footprint of our science and with an ever-expanding need for ocean data, how we work efficiently and cooperatively to generate the 'Science we need for the Ocean we want'.

In this talk I will discuss the currently available technology, the UK and International technology road map, the development of the digital ocean approach and current planning around Net Zero Oceanography.

1045 **Prof John Pinnegar.** 150 years of fisheries science in the United Kingdom: learning from the past and preparing for the future.

Abstract: 150 years ago there was growing concern that fish stocks in the North Sea were already declining. In the 1870s, a series of high-profile Royal Commissions were appointed to investigate these perceived declines, but at the time understanding of the marine environment was very limited. In 1902 countries surrounding the North Sea came together to form the International Council for the Exploration of the Sea (ICES) – the world's oldest Intergovernmental science organisation. The UK contribution to ICES involved creation of two laboratories (one in England, one in Scotland), specifically tasked to carry out fisheries investigations.

Based on long-term datasets, Cefas scientists have documented a significant warming of waters around the UK over the past 100 years by more than 3°C, that the seas have become more turbid (murkier), that the distribution of most fish species has shifted 'northward' as a result of rising temperatures but also historic over-fishing.

Scientists are now able to make use of sophisticated mathematical models to anticipate how future climate change might impact the distribution of key fishery species. Species turnover will result in both opportunities and threats

to the UK fishing industry. Key challenges that remain include: (1) dealing with the data deluge – as automated monitoring systems become more commonplace; (2) the need for reliable near-term climate 'forecasts' and knowledge of how fish stocks might respond; (3) understanding ocean acidification – whether it represents a threat or not?; (4) weighing up multiple pressures and socio-economic trade-offs.

1115 **Prof Nick Owens.** "Oh, I do like to be beside the seaside": 150 years on from 'HMS Challenger' and the conflicting demands on our future seas.

Abstract: Historically, humans have had an important interaction with the sea, arguably almost as long as there have been humans. This has shaped society, its development and culture throughout the ages to that which we know today. In many ways the ocean and seas the HMS Challenger explored were not that different from now but in others there are profound differences, almost exclusively the result of human impact. And this impact has had one cause – largely unmanaged exploitation. Current pressures from increasing populations, food and energy demands, impacts from climate change and the burgeoning belief of a substantial 'blue-economy' can only exacerbate exploitation. While the 'Challenger scientists' did an extraordinary job, today's marine scientists are faced with a very different challenge. Yes, new and fundamental discoveries are needed, just as they were 150 years ago, but there is now a more pressing social dimension that drives the scientific need. Today's equivalent of the Challenger expedition requires us to provide knowledge, for example: to manage the multiple overlapping uses that we expect the sea to provide; to examine whether bio-geoengineering might be a useful tool to ameliorate the climate crisis; to test whether MPAs and 'rewilding' might reverse the loss of biodiversity. These and multiple other questions now must be answered in the context of a society that is: firstly, arguably more dependent on the sea; and secondly, one that expects a say, if not to give a 'social license' to interventions, in ways that probably did not exist 150 years ago. In this talk I shall consider current and future marine science in the context of societal needs and, with an occasional reference to the Challenger expedition, comment on why it is important for us to 'like being beside the seaside'.

1200-1315 Lunch at RGS

1315-1515 Science Sessions 1a

RGS Ondaatje

T1 - Deep Sea Mining 1 - geology, resource, legal, technical and societal aspects
Chairs: Teagle D; Herrington R; Mills R

1315 **Ian Lipton.** Polymetallic Nodules: Progressing from Mineral Resource towards Mineral Reserve.

1330 **Ulrich Schwarz-Schampera.** Resource prospects of seabed minerals of the Area.

1345 **Marie Bourrel-Mckinnon.** International policy framework in support of the stewardship of the Area and its resources for the whole of humanity

1400 **Michael Clarke.** Monitoring of the Technical and Environmental Performance of a Prototype Polymetallic Nodule Collector System in the Clarion Clipperton Zone.

1415 **Pierre Josso.** Application of random-forest machine learning algorithms for mineral predictive mapping of Fe-Mn crusts in the world Ocean.

1430 **Bramley Murton.** Giant seafloor massive sulphide deposits forming at dying ocean core complexes.

1445 **Andrew Serdy.** The common heritage regime for deep seabed minerals: a legal product of its time.

1500 **Stephen Roberts.** What lies beneath? Using scientific ocean drilling to investigate the subsurface below actively forming sea-floor massive sulphide deposits.

1515 **Sam Robinson.** Challenging the Manganese: HMS Challenger, John Mero, and the Extractive Ocean Imaginary.

RGS Lowther

T12 - Interactions between plastics and marine ecosystem
Chairs: Manno C; Cole M; Rowlands E

1315 **Matthew Cole.** ***Keynote*** Development and application of partial life-cycle toxicity test for anthropogenic particulates.

1330 **Emily Rowlands.** Scoping intergenerational effects of nanoplastic on Antarctic krill embryos.

1345 **Jake Bowley.** Pathogens transported by plastics: does this vector pose a risk to marine ecosystems?

1400 **Georgie Savage.** Microplastic uptake by the snakelocks anemone (*Anemonia viridis*): investigating environmental and physical factors that alter uptake.

1415 **Jack Buckingham.** A record of microplastics in the marine nearshore waters of South Georgia.

1430 **Stephanie Andrews.** The distribution and abundance of microplastics in the waters and organisms of the River Thames, UK.

1445 **Daniel Wilson.** Modelling the transport of microplastic pollution in the Southern Ocean.

1500 **Aidan Hunter.** Modelling microplastic in Antarctic krill diets and the impacts on carbon export.

1515 **Nia Jones.** Modelling microplastic dispersal in a well-mixed estuary.

1530 **Katie Deakin.** Science to Solutions: Plastic pollution in the Galápagos marine ecosystem.

RGS Drayson

T4 - Shackleton Session: Marine Sedimentary Carbon
Chairs: Woulds C

1315 **Stergios Zarkogiannis.** The role of oceanic density on planktonic calcification.

1330 **Lisa Curti.** The role of carboxyl groups in retarding and inhibiting the microbial remineralisation of organic carbon during adsorption to iron (oxyhydr)oxides.

1345 **Oliver Moore.** The transformation and preservation of mineral-associated organic carbon within marine sediments.

1400 **Peyman Babakhani.** Dissolved organic carbon, the lost piece of the carbon cycling-preservation puzzle in global marine sediments.

T22 - Strengthening Equality, Diversity, Inclusivity and Accessibility in Marine Science
Chairs: McGregor A; Damerell G; Woolf D; Rabe B

This session is followed by a round-table EDIA discussion in RGS Ondaatje at 1530-1600.

1415 **Cat Morgan.** Enabling Neurodiversity-Inclusive Marine Science Careers – A Way Forward.

1430 **Jo Clarke.** Amplifying our students' voice: the co-production of an undergraduate field courses to address EDI.

1445 **Nicholas Higgs.** Women Scientists at Sea in the 19th Century: the pioneering Bahama Expedition of 1893.

Imperial RSM G.41

T7 - Pushing the limits in autonomous oceanography in a net zero carbon world
Chairs: Carvalho F; Porter M; Brearley JA; Dall'Olmo G

1315 **Fredrik Søreide. *Keynote*** Towards the Unmanned Research Vessel.

1330 **Philip Leadbitter. *Keynote*** NBP2202: A case study in using complementary autonomous vehicle and ship-based observations for a synoptic view of atmosphere-ice-ocean interactions.

1345 **Matt Lewis.** measuring hydrodynamics with videos from low cost drones.

1400 **Witek Tatkiewicz.** Autonomous oceanography for improved estimates of sea-air CO2 exchange.

1415 **Sarah Cryer.** Using a biogeochemical sensor suite mounted on an autonomous surface vehicle to investigate riverine input on coastal ocean acidification.

1430 **Neil Fraser.** Boundary current structure and variability characterized using repeat glider observations.

1445 **Natasha Lucas.** Birth and death of a 'megaberg'. A multidisciplinary study of iceberg A68 near South Georgia, Southern Ocean.

Imperial RSM G.38

T27 - Physical Oceanography Open Session – Physical Drivers of Ocean Productivity
Chairs: Fernandez Castro B

1315 **Megan O'Hara.** Upwelling statistics around seven Atolls in the Pacific Ocean.

1330 **Edward Robinson.** Internal waves: Ecosystem impacts from localised oceanographic processes at a tropical seamount.

1345 **Nikolaos Skliris.** Physical drivers of post-2011 inter-annual variability in Sargassum blooms in the Central West Atlantic.

1400 **Yueng Lenn.** PEANUTS: Primary productivity driven by escalating Arctic nutrients fluxes?

1415 **Charlotte Williams.** Autumnal Diapycnal Oxygen Fluxes in the North Sea.

1430 **Russell Arnott.** Convective mixing in mesocosms: A novel approach to realistic turbulence generation to study climate change.

Tuesday

T10 - Micro to macro: linking bottom-up and top-down approaches that investigate the function, resilience and conservation of polar ecosystems
Chairs: Freer J; Dornan T; Liszka C; Belcher A; Bonnet-Lebrun A-S; Cook K

1315 **Emma Cavan. *Keynote*** Simulating Antarctic krill carbon export in a biogeochemical model.

1330 **Kate Hendry.** A new macronutrient database from the highly productive island of South Georgia, the Scotia Sea and the west Antarctic Peninsula.

1345 **Sian Henley.** Nutrient biogeochemistry in Antarctic land-fast sea ice and exchange with the surface ocean.

1400 **Sophy Oliver.** When and where can't you balance the mesopelagic budget in the Southern Ocean?

1415 **Anna Belcher.** Ecological drivers of carbon flux in the Scotia Sea, Southern Ocean: A stable isotope approach.

1430 **Clara Douglas.** Annual sea ice retreat crucial for modulating biological carbon pump in the Weddell Gyre.

1445 **Alex Poulton.** Upper ocean carbon, nitrogen and silica cycling in the South Georgia bloom.

1500 **Ben Fisher.** Biogeochemical implications of climate driven species shifts among Southern Ocean primary producers.

1530-1600 Equity, Diversity, Inclusivity & Accessibility (EDIA) Panel Discussion

RGS Ondaatje Theatre

Panel Members: **Prof Angela Hatton**, National Oceanography Centre; **Dr Kate Hendry**, British Antarctic Survey; **Mr Ben Fisher,** University of Edinburgh; **Dr Emma Cavan**, Imperial College

1600-1830 Poster Session at RGS, with refreshments

We would like to acknowledge Fullers Brewery for sponsoring the Challenger 150 Poster Session

1900-2030 Early-Career Mixer Event

Imperial RSM G.41

Wednesday 7th September

0800-0830 **Registration open at RGS**

0830-1030 Plenary 2: Ocean Challenges, Ocean Solutions

Chair: Prof Rachel Mills, Provost, University of Sussex

RGS - Ondaatje Theatre

0830 **Prof Carol Robinson (Challenger Medal Winner).** Microbial respiration - a crucial constraint on the biological carbon pump in a changing ocean.

Abstract: Marine microbial respiration is a key determinant in the balance between oceanic storage of organic carbon and production of carbon dioxide. Yet, despite its pivotal role, it remains one of the least constrained microbial metabolic processes. Accurate determination of the amount of organic carbon stored in the ocean is needed to define the societal changes required to reach global climate targets and to evaluate the ocean-based negative emission approaches required to avoid a temperature rise of greater than 1.5 oC above pre-industrial levels. In a changing climate, it is imperative to predict how respiration and thus carbon storage may change and potentially contribute via positive feedback to increased warming.

The challenge of determining the magnitude and variability of microbial respiration and the climate related drivers of variability, such as temperature and dissolved oxygen, is being addressed across a range of spatial and temporal scales. A new generation of methods including the use of sensor data deployed on autonomous platforms such as Biogeochemical Argo floats and gliders, in-situ incubators which avoid pressure and sample manipulation artefacts, and the finessing of the cellular electron transport system technique, are providing new perspectives to progress understanding and predictive capability. This presentation will take a cellular to sub-basin scale, historical to future view of the challenges and potential solutions to constraining microbial respiration and thus ocean carbon storage.

0900 **Prof Alberto Naveira Garabato (Challenger Medal Winner).** How small-scale turbulence drives deep-ocean upwelling: A new view?

*Abstract: Since the seminal work of Walter Munk in the 1960s ('Abyssal Recipes'), oceanographers have believed that the upwelling of cold, abyssal waters that regulates the deep ocean's ability to sequester heat and carbon for decades to millennia is driven by centimetre-scale turbulent mixing associated with breaking internal waves in the ocean interior. Measurements of deep-ocean turbulence over the last >20 years, however, have contested this scenario, and instead suggest that mixing by breaking internal waves drives *downwelling* of abyssal waters. Inspired by this conundrum, recent theoretical investigations have developed an alternative view of the role of mixing in sustaining deep-ocean upwelling. In this new view, upwelling is driven by highly localised turbulence within thin (typically tens of metres thick) layers near the seafloor, known collectively as the bottom boundary layer. In the ongoing BLT Recipes experiment, we set out to test this new view, and figure out how it works, by obtaining the first set of concurrent, systematic measurements of (1) large-scale mixing and upwelling, (2) their interior and bottom boundary layer contributions, and (3) the processes underpinning these contributions, in a representative deep-ocean basin (the Rockall Trough, in the Northeast Atlantic). This talk will review the initial insights emerging from the BLT Recipes experiment, and offer an outlook on how they might re-shape out view of deep-ocean upwelling.*

0930 **Prof Gary Carvalho.** Genes, Fish and Fisheries: interdisciplinary contributions to conservation and management

Abstract: Molecular genetic markers have a long and complex history of application in the marine environment. Early tools included blood pigments and allozymes, and in more recent times have been revolutionised through genomic technologies and high throughput gene sequencing. Alongside the many exciting questions that can now be tackled has been the paradigm shift from a focus on biological units such as populations and species, to more expansive consideration of how these units interact with each other and their environment, thereby impacting the structure and functioning of ecosystem-wide processes. Such breadth necessarily demands complementary knowledge of physical and chemical data across short and historical timescales. Here I illustrate

milestones and challenges in the application of molecular genetic tools to marine science by examining the spatial and temporal dynamics of fish populations. I highlight, how and why, so-called fisheries genetics provides fertile ground for marine interdisciplinary science, from provision of core biological information through to the underpinning of conservation and management strategies. Typically, molecular genetic markers afford two categories of utility: their use as "natural tags" to identify individuals, populations, and species, and the rather more prosaic, but fundamental role that population diversity plays in resilience and recovery of exploited populations. Illustrative examples will consider species discovery, population structure and traceability, connectivity, adaptive variation, and insights afforded at community and ecosystem levels. Reasons for the slow, though progressive uptake of molecular data in fisheries will be highlighted, alongside presentation of case studies demonstrating impact and new avenues of opportunity.

1000 **Dr Katherine Duncan.** Medicines from the Sea – Microbial Natural Product Discovery

Abstract: Our ability to discover novel chemistry is fundamental to tackling key global challenges including environmental sustainability and human health. Understanding the role of chemical interactions in the marine environment (chemical ecology) is particularly relevant as we consider the impact of future climates. Despite underpinning every biological process on Earth, the effects of biotic and abiotic factors on microbial chemical exchange in the Oceans is largely unknown. In terms of chemical novelty and diversity, natural products from the bacterial order Actinomycetales (often called actinomycetes) are unsurpassed. However, since the golden age of microbial natural products in the 1940s-1970s, antibiotic discovery has been hampered by two main problems: i) the same molecules ('low hanging fruit') are repeatedly rediscovered and ii) only approximately 3% of the total possible metabolites a bacterium may produce in nature, are produced in a laboratory setting. Until now, chemical discovery, has been a random (organism, source, process) and occasionally fortuitous expedition. Yet, all microorganisms communicate using a chemical language. These metabolites are produced in nature for a reason, and there are likely patterns. Therefore, to uncover areas of completely uncharted chemical space and to effectively manipulate microorganisms in a laboratory, it is imperative we understand the ecological functions of these specialised metabolites in nature. This talk will focus on three biological questions; 1) what role do biotic interactions play in microbial chemical exchange, 2) which environmental variables impact the chemical potential of rare actinomycetes and 3) can chemical discovery be accelerated through integrated comparative 'omics (genes to molecules) approaches?

1030-1100 Tea, Coffee at RGS

1100-1300 Science Sessions 2a

RGS Ondaatje

T2 - Deep Sea Mining 2 - environmental aspects: baselines, impacts, monitoring
Chairs: Glover AG; Woulds C

1100 **Craig Smith.** ***Keynote*** From science to policy: the design, implementation, and revision of no-mining areas to conserve biodiversity during nodule mining in the Clarion-Clipperton Zone.

1115 **Jon Copley.** ***Keynote*** Understanding the ecological context of polymetallic sulfide deposits formed by deep-sea hydrothermal vents: challenges and knowledge gaps.

1130 **Muriel Rabone.** Current state of metazoan biodiversity knowledge in the world's largest mineral exploration frontier.

1145 **Alastair Lough.** Spatial variability in benthic organic matter quality within a Mn-nodule mining claim area of the Clarion Clipperton Fracture Zone.

1200 **Tanja Stratmann.** Role of polymetallic-nodule dependent fauna on carbon cycling in the eastern Clarion-Clipperton Fracture Zone (Pacific).

1215 **Adrian Glover.** The DEEPEND Project: an informed societal decision on deep-sea mining requires scientists to show the benefits of protected areas.

1230 **Eva Stewart.** Biodiversity, biogeography, and connectivity of polychaetes in the world's largest marine minerals exploration frontier.

1245 **Stamatia Galata.** The impact of mining plumes at the organic matter quality and quantity at two areas of the Clarion-Clipperton Zone.

1300 **Oystein Bruncell Larsen.** 40 years of exploration in the Area -science technology and knowledge.

RGS Lowther

T25 - Physical Oceanography Open Session – Energetics and Mixing
Chairs: Tedesco P; Baker L

1100 **Qinbiao Ni.** Impact of mesoscale eddies on near-inertial energy in the global ocean.

1115 **Emyr Martyn Roberts.** Changing the layer cake: Stratification trends in the Barents-Kara Seas (BKS).

1130 **Pauline Tedesco.** Mixed layer energetic dynamics across scales in the Drake Passage.

1145 **Aaron Wienkers.** Vertical transport and mixing driven by symmetric instability in strong ocean fronts.

1200 **Jennifer Dingwall.** Modelling the accumulation of buoyant particles under wind-driven and convective turbulence in the ocean mixed layer.

1215 **Ria Oelerich.** Stirring Across the Antarctic Circumpolar Current's Southern Boundary at the Greenwich Meridian.

1230 **Lois Baker.** Upwelling of abyssal waters by boundary turbulence.

1245 **Carl Spingys.** Observations of turbulence, temperature variance and mixing on a sloping bottom boundary.

1300 **Julian Mak.** On the choice of turbulence eddy fluxes to learn from in data-driven methods

RGS Drayson

T28 - Physical Oceanography Open Session – Tides, Coasts and Shelf Seas
Chairs: Czerski H

1100 **Dario De Benedictis.** Climatological challenges for the development of offshore wind farms off NW Scotland.

1115 **Ben Lincoln.** Anthropogenic mixing by floating wind farms in stratified shelf seas.

1130 **Sandy Avrutin.** Nonlinear land-ice interactions from the observational record and their implications for sea level projected sea level rise.

1145 **Anrijs Abele.** Sources of sea-level variability on the shelf of the U.S. Atlantic coast.

1200 **David Woolf.** CHASANS – Dispersion and connectivity of hard-substrate organisms in the central North Sea and their interaction with offshore energy infrastructure.

1215 **Julia Rulent.** Simulation of pollutants dispersal from XPP disaster.

1230 **Anthony Wise.** A simple conceptual model to connect coastal sea level variability with the continental slope current and deep ocean circulation.

1245 **Louis Clement.** Cessation of Labrador Sea Convection by Freshening through Submesoscale Flows.

1300 **John Taylor.** Submesoscales under near-resonant inertial shear experiment (SUNRISE)

Imperial RSM G.41

T7 - Pushing the limits in autonomous oceanography in a net zero carbon world (contd…)
Chairs: Carvalho F; Porter M; Brearley JA; Dall'Olmo G

1100 **Ryan Patmore.** Investigating glider sampling strategies by emulation.

1115 **Andrea Rochner.** Can assimilating Biogeochemical-Argo data improve carbon flux estimates?

1130 **Alexander Phillips.** Autosub5 the UK's new Workclass AUV for Deep Water and Under Ice: Introducing the Platform, Early Science Deployments and Development Roadmap.

1145 **Matthew Patey.** Demonstration of new in-situ biogeochemical sensors integrated in the Autosub Long Range (aka 'Boaty McBoatface').

1200 **Sara Fowell.** Autonomous Lab-on-Chip Biogeochemical Sensors on the RAPID East Mooring Array.

1215 **Adrian Nightingale.** Anti-fouling copper surfaces interfere with wet chemical nitrate sensors and Griess-based nitrate assays.

Imperial RSM G.38

T21 - Trait-based approaches to improve conservation, management, and restoration of our oceans
Chairs: Campanyà-Llovet N

1100 **Katia Aparecido.** Mesopelagic fishes of Western Tropical Atlantic: insights from functional diversity.

1115 **Fanny Monteiro.** Revealing the ecological impact of coccolithophore diversity through mechanistic and statistical modelling.

1130 **Neus Campanyà-Llovet.** Applying trait-based approaches to Marine Protected Areas from the Mid-Atlantic Ridge

1145 **Oliver Blackburn.** Benthic functional diversity in deep-sea coral reefs across a habitat complexity gradient in the Rockall Bank, NE Atlantic.

1200 **Joanna Harris.** Fine-scale oceanographic drivers of reef manta ray (*Mobula alfredi*) visitation patterns at a feeding aggregation site.

1215 **Emma Smith.** Tracing particulate organic matter pathways in deep-sea ecosystems: Food supply and partitioning in Whittard canyon vulnerable marine ecosystems dominated by filter feeders

NHM Flett

T10 - Micro to macro: linking bottom-up and top-down approaches that investigate the function, resilience and conservation of polar ecosystems (contd…)
Chairs: Freer J; Dornan T; Liszka C; Belcher A; Bonnet-Lebrun A-S; Cook K

1100 **Christopher McQuaid.** Top-down and bottom-up drivers of Southern Ocean ecosystems.

1115 **Flo Atherden.** Delving deeper into the physiology of a high latitude copepod using untargeted metabolomics.

1130 **Cecilia Liszka.** Plankton and nekton community structure in the vicinity of the South Sandwich Islands (Southern Ocean) and the influence of environmental factors.

1145 **Tracey Dornan.** Temporal trends in South Georgia zooplankton: insights from a moored echosounder.

1200 **Natalie Nickells.** Quantifying the role of Antarctic krill and salps on carbon flux to depth in the Southern Ocean.

1215 **Dominik Bahlburg.** From individuals to swarms – using model ensemble runs to account for model-specific biases on life history simulations of Antarctic krill.

1230 **Nadine Johnston.** Outcomes of the first Marine Ecosystem Assessment for the Southern Ocean (MEASO).

1300-1400 Lunch at RGS and at NHM Flett (for Polar Session)

1345-1545 Science Sessions 2b

RGS Ondaatje

T2 - Deep Sea Mining 2 - environmental aspects: baselines, impacts, monitoring (contd..)
Chairs: Glover AG; Woulds C

1345 **Philip Weaver.** Progress in developing a Regional Environmental Management Plan for the Polymetallic sulphide deposits of the North Atlantic.

1400 **Thomas Dahlgren.** Genetic barcode repository gap analysis – contrasting the beauty with the beast.

1415 **Guadalupe Bribiesca-Contreras.** Biodiversity of abyssal invertebrates associated with polymetallic nodules.

1430 **Felix Janssen.** Baseline benthic activity in the Clarion Clipperton Fracture Zone: In situ oxygen observation as a proxy for short-term impacts of manganese nodule mining.

1445 **Teresa Radziejewska.** Reiterating the importance of and the need for environmental monitoring in impact studies related to deep-sea mining.

1500 **Andrew Sweetman.** Unique oxygen dynamics at the abyssal seafloor of the Clarion-Clipperton Fracture Zone points to a previously uncharacterized biogeochemical process.

1515 **Luciana Genio.** Advancing global understanding of knowledge of deep-sea science through international cooperation : the role of ISA

RGS Lowther

T19 - Mathematics of Satellite Oceanography
Chairs: Holm D; Crisan D; Chapron B; Memin E

1345 **B. B. Cael.** Detecting trends in ocean colour over the satellite era.

1400 **Oliver Street.** Coupling of waves to sea surface currents via horizontal density gradients.

1415 **Cait McCarry.** Detecting zooplankton from space.

1430 **Said Ouala.** Analysis of ocean heat wave dynamics and predictability.

Imperial RSM G.41

T15 - Carbon cycling in the global ocean and the role of blue carbon in climate mitigation
Chairs: Belcher A; Cavan E; Barnes D; Rogers A

1400 **Chester Sands.** ***Keynote*** Who's Blue Washing? Nature based solutions are not just economic targets but ecological processes that can help balance out a profound anthropogenically inflicted problem.

1415 **Terri Souster.** Barents Sea Benthic Blue Carbon with respect to different habitats and its role as nature based solution to climate change.

1430 **Simon Morley.** Valuing intact marine benthic biodiversity to help mitigate against climate and biodiversity crises.

1445 **Alejandra Zazueta-Lopez.** Influence of macroalgae mats on sediment carbon storage in coastal environments.

1500 **Ruth Parker.** Shelf seabed blue carbon: What is the potential of the English seabed sediment for climate mitigation under future marine management?

1515 **Clare Hynes.** Colours of Carbon: insights from the Alkanes

Imperial RSM G.38

T6 - Towards a Net Zero Oceanographic Capability
Chairs: Darlington E; Hendry K; Fletcher S; Lorenzo A

1400 **Mark Moore.** Towards net zero hollistic observational biogeochemistry: preliminary overview of the DY149 trials cruise.

1415 **Juan Ward.** Making the most of data.

1430 **Matt Mowlem.** Technologies for Ocean Sensing (TechOceanS project).

1445 **Justin Buck.** Digital twins and their potential role in Net Zero Oceanographic Capability (NZOC).

1500 **Georgios Salavasidis.** Automated Piloting Framework for Efficient Use of Marine Autonomous Robotic Systems.

1515 **Alexander Phillips.** Autosub Long Range: towards a shore launch shore recover AUV capability.

NHM Flett

T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers
Chairs: Scott W; Davis P; White E; Maxwell J

1345 **Bradley Reed.** Recent irreversible retreat of Pine Island Glacier.

1400 **Alessandro Silvano.** Simulated warm water access to the Amundsen Sea continental shelf.

1415 **Shenjie Zhou.** A multidecadal decline in the densest water exported from the Weddell Sea, Antarctica, forced by wind-driven sea ice changes.

1430 **Nadescha Zwerschke.** Blue Carbon Potential of Polar Region Fjords.

1445 **Regan Drennan.** Cool for cats – phylogeographic structure in the Southern Ocean circumpolar catworm, Aglaophamus trissophyllus (Annelida: Nephtyidae).

1500 **Piotr Balazy.** Year-round foraging activity of Arctic filter feeders studied with time-lapse photography.

1515 **Birthe Zaencker.** Fungal communities across Greenland's shelf sea ice ecosystems and the wider Central Arctic Ocean.

1530 **Stephen Long.** Deep sea trawling and the impact on vulnerable marine ecosystems – A case study of sea pen fields in West Greenland.

1530-1600 Tea, Coffee at TGS and at NHM Flett (for Polar Session)

1600-1800 Science Sessions 2c

RGS Ondaatje

T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans
Chairs: Jones R; Olivelli A; Robinson S; Annett A; Branson O; Jurikova H

1600 **Daniela Koenig. *Keynote*** Impact of climate variability on the oceanic cycling of iron and its isotopes.

1615 **Matthew Humphreys. *Keynote*** PyCO2SYS and beyond: what next for seawater chemical equilibrium modelling?

1630 **Arianna Olivelli.** Lead concentrations and isotope compositions of surface waters from the western South Atlantic Ocean.

1645 **Oliver Flanagan.** Particle Trace Metal Geochemistry of the Rainbow and TAG Hydrothermal Vent Plumes.

1700 **Isabelle J. Cooper.** Applying 224Ra/228Th Disequilibrium to Investigate Faunal Contributions to Benthic Flux Processes.

1715 **Rachel Shelley.** Is aerosol trace element fractional solubility a function of total atmospheric loading?

1730 **Alessandro Tagliabue.** Escaping the ligand trap: authigenic mineral phases control the ocean iron cycle.

1745 **Millie Goddard-Dwyer.** Biogeochemical Cycling of Iron Binding Humic Ligands in the South-West Indian Sector of the Southern Ocean.

RGS Lowther

T15 - Carbon cycling in the global ocean and the role of blue carbon in climate mitigation (contd…)
Chairs: Belcher A; Cavan E; Barnes D; Rogers A

1600 **Arianna Zampollo.** The potential effecs of wind farms on primary production.

1615 **Stephanie Henson.** Uncertain response of ocean biological carbon export in a changing world.

1630 **Jack Williams.** In situ Particle Measurements Deemphasize the Role of Size in Governing Particle Sinking Velocity.

1645 **Tereza Jarníková.** Understanding the Changing Role of Stratospheric Ozone in Modifying the Southern Ocean Carbon Sink.

1700 **Marika Takeuchi.** Size distribution of aggregates in coastal and pelagic waters: potential roles of aggregates in the oligotrophic wood webs.

1715 **Katrin Schmidt** Do ice algae fuel the lipid pump in the central Arctic Ocean?

Imperial RSM G.41

T14 - A decade of deep ocean science for sustainable development
Chairs: Howell K; Vieira R

1600 **Thomas Linley.** New hadal snailfish species represents an independent radiation of vertebrates into the hadal zone.

1615 **Pierre Methou.** Reproduction in deep-sea vent shrimps is influenced by diet, with rhythms apparently unlinked to surface production.

1630 **Kerry Howell.** Performance of deep-sea habitat suitability models assessed using independent data, and implications for use in sustainable management.

1645 **Amelia Bridges.** Review of the Central and South Atlantic Deep Sea: Science, Policy and Management.

1700 **Kirsty McQuaid.** Broad-scale benthic habitat classification of the South Atlantic.

1715 **Anna Gebruk.** At the interface of deep-sea science – cross-sector research collaboration to study the world's most famous deep-sea wreck during the OceanGate 2022 Titanic Expedition.

1730 **Leandro Nole Eduardo.** The crucial role of international cooperation in deep-sea science: a case study of a 7-year French-Brazilian partnership.

1745 **Otis Brunner.** Dispersal's Role in Structuring Diversity at Hydrothermal Vents, a Model System for Studying Connectivity and Conservation.

Imperial RSM G.38

T24 - The Atlantic Meridional Overturning Circulation: Observations, Simulations and Equations
Chairs: Fraser N; Jones S; Sanchez-Franks A

1600 **Pete Brown.** Enhanced northward ocean transport of anthropogenic carbon through recovery of overturning circulation may be affecting North Atlantic CO2 uptake efficiency.

1615 **Sam Jones.** Observation-based estimates of volume, heat and freshwater exchanges between the subpolar North Atlantic interior, its boundary currents and the atmosphere.

1630 **Fraser Goldsworth.** Symmetric instability in components of the Atlantic Meridional Overturning Circulation.

1645 **Charlotte Marris.** Attributing Recent Variability in the AMOC to Subpolar Surface Buoyancy-Forcing.

1700 **D. Gwyn Evans.** Mixing and air-sea buoyancy fluxes drive the overturning circulation in the subpolar North Atlantic.

1715 **Hemant Khatri.** Inter-annual Variability in the Subpolar Overturning Circulation: A Sensitivity Analysis.

1730 **Kristin Burmeister.** How do different wind forcing products impact the tropical Atlantic Ocean circulation?

1745 **Alan D. Fox.** Exceptional freshening and cooling in the eastern subpolar North Atlantic caused by reduced Labrador Sea surface heat loss.

NHM Flett

T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers (contd…)
Chairs: Scott W; Davis P; White E; Maxwell J

1600 **Yixi Zheng.** Intense upper-ocean cooling and salinification in the Amundsen Sea Polynya in austral autumn.

1615 **Sam Hartharn-Evans.** The Interaction of Internal Solitary Waves and Sea Ice in the laboratory.

1630 **Katy Sheen.** Bathymetric sills, turbulent mixing and glacier retreat in the west Antarctic Peninsula.

1645 **Joanna Zanker.** Variability in circulation and exchange in a sub-Antarctic island fjord.

1700 **Peter Sheehan.** Sources and transport of glacial meltwater in the Bellingshausen Sea, Antarctica.

1715 **Phoebe Hudson.** Key drivers of interannual variability in the Laptev Sea from satellite based sea surface salinity.

1730 **Krissy Reeve.** East versus West: the influence of Weddell Gyre circulation on long-term trends in surface nutrient concentrations.

1745 **Jasmine (Zhengxin) Yang.** CMIP6 climate change projections for the Southern Ocean sea ice and biological carbon sink.

1800 **Gillian Damerell.** New observations of the Antarctic Slope Undercurrent.

1900-2230 Conference Banquet, Natural History Museum Hintze Hall

Entrance to the Conference Banquet is at 1900 via Darwin Centre on Queen's Gate.
Ticket holders only. No strict dress code, but it's a smart dinner.

Thursday 8th September

0800-0830 **Registration open at RGS**

0830-1030 Plenary 3: Oceans and Climate

Chair: Dr Yves Plancherel, Imperial College

RGS Ondaatje Theatre

0830 Official Notice: Handing over the Presidency of the Challenger Society
0830 **Prof Michael Meredith.** Climate change and Planet Earth: a view from the poles

Abstract: Despite being remote to many of the major population centres of the planet, the polar regions are critical components of the Earth System. They are central to the planetary-scale ocean circulation, they strongly govern and modulate our climate, they are home to the last remaining ice sheets, and coupled processes here exert huge influence on global ocean productivity. The polar oceans are disproportionately threatened by climate change: they are warming rapidly, sea ice is retreating, and acidification is advancing strongly. These changes have potential to disrupt the marine ecosystem, with consequences for food security and sustainable livelihoods, both for local and Indigenous populations and beyond. Further rapid transformations are predicted throughout this century, though the severity of their impacts will depend strongly on action taken now to mitigate climate change. This talk will provide an overview of the changing polar regions and their importance to Planet Earth and its inhabitants, drawing on findings from recent and ongoing research programmes and assessments, including the recent IPCC Special Report on the Ocean and Cryosphere.

0900 **Prof Karen Heywood.** A long time ago in a glacier far, far away….

Abstract: The Amundsen Sea, Antarctica, hosts some of the world's most rapidly-thinning ice shelves. These floating ice shelves buttress the Antarctic ice sheet, so as the ice shelves thin and unstick from pinning points, there is greater Antarctic glacial ice melt leading to global sea level rise. The urgent need to better constrain future sea level rise has led to extensive international effort in the Amundsen Sea in recent decades to better understand the ocean's role in ice shelf thinning and disintegration. This has involved collaborations between glaciologists and oceanographers, between observationalists and numerical modellers, and between scientists from many countries. In this presentation I will review what we have learnt from some of these efforts and discuss what questions remain.

Much of the current research into the understanding of the Amundsen Sea ice shelves is being done under the auspices of the International Thwaites Glacier Collaboration (ITGC). I will focus particularly on the Pine Island and Thwaites glaciers in the eastern Amundsen Sea. Relatively warm Circumpolar Deep Water accesses the continental shelf through several deep troughs that facilitate flow into the cavities beneath the ice shelves, providing a flux of heat available for melting. The resultant meltwater is fresher and more buoyant; it flows westward in coastal currents. Observations from ship-based campaigns, autonomous vehicles, tagged marine mammals, moorings and earth-observing satellites have been complemented by process models; together these have enabled us to begin to identify the key mechanisms that our future climate models will need to include or parameterise.

0930 **Prof Aradhna Tripati.** Frontiers of carbonate clumped isotope geochemistry as an applied tool in oceanography, within an inclusive science framework

Abstract: The emergence of new proxies enables us to address fundamental questions about Earth's climate evolution. A promising tool for the study of past oceanographic conditions is the carbonate clumped isotope thermometer. In principle, this technique can provide a thermodynamically-based estimate of carbonate mineral formation temperature and a relatively assumption-free calculation of the oxygen isotopic composition of seawater. Over the past fifteen years, I have worked to develop its usability for oceanographic reconstructions. These efforts include studying the systematics of carbonate clumped isotopes in field-collected and cultured foraminifera and coccoliths and other archives including coral, mollusks, and lacustrine carbonates, measuring

inorganic samples that are experimentally grown, and advancing theory. In this talk, I will summarize work we have done to improve measurement capabilities, advance Bayesian tools, and highlight several applications to reconstruct ocean temperatures. Our work is being done in fields that have extremely low levels of diversity - oceanography and geochemistry - with negative impacts on culture, the health of the discipline, and scientific innovation. I will describe our work to address this issue.

1000 **Prof Paul Wilson.** How old is the Sahara Desert?

Abstract: A main goal of the Challenger Expedition was to ascertain the physical and chemical character of deep-sea deposits and their sources. Among its achievements was the identification of changes in the preponderance of biogenic oozes and inorganic red clays covering the sea floor.

The origin of the clays was hotly debated. Yet many contemporary seafaring accounts reported on-deck encounters with windblown dust. These include one from Charles Darwin aboard HMS Beagle off the Cape Verde Islands who documented ... excessively fine-grained material of a reddish brown colour... and went on to conclude... that there can be no doubt that the dust which falls in the Atlantic does come from Africa.

The North African Sahara is the largest hot desert on Earth and responsible for >50% of the global atmospheric dust load, impacting Earth's radiation budget and fertilizing productivity in far flung oceanic and terrestrial settings. Properly read, the record of dust accumulation in deep sea sediments also provides a powerful signal of past change in aridity and humidity on the continents. Here I will present new records developed from Ocean Drilling Program drillcores to address an old question: How old is the Sahara Desert?

Our findings overturn some canonical views and provide valuable context for understanding the response of the hydrological cycle to changes in global warmth and evolutionary outcomes in Africa, including those of our ancient hominid ancestors.

1030-1100 Tea, Coffee at RGS

1100-1300 Science Sessions 3a

RGS Ondaatje

T24 - The Atlantic Meridional Overturning Circulation: Observations, Simulations and Equations (contd..)
Chairs: Fraser N; Jones S; Sanchez-Franks A

1100 **Michael Bell.** Interpretation of net surface heat fluxes and Meridional Overturning Circulations in global coupled UK-HadGEM3 climate simulations.

1115 **Nick Reynard.** The role of ocean interior turbulent mixing in climate change induced internal variability.

1130 **Adam Blaker.** Wind-driven Oscillations in the Meridional Overturning Circulation near the equator.

1145 **Simon Josey.** Increasing Role for the Ocean in Setting Interannual Variability of Subpolar Atlantic Mixed Layer Heat Content.

1200 **Alice Marzocchi.** Surface atmospheric forcing as the driver of long-term pathways and timescales of ocean ventilation.

1215 **Rachael Sanders.** Causes of the 2015 North Atlantic cold anomaly in the ECCOv4 state estimate.

1230 **Oliver Tooth.** Seasonal overturning variability in the eastern subpolar North Atlantic Ocean: A Lagrangian perspective.

1245 **Sophie-Berenice Wilmes.** Was tidal mixing in the glacial ocean enhanced?

RGS Lowther

T14 - A decade of deep ocean science for sustainable development (contd..)
Chairs: Howell K; Vieira R

1100 **Giulia La Bianca.** From theory to practice: development of an ecosystem services framework for the deep sea.

1115 **Nils Piechaud.** Can Artificial Intelligence help deep-sea ecologists support sustainable development?

1130 **María Belén Arias.** Population structure and connectivity of two cold-water corals in the Southern Ocean.

1145 **Jessica Gordon.** Population structure of deep-sea octocoral Acanella arbuscula (Isididae) across the North Atlantic, using SNPs generated from UCE sequencing.

1200 **Clara Diaz.** Mesophotic Coral Ecosystems of the Chagos Archipelago.

1215 **Jenny Neuhaus.** What is the IceDivA project? Research expeditions and science in the face of Covid-19.

1230 **Leandro Nole Eduardo.** From the light blue sky to the dark deep sea: the food web structure of a tropical island revealed by stable isotope analyses.

1245 **Dannielle Eager.** Changes in fish aggregations in relation to oceanographic processes around a tropical seamount.

1300 **Sophie Arnaud Haond.** eDNAbyss: A DNA-based exploration of the largest biome on Earth

RGS Drayson

T16 - How Art-Science Collaborations can Inspire Societal Change
Chairs: Mills E; Ladd-Jones H

This session follows an open format from 1100-1200. It is followed by short presentations from T16 poster presenters.

Laurence Publicover. Arts, Sciences, and the Seafloor: Teaching and Research Challenges and Possibilities.

Geraint Rhys Whittaker. Creating space for something more? Reflections on measuring the Success of Art Science Collaborations.

Inge Panneels. Ocean ARTic: cultural ecosystem services connect society to marine ecosystem services.

Emma Hall. Seas of the Outer Hebrides: Learning from collaborative, creative approaches to public engagement.

Presentation of T16 Posters (1 min each).

T18 - HMS Challenger collections as a benchmark for oceanographic studies
Chairs: Miller G; Stukins S

1200 **Lauren Hughes.** Invertebrate Statistics from the HMS Challenger collection at the NHM, London.

1215 **C. Giles Miller.** Making the most of a collection that illuminates the debate on anthropogenic climate change: The HMS Challenger and Ocean Bottom Deposits Collection at The Natural History Museum.

1230 **Hugh Carter.** Mapping stars in the wake of Challenger: The Challenger Asteroidea and the pattern of life in the abyssal oceans.

1245 **Gillen Wood.** The Oceans 1876 Project: An Introduction.

1300 **Chris Bowler.** Tara Oceans: A Challenger expedition for the 21st century.

Imperial RSM G.41

T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans (contd…)
Chairs: Jones R; Olivelli A; Robinson S; Annett A; Branson O; Jurikova H

1100 **Lukas Marx.** The role of cyanobacteria on the biogeochemistry of nutrients and carbon in the subtropical North Atlantic gyre.

1115 **Léo Mahieu.** Iron-binding ligands distribution and binding strength in the shallow hydrothermal system of the Tonga Arc compared to surrounding deep waters.

1130 **Gemma Portlock.** Distribution of thiol and humic substances during the 2019 TONGA cruise.

1145 **Sam Wilson.** Oceanic nitrogen fixation in a changing climate.

1200 **Adam Francis.** Investigating the Extent and Controls of Nitrogen Fixation in the Mediterranean Sea.

1215 **Neil Wyatt.** Phytoplankton responses to dust addition in the Fe(Mn) co-limited Eastern Pacific sub-Antarctic differ by source region.

1230 **Rachel Rayne.** Linking high-resolution dissolved organic matter characterisation to prokaryotic metabolism in the Benguela upwelling.

Imperial RSM G.38

T5 - The role of mixoplankton and mixotrophy in the global carbon cycle
Chairs: Cormier M-A; Rickaby R; Whichello G

1100 **Ben Ward.** ***Keynote*** The ecological and biogeochemical role of mixotrophy: addressing a false dichotomy in the foundation of ocean food-webs.

1115 **Clémence Boucher.** Quantifying the growth and phagotrophic activity of the mixotrophic microalga Prymnesium parvum under different phosphorus conditions.

1130 **Marco Puglia.** Modelling the 21st century response of a mixotrophic marine ecosystem.

1145 **Leila Basti.** Mixotrophy in Harmful Algal Blooms: the Genus Dinophysis.

1200 **Marc-Andre Cormier.** Hydrogen isotope ratio in lipids is highly sensitive to the carbon metabolism protists.

1215 **Nicole Millette.** Estimating the proportion of mixoplankton in existing phytoplankton samples.

NHM Flett

T20 - Evidence to support international oceans policy
Chairs: Whomersley P

1100 **Tiago A. M. Silva.** Assessing resilience of King Scallop (*Pecten maximus*) populations through larval dispersal.

1115 **Heath Cook.** The Northeast Fisheries Science Center Bottom Trawl Survey: 60 years of surveying the western North Atlantic continental shelf, slope, and canyons.

1130 **Imali Udeshika Manikarachchi Manikarachchige.** Investigating the potential of marine science education in building marine science-policy nexus: Perspectives from a developing island nation.

1145 **James Bell.** Grading on a curve: Determining Significant Adverse Impact reference points for Vulnerable Marine Ecosystem indicator species in the northwest Atlantic.

1200 **Jazel Ouled-Cheikh.** Stronger together: fisheries enhance pressure on Mediterranean regions and pelagic species already impacted by climate change.

1215 **Jon Pitchford.** Pyramids of life – fishing for biodiversity and conservation.

1230 **Martin Collins.** Resolving ecosystem effects of the South Georgia winter krill fishery.

1245 **Carlos Veloy.** Understanding the rise of cephalopods in the western Mediterranean using biodiversity indicators.

1300-1345 Lunch at RGS and poster session

1345-1530 Science Sessions 3b

RGS Ondaatje

T17 - Physical and chemical drivers of air-sea exchange processes: waves, bubbles, aerosols and surface chemistry
Chairs: Callaghan A; Czerski H

1345 **Ryan Pereira.** ***Keynote*** Breathing Oceans: understanding the role of surface-active organic matter composition in the ocean skin layer to modulate gas exchange between the atmosphere and ocean (BOOGIE).

1400 **Thomas Bell.** Investigating the potential of radar backscatter to determine CO2 gas transfer velocities and air/sea fluxes from space.

1415 **Andrew Smith.** Parameterising CO2 air-sea gas transfer with wave breaking energy dissipation rate, sea state, and wind speed.

1430 **David Woolf.** A categorical framework for the modelling of air-sea exchange at a broken surface.

1445 **Wouter Mostert.** Dimensional and depth dependencies in energy dissipation of breaking waves.

1500 **Rui Cao.** Subsurface bubble plumes, bubble size distributions and air fraction of the two-phase flows by wave breaking under direct wind shear stress.

1515 **Joseph Peach.** Statistical distributions of whitecap variables using a novel remote sensing technique to detect and track individual whitecaps in digital sea surface images.

1530 **Helen Czerski.** Current capability, future projects and future collaboration in UK air-sea exchange research (Discussion).

RGS Lowther

T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans (contd..)
Chairs: Jones R; Olivelli A; Robinson S; Annett A; Branson O; Jurikova H

1345 **Stephan Krisch.** The Arctic Ocean is a net source of dissolved Fe and Co toward the Atlantic Ocean through the gateway of Fram Strait.

1400 **William Homoky.** The unreconciled significance of terrigenous iron supply for the ocean carbon cycle.

1415 **Rosalind Rickaby.** Global patterns of trace metal limitation shape the distribution of dominant phytoplankton in the ocean.

1430 **Leanne Murray.** A flair for phosphonates; *Roseovarius nubinhibens* obtains phosphorus from diverse substrates by expanding old pathways.

1445 **Jason Chin.** Shining a light on microbial phosphorus cycling reveals underappreciated processes.

RGS Drayson

T20 - Evidence to support international oceans policy (contd..)
Chairs: Whomersley P

1345 **Jennifer Graham.** Modelling for the Ocean Country Partnership Programme.

1400 **Matthew Palmer.** Building capacity for using marine autonomy in the Western Indian Ocean (WIO) region.

1415 **Sophie Ward.** How offshore renewable energy installations and climate change may alter marine population connectivity in the Irish Sea.

T23 - Unlocking Climate Histories from Marine Sediments
Chairs: Crocker A

1430 **Harry Baker.** Palaeomagnetic dating: an inherent issue and an improved solution

1445 **Marisa Rydzy.** Lessons Learned about Natural Gas Hydrates from 50 Years of Scientific Ocean Drilling Expeditions within DSDP/ODP/IODP Programs – A Review.

1500 **S Stainbank.** *The Maldivian archipelago marine sediment archives: Exploring the last ~500 kyr*

1515 **M Saavedra-Pellitero.** *Coccolithophores: the art of Equatorial Pacific SST and productivity reconstructions during lockdown*

Imperial RSM G.41

T26 - Physical Oceanography Open Session – Large Scale Physical Oceanography

Chairs: Brearley A

1345 **Tiago Segabinazzi Dotto.** Ocean Circulation and Heat Fluxes in Front of the Dotson Ice Shelf, Antarctica.

1400 **Jonathan Rosser.** Southern Ocean Centennial Oscillations in CMIP6 Models.

1415 **Dave Munday.** Semi-optimal perturbations to South Atlantic heat content in an eddy-resolving Southern Ocean model and a global state estimate.

1430 **Alexander Brearley.** Mixing of water masses over Discovery Bank in the Weddell-Scotia confluence of the Southern Ocean.

1445 **Bieito Fernández Castro.** Lagrangian pathways for heat, nutrients and carbon subduction with sub-Antarctic Mode Waters.

1500 **Ciara Pimm.** Quantifying the relative importance of external forcing in determining Subantarctic mode water properties across the south Pacific.

1515 **Ophélie Meuriot.** Antarctic Intermediate Water's response to climate change in CMIP6 models.

1530-1600 Tea, Coffee, Cakes at RGS

1600-1730 Plenary 4: Ocean Challenges Past and Present
Closing Ceremony & Prize Giving

Chair: Dr Adrian Glover, Natural History Museum

RGS Ondaatje Theatre

1600 **Dr Erika Jones.** From Warship to Research Vessel: Exploring the Ocean's Depths with the Challenger Expedition (1872-76)

Abstract: Oceanography today is a sophisticated, international, multidisciplinary discipline in which scientists study the ocean, Earth's largest ecosystem on which all life depends. Researchers deploy a range of specialized equipment, including ROVs (remotely operated underwater vehicles), deep sea submersibles, satellites and sophisticated computer models to investigate questions that range from the local habits of bottlenose dolphins to the drivers of climate change. But how was the ocean – and especially the deep sea – explored 150 years ago? What does oceanography today have in common with 19th century ocean science? In this talk, historian of science Dr Erika Jones takes a closer look at the Challenger Expedition (1872-76), a seminal voyage in the development of oceanography as a modern scientific discipline. Drawing on years of archival research, she dispels assumptions and myths often associated with the expedition, while bringing out how the project was shaped and aided by 19th century politics, scientific debates and technological revolutions in communication, transport and publishing practices that have come to define our increasingly connected world.

1630 **Dr Autun Purser.** Newly discovered ecosystems of the polar deeps

Abstract: Since the Challenger expedition, a plethora of deep sea ecosystems have been discovered and explored with a host of tools. The paradigm that the depths of the ocean are lifeless wastelands has been dispatched. During the last 150 years the deep sea has been revealed to be made up of a patchwork of abyssal plains, seamounts, ridges, hydrothermal provinces, methane seeps, canyons and trenches, amongst other environmental niches where life has been found to flourish.

Into the 21st century, great advances in the use of camera and acoustic systems for surveying the deep sea are showing that extensive and arresting ecosystems can still be discovered within the deeps of the world ocean.

During the last decade the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research has used the research icebreaker RV POLARSTERN, coupled with an advanced towed research platform to discover and map wholly new ecosystems from beneath the ice covered polar waters of the Arctic and Antarctic. The Ocean Floor Observation and Bathymetry System (OFOBS) combines sidescan acoustic systems and high resolution cameras to map and image remote areas of seafloor as the towing icebreaker smashes a path through sea ice.

In this presentation, the recent discoveries of the crawling sponge grounds of the high Arctic and the extensive ice fish nest arrays of the Weddell Sea, Antarctica, discoveries both made with the system, are introduced with images, videos and acoustic data collected by OFOBS during these discovery expeditions, and the future deployments of the system discussed.

1700 **Prize giving and Closing Ceremony by Prof Rosalind Rickaby, Past-President of the Challenger Society**
1730 **The Challenger Conference 2024 by Prof Nick Owens**
1745 **Conference Close**

Friday 9th September

Side Event: NHM Flett Theatre

1000-1750 **Ocean Modelling Special Interest Group (SIG)** contact: danday@bas.ac.uk

Side Event: Imperial College RSM G.41

0900-1030 ; 1600-1730 **Deep-Sea Biology Society AGM c**ontact: michelle.taylor@essex.ac.uk

All Posters by Theme and Session

Note that Poster Numbers here are the numbers used to locate the poster boards, these are organised by surname in the subsequent section.

Environment, Conservation & Governance

T1 - Deep Sea Mining 1 - geology, resource, legal, technical and societal aspects

#1 **Anna Weatherley.** Contextualising contemporary deep-sea mining debates through an analysis of a failed project located in Papua New Guinea waters.

#2 **Lucy Harris.** A Cost-Benefit Analysis of Deep-Sea Mining, With a Focus on Economic Viability and the Environmental Impacts of Removal.

T2 - Deep Sea Mining 2 - environmental aspects: baselines, impacts, monitoring

#3 **Bethany Fleming.** Variation in megafaunal diversity across different spatial scales in a mining licence area of the Clarion-Clipperton Zone.

#4 **Jon Thomassen Hestetun.** Integrated metabarcoding and morphological taxonomy: A case study from the Norwegian shelf and the potential for deep-sea applications.

#5 **Philip Weaver.** Comparison of the environmental impacts of deep-sea mining for manganese nodules, cobalt crusts and polymetallic sulphides.

#6 **Kealan Tate.** Deep-sea reducing ecosystems under a future worst-case scenario: Combining anthropogenic impacts.

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Abele A[1]; Royston S; Bamber J
[1]University of Bristol.
Talk: Abstract #172 / Session T28 - Physical Oceanography Open Session - Coastal Physics

Sources of sea-level variability on the shelf of the U.S. Atlantic coast

The gap in understanding the change of variability on approach to the coast is slowly closing with several studies considering decadal scale changes at tide gauges (Dangendorf et al., 2021; Wang et al., 2021). However, a significant proportion of sea level variability in the coastal region is higher frequency than in nearby open ocean (Ponte et al., 2019), but these sources are omitted from the assessments despite at least partly being captured by the observation systems. In this study, we present the explained variance of selected sea level variability drivers at shorter timescales (less than interannual) on the coastal shelf of the U.S. Atlantic coast and link those drivers to the modes of atmosphere circulation. We selected this region because it is a known hotspot of sea-level rise (Gehrels et al., 2020) and shows spatial differences in variability at longer timescales (interannual and longer) (Calafat et al., 2018). We used the output of GOFS/HYCOM, an eddy-resolving global ocean forecast system (Metzger et al., 2014), in addition to sea surface height anomalies derived from coastal retracked Sentinel-3A synthetic aperture radar altimeter (Dinardo et al., 2021), and hourly tide gauge total water level from UHSLC (Caldwell et al., 2015). The explored sources of higher frequency variability are wind, freshwater discharge, steric advection and buoyancy components, and manometric component of sea level, including gravitational, rotational and solid Earth deformational changes. We used principal component analysis to establish the explained variance of each component and cross-correlated the timeseries with indices of atmospheric modes.

Abrahamsen P[1]; Meredith M; Auckland C; Buckingham C; Huber B; Gordon A; Nicholls K; Frajka-Williams E; Spingys C; Garabato AN
[1]British Antarctic Survey.
Poster: Abstract #292 / Session T26 - Physical Oceanography Open Session - Water Masses

Exports of Weddell Sea Deep Water through Orkney Passage

Orkney Passage is a deep gap in South Scotia Ridge, with a sill depth of around 3650 m, and is a major export route of Weddell Sea Deep Water, a precursor of globally important Antarctic Bottom Water, which contributes to the lower limb of the Meridional Overturning Circulation. We present a time series from moorings in Orkney Passage, showing the variability in WSDW and LWSDW exports from 2011-2019, and its relation to the variability of deep water masses upstream, local mixing processes, and regional and global climate variability.

Andrews S[1]; Lewis C; Galloway T
[1]University of Exeter.
Talk: Abstract #305 / Session T12 - Interactions between plastics and marine ecosystem

The distribution and abundance of microplastics in the waters and organisms of the River Thames, UK.

Freshwater systems, specifically rivers, are important in the translocation of microplastics from terrestrial sources to the marine environment. This makes it vital to understand the abundance and distribution of plastics within them and any potential effects on freshwater organisms. The River Thames is the UK's second largest river and has multiple anthropogenic stressors and pathways of microplastic contamination along its trajectory. This study aims to determine the distribution and abundance of microplastics in the waters and benthic organisms that inhabit the River Thames. It explores how location and proximity to sites of potential contamination, and feeding type influence the ingestion of microplastics in organisms. Water samples were collected from the river in May 2019 along with benthic dwelling organisms from 3 sites of suspected microplastic contamination. Initial findings reveal a high abundance of microplastics in all water samples and abundance increases along the trajectory of the river. In all sites sampled, fragments and fibres were the dominant particle shapes. Filter feeders ingested the

highest abundance of microplastic fibres whilst grazers had the highest abundance of ingested fragments. The abundance of particles ingested by invertebrates differed across study sites showing varying levels of contamination. The presence of microplastics in a range of benthic taxa aligned with differences in dominant particle shapes in species with distinct feeding modes indicates widespread contamination with potential ecological impacts of microplastics in freshwater species of the River Thames.

Anselin J[1]; Holland P; Taylor J; Patmore R; Jenkins A
[1]British Antarctic Survey.
Poster: Abstract #14 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

Turbulence in the ice shelf-ocean boundary layer and its impact on basal melting of Antarctic ice shelves

Climate modelling studies seek to forecast the rate at which the Antarctic Ice sheet will continue to contribute to global sea-level rise in a warming future. Constrained by computational cost, the General Circulation Models used for these studies typically employ a vertical resolution that is too coarse to resolve the ocean boundary layer beneath ice shelves. As a result, they rely on poorly constrained parameterisations to represent the effect of small-scale boundary layer turbulence on ocean-driven ice shelf melt. Here we use a high-resolution General Circulation Model with periodic boundary conditions to study the turbulent processes that are unresolved in larger-scale climate models. By means of high-resolution simulations we first characterise the structure and dynamics of the ice shelf-ocean boundary layer for a range of conditions representative of the Antarctic sub-ice shelf environment. We then coarsen the vertical resolution of our model to identify the turbulent flow features that are not captured by existing parameterisations of mixing and melting beneath ice shelves. This assessment will be a step towards improved estimations of ocean-driven ice shelf melt in models that do not resolve the ice shelf-ocean boundary layer.

Anugerahanti P[1]; Tagliabue A
[1]University of Liverpool.
Poster: Abstract #8 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

Role of micronutrient limitation of phytoplankton primary productivity and community composition in a changing climate

Micronutrients, such as iron, are essential for marine phytoplankton photosynthesis and present at very low concentrations in the ocean. Many studies have shown that iron is one of the major limiting nutrients for phytoplankton growth and is consequently often explicitly represented in ocean biogeochemical models. However, the potential role for other micronutrients has not received the same attention. For example, although manganese is essential to oxygen production in photosystem II and may be present a low concentrations in some ocean regions, we lack a clear understanding of how it may combine with iron, and other major nutrients to shape biological activity. Here we use a state of the art 3D ocean biogeochemical model, PISCES-QUOTA, to assess how micronutrients regulate ocean biogeochemical cycles in a changing climate. Our model resolves three different phytoplankton functional types, two zooplankton and explicitly represents the cycling of carbon, nitrogen, phosphorus, silica, iron, manganese and zinc, with explicit phytoplankton physiological demands. We expore how different assumptions around the physiological traits associated with iron and manganese in particular contribute to uncertainty in the response of carbon fixation, export and community composition in response to climate variations.

Aparecido K[1]; Frédou T; Eduardo LN; Mincarone MM; Lima RS; Morais MFdS; Mérigot B
[1]MARBEC, Université de Montpellier , Universidade Federal Rural de Pernambuco.
Talk: Abstract #193 / Session T21 - Trait-based approaches to improve conservation, management, and restoration of our oceans

Mesopelagic fishes of Western Tropical Atlantic: insights from functional diversity

Mesopelagic fishes (200–1000 m depth) inhabit an environment characterized by cold waters and low levels of food, light, and sometimes oxygen. Consequently, these animals developed several adaptations to overcome challenges imposed by this hostile habitat. Despite its importance within intermediate trophic levels, contributing to energy transport to deeper layers acting as carbon pump, few studies on the biology and the ecology of mesopelagic fishes are available. This is mainly due to the difficulty and high cost of collecting these animals. In addition, these animals are under new threats such as climate change, deep-sea mining and fishing (as bycatch). It is thus urgent to understand the relationships between species and the environment. In this context, studies on functional diversity of communities aims to quantify species traits and to assess the effects of environmental and anthropogenic variables. Here, we identify 18 qualitative functional traits related to feeding, reproduction, survival, and locomotion of 200 species collected in the tropical western Atlantic during the 'Acoustic along the BRAzilian COaSt' surveys, carried out 2015 and 2017. We assess the functional diversity using complementary indices such as functional richness, evenness, divergence, and dispersion. We then characterize spatial distribution of functional diversity nearby oceanic islands and along the continental slope of North-eastern Brazil which are characterized by contrasted environmental and anthropogenic conditions.

Arias M[1]; Etsebeth K; Vieira R; Gordon J; Taylor M
[1]University of Essex.
Talk: Abstract #335 / Session T14 - A decade of deep ocean science for sustainable development

Population structure and connectivity of two cold-water corals in the Southern Ocean

Primnoidae is a dominant family of cold-water corals present in both deep-sea and polar regions. Their colonies create three-dimensional structures, which provide habitat for other epibenthic fauna. It has been acknowledged that cold-water corals face multiple pressures, including climate change and accidental removal from fisheries. The Southern Ocean is considered one of the most rapidly warming regions, increasing the melting of ice sheets and glaciers, threatening sessile organisms, such as corals, because they have limited dispersal abilities. Despite their ecological role in polar regions, little is known about the genetic diversity, dispersal, gene flow, and population connectivity, which are important background information to consider in the design of ecologically relevant networks of Marine Protected Areas (MPAs). Here, we used Ultra Conserved Elements (UCEs) data to screen for single nucleotide polymorphisms (SNPs) and investigate the genetic diversity, structure, and molecular connectivity of the cold-water corals, Primnoella chilensis and Dasystenella acanthina. Over 180 specimens were collected from five areas covering different bathymetrical ranges, spanning ca. 9,000 km in the sub-Antarctic and Indian Ocean. We obtained ca. 2,500 SNPs, which identified a clear genetic structure separating the populations into two distinct genetic clusters segregated by depth. Specimens inhabiting areas between 320 to 800 m formed a single cluster (Shallow-cluster), while those dwelling in depths from 900 to 1,200 m formed another (Deep-cluster). The strongest potential barrier was identified at ~900 m isobath. We will discuss these results concerning geographic distance and circulation patterns. Our results highlight the gene flow occurring across isobaths in the deep-sea, and at the same time, we identified populations with limited connectivity.

Arnott R[1]; Wain D; Cherif M; Bryant L
[1]University of Bath.
Talk: Abstract #19 / Session T27 - Physical Oceanography Open Session – Physical Drivers of Ocean Productivity

Convective mixing in mesocosms: A novel approach to realistic turbulence generation to study climate change

With climate change predicted to alter the water column stability across the world's ocean (Hallegraeff, 2010; Hinder et al., 2012; Liblik and Lips, 2019; Li et al., 2020), a mesocosm experiment was designed to ascertain how a natural phytoplankton community would respond to these changes. As a departure from other biological-physical mesocosm experiments, convective heating and cooling was used to produce four different climate scenarios ranging from well-mixed water columns ($\varepsilon = 3 \times 10^{-8}$ W/kg) through to stable stratification ($\varepsilon = 5 \times 10^{-10}$ W/kg). This method of turbulence-generation is an improvement on previous techniques (e.g., grid, shaker, aeration) which tend to produce excessive dissipation rates inconsistent with oceanic turbulence observations (Peters and Marrasé, 2000; Arnott et al., 2021; Franks et al., 2022). Chlorophyll-a profiles and cell enumeration showed a clear biological response to the different climate scenarios; motile dinoflagellates were able to persist in more quiescent scenarios while heavier, immotile diatoms were able to maintain a stable populations under more turbulent scenarios. These results suggest that our ocean may indeed experience a community shift towards

dinoflagellate species as surface stratification increases. As a majority of harmful algal bloom species are dinoflagellates (Lundholm, 2009), this potential community shift would have wide-ranging detrimental ecological and economic repercussions across the global ocean.

Atherden F[1]; Cook K; Lucas C; Lloyd G; Southam A; Weber R; Viant M; Mayor D
[1]University of Southampton, National Oceanography Centre Southampton.
Talk: Abstract #155 / Session T10 - Micro to macro: linking bottom-up and top-down approaches that investigate the function, resilience and conservation of polar ecosystems

Delving deeper into the physiology of a high latitude copepod using untargeted metabolomics

The marine copepod, Calanus finmarchicus, dominates the mesozooplankton communities throughout much of the North Atlantic and Arctic Oceans and plays important roles in food webs and the global carbon cycle. Their highly plastic life-cycle involves feeding in surface waters during the productive months and subsequent migration to depths > 500m, where they enter diapause: overwintering for > 6 months using extensive internal lipid reserves. Remaining lipid reserves then support sexual development as animals emerge at the surface during the following spring, at least partially reproductively mature. However, key questions about their enigmatic physiology remain unanswered. For example, how do they balance energetic demands with buoyancy regulation? Both of which are dependent on specific lipid compositions which are ultimately sourced from ingested phytoplankton. How do internal reserves support reproductive efforts once females have re-emerged at the surface in spring; are females able to improve reproductive output by using surplus lipids after diapause, or is reproduction solely dependent on spring grazing conditions? Answering these questions is critical for understanding how the ecological and biogeochemical functioning of high latitude ecosystems will respond to rapid climate change. In this talk I will provide an overview of how I have used metabolomics to generate unprecedented insight into the metabolism of C. finmarchicus. In particular, I will discuss exciting new hypotheses relating to how these animals simultaneously maintain neutral buoyancy and metabolic accessibility of their lipid reserves whilst experiencing near-freezing temperatures and crushing pressures in the deep sea.

Atherden F[1]; Cook K; Lucas C; Lloyd G; Southam A; Weber R; Mayor MVaD
[1]University of Southampton, National Oceanography Centre Southampton.
Talk: Abstract #155 / Session T15 - Carbon cycling in the global ocean and the role of blue carbon in climate mitigation

Delving deeper into the physiology of a high latitude copepod using untargeted metabolomics

The marine copepod, Calanus finmarchicus, dominates the mesozooplankton communities throughout much of the North Atlantic and Arctic Oceans and plays important roles in food webs and the global carbon cycle. Their highly plastic life-cycle involves feeding in surface waters during the productive months and subsequent migration to depths > 500m, where they enter diapause: overwintering for > 6 months using extensive internal lipid reserves. Remaining lipid reserves then support sexual development as animals emerge at the surface during the following spring, at least partially reproductively mature. However, key questions about their enigmatic physiology remain unanswered. For example, how do they balance energetic demands with buoyancy regulation? Both of which are dependent on specific lipid compositions which are ultimately sourced from ingested phytoplankton. How do internal reserves support reproductive efforts once females have re-emerged at the surface in spring; are females able to improve reproductive output by using surplus lipids after diapause, or is reproduction solely dependent on spring grazing conditions? Answering these questions is critical for understanding how the ecological and biogeochemical functioning of high latitude ecosystems will respond to rapid climate change. In this talk I will provide an overview of how I have used metabolomics to generate unprecedented insight into the metabolism of C. finmarchicus. In particular, I will discuss exciting new hypotheses relating to how these animals simultaneously maintain neutral buoyancy and metabolic accessibility of their lipid reserves whilst experiencing near-freezing temperatures and crushing pressures in the deep sea.

Avrutin S[1]; Goodwin P; Haigh I; Nicholls R
[1]University of Southampton.
Talk: Abstract #263 / Session T28 - Physical Oceanography Open Session - Coastal Physics

nonlinear land-ice interactions from the observational record and their implications for sea level projected sea level rise

Different methods to project sea level rise (SLR) are subject to disagreement (Orlic & Pasaric, 2013). One potential reason for this is the representation of land-ice response to warming. Most existing low-complexity models treat the relationship between warming and ice-melt as linear, even though nonlinearities exist within processes affecting this response. These non-linear processes take two forms: those that have not yet affected the observational record (e.g. tipping points as warming crosses some threshold) or those that have already occurred (they apply across all levels of warming, or the threshold has been passed). Here, we examine the effect on projections of SLR of nonlinearities that have already occurred. Results suggest that nonlinearities can be positive, negative or linear – with high-impact, low-probability super-linear interactions that can lead to sea level rise 6x faster than present (95th percentile) at 4x the level of warming. However, future warming contributes more to uncertainty in projections. It is key to note potential future nonlinearities are not considered – these will increase projections of SLR (e.g. DeConto et al., 2021).

DeConto, R. M., Pollard, D., Alley, R. B., Velicogna, I., Gasson, E., Gomez, N., Sadai, S., Condron, A., Gilford, D. M., Ashe, E. L., Kopp, R. E., Li, D., & Dutton, A. (2021). The Paris Climate Agreement and future sea-level rise from Antarctica. Nature, 593(7857), 83–89. https://doi.org/10.1038/s41586-021-03427-0
Orlić, M., & Pasarić, Z. (2013). Semi-empirical versus process-based sea-level projections for the twenty-first century. Nature Climate Change, 3(8), 735–738. https://doi.org/10.1038/nclimate1877

Babakhani P[1]; Dale AW; Woulds C; Moore O; XiaoK-Q; Curti L; Zhao M; Peacock C
[1]Earth Surface Science Institute, School of Earth and Environment, University of Leeds, Leeds LS2 9JT, UK
Talk: Session T4 - Shackleton Session: Marine Sedimentary Carbon

Dissolved organic carbon, the lost piece of the carbon cycling-preservation puzzle in global marine sediments

The unknown fate of DOC in marine sediments has fuelled the enigma about the origin of old DOC in global ocean bottom waters, which might have played a marked role in atmospheric carbon dioxide concentrations thereby regulating the Earth's climate. Several widely debated mechanisms contributing to organic carbon (OC) cycling and preservation in marine sediments are yet to be considered in mechanistic models. We develop a new modelling platform that combines a novel mechanistically-resolved reactive-transport model with artificial intelligence and Monte Carlo techniques, to take into account hydrolysis, kinetic and equilibrium sorption and geopolymerisation on a global scale in addition to all commonly known biogeochemical processes (e.g., burial, bio-turbation/-irrigation, etc.). We find that sorption and geopolymerisation are generally more important in dissolved OC cycling and preservation than some of the formerly recognised processes like bio-turbation/-irrigation and remineralisation. We show that minerals act as a shuttle, taking up DOC in the active, bioturbated sediment layer and releasing it in deeper layers, while at the depth of 1 m globally, ~60% of solid-phase OC has experienced hydrolysis and sorption. We also show that effluxes of geopolymerised OC and unreactive dissolved OC are not a substantial contributor to old DOC in ocean bottom waters (<1% of total POC mass deposited at sediment surface) while effluxes of semi-labile and labile fractions of DOC are remarkable (~23% of total POC mass deposited).

Bahlburg D[1]; Thorpe S; Murphy E; Meyer B; Berger U
[1]Technical University Dresden, UFZ Leipzig.
Talk: Abstract #339 / Session T10 - Micro to macro: linking bottom-up and top-down approaches that investigate the function, resilience and conservation of polar ecosystems

From individuals to swarms – using model ensemble runs to account for model-specific biases on life history simulations of Antarctic krill

Antarctic krill (*Euphausia superba*, hereafter krill) is a key species of the Southern Ocean Ecosystem and the target of a growing fishery. To inform science and krill management, researchers have developed numerous numerical models simulating the life history of krill under the influence of different environmental variables such as temperature or food availability. While some of these models are still regularly used, others were published and subsequently ignored. Many modeling studies also make use of only single models, leaving their conclusions prone to model-specific design choices and biases. Taking on these issues, we present the first inter-model

comparison of krill growth models. As a first step, we make the numerous existing models more accessible by implementing them in the open-source programming language R. We then simulate the models using the same set of environmental input data and use the resulting range of predictions to analyze inter-model variability and model-specific biases. By doing so, we a) provide a first systematical overview of krill growth model variability and individual bias, b) provide an easy-to-use and open-access resource for other researchers and c) build a framework that enables krill growth model ensemble runs utilizing the whole diversity of published krill growth models.

Baker H[1]; Howlett C; Xuan C; Oda H
[1]National Oceanography Centre, University of Southampton.
Talk: Abstract #294 / Session T23 - Unlocking Climate Histories from Marine Sediments

Robust evaluation of the SRM measurement deconvolution software 'UDECON' using a constructed synthetic u-channel sample, genuine marine sediment, and modern 3D printing technology.

Palaeomagnetism is an excellent tool for precisely dating climate indicators within sediments such as those collected on board IODP expeditions. Superconducting Rock Magnetometers (SRMs) are frequently used in palaeomagnetic study to perform pass-through measurements of continuous sediment records. However, these measurements are smoothed and distorted due to a convolution effect caused by the SRM sensor response. This obscures centimetre-scale variation, reducing the effective resolution of the data and limiting the effectiveness of palaeomagnetic sediment dating. Therefore, data deconvolution is necessary. UDECON is a software package capable of reading SRM measurements and performing optimised deconvolution. However, palaeomagnetic deconvolution is yet to be robustly tested. Here, we test the ability of UDECON to restore high resolution palaeomagnetic data through the construction and use of a 20cm synthetic segmented u-channel sample, made with authentic marine sediment utilising modern 3D printing technology. A synthetic signal containing a short-lived geomagnetic event (an excursion) is acquired by the sample and measured on an SRM both discretely and continuously. We find that the signal is almost completely obscured when measured continuously. UDECON then excellently restores the original signal in both direction and intensity, allowing the excursion to re-emerge. About 80% of the data is restored to within 10% of the original record in both direction and intensity, with a standard deviation of <5% of the total record intensity over 50 repeat measurements. Through further study we hope to understand why certain measurement points were not fully restored and to provide an improved tool for palaeomagnetic deconvolution.

Baker L[1]; Mashayek A; Naveira-Garabato A
[1]Imperial College London.
Talk: Abstract #18 / Session T25 - Physical Oceanography Open Session - Ocean Eddies

Upwelling of abyssal waters by boundary turbulence

Water mass transformation caused by turbulent mixing in the ocean is key to regulating the overturning meridional circulation, allowing deep abyssal waters to upwell and eventually ventilate at the ocean surface. Recently, evidence has been mounting that much of this upwelling must occur in the bottom boundary layer close to sea-floor topography. However, the mechanisms by which this upwelling takes place and the physical processes that facilitate boundary layer turbulence are not well understood. Here, we verify the upwelling of abyssal waters in a realistic model of the Drake Passage in the Southern Ocean, and investigate the mechanisms underpinning it. The Southern Ocean is a key location for abyssal mixing of dense Antarctic Bottom Water that is formed at high latitudes and sinks to the bottom before creeping northwards while mixing with lighter waters above. The Drake Passage in particular plays an important role in mixing abyssal waters due to the very rough topography in the region, which interacts with the energetic mesoscale eddy field of the Antarctic Circumpolar Current. We show that water mass transformation in the model implies upwelling of dense abyssal waters, and that this result is largely dependent on the near boundary stratification. This regime is characterised by sporadic overturning events, whereby unstable overturns develop due to vertically sheared flows interacting with the bottom boundary. We discuss some of the mechanisms for this development of shear, including bottom Ekman layers, internal waves, and geostrophic adjustment of the highly stratified interface of separate water masses.

Bakker D[1]; Alin SR; Becker M; Bittig H; Castaño-Primo R; Kadono K; Kozyr A; Munro DR; Nakaoka S; Nojiri Y; O'Brien KM; Pfeil B; Pierrot D; Sutton A; Tilbrook B; Wada C; Wanninkhof R; Wranne AW; and more than 100 other SOCAT contributors from around the world
[1]Centre for Ocean and Atmospheric Sciences, School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, United Kingdom.
Poster: Abstract #55 / Session T17 - Physical and chemical drivers of air-sea exchange processes: waves, bubbles, aerosols and surface chemistry

The Surface Ocean CO2 Atlas for quantification of ocean CO2 uptake

The ocean absorbs a quarter of the global CO2 (carbon dioxide) emissions from human activity. The community-led Surface Ocean CO2 Atlas (SOCAT, www.socat.info) is key for the quantification of ocean CO2 uptake and its variation, now and in the future, as humankind moves towards net zero CO2 emissions. The quality-controlled SOCAT synthesis products contain more than 30 million in situ surface ocean CO2 measurements with an estimated accuracy of < 5 µatm. Additional CO2 sensor data with an accuracy of 5 to 10 µatm are separately available. SOCAT synthesis products have an annual public release, typically in mid-June. SOCAT is used for quantification of ocean CO2 uptake and ocean acidification and for evaluation of sensor data and climate models. SOCAT contributes towards United Nations Sustainable Development Goal (SDG) 14.3.1 ocean acidification via the IOC-led (Intergovernmental Oceanographic Commission) initiative for a federated data system via ERDDAP. The SOCAT synthesis products are an essential part of the value chain based on in situ inorganic carbon measurements of the oceans, which provides policy makers with essential information in climate negotiations. The global need for accurate knowledge of ocean CO2 uptake and its (future) variation makes sustained, long-term funding for in situ surface ocean CO2 measurements and their synthesis imperative.

Balazy P[1]; Romero-Ramirez A; Luna HLM; Chelchowski M; Kuklinski P; Dąbrowska AM; Balazy K
[1]Institute of Oceanology Polish Academy of Sciences (IO PAN).
Talk: Abstract #79 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

Year-round foraging activity of Arctic filter feeders studied with time-lapse photography

In the European Artic and Spitsbergen island the sea water temperatures and ice conditions in recent years are similar to what models have predicted for most of the Artic coastal areas in the second half of this century. This contrasted with the Nothern Norway, representing the "Gate to the Artic", constitutes a perfect system for ecological studies providing an insight into the "Artic of the future". Within this context, long term data from the benthic marine realm from these regions are very valuable but still scarce. In order to investigate the foraging activity of artic filter feeders, we monitored Semibalanus balanoides barnacles continuously from July 2019 to July 2020 with 30 minutes intervals with time-lapse photography, simultaneously in Isfjorden (Spitsbergen, 78° N) and in Ramfjorden (Northern Norway, 69° N). These remote observations were accompanied with time-synchronized measurements of basic sea water parameters (temperature, light, water level, currents, chlorophyll a, turbidity) at each site. Additionally bacterio- and mesozooplankton samples were collected seasonally. As a proxy of animal feeding, the images were analysed to detect the presence of barnacle cirri and subsequently correlated with the environmental data. The results shed new light on the biology and ecology of filter feeders, especially during poorly studied period of the polar night but most importantly have the possibility to explore the environmental plasticity of feeding strategies of filter feeders under distinct conditions.

This study has been performed within the framework of a National Science Center project No. 2018/29/B/NZ8/02340

Blackburn O[1], Baldwin H[1]; Treloar E; Mienis F; Duineveld GC; Lavaleye M; Davies AJ; Robertson CM
[1]Bangor University.
Talk: Abstract #330 / Session T21 - Trait-based approaches to improve conservation, management, and restoration of our oceans

Benthic functional diversity in deep-sea coral reefs across a habitat complexity gradient in the Rockall Bank, NE Atlantic

There is a growing need for ecological indicators, such as measures of functional diversity (FD), to inform marine ecological understanding. Although baseline studies provide valuable biodiversity information, there is a need to understand the nuance of functional services provided by resident benthic fauna within an ecosystem. The use of functional indices is essential to understanding the relationships between benthic ecosystem functioning and community resilience, anthropogenic impacts and changing oceanic conditions. This study aimed to address knowledge gaps in benthic FD and use FD indices to better understand benthic macrofaunal community assemblages associated with Desmophyllum pertusum cold-water coral reefs in the Logachev Mound Province, of the Rockall Bank (UK). Habitat complexity gradient (coral framework L m2) was defined across four biotopes: coral rubble, low coral framework, dead coral framework and live coral framework, from boxcore samples collected from two-cross mound transects from the Haas Mound, to draw comparisons between habitat heterogeneity and FD of benthic assemblages. FD was assessed through functional trait analysis (FTA), using a selection of functional traits assigned to taxa families to calculate FD indices. Pearson's rank. Pearson's rank correlation was conducted to verify the relationships between FD and habitat heterogeneity. The study hypothesis that FD indices positively corresponds to increased habitat complexity, was accepted. The findings highlight the usefulness of using trait-based approaches as a tool for assessing ecosystem functioning and enhance our understanding of ecosystem resilience and services in deep-sea coral habitats. More baseline data regarding keystone benthic species is required, to give a more comprehensive understanding of the effect of functional diversity on ecosystem resilience and functioning.

Basti L[1]; Nagai S
[1]Japan Fisheries Research and Education Agency; Tokyo University of Marine Science and Technology; United Arab Emirates University.
Talk: Abstract #318 / Session T5 - The role of mixoplankton and mixotrophy in the global carbon cycle

Mixotrophy in Harmful Algal Blooms: the Genus Dinophysis

Mixotrophy is a constitutive part of planktonic ecosystems and food webs; enhancing primary production, transferring biomass to higher trophic levels, and contributing to the functioning of the biological carbon pump. The discovery of mixotrophy has changed perception of blooms of several species of harmful algae (HAB) in coastal and open waters, notably regarding the outbreak of the harmful events, the dominance of a species during an outbreak, and the succession of species in consecutive outbreaks. The trade-offs between phototrophy (inorganic nutrients) and phagotrophy (predation) by mixotrophic HAB remains to be better understood and modeled, specifically for those species that occur at very low cell densities but form blooms in thin oceanic layers, such as harmful species of the genus Dinophysis (Stoecker et al., 2006; 2017; Burkholder et al., 2008; Jeong et al., 2010; Davidson et al., 2012; Glibert et val., 2018a; Blossom and Hansen, 2020; Li et al., 2022) . For long, the inability to culture Dinophysis spp. has hampered understanding its ecophysiology, bloom formation, and toxin production until the discovery of its mixotrophy. Since then, several strains of a few species have been cultured under laboratory conditions, albeit in a few locations around the world (Basti et al., 2018; Nagai et al., 2020). In the present talk, we share our experiments and results regarding feeding, growth and toxin production of several cosmopolitan species of Dinophysis based on an assemblage cryptophyte-ciliate-dinoflagellate (e.g. Nishitani et al., 2008a,b; 2012; Nagai et al., 2012; Basti et al., 2015; 2018; Hongo et al., 2019).

Beighton C[1]; Burgess G; Davenport R
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Poster: Abstract #197 / Session T12 - Interactions between plastics and marine ecosystem

Exploring the extent of microbially driven plastic degradation in the marine environment.

Plastic pollution is a growing environmental threat with the quantity of plastics entering the marine environment increasing annually. The plastics entering the ocean cause a variety of environmental problems. Previous research has focused on identifying bacteria in the plastisphere and elucidating their ecological roles. However, the nature of the relationship between attached bacteria and plastics in the marine environment is unknown. This aim of this study was to further understand the fate of plastics in the marine environment, with particular emphasis on microbial attachment to and potential degradation of marine plastics. The presence of polycaprolactone (PCL) degrading bacteria, was investigated by measuring the rate of PCL degradation, measuring the adhesive strength of each strain and determining if there is preferential adhesion to plastics over other non plastic surfaces. Sixteen strains have been screened for polymer degradative ability on PCL plates, with 9 producing positive results. Rates

of degradation were measured using gravimetric weight loss. Comparative adhesive studies were performed using a water jet apparatus. This study has an emphasis on comparing the efficiency of multiple species capable of polymer degradation, their adhesive capabilities and preferential attachment, and will provide a more thorough understanding of the processes of microbial attachment and degradation of plastics in the marine environment.

Belcher A[1]; Henley S; Hendry K; Manno C
[1]British Antarctic Survey.
Talk: Abstract #9 / Session T10 - Micro to macro: linking bottom-up and top-down approaches that investigate the function, resilience and conservation of polar ecosystems

Ecological drivers of carbon flux in the Scotia Sea, Southern Ocean: A stable isotope approach

The biological carbon pump is responsible for much of the decadal variability in the ocean CO2 sink, driving the transfer of carbon from the atmosphere to the deep ocean. Yet the flux of sinking particulate organic matter (POC) varies greatly on regional and global scales, as well as seasonally and interannually. Mechanistic understanding the ecological drivers of POC flux is therefore key to both the assessment of the magnitude of the ocean CO2 sink, as well as for accurate predictions as to how this will change with changing climate. The Scotia Sea is one of the most productive regions of the Southern Ocean with large and long-lasting phytoplankton blooms that support high fluxes of sinking POC to the deep sea. We present results from two sediment traps, deployed at 400 and 2000 m, in the iron fertilised region off South Georgia. We see a clear seasonal cycle in POC and biogenic silica fluxes, with high flux periods in the spring and summer months and low fluxes in the winter. Stable isotopes suggest different ecological drivers of the high flux periods supported by assessment of the phytoplankton community in the trap material. We assess how changing phytoplankton community structure can impact isotopic signatures of particulate organic carbon and nitrogen (δ13Cpoc and δ15NPN) and biogeochemical cycling.

Bell J[1]; Kenny A; Blasdale T; Downie A; Kenchington E; Koen-Alonso M; Neves B; Ollerhead N; Pepin P; Sacau M
[1]Cefas.
Talk: Abstract #103 / Session T20 - Evidence to support international oceans policy

Grading on a curve: Determining Significant Adverse Impact reference points for Vulnerable Marine Ecosystem indicator species in the northwest Atlantic

The Food and Agriculture Organisation guidelines for Deep-Sea Fisheries (2006) state that Authorities and States should seek to avoid significant adverse impacts (SAI) from fishing upon deep-sea ecosystems. However, it has since not been possible to explicitly define SAI, or to determine where they may have already occurred. Since 2010, the Northwest Atlantic Fisheries Organisation (NAFO) have been engaged in a programme of work that aims to understand the extent of SAI in its regulatory area. Here, we describe the process and analysis framework that this programme has taken; first in defining and mapping the significant extents of different vulnerable marine ecosystems in the NW Atlantic, and second in understanding their particular responses to fishing intensity, predominantly demersal trawling, which occurs widely in this area. We find that, although many VME indicator species share the same basic 'response curve' to fishing intensity, the specific values at which SAI are likely to have occurred vary strongly between species groups, as does the degree to which existing management measure are likely effective. At the reference points currently proposed, between 4.7 and 51.4 % of the area of each of the VME types within the NAFO regulatory area are judged to have been subject to SAI between 2010 and 2019. By comparison, together with VME areas outside of the established fishing footprint, NAFO bottom closures prohibit fishing in 0.6 – 64.2 % of the areas of each VME type.

Bell M[1]; Storkey GND
[1]Met Office.
Talk: Abstract #295 / Session T24 - The Atlantic Meridional Overturning Circulation: Observations, Simulations and Equations

Interpretation of net surface heat fluxes and Meridional Overturning Circulations in global coupled UK-HadGEM3 climate simulations

The annual mean net surface heat fluxes (NSHFs) from the ocean to the atmosphere play an important role in driving both atmospheric circulations and oceanic meridional overturning circulations. Those generated by historical forcing simulations using the UK HadGEM3-GC3.1 coupled climate model are shown to be relatively independent of resolution, for model horizontal grid spacings between 1o and 1/12o, and to agree well with those based on the DEEPC analyses for the period 2000--2009. Interpretations of the geographical patterns of the NSHFs are suggested that are based on relatively simple dynamical ideas. As a step toward investigation of their validity, we examine the contributions to the rate of change of the active tracers (potential temperature, salinity and potential density) from the main terms in their prognostic equations as a function of the active tracer and latitude. We find that the main contributions from vertical mixing occur in ``near surface'' layers and that, except at high latitudes, the time-mean advection of potential temperature and density is well anti-correlated with the sum of the surface fluxes and vertical diffusion. By contrast, the tracer budget for the salinity has at least four terms of comparable magnitude. The heat input by latitude bands is shown to be dominated by the NSHFs, the time-mean advection, and the equatorial Pacific. Expressions for global integrals of the salt and heat content tendencies due to advection as a function of salinity and potential temperature respectively are derived and shown to make contributions that should not be neglected.

Bell T[1]; Yang M; Dong Y; Kitidis V; Marie L; Smyth T
[1]Plymouth Marine Laboratory.
Talk: Abstract #319 / Session T17 - Physical and chemical drivers of air-sea exchange processes: waves, bubbles, aerosols and surface chemistry

Investigating the potential of radar backscatter to determine CO2 gas transfer velocities and air/sea fluxes from space

The gas transfer velocity of carbon dioxide (KCO2) describes the rate at which CO2 transfers across the air/sea interface. KCO2 is influenced by near surface turbulence or roughness, but in practice is often parameterized using wind speed. Satellite backscatter/roughness measurements are typically used to infer sea surface wind stress/speed, and these have been used to estimate global air/sea CO2 fluxes. Polarized synthetic aperture radar (SAR) measurements of surface roughness are influenced by non-breaking waves and other surface properties such as foam/whitecaps and surface 'slicks' (which indicate the presence of surfactants). Bubbles and surfactants are important for air/sea gas exchange and a potential source of variance in the KCO2-wind speed relationship. Concurrent observations will be presented of KCO2 and shipborne C-band (SAR) backscatter from two Atlantic Meridional Transect (AMT) cruises (AMT-28, Oct. 2018; AMT-29, Oct. 2019). Measurements of eddy covariance CO2 fluxes (FCO2) and the air/sea CO2 concentration difference (ΔCO2) were used to calculate KCO2 (= FCO2/ΔCO2). The data span a 2-15 m/s range in wind speed, encompassing conditions when waves break and bubbles/whitecaps form. The relationship between KCO2 and in situ wind speed agrees well with recent parameterisations of KCO2. The in situ SAR observations explain more variance in KCO2 than wind speed. Different polarizations and incidence angles were investigated, with a maximum correlation achieved using horizontal-vertical polarized backscatter at a 50° angle. The possibility of using satellite backscatter retrievals as a more direct and accurate estimate of KCO2 and for global air/sea CO2 flux estimates will be discussed.

Birchenall P[1]; Jones-Williams K; Rowlands E; Johnston L; Manno C
[1]British Antarctic Survey.
Poster: Abstract #110 / Session T12 - Interactions between plastics and marine ecosystem

Microplastic distribution and characteristics around the South Sandwich Islands, Southern Ocean.

Nine billion metric tonnes of plastic has been produced from 1950-2000, with an estimated 59% discarded as waste. The Southern Ocean (SO) is considered an area of low plastic pollution, but not exempt, with the role of strong circumpolar frontal systems in physically isolating the region as biogeographic barriers often exaggerated. Furthermore, SO organisms are more vulnerable to anthropogenic environmental stressors than species of lower latitudes; due to specialized adaptions to extreme yet stable environmental conditions. This study investigated the distribution and characteristics of sea surface microplastic pollution sampled from surface seawaters in the Atlantic sector of the Southern Ocean; and are characterized by increasing shipping traffic from fishing and the growing tourism market. Samples were collected during a cruise research expedition around the South Sandwich

Islands on the RRS Discovery using a modified surface-towed neuston net comprising of two nets with different mesh sizes (100 and 300 micron). Microplastic polymers were identified using Fourier Transform Infra-Red Spectroscopy. Preliminary results indicate that microplastic abundance, shape, and type vary between stations. We also observed that significant amounts of microplastic were associated with ship traffic, such as paint chips (from anti-fouling paint) and black rubber. The amount of microplastic in pelagic amphipods collected with the net was investigated opportunistically, finding that microplastic was present in groups tested. This study highlighted the need to prioritize long-term comparative investigations into seawater and biota microplastic distributions to develop a more comprehensive understanding of microplastic pollution interactions to Southern Ocean marine ecosystems.

Birchill A[1]; Baker C; Martin A; Ussher S; Milne A; Turnbull I; Wyatt N; Moore M
[1]University of Portsmouth.
Poster: Abstract #187 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

The Pacific Antarctic Ridge and Southern East Pacific Rise as key sources of iron and manganese to the Southern Ocean

The availability of iron (Fe) is known to limit the efficiency of the biological carbon pump over large areas of the ocean and recent evidence also suggests manganese is co-limiting in certain regions of the Southern Ocean. Fe and Mn are far more concentrated in hydrothermal fluids (by a factor of >106) relative to background seawater and hydrothermal venting is estimated to supply 4 ± 1 Gmol dFe yr-1 to the deep ocean. Due to the inhibition of vertical mixing in the deep ocean, hydrothermal plumes travel predominantly along isopycnals that can eventually shoal and outcrop into intermediate and surface waters, meaning hydrothermal sources of trace metals can reach the surface and influencing the seasonal biological pump. Here we report the first full depth trace metal profiles of the poorly studied southeast Pacific sector of the Southern Ocean (54.4 S, 89 W to 60 S , 89 W) during the UK-led CUSTARD project. This revealed a significant mid-depth (ca. 2000m) hydrothermal dFe and dMn signal. Elevated Fe and Mn deep water concentrations were evident along an entire north-south transect in the region. Using co-located historic helium (He) isotope measurements and Lagrangian particle tracking experiments, we argue that this signal results from direct input of dFe into the Circumpolar Deep Waters of the SO from basin scale transport of hydrothermal Fe and Mn transport from the Pacific Antarctic Ridge (PAR) and southern East Pacific Rise (SEPR).

Bischof H[1]; Goldberg D; Henley S; Fraser N
[1]University of Edinburgh.
Poster: Abstract #209 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

Spatial variations in the sea ice-mixed layer depth relationship in the West Antarctic Peninsula

The impacts of upper-ocean mixing on primary productivity are complex and range from an entrainment of nutrients to modulating light limitations. Sea ice in turn plays an important role in determining mixing conditions through its cycles of formation and melt, and by moderating wind forcing. With sea ice conditions projected to undergo large changes over the course of the century, understanding the relationship between sea ice and upper-ocean mixing is crucial for understanding the impacts of climate change on biological production in the polar regions. Due to the inaccessibility of sea ice-covered waters however, mixed layer depth observations are often not available at a high temporal and spatial resolution. Here we present an analysis of sea ice-mixed layer depth relationships during a 40-year regional ocean-sea ice simulation of the West Antarctic Peninsula (WAP) and Bellingshausen Sea, a highly biologically productive region of global importance. The relationship between winter sea ice and spring mixed layer depth shows clear differences on and off the WAP continental shelf, with decadal variations in the location of the boundary between negative and positive correlations. Mechanisms considered include the nonlinear relationship between sea ice cover and turbulent mixing, the upwelling of warm Circumpolar Deep Water, and a difference in the sea ice seasonal cycle between the two regions. The presented findings have implications for the spatial distribution of primary producers in a more ice-free future West Antarctic Peninsula.

Blaker A[1]; Bell M; Hirschi J; Baker L
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Talk: Abstract #36 / Session T24 - The Atlantic Meridional Overturning Circulation: Observations, Simulations and Equations

Wind-driven Oscillations in the Meridional Overturning Circulation near the equator

Numerical model studies have shown the meridional overturning circulation (MOC) to exhibit variability on near-inertial timescales, and also indicate a region of enhanced variability on the equator. We present an analysis of a set of integrations of a global configuration of a numerical ocean model, which show very large amplitude oscillations in the MOCs in the Atlantic, Indian and Pacific oceans confined to the equatorial region. The amplitude of these oscillations is proportional to the width of the ocean basin, typically about 100 (200) Sv in the Atlantic (Pacific). We show that these oscillations are driven by surface winds within 10°N/S of the equator, and their periods (typically 4-10 days) correspond to a small number of low mode equatorially trapped planetary waves. Furthermore, the oscillations can be well reproduced by idealised wind-driven simulations linearised about a state of rest, indicating that they are highly predictable if the surface wind field is well-known. Observations of dynamic height from the Tropical Atmosphere Ocean (TAO) mooring array in the equatorial Pacific also exhibit spectral peaks consistent with the dispersion relation for equatorially trapped waves. Here, we revisit the TAO observations to confirm that the amplitude of the oscillations is consistent with the simulations, supporting the modelled large amplitude MOC oscillations. Our results raise questions about the roles of inertia-gravity waves near the equator in the vertical transfer of heat and momentum and whether these transfers will be explicitly resolved by ocean models or need to be parameterised.

Boucher C[1]; Julie A; Damien R; Thomas L; Francis M; Juel HP
[1]IFREMER National Institute for Ocean Science.
Talk: Abstract #66 / Session T5 - The role of mixoplankton and mixotrophy in the global carbon cycle

Quantifying the growth and phagotrophic activity of the mixotrophic microalga Prymnesium parvum under different phosphorus conditions

Prey ingestion can significantly increase the growth rate of some harmful algae and may explain their ecological success. This trophic mode is generally enhanced when environmental conditions are not optimal for growth. Using the ichthyotoxic haptophyte Prymnesium parvum as a model, laboratory experiments were conducted over a month to test the effects of phosphorus (P) sufficiency and deficiency on its growth and phagotrophic activity. P-deficient P. parvum cultures were grown with or without addition of phosphorus (P) as either inorganic nutrient and/or algal prey (i.e. the cryptophyte Teleaulax amphioxeia). Detection and quantification of the phagotrophic activity of P. parvum was performed using a combination of confocal microscopic observations, cell sorting and flow cytometry fluorescence measurements. The feeding rate of P. parvum on T. amphioxeia was calculated based on the phycoerythrin (PE) fluorescence signal. In P-deficient cultures, the mean growth rate of P. parvum was higher with the addition of prey than with inorganic P (0.58 ± 0.02 vs. 0.42 ± 0.05 d-1) and was maximal when both sources of P were added (0.79 ± 0.07 d-1). The amount of T. amphioxeia ingested per P. parvum reached a maximum of 0.4 and 0.66 prey cells per day when grown with and without addition of inorganic P, respectively. Therefore, the ingestion of organic phosphorus played an important role in P. parvum growth, and could explain its efficiency in forming blooms. Furthermore, our results suggest that the ingestion rate depends on the prey/predator ratio, rather than on the abundance of prey, indicating a role of released toxins for the capture of prey cells. Further experiments assessing the production of toxic compounds (intra and extra cellular) will allow us to study the link between mixotrophy, toxicity, growth and the physiological state of P. parvum.

Bowler C[1]
[1]Ecole normale supérieure.
Talk: Abstract #145 / Session T18 - HMS Challenger collections as a benchmark for oceanographic studies

Tara Oceans: A Challenger expedition for the 21st century

Inspired by Darwin's voyage on the Beagle and the HMS Challenger expedition 50 years later, a multidisciplinary consortium, Tara Oceans, was formed around the 36m research schooner Tara, and sampled plankton at more than 210 sites and multiple depth layers in all the major oceanic regions during two circumglobal navigations

from 2009-2013 (Karsenti et al. Plos Biol., 2011). This talk will summarize the foundational resources from the project, which collectively represent the largest DNA sequencing effort for the oceans (see Science special issue May 22, 2015 and Sunagawa et al. Nature Rev. Microbiol. (2020)), and analyses that illustrate several aspects of the Tara Oceans' eco-systems biology approach to address microbial contributions to ecological and evolutionary processes. The project provides unique resources for several scientific disciplines that are foundational for mapping ocean biodiversity of a wide range of organisms that are rarely studied together, exploring their interactions, and integrating biology into our physico-chemical understanding of the ocean, as well as for identifying new organisms and genes of biotechnological interest. Hundreds of research papers based on exploration of Tara Oceans data have already been published, some of which have compared samples collected by Tara with those collected by the Challenger expedition 150 years ago, notably to study the impact of ocean acidification on foraminifera. These advances, and the scientific innovations emerging to disentangle the huge multi-dimensional datasets, are furthermore critical for developing baseline ecological context and the predictive power needed to track the impact of climate change on ocean ecosystems and the services they perform.

Bowley J[1]; Lewis C; Baker-Austin C; Michell S
[1]University of Exeter.
Talk: Abstract #274 / Session T12 - Interactions between plastics and marine ecosystem

Pathogens transported by plastics: does this vector pose a risk to marine ecosystems?

There is increasing interest and evidence that pathogens attach to microplastics and this is raising concerns that microplastics might act as a vector for pathogen transport within marine ecosystems. First coined the 'plastisphere' in 2013, the plastisphere is originally comprised of an assortment of bacteria that develops a biofilm on its surface. Many potential pathogens have been found to be incorporated within the plastisphere community. Here we will review what is and is not currently known about pathogen attachment and the potential transfer of pathogens from ingested microplastics into marine organisms. Given the limited understanding of pathogen attachment processes over time and presence of pathotypes, we will present our field experiment to address this knowledge gap. We conducted a series of experiments in Fleet Lagoon, Weymouth (a known pathogen hotspot). Three polymers (Polypropylene, Polyethylene and Polystyrene) were incubated at three different sites with three time points, 1 week, 2 weeks and 4, weeks to examine pathogen presence and succession within the plastisphere. 16S Illumina amplicon sequencing was used for community analysis to determine if any potential pathogens were present. From this data, qPCR was used to examine any ASVs (amplicon sequence variant) of interest by examining for virulence genes within the samples. We will discuss how the plastisphere community develops over time as well as comparisons to the prevailing planktonic and particle attached fraction and glass beads, which was used as a natural control. This all adds to our understanding of plastics as a novel vector of pathogens.

Brearley A[1]; Girton J; Lucas N; Thurnherr A; Meredith M; Abrahamsen P; Venables H
[1]British Antarctic Survey.
Talk: Abstract #153 / Session T26 - Physical Oceanography Open Session - Water Masses

Mixing of water masses over Discovery Bank in the Weddell-Scotia confluence of the Southern Ocean

Seamounts in the Southern Ocean, through their interaction with deep-reaching geostrophic flows and barotropic tides, play a key role in mixing and water mass transformation, important processes in the global Meridional Overturning Circulation. The Weddell-Scotia Confluence (WSC), which separates the Antarctic Circumpolar Current (ACC) to the north from the Weddell Gyre (WG) to the south, lies above a region of highly complex topography, including the seamounts of Discovery Bank and Bruce Bank. In this presentation, we present results from a targeted experiment over Discovery Bank in early 2019, incorporating ship-based CTD, lowered ADCP and microstructure measurements, glider sections and fine-scale velocity data from 2 EM-APEX floats. While the CTD, ADCP and float data demonstrate the large-scale flow is consistent with a stratified Taylor-column structure that retains water over the seamount for long periods, there are regions of the seamount where the float trajectories "loop", and where under where vertical shear and dissipation of turbulent kinetic energy is significantly enhanced compared with background levels. In these areas, the slow "blending" of the seamount on the flows may be short-circuited by more rapid turbulent mixing processes. Ongoing analysis is focusing on the relative contributions of these particular locations compared to the large-scale circulation structure in mediating exchanges between the WG, and on the relative importance of tides versus geostrophic flows in generating these hotspots of enhanced mixing.

Bribiesca-Contreras G[1]; Wiklund H; Dahlgren T; Drennan R; Smith C; Glover A
[1]Natural History Museum.
Talk: Abstract #298 / Session T2 - Deep Sea Mining 2 - environmental aspects: baselines, impacts, monitoring

Biodiversity of abyssal invertebrates associated with polymetallic nodules

The Clarion-Clipperton Zone (CCZ), a large abyssal area in the central Pacific Ocean, has the largest concentrations of polymetallic nodules[1]. These potato-size rocks contain commercially valuable metals such as copper, nickel, and cobalt, which are commonly used in electronics[2]. But they also represent an important habitat in abyssal ecosystems, being mostly the only form of hard substrate. Most taxa of nodule fauna require attaching to hard substrate in order to survive and are not represented in sediment fauna. Hence, the removal of nodules would have a direct impact on the biodiversity of nodule fauna. Despite the numerous expeditions to the CCZ, nodule-associated fauna for the region remains poorly characterised. Megafaunal surveys from seafloor images have described diversity patterns of nodule-associated megafauna, but smaller organisms have been overlooked. Here, we present data from a large quantitative study of 98 box cores taken across different areas in the eastern CCZ. The number of nodule fauna ranged from 39 to 44 specimens per box, with species of bryozoans and sponges representing most of the nodule fauna.

[1]Wedding, L. M., Friedlander, A. M., Kittinger, J. N., Watling, L., Gaines, S. D., Bennett, M., ... & Smith, C. R. (2013). From principles to practice: a spatial approach to systematic conservation planning in the deep sea. Proceedings of the Royal Society B: Biological Sciences, 280(1773), 20131684.
[2]Hein, J. R., Koschinsky, A., & Kuhn, T. (2020). Deep-ocean polymetallic nodules as a resource for critical materials. Nature Reviews Earth & Environment, 1(3), 158-169.

Bridges A[1]; McQuaid K; Butt S; Sink K; Atkinson L; Brandt A; Braga-Henriques A; Stevenson A; Saeedi H; Bax N; Freiwald A; Beuck L; Carranza A; Gaudron SM; Perez JAA; Amaro T; Vieira R; MG; Pearman TRR; Horton T; Wienberg C; Hebbeln D; Milligan RJ; Doti BL; Lauretta D; Titschack J; Vinha B; Huvenne V; Gori A; Orejas C; Bravo ME; Narayanaswamy BE; Howell KL
[1]University of Plymouth.
Talk: Abstract #258 / Session T14 - A decade of deep ocean science for sustainable development

Review of the Central and South Atlantic Deep Sea: Science, Policy and Management

The Central and South Atlantic represents a vast ocean area, home to a diverse range of ecosystems and species. Nevertheless, and similarly to the rest of the global south, the area is comparatively understudied yet exposed to increasing levels of multi-sectoral exploitation. To counteract this, the level of scientific exploration in the Central and South Atlantic has increased in recent years and will likely continue to do so within the context of the United Nations (UN) Decade of Ocean Science for Sustainable Development. Here, we compile the literature to investigate the distribution of previous scientific exploration of offshore (30 m+) ecosystems in the Central and South Atlantic both within and beyond national jurisdiction, allowing us to synthesise overall patterns of biodiversity and link them to key environmental parameters. Through this exercise, we have identified key knowledge gaps, both spatial and thematic, that represent priorities for future research in the area. Furthermore, through the lens of sustainable management, we have reviewed the existing pressures and associated management measures relevant to the region and commented on how these may be best incorporated into, or enhanced through, future management measures such as those in discussion at the UN Biodiversity Beyond National Jurisdiction negotiations. We hope this review represents a comprehensive summary of work for scientists and managers alike looking to understand the key topographical, biological and legislative features of the Central and South Atlantic.

Brown L[1]; Woulds C; Parker R; Kröger S
[1]University of Leeds.
Poster: Abstract #30 / Session T4 - Shackleton Session: Marine Sedimentary Carbon

Characterizing sedimentary organic carbon in UK shelf seas: A case study of the northern North Sea

Marine sediments are one of the largest carbon reservoirs in the world, playing an important role in climate regulation. It is essential that there is a better understanding of the distribution, sources, lability and vulnerability to degradation of carbon within shelf sediments. This will enable better and more targeted management of carbon storage as an ecosystem service. It is becoming clear that a combination of methods are required to gain such an understanding, which could include TOC, TN, δ13C, δ15N and the amino acid based degradation index. This poster will present such a multi-parameter data set for a sample set from the northern North Sea. Relationships with potential controlling environmental factors will be examined, and conclusions drawn regarding organic C source, transport and degradation. The utility of multi-parameter data sets and higher spatial resolution sampling will be considered for future surveying and monitoring of shelf sea organic C stores.

Brown P[1]; McDonagh E; Sanders R; Schuster U; Watson A; King, B; Moat, B; Frajka-Williams E; Flohr, A; Baringer M; Wanninkhof R
[1]National Oceanography Centre, Southampton.
Talk: Abstract #277 / Session T24 - The Atlantic Meridional Overturning Circulation: Observations, Simulations and Equations

Enhanced northward ocean transport of anthropogenic carbon through recovery of overturning circulation may be affecting North Atlantic CO2 uptake efficiency.

Of the additional carbon dioxide added to the atmosphere by human activities the ocean absorbs approximately a quarter, with a disproportionate fraction accumulating at depth in the North Atlantic due to the combined action of northward ocean transport (through the meridional overturning circulation) and strong air-sea fluxes. Combining repeat hydrography with circulation estimates from the RAPID mooring array at 26N it was found that between 2004 and 2012 these two processes were roughly equal in magnitude, but decreasing ocean transports were tipping the balance more towards air-sea uptake over time as the AMOC weakened. New observations from 2012 to 2020 show that this process has now reversed - a recovering AMOC combined with increasing loadings of carbon is now transporting substantially greater quantities of anthropogenic carbon northwards into the North Atlantic. Changes in regional air-sea fluxes suggests that the increased northward ocean carbon transport may be affecting CO2 uptake capacity downstream.

Brunner O[1]; Mitarai S
[1]Okinawa Institute of Science and Technology.
Talk: Abstract #160 / Session T14 - A decade of deep ocean science for sustainable development

Dispersal's Role in Structuring Diversity at Hydrothermal Vents, a Model System for Studying Connectivity and Conservation

Connectivity among marine habitats is crucial for maintaining the structure and function of biodiversity in ecosystems threatened by anthropogenic activity. The dispersal of planktonic larvae is the primary facilitator of connectivity among most marine ecosystems. However, dispersal's role in connectivity is unclear due to the interacting effects of local environmental and biological filtering. Hydrothermal vents present a natural laboratory to study the role dispersal plays in connectivity, as an 'island-like' ecosystem that is truly discrete in space and connected via dispersal on relatively stable and predictable deep-ocean currents. Here we present a novel approach which uses empirical data of species' distributions and simulations of larval dispersal to explore connectivity among a network of hydrothermal vents in the Northwest Pacific. This approach uses methods from graph theory to combine empirical observations and simulated data under paradigms of metacommunity dynamics. The resultant model clarifies the interacting effect regional dispersal and local selection has on structuring diversity at hydrothermal vents currently threatened by mining activity. This model can be adjusted to incorporate anthropogenic impacts such as mining or global climate change to predict their effect on diversity at this vulnerable marine ecosystem.

Bryant R[1]; McClain C
[1]University of Louisiana at Lafayette.

Talk: Abstract #262 / Session T21 - Trait-based approaches to improve conservation, management, and restoration of our oceans

Functional diversity analysis reveals deep-sea energetic niche expansion driven by trait tradeoffs

Anthropogenic stressors are already influencing deep-sea communities, and global climate change continues shifting the landscape of energy availability in the oceans. This is predicted to have impacts on community composition, largely determined by functional diversity. Shifts in functional diversity have strong impacts on ecosystem functioning, so understanding the effects of energy on functional diversity in the deep sea is of vital importance. We investigate patterns of functional diversity, functional niches, and functional traits in bivalve communities across the energetic gradient of the deep Atlantic Ocean. We use three functional traits related to energetic demands to define the axes of functional space, and the unique combination of these traits as functional niches. As species richness increases with energy, new species are added into functional space through niche expansion rather than niche packing. Underlying this pattern are complex dynamics of gains and losses of individual functional niches, with few adapted to the low- and high-energy extremes, and most occurring within intermediate energy regimes. Adaptive qualities of specific traits are evidenced by those functional niches occurring at energetic extremes. Tradeoffs between these traits within the intermediate energy zone underlie an increased coexistence of functional niches, which in turn drives a unimodal pattern of functional niches and expansion of utilized functional space. This work suggests that deep-sea benthic communities may be especially vulnerable to continued shifts in food availability through the Anthropocene, as this may have long-term effects on community composition and ultimately lead to declines in ecosystem functioning of the deep benthos.

Buck J[1]; Siddorn J; Carse F; Lopez AL
[1]National Oceanography Centre (NOC), UK.
Talk: Abstract #280 / Session T6 - Towards a Net Zero Oceanographic Capability

Digital twins and their potential role in Net Zero Oceanographic Capability (NZOC)

The 2021 Net Zero Oceanographic Capability (NZOC, https://noc.ac.uk/facilities/ships/net-zero-oceanographic-capability) scoping report defined a conceptual digital eco-system required to underpin the transition of ocean observation to net zero. This includes the digital infrastructure to directly support the data collection from ships and autonomous vehicles comprised of:

- the scientific software and architecture on board the ship that facilitates research data collection on the NZOC
- The data infrastructure and communication between AUV, ship and other data systems (including, but not necessarily exclusively, archiving facilities) that support research data collection on the NZOC
- The data infrastructure and communications to allow scientific and other users, onshore and onboard, to engage with the observation collection process
- Data infrastructure and software to support public good and commercial (where appropriate) re-use of NZOC data and capabilities

The envisaged NZOC digital eco-system is based on descriptions of a digital twin, which provides a useful framework in which to describe a future NZOC data eco-system, includes all the components needed for the NZOC ecosystem, and if fully implemented will maximise the value in our observing capability. In this presentation we will present the concepts of the NZOC digital eco-system and its alignment with related work to develop a digital twin of the ocean, summarise the steps to achieve the digital eco-system, and highlight initial scoping work undertaken to define an information management framework to underpin its development.

Buckingham J[1]; Waller, C; Manno C; Waluda C
[1]University of Hull, Energy & Environment Institute , British Antarctic Survey.
Talk: Abstract #208 / Session T12 - Interactions between plastics and marine ecosystem

A record of microplastics in the marine nearshore waters of South Georgia

Presented here is a baseline estimate of microplastics in the nearshore, marine waters of South Georgia, the first systematic study of the north-east coast of the island. We estimate the mean concentration of microplastics in seawater to be 2.39 ± 3.58/L (± SD), approximately one order of magnitude higher than the majority of other

studies of sea surface waters south of the Polar Front. The maximum concentration of microplastics in wastewater from King Edward Point research station was 1.44 ± 4.93/L (mean ± SD). Following FT-IR polymer analysis and categorisation of microplastics solely by material, multivariate analysis revealed a 22% similarity in the microplastic profiles of wastewater and the seawater it enters. We hypothesise that microplastic pollution from the research base constitutes a fraction of the input into the local marine environment. To explain the observed discrepancy, we hypothesise alternative sources of contamination to be microplastic transported from afar, microplastic from ships (estimated to be up to 36.8 million synthetic fibres per year) and precipitation based on the concentration of microplastic in a single snow sample (15.89 ± 23.72/L, mean ± SD). There was no significant difference in the microplastic concentration between seawater sites, and no significant bilateral relationship between concentration and distance from the research station outlet, however we recommend further finescale mapping of the nearshore hydrological regime to develop a holistic picture of microplastic dispersal and retention at the coast.

Burmeister K[1]; Schwarzkopf FU; Biastoch A; Brandt P; Lübbecke JF; Rath W; MI
[1]Scottish Association for Marine Science (SAMS).
Talk: Abstract #119 / Session T24 - The Atlantic Meridional Overturning Circulation: Observations, Simulations and Equations

How do different wind forcing products impact the tropical Atlantic Ocean circulation?

The upper wind-driven circulation in the tropical Atlantic Ocean plays a key role in the basin wide distribution of heat, freshwater, and biogeochemical components. About one third of the water masses transported northward by the AMOC is recirculated and modified within the zonal current system of the tropical Atlantic. Improving our understanding of the long-term variability of the upper wind-driven circulation in the tropical Atlantic Ocean largely relies on model simulations due to sparse observational data coverage in earlier periods. This study analyses OGCM simulations forced by the Coordinated Ocean-Ice Reference Experiments (CORE) v2 dataset (Griffies et al., 2009) and by the JRA55-do surface dataset (Tsujino et al., 2018). CORE covers the period 1948 to 2009 and has a horizontal resolution of 2°x2° and temporal resolution of 6-hours. JRA55-do stands out due to its high horizontal (~55 km) and temporal resolution (3 h) which covers the entire observational period (1958 to present). We found discrepancies in mean and variability of simulated currents between both wind forcing products. CORE captures better the seasonal cycle of the equatorial current field while JRA better reproduces the mean current strength compared to observations. The forcings simulate distinct multidecadal current variability with generally stronger anomalies in CORE. This study highlights the necessity of long-term current observations.

Griffies, S. M, et al. (2009). Coordinated Ocean-ice Reference Experiments (COREs), Ocean Modelling, 26, 1–46. https://doi.org/10.1016/j.ocemod.2008.08.007
Tsujino, H., et al. (2018). JRA-55 based surface dataset for driving ocean–sea-ice models (JRA55-do), Ocean Modelling, 130, 79–139. https://doi.org/10.1016/j.ocemod.2018.07.002

Cael B[1]; Bisson K; Henson S; Dutkiewicz S
[1]NOC.
Talk: Abstract #2 / Session T19 - Mathematics of Satellite Oceanography

Detecting trends in ocean colour over the satellite era

Ocean ecosystems are thought to be changing with climate. Detecting such changes is difficult, though, because it is well-established that a few decades of measurements are required to detect a trend in satellite chlorophyll, whereas the satellite ocean colour record is only two decades long. Remote sensing reflectance (Rrs), however, is measured at multiple wavelengths, meaning it may be possible to detect climatic trends over shorter time intervals because the overall signal-to-noise ratio is higher than for a single variable (i.e. chlorphyll). Here we use a multivariate regression technique that accounts for correlations between Rrs wavelengths to detect trends in ocean colour from the satellite record. We show that while satellite-derived chlorophyll has only changed significantly over a small fraction of the ocean in the past 20 years, ocean colour has changed significantly over a much greater region. The largest contiguous region where ocean colour has changed is in midlatitudes in the Southern Ocean. Using a marine ecosystem model that calculates Rrs, we show that 20 years is sufficiently long to detect a climatic trend in Rrs, meaning these trends are plausibly due to climate change rather than decadal variability in ocean colour. We discuss the ecological and biogeochemical implications of the observed colour

changes and the implications of our findings for using Rrs directly as a sentinel of surface ocean ecosystem change rather than products derived from Rrs.

Cala B[1]; Sulpis O; Wolthers M; Humphreys M
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Poster: Abstract #64 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

Disentangling the drivers of carbonate mineral dissolution

Carbonate mineral dissolution has the potential to neutralise anthropogenic CO2 and act as a buffer against ocean acidification. To accurately quantify these effects, we need to understand where in the water column dissolution occurs and what its drivers are. Still, our current understanding of dissolution is incomplete: for instance, excess alkalinity production in the mesopelagic suggests that carbonates dissolve where seawater is oversaturated. In situ measurements of the dissolution rate can help to determine which other environmental factors - apart from the saturation state - drive dissolution. However, those measurements are scarce and even though they measure the same phenomenon, the resulting rates differ by up to two magnitudes between the available studies. Additionally, the dissolution patterns with depth are also not consistent with each other. Possible explanations for these variances include differences in methodologies and sample types, or the respective physical and chemical environments. This work aims to disentangle those factors and determine the real qualitative and quantitative value of the existing datasets. This is achieved through review of the literature and the development of a simple model that predicts dissolution based on sample type and the corrosiveness of the surrounding water, highlighting areas where a different approach is needed to explain the measured rates. Ensuring the reliability and usefulness of the data is vital so that it can be used in further analysis, such as testing the correlation with other possible environmental controls on dissolution rate and mechanism.

Callaghan A[1]
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Poster: Abstract #245 / Session T17 - Physical and chemical drivers of air-sea exchange processes: waves, bubbles, aerosols and surface chemistry

A comparison of laboratory breaking waves and oceanic whitecaps using visible imagery

Sufficiently energetic breaking ocean waves produce distinctive visible foam signatures on the water surface called whitecaps. The mixture of surface whitecap foam cells and sub-surface bubbles result in the broad-band scattering of light that allow whitecaps to be measured with cameras operating in the visible portion of the electromagnetic spectrum. In this paper the temporal evolution of whitecap foam area from laboratory and oceanic breaking is compared. When appropriately scaled, it is found that the foam area time series for both laboratory and oceanic breaking waves collapse, despite occurring in vastly different settings. Distinct similarities of the signature of foam stabilisation due to the presence of surfactants in the controlled laboratory experiments are also found in the field suggesting foam stabilisation may be a means to remotely sense the presence/absence or concentration of surfactants in the ocean. In addition, probability density distributions of key whitecap variables such as foam area growth and decay timescales and maximum foam area are compared between laboratory and oceanic whitecaps. The oceanic whitecaps are much larger in scale than the laboratory breaking waves, whereas the whitecap growth and decay timescales are similar in magnitude, the latter suggesting that bubble plume penetration depths in the field are relatively shallow. The aggregated whitecap statistics are used to estimate the energy dissipation of individual whitecaps in a novel manner.

Campanyà-Llovet N[1]; Bates A; Cuvelier D; Colaço A
[1] University of the Azores; IICM - OKEANOS, Portugal
Talk: Abstract #311 / Session T21 - Trait-based approaches to improve conservation, management, and restoration of our oceans

Applying trait-based approaches to Marine Protected Areas from the Mid-Atlantic Ridge

Quantifying community structure and diversity based on species and biological/ecological traits can combine to provide tools for monitoring conservation outcomes and targets of Marine Protected Areas. Dr. João de Castro is a shallow-water hydrothermal vent and as such provide unique food webs where photosynthesis and chemosynthesis coexist. It is also an MPA included in the Azores Marine Park MPA network at the Mid-Atlantic Ridge (MAR). We explore ecosystem vulnerability to warming water temperatures (+3 C above mean max water temperature recorded in the area). These conditions correspond to temperature predicted for 2040-2099, according to (B1, A1B and A2 scenarios) SSP3-7.0 scenario (IPCC 2021). Using a trait-based approach and we further investigate the long-term effects these threats may have on overall ecosystem function and food web ecology. Taxonomically molluscs were the group mostly affected by increased temperatures, which explains the reduction in organisms of a few cm in size. There is also a loss of representation of pelagic over benthic and benthopelagic species. There is also a gain in the proportion of predators over lower trophic levels. This will have implications on key ecosystem functions such as the carbon flow on the trophic food webs and the benthopelagic coupling within the ecosystem.

Cao R[1]; Callaghan AH
[1]Imperial College London.
Talk: Abstract #226 / Session T17 - Physical and chemical drivers of air-sea exchange processes: waves, bubbles, aerosols and surface chemistry

Subsurface bubble plumes, bubble size distributions and air fraction of the two-phase flows by wave breaking under direct wind shear stress

Bubble plumes within the two-phase flow as a result of white-capping is critical to the enhancement of the exchange of mass and gas between the ocean and atmosphere. Upon breaking, bubbles of radius ranging from order tens of microns to centimetres are produced. Therefore, more accurate models of bubble-mediated gas exchange and aerosol production flux require accurate determinations of air entrainment rates and bubble size distributions. We report experimental measurements of time- and space-evolving bubble plume and bubble size distribution in 2-D breaking waves. The bubble plumes and bubbles were measured with high resolution digital images using a range of novel image processing and object detection techniques. A wide range of sea states were considered by altering the underlying scale, nonlinearity and spectral bandwidth of the dispersively-focused wave groups and varying wind speeds to replicate the effects of different wave age. The experimental results demonstrate that underlying wave scale, non-linearity, spectral bandwidth and wave age all have a measurable influence on the evolution of the two-phase flow and bubble size distributions within the breaking waves, highlighting the complexity of the air entrainment over the breaking process. Particularly, we show that compared to breaking waves without wind stress, wind-forced breakers produce shallower but wider bubble plumes, resulting in significantly different spatial distribution of bubbles and air fraction. We also point out the importance of wind in affecting sub-Hinze scale bubbles. The relative magnitude and importance of other influences besides wave age will also be discussed in detail in the present work.

Carter H[1]; Bribriesca-Contreras G; Williams S
[1]University College London, Natural History Museum London.
Talk: Abstract #296 / Session T18 - HMS Challenger collections as a benchmark for oceanographic studies

Mapping stars in the wake of Challenger: The Challenger Asteroidea and the pattern of life in the abyssal oceans.

Challenger made an enormous contribution to our understanding of marine biology, not least for the Asteroidea (starfish), a class for which fully 10% (194/1921) of all known species were described by the expedition. Some deep-sea genera, went from small curiosities with a handful of members, to fully fledged families with 30-40 new species. But perhaps more interesting than the new species themselves, is where they were collected - many of the Challenger samples were from remote areas of the deep sea which have rarely, or never, been re-explored. They provide rare, fleeting windows into the composition of life at great abyssal depths. We have used these hundreds of specimens and associated locality data, or records from Sladen's Challenger Asteroidea as the backbone for a comprehensive study of the biogeographic distribution of starfish from the intertidal to the abyssal zone (~6,000 m). Here we present a rigorously validated global and near taxonomically complete (91.4% species, 98.3% genera) dataset of ~258,000, combining records taken from the Challenger Expedition through to the present day. We have used these data to produce, for the first time, a three-dimensional overview of benthic

diversity throughout the entire spread of the global oceans. We show that, unlike high tropical shallow diversity, species richness at bathyal and abyssal depths peaks in temperate waters either side of the equator. We show that this unique deep-water pattern differs across spatial, bathymetric and taxonomic scales but can be explained through competing environmental factors, limited by the contours of geographic complexity.

Carvalho F[1]; Henson S; Briggs, N; (HV; Martin A; Trucco-Pignata P
[1]National Oceanography Centre (NOC).
Poster: Abstract #359 / Session T24 - The Atlantic Meridional Overturning Circulation: Observations, Simulations and Equations

Multi-year upper ocean dynamics at the OOI Southern Ocean Global Array using an array of autonomous platforms

Phytoplankton are responsible for half of the photosynthesis on Earth and are fundamental players in the global carbon cycle. The Southern Ocean, a well know High-Nitrate Low-Chlorophyll (HNLC) region, is a key location to understand this important carbon uptake. The Ocean Observatories Initiative (OOI) deploys sensors that measure key biogeochemical properties on both moored and mobile autonomous platforms across ocean observing arrays in the Atlantic, Pacific, and Southern Oceans. In this work we build on the existing dataset at the OOI Southern Ocean array to analyse a 5-year timeseries from 2015 to 2020, consisting of moorings with profilers and gliders. The upper ocean physical setting is characterised and phytoplankton dynamics and upper ocean biogeochemistry are evaluated within that physical context. We evaluate the effect of years of deep winter mixing in the following year's bloom which then lead to important consequences to the carbon export in that region.

Cavan E[1]; Lee H; Murphy E
[1]Imperial College London.
Talk: Abstract #151 / Session T10 - Micro to macro: linking bottom-up and top-down approaches that investigate the function, resilience and conservation of polar ecosystems

Simulating Antarctic krill carbon export in a biogeochemical model

Antarctic krill are recognised as important to Southern Ocean nutrient and carbon cycles, as well as the Southern Ocean krill fishery and wider Antarctic ecosystem. Discreet observations in time and geographical space have shown their dominance in Particulate Organic Carbon (POC) fluxes due to their fast-sinking faecal pellets, particularly in spring and summer months. However, we lack the observations to know krill POC export at high spatial and temporal resolution. I present a classic Nutrient-Phytoplankton-Krill-Detritus (NPZD) model with the addition of krill as a state variable (NPZDK). Calibrating our model using krill abundance from KRILLBASE and time-series data we simulate the krill contribution to total POC export over an annual cycle and wide geographic area in the Atlantic Southern Ocean. I discuss the complexities of modelling high trophic level, mobile organisms in a biogeochemical model and finish on how future results could inform policy, including setting seasonal krill fishing quotas and increasing marine protected areas around Antarctica.

Charidemou M[1]; MacLachlan S
[1]National Oceanography Centre.
Poster: Abstract #45 / Session T23 - Unlocking Climate Histories from Marine Sediments

The British Ocean Sediment Core Research Facility (BOSCORF): providing a unique and strategic service to the UK oceanographic research community

Marine sediment cores are an immensely valuable resource that are fundamental to oceanographic research. Sediment cores are used to study the physical and biogeochemical processes occurring on and below the seafloor, to explore the mineral and biological resources of the deep ocean, and to reconstruct the geological history of ocean basins. The British Ocean Sediment Core Research Facility (BOSCORF) serves as the United Kingdom's national deep-sea sediment core repository. The facility is responsible for the long-term storage and curation of 14 km of marine sediment cores collected from all major ocean basins. Part of BOSCORF's mission is to provide long-term storage for sediment cores under controlled conditions to ensure optimum preservation, and to promote secondary usage of these valuable materials to achieve maximum scientific returns. In addition, BOSCORF serves

the scientific community by operating the UK's most comprehensive open-access sediment core analysis facility and provides training in core logging, advanced core analysis and data visualisation techniques. In this session, we will introduce BOSCORF's key services and facilities and give numerous examples of the types of research BOSCORF has recently supported, ranging from small-scale pilot studies to major national and international research projects. We will discuss how BOSCORF supports and enables international and interdisciplinary oceanographic research, as well as providing individual researchers with the opportunity to discuss how we can support their current and future research projects.

Chin J[1]; Murray L; McGrath J
[1]Queen's University Belfast.
Talk: Abstract #94 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

Shining a light on microbial phosphorus cycling reveals underappreciated processes

Marine microbes are key actors in global biogeochemistry and form the base of the marine food web, and so their ability to capture nutrients such as phosphorus (P) and grow is critical for healthy oceans. These microbes are challenged by extremely low (potentially <10 nM) levels of orthophosphate in surface waters which may limit their growth. Global warming may increase ocean stratification and prevent surface waters mixing with nutrient-rich deep waters, exacerbating this P scarcity. The ability of the marine microbial community to adapt to this nutrient limitation is not well understood, nor is the relative importance of different processes for P metabolism. We examined the Tara Oceans metagenomic dataset to compare the prevalence of diverse P cycling genes in order to understand their relative importance for marine nutrient cycling. We found that polyphosphate cycling genes are extremely abundant despite this being one of the least characterised processes for P metabolism, suggesting an important pool of polyphosphate in the oceans. We also found varying relationships between organic P metabolism genes and orthophosphate levels, suggesting that these processes are not always directly regulated by P scarcity as is often assumed in the literature. Finally, the synthesis of organophosphonates appears to be extremely prevalent, supporting previous research which proposed an important cycle of phosphorus reduction and oxidation. These data show that our models of marine P cycling are still incomplete, and need to be developed further if we are to understand these key habitats and predict the impacts of climate change.

Clarke J[1]; Quaggiotto M
[1]University of Stirling.
Talk: Abstract #137 / Session T22 - Strengthening Equality, Diversity, Inclusivity and Accessibility in Marine Science

Amplifying our students' voice: the co-production of an undergraduate field courses to address EDI.

Making education equal, diverse, and inclusive (EDI) is a crucial topic in Higher Education, including within Environmental and Marine Sciences. Academics leading students on fieldwork only have access to a limited set of their protected characteristics to help prepare in planning, such as disclosed disabilities. However, many barriers and challenges to participating in fieldwork can be linked to identity characteristics (e.g. socio-economic status) that are not disclosed. Co-production of curricula is a proposed method to improve EDI, but only when participants are involved at every step and their lived experience is the main focus. Putting undergraduate students at the centre of field-course planning (Bovill et al., 2011) via collaborative inclusivity is at the core of our project. In this talk we will describe the potential barriers experienced by undergraduate students during field work and share our approach to the co-production of a residential field course with the aim to improve access to field skills for all students. There is not a set checklist or toolkit that helps to prepare and plan because "one size will never fit all" (Lawrence & Dowey, 2021). However, we will here demonstrate that with students at the centre of planning we can make field-courses more equitable, diverse, and inclusive for each unique cohort.

Bovill, C., Cook Sather, A., and Felten, P. (2011). Students as co-creators of teaching approaches, course design, and curricula: Implications for academic developers. International Journal for Academic Development, 16(2), 133–145. https://doi.org/10.1080/1360144X.2011.568690
Lawrence, A. and Dowey, N. (2021). Six simple steps towards making GEES fieldwork more accessible and inclusive. Area, 00, 1–8. https://doi.org/10.1111/area.12747

Clarke M[1]; Marsh L
[1]The Nauru Ocean Resources, Inc. (NORI).
Talk: Abstract #96 / Session T1 - Deep Sea Mining 1 - geology, resource, legal, technical and societal aspects

Monitoring of the Technical and Environmental Performance of a Prototype Polymetallic Nodule Collector System in the Clarion Clipperton Zone

The Nauru Ocean Resources, Inc. (NORI) is a wholly-owned subsidiary of The Metals Company. In 2011, the International Seabed Authority (ISA) granted a polymetallic nodule exploration contract in the Clarion Clipperton Zone (CCZ) to NORI, sponsored by the government of the Republic of Nauru. In mid-2022, NORI plans to test a prototype polymetallic nodule collector system in the CCZ. The system will consist of a collector vehicle, riser pipe, surface vessel, and return water pipe. The presentation will describe how the technical and environmental performance of the system is measured and evaluated.The Collector System will be deployed, operated, and recovered by Allseas from the SSV Hidden Gem. The science and monitoring studies will be coordinated by NORI from the OSV Island Pride operated by Ocean Infinity. Environmental monitoring studies will be conducted by a team of independent researchers from The Natural History Museum (UK), National Oceanography Centre (UK), University of Gothenburg (SE), The University of Hawaii at Manoa (US), Florida State University (US), Texas A&M University (US), Eckerd College, Florida (US), University of Leeds (UK) and Heriot-Watt University (UK). The parameters of the collector system€™s performance that will be quantified include the maneuverability and nodule pick-up efficiency of the collector vehicle; the dynamics of the mid-water and benthic plumes; pre-and post-disturbance fauna distribution; noise generation; and changes in water chemistry. The collector test monitoring campaign will be in progress at the time of the Challenger 150 Conference. The presentation will provide a background to the campaign€™s planning and an update on progress.

Clement L[1]; Frajka-Williams E; Oppeln-Bronikowski Nv; Goszczko I; Young Bd
[1]National Oceanography Centre, Southampton, UK.
Talk: Abstract #338 / Session T28 - Physical Oceanography Open Session – Tides, Coasts and Shelf Seas

Cessation of Labrador Sea Convection by Freshening through Submesoscale Flows

The role of submesoscale flows in ending the Labrador Sea deep convection is disclosed by three winter glider deployments. Two vehicles crossed the convective region boundaries over the continental slope while the latter one remained in the region towards the end of convection. In January, gravitational instabilities triggered by air-sea heat fluxes generate deep mixed layer depths (>500 m). In February--March, an upward deep saltwater flux maintains deep mixed layer depths while submesoscale motions can shoal them. For example, symmetric unstable flows appear in the presence of lateral stratification, i.e. two weeks prior restratification in the convective region or earlier at its boundaries. Strong winter surface heat flux and along-front winds enhance lateral stratification inciting unstable flows. Counterintuitively, winter atmospheric conditions (instead of warm surface heat flux) stop convection by adding freshwater through the decay of light intrusions (eddies and filaments). Submesoscale flows extract energy from the fronts found around these intrusions that mostly carry fresh anomalies. As such, cold and fresh intrusions originating in the shallow Labrador Current participate in halting convection by lightening the basin interior, instead of warm and salty intrusions originating in the subsurface Irminger Current. This narrow region of freshwater transports offshore the Labrador Current was overlooked due to its transient state involving submesoscale dynamics. A direct link was established between winter deep convection and freshwater fluxes of Arctic and Greenland origins, expected to increase under a changing climate.

Cocks J[1]; Marzocchi A; Naveira-Garabato A; Silvano A; Schifano N; Dragomir O; Hogg AE
[1]National Oceanography Centre.
Poster: Abstract #67 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

Detecting Antarctic Bottom Water formation with satellite altimetry

Formation of deep water in the Southern Ocean (SO) is a key component of the global overturning circulation, drawing excess anthropogenic heat and carbon out of the atmosphere and ventilating the abyssal ocean. Deep water forms as high salinity brine is rejected from seawater during sea ice production, resulting in a more saline and dense water column. Steric height is the component of sea surface height (SSH) related to change in density. A relatively dense water column has a negative steric height anomaly (SHA) compared to a less dense, more buoyant water column. In the SO, where the temperature is consistently low, density anomalies are dominated by changes in salinity. Therefore, steric height can be indicative of patterns of deep water formation, with a negative SHA corresponding to increased deep water formation. We present a gridded dataset of SHA computed using satellite altimetry data between July 2002 and July 2018 for the SO south of 50°S, at a 0.5° resolution. SHA is calculated by subtracting the Eustatic Height Anomaly (from GRACE) from the Dynamic Ocean Topography (from a dataset containing merged CRYOSAT2 and ENVISAT data). The SHA dataset has been validated against geopotential height anomaly computed using SOCCOM floats and MEOP (https://www.meop.net/) profiles and shows good agreement in many regions of the SO. Maps of SHA seasonal anomalies reveal spatial variability in water column density, from which deep water formation and water mass movements/transformations may be inferred.

Cole M[1]; Coppock R; Rees T; Lindeque P
[1]Plymouth Marine Laboratory.
Talk: Abstract #56 / Session T12 - Interactions between plastics and marine ecosystem

Development and application of partial life-cycle toxicity test for anthropogenic particulates

To determine the risks posed by microplastics requires standardised toxicity tests that can be used to determine thresholds for lethal and sub-lethal effects in representative biota. A plethora of toxicity tests are available for waterborne chemicals, but these protocols are often inappropriate for testing anthropogenic particulates such as microplastics. Here we develop and optimise a standardised partial life-cycle toxicity test for anthropogenic particles using the globally-distributed, coastal and estuarine copepod Acartia tonsa. Trial exposures used 0, 0.01, 0.1, 1 and 10 µg/mL of a tripolymer microplastic blend comprising cryoground polyethylene, polypropylene and nylon particles (5-100 µm). Adult female copepods were incubated with microplastics for 5 days and subsequently used in a 24-hour feeding and egg production experiment, allowing for determination of adult mortality, feeding rate, egg production rate and egg size. Copepod eggs were then incubated until >50% of progeny had moulted into copepodite stage; preserved samples were subsequently used to calculate hatching success, juvenile mortality, larval development ratio and copepodite size. Here we present our optimised protocols alongside lethal and sub-lethal (feeding, fecundity, development, growth) dose concentrations for a range of anthropogenic particles including microplastics, microfibres, bio-degradable bioplastics and tyre particles. The test provides a standardised method for establishing comparative toxicity of anthropogenic particles, with the focus on apical endpoints (survival, growth, reproduction) being of high relevance to ecosystem health.

Collins M[1]; Dornan T; Owen K; Goggins M; Lloyd I; Irvine R; Liszka C; Calderan S; Leaper R; Olson P; Pütz K; Belchier M; Gregory G; Trathan PN; Murphy EJ; Ratcliffe N; Jackson J; Fielding S; Tarling GA
[1]British Antarctic Survey.
Talk: Abstract #347 / Session T20 - Evidence to support international oceans policy

Resolving ecosystem effects of the South Georgia winter krill fishery

The fishery for Antarctic krill is focussed on the Atlantic sector of the Southern Ocean and, with the advent of new trawling technology, is increasing. Around South Georgia, the fishery is restricted to winter to avoid competition with krill-eating predators, particularly those constrained in their foraging range whilst provisioning young. Nevertheless, the winter fishery may still impact krill predators through direct spatio-temporal overlap during winter or by carry-over effects into spring and summer. To date, understanding this has been hampered by a lack of winter data on both krill and krill-dependent predators (e.g. seals, penguins & whales). Here, we report how we are addressing this gap by fitting a scientific echosounder to the South Georgia patrol vessel to undertake winter acoustic surveys, enhanced by marine mammal and seabird observations, together with satellite tracking of penguins. Our first survey in May 2022 revealed large aggregations of small krill (10-35 mm TL) in association with foraging fin and humpback whales, in the area normally occupied by the fishery. During May and early June, eight satellite tracked gentoo penguins mostly foraged in inshore waters, within the 30 km no-

take zone that surrounds South Georgia. Further surveys are planned in July and September 2022, with repeats in 2023. Data from the surveys will help quantify krill biomass before, during and after the fishery; characterise diurnal patterns of krill distribution; help understand the winter demand of krill-eating predators and contribute to management by CCAMLR and the Government of South Georgia & South Sandwich Islands.

Cook H[1]; Shulman L
[1]Integrated Statistics, Inc., Previously Under Contract to the National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, MA, United States, currently at Department of Ecology and Evolutionary Biology, Cornell University, Ithaca, NY, United States.
Talk: Abstract #317 / Session T20 - Evidence to support international oceans policy

The Northeast Fisheries Science Center Bottom Trawl Survey: 60 years of surveying the western North Atlantic continental shelf, slope, and canyons.

The NOAA Fisheries Service bi-annual bottom trawl survey has monitored continental shelf, slope, and canyon habitats since its start aboard the RV Albatross IV in 1963. It is a random-stratified standardised survey that is currently conducted aboard the RV Henry B. Bigelow between Cape Hatteras, United States and the Scotian Shelf, Canada. The survey tows a 4-seam trawl net at an annual average of 740 stations and covers depths from 16m to 370m, 1340km of continental slope, and 31 major canyons. In its role for monitoring the regions biodiversity, more than 1000 species of fishes and invertebrates have been recovered, with many deposited in museum collections worldwide. Stock assessment indexes produced from the survey are used to manage 45 stocks of commercial and recreational species. The interdisciplinary long time series and sheer volume of biological, oceanographic, and bathymetric data collected is a goldmine for scientists studying these environments. However, there are many challenges to maintaining a continuous standardised survey over such a considerable period, including: logistical difficulties related to bottom trawling at depth and in complex bathymetry; collecting and storing a large volume of data; balancing stakeholder demands; and reluctance of management agencies to invest in research. Survey origins, history, and challenges are detailed coupled with the insights that have been gained overcoming these challenges.

Cooper I[1]; Aldis AM; Cockram CE; Sword I
[1]Accessibility in Polar Research.
Poster: Abstract #192 / Session T22 - Strengthening Equality, Diversity, Inclusivity and Accessibility in Marine Science

Polar Challenges: Access Polar, Disabled Inclusion, and Polar Research

Navigating the field of polar research is tricky, especially for people with disabilities. Whilst the field has progressed, there are still accommodations that need to be made, and discussions that need to be had regarding inclusivity. Accessibility in Polar Research (APR) was founded during the pandemic by a small group of disabled researchers who have all faced adversities in the field due to their disabilities. In just under two months, we found ourselves with a platform exceeding 700 followers on Twitter (@accesspolar). APR's first initiative was to understand how the polar field is restricting disabled researchers. Through collating this information from fellow researchers who have experienced adversity, APR has identified key areas in need of improvement. Additionally, APR has hosted multiple speaking events, been invited to panels/podcasts, made some useful resources on quick-fix accessibility tips for science, and sparked lively debates on frequently avoided topics. From this work, the network has created an excellent platform to carry out some of our aims: (i) Highlight the positives of disabilities (ii) help spread awareness of difficulties researchers face and, (iii) provide/distribute resources and suggestions to improve inclusivity. Here we will give you a taste of APR advocacy, a summary of the key issues identified, what the organisation is aiming to do in the future, and why the polar field needs to become more inclusive (using our own experiences). We will also share some of our top tips on how to make your research more accessible.

Cooper I[1]; Godbold JA; Annett AL
[1]School of Ocean and Earth Sciences, University of Southampton.

Talk: Abstract #37 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

Applying 224Ra/228Th Disequilibrium to Investigate Faunal Contributions to Benthic Flux Processes

The benthic flux of solutes (nutrients, carbon, trace metals, pollutants) is key in setting global ocean chemistry, supporting the base of the marine food chain, and stimulating ecological and climatic change. Process estimates are however, limited and highly variable, representing one of the largest sources of biogeochemical uncertainty within current modelling efforts. Traditional techniques for benthic flux quantification each have considerable limitations, neglecting the influence of external advective processes and perturbing natural conditions. Foci between geochemists and benthic biologists are also divergent, with geochemical approaches generally ignoring contributions from benthic fauna, while biological studies often fail to undertake detailed chemical analyses. The new 224Ra/228Th disequilibrium technique is promising in its potential to incorporate a wider range of benthic flux drivers, and to provide detailed rate estimates with greater accuracy than previous methodology. This approach examines deficits of soluble radium in relation to its sediment-bound parent, thorium, comparing this to porewater measurements of the solutes of interest. As yet however, this technique has not been applied to investigate the influence of benthic fauna on flux dynamics. We present first results using 224Ra/228Th disequilibrium to examine the influence of five macrobenthic infaunal invertebrate species on the flux of nutrients (NH4+, NO3-, NO2-, PO43) between the sediment and water column. On the basis of this work and a review of recent benthic flux literature, we propose a more holistic approach to benthic flux quantification, utilising the 224Ra/228Th disequilibrium technique and giving due consideration to both biological and geochemical components.

Copley J[1]
[1]University of Southampton.
Talk: Abstract #248 / Session T2 - Deep Sea Mining 2 - environmental aspects: baselines, impacts, monitoring

Understanding the ecological context of polymetallic sulfide deposits formed by deep-sea hydrothermal vents: challenges and knowledge gaps

Deep-sea polymetallic sulfide deposits, typically occurring as “seafloor massive sulfides”, are formed by hydrothermal activity associated with seafloor spreading centres and other submarine volcanism. The total area of polymetallic sulfide deposits at active hydrothermal vent fields worldwide presents an extreme contrast to the much larger area of polymetallic nodule deposits in abyssal plain environments, and the small global area of active vent fields provides a habitat for several hundred species of animals not found in other environments. Ecological patterns such as biogeography and succession at hydrothermal vents present particular challenges for managing environmental impacts from exploitation of sulfides at active vents, and there is currently limited understanding of the drivers of variation in faunal assemblage composition at vent fields within biogeographic provinces on slower-spreading ridges, which represent ~50% of the global mid-ocean ridge system. Inactive sulfide deposits may be less vulnerable to impacts than active vent habitats, but vent fields often combine active and inactive deposits, and knowledge gaps remain about the potential endemic ecology of inactive sulfides.

Cormier M[1]; Berard J; Flynn KJ; Bougaran G; Rickaby REM
[1]University of Oxford.
Talk: Abstract #316 / Session T5 - The role of mixoplankton and mixotrophy in the global carbon cycle

Hydrogen isotope ratio in lipids is highly sensitive to the carbon metabolism protists

Variations in the relative abundance of stable isotopes of diverse elements (e.g. hydrogen, carbon, nitrogen and oxygen) give important information about (bio)geochemistry and palaeoclimate. Stable isotope measurements, as preserved in geological and biological archives (e.g. sediment cores, tree rings, plankton and herbaria), is ubiquitous over a broad range of earth science studies. There are indications that the relative abundance of hydrogen isotopes in lipids (expressed as δD values) is highly sensitive to the carbon metabolism of bacteria, vascular plants, in particular orchids, and parasitic plants and protists. This suggests that δD values could be used as a new tool for quantifying aquatic mixotrophy. Despite these indications, the application of the deuterium (D) content in organic biomarkers has been largely limited to (palaeo)hydrological studies. This is because the

mechanisms shaping δD values are still poorly understood. Amongst these mechanisms, a strong D-fractionation occurs during initial reduction of carbon in the Calvin-Cycle, resulting in low δD values of triosephosphates relative to water δD values. This corresponds to the autotrophic fractionation factor (εA). Further D-fractionation occurs during the triose-hexose phosphate conversions, causing 2H-enrichment of the resulting pool of triose-hexose phosphate. This corresponds to the heterotrophic fractionation factor (εH). To use lipid δD values as a proxy for mixotrophy, it is critical to determine the stability of εA. Here, we will present new experimental data suggesting that εA is not influenced by the light intensity and likely constant. If confirmed, this would support the idea of using δD values as a proxy for mixotrophy.

Cryer S[1]; Carvalho F; Wood T; Strong J; Felgate S; Brown P; Goddard-Dwyer M; Loucaides S; Young A; Sanders R; Evans C
[1]University of Southampton, National Oceanography Centre.
Talk: Abstract #256 / Session T7 - Pushing the limits in autonomous oceanography in a net zero carbon world

Using a biogeochemical sensor suite mounted on an autonomous surface vehicle to investigate riverine input on coastal ocean acidification

The coastal ocean is a highly dynamic, heterogeneous environment, fundamental to the biogeochemical cycling of carbon. Investigations along the coast that use traditional sampling methods (discrete bottle samples), are logistically difficult and are limited in terms of data coverage. These limitations have historically presented a barrier to gaining a comprehensive understanding of coastal ocean acidification. We present a solution through the application of an autonomous surface vehicle (ASV) mounted with a biogeochemical sensor suite (including pH, pCO2, O2, chlorophyll, CDOM, nitrate, salinity and temperature). We deployed the ASV C-worker 4 in Belize's coastal ocean to investigate the role of riverine input on coastal ocean acidification. Belize is the most forested country in Central America, but is being actively deforested, with the major focus of this activity being within the Belize River watershed. The transformation of pristine catchment forests to agricultural land is potentially enhancing carbon flux to the coastal ocean. We demonstrate the versatility of the ASV approach, acquiring high-resolution data in the Belize River estuary and coastal ocean. Additional discrete water samples were taken for sensor calibration, as well as additional parameters. Our results show that there is a flux of high CO2, low pH riverine water to the coastal environment in Belize. We additionally identified spatial changes in carbonate chemistry, i.e. increase in pH over seagrass beds, indicating the importance of ecosystems in coastal ocean acidification. We show that ASV-mounted sensors is a promising approach to understanding controls on coastal ocean acidification.

Curti L[1]; Xiao K; Babakhani P; Moore O; Woulds C; Kazemian M; Kaulich B; Peacock CL
[1]University of Leeds.
Talk: Abstract #109 / Session T4 - Shackleton Session: Marine Sedimentary Carbon

The role of carboxyl groups in retarding and inhibiting the microbial remineralisation of organic carbon during adsorption to iron (oxyhydr)oxides.

Organic carbon (OC) preservation exerts a first-order control on both atmospheric CO2 and O2 concentrations over geological time (Berner, 1989). Iron (oxyhydr)oxides are ubiquitous in both soils and sediments and therefore play an important role in the stabilisation of OC (Kaiser et al., 2002; Lalonde et al., 2012), however the precise mechanism by which OC is sequestered by iron (oxyhydr)oxides and to what extent this mechanism might protect OC from microbial remineralisation is poorly understood (Kleber et al., 2021). We use STXM-NEXAFS to determine the precise OC sequestration mechanisms, in addition to microbial incubation experiments to test if the adsorption of OC via carboxyl groups protects the OC from microbial remineralisation and how this varies with carboxyl richness. Our results show that carboxyl-rich OC undergoes multi-carboxyl ligand exchange with ferrihydrite, increasingly protecting OC from microbial remineralisation with increasing carboxyl richness.

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Czerski H[1]
[1]University College London.
Talk: Abstract #100 / Session T17 - Physical and chemical drivers of air-sea exchange processes: waves, bubbles, aerosols and surface chemistry

Current capability, future projects and future collaboration in UK air-sea exchange research.

The air-sea exchange community is very international, and involves a wide range of disciplines. However, the community in the UK is perhaps less connected than it once was, with little shared knowledge about what is available and what the priorities of different groups are. We would like to kickstart a more locally collaborative period. This "talk" will be a structured discussion session on the current UK projects and capabilities and how what we need to collaborate effectively in the future. This will include equipment (inc national capabiltiy), funding and creating a supportive environment for ECRs.

Dahlgren TG[1]; Hestetun JT; Rabone M; Glover AG
[1]NORCE Norwegian Research Centre.
Talk: Abstract #167 / Session T2 - Deep Sea Mining 2 - environmental aspects: baselines, impacts, monitoring

Genetic barcode repository gap analysis – contrasting the beauty with the beast

A new deep-sea 'blue economy' will require long-term environmental monitoring of deep benthic ecosystems. To achieve this, metabarcoding of environmental DNA samples has been suggested as a possible complement or alternative to current morphological methods to assess biodiversity. However, as 95% of the deep-sea fauna is yet to be described, let alone with molecular data, the use of existing taxonomic resources with this methodology may be questioned. For the method to successfully characterise species assemblages, a public sequence database is necessary to match barcodes to species identity, however, these public sequence libraries must be expanded, and subjected to at least some degree of quality control. The oil and gas industry conducts large-scale environmental monitoring in the North Sea, one of the most heavily sampled marine areas worldwide and could therefore be considered a 'best-case scenario' for macrofaunal metabarcoding. In a recent study, we investigated the database coverage of two common metabarcoding markers, mitochondrial COI and the ribosomal rRNA 18S gene, for a complete list of 1802 macrofauna taxa reported from the North Sea monitoring region IV. For COI, species level barcode coverage was 50.4% in GenBank and 42.4% for public sequences in BOLD. For 18S, species level coverage was 36.4% in GenBank and 27.1% in SILVA. Results from this study is contrasted with data from an emerging deep-sea industrial target – the Clarion-Clipperton Zone (CCZ) in the equatorial Pacific. The critical need for molecular taxonomy in the deep-sea is highlighted through a comparison of recent metabarcoding studies both in the (relatively) well barcoded North Sea and the less catalogued CCZ.

Damerell G[1]; Heywood KJ
[1]University of East Anglia.
Talk: Abstract #249 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

New observations of the Antarctic Slope Undercurrent

The Antarctic Slope Undercurrent has only been observed a handful of times, yet it is an important component in the processes transporting warm water onto the Antarctic continental shelf which can lead to basal melting of ice shelves. We present new observations of the Undercurrent taken to the west of Dotson Trough (between 72° 14' - 72° 35' S, 118° 45' - 120° 9' W) in the Amundsen Sea sector in January 2022, using glider based observations which provide higher spatial resolution than most traditional ship-based surveys. Three cross-slope sections were completed over 7 days containing 110 profiles. Water depths ranged from 450 m to 1200 m, with the gliders

providing observations to a maximum of 1000 m depth. Geostrophic shear referenced to dive averaged currents is compared to that referenced to surface altimetry, and variability between the three sections discussed. The Antarctic Slope Current is observed over the shelf break with maximum velocities of 15 cm/s at depths around 200 m. The eastward-flowing Antarctic Slope Undercurrent, carrying warm, saline and low oxygen Upper Circumpolar Deep Water, is observed at depths from 300 m to 1000 m, with maximum velocities of 13 cm/s and an estimated transport of 0.5 Sv. We calculate the gradient of potential vorticity on density surfaces and discuss shoreward eddy flux.

Damerell G[1]; Hendry KR; Annett A; Bhatia R; Fielding S; Firing YL; Frajka-Williams E; Hartman S; Henley SF; Heywood KJ; Holliday P; Huvenne VA; Mills RA; Rabe B; Robinson C; Sanchez-Franks A; Smythe-Wright D; Taylor ML; Yelland M
[1]University of East Anglia.
Poster: Abstract #124 / Session T22 - Strengthening Equality, Diversity, Inclusivity and Accessibility in Marine Science

Equity at sea: Gender and inclusivity in UK sea-going science

Today, we can celebrate a strong representation of women in sea-going science in the United Kingdom, providing positive role models for early-career female marine scientists. However, women continue to face challenges to their progression in their marine science careers, especially those who are also members of other under-represented groups. Here we consider gender equity and equality in participation and leadership in sea-going marine science in the UK, discussing successes and lessons learned for the future. After a brief history of UK women in ocean science, and a summary of some recent advances in gender equality, we look at further areas in need of improvement, and ask whether successes in improved gender equality can be transferred to tackling other forms of under-representation in sea-going science.

Davis A[1]
[1]Liverpool John Moores - School of Arts and Sciences.
Poster: Abstract #309 / Session T16 - How Art-Science Collaborations can Inspire Societal Change

Art-Science in the global ocean - exploring future landscapes.

To explore future landscapes is not just to anticipate atmospheric, biogeochemical cycles, or microbial change; it is to look towards how institutions themselves may develop in the coming decades and what this means for the global ocean. In the past 30 years, centres of Art-Science interaction have emerged in the prominent institutions of CERN and MIT. Here, through extended creative research labs, a fostering of radical conversations between art, science, and technology is being designed. These transdisciplinary hubs connect what was once considered disparate disciplines, ranging from visualising particle physics, the social role of robotics, 3D printed textiles, and BioArt. Should artists and scientists focusing on the ocean begin to explore similar landscapes? How can artists and scientists explore ocean regions together? What role can art play in illuminating hidden worlds? Where next for science communication in collaboration with the arts?

De Benedictis D[1]; Alexander K; Woolf D
[1]Heriot-Watt University.
Talk: Abstract #115 / Session T28 - Physical Oceanography Open Session - Coastal Physics

Climatological challenges for the development of offshore wind farms off NW Scotland

Crown Estate Scotland defines 17 selected projects that are awarded rights to areas of the seabed in Scottish waters ("ScotWind"), including 4 sites to the north and west of Scotland in conditions dictated by exposure to Atlantic storms and waves. The exposure of the 4 sites presents challenges for installation, operation and maintenance (O&M) activities. The resulting effects on wind farm availability, productivity and revenues should be considered. The aim of the study is to assist offshore wind developers to understand the challenges posed by the wave climate in such environments and to design well-informed installation and maintenance practices. A critical review of the literature on offshore practice and an analysis of available metocean data underpins a

qualitative and quantitative analysis of the weather-related risk parameters and challenges to the ScotWind concessions offshore of NW Scotland. Persistently strong winds and a large fetch for waves account for a characteristic wave regime featuring large significant wave heights during most of the year. This regime affects accessibility of the sites in terms of suitable vessels and delays awaiting suitable weather windows. The technical performance of the offshore wind farm equipment must be suitable for the environmental conditions and required outcomes, involving the entire supply chain and various stakeholders. However, there is fragmentation of public information on the weather-related risks and, more generally, on O&M issues. More accessible and comprehensive studies and information are needed to improve and standardize the installation, O&M, planning, and other practices, especially for short-term operational procedures.

Deakin K[1]; Jones J; Savage G; Porter A; Lewis C
[1]University of Exeter.
Talk: Abstract #326 / Session T12 - Interactions between plastics and marine ecosystem

Science to Solutions: Plastic pollution in the Galápagos marine ecosystem.

Plastic leakage from Eastern Pacific rim countries of Ecuador and Peru, is captured by the South Pacific Subtropical Gyre polluting the open ocean and oceanic islands such as Galápagos, famous for its unique biodiversity and a global conservation priority. Here we report on our collaborative programme working to firstly quantify the widespread plastic contamination of the Galápagos marine ecosystem, and secondly, to develop local and regional monitoring and management plans, aiming to reduce plastic input and wildlife impacts for this iconic archipelago. Several field sampling campaigns, primarily on San Cristóbal island, have been undertaken since 2018, combining sampling sea surface microplastics and beach macroplastics together with a more recent assessment of the plastic contamination of Galápagos mangrove systems. Two techniques for sampling sea surface microplastics, using a 200 µm plankton net and 1 litre whole water samples were compared. This reveals insight into how differing methodologies impact the representation of beach sea surface microplastic pollution, guiding future exploration. Our data also reveals widespread macroplastic contamination of the seas surrounding San Cristóbal with contamination ranging from 0.0005 – 2.3636 items per m2 across the beaches sampled. Highest beach plastic accumulation occurs on the eastern coast indicating major input of plastic waste to Galápagos from the Humboldt Current. Mangrove data supports the idea that mangroves can act as plastic traps with accumulation observed. We discuss how these data are being used by the Galápagos national park and local NGOs to clean up plastic pollution, reducing its impacts to the unique biodiversity found there.

Diaz C[1]; Howell K; Hosegood P; Robinson E; Stashchuk N; Vlasenko V; Attrill M; Foster N
[1]University of Plymouth.
Talk: Abstract #181 / Session T14 - A decade of deep ocean science for sustainable development

Mesophotic Coral Ecosystems of the Chagos Archipelago

Mesophotic coral ecosystems (MCEs) are light-dependent communities occurring deeper than the brightly lit shallow coral reefs, between 30 and 150m deep. Despite the exponential growth in research on MCEs in recent years, their study is still in its infancy. This is mostly due to the logistical difficulties and safety issues with conventional scuba diving encountered at these depths and the expense of using deep-diving technologies in these 'too shallow' environments. In addition, geographical disparities are observed among MCE research, with the Indian Ocean remaining relatively unexplored, with only 1% of global studies based in this region. The Chagos Archipelago, considered a biodiversity hotspot in the middle of the Indian Ocean, is a relatively unperturbed ecosystem due to its protected status – one of the largest no-take marine protected areas (MPAs) – and its remote location. Here, we present the first extensive survey of community structure of MCEs and their environmental drivers in the Chagos Archipelago. Using a Remotely Operated Vehicle, video transects were collected at multiple depths from shallow reefs (15 m) to the lower mesophotic zone (160 m), in addition to environmental data. Results reveal highly diverse, unique benthic communities at mesophotic depths. However, the impacts of anthropogenic disturbances are already evident at these depths. This study provides essential knowledge on the diversity of MCEs along their entire depth range, revealing the importance of these mesophotic ecosystems. Such data are not readily included in MPA planning and this study contributes critical data to the development of management plans for the region.

Dingwall J[1]; Taylor JR
[1]University of Cambridge.
Talk: Abstract #39 / Session T25 - Physical Oceanography Open Session - Ocean Eddies

Modelling the accumulation of buoyant particles under wind-driven and convective turbulence in the ocean mixed layer

Buoyant material such as microplastics tend to accumulate near the ocean surface in regions with convergent surface currents where they can be harmful to marine life. We investigate the transport and accumulation of buoyant material by small-scale turbulence in the ocean mixed layer under combined wind and convective forcing using large-eddy simulations. We model non-inertial buoyant particles with a combination of buoyant tracers and Lagrangian surface particles, which allows us to explore a wide range of buoyancies. Surface cooling drives convection, and under this regime persistent convective vortices form which trap buoyant material, leading to large concentrations. Despite their small size, the convective vortices that form exhibit a bias towards cyclonic vorticity. We find that the average time a particle spends inside a convective vortex is long enough for vortex stretching to amplify planetary vorticity and that subsequently particle vorticity increases exponentially. For sufficiently weak winds, convective vortices survive but become less effective at clustering material as the wind stress increases. Under strong wind forcing, convective vortices are no longer visible, but some particle clustering occurs in downwelling regions associated with longitudinal wind rolls.

Dornan T[1]; Fielding S; Tarling G
[1]British Antarctic Survey.
Talk: Abstract #169 / Session T10 - Micro to macro: linking bottom-up and top-down approaches that investigate the function, resilience and conservation of polar ecosystems

Temporal trends in South Georgia zooplankton: insights from a moored echosounder

Antarctic krill (*Euphausia superba*) are a key zooplankton species in the Southern Ocean ecosystem, supporting large populations of marine mammals and seabirds, and contributing to the sequestration of carbon to the ocean interior. Krill are also the focus of a commercial winter fishery at South Georgia. While krill stocks are routinely monitored using ship based acoustic surveys, the remoteness and challenging environment of the Southern Ocean has largely restricted scientific observations to summer months, leaving key knowledge gaps regarding inter- and intra-annual variability in krill distribution and biomass during winter. Here we present details of the deployment, and preliminary results, from 4 years of moored echosounder 120 kHz acoustic backscatter data from South Georgia. These data indicate considerable seasonal and interannual variability in winter krill swarm presence, size and shape. We present these results in the context of challenges and opportunities for the increased use of moorings in the Southern Ocean to monitor krill density and behaviour.

Douglas C[1]; Brown P; Briggs N; MacGilchrist G; Garabato AN
[1]National Oceanography Centre, University of Southampton.
Talk: Abstract #270 / Session T10 - Micro to macro: linking bottom-up and top-down approaches that investigate the function, resilience and conservation of polar ecosystems

Annual sea ice retreat crucial for modulating biological carbon pump in the Weddell Gyre

Primary production (PP) is vital in driving the net carbon sink in the Southern Ocean, with deep-water formation and gyre circulation providing key pathways for carbon sequestration. Alongside driving the biological carbon pump (BCP), phytoplankton also provide important ecosystem services. Changes to the Southern Ocean system will likely affect the amount of PP that takes place, so it is important to understand what drives the BCP and how changes may influence the ecosystem in the future. Some of the highest rates of PP in the Southern Ocean occur within the seasonal sea ice zone, and research suggests that PP is greatly influenced by sea ice dynamics. Here, we analysed data from satellites and autonomous biogeochemical floats to assess the drivers of PP in the Weddell Gyre. We report that a significant proportion (>48%) of the inter-annual variability is explained by the area of ice-free water. The length of the phytoplankton growing season is also important in predicting annual PP. Consequently, we see that the open ocean, which experiences comparatively lower rates of PP compared to the

shelf region, accounts for 95% of the total carbon uptake by phytoplankton in the Weddell Gyre. We use biogeochemical floats to look closer at spatial patterns in PP and to estimate the amount of chlorophyll that is potentially missed by satellites (~30%). Estimates of export production derived from float estimates of net community production and particulate organic carbon are related to PP and placed within the context of key carbon sequestration pathways.

Dragomir O[1]; Silvano A; Hogg AE; Meredith MP; Nurser AJG; Garabato ACN
[1]University of Southampton.
Poster: Abstract #156 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

Coastal and offshore controls on the variability of the Undercurrent in the Amundsen Sea

The marine-terminating glaciers of the Amundsen Sea are experiencing increased basal melting associated with an inflow of warm and salty water from the deep ocean onto the shelf via submarine glacial troughs. Modelling work suggests that variability in the transport of this source of heat across the shelf-break and onto the Dotson Trough in the western Amundsen Sea is regulated by wind-driven changes in an eastward undercurrent that flows along the continental slope. What controls the strength and variability of the undercurrent, however, is not well documented due to a lack of observations in the region. Here, we use mooring records of undercurrent velocity near the shelf break in the Amundsen Sea throughs in conjunction with a novel 16-year altimetric sea level product that includes measurements in regions of near-perennial ice cover to describe the connection between undercurrent variability and climate modes on seasonal to interannual time scales. We find a robust signature of the undercurrent variability that is linked to both a circumpolar coastal sea level signal as well as to the sea level in an offshore region in the Amundsen Sea. We discuss the implications of this undercurrent-sea level covariability in the context of atmospheric climate modes and we further explore what this link conveys about the undercurrent variability on longer timescales by using of our full altimetry record.

Drennan R[1]; Dahlgren T; Linse K; Glover JCA
[1]NHM London, University of Southampton.
Talk: Abstract #229 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

Cool for cats – phylogeographic structure in the Southern Ocean circumpolar catworm, Aglaophamus trissophyllus (Annelida: Nephtyidae)

Southern ocean ecosystems face significant threats from anthropogenic climate change, with regions of Antarctica experiencing amongst the fastest rates of ocean warming on the planet. In this context, recent molecular investigations into widespread benthic Antarctic species have discovered previously unrecognised diversity and genetic structure, suggesting that our current understandings of Antarctic marine biodiversity may be considerably underestimated, limiting our ability to anticipate the full impacts of future environmental change. The catworm Aglaophamus trissophyllus is a common Antarctic annelid found throughout the Southern Ocean, frequently collected and easily recognisable in benthic investigations due to its large size and striking iridescent colours. The taxonomic history and status of this species has seen considerable confusion over the past century, while recent molecular work has begun to find evidence of cryptic diversity within the currently recognised circumpolar taxon. In this talk, we present the first results of a large-scale phylogeographic investigation into Antarctic A. trissophyllus populations using both genetic and genomic methods, with the aim to examine genetic structure, cryptic diversity, and gene flow around the continent. Collating accurate taxonomic and distributional data is necessary for establishing a baseline to monitor Southern Ocean ecosystems and understanding potential impacts, while investigations into evolutionary and phylogeographic history may reveal how both Antarctic biotas and ice sheets responded to past periods of warming (e.g MIS 5e) and provide secondary lines of evidence to inform current glacial models and projections.

Eager D[1]; Robinson E; Hosegood P; Williamson BJ; Embling CB
[1]University of Plymouth.
Talk: Abstract #149 / Session T14 - A decade of deep ocean science for sustainable development

Changes in fish aggregations in relation to oceanographic processes around a tropical seamount

The Chagos Archipelago Marine Protected Area covers 640,000 km2 of ocean, incorporating numerous topographic features including Sandes seamount. This tropical seamount is a highly biodiverse pinnacle home to apex predators, migratory and endangered species. The physical drivers influencing the distribution and behaviour of fish that encourage these species to remain in the region are unknown. A joint fisheries acoustic and physical oceanographic study was conducted to identify drivers of biodiversity around the seamount. Concurrent acoustic measurements with a Simrad ES70 and acoustic doppler current profiler (ADCP) were conducted during March 2022 at Sandes seamount. Using two frequencies at 38 and 200 kHz, fisheries data was collected to identify the distribution and behaviour of fish over the seamount. Generalized linear models with generalised estimating equations were applied to statistically compare biological variables to oceanographic processes. Fish displayed schooling preferences dependent on the oceanographic conditions observed within the depth band they were situated in. These depth bands are defined by whether conditions are generated by wind, internal waves or processes below the thermocline. Fish aggregations increased with larger schools and apex predators observed during internal wave activity demonstrating that sub-mesoscale oceanographic processes are driving the distribution and behaviour of pelagic fish. By understanding how these drivers promote high biodiversity around Sandes seamount we can learn how spatially important these regions are to the global marine environment.

Eager D[1]; Diaz C; Harris J; Robinson E; Foster N; Embling C; Stevens G; Howell K; Williamson B; Hosegood P
[1]University of Plymouth.
Poster: Abstract #183 / Session T20 - Evidence to support international oceans policy

Biodiversity hotspots: a multidisciplinary study of a protected tropical marine ecosystem

Evidence on the urgent need and importance of marine protected areas (MPAs) is increasing with this topic at the forefront of ocean conservation with supporters championing for the improved monitoring, protection and management of these sites. By investigating the pristine and understudied no take MPA of the Chagos Archipelago we will present a baseline understanding of what a marine environment looks like with minimal anthropogenic interference. We look at the lessons learnt from a decade of research (Hays et al., 2020) in the Chagos Archipelago MPA and how a fine scale multidisciplinary approach may provide answers to some of the questions surrounding large MPA conservation strategies. Our multidisciplinary approach emphasises links between climatic-oceanographic regimes with mesophotic coral ecosystems, pelagic fish, and manta rays. We consider how in the absence of anthropogenic disturbance, climate change, and other environmental factors, drive changes in the distributions of benthic and pelagic organisms within seamount, island, and atoll ecosystems. We aim to inform global stakeholders about how understanding fine scale biological-physical interactions can enhance the efficiency of an MPA supporting sustainable development benefitting the marine environment.

Evans D[1]; Holliday NP; Bacon S
[1]National Oceanography Centre.
Talk: Abstract #189 / Session T24 - The Atlantic Meridional Overturning Circulation: Observations, Simulations and Equations

Mixing and air-sea buoyancy fluxes drive the overturning circulation in the subpolar North Atlantic

The overturning streamfunction as measured at the OSNAP (Overturning in the Subpolar North Atlantic Program) mooring array represents the transformation of warm/salty Atlantic Water into cold/fresh North Atlantic Deep Water (NADW). The magnitude and variability of the overturning at the OSNAP mooring array can therefore be linked to the water mass transformation by air--sea buoyancy fluxes and mixing in the region to the north of the OSNAP array. Here, we estimate these water mass transformations using a combination of observational-based, reanalysis-based and model-based datasets. Our results highlight the complementary roles of air--sea buoyancy flues and mixing in setting the time-mean magnitude of the overturning at OSNAP. A cooling by air--sea heat fluxes and a mixing-driven freshening in the Nordics Seas, Iceland basin and Irminger basin, precondition the warm/salty Atlantic Water, forming subpolar mode water classes. Mixing in the interior of the Nordic Seas, over the Greenland-Scotland ridge and along the boundaries of the Irminger and Iceland basins drive a water mass

transformation that leads to the convergence of volume in the water mass classes associated with NADW. The seasonal variability of the overturning streamfunction at OSNAP cannot be linked to changes in the transformation by air--sea fluxes and mixing. This implies that water mass transformation anomalies in the region to the north of the OSNAP array don't manifest as overturning variability at the latitude of the OSNAP array on seasonal timescales.

Fernández Castro B[1]; Mazloff M; Williams RG; Naveira-Garabato AC
[1]University of Southampton.
Talk: Abstract #180 / Session T26 - Physical Oceanography Open Session - Water Masses

Lagrangian pathways for heat, nutrients and carbon subduction with sub-Antarctic Mode Waters

Sub-Antarctic Mode Waters (SAMW), forming in the deep winter mixed layers in the Sub-Antarctic Zone (SAZ) to the north of the Antarctic Circumpolar Current (ACC), connect the ocean thermocline with the atmosphere, contributing to ocean carbon and heat uptake and transporting high-latitude nutrients northward, to fuel primary production at low latitudes. The important climatic role of SAMW is controlled by the rate of fluid subduction from the deep winter mixed layers and the concentration of heat, carbon and nutrients at the end of winter. These concentrations depend on a range of processes, both physical (air-sea exchange, transport of Antarctic waters across the ACC, along ACC advection, eddy fluxes, diapycnal mixing, etc.) and biogeochemical (biological uptake, export and remineralisation), whose relative contributions are very poorly understood. With a Lagrangian particle-tracking experiment in a data-assimilative coupled physico-biogeochemical model of the Southern Ocean (B-SOSE), we assess the origin of the water masses reaching SAMW formation regions and the physico- and biogeochemical transformations occurring along their transport pathways. Our results underline the importance of the advection of subtropical waters along the ACC for the sequestration of heat and anthropogenic carbon and in modulating the fertilization of the low-latitude thermocline.

Fisher B[1]; Poulton A; Davidson K; Meredith M; McNeill S; Smith A; Henley S
[1]University of Edinburgh.
Talk: Abstract #138 / Session T10 - Micro to macro: linking bottom-up and top-down approaches that investigate the function, resilience and conservation of polar ecosystems

Biogeochemical implications of climate driven species shifts among Southern Ocean primary producers.

Across the Southern Ocean, the physical effects of climate change manifest in reduced salinity, increased stratification, strengthened nutrient supplies and increased light availability (Moore et al., 2018). These changes modulate the abiotic conditions in the upper ocean and is expected to result in an ecological shift towards an increased abundance of small phytoplankton species (e.g. cryptophytes and haptophytes) (Henson, Cael, Allen and Dutkiewicz, 2021). Marine phytoplankton in the Southern Ocean play an important role globally in the recycling of nutrients for export across the thermocline, and additionally in the regional uptake of nitrogen and carbon for organic matter supply to the ecosystem (Henley et al., 2020). The close link between phytoplankton and marine chemistry suggests that ecological shifts in primary producers can be expected to be observed in biogeochemical cycles. Here, we use culture experiments of five different Southern Ocean phytoplankton species to determine their rates of carbon and nitrogen uptake. Results from this experiment provide an insight in to biological carbon and nitrogen dynamics associated with restructured phytoplankton communities under continued climate change.

Moore, J., Fu, W., Primeau, F., Britten, G., Lindsay, K., Long, et al. (2018). Sustained climate warming drives declining marine biological productivity. Science, 359(6380), pp.1139-1143.
Henson, S., Cael, B., Allen, S. and Dutkiewicz, S., (2021). Future phytoplankton diversity in a changing climate. Nature Communications, 12(1).
Henley, S., Cavan, E., Fawcett, S., Kerr, R., Monteiro, T., & Sherrell, R. et al. (2020). Changing Biogeochemistry of the Southern Ocean and Its Ecosystem Implications. Frontiers In Marine Science, 7.

Flanagan O[1]; Lough A; Annett A; Lohan M
[1]University of Southampton.

Talk: Abstract #85 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

Particle Trace Metal Geochemistry of the Rainbow and TAG Hydrothermal Vent Plumes

Observations of trace metal persistence in distal aspects of hydrothermal plumes has highlighted a need to better understand the mechanisms by which these metals are stabilised over such large distances (some greater than 4000 km, Fitzsimmons et al., 2017). Current theories propose dynamic exchanges occur between the particulate and dissolved phases (Roshan et al., 2020), however, this mechanism is still poorly constrained and the role of nanoparticulates is not fully understood. Here we present a subset of new particle trace metal composition data produced from the GEOTRACES GA13 cruise along the Mid-Atlantic Ridge. We compare the variation in the plume particle chemistry between the Rainbow and TAG hydrothermal vent fields which present differences in both basement geology and vent fluid composition. We observed significantly higher concentrations in all elements in the Rainbow plume compared to TAG, most obvious in pFe (3.77 μM and 93.4 nM respectively). Strong correlations exist between pFe and pCu (R2 = 0.999), pCo (R2 = 0.999), and pZn (R2 = 0.995) which displayed nearly constant Fe/Me ratios in the core of the Rainbow plume, suggesting a co-precipitation of these elements with or adsorption to Fe minerals in a constant molar ratio. However, these relationships are not always mirrored in the TAG plume. We explore the differences in particle composition further by incorporating scanning electron microscopy of filtered particles to better elucidate the morphology of particle aggregates and their elemental distributions.

Fleming B[1]; Simon-Lledó E; Benoist N; Jones DO
[1]National Oceanography Centre, Southampton.
Poster: Abstract #184 / Session T2 - Deep Sea Mining 2 - environmental aspects: baselines, impacts, monitoring

Variation in megafaunal diversity across different spatial scales in a mining licence area of the Clarion-Clipperton Zone.

The abyssal seafloor (3000-6000m) provides a unique environment to study the impact of spatial scale on biodiversity as many environmental conditions are relatively stable over large areas. The abyssal Clarion-Clipperton Zone (CCZ) contains extensive polymetallic nodule fields, much of which are currently under mining exploration licences. This study aims to assess the influence of spatial scale on megafaunal density, diversity and community composition using images of the seafloor collected by a remotely operated vehicle. Quantitative photo transects were collected in 4 study areas (five 2 km transects in each area) separated by distances of approximately 1 km to >100 km. The study areas incorporate a range of seafloor types (three different nodule types, nodule-free and rock fragment areas) and include a proposed mining area and preservation reference zone (PRZ). Early results suggest that megafauna density, diversity and community composition vary between study areas. In particular, PRZ has lower mean density of megafauna and a different community composition compared to the other study areas. This is likely owing to the greater variation in seafloor type found in this area. This indicates that seafloor type and habitat heterogeneity are likely important for influencing biodiversity patterns in the abyss over the spatial scales explored in this study (10s-100s km). As data was collected from a mining licence area, the results also provide important baseline biodiversity information and will have implications for future monitoring.

Fowell S[1]; Papadimitriou S; Flohr A; Schaap A; Loucaides S; Saw K; Brown R; Paxton D; Brown P
[1]National Oceanography Centre.
Talk: Abstract #60 / Session T7 - Pushing the limits in autonomous oceanography in a net zero carbon world

Autonomous Lab-on-Chip Biogeochemical Sensors on the RAPID East Mooring Array

Biogeochemical parameters such as Total Alkalinity (TA) and Dissolved Inorganic Carbon (DIC) are commonly measured on research cruises by manually sampling seawater from CTD depth profiles and analysing the samples using benchtop techniques in the laboratory. This is both laborious and expensive and provides us with only low spatial and temporal resolution data. In the new age of Net Zero oceanography, autonomous sensor technology can provide higher resolution data for a reduced logistical and analytical effort. We deployed multiple

autonomous microfluidic lab-on-chip (LOC) pH, TA, nitrate/nitrite, and phosphate sensors at depths ranging from 50m to 3000m on the RAPID East (26°N) moorings. These novel sensors were deployed on custom-made frames alongside custom-designed battery housing technology, all pressure rated to 600 bar (6000m). The LOC sensors are collecting high resolution biogeochemical data for up to 21 months, the longest unattended deployment to date, alongside the traditional suite of commercial instruments for measuring physical and biogeochemical parameters on the RAPID array. Additionally, during the cruise DY146, a pH and a TA LOC sensor were deployed on 18 and 8 CTD casts respectively, to a maximum depth of 5000m for the first time. Concurrently sampling seawater from the Niskin bottles for the analysis of nutrients, pH, TA, dissolved oxygen, and DIC allows us to compare the efficacy of autonomously collected pH and TA data against traditional benchtop chemical analyses.

Fox A[1]; Biastoch A; Cunningham S; Fraser N; Handmann P; Holliday NP; Johnson C; Martin T; Oltmanns M; Rath W; Rühs S; Sanchez-Franks A; Schmidt C
[1]Scottish Association for Marine Science.
Talk: Abstract #111 / Session T24 - The Atlantic Meridional Overturning Circulation: Observations, Simulations and Equations

Exceptional freshening and cooling in the eastern subpolar North Atlantic caused by reduced Labrador Sea surface heat loss

Observations of the eastern subpolar North Atlantic in the 2010s show exceptional freshening and cooling of the upper ocean, peaking in 2016 with the lowest salinities recorded for 120 years. Published theories for the mechanisms driving the freshening include: reduced transport of saltier, warmer surface waters northwards from the subtropics; shifts in the pathways of fresher, cooler surface water from the Labrador Sea driven by changing patterns of wind stress; and the eastward expansion of the subpolar gyre. Tracking virtual fluid particles backwards from the eastern subpolar North Atlantic in a high-resolution model shows the primary immediate cause of the freshening and cooling to be an increased outflow of relatively fresh and cold surface waters from the Labrador Sea; with a minor contribution from reduced transport of warmer, saltier surface water northward from the subtropics. The cooling, but not the freshening, produced by this changing proportions of source waters is mitigated by reduced along-track heat loss to the atmosphere in the North Atlantic Current. Modelled boundary exchanges and water mass transformation in the Labrador Sea show that the increasing outflow of lighter surface waters is due to reduced surface heat loss in the Labrador Sea beginning in the early 2000s. Tracking particles further upstream reveals the primary source of the increased volume of lighter water transported out of the Labrador Sea is increased recirculation of water, and therefore longer residence times, in the upper 500—1000 m of the subpolar gyre.

Francis A[1]; Tuerena R; Ganeshram R
[1]The University of Edinburgh.
Talk: Abstract #152 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

Investigating the Extent and Controls of Nitrogen Fixation in the Mediterranean Sea

The marine nitrogen cycle is essential for sustaining life in global oceans. Nitrogen fixation, a part of this cycle, involves organisms converting atmospheric nitrogen into bioavailable forms and is the primary process introducing these forms into the ocean. Recent studies have revealed many new aspects of marine nitrogen fixation but knowledge gaps still remain, especially with regard to specific controls on fixation and its extent within smaller basins and seas. This project investigates these issues within the Mediterranean, a large semi-enclosed sea with unique hydrography and biogeochemistry. It has lower nutrient concentrations and considerably higher Nitrogen to Phosphorus (N:P) ratios than the rest of the global ocean. This has an important influence on primary productivity in this basin but the origin of these anomalous ratios is unclear. Previous studies have shown that fixation is important for nitrogen dynamics in the Mediterranean and could be an explanation for the N:P ratios. However, findings are conflicting on the spatial extent of fixation and how it impacts the overall biogeochemistry and productivity of the Mediterranean. This project uses extensive sampling areas and stable isotopic analysis of multiple nitrogen species (nitrate, TDN, DON and PON) to answer these existing knowledge gaps. This is the most in depth study to date in terms of spatial coverage and the range of nitrogen species utilised. It also contributes to the understanding of the key nutrient and recycling controls on Mediterranean fixation and the changes expected with climate change, all unclear aspects of Mediterranean nitrogen dynamics.

Fraser N[1]; Drysdale L; Porter M; Inall M
[1]The Scottish Association for Marine Science (SAMS).
Talk: Abstract #65 / Session T7 - Pushing the limits in autonomous oceanography in a net zero carbon world

Boundary current structure and variability characterized using repeat glider observations.

The European Slope Current (ESC) is key pathway for oceanic heat, salt, and nutrients towards the Norwegian and North Seas. Furthermore, exchanges between the ESC and the continental shelf are a dominant factor in determining the oceanographic conditions around the British Isles. However, due to its fine spatial scales and high synoptic variability, the ESC volume transport remains poorly constrained by both hydrographic both satellite observations. We gathered 110 glider transects over 22 months to which capture the ESC velocity field in unprecedented detail. As gliders follow crooked and inconsistent trajectories, we developed an along-isobath transformation which allows us to analyse different transects on a common zonal section. Individual transects are impacted by synoptic scale variability, however the number of transects gathered is sufficient to characterise both the mean state and the emergent seasonal variability. The velocity fields also reveal the year-round presence of a southward counter-current over the lower slope. This previously unobserved feature exhibits substantial variability in structure and strength, thus modulating net northward transport in the Eastern boundary current system.

Freer J[1]; Banas N; Tarling G
[1]British Antarctic Survey.
Poster: Abstract #146 / Session T10 - Micro to macro: linking bottom-up and top-down approaches that investigate the function, resilience and conservation of polar ecosystems

Can Calanus finmarchicus succeed in the Arctic? Evidence from project DIAPOD

The Changing Arctic Ocean DIAPOD project led an interdisciplinary team to examine how changes in the Arctic environment are influencing a key zooplankton species, Calanus finmarchicus. Its findings are now providing novel insights in to its ecology, function, distribution, and response to change. Here we summarise evidence from modelling and in situ field sampling, which supports the conclusion that this Atlantic-associated species is capable of completing its life cycle in regions that have recently increased in suitability both spatially and temporally. First, an ecological niche model was used to predict the seasonal distribution of C. finmarchicus in two eras; 1955–1984 and 1985–2017. The model predicts that areas close to the ice-edge in the Fram Strait have become increasingly favourable to C. finmarchicus since 1980s. Field-sampling within this area of increased suitability revealed part of the population there to be capable of amassing enough reserves to overwinter. Early developmental stages were also present in early summer, suggesting successful local recruitment. This is supported by particle tracking simulations of oceanographic currents in the region, which show that the larval stages found at the sampling stations were likely to have been spawned at similar latitudes. Increasingly favourable conditions at the northward range edge of C. finmarchicus is most likely facilitated by the long-term retreat of the ice-edge and associated phenological changes. We discuss the implications our findings in relation to Arctic food webs, Calanus life-history, and future scenarios of Arctic warming and sea-ice loss.

Furby J[1]; Wyatt N; Birchill A; Ussher S; Milne A; Porpatsava K; Milton A; Martin A; Moore C
[1]University of Southampton.
Poster: Abstract #176 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

Multi-Element Stoichiometries of Mixed Diatom Communities from the S.E. Pacific Sector of the Southern Ocean, using Laser-Ablation Inductively-Coupled-Plasma Time-of-Flight Mass-Spectrometry

Primary productivity in the surface global ocean largely defines the cycling of macro- and micro-nutrient elements through uptake and assimilation. Hence, accurately quantifying multi-element quotas and uptake ratios of marine phytoplankton assemblages provides invaluable insight into biogeochemical cycles and carbon sequestration. Recent advances in analytical techniques have facilitated the emergence of multi-element stoichiometry analysis

on a single cell basis, revealing significant intracellular deviations from standard bulk analysis methodologies across both cultured and natural phytoplankton communities. This study aimed to test and develop the methodology for applying Time-of-Flight (ToF) Inductively-Coupled-Plasma Mass-Spectrometry (ICP MS) to the single cell analysis (SCA) of natural diatom communities. This was achieved using Laser Ablation (LA) to generate 2D element concentration maps of samples taken along a meridional transect in the remote South-East Pacific Sector of the Southern Ocean. Averaged P-normalised element ratios for Si, Mg, Mn, Fe, Cu, and Zn, of both community-averaged and isolated Chaetoceros spp. chains, followed reasonably closely to expected multi-element stoichiometries of natural assemblages in published literature using SCA techniques. We further discovered significant differences between station means of element-P ratios, highlighting the plasticity of multi-element stoichiometries across different biogeochemical provinces. LA ICPToF- MS used in this study has demonstrated the ability to investigate variations in multi-element stoichiometries at incredible precision and high throughput speeds, with the potential for SCA across ocean basin scales, and in so doing, can best train biogeochemical models to better predict regional responses of the Earth and ocean system to changes over time.

Galata S[1]; Kiriakoulakis K; Amaro T
[1]Liverpool John Moores University.
Talk: Abstract #125 / Session T2 - Deep Sea Mining 2 - environmental aspects: baselines, impacts, monitoring

The impact of mining plumes at the organic matter quality and quantity at two areas of the Clarion-Clipperton Zone

The deep sea, water and seafloor areas below 200 meters, compromises 90% of the biosphere. It is a vast, pristine and uncharted area with rich biodiversity and biophysical systems, which support crucial processes in carbon sequestration, affecting global carbon cycles and climate regulation. Furthermore, the deep sea provides a wealth of mineral resources, such as manganese nodules, massive seafloor sulphides and cobalt-rich crusts, which has led to an increasing interest in exploitation by industries. It is becoming the next frontier for the discovery of valuable resources with a growing interest in exploration and industrial exploitation of a wide range of raw materials. However, the risk of a potential environmental mining impact is enormous, but to date, its significance and measurability are mostly undetermined. In this context, the proposed research project MiningImpact2 (JPI Oceans project -Pilot Action 2) project aimed to investigate the mechanisms underlying the impacts of mining in the Clarion-Clipperton Fracture Zone (CCZ) situated in the NE Pacific. This area contains high abundances of polymetallic manganese nodules on the abyssal seafloor, which are potentially valuable sources of cobalt, copper, manganese and nickel (among other metals), and therefore became a focal area for mining interests. Within this line, the two key objectives of this work were to investigate: a) The effects of the settling and resuspension of plume material on the nutritional quality of organic matter, as indicated by the abundance and composition of lipids, which serves as the only energy source for the benthos, at the CCZ, b) The impact of mining on the nutrition of deep-sea holothurians, keystone organisms of deep-sea ecosystems, was also explored. To achieve the objectives, 28 sediment samples (down to 10 cm; sampled by a multicorer) and 23 surface deposit-feeder holothurians samples were collected during two cruises to two contracted areas of the CCZ (Belgian and German contracts), one before (RV SO268 27.2-27.05.2019) and another after testing mining operations (IP21 11.4-15.5.2021). Preliminary results show enrichment of lipids in subsurface sediments (1-10cm) after the test mining, providing initial indications for a measurable ad potentially significant impact on OM availability and quality. Analyses of holothurians are currently underway.

Gebruk A[1]; Roberts JM; Henry L; Biastoch A; Schulzki T; Rakka M; McClenaghan B; Hajibabaei M; Ross SW; Eggleton J; Cardy C
[1]University of Edinburgh.
Talk: Abstract #235 / Session T24 - The Atlantic Meridional Overturning Circulation: Observations, Simulations and Equations

At the interface of deep-sea science – cross-sector research collaboration to study the world's most famous deep-sea wreck during the OceanGate 2022 Titanic Expedition

In summer 2022 five marine expeditions were organised by OceanGate Expeditions, in partnership with OceanGate Foundation, to study the Titanic wreck at approximately 3,800 m depth offshore Newfoundland, Canada. These expeditions constitute a unique collaboration example between academia (e.g., the iAtlantic research programme), industrial partners (eDNAtec and Nortek), and the private sector. 2022 Titanic Expedition

illustrates how interests of private sector, and specifically the developing field of deep-sea tourism and exploration, can enable continuous multidisciplinary observations and data collection in otherwise extremely difficult to access research sites. Through collecting water samples, observations and in-situ measurements the expedition aimed to describe and document oceanographic conditions and biological communities in and surrounding the wreck, and better understand the impacts of the wreck on deep-sea biodiversity, including modelling the dispersal of cold-water larvae to and from the wreck. Collecting biological and oceanographic data from the Titanic site, namely, series of continues measurements of deep-sea currents, can strengthen the biophysical models of cold-water larval dispersal both from and to the wreck, ultimately helping us to answer an important ecological question – to what extent may the Titanic wreck act as a source of larvae for new populations of cold-water corals in the Atlantic? The expedition used cutting edge research technologies, including environmental DNA analysis and autonomous deep-sea current meters, which also provides an important case study demonstrating how collecting environmental data can complement and strengthen biodiversity research. The data from the expedition will improve our understanding of deep-sea biological fouling of artificial substrates, also contributing to the diverse knowledge system of the Atlantic deep-sea ecosystems.

Giering S[1]; Culverhouse PF; Johns DG; McQuatters-Gollop A; Pitois SG
[1]National Oceanography Centre (NOC).
Poster: Abstract #358 / Session T24 - The Atlantic Meridional Overturning Circulation: Observations, Simulations and Equations

Are plankton nets a thing of the past? An assessment of in situ imaging of zooplankton for large-scale ecosystem assessment and policy decision-making

Small planktonic animals ('zooplankton') are fundamental to multiple aquatic ecosystem services such as carbon and nutrient cycling and oxygen production. A robust evidence base of how zooplankton respond to changes in anthropogenic pressures, such as climate change and nutrient loading, is hence key to implementing effective policy-making and management measures. Currently, the needed evidence, such as long time-series and large-scale datasets of zooplankton distribution and community composition, are too sparse owing to practical limitations in traditional collection and analysis methods. The advance of in situ imaging technologies that can be deployed at large scales on autonomous platforms coupled with artificial intelligence and machine learning (AI/ML) for image analysis promise a solution. However, it is currently unclear whether imaging could reasonably replace physical samples, and whether AI/ML can achieve a taxonomic resolution that scientists trust. We here build a roadmap for imaging and AI/ML for future zooplankton monitoring and research based on community consensus. To do so, we determined current perceptions of the zooplankton community with a particular focus on their experience and trust in the new technologies. Our survey revealed a clear consensus that traditional net sampling and taxonomy must be retained, yet imaging will play an important part in the future of zooplankton monitoring and research. There must be a period of overlapping use of imaging and physical sampling systems before imaging can reasonably replace physical sampling for widespread time-series zooplankton monitoring. In addition, comprehensive improvements in AI/ML and close collaboration between zooplankton researchers and AI developers are needed for AI-based taxonomy to be trusted and fully adopted.

Glover A[1]; Rabone M; Jaspars M; Duncan K; Horton T; Copley JT; Oluwabusola R; Scobie D; Ginigini J; Soapi K; Parianos J; Herman A; Browne R
[1]Natural History Museum.
Talk: Abstract #340 / Session T2 - Deep Sea Mining 2 - environmental aspects: baselines, impacts, monitoring

The DEEPEND project: an informed societal decision on deep-sea mining requires scientists to show the benefits of protected areas

Deep-sea mining in international waters, and in most national waters is currently not permitted. The current regulatory regime for exploration is highly precautionary and requires extensive biodiversity survey in potential targeted regions, and control sites that would be used for future monitoring. Within international waters, no industrial or nation state contractor has so far completed an exploration survey and been allowed to move to a commercial phase. All deep-sea mining environmental plans include leaving large proportions of the deep sea undisturbed and protected. Future societal decisions on seabed mining will depend as much on understanding the value of preserved regions as it will the actual impacts on the targeted areas. Without this knowledge, it will not be possible to make the seemingly simple (but actually complex) comparison between the impacts of deep-sea mining and terrestrial mining. With this basic question in mind, we have launched a new project called

DEEPEND which aims to further our understanding of the intrinsic and natural product value of biodiversity in newly-explored deep-sea regions that are protected from deep-sea mining.

Goddard-Dwyer M[1]; Ryan-Keogh T; Hamelin B; Liao W; González-Santana D; Baudet C; Vorrath M; Lemaitre N; LoMonaco C; Barut G; Fin J; Mignon C; Vivier F; Kestenare E; Eldin G; Clerc C; Izard L; Sergi S; Planquette H; Jeandel C; Tagliabue A; Whitby H
[1]University of Liverpool, UK.
Talk: Abstract #195 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

Biogeochemical Cycling of Iron Binding Humic Ligands in the South-West Indian Sector of the Southern Ocean.

The availability of iron (Fe) regulates the carbon cycle over much of the ocean via control of primary production. Fe availability is mediated by a diverse group of Fe binding organic molecules called ligands. Of this Fe binding ligand pool, humic ligands (HL) are thought to play a significant role. However, HL distribution in key Fe limited regions and the processes involved in its cycling are largely unknown. The South-West Indian Sector of the Southern Ocean is a largely Fe-limited region with patches of Fe-replete waters derived from sub-Antarctic islands. We present the first large-scale quantification of natural Fe-HL and total HL concentration in this region measured by cathodic stripping voltammetry on SWINGS GSO2 (GEOTRACES) transect. We use these data to infer links between biological processes such as primary production and organic matter remineralisation with Fe-HL biogeochemistry. Ultimately, these data help understand how Fe from sub-Antarctic islands is supplied and subsequently cycled through the Southern Ocean which consequently controls carbon cycling in the region.

Goldsworth F[1]; Johnson H; Marshall D
[1]University of Oxford.
Talk: Abstract #196 / Session T24 - The Atlantic Meridional Overturning Circulation: Observations, Simulations and Equations

Symmetric instability in components of the Atlantic Meridional Overturning Circulation

Over the last few decades our understanding of the Atlantic Meridional Overturning Circulation (AMOC) has progressed, with us no longer seeing it as a coherent "global conveyor", but as having contributions from many different current systems, which vary across a variety of temporal and spatial scales. In particular, the role of mesoscale variability has become better understood. In this talk I will zoom in even further, and examine the role of sub-mesoscale instability in idealised models of three western boundary currents which are known to be important AMOC pathways – in particular, the North Brazil Current, the Deep Western Boundary Current as it crosses the equator, and the Irminger Current. I will explain the different mechanisms generating sub-mesoscale instabilities, and attempt to quantify the amount of diapycnal mixing and water mass transformation produced by these instabilities.

Gordon J[1]; Taylor M; Wareham-Hayes V; Howell K; Quattrini A; Arias MB
[1]University of Essex.
Talk: Abstract #336 / Session T14 - A decade of deep ocean science for sustainable development

Population structure of deep-sea octocoral Acanella arbuscula *(Isididae) across the North Atlantic, using SNPs generated from UCE sequencing*

Deep-sea coral gardens provide essential ecosystem services to marine organisms at various stages of their life histories, providing shelter, breeding grounds, and food. These vulnerable marine ecosystems are targets for fishing, because they host economically important species. Trawling destroys cold water coral reefs, and areas subjected to repeated bottom fishing activity have experienced the terrestrial equivalent of clear cutting a forest, with little signs of recovery post-trawling. Large gardens of *Acanella arbus*cula growing in soft sediments, which can stretch several kilometers, are uprooted and destroyed when contact with fishing gear occurs. These octocorals are ecologically important, because *A. arbuscula* are known to host species for many invertebrates. In order to protect these vulnerable marine ecosystems, understanding population connectivity is essential to

informing marine protected area (MPA) design. To investigate population connectivity of *A. arbuscula* across the North Atlantic, specimens were collected at multiple parallel depth bands from Newfoundland and Labrador, Scotland, The Celtic Sea, and The Sea of Biscay. Identifying source populations for recovery and overall connectivity across the North Atlantic will support the design of an effective MPA network. This population structure will be inferred from the analysis of single nucleotide polymorphisms (SNPs) generated through high throughput sequencing of ultra-conserved elements. Furthermore, the SNPs will be used to test the depth differentiation hypothesis across the North Atlantic which proposes that there is greater genetic differentiation across depth ranges as opposed to geographical distance. It is suspected that some barriers to connectivity exist including those associated with currents, temperature, salinity, oxygen, and nutrient availability.

Graham J[1]; Harrison L; Liu H; Silva T; Haverson D; Devlin M
[1]Cefas.
Talk: Abstract #117 / Session T20 - Evidence to support international oceans policy

Modelling for the Ocean Country Partnership Programme

Through the Ocean Country Partnership Programme (OCPP), Cefas is working with many countries, throughout the Indian and Pacific Oceans, to advise on monitoring and management of their coastal and marine environments. As the number of observations in many regions can be limited, modelling can play a crucial role in understanding the current state and variability of coastal environments, as well as assessing the impact of future changes. Modelling work within the OCPP Pollution theme has focussed on the development of tools that can be used to assess the dispersal of pollutants, including litter, within the marine environment. While model development has initially been focussed on certain locations or for certain applications, the aim is to develop tools that can potentially be applied in other areas of interest, or for broader applications, in future years. Many different modelling approaches can be used, depending on the region and topics of interest. For example, modelling outcomes can represent dispersal of pollutants from coastal outflows through tracer-release scenarios, or using particle tracking to simulate the dispersal of floating debris. In this presentation, we will demonstrate different modelling approaches and how they relate to the topics of concern for local policy.

Grantham E[1]; Publicover L; Hendry K; McCarthy L
[1]University of Bristol.
Poster: Abstract #61 / Session T20 - Evidence to support international oceans policy

Bottom Trawling in the North Sea: Science, Culture and Governance

Bottom trawling, used to catch fish, crustaceans, and bivalves living on the seabed, is the most widespread human activity affecting seabed habitats. In the North Sea, the proportion of available surface area trawled at least once a year (the trawling footprint) is estimated at 60% of its seabed (Rijnsdorp et al., 2020). Research has shown that bottom trawling can cause habitat loss, alterations in benthic community structures and changes in biogeochemical cycles that can affect even global climate dynamics. Despite extensive studies investigating the scientific impacts of bottom trawling on the North Sea, it is still a popular fishing practice in the region. Few studies have investigated why this is the case. To tackle this research area, I aim to develop a research project that assesses holistically the causes and impacts of this practice. I consider the main scientific impacts and effects of bottom trawling on the North Sea benthic environment. I conduct an in-depth analysis into the political powers and legislation that manage this practice, with a particular focus on corporate bottom trawling. I also investigate the role of European cultural attitudes towards the North Sea, and more specifically the seafloor, in influencing perceptions of this environment and therefore shaping conservation concerns.

Rijnsdorp, A. D., Hiddink, J. G., Van Denderen, P. D., Hintzen, N. T., Eigaard, O. R., Valanko, S., & Van Kooten, T. (2020). Different bottom trawl fisheries have a differential impact on the status of the North Sea seafloor habitats. ICES Journal of Marine Science, 77(5), 1772-1786.

Graves C[1]; Graves C; Benson L; Aldridge J; Austin W; Dal-Molin F; Fonseca V; Hicks NR; Hynes C; Kröger S; Lamb P; Mason C; Powell C; Smeaton C; Wexler SK; Woulds C; Parker ER
[1]Cefas.

Poster: Abstract #49 / Session T15 - Carbon cycling in the global ocean and the role of blue carbon in climate mitigation

Sedimentary carbon on the continental shelf: Emerging capabilities and research priorities for Blue Carbon

In the context of an expanding 'Blue Carbon' (BC) concept, research interest in the quantity and vulnerability of carbon stored in continental shelf, slope, and deep ocean sediments is increasing. In these systems, carbon is less directly coupled to primary productivity than in coastal vegetated 'traditional' BC habitats. The methodological approaches needed to obtain the evidence to assess shelf sea sediment carbon manageability and vulnerability within an evolving BC framework thus cannot be transferred directly from those applied in traditional BC habitats. We set out how to obtain the evidence needed to establish where and when marine carbon in offshore sediments can contribute to climate mitigation, focusing on continental shelf sediments. The key questions to be addressed in this context are: (i) stock: how much carbon is there and how is it distributed? (ii) accumulation: how rapidly is carbon being added or removed? and (iii) anthropogenic pressures: is carbon stock and/or accumulation vulnerable to manageable human activities? These BC-focused questions link directly to the marine carbon cycling questions of carbon provenance and carbon reactivity. Marine scientists have a range of measurement and modelling tools available to provide answers to these questions, from routine, rapid, low-cost analyses to highly specialised techniques and methods which are still in development. We compile relevant techniques to present a marine sediment carbon 'toolbox' from which appropriate sampling and analytical approaches can be chosen for the studies which will fill the evidence gaps identified and enable improved assessment of the climate mitigation role of the seabed.

Green M[1]; Hadley-Pryce D; Davies H; Scotese C
[1]Bangor University.
Poster: Abstract #107 / Session T28 - Physical Oceanography Open Session - Coastal Physics

1750000000 years of tides

Ocean tides impact a range of Earth system processes, including driving primary production, sustaining the climate-regulating global overturning circulation, and setting the environment for key evolution events. The dissipation of tidal energy also slows down Earth's spin and forces the moon to recede in an effort to conserve angular momentum, meaning the tides are first-order controller of daylength. Here, we use a well-established and dedicated numerical tidal model and the latest tectonic reconstruction to investigate how the tides have changed over long-time scales, both in the past and the future. The results show tides that have, on average, dissipated energy at about 40% of the present-day rates with potentially far-reaching consequences for other parts of the Earth system. These rates can vary with over an order of magnitude as Earth goes in and out of geologically brief – 10-25 Myr – tidal maxima linked to the supercontinent cycle. We show that Earth is on the way out of the current maxima, and that a previously unknown maximum occurred around 150 Ma. Whilst dynamically sound, the need for tidal proxies is evident, as is better constrained boundary conditions.

Griffiths A[1]; Cavan E; Tarling G; Belcher A
[1]Imperial College London.
Poster: Abstract #162 / Session T10 - Micro to macro: linking bottom-up and top-down approaches that investigate the function, resilience and conservation of polar ecosystems

What drives krill and macrozooplankton diversity in the Southern Ocean?

Krill (Euphasia superba) represents a vital link between trophic levels in the Southern Ocean, supporting a plethora of food-webs, a regional fishery and vital carbon sequestration. For the first time, macrozooplankton communities in South Georgia have been analysed over a full decade, comparing abundance data with variability in chlorophyll-a concentration, sea surface temperature and shelf region. Although no one explanatory variable was identified, the influence of bathymetry and large climate signals on krill was observed in this study. Overlapping communities indicated the presence of two food-webs, impacted by depth and top-down control by predation. The preferential range of krill and fluctuating abundances, compared to the versatility and consistency of salps, indicated the potential for a shift in dominance. These changes in community composition pose threats to current food-web dynamics, and global carbon storage. This paper analysed community with metrics such as species

composition, abundance, biomass and diversity. Environmental factors that may influence the biology of macrozooplankton were examined using in-situ and satellite data. Potential future consequences on biogeochemical cycles, and food-web structure are discussed.

Guo B[1]; Byrne HM; Green JAM; Hadley-Pryce D
[1]Bangor University, School of Ocean Science.
Poster: Abstract #341 / Session T23 - Unlocking Climate Histories from Marine Sediments

Deep time tidal modelling and validation using palaeotidal range proxies for the Early Devonian

Dynamic palaeotidal modelling provides insights into the evolution of shallow marine and coastal organisms, the evolution of the Earth-Moon system's orbital configuration, etc. However, there is limited research about the validation of paleotidal modelling, which should be attributed to a lack of available observational data (tidal proxy) and the great uncertainties in paleotidal model configurations. In this study, dedicated palaeotidal models for the Early Devonian (400 Ma) were established and validated with multiple tidal proxies. The model performance and sensitivity with different sources of paleogeographic reconstructions, different values of bottom frictions, and stratification coefficients were investigated by comparing the corresponding model predictions with the tidal proxies. The results show that the model predictions with either palaeogeographic reconstructions from Scotese and Blakey generally match with the tidal proxies. However, the model with palaeogeography reconstructed by Scotese predicts a microtidal regime in the Rēzekne and Pärnu Formations (present day Baltic states), which disagrees with the meso-macrotidal regime as suggested by the proxy on this site. Furthermore, the model predictions are insensitive to the changes in stratification values ranging from 0.5 to 2, while the predicted harmonics constituents M2 and S2 slightly increase with the decrease of the bottom friction coefficient in the range of 0.0015 - 0.006. The paleotidal modelling validation process presents a practical constraining to the palaeogeography reconstruction and the model configurations.

Hall E[1]
[1]Creative Carbon Scotland , University of Glasgow.
Talk: Abstract #185 / Session T16 - How Art-Science Collaborations can Inspire Societal Change

Seas of the Outer Hebrides: Learning from collaborative, creative approaches to public engagement

Scottish Marine Protected Areas (MPAs) have traditionally been designated and managed through a top-down approach, but the MarPAMM Seas of the Outer Hebrides (SEASOH) project sought to engage island communities to identify the best way to manage MPAs for both people and nature. Creative Carbon Scotland partnered with the SEASOH project team to bring inclusive, creative approaches to the process of working with Outer Hebrides communities. Research was conducted to understand the benefits of using creative approaches for public engagement, the conditions necessary to support these types of collaborations, and lessons learnt for future projects looking to incorporate this approach. Sources of evidence collected included participant surveys, event observations, focus groups, and interviews with both creative practitioners and the SEASOH project team. Creative approaches were observed to catalyse effective public engagement by creating a relaxed tone and immersive atmosphere, generating physical and emotive connections to marine issues, and stimulating trust and confidence through two-way exchange. Marine practitioners identified that taking a collaborative, creative approach had also influenced their own practice and methods for delivering project outcomes in more inclusive and innovative ways. Reflections by the SEASOH project team on the challenges and lessons learnt from the project were used to inform a set of recommendations for future art-science collaborations, which will be shared during the Plenary Session to inspire and inform future project work. Building creative engagement and interdisciplinary perspectives more systematically into a diversity of marine programmes and projects has the potential to achieve even more effective and deep-rooted impacts.

Hammermeister E[1]; Loucaides S; Arundell M; Papadimitriou E; Schaap A
[1]National Oceanography Centre, University of Southampton.
Poster: Abstract #207 / Session T7 - Pushing the limits in autonomous oceanography in a net zero carbon world

State of the Art Autonomous CO2 System Measurements Onboard Boaty McBoatface: Results from an 8-day Mission in the Celtic Sea.

In a world where the climatic response to human carbon emissions has reached a critical point in time, understanding the ocean's role in carbon cycling has become a major focus for scientific observation and intervention. The development of marine autonomous platforms provides observations of higher spatiotemporal resolution, which can be used to further measure, characterize, and model ocean carbon. As a part of the pioneering OCEANIDS programme, novel carbonate chemistry sensors were integrated on the Autosub Long Range (ALR) Autonomous Underwater Vehicle (Boaty McBoatface) and deployed in the Celtic Sea. The project utilized three autonomous Lab-On-Chip (LOC) sensors measuring pH, Total Alkalinity (TA), and Dissolved Inorganic Carbon (DIC). Together, these sensors enable characterization of the marine carbonate system based on direct in situ measurements. This unprecedented technology has the potential to improve our understanding of the inorganic carbon cycle in the ocean and enable ocean acidification monitoring at a higher spatial and temporal resolution than currently possible. Additionally, it presents a powerful tool for CO2 leak detection from sub-seafloor carbon sequestration and storage (CCS) sites and paves the way towards decarbonization of ocean observations. Preliminary results collected in March 2022 during a multi day ALR mission in the Celtic Sea from surface waters to 600m depth will be presented. Sensor data will be validated against discrete water samples collected along the ALR's track. The performance of the new technology and its potential as an observing tool for ocean CO2 observations will be evaluated.

Haond S-A & the eDNAbyss consortium
[1]MARBEC, University of Montpellier, Ifremer, IRD, CNRS, Sète, France
Talk: Session T14 - A decade of deep ocean science for sustainable development

eDNAbyss: A DNA-based exploration of the largest biome on Earth

The largest biome on Earth is by far the deep sea floor, yet the biodiversity it encompasses and the way it contributes to large biogeochemical cycles remain largely unknown. Technical challenges associated to its remote access, to the amount of material needed, and to integrate inventories based on distinct sampling strategies and performed by different experts in distinct areas of the world prevent a comprehensive appraisal of benthic biodiversity in the deep sea floor. The relatively small amount of material required to perform metabarcoding and metagenomics assessments based on eDNA, and the level of standardization they allow offered new promises to advance toward complementary and interoperable biodiversity assessment and improve our understanding of the extent and drivers of deep sea biodiversity. It may also allow unravelling completely unknown lineages, the so-called "dark matter", which identification requires challenging bioinformatics analysis to separate wheat from the chaff. In the framework of the projects Pourquoi Pas les Abysses (2016-2019), launched by Ifremer in 2016 and eDNAbyss (2018-ongoing) supported by the funding of France Génomique and the national Genoscope platform, we developed a series of standard protocols from sampling to bioinformatics analysis, to assess benthic diversity of the deep sea floor across the tree of life. These protocols were applied to a diversity of ecosystems already, allowing to foresee the ability to gather concerted efforts across the international community, to gain a global holistic appraisal of the large reservoir of biodiversity in the deep ocean.

Harris J[1]; Stevens G; Embling C; Robinson E; Hosegood P
[1]University of Plymouth.
Talk: Abstract #202 / Session T21 - Trait-based approaches to improve conservation, management, and restoration of our oceans

Fine-scale oceanographic drivers of reef manta ray (Mobula alfredi) visitation patterns at a feeding aggregation site

A better understanding of the feeding ecology of reef manta rays (Mobula alfredi), a species threatened with extinction, is essential as they are particularly vulnerable to exploitation and disturbance at feeding aggregation sites (Harris et al., 2020). Broad-scale associations between aggregations and physical factors such as wind speed, moon phase, sea surface temperature and tidal phase have been described (Couturier et al., 2018; Dewar et al., 2008; Jaine et al., 2012; Peel et al., 2019). However, feeding activity can change dramatically at aggregation sites with little apparent change in broad-scale conditions. Therefore, a greater understanding of the fine-scale environmental drivers is required. In this unique study, Harris et al. (2021) use passive acoustic telemetry and a suite of oceanographic technologies to investigate the fine-scale (5-min) influence of oceanographic drivers on the M. alfredi visitation patterns at a remote feeding aggregation site in the Indian Ocean. Processes inferred from

boosted regression trees indicate that internal waves and cold-water bores potentially transport zooplankton from the thermocline providing temporally limited feeding opportunities which are enhanced by the tide. Furthermore, they suggest that persistent oceanographic processes such as Langmuir Circulation may provide extended foraging opportunities by transporting and concentrating zooplankton. Identifying these dynamic syntheses of fine-scale oceanographic processes that influence feeding aggregations has advanced our understanding of the species foraging ecology.

Harris L[1]; Baker M; Copley J
[1]Ocean and Earth Sciences, University of Southampton, UK.
Poster: Abstract #267 / Session T1 - Deep Sea Mining 1 - geology, resource, legal, technical and societal aspects

A Cost-Benefit Analysis of Deep-Sea Mining, With a Focus on Economic Viability and the Environmental Impacts of Removal

Deep-sea mining (DSM) retrieves metal-rich deposits from the seafloor below 200 m, which could provide resources for a growing technology sector and "green-energy" transition, whilst moving away from unethical, depleted terrestrial resources. DSM will aim to extract polymetallic manganese nodules, seafloor massive sulphides or cobalt-rich ferromanganese crusts. These deposits are rich in high-value metals many of which are crucial for technology and battery manufacture. However, the inaccessible nature of deep-sea environments, renders the understanding of mining impacts on these ecosystems especially limited. This is a major concern for the ultimate decision to mine these sites and the efficacy of current Environmental Impact Assessments for marine extraction. This study conducts a comprehensive review of likely environmental service and ecosystem impacts and aims to quantify the natural capital costs and benefits of DSM using traditional dredging technology, versus an environmentally conscious hovering, AI technology and current terrestrial mining practices. The study proposes a regulatory framework and environmental standards designed to better inform the ISA's exploitation regulations, including the involvement of the "mitigation hierarchy", improved application of the "precautionary principle" and the meaningful consideration of alternatives. Moreover, if DSM is going to occur, well-informed and cautious regulations to limit costs and maximise benefits are of paramount importance if these ecosystems and their services are to be sufficiently protected.

Hartharn-Evans S[1]; Carr M
[1]Newcastle University.
Talk: Abstract #40 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

The Interaction of Internal Solitary Waves and Sea Ice in the laboratory

Internal Waves are commonly observed along density interfaces across the world's oceans. In the Arctic Ocean, the internal wave field is much less energetic than at lower latitudes, but due to relative quiescence of the region, nonlinear internal waves are particularly important for mixing there. This mixing is responsible for bringing heat from warm Atlantic Water at intermediate depth towards the surface where it has ramifications for the formation and melt of sea ice, as well as the general circulation of the Arctic Ocean. In the rapidly changing Arctic Ocean, as sea ice extent declines, understanding how internal waves interact with sea ice, and how sea ice affects them is crucial, particularly in the marginal ice zone. Using laboratory experiments of internal solitary waves (ISWs) propagating under model ice the interaction of ice and internal solitary waves is investigated. Particle Tracking Velocimetry is used to measure the motion of floating polystyrene discs (with the same density as sea ice - 910kg/m^3). The motion of these discs is compared to the output of numerical models, in order to quantify how ice moves in response to the near-surface internal wave-induced flow. Particle Image Velocimetry is then used to determine how the near-surface internal wave-induced flow dynamics are impacted by the presence and motion of the model sea-ice, which acts as a rough upper boundary condition and moves with the flow.

Hartman S[1]; Gates A; Carvalho F; Pebody C
[1]nOC.

Poster: Abstract #173 / Session T7 - Pushing the limits in autonomous oceanography in a net zero carbon world

Eddies at the Porcupine Abyssal Plain Sustained Observatory: a multi-platform investigation of size, structure and longevity

Here we present on three gliders, deployed at the Porcupine Abyssal Plain Sustained Observatory (PAP-SO), on RRS Discovery Cruise 130 (DY130) in April 2021. The PAP-SO long-term time series site attracts process studies because of the extensive in situ measurements available. The gliders were funded internationally as part of the National Oceanography Centre's collaboration with the NASA EXPORTS programme to quantify export and upper ocean fate of net primary productivity, with further contribution from the iFADO and GOCART projects. The ship enabled close intercalibration with CTDs onboard at the time of deployment of the autonomous systems. There was also extensive sampling around the mission, including additional HPLC, dissolved oxygen and DOM samples. The samples were used to characterise the waters and validate the autonomous sensors on both on the gliders and the year-round moorings at the PAP-SO. Gliders were sent in 3 directions from the ship to sample nearby eddies – the Glider cross-sections identified eddy structure and characterised the cores. We also assessed the longevity of eddys by transecting them using ship ADCP. Eventually focusing on one eddy (A2) – one Seaglider recording the eddy core, the Slocum glider (UK) characterising the eddy structure and the second seaglider focusing on spatial variability using other eddies in the region. The DY130 cruise was followed by a 3-ship occupation of the PAP-SO site by the EXPORTS project, focused on the identified eddy A2.

Hendry K[1]; Whitehouse MJ; Tarling G; Thorpe S; Hoopen PT
[1]British Antarctic Survey.
Talk: Abstract #3 / Session T10 - Micro to macro: linking bottom-up and top-down approaches that investigate the function, resilience and conservation of polar ecosystems

A new macronutrient database from the highly productive island of South Georgia, the Scotia Sea and the west Antarctic Peninsula

One of the key challenges in understanding carbon cycling in the Southern Ocean is disentangling long-term responses from significant spatial and temporal variability in physical and biogeochemical parameters. As such, there is a critical need for regional long-term observational datasets for the model validation and hypothesis testing needed for a better mechanistic understanding of the drivers of primary production. Here, we present a new macronutrient data product, including depth profiles and continuous underway surface measurements of nitrate, nitrite, ammonium, phosphate, silicic acid and co-located temperature and salinity measurements, from 1980 to 2009. The data were collected during all months of the year (with the exceptions of May and June) on a series of sea-going expeditions on the RRS John Biscoe and RRS James Clark Ross, largely part of the British Antarctic Survey's offshore biological programmes to study the ecology of the South Atlantic sector of the Southern Ocean. The new data product provides an unprecedented view of biogeochemical cycling and variability in biologically productive regions of the Southern Ocean across a critical period in recent climate history, and illustrates the importance of building these scientifically valuable and FAIR (findability, accessibility, interoperability, and reusability) observational datasets.

Hendry K[1]; Fisher B; Anderson M; McGregor A; Darlington E; Fielding S; Joshi S; Landeghem KV; Maas B; Marzocchi A; Powney N; Sieradzan K
[1]British Antarctic Survey.
Talk: Abstract #78 / Session T22 - Strengthening Equality, Diversity, Inclusivity and Accessibility in Marine Science

Find A Science Berth: Supporting fieldwork experience on marine research vessels through a software add-on to the Marine Facilities Planning portal

Access to scientific research vessels is fundamental when conducting marine scientific research, however there are a limited number of vessels available in the UK, they are costly to run, and they have a limited capacity for personnel. We connect two main problems here: that diversity in environmental sciences is far lower than in other science disciplines, and that many research cruises are conducted regardless of whether a vessel's personnel

capacity is full. Our survey of available berths on UK scientific vessels, together with case studies of previous cruise participants, revealed that ships often had spare capacity but that individuals only found out about this capacity either through chance encounters or by having pre-existing networks. As part of NERC's EDI Hackathon, we developed FindAScienceBerth (FASB), an online tool designed to help individuals overcome this barrier by creating a searchable system to connect available berths with those looking to gain sea-going experience on UK-based cruises, open to all regardless of career stage or pre-existing connections. The system is designed in collaboration with the software engineers of the Marine Facilities Planning system, which serves to coordinate the use of ships across different research projects, such that it fully integrates with the existing ship planning tools and that it has the capability of expanding internationally. Through the implementation of an inclusivity-focused selection process, FASB aims to support those who have had limited access in the past to have equal access to opportunities, and thus ultimately to improve diversity at sea.

Henley S[1]; Cozzi S; Fripiat F; Meiners KM; Vancoppenolle M; Lannuzel D; Thomas DN; Nomura D; Arrigo K; Delille B; Deman F; Stefels J; Leeuwe Mv; Jones EM; Fransson A; Chierici M; Moreau S
[1]University of Edinburgh.
Talk: Abstract #129 / Session T10 - Micro to macro: linking bottom-up and top-down approaches that investigate the function, resilience and conservation of polar ecosystems

Nutrient biogeochemistry in Antarctic land-fast sea ice and exchange with the surface ocean

Antarctic sea ice biogeochemistry exerts a strong impact on upper ocean processes and air-sea exchange. Observational and modelling studies have contributed much to our knowledge of this important area of Southern Ocean research over recent years, but there remain many unanswered questions and a lack of sufficient data to support modelling efforts of current processes and ongoing change. Here we present an international compilation of macronutrient (nitrate, nitrite, ammonium, phosphate, silicic acid) concentration data from land-fast sea ice around Antarctica collected between 1997 and 2021. We show the major seasonal trends in sea ice nutrient dynamics and how they relate to physical, chemical and biological processes within and around the sea ice, as well as their interplay with nutrient dynamics in the underlying surface waters. We discuss the sources of nutrients to the sea ice matrix, their uptake during spring and summer by ice microbial communities and their recycling on a year-round basis. This internationally collaborative effort will provide the community with a publically available database of nutrient concentration data from Antarctic land-fast sea ice, which is envisioned as a living and developing resource with new datasets added as they become available. This database will drive a step change in our ability to understand and model land-fast sea ice nutrient dynamics around Antarctica and their importance for regional biogeochemistry and marine productivity now and into the future.

Henson S[1]; Laufkoetter C; Leung S; Giering S; Palevsky H; Cavan E
[1]National Oceanography Centre.
Talk: Abstract #4 / Session T15 - Carbon cycling in the global ocean and the role of blue carbon in climate mitigation

Uncertain response of ocean biological carbon export in a changing world

The transfer of organic carbon from the upper to the deep ocean by particulate export flux is the starting point for the long-term storage of photosynthetically fixed carbon. This 'biological carbon pump' is a critical component of the global carbon cycle, reducing atmospheric CO2 levels by ~200 ppm relative to a world without export flux. This carbon flux also fuels the productivity of the mesopelagic zone, including important fisheries. Here we show that, despite its importance for understanding future ocean carbon cycling, Earth system models disagree on the projected response of the global export flux to climate change, with estimates ranging from −41% to +1.8%. Fundamental constraints to understanding export flux arise because a myriad of interconnected processes make the biological carbon pump challenging to both observe and model. Our synthesis prioritizes the processes likely to be most important to include in modern-day estimates (particle fragmentation and zooplankton vertical migration) and future projections (phytoplankton and particle size spectra and temperature-dependent remineralization) of export. We also identify the observations required to achieve more robust characterization, and hence improved model parameterization, of export flux and thus reduce uncertainties in current and future estimates in the overall cycling of carbon in the ocean.

Heorton H[1]; Tsamados M
[1]UCL CPOM.
Poster: Abstract #44 / Session T19 - Mathematics of Satellite Oceanography

CryoSat-2 significant wave height in the Arctic Ocean 2011-2022

We retrieve significant ocean surface wave heights in the Arctic and Southern Oceans from CryoSat-2 data. We use a semi-analytical model for an idealised synthetic aperture satellite radar or pulse-limited radar altimeter echo power. We develop a processing methodology that specifically considers both the Synthetic Aperture and Pulse Limited modes of the radar that change close to the sea ice edge within the Arctic Ocean. All CryoSat-2 echoes to date were matched by our idealised echo revealing wave heights over the period 2011-2019 (Updated to 2022). Our retrieved data was contrasted to existing processing of CryoSat-2 data and wave model data, showing the improved fidelity and accuracy of the semi-analytical echo power model and the newly developed processing methods. We contrasted our data to in-situ wave buoy measurements, showing improved data retrievals in seasonal sea ice-covered seas. We have shown the importance of directly considering the correct satellite mode of operation in the Arctic Ocean where SAR is the dominant operating mode. Our new data is of specific use for wave model validation close to the sea ice edge and is available at http://www.cpom.ucl.ac.uk/ocean_wave_height/.

Hestetun J[1]; Lanzén A; Brandt MI; Kongsrud J; Dahlgren T
[1]NORCE Climate and Environment.
Poster: Abstract #236 / Session T2 - Deep Sea Mining 2 - environmental aspects: baselines, impacts, monitoring

Integrated metabarcoding and morphological taxonomy: A case study from the Norwegian shelf and the potential for deep-sea applications

Metabarcoding is a powerful tool to complement existing methods to characterise benthic biodiversity and understand species distribution. Yet, there are many ways to implement this method, muddying the waters for analysis between studies. Furthermore, a lack of frame of reference from a large body of existing metabarcoding data limits interpretation when compared to morphological taxonomy community data, which restricts its ability to draw ecological conclusions. On the Norwegian continental shelf and slope, the MetaMon and MetaBridge projects conduct metabarcoding sampling alongside regular monitoring based on morphological macrofaunal identification and chemical impact parameters, providing a unique opportunity to compare metabarcoding biodiversity data against a complementary dataset of sediment macrofauna both as a general baseline biodiversity tool, and as a measure of anthropogenic impact. Here, we present some major findings and lessons learned from several studies connected to this work, comprising COI macrofauna and 18S eukaryote metabarcoding data from sediment environmental DNA and faunal bulk samples, and morphological taxonomy. We show that metabarcoding can be applied in several ways depending on specific research goals, governing choice of target organism groups, sample type, sampling intensity and degree of integration with morphological taxonomy. Further, we emphasise how metabarcoding compliments traditional taxonomy in biodiversity biomonitoring: Studies combining taxonomic competence and complimentary metabarcoding data represent an especially attractive strategy for poorly known areas such as the deep sea, where they can enable simultaneous gains in both biodiversity and connectivity for baseline research and impact-related monitoring and assessment of extinction risk.

Hibbert A[1]; Bradshaw E; Hargreaves G; Hill E; Jones D; Mack S; Pérez-Gómez B; Pugh J; Williams S
[1]National Oceanography Centre.
Poster: Abstract #24 / Session T7 - Pushing the limits in autonomous oceanography in a net zero carbon world

Advances in Sea Level Monitoring Technology

Sea levels vary on multiple timescales, from high frequency events like waves, tides and tsunamis, to seasonal and interannual changes and the longer-term trends associated with Climate Change. Tide gauges can capture the full extent of this variability, but can be costly to maintain, particularly where they are used in the long-term

monitoring of sea level for climate resilience, which has more stringent accuracy requirements than for short-term operational forecasting. A related problem is that large uncertainties in rates of land motion at the coast hamper the estimation of long-term sea level trends. Through the Horizon Europe EuroSea project and the National Oceanography Centre's (NOC) UK Tide Gauge project, we have devised prototype low-cost and largely maintenance-free tide gauge systems, which can be powered by renewable energy and which monitor both land motion and sea level, using novel techniques such as ground-based Global Navigation Satellite System Interferometric Reflectometry (GNSS-IR). The systems allow for customisation to local monitoring needs incorporating, for example, sensors for lightning detection and wave height. This builds on the NOC's designs for robust systems operating in the South Atlantic Tide Gauge Network and the hurricane-prone Caribbean Sea and there is potential to advance these technological solutions as a global standard, via the Global Sea Level Observing System (GLOSS) community.

Hibbert A[1]; Matthews A; Pérez-Gómez B; Williams S
[1]National Oceanography Centre.
Poster: Abstract #25 / Session T7 - Pushing the limits in autonomous oceanography in a net zero carbon world

A new global sea level data portal from the novel technique of GNSS-IR

Global Navigation Satellite System (GNSS) receivers are conventionally used to monitor vertical land motion, but where these instruments are located at the coast, the GNSS-Interferometric Reflectometry (GNSS-IR) technique can be used to infer sea level height from a periodic variation in the signal-to-noise ratio between a direct GNSS signal and its reflection by the sea surface. Funded by the Horizon Europe EuroSea project and co-ordinated by the EuroGOOS Tide Gauge Task Team, scientists at the National Oceanography Centre, the Permanent Service for Mean Sea Level (PSMSL) and Puertos del Estado (Spain) have applied this technique to GNSS data from over 300 locations globally. The resulting sea level records and supporting metadata have been incorporated into a new web-based data portal that is hosted at the PSMSL(https://psmsl.org/data/gnssir/). This has increased sea level data availability significantly, with some new sea level records extending back over 15 years. In addition, since GNSS receivers are capable of measuring both sea level and land motion via a single instrument, the new data portal allows scientists to assess the different contributions that are made by each process to the long-term trends observed in tide gauge records. This will improve understanding and predictability of the sea level rise that is associated with climate change. The data portal also incorporates a tool that allows users to identify suitable locations for new GNSS-based tide gauges and envisage the area of the sea surface that can be observed by an instrument at each location. This could prove to be a very valuable tool for the global sea level community.

Higgs N[1]; Adrain T; Rozwadowski H
[1]Cape Eleuthera Institute.
Talk: Abstract #142 / Session T22 - Strengthening Equality, Diversity, Inclusivity and Accessibility in Marine Science

Women Scientists at Sea in the 19th Century: the pioneering Bahama Expedition of 1893

In 1893 a Professor Charles Nutting led an innovative scientific voyage to study marine life around The Bahamas with a group of academics and graduate students from the State University of Iowa. The expedition included women as well as men and spent three months sailing around The Bahamas, Cuba and the Florida Keys undertaking deep-sea dredging operations. Claiming direct lineage from the Challenger Expedition 20 years prior, this expedition set out with great ambition as another of the grand national voyages inspired by the Challenger and was an overwhelming success in many aspects.
This presentation will use the wonderful photographic and documentary evidence from the Bahama Expedition to explore the ways in which it broke new ground for marine science, specifically in:
(1) the participation of women scientists in ocean-going voyages,
(2) making marine science more affordable and therefore accessible, and
(3) bringing marine science to inland institutions.
The involvement of women in all aspects of the endeavour, including living and working aboard the vessel, participating fully in the scientific activities stands in stark contrast to the strong twentieth-century tradition of preventing women from engaging in ocean-going science. So, what was the legacy of The Bahama Expedition and what can we learn from it today to make oceanography more inclusive and accessible?

Higgs N[1]; Finlayson M; Hénaff ML; Rivero U; Rawson G; Bringas F; Goni G
[1]Cape Eleuthera Institute, The Island School.
Poster: Abstract #325 / Session T7 - Pushing the limits in autonomous oceanography in a net zero carbon world

Successful Capacity-Building Using Underwater Glider Observations to Support Hurricane Intensity Research and Forecasts

In 2019, the Island School's Cape Eleuthera Institute in The Bahamas established a base station for underwater glider operations in the tropical western Atlantic in collaboration with the University of Miami's Cooperative Institute for Marine & Atmospheric Studies and NOAA's Atlantic Oceanographic and Meteorological Laboratory. Now in its second season, this project joins a wider network of glider operations across the Caribbean that provides real-time upper ocean data on subsurface temperature, salinity and density. The overall aim of this network is to improve our understanding of the interactions between the upper ocean and tropical cyclones to improve wind intensification forecasts. As well as helping achieve scientific goals, the project has provided leverage for the development of an Ocean Technology Laboratory at the Cape Eleuthera Institute allowing us to branch out into physical marine sciences for the first time. It has funded the participation of two Bahamian scientists in the project, including glider operations and piloting training. The glider project is also used as a tool for teaching ocean science to school children and connecting it to meaningful and tangible outcomes that are locally relevant. This project stands out as a successful case study in capacity building in ocean science, attributable to three key factors: – Investing in local infrastructure – Investing in local scientists – Providing valuable outputs to local stakeholders As we seek to promote a Decade of Ocean Science for sustainable development, examples such as this provide a valuable template for future capacity building work.

Hill D[1]; Forster R
[1]University of Hull.
Poster: Abstract #320 / Session T15 - Carbon cycling in the global ocean and the role of blue carbon in climate mitigation

Controls on phytoplankton blooms and productivity in coastal waters of north-east England

Primary production is critical in supporting biodiversity and higher trophic level fishery catches, and an important regional economic sector along the north-east coast is dependent upon fisheries and tourism. Initial runs for stations off the Yorkshire coast using the Shelf Sea Physics and Primary Production (S2P3) indicated that primary production was very low at offshore stations in the important Yorkshire crab and lobster fishery area. Modelling showed that the water column is too deep and too well-mixed to support phytoplankton growth, partly as a result of very high light attenuation. These findings are based on remote sensing observations and need to be supported by field measurements. Further impetus for understanding biological processes in this area has been given by a series of mysterious die-offs of sea life, possible related to harmful algal blooms. Data collection in the spring and summer of 2022 uses research vessels-of-opportunity (EA, Cefas) to measure spectral irradiance and water column properties, combined with fluorescence-based productivity measurements (FastAct). Additional water samples have been collected by the inshore fishing fleet. I use the in situ data to repeat S2P3 modelling and improve regional estimates of phytoplankton primary production. This will help to understand the implications of low or variable primary production on the surrounding Yorkshire coastal environment.

Homoky WB[1]; Lough AJM; Blackbird SJ; Cowie GL; Dunlea AG; Faust JC; Jeffreys R; Mair AM; Sweetman AK; Wolff GA; Woulds C; Xiong Y
[1]University of Leeds.
Poster: Abstract #321 / Session T2 - Deep Sea Mining 2 - environmental aspects: baselines, impacts, monitoring

Towards a baseline physical and biogeochemical impact assessemnt of experimental deep sea mining in sediments of the Clarion Clippteron Zone

Over geological time, seafloor sediments in Eastern Equatorial Pacific's Clarion Clipperton Zone (CCZ), have formed Manganese (Mn)-nodules with enrichments of nickel, copper and cobalt. The feasibility to collect these Mn-nodules is being investigated to meet growing technological demand for these metals worldwide. Mn-nodules of the CCZ lie within a unique and understudied deep-sea biome in international waters, where a licence for extraction is regulated by the International Seabed Authority (ISA), established by the United Nations Convention on the Law of the Sea (UNCLOS), and first requires an extensive environmental impact and monitoring assessment programme that must be built upon a detailed understanding of the existing seafloor biogeochemistry in the CCZ. Funded by The Metals Company and NORI, our project seeks to: (1) determine the baseline physical and biogeochemical characteristics of seafloor sediments across the NORI-D claim area of the Eastern CCZ, and (2) assess the potential biogeochemical impacts of Mn-nodule collection following experimental test-mining activities in this area. Here, we provide an overview of our project design and its scope of work. We collate a wide range of physical properties and organic and inorganic analytes required for environmental baseline assessment by the ISA at shallow cm-depth scales from spatially-distributed sites within the NORI-D claim area of the CCZ. The variety and resolution of these data is unprecedented in the CCZ and is arguably so compared to any previous studies of the abyssal seafloor, such that they can provide a valuable new baseline for environmental impact assessment and monitoring in NORI-D.

Homoky WB[1]
[1]University of Leeds.
Talk: Abstract #322 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

The unreconciled significance of terrigenous iron supply for the ocean carbon cycle

Terrigenous sediments have long been recognised as an important external source of dissolved iron for marine phytoplankton and therefore the ocean's biological carbon pump. In recent decades, evidence from field observations and model evaluations of iron distribution and isotopic composition in the ocean has demonstrated the central importance of sediments as a contributor of dissolved iron to the ocean's margins and interior, and subsequently for primary production and carbon cycling[1]. However, an intrinsic assumption has often gone unchallenged, that 'dissolved iron' (filtered through 0.2 microns) is primarily important because of its potential to alleviate iron-limited growth of primary producers. In this talk, I will present the evidence derived from deep-ocean sediment porewater which shows the inventory of dissolved iron available to the ocean interior from weathering of terrigenous material on continental slopes, is in the form of iron colloids, or nano-scale organominerals[2], the fate and accessibility of which to phytoplankton remains unclear. I will highlight parallels between these findings and emerging evidence from elsewhere that iron nanominerals complex and preserve organic carbon in marine sediments (e.g.[3]), and advocate why it is now an exciting time to reconcile perspectives that terrigenous iron is a potential stimulus for marine carbon fixation and carbon preservation in the ocean over geological timescales and those relevant to anthropogenic climate change.

[1] Tagliabue, A. et al. (2017) The integral role of iron in ocean biogeochemistry. Nature 543, 51–59.
[2] Homoky, W.B. et al. (2021) Iron colloids dominate sedimentary supply to the ocean interior. PNAS 118(13).
[3] Moore, O.W. et al. Long-term organic carbon preservation enhanced by iron and manganese. Nature (In revision)

Howell K[1]**; Bridges AE; Graves KP; La Bianca G; Donaldson S; Allcock L; Ventura-Costa C; Downie A; Furey T; McGrath F; Ross R**
[1]Plymouth University.
Talk: Abstract #269 / Session T14 - A decade of deep ocean science for sustainable development

Performance of deep-sea habitat suitability models assessed using independent data, and implications for use in sustainable management.

Effective sustainable management requires accurate data on species and habitat distributions. In the deep sea, these data are lacking. Habitat suitability modelling offers a robust defensible means to fill data gaps, provided models are sufficiently reliable. We test the performance of published models of two deep-sea habitat-forming taxa at low and high resolutions (~1 km and 200 m grid-cell size), across the extended EEZs of UK and Ireland. Results of independent validation suggest all published models perform worse than expected considering original

cross-validation results, but model performance is still good or fair for Desmophyllum pertusum reef, with poorer performance for Pheronema carpenteri sponge models. High-resolution models using multibeam data outperform low-resolution GEBCO-based models. We conclude high-resolution models of D. pertusum reef distribution are a useful tool in spatial management. The poorer performing P. carpenteri model indicate areas for more detailed study. Whilst low-resolution models can provide conservative estimates of percentage area-based conservation targets following the precautionary principle, high-resolution sea-floor mapping supports the development of better-performing models. We comment on the role of Ocean Decade programmes like Seabed 2030 and Challenger 150 collectively enabling large scale high resolution mapping of species and habitat distributions to inform spatial management.

Howton K[1]
[1]Newcastle University.
Poster: Abstract #198 / Session T12 - Interactions between plastics and marine ecosystem

The influence of biofilms on the sinking behaviour of microplastics in seawater

Plastic pollution in the marine environment is a serious environmental threat. Despite this, the ultimate transport, fate, and impact of these plastics and specifically microplastics (MP) are still relatively unknown. One aspect which is not well understood is the impact of fouling on MP dynamics. Numerical models coupled with environmental sampling have been used to further understand MP distribution. Therefore, this study examines the impact of microbial biofilms on the settling velocity of three types of MPs, polyethylene terephthalate (PET) discs, poly (methyl methacrylate) (PMMA) spheres, and polypropylene (PP) spheres with the aim of deriving parameterizations of sinking rates to aid in generating accurate MP distribution models. Heterotrophic bacteria were isolated from North Sea surface water and incubated with MP samples for a duration of 6-weeks with the addition of fresh broth every 72-hours. Pseudoalteromonas atlantica was also used as a single strain microbial biofilm. The sinking velocity of MP particles over this period was measured at 2-week intervals and the extent of fouling was estimated using crystal violet assays to quantify biofilm formation. Sinking velocity was measured in a 2 m acrylic column filled with artificial seawater. The majority of bacterial biofilms did not significantly alter the sinking velocity of the MPs compared to unfouled MPs. Furthermore, bacterial biofilms did not induce sinking in PP, a positively buoyant plastic. These results will be used to develop empirical parameters to allow more accurate distributional models of MP fate to be developed.

Hudson P[1]; Martin A; Angeloudis A; Josey S; Marzocchi A
[1]University of Edinburgh.
Talk: Abstract #128 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

Key drivers of interannual variability in the Laptev Sea from satellite based sea surface salinity

Arctic surface air temperatures are warming twice as fast as global average temperatures. This has caused ocean warming, an intensification of the hydrological cycle, snow and ice melt, and increases in river runoff. Rivers play a central role in linking the components of the water cycle, and Russian rivers alone contribute ~1/4 of the total freshwater to the Arctic Ocean, maintaining the halocline that covers the Arctic, and dominates circulation. Increases in river runoff could further freshen this layer and increase Arctic Ocean stratification. However, the increase in atmosphere-ocean momentum transfer with sea ice loss could counteract or alter this pattern of circulation, mixing this cold fresh water with the warm salty water that currently sits below it. Therefore, this project aims to combine satellite data, particularly SMAP and SMOS sea surface salinity (SSS) data with model output to improve our understanding of interactions between the components of the Arctic hydrological cycle and how this is changing with our changing climate. The Laptev Sea was chosen as an initial region of focus for analysis, as the Lena river outflows as a large, shallow plume, which is clearly observable from satellite SSS data. The spatial pattern of the Lena river plume varies considerably interannually, responding to variability in atmospheric and oceanic forcing, sea ice extent, and in the magnitude of river runoff. Numerical model output and satellite products confirm what has previously been suggested from in-situ data: that wind forcing is the main driver of river plume variability.

Hughes L[1]
[1]Natural History Museum London.
Talk: Abstract #287 / Session T18 - HMS Challenger collections as a benchmark for oceanographic studies

Invertebrate Statistics from the HMS Challenger collection at the NHM, London

The marine invertebrate collections resulting from the HMS Challenger voyage, were variously distributed among experts and institutions with the largest single holding from the cruise residing with the Natural History Museum, London. As the scientific reports were published across a 50 year period, the tendency was for specimens to be registered into the NHM collection after the scientific papers was published, with the curator's taking the unusual practice of using the newly printed publication volumes as the museum register. The original cruise report station list, the listing of collection material the scientific papers and label associated with the physical specimen collection are long known to show disparities in reporting. Exploring the non-conformities in recording is essential curation practice. Although intriguing in itself, and a source of surprise to researchers consulting this historic material, it directly impacts the statistical reporting of the voyage, rendering basic questions difficult to deduce, such as How many specimens were collected? How many new species were described from cruise material and How many species from each phyla were collected? In this talk we attempt to answer these questions for the wider marine invertebrates holdings in the NHM collections following the dedicated efforts to electronically database the NHM holding of the HMS Challenger collection as part of the 150th Anniversary.

Humphreys M[1]
[1]NIOZ Royal Netherlands Institute for Sea Research.
Talk: Abstract #68 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

PyCO2SYS and beyond: what next for seawater chemical equilibrium modelling?

The ocean absorbs about a quarter of anthropogenic CO_2 emissions each year, reducing the rate of human-driven climate change. But adding CO_2 to seawater lowers its pH, shifting the balance of many chemical equilibria, which makes carbonate minerals less stable and alters the bioavailability of certain nutrients. Adjusting seawater alkalinity, as occurs in natural biogeochemical processes and proposed as a geoengineering strategy, also perturbs these equilibria. To understand the impacts of changes in CO_2 and alkalinity, we often need to calculate the concentration of each individual chemical species. For this, we need to measure or estimate the total concentration and equilibrium constant(s) of each equilibrating system and then represent all the equilibria and solute interactions in a set of equations: a speciation model. Here, we present an overview of the capabilities of existing seawater speciation models, with a focus on the CO2SYS family (one of the most widely used tools where CO_2 is of interest, recently updated and implemented in Python). We highlight areas where the software is ahead of the science, such as uncertainty propagation. We also discuss current limitations, such as accounting for variations in major ion composition, interactions with dissolved organic matter, and isotopic equilibration. While each of these issues can already be tackled with its own disparate model, these each have their own limitations, and a unified approach that is validated for seawater – with the accuracy necessary to detect anthropogenic signals – remains elusive.

Hunter A[1]
[1]British Antarctic Survey.
Talk: Abstract #86 / Session T12 - Interactions between plastics and marine ecosystem

Modelling microplastic in Antarctic krill diets and the impacts on carbon export

How do buoyant marine microplastics eaten by zooplankton influence the carbon pump? Experiments showing that zooplankton will eat microplastics, which alter the density of their faecal pellets, prompted the hypothesis that buoyant plastics consumed in the open ocean are transported to depth embedded within sinking faecal pellets and that these plastics may disrupt/diminish carbon export. In the Southern Ocean much of the zooplankton biomass comprises Antarctic krill, a keystone species that exports substantial quantities of carbon to depth as large pulses of faecal pellets. We develop a data-driven model of Antarctic krill grazing in microplastic-contaminated environments and excreting plastic-laden faecal pellets. The model quantifies disruption to carbon

export as a function of microplastic pollution rate. It should also provide insight into a cyclical vertical transport pathway for buoyant plastics consumed by zooplankton. Although less polluted than lower latitude seas, the Southern Ocean is being contaminated by plastics at an increasing rate. The model will estimate the effects of increased plastic pollution upon detrital dynamics and carbon export under forecasted future scenarios.

Hynes C[1], Powell C; Graves C; Austin B; Brabben E; Brown N; Dal-Molin F; Garcia C; I'Anson K; Limpenny C; Mason C; Nelson P; Smeaton C; Wexler S; Parker R
[1]Cefas.
Talk: Abstract #314 / Session T15 - Carbon cycling in the global ocean and the role of blue carbon in climate mitigation

Colours of Carbon: Insights from the Alkanes

A key knowledge gap in our understanding of 'Blue Carbon' environments is in determining the origin or source of that carbon. Traditional temperate blue carbon ecosystems include seagrass beds and wetlands such as salt marsh and mudflats. However, the seabed also holds significant carbon stocks and the ability to sequester carbon. This may be thought of as a climate regulation tool and thus a Nature Based Solution (NBS) towards climate mitigation. Here we demonstrate how hydrocarbon fingerprinting may be used to elucidate on and track carbon provenance, knowledge of which may support the management of important seabed carbon stores. The n-alkane biomarkers in particular offer much promise in identifying carbon sources and, importantly for carbon budgets and accounting, in separating marine versus terrestrial inputs. Diagnostic features of the alkanes include chain length and the number of carbon atoms present. Other hydrocarbons such as Polycyclic Aromatic Hydrocarbons (PAHs) inform on the anthropogenic carbon stored within the seabed. We present an application of this novel approach using core samples from the English continental shelf in the North Sea.

Janssen F[1]; Boetius A; Haeckel M; Molari M; Sevilgen DS; Wenzhöfer F; Yapan BC
[1]Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, HGF-MPG Joint Research Group for Deep-Sea Ecology and Technology, Bremerhaven, Germany.
Talk: Abstract #147 / Session T2 - Deep Sea Mining 2 - environmental aspects: baselines, impacts, monitoring

Baseline benthic activity in the Clarion Clipperton Fracture Zone: In situ oxygen observation as a proxy for short-term impacts of manganese nodule mining

Oxygen availability and fluxes in sediments are key variables to assess benthic biogeochemical conditions and processes connected to respiration and organic matter remineralization, both important functions of seafloor ecosystems. The total flux or 'sediment community oxygen consumption' is recommended by the International Seabed Authority to establish ecological baselines and to identify effects of mining-related impacts (document ISBA/25/LTC/6). Baseline oxygen uptake measurements were carried out in the German and Belgian exploration contract areas in the Clarion Clipperton Fracture Zone at locations approx. 1000 km apart during expeditions in 2019 and 2021. In both areas, replicate measurements were obtained at different sites several kilometres apart from each other. To establish a baseline that accounts for natural variability, replicate oxygen observations were carried out in situ with microprofilers and benthic chambers using a Remotely Operated Vehicle. During the 2021 expedition, post-impact measurements were performed after test deployments of the pre-prototype nodule collector PATANIA II were carried out by the Belgian company DEME-GSR. The presentation compares baseline and post-impact measurements of oxygen availability and consumption in combination with model-based analyses of the effects of sediment redistribution and blanketing induced by the collector. The presentation discusses the requirements (replication, relevant scales, methodology) for in situ observations as a tool to quantify the degree of mining-induced impact and recovery of biogeochemical conditions in the sediments of deep-sea nodule ecosystems. The study was carried out in the framework of the European collaborative project MiningImpact under the Joint Programming Initiative Healthy and Productive Seas and Oceans (JPI Oceans).

Jarníková T[1]; Quéré CL; Willis D; Rumbold S; Jones C
[1]University of East Anglia.
Talk: Abstract #201 / Session T15 - Carbon cycling in the global ocean and the role of blue carbon in climate mitigation

Understanding the Changing Role of Stratospheric Ozone in Modifying the Southern Ocean Carbon Sink

As the largest oceanic sink of anthropogenic CO2, the Southern Ocean (SO) plays a key role for climate and climate change, absorbing between 5 and 10 percent of the global CO2 emissions from human activities each year. Factors influencing the efficiency of the Southern Ocean CO2 sink include, for example, the rate and level of change of CO2 in the atmosphere and the associated changes in climate, including warming and winds. In particular, winds in the Southern Ocean have been observed to increase in the past 50 years, with this increase linked both to the change of stratospheric ozone and to the observed increase in greenhouse gasses. Here, using a set of model simulations with the UKESM1 model run from 1950 to the end of the 21st century, we explore the relative contribution of changing greenhouse gases and ozone recovery in driving the evolution of the Southern Ocean carbon sink. Our runs encompass three sets of forcing: one with no ozone, one with ozone but no ozone recovery, and one with best estimated ozone recovery. This set therefore bookends possible evolution of ozone this century and thus the response of the ocean carbon state. Our results demonstrate the critical role of ozone-affected changes in wind distribution in the likely evolution of the SO carbon sink over the course of the 21st century.

Johnston N[1]; Murphy EJ; Atkinson, A; Constable AJ; Cotté C; Cox M; Daly KL; Driscoll R; Flores H; Halfter S; Henschke N; Hill SL; Höfer J; Hunt BPV; Kawaguchi S; Lindsay D; Liszka C; Loeb V; Manno C; Meyer B; Pakhomov EA; Pinkerton MH; Reiss CS; Richerson K; Jr. WOS; Steinberg DK; Swadling KM; Tarling GA; Thorpe SE; Veytia D; Ward P; Weldrick CK; Yang G
[1]British Antarctic Survey.
Poster: Abstract #291 / Session T10 - Micro to macro: linking bottom-up and top-down approaches that investigate the function, resilience and conservation of polar ecosystems

Status and future changes in Southern Ocean zooplankton: A contribution to the Marine Ecosystem Assessment of the Southern Ocean (MEASO)

Several Southern Ocean (SO) zooplankton taxa are notable for their biomass, abundance, and roles in maintaining food webs, ecosystem structure and function, and supporting globally important 'ecosystem services'. These groups are consumers of microbes, primary and secondary producers, and are prey for fish, cephalopods, seabirds, and marine mammals. In providing a link between microbes, primary and secondary producers, and higher trophic levels these groups influence energy flows, biological production and biomass, biogeochemical cycles, carbon flux, and food web interactions thereby modulating the structure and functioning of ecosystems. Antarctic krill (*Euphausia superba*) and various fish species also support international fisheries. Global and local drivers of change are expected to affect the zooplankton dynamics, which may have potentially profound and wide-ranging implications for SO ecosystems and services. In this contribution to MEASO, we assess the current understanding of the dominant metazoan zooplankton within the SO, including Antarctic krill and other key euphausiid, copepod, salp, and pteropods. We provide a systematic of observed and potential future responses of these taxa to a changing SO and the functional relationships by which drivers may impact them. We also identify knowledge gaps and priorities for SO zooplankton research to support future ecosystem assessments and conservation and management strategies.

Johnston N[1]; Constable A; Melbourne-Thomas J; Bestley S; Brasier M; Caccavo J; Cavanagh R; Costa D; Figuerola B; Grant S; Griffiths H; Gutt J; Hallowed A; Hancock A; Henley S; Höfer J; Hofmann E; Kauko H; Muelbert M; McCormack S; Morley S; Murphy E; Pinkerton M; Piñones A; Press A; Roberts L; Ropert-Coudert Y; Sergi S; Schloss I; Schofield O; Solomonsz J; Putte AVd; Weldrick C
[1]British Antarctic Survey.
Talk: Abstract #290 / Session T10 - Micro to macro: linking bottom-up and top-down approaches that investigate the function, resilience and conservation of polar ecosystems

Outcomes of the first Marine Ecosystem Assessment for the Southern Ocean (MEASO)

The first Marine Ecosystem Assessment for the Southern Ocean (MEASO, 2021) has undertaken a comprehensive synthesis of the status and changes in habitats, species, and food webs to identify how dangerous future global change will be for Southern Ocean ecosystems and their services. The extent to which climate change mitigation

is needed, alongside conservation and management strategies that can take account of the impacts of human-induced change, is also assessed. MEASO has harmonised this scientific information to inform policy makers at local, national, and global scales. MEASO represents a truly international collaboration of over 200 researchers from 19 countries, with a strong engagement of Early Career Researchers, ECRs (one third of the authors; 11 of the 25 papers were led by ECRs). MEASO has shown that Antarctic and Southern Ocean ecosystems are under increasing pressure from global climate change and direct human impacts, which are causing significant changes at the circumpolar scale and beyond. Global reductions in greenhouse gas emissions and climate recovery are therefore urgently required to avoid irreversible deterioration of these ecosystems and associated loss of their wide-ranging societal benefits. Only by mitigating global climate change, alongside effective local conservation and management, can we safeguard these vulnerable polar oceans and their societal benefits now and into the future. It is envisaged that this assessment will be repeated at regular time intervals to assess and quantify ongoing changes in the system and underpin effective decision-making around climate change mitigation, conservation and management of environmental change in this climate-sensitive region.

Jones N[1]; Neil S; Lewis M; Robins P
[1]Bangor University.
Talk: Abstract #177 / Session T12 - Interactions between plastics and marine ecosystem

Modelling microplastic dispersal in a well-mixed estuary

Rivers and estuaries act as conduits of microplastic transport, linking terrestrial and marine environments. In densely populated catchments, microplastic pollution could impact human populations and natural ecosystems including through industry, domestic activities or direct exposure. The physical behaviour and movement of microplastics in estuaries and coastal areas is still a relatively unexplored area of research. An investigation into the dynamics of microplastic behaviour within estuarine systems will allow for a greater understanding of plastic retention and exportation to coastal and offshore environments. This study aims to combine high resolution modelling of estuarine processes with current and future projections of microplastic concentrations to determine local exposure levels, residence times and temporal variability. The Conwy Estuary (UK) is a well-mixed macro-tidal, embayment type system connecting the Conwy catchment to the North Wales coast and Irish Sea – where waters are used for leisure and aquaculture. Microplastics derived from the catchment population, industry and agriculture are thought to flow into the estuary primarily from the Conwy River network. A D-Flow Flexible Mesh (D-Flow FM) model, a module of the Delft3D-FM suite, has been set up and validated for the Conwy Estuary and North-Wales coast in three-dimensions, showing highly accurate results both in and outside the estuary. The results of the model validation as well as preliminary plastic dispersal simulations will be presented.

Jones R[1]; Jariel C; Annett A; Lohan M; Middag R
[1]University of Southampton.
Poster: Abstract #279 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

Investigating the behaviour of Fe during resuspension of margin sediments along the Denmark Strait

Iron availability limits primary production in much of the global surface ocean. The supply of iron (Fe) through margin sediment resuspension is a vital source of bioavailable Fe to the water column, yet the flux magnitude and longevity of this Fe in seawater is poorly quantified. We compare the short-term exchange of Fe between sediments and bottom waters from the Denmark Strait to evaluate the role of sediment resuspension events upon Fe cycling and bioavailability in the North Atlantic. During boreal summer 2021, we performed sediment-water incubation experiments at five locations of varying depth along the Denmark Strait, spiking bottom water with coretop sediment from the same locality. Subsampling for dissolved, soluble and unfiltered Fe was performed over 48 h, alongside additional biogeochemical parameters. Sediment incubation experiments indicated a gradual increase in dissolved Fe from a background of 0.5 nM to a maximum of ~2.5 nM, exhibiting varying rates of Fe release between locations. Accompanying soluble and unfiltered Fe concentrations will be presented, alongside the mineralogical composition of coretop sediments used in these incubations. Contrasting rates of concentration change indicate a differing reactivity between the seafloor surface sediments along the Denmark Strait, with implications for the longevity and availability of iron derived from sediment resuspension events in these environments.

Jones S[1]; Fraser N; Cunningham S; Fox A; Inall M
[1]Scottish Association for Marine Science (SAMS).
Talk: Abstract #231 / Session T24 - The Atlantic Meridional Overturning Circulation: Observations, Simulations and Equations

Observation-based estimates of volume, heat and freshwater exchanges between the subpolar North Atlantic interior, its boundary currents and the atmosphere

The interior of the North Atlantic Subpolar Gyre (SPG) is responsible for the much of the water mass transformation in the Atlantic Meridional Overturning Circulation (AMOC), and the export of this water to intensified boundary currents is crucial for projecting air-sea interaction onto the strength of the AMOC. However, the magnitude and location of exchange between the SPG and the boundary remains unclear. We present a novel climatology of the SPG boundary using quality controlled CTD and Argo hydrography. We define the SPG as the oceanic region bounded by 47° N and the 1000m isobath. From this hydrography we compute geostrophic currents referenced to altimetry across the SPG boundary. We estimate average heat and freshwater fluxes into the SPG to be +0.18 ± 0.05 PW and -0.10 ± 0.03 Sv respectively. These estimates approximately balance the surface heat and freshwater fluxes over the SPG domain. Overturning in the SPG has a mean strength of 7.36 ± 1.48 Sv. The primary density of maximum overturning is at 27.30 kgm-3, with a secondary, smaller maximum at 27.54 kgm-3. Upper waters ($\sigma 0 < 27.30$ kgm-3) are transformed in the interior then exported as either intermediate water (27.30-27.54 kgm-3) in the NAC or as dense water ($\sigma 0 > 27.54$ kgm-3) exiting to the south. Our results support the present consensus that the formation and pre-conditioning of subpolar Mode Water in the north-eastern Atlantic is a key driver and modulator of AMOC strength.

Josey S[1]; Sinha B
[1]National Oceanography Centre.
Talk: Abstract #50 / Session T24 - The Atlantic Meridional Overturning Circulation: Observations, Simulations and Equations

Increasing Role for the Ocean in Setting Interannual Variability of Subpolar Atlantic Mixed Layer Heat Content

Cold conditions in the upper subpolar North Atlantic, at a time of pervasive warming elsewhere, have provoked significant debate. Uncertainty arises both from potential causes (surface heat loss and ocean circulation changes) and characteristic timescales (interannual to multidecadal). Resolution of these uncertainties is important as cold conditions have been linked to recent European weather extremes and a decline in the Atlantic overturning circulation. Using observations, supported by high resolution climate model analysis, we show that a surprisingly active ocean regularly generates both cold and warm interannual anomalies in addition to those generated by surface heat exchange. Furthermore, we identify distinct sea surface temperature patterns that characterise whether the ocean or atmosphere has the strongest influence in a particular year. Applying these new insights to observations, we find an increasing role for the ocean in setting North Atlantic mixed layer heat content variability since 1960.

Josso P[1]
[1]British Geological Survey.
Talk: Abstract #349 / Session T1 - Deep Sea Mining 1 - geology, resource, legal, technical and societal aspects

Application of random-forest machine learning algorithms for mineral predictive mapping of Fe-Mn crusts in the world Ocean

The continuously increasing demand for minerals and metals in the context of decarbonizing societies is pushing mineral exploration into new frontiers (Lusty and Murton, 2018). Over the last decade, the interest in the potential for deep-ocean mineral deposits to make a significant contribution to global future raw material supply has increased dramatically. Covering more than 70% of the surface of the planet with an average depth of 3700 m, exploration of deep-ocean mineral deposits constitutes a technological and economic challenge, which is why determining areas of high prospectivity is of paramount importance to optimize exploration efforts and investments. Mineral prospectivity mapping is a complex multi-criteria decision task aimed at delineating prospective areas for exploring undiscovered mineral deposits (Carranza and Laborte, 2015). This study presents

the results of random-forest mineral prospectivity mapping for Fe-Mn crust deposits at the world scale. The random forest algorithm is an iterative and randomized succession of regression tree analysis. About 4,000 deposit location were compiled along 70,000 thousand non-deposit locations to train the model against more than thirty predictors of environmental variables and seafloor geomorphological classifications. Predictions at a scale of 0.03 degree were achieved over the whole surface covered by all continuous predictors. We will compare results obtained by this data-driven analysis against expert-driven approaches and compare benefits and drawbacks of both approaches.

Lusty, P.A.J. and Murton, B.J. (2018). Elements 14, 301-306.
Carranza, E.J.M. and Laborte, A.G. (2015). Ore Geology Reviews 71, 777-787.

Khatri H[1]; Williams R; Woollings T; Smith D
[1]University of Liverpool, UK.
Talk: Abstract #121 / Session T24 - The Atlantic Meridional Overturning Circulation: Observations, Simulations and Equations

Inter-annual Variability in the Subpolar Overturning Circulation: A Sensitivity Analysis

We employ multi-ensemble Met Office Decadal Prediction System hindcasts to analyse the impact of atmospheric winds and North Atlantic Oscillation (NAO) phases on the overturning circulation in the North Atlantic Ocean. A positive NAO phase is generally associated with an anomalously strong and/or northward shifted jet stream in the North Atlantic, and the vice-versa is true for a negative NAO phase. As a consequence of relatively strong winds, oceans tend to lose more heat to the atmosphere in winter in many parts of the subpolar North Atlantic Ocean. This process is expected to create negative anomalies in sea surface temperature and generate more dense water on the ocean surface at high latitudes resulting in a strengthening in the overturning circulation. Here, we examine the sensitivity of the overturning circulation (computed in density space) to NAO phases in multi-ensemble decadal hindcasts to understand how the interior ocean responds to different NAO phases. For this purpose, we analyse the changes in east-west density contrasts, upper ocean heat content, mixed-layer depth, meridional heat transport in different oceanic regions, i.e. Labrador Sea, Irminger Sea and Nordic Seas. In particular, we perform a linear regression analysis for the above-mentioned diagnostics and NAO indices to assess how sensitive the upper ocean is to changes in the atmospheric state.

Koenig D[1]; Tagliabue A
[1]University of Liverpool.
Talk: Abstract #99 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

Impact of climate variability on the oceanic cycling of iron and its isotopes

Iron is a key regulator of primary production in many parts of the global ocean, as it is essential to phytoplankton growth, but often only present in trace amounts. However, many components of the ocean iron cycle are poorly constrained, which limits our ability to assess the impact of environmental change on ocean ecosystem, such as the oceanic response to climate change or natural variablity. In recent years, iron isotopes have been increasingly used as a tool to disentangle different aspects of the marine iron cycle. This approach takes advantage of the often distinct isotopic signatures of external iron sources or the assumed isotopic fractionation during internal cycling processes, such as uptake by phytoplankton or recycling. Due to the relative novelty of these isotope measurements, it is unclear how changes in climate forcing and the responses of ocean physics and biogeochemistry impact the distribution of dissolved iron isotopes in the ocean. To explore this, we conducted simulations from 1836-2021 based on atmospheric reanalysis using a global biogeochemical ocean model with active iron isotopes. We find that whether phytoplankton are limited by nitrogen or iron is an important source of inter-annual variability in upper ocean dissolved iron isotopes cycling. This temporal variability is most pronounced in the tropical Pacific, where nutrient limitation patterns respond to changes in the El Niño–Southern Oscillation. In some regions, the role of changes in ocean physics in transporting sediment iron inputs is also important. Overall, the response of iron isotopes integrate the impact of decadal climate variability and may emerge as a useful tool to diagnose responses of iron supply and ocean nutrient limitation.

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[1]Vrije Universiteit Brussel, 1050 Brussels, Belgium.
Poster: Abstract #310 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

Dissolved barium as a tracer of Mediterranean Outflow Water in the northeast Atlantic Ocean

The dissolved barium (Bad) distribution in the upper 1500 m water column was investigated along a transect across the Bay of Biscay to the Cape Finisterre and further south in open ocean waters along the Iberian Margin. Seawater samples were collected during the RV Belgica cruise in May 2014 and analyzed for Bad concentrations by isotope dilution inductively coupled plasma mass spectrometry. Bad concentrations were low in the surface waters and increased with the depth, reflecting the global depth distributional pattern of Bad and a nutrient-like behaviour in oceans. Bad profiles indicate a mesopelagic maximum (47-56 nmol L-1 at the depth range of 200-500 m) and a deep maximum (49-77 nmol L-1 at the depth range of 800-1200 m). Based on the Bad distributions and hydrographic observations, it appears that increased concentrations of Bad in mesopelagic waters are mainly associated with the Eastern North Atlantic Central Water (ENACW), whereas the enrichment of Bad in the deeper waters (800-1200 m) was found to cause by warm, saline, nutrient-rich Mediterranean Outflow Water (MOW) that deflected northward and flowing along the Iberian Margin. The observed deep Bad maximum coincides with a salinity maxima that existed at the depths of 900-1200 m. In the depths of deep Bad maximum, the distribution of Bad and salinity are significantly correlated ($p<0.05$) and both marked a prominent south to north decreasing trend. These findings suggest that in combination with salinity, Bad has a potential as a tracer of MOW in the northeast Atlantic Ocean.

Kokuhennadige HN[1,2]; Humphreys MP; Whiteside JH; Achterberg EP; Connelly DP
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Poster: Abstract #332 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

Processes controlling dissolved inorganic carbon (DIC) in the Benguela Upwelling System: insights from stable carbon isotopes of DIC

Stable carbon isotopes of dissolved inorganic carbon ($\delta^{13}C_{DIC}$), DIC, nutrients (phosphate, nitrate and silicate) and dissolved O_2 in the upper 200 m water column were examined (in summer 2015) in the Benguela Upwelling System (BUS) off the southwestern coast of Africa -. DIC concentrations increased from 2146-2247 µmol kg^{-1} at the surface to 2268-2308 µmol kg^{-1} at depths of 200 m in the BUS. The southern and northern subsystems of the BUS marked with higher DIC concentrations compared to the Lüderitz Upwelling Cell (LUC). $\delta^{13}C_{DIC}$ in the surface waters at the LUC was relatively higher (-0.20‰) than those at the NBUS (-2.07‰) and SBUS, this was consistent with $\delta^{13}C_{DIC}$ in the entire water column at the LUC (-1.53‰ - -0.08‰) and NBUS and SBUS (-2.07‰ - -0.50‰). The measured $\delta^{13}C_{DIC}$ values are unvaryingly lighter than those reported in the open ocean of the southeastern Atlantic, and this variance is mainly attributed to the upwelling of $\delta^{13}C_{DIC}$ depleted waters and its associated processes in the BUS. The observed higher $\delta^{13}C_{DIC}$ values with low levels of DIC and nutrients at the LUC indicate that increased biological productivity overrides the effect of $\delta^{13}C_{DIC}$ depleted upwelling waters on the DIC distribution. Contrariwise, recorded lower $\delta^{13}C_{DIC}$ values with high levels of DIC and nutrients at the NBUS and SBUS denote that upwelling and mixing of $\delta^{13}C_{DIC}$ depleted waters and allied organic matter decomposition dominate over the effect of its biological productivity on DIC. This study suggest that upwelling waters and associated organic matter decomposition are the main sources and controlling processes of DIC in the BUS.

Krisch S[1]; Huhn O; Al-Hashem A; Hopwood MJ; Lodeiro P; Achterberg EP
[1]GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany
Poster: Abstract #323 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

On the controls of subglacial dissolved Fe and Pb supply; a case study at Nioghalvfjerdsbrae

Glacial freshwater discharge is a source of trace elements and micronutrients to shelf waters. Approximately half of freshwater discharge from the Greenland and Antarctic Ice Sheets enters the marine environment subsurface beneath large floating ice tongues or ice shelves. Yet, due to the inaccessibility of these subglacial cavities, only few studies investigated on the factors constraining subglacial trace element and micronutrient export to adjacent shelf regions. Here, we present results from GEOTRACES expedition GN05 investigating trace element and micronutrient cycling immediately adjacent to Nioghalvfjerdsbrae ("the 79N Glacier") and on the NE Greenland Shelf. Using helium and neon as tracers of subglacial meltwater on the shelf, our results suggests freshwater addition beneath the floating ice tongue is only a minor source of dissolved iron (dFe) and lead (dPb), with the dominant fraction likely derived from glacial bedrock and cavity sediments (e.g. 90% in the case of dPb). The extended residence time of waters underneath the floating ice tongue of several months to a year results in a near-steady state between addition of dFe and dPb and removal of the non-stabilized fraction. This suggests that subglacial dFe and dPb export may scale with the rate of cavity water renewal and is perhaps rather independent from freshwater discharge. In future, the retreat of the marine-terminus, as observed with the disintegration of Spalte Glacier in July 2020, is likely altering subglacial trace element and micronutrient export from Nioghalvfjerdsbrae, with the potential to increase dFe and dPb supply to coastal surface waters in NE Greenland.

Krisch S[1]; Browning TJ; Hopwood MJ; Lodeiro P; Rutgers van der Loeff MM; Achterberg EP
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Talk: Abstract #213 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

The Arctic Ocean is a net source of dissolved Fe and Co toward the Atlantic Ocean through the gateway of Fram Strait

Recent studies have suggested that the Arctic Ocean is a source of micronutrients such as dissolved iron (dFe) and Co (dCo) through the gateway of Fram Strait which may influence nutrient stoichiometry in the Greenland Sea and the dFe-limited primary production of the high-latitude North Atlantic. However, until now, trace element data from across Fram Strait has been lacking and so the extent of Arctic micronutrient supply to the Atlantic and its effect on primary production in Fram Strait remained unquantified. In summer 2016, GEOTRACES expedition GN05 sampled for dissolved micronutrients and macronutrients and conducted incubation experiments to determine the extent of nutrient availability and phytoplankton growth across Fram Strait. GN05 observed an east-to-west gradient in nutrient availability, with dFe, dCo and Si(OH)4 concentrations increasing and fixed N concentrations decreasing from Svalbard towards NE Greenland. Incubation experiments evidenced widespread N-limited phytoplankton growth with conditions potentially approaching secondary Fe-limitation in Atlantic Waters near Svalbard. Our results suggest that Atlantic-derived fixed N, and Arctic-derived dFe and dCo from riverine discharge to Siberian Shelf regions, advected across the North Pole, are important factors determining nutrient stoichiometry in Fram Strait. Calculation of micronutrient fluxes suggests that the Arctic Ocean is a net source of 2.3 ± 1.7 Gg·a-1 dFe and 0.2 ± 0.2 Gg·a-1 dCo through Fram Strait and toward the North Atlantic. Ongoing changes to shelf inputs and sea ice dynamics in the Arctic, especially in Siberian shelf regions, are likely affecting micronutrient availability in Fram Strait and the high-latitude North Atlantic Ocean.

La Bianca G[1]; Rees S; Attrill MJ; Lombard AT; McQuaid K; Niner H; van Rein H; Sink K; Howell KL
[1]University of Plymouth.
Talk: Abstract #284 / Session T14 - A decade of deep ocean science for sustainable development

From theory to practice: development of an ecosystem services framework for the deep sea

Anthropogenic impacts and changes to the structure of deep seafloor are already noticeable. In terrestrial and shallow marine environments, demonstrating how ecosystems support human well-being has been instrumental for setting policy and management objectives for sustainable resource use. Foundational to this approach is a framework of ecosystem service (ES) classification and a synthesis of the knowledge base, which can then be used to structure decision-support tools. At present, no such framework exists for the deep sea. There is thus an urgent need to determine and assess the ES provided by deep-sea habitats and species, before (potentially irreversible) decisions are made about deep-sea habitat use and governance. As a first step, we undertake two systematic reviews of the scientific literature. This was to define a comparative ES framework and to synthesise

the current evidence base for how deep-sea habitats support ES. Our framework proposes four supporting services and 10 final services for which there is an established and growing body of evidence for the role of deep-sea habitats. Our proposed ES framework provides a structure for deep-sea ES. For future application, this could provide the foundation for the development of habitat-service matrices, which are a critical component for truly accounting for ES in decision-making, particularly spatial management. This framework has significant implications for deep-sea conservation, as it provides an ES-based tool that can be used in any deep-sea ecosystems management, and we also discuss how important these data gaps are for today's decisions and how seriously they should be considered.

Lanham J[1]; Mashayekhi A; Reynard N
[1]Imperial College London.
Poster: Abstract #51 / Session T24 - The Atlantic Meridional Overturning Circulation: Observations, Simulations and Equations

Sensitivity of AMOC weakening to turbulent diapycnal mixing

The strength of the Atlantic Meridional Overturning Circulation (AMOC) is known to vary with the magnitude of North Atlantic Deep Water (NADW) formation at high latitudes. There is increasing evidence in the observational record that anthropogenic climate change has driven a weakening in AMOC; increased freshwater flux from high-latitude sea ice melt increases buoyancy anomalies and reduces NADW formation. Earth system models (ESMs) project a future weakening in AMOC due to ice melt driven by anthropogenic warming and Arctic amplification, albeit with significant uncertainty surrounding the magnitude of change. An improvement to such projections arises from improving the parameterisation of ocean mixing in ESMs. Recent studies show that the overturning circulation is highly sensitive to turbulent mixing below the traditional 'mixed layer'; diapycnal mixing enables NADW formed at high latitudes to resurface at low latitudes. Large-scale models generally assume turbulent mixing in the ocean interior to be essentially constant in time. However, there is an emerging consensus over the importance of time-evolution of both mixing and mixing efficiency. Recent studies show significant improvements in modelling ocean circulation with parameterisations that allow it to adapt throughout the simulation. Here, we investigate the impact of incorporating this new approach in projections of Arctic-driven modifications to AMOC. An idealised low-complexity ocean model is run with historical, contemporary and future modelled buoyancy profiles, along with constant and adaptive mixing parameterisations. We show that the choice of mixing parameterisation has a leading order impact on the response of AMOC to future high-latitude buoyancy changes.

Leadbitter P[1]; Heywood K; Hall R; The TARSAN teams on the NBP2202
[1]University of East Anglia.
Talk: Abstract #179 / Session T7 - Pushing the limits in autonomous oceanography in a net zero carbon world

NBP2202: A case study in using complementary autonomous vehicle and ship-based observations for a synoptic view of atmosphere-ice-ocean interactions

In January-March 2022 as part of the TARSAN and ARTEMIS International Thwaites Glacier Collaboration projects, 7 autonomous underwater vehicles (AUVs) ranging in size, speed, endurance and sensor capabilities (4 Seagliders, 1 Seaexplorer, 1 Autosub Long Range (ALR) and 1 Hugin) were deployed from RVIB Nathaniel B Palmer to support investigations of atmospheric, cryospheric and oceanic process influencing the Thwaites and Dotson Ice Shelves in the Amundsen Sea, Antarctica. The AUVs provided a wider synoptic picture, including measurements from regions inaccessible to ship-based surveys (e.g., under the ice shelves). Hugin and ALR are large, propeller-driven AUVs and can carry physically larger and high-current-draw sensors, including side scan sonar, swath multibeam and acoustic Doppler current profilers. A total of 26 bespoke missions (order 1 day) included mapping the seabed and ice draft within the Dotson Ice Shelf cavity and taking water samples. Smaller, slower buoyancy-driven gliders carry specially designed low-current-draw sensors (including pH, optical backscatter, fluorescence and microstructure) allowing them to be deployed for much longer (order 1 month), culminating in approximately 150 glider-days' worth of deployments. The Gliders provided a broader spatial and temporal picture of the region, and, when combined with the ship and two larger AUVs, allowed simultaneous measurements to be taken at 8 different locations across the Amundsen Sea and within the ice shelf cavity. Although the successful operation of a fleet of AUVs used valuable science time and required flexible scheduling of ship-based activities, the overall efficiency and scientific scope of the cruise was considerably extended.

Lenn Y[1]; Rippeth T; Lincoln B; Scannell B; Shankle M; Hessing Nv; Janout M; Torres-Valdes S; Schiulz K; Tippenhauer S; Hopkins J; Drysdale L; Banas N; Grosse F
[1]Bangor University, Wales.
Talk: Abstract #32 / Session T27 - Physical Oceanography Open Session - Physics-Biology Interactions

PEANUTS: Primary producitivity driven by escalating Arctic nutrients fluxes?

From sea ice decline to Atlantification, the Arctic Ocean's response to climate change has been both rapid and dramatic. One of these changes is increases in primary production that cannot be explained by increased light availability alone. The PEANUTS project set out to investigate if changes to Arctic stratification and mixing may be contributing to escalating nutrient fluxes that could be driving this enhanced productivity. We present evidence for the impact of Atlantification on Arctic sea ice, we discuss mixing mechanisms not previously observed in the Eurasian Arctic that are associated with enhanced nutrient fluxes, and model results exploring the impact of nutrient fluxes on late summer blooms along the Beaufort slope.

Lewis M[1]; Williamson B; Fairley I; McIlvenny J; Masters I; Reeve D; Neill S
[1]Bangor University.
Talk: Abstract #118 / Session T7 - Pushing the limits in autonomous oceanography in a net zero carbon world

measuring hydrodynamics with videos from low cost drones

Traditional oceanographic techniques successfully quantify temporal variability from single-point measurements, whilst traditional spatial variability mapping techniques have clear limitations; for example, boat surveys (limited by water depth), fixed-vantage-point cameras (weather), and finer-scale spatial variability cannot be resolved from satellites. Therefore, where strong currents and shallow water present risk to instrument deployment and recovery, we find an absence of data from physically challenging and remote coastal regions: such as at potential tidal-stream energy sites. Identifying and tracking objects, within the video from low cost and publicly available unmanned aerial vehicle (UAVs or "drones"), has been shown to measure currents in rivers and laboratories but not within coastal oceanography – where enhanced impact of wind, waves and 3D velocity variability will decrease accuracy. The EPSRC Supergen-ORE funded V-SCORES project's objective was comprehensive validation of UAV techniques for surface current spatial mapping at 1-minute ensembles. Field campaigns were conducted at Pentland Firth (Scotland) and Ramsey Sound (Wales) with a range of instruments and methods (i.e. particle image and track velocimetry). Comparison to observations (drifters, bottom mounted ADCPs and vessel survey ADCPs), showed accuracy that increased with higher currents (RMSE 0.38 to 0.34m/s). Accuracy variations were attributed to wind (RMSE of 0.44 m/s for wind of 19.5 mph compared to 0.22 m/s for wind of 6.3 mph) and site geometry (e.g. importance of upstream bathymetry generating trackable surface features). Fitting of a power-law velocity profile to surface current observations also revealed similar accuracy throughout the water-column.

Lincoln B[1]; Rippeth T; Scannell B; Shen S; Smart R
[1]Bangor University.
Talk: Abstract #313 / Session T28 - Physical Oceanography Open Session - Coastal Physics

Anthropogenic mixing by floating wind farms in stratified shelf seas

The drive to achieve net zero carbon has motivated the development of offshore wind into deeper waters further from shore. The relatively weak tidal currents and deep water of future development sites means that infrastructure will, for the first time, be deployed at scale in seasonally stratified waters. Current designs for floating turbines have sub-structures which penetrate this stratification. Tidal flow past such substructures generates turbulent wakes which can locally enhance the very low levels of internal mixing observed in the seasonal thermocline. These low natural mixing rates drive nutrient fluxes which sustain phytoplankton growth at the subsurface chlorophyll maximum through the summer months and are responsible for 50% of the primary production in shelf seas. Since this production supports the marine food web, changes to the physical drivers will fundamentally impact the marine food web. Therefore, an anthropogenic source of turbulent mixing at the seasonal thermocline, has the potential to cause fundamental biogeochemical changes, impacting ecosystems, and fisheries in shelf seas. We present new measurements which show strongly elevated turbulence within wakes at a shallow water wind farm. Strongly enhanced mixing is observed in the wake, and across the wider wind farm area and is

associated with reduced stratification. These observations and our estimates for deeper water wakes suggest that mixing from these structures can be significant, emphasising the need for further research to quantify the impact of this new source of anthropogenic mixing.

Linley T[1]; Gerringer ME; Ritchie H; Weston JNJ; Scott-Murray A; Fernandez V; Canto JL; Wenzhöfer F; Glud RN; Jamieson AJ
[1]Newcastle University, Armatus Oceanic Ltd.
Talk: Abstract #52 / Session T14 - A decade of deep ocean science for sustainable development

New hadal snailfish species represents an independent radiation of vertebrates into the hadal zone

Snailfishes (Liparidae) are among the most rapidly radiating families of marine fishes, resulting in a global distribution from the coastal intertidal to deep subduction trenches. The true diversity and distribution of deep-water snailfishes, particularly at hadal depths (>6000 m) and in the Southern Hemisphere, remains uncertain due to the rarity of samples. Three hadal snailfishes were observed in the Atacama Trench, which runs along the southwest coast of South America. One snailfish specimen was recovered from 6714 m, and has now been described. The new species represents the first hadal Paraliparis and is revealed to be an independent radiation into the ocean's deepest zone. There is evidence that this independent radiation originated from the highly diverse snailfishes of the Southern Ocean. The liparids continue to reveal themselves as a family particularly suited to adapting to life in the hadal zone.

Lipton I[1]
[1]AMC Consultants Pty Ltd.
Talk: Abstract #171 / Session T1 - Deep Sea Mining 1 - geology, resource, legal, technical and societal aspects

Polymetallic Nodules: Progressing from Mineral Resource towards Mineral Reserve

The existence of polymetallic nodules on the deep seafloor has been known since the Challenger expedition in 1872. Since the 1960s, various academic, government and commercial organizations have conducted systematic data collection programmes in areas rich in polymetallic nodules, in order to characterize and estimate the quantity and quality of Mineral Resources. While estimates of Mineral Resources quantify the valuable material on or under the seafloor, and assume potential for development of mining operations, they lack the detailed engineering, metallurgical, environmental, social, and economic assessments necessary for permitting and project development. In order to make a reliable technical and economic evaluation and provide a basis for environmental and social impact assessment, and permitting, a Mineral Resource must be converted to a Mineral Reserve. This paper considers the development of Mineral Reserve estimates for polymetallic nodule deposits on the floor of the Pacific Ocean. Economic recovery of polymetallic nodules will entail the use of technologies that are new, or adaptations of componentry and systems developed for terrestrial environments, shallower waters, or other industries. Novel technology will require innovative approaches to mine planning and operations. Operations in the marine environment will require new adaptive management strategies. In contrast to terrestrial mines, seafloor mining systems for polymetallic nodules will have high mobility and will not have any waste material to move or store. It is therefore expected that seafloor operations will be highly adaptable and able to respond rapidly to changes in the operating environment.

Liszka CM[1]; Thorpe SE; Wootton M; Fielding S; Murphy EJ; Tarling GA
[1]British Antarctic Survey.
Talk: Abstract #334 / Session T10 - Micro to macro: linking bottom-up and top-down approaches that investigate the function, resilience and conservation of polar ecosystems

Plankton and nekton community structure in the vicinity of the South Sandwich Islands (Southern Ocean) and the influence of environmental factors

The South Sandwich Islands (SSI) are a biologically diverse and productive archipelago of 11 islands in the eastern Scotia Sea, located to the south of the Antarctic Circumpolar Current (ACC). The islands support important populations of higher predators, including penguins, seals and whales. However, the plankton that underpins this

biodiverse region, including its ecology and environmental drivers, has been little studied to date. During the CCAMLR Area 48 Survey in January/February 2019, we conducted a comprehensive net and bottle sampling campaign incorporating three trophic levels: phytoplankton, mesozooplankton and macrozooplankton/nekton. We conducted multivariate analyses to examine the biogeographic structure of the three different plankton communities, and potential congruence between them. We also collected simultaneous oceanographic and satellite data to investigate the environmental controls driving the observed community structure. Our results revealed distinct mesoscale structure within the plankton community, with four spatially defined groups of phytoplankton and macrozooplankton/nekton, and three cluster groups of mesozooplankton. We observed some spatial congruence between the plankton communities related to the position of the Southern Boundary of the SACCF and, to some degree, the development of a phytoplankton bloom on the eastern edge of the archipelago, yet we also observed some trophic mismatch, particularly between the meso- and macrozooplankton. In this talk I will present the results and implications of this work, and discuss the drivers of the observed structure, along with potential explanations for the trophic mismatch.

Long S[1]; Lam P; Rees A
[1]University of Southampton.
Poster: Abstract #62 / Session T15 - Carbon cycling in the global ocean and the role of blue carbon in climate mitigation

Nitrifier ecology in coastal and estuarine systems

Coastal and estuarine systems are critical buffer zones for nutrient transport between land and sea, and are influenced by both natural and anthropogenic variables to different extents. Nitrification - a process that regenerates nitrate from reduced nitrogen - is generally believed to be most active in fresher waters, though it's regulation by nitrifying microorganisms and their interactions with environmental factors throughout estuarine environments is yet to be fully explored. Here, over a 3-year period, we assess the seasonality of physio-chemical characteristics and microbial community structure along the salinity gradient of the Tamar estuary, Plymouth, and the coastal waters of Western Channel Observatory station L4. We show via 16S rRNA gene sequencing alongside fluorescence in situ hybridisation that archaea are the dominant ammonia oxidisers in both systems, consistently found in greater numbers than their bacterial counterparts across the salinity gradient. In contrast to similar studies, archaeal cell densities were found to be highest (up to ~1.41 x 105 cells/mL) in spring months at intermediate salinities, despite their relative abundance (ranging from ~0.81% to ~25.9% of cells) peaking at depth in the L4 water column and largely correlating with increasing salinity and decreasing ammonium and nitrate concentrations. Additionally, at various sites, we detected the presence of the recently discovered comammox bacteria Nitrospira, further highlighting the prevalence of this nitrifier in marine systems. Altogether, this study increases our understanding of the abundance and diversity of nitrifiers in coastal systems, shedding new light into what dictates their distribution in complex and dynamic waters.

Long S[1]; Yesson C
[1]Zoological Society of London.
Talk: Abstract #206 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

Deep sea trawling and the impact on vulnerable marine ecosystems – A case study of sea pen fields in West Greenland

In west Greenland, the economically important offshore Greenland halibut (Reinhardtius hippoglossoides), trawls the seabed at depths of 800 – 1400 m. Initial assessments of sustainability highlighted the paucity of knowledge of benthic habitats and trawling impacts. Since 2017 we have been addressing this knowledge gap by performing low-cost benthic video sled surveys to determine the nature and distribution of habitats in relation to fishing effort. A particular focus has been to identify potential vulnerable marine ecosystems (VMEs), which are those habitats that are both of ecological importance and sensitive to disturbance. We present evidence of three potential VMEs in the area: (i) Flabellum alabastrum cup coral meadows; (ii) a Balticina finmarchica sea pen field; and (iii) areas exhibiting mixed assemblages of VME indicators. Of immediate conservation concern are observations of a B. finmarchica sea-pen field. This habitat seems to be at least regionally rare, is situated within the fringes of existing trawling effort and is currently afforded no protection by management measures. We will present evidence of the longevity of physical impacts on the seabed from trawling down to 1400m and how this has impacted habitats

in the region. The history and fate of the sea pen field will be discussed in the context of our efforts to inform evidence-based fishery management and ensure adequate protection of sensitive benthic habitats.

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[1]Ocean Technology and Engineering Group, National Oceanography Centre, Southampton, UK.
Poster: Abstract #240 / Session T22 - Strengthening Equality, Diversity, Inclusivity and Accessibility in Marine Science

OceanGliders Oxygen SOP v1.0.0: A good example of open collaborative scientific work.

During the OceanGliders Best Practices virtual Workshop in May 2021, a group of enthusiastic glider experts, sensor developers and end users wrote a first draft of a Standard Operating Procedure (SOP) for the use of oxygen sensors in autonomous vehicles. The principal aim of this collective effort was to ensure that the valuable data acquired by gliders in Europe and around the globe will be inter-comparable and of use to a broader community. Expertise and knowledge are scattered across many countries and, without an established standard, variations exist between the protocols followed by different user groups. Any effort to develop and maintain best practice documents must be both easy to update and attract the inputs of a broad spectrum of users. So developing the SOP had to be fully transparent, open, version controlled and with good document governance. GitHub [1] was selected as the platform for writing the SOP and for an open community review, allowing us to have a well-governed, up-to-date living document with regular releases. Contributions to the document are facilitated by a suite of continuous integration/deployment workflows, which preview changes for pull requests and publish updated versions of the document on the SOP website using the JupyterBook framework [2]. More than 20 collaborators from all around the world have been involved and training sessions have been organised to support this process.
Version 1.0.0 of the SOP was released on 2nd June 2022 in the Ocean Best Practices System (OBPS) repository, with a shorter version planned to be submitted to Frontiers: Research Topic Best Practices in Ocean Observing for peer-review. Meanwhile, our GitHub repository is open for new contributions and updates covering everything from deployment and mission planning through to data quality control. Read the SOP here [3].
This work was supported by OceanGliders, EuroGOOS Glider Task Team, H2020 Eurosea (GA No 862626), H2020 GROOM II (GA No 951842), H2020 TechOceanS (GA No 101000858) and AlterEco (Grant numbers NE/P013899/1, NE/P013902/2, NE/P013740/1 and NE/P013864/1) projects.
[1] https://github.com/OceanGlidersCommunity/Oxygen_SOP
[2] https://zenodo.org/record/4539666#.Yp-j9S-B30o
[3] https://oceangliderscommunity.github.io/Oxygen_SOP/README.html

Lopez-Garcia P[1]; Beaton A; Cardwell C; Cooper K; Forrester R; Hanz R; Ludgate J; Morris A; Patey MD; Rogers DS; Saw K; Schaap A; Steigenberger S; Tong D; Walk J; Wyatt J; Mowlem M
[1]National Oceanography Centre (NOC).
Talk: Abstract #237 / Session T7 - Pushing the limits in autonomous oceanography in a net zero carbon world

Demonstration of new in-situ biogeochemical sensors integrated in the Autosub Long Range (aka 'Boaty McBoatface')

The NERC Oceanids Programme aims to deliver new strategic sensing capability for marine autonomy as part of the wider UKRI Industrial Strategy Challenge Fund (ISCF). Cruise DY149 was the scientific validation and trials cruise for most of the sensor development projects under the programme, including AutoNuts which aims to deliver six new operational lab-on-chip (LOC) systems for inorganic macronutrients and iron crucial for advancing our knowledge of how marine ecosystems work and how they respond to change. DY149 took place on board RRS Discovery within the Celtic Sea and adjacent shelf break/slope and near-slope North East Atlantic Ocean from 14th – 30th March 2022 alongside two other Oceanids sensor projects and autonomous platforms from the UK Marine Equipment Pool. Multiple nutrient sensors were successfully integrated with the autonomous platform Autosub Long Range (aka 'Boaty McBoatface') as well as attached to the CTD frame for profiling and monitoring the surface seawater onboard the research vessel through the ships underway systems. All sensors produced new high-resolution datasets showing a variety of vertical and horizontal profiles. A key outcome was validation vs traditional methods, of the sensors on autonomy, demonstration of a powerful new capability for simultaneous and autonomous nutrient sensing in the ocean. It is anticipated that data collected from these systems on autonomy will enable enhanced scientific study across new spatio- and temporal scales, will open up new

opportunities for investigation and will enable chemical data acquisition in the remote ocean at reduced carbon cost thus contributing to the UKRI and UK mission to reach NetZero by 2050. We will present data collected across the inorganic nutrient LOC sensors for Nitrate+Nitrite, Nitrite, phosphate, silicate, and ammonia.

Lough A[1]; Blackbird SJ; Wolff GA; Jeffreys R; Sweetman AK; Homoky WB; Woulds C
[1]University of Leeds.
Talk: Abstract #301 / Session T2 - Deep Sea Mining 2 - environmental aspects: baselines, impacts, monitoring

Spatial variability in benthic organic matter quality within a Mn-nodule mining claim area of the Clarion Clipperton Fracture Zone

Deposition of organic matter (OM) provides a food source for seafloor benthic communities. Proposed mining of manganese nodules on the surface of deep-sea sediments is likely to redistribute and potentially alter OM composition in this environment. Little is known about the variability in organic matter concentration and quality within the km-scales of mining claim areas. We aimed to test the extent to which bioturbation alters OM quality of deep sea sediments from 19 sites within a 120 km2 claim area of the Eastern CCZ. Total organic carbon (TOC) profiles were similar between sites (0.6-0.2 wt % decreasing down core) and are within the range previously observed in the CCZ. Despite uniformity in TOC concentrations, lipid concentrations varied more substantially (890 to 2551 □g/gC). Indices of organic matter lability (C20:5(n-3) + C22:6(n-3)/total PUFA) varied from 0.1 to 78 % in surface sediments and all values >15 % were found in abyssal plain environments. We observed a significant correlation (p = <0.05) between the ratio of total mono- and polyunsaturated fatty acids (r2 = 0.33) and deviations from modelled 210Pb profiles (a proxy for bioturbation) that is suggestive of an ecological relationship between OM quality and bioturbating fauna. Our study highlights the importance of assessing OM quality as well as quantity in deep-sea environments as a means to monitor potential ecological impacts of mining disturbance at the seafloor. We will compare our lipid results to foram, macro and mega fauna abundance to further constrain the relationship between deep-sea benthos and OM quality.

Lucas N[1]; Brearley A; Abrahamsen P; Meredith M; Hendry K; Manno C; Liszka C; Gerrish L; Shepherd A; Braakmann-Folgmann A; Fleming A; Ratcliffe N; Collins M; Murphy E; Barnes D; Tarling G
[1]BAS.
Talk: Abstract #54 / Session T7 - Pushing the limits in autonomous oceanography in a net zero carbon world

Birth and death of a 'megaberg'. A multidisciplinary study of iceberg A68 near South Georgia, Southern Ocean.

Giant icebergs can greatly impact the mass, freshwater and nutrient budgets of the ocean. They can deposit large amounts of freshwater at great distances from their origins, impacting upper-ocean stratification and mixing, and they can be important vectors for micronutrient delivery with impacts on primary production and carbon drawdown. Their impacts on advection, productivity and blocking of flows can be critical for zooplankton and regional ecosystem functioning, with consequences for higher trophic levels and local fisheries. In 2017, the A68 iceberg (~6000 km2) calved from the Larsen C Ice Shelf on the Antarctic Peninsula. It subsequently moved northeast crossing the Scotia Sea virtually intact to within 300 km of the island of South Georgia (SG) in late 2020. This caused concern following the impact of a previous iceberg, A38, on the SG ecosystem in 2003-2004. Given the advances in observing technology since the time of A38, it afforded an unparalleled opportunity to study the impacts of giant bergs on the ocean physical, biogeochemical and biological systems. Diverse datasets were collected in response to this event. A research cruise on RRS James Cook was mobilised and studied physical and biogeochemical parameters. Ocean gliders, deployed from the ship, surveyed the largest iceberg fragment in extremely close proximity. Concurrently, Earth Observation (EO) techniques were employed including satellite imagery, radar and laser altimetry. A sediment trap is studied on a mooring downstream of SG, while enhanced observations were undertaken on higher predator colonies. This presentation will discuss findings from these studies.

Ludgate J[1]
[1]National Oceanography Centre.
Poster: Abstract #239 / Session T7 - Pushing the limits in autonomous oceanography in a net zero carbon world

Novel solution to the integration of sensors onto autonomous platforms

Autonomous platforms present new and unprecedented opportunities for gathering oceanographic data. However, the integration of sensors with these platforms can be non-trivial. A platform will often define its own protocol for communicating with sensors, which is typically incompatible with the protocol of the sensor itself. The NOC sensor hub has been designed to solve this problem by providing the necessary protocol translation between platform and sensor in order to enable integration. The NOC sensor hub is designed to sit in-line between the vehicle and sensor. It has a dedicated platform port and multiple sensor ports, each of which support RS232 serial communications. It derives power from the platform, and can switch the power to each of the sensor ports. An onboard microprocessor makes the device fully programmable, and capable of performing any degree of protocol translation, or capable of supporting additional mission logic. Its small form factor and low power requirements mean it places little overhead on the platform. The NOC sensor hub has already proven itself on several combinations of in-house and commercial platforms and sensors. The most notable is the integration of various sensors with the Liquid Robotics Wave Glider, including a NOC lab-on-chip sensor, a CO2 sensor developed by Exeter University, and a pH sensor from ANB Sensors. In each case the hub enabled real-time data collection from the sensor.

Mackay N[1]; Watson A; Zika J; Sohail T
[1]University of Exeter.
Poster: Abstract #148 / Session T26 - Physical Oceanography Open Session - Water Masses

A minimum transformation method applied to diagnosing ocean uptake and redistribution of anthropogenic carbon

The ocean is an important sink of anthropogenic carbon (Cant), having absorbed around a quarter of all emissions. Two categories of estimates of the sink are (i) those that calculate the air-sea flux from the difference in the partial pressure of CO2 at the interface combined with a gas transfer parameterization and (ii) those that estimate the evolution of Cant in the ocean interior. These estimates need reconciling for a comprehensive understanding of the sink, and this requires an understanding of how carbon is redistributed within the ocean in response to changes in the ocean circulation. Here we demonstrate the validation of a novel method to estimate the redistribution of carbon in the ocean interior, using outputs from the UK Earth System Model. The method uses a water mass-based coordinate system and diagnoses the minimum transformation required to change an observed distribution of water masses at time t1 to its distribution at later time t2, subject to constraints and to knowledge of air-sea fluxes of heat and freshwater. By using such a framework, we can infer the interior transports and mixing of heat, salt, and carbon without prior knowledge of the ocean circulation. For the validation, we combine the diagnosed interior transports and mixing with the model's carbon distribution and infer the surface CO2 flux as a residual, to then be compared to the known model CO2 fluxes.

MacNeil C[1]
[1]University of Southampton, UK.
Poster: Abstract #264 / Session T14 - A decade of deep ocean science for sustainable development

Reproductive Biology of a Hydrothermal Vent Limpet (Mollusca: Gastropoda) from the Aurora Vent Field, Arctic Ocean

In 2021, a species of cocculinid limpet was discovered and sampled during investigations of the hydrothermal vents on the Gakkel Ridge in the Arctic Ocean (HACON 21). Limpets often inhabit vents and cocculinids are known from organic falls, but the first vent cocculinid limpet (Cocculina enigmadonta) was previously discovered living on the Kemp Caldera, Weddel Sea, Antarctica (Chen & Linse, 2020). This study investigates the reproductive ecology and strategy of the Arctic cocculinid vent limpets with a view to adding to the knowledge base for hydrothermal vent ecology. Current data on vent communities identify 11 biogeographic provinces but, their delineation is still under debate (Bachraty et al., 2009; Rogers et al., 2012). The Gakkel Ridge had been identified during the ChEss-Census of Marine Life programme as a key missing piece of the global biogeographic puzzle of vent species (Ramirez-Llodra et al., 2007). Arctic vent fields may serve as a connectivity pathway between North Pacific and Atlantic vent fauna, either in terms of contemporary gene flow between conspecific

populations, or as an evolutionary stepping-stone for the diversification of vent-taxa with subsequent speciation. Currently, more than 60% of hydrothermal vent molluscs are listed as endangered by the International Union for Conservation of Nature, and it is therefore imperative that effective protection and policies are put in place to conserve these species.

Mahieu L[1]; Whitby H; Dulaquais G; Tilliette C; Bressac M; Arnone V; González-Santana D; Sarthou G; Planquette H; Guieu C; Bonnet S; Salaün P
[1]University of Liverpool.
Talk: Abstract #90 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

Iron-binding ligands distribution and binding strength in the shallow hydrothermal system of the Tonga Arc compared to surrounding deep waters

Phytoplankton growth is dependent on the availability of essential nutrients, notably nitrogen (N) and iron (Fe). The Western Tropical South Pacific Ocean is a major source of N for the global ocean due to high diazotroph activity, possibly fuelled by Fe originating from shallow hydrothermal sources. Here we present the conditional concentrations and stability constants of Fe-binding ligands in 95 samples collected during the GEOTRACES GPpr14 cruise in 2019 (https://doi.org/10.17600/18000884). The section covered part of the Melanesian waters and of the South Pacific Gyre, and crossed the Lau Basin and the Tonga Arc. The Competitive Ligand Exchange followed by Adsorptive Cathodic Stripping Voltammetry (CLE-AdCSV) was used, using 25 µM of salycilaldoxime as the added ligand. Our results highlight relatively high background concentrations of strong ligands of 4.7 ± 1.0 nanomolar equivalent of Fe (nMeqFe) throughout the transect, in large excess compared to most of the observed dissolved Fe (dFe) concentrations. The averaged conditional stability constant expressed as log K'FeL was 11.8 ± 0.3, ranging from 11 to 12 in the Melanesian waters and the South Pacific Gyre, and from 11.5 to 12.5 in the Lau Basin, where diazotrophs thrive. The highest stability constants were observed in subsurface waters, suggesting a biological production of strong ligands. An increase in ligand concentrations and a decrease in binding strengths with depth were observed, suggesting a source of weaker ligands from remineralisation of organic matter.

Mak J[1]; Yan FE; Wang Y
[1]HKUST.
Talk: Abstract #134 / Session T25 - Physical Oceanography Open Session – Energetics and Mixing

On the choice of turbulence eddy fluxes to learn from in data-driven methods

Recent works have demonstrated the viability of employing data-driven / machine learning methods for the purposes of learning more about ocean turbulence, with applications to turbulence parameterisations in ocean general circulation models. Focusing on mesoscale geostrophic turbulence in the ocean context, work thus far have mostly focused on the choice of algorithms and testing of trained up models. Here we focus instead on the choice of eddy flux data to learn from. We argue that, for mesoscale geostrophic turbulence, it might be beneficial from a theoretical as well as practical point of view to learn from eddy fluxes with dynamically inert rotational fluxes removed (ideally in a gauge invariant fashion), instead of the divergence of the eddy fluxes as has been considered thus far. Outlooks for physically constrained and interpretable machine learning will be given in light of the results.

Manikarachchige I[1]; Niroshana KH
[1]Ocean University of Sri Lanka, Sri Lanka.
Talk: Abstract #293 / Session T20 - Evidence to support international oceans policy

Investigating the potential of marine science education in building marine science-policy nexus: Perspectives from a developing island nation

"Evidence based polices" are essential in development agendas and how science education can be part of the process is a valid question to ask. This paper reflects the status of marine science education in Sri Lanka, a developing Island nation in the Indian ocean, and its contribution to bridge the science policy gap that exists

mostly in the developing world, has also been discussed. In Sri Lankan public education system, there is a significant void in marine science education at primary and secondary school levels while it is mainly facilitated at the university level. There is a publicly funded national university for marine and maritime studies and several other universities offer specialized degree programmes or compulsory/optional courses in marine sciences. The interdisciplinary nature of marine sciences is generally attributed in most undergraduate curricula. Students are more driven towards quantitative research and most are keen on publishing them in conference proceedings rather than in academic journals. There is no mechanism to integrate these research findings in national marine related policies. Not all students end up in careers that are directly relevant to the degrees that they pursue. Some join with fisheries production related jobs or entry level research careers while most enrol in higher education before settling in a career path. Universities are generally represented by the participation of academic staff in national policy making discussions, however, academic research findings are poorly referred in many of the discussions. A direct pathway for academic research to signal the needs of policy formulations and alterations is recommended.

Manno C[1]; Bjorg A; Rad S; Peter E; Elisa B
[1]BAS.
Poster: Abstract #230 / Session T12 - Interactions between plastics and marine ecosystem

The Ocean Plastic Incubator Chamber (OPIC) system to monitor in situ plastic degradation at sea

Marine plastic pollution is a global and pervasive environmental issue. Knowledge on plastic degradation in natural settings is still very limited due to current technological limitations, hampering our understanding of plastic fate (including its breakdown into micro- and nanoplastics) and of its risk for marine ecosystems. Here we describe the Ocean Plastic Incubator Chamber (OPIC), a novel equipment to follow plastic degradation in situ at sea over time. OPIC consists of a frame containing a motorized rotating stage with transparent tubes sub-assemblies where reference plastic materials are incubated and exposed to natural weathering conditions for multiyear periods. OPIC has been designed, tested and adapted for deployment with mooring line platforms in the Open Ocean and remote environments at different depths (from shallow waters to deep-sea environments). This equipment will allow us to examine and measure different markers of plastic aging in situ for the first time, with high temporal and spatial resolution. Data collected through OPIC will provide new insights into the multiple and locally driven dynamics regulating plastic transformations and fate at sea.

Marris C[1]; Marsh R
[1]University of Southampton.
Talk: Abstract #191 / Session T24 - The Atlantic Meridional Overturning Circulation: Observations, Simulations and Equations

Attributing Recent Variability in the AMOC to Subpolar Surface Buoyancy-Forcing

Variability in the Atlantic Meridional Overturning Circulation (AMOC) on interannual to multidecadal timescales can primarily be linked to the strength of deep-water formation in the Subpolar North Atlantic, where surface buoyancy-forcing transforms light surface waters to the dense waters of the southward-flowing lower-limb of the AMOC. The role of surface buoyancy-forcing in driving AMOC variability is of consequence for the regional transport and distribution of heat, carbon, and nutrients, and thus its quantification is essential for predicting how the AMOC will respond to and influence future global climate change. In a water mass transformation (WMT) framework, fields of surface density and surface density flux from the GODAS reanalysis are used to reconstruct the surface-forced overturning circulation (SFOC) streamfunction for the Subpolar North Atlantic (48-65 °N) over 1980-2020. The SFOC reconstruction is longitudinally partitioned into an East component, comprising the Irminger/Iceland basins, and a West component, comprising the Labrador Sea. Interannual and multidecadal changes in the dominant location of deep-water formation in the Subpolar North Atlantic are thus elucidated. The analysis provides transport estimates complementary to those obtained with observations from the RAPID array since 2004, and OSNAP array since 2014, revealing that recent (post-2014) domination of overturning in the Eastern Subpolar Gyre may be transient.

Marx L[1]; Reynolds S; Hale M; Birchill A; Cael BB

[1]University of Portsmouth.
Poster: Abstract #82 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

Seasonal fluctuations in biogeochemical cycling – a year-long monitoring of Langstone Harbour in Portsmouth, UK

Temperate coastal environments are under ever increasing threats of climate change as well as further anthropogenic pressures such as nutrient pollution from agriculture and waste water outputs. Coastal environments are highly productive, biodiverse and crucial for carbon storage. Langstone harbour on the south coast of the UK is an exemplary and highly conserved area (e.g. SSSI, RAMSAR, RSPB). Consistent monitoring of such coastal sites enables an assessment of the impacts of anthropogenic pressure such as nutrient pollution, rising seawater level and temperatures and increasing ocean acidification. At Langstone Harbour, we have monitored biogeochemical parameters on a weekly basis to produce an annual dataset. We present inorganic and organic nutrient and carbon concentrations, both dissolved and particulate from May 2021 to summer 2022. Local inorganic nutrient availability is generally higher in winter (NO_3 > 5 µM and PO_4 > 0.3 µM) and the associated N:P ratio is below Redfield (16:1) during summer. Chlorophyll a and microbial community structure measurements enable us to explore both the natural state of the microbial ecosystem as well as the response to anthropogenic perturbations. We observed a drastic drop in Chl a (> 0.1 µg/L) during a heatwave in July 2021, as well as algal blooming events in spring and late summer (> 3.5 µg/L, > 5.5 µg/L, respectively). Our year long dataset provides a vital insight to how Langstone Harbour is responding to ever-growing anthropogenic pressures, and is a springboard for a continuing monitoring to observe the impact of longer term environmental changes due to climate change.

Marx L[1]; Reynolds S; Hale M; Cael BB; Mawji E
[1]University of Portsmouth.
Talk: Abstract #81 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

The role of cyanobacteria on the biogeochemistry of nutrients and carbon in the subtropical North Atlantic gyre

Nutrients nitrogen (N) and phosphorus (P) and their spatial limited supply to the euphotic zone in oligotrophic ocean regions govern the distribution and abundance of primary producers such as Prochlorococcus and Synechococcus. Although depleted in N (< 50 nM) and P (< 10 nM), the oligotrophic subtropical North Atlantic gyre (NASG) supports primary production and therefore a substantial sequestration of atmospheric CO_2. However, questions remain to the role that cyanobacteria play in the biogeochemical cycling of nutrients and carbon in both the contemporary and future oceans. Here, we present data from a west-east transect survey throughout the NASG at 24N, during which 38 stations were sampled for dissolved and particulate nutrient and carbon pools and cyanobacterial distribution. Dissolved organic pools carry the majority of bioavailable nutrients in the central NASG (e.g. DOP > 80 % of total P), whereas inorganic nutrients are supplied by upwelling to the eastern boundary system, supporting primary production and henceforth conversion into particulate fractions. The community throughout the NASG is dominated by Prochlorococcus, whereas Synechococcus is limited to surface waters (< 100 m depth) and increasingly abundant in the more productive boundary systems; particulate nutrient and carbon pools are similarly distributed. Additionally, at 7 locations along the transect, mesocosm incubations were conducted to mimic increasing P-limitation, revealing enhanced drawdown of DOP throughout the NASG and increased conversion into particulates at the boundaries under future nutrient resources. This elucidates the impact of progressing climate change on the cyanobacterial community and on the biogeochemical cycling in surface waters of the NASG.

Marzocchi A[1]; Nurser G; Clément L; McDonagh E
[1]National Oceanography Centre, Southampton.
Talk: Abstract #31 / Session T24 - The Atlantic Meridional Overturning Circulation: Observations, Simulations and Equations

Surface atmospheric forcing as the driver of long-term pathways and timescales of ocean ventilation

The ocean takes up 93 % of the excess heat in the climate system and approximately a quarter of the anthropogenic carbon via air–sea fluxes. Ocean ventilation and subduction are key processes that regulate the transport of water from the surface mixed layer to the ocean's interior, which is isolated from the atmosphere for a timescale set by the large-scale circulation. Utilising numerical simulations with an ocean-sea-ice (NEMO), we assess where the ocean subducts water and, thus, takes up properties from the atmosphere; how ocean currents transport and redistribute these properties; and how, where, and when these waters are ventilated. Here, the strength and patterns of the net uptake of water and associated properties are analysed by including simulated seawater vintage dyes that are passive tracers released annually into the ocean surface layers (1958-2017). The dyes' distribution is shown to capture years of strong and weak convection at deep and mode water formation sites in both hemispheres, especially when compared to observations in the North Atlantic. Using this approach, relevant to any passive tracer in the ocean, we evaluate the regional and depth distribution of the tracers, and determine their variability on interannual to multidecadal timescales. We highlight the key role of variations in the subduction rate driven by changes in surface atmospheric forcing in setting the different sizes of the long-term inventory of the dyes released in different years; the evolution of their distribution; and implications for the uptake and storage of anthropogenic heat and carbon in the ocean.

Mawji E[1]; Izatt-Barton CJ; Flohr A; Major W; Hartman S
[1]National Oceanography Centre.
Poster: Abstract #272 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

Seasonal and inter-annual variations of dissolved oxygen in the North Atlantic over a 7-year time period (PAP-SO)

Oxygen is a key gas in ocean waters fundamental for many metabolic and chemical processes as well as a being utilised as a tracer to interpret water mass properties and biological productivity. Dissolved oxygen concentrations in the global ocean are changing due to anthropogenic pressures from both climate change and pollution. It is important to monitor oceanic oxygen trends as it is a proxy for monitoring ocean state due to its high sensitivity to climate forcing. Here we present a 7-year time series of dissolved oxygen concentrations at the Porcupine Abyssal Plain Sustained Observatory (PAP-SO) in the Northeast Atlantic Ocean. Data was obtained from a moored 30 m sensor frame, CTD, bottle data and satellites. The seasonal analysis of the oxygen show low winter concentrations, a rapid peak in spring followed by a gradual decrease over the summer until the autumn minimum was reached. These trends are attributed to significant biological activity in the spring, temperature fluctuations and mixing in the winter and summer/autumn. The long-term analysis of oxygen shows a gradual increase in the autumn minimum but more varied spring measurements over the time series. The gradual increase in oxygen is due to increases in productivity initiated by temperature increases and MLD decreases over the study period. The variability in the spring oxygen concentrations are attributed to the high variability of the spring bloom at the site. Time series such as the PAP Observatory provide a vital service in understanding long term trends and perturbations in the global ocean.

McCarry C[1]; McKee D; Basedow S; Davies E
[1]University of Strathclyde.
Talk: Abstract #10 / Session T19 - Mathematics of Satellite Oceanography

Detecting zooplankton from space

The zooplankton Calanus finmarchicus is a keystone species that is commercially harvested and critical in sustaining many important fisheries in the Arctic. However, due to their patchy and ephemeral population distributions, they are notoriously difficult to map using traditional ship- based techniques. This research involves the use of a combined approach of globally consistent ocean colour imagery and radiative transfer modelling to identify reflectance anomalies potentially caused by surface swarms of Calanus. Results show that ‘patches’ of red pixels within the Lofoten- Vesteralen region of Norway (where in situ measurements indicate the presence of high concentrations of Calanus at the surface) are not well described by varying concentration combinations of chlorophyll, sediment and dissolved organic matter alone. A greater degree of closure between modelled and satellite derived reflectance signals is only achieved in these patches through the addition of Calanus absorption. Further, visual similarity in the RGB colour values of the satellite and modelled spectra were quantified using the Delta E metric and utilised to produce anomaly maps. These maps show a relatively high degree of anomaly

within the patches compared to the surrounding waters, indicating the presence of something other than the material traditionally thought to drive the optical properties of the water column. This provides further evidence for the potential of surface swarms to influence remote sensing reflectance signals, and as a result they can be identified through satellite imagery. The methods described have the potential to be applied to other key groups of zooplankton, such as krill.

McClain C[1]; Hanks GW; Manlick PJ; Boolukos CM; Bryant SRD; Hiley AS; Junker JR; Nunnally C; Romano C; Rouse GW; JPW; Newsome SD
[1]LUMCON.
Talk: Abstract #259 / Session T21 - Trait-based approaches to improve conservation, management, and restoration of our oceans

Abundance, Niche Diversity, and Differential Species Effects Impact Ecosystem Function on the Bottom of the Ocean

Biodiversity-ecosystem function (BEF) research stems back decades and has seen a recent exponential growth of the field. Many questions remain about the importance of functional diversity (complementarity) versus redundancy, differential species effects, and the effects of abundance versus different diversity components. We examined the BEF relationship in deep-sea xylophagous bivalve communities using 63 experimental wood falls deployed ~2000m deep in the Gulf of Mexico. We quantified the relationships between spatial and trophic partitioning, species dominance, individual species effects, and community level properties on total wood consumption, our metric for ecosystem function. A total of 26,324 individuals from 12 xylophagous bivalve species were identified. Individual species inhabited complementary spatial and trophic niches, but species effects on total wood consumption greatly varied. The amount of wood consumed increased significantly with total abundance and species richness, although richness effects reflected increases in abundance. Ecosystem function among wood fall appears to be predominately a feature of highly abundant core species with greater functional diversity.

McGregor A[1]; Fisher B; Baker CA; Robinson C; Damerell GM; Liszka CM; Simmonds N; Fielding S; Muschitiello P; Cotgrove L; Chunara R
[1]University of Glasgow.
Poster: Abstract #217 / Session T22 - Strengthening Equality, Diversity, Inclusivity and Accessibility in Marine Science

Perceptions of marine science as a field-based discipline: Highlighting digital twinning of the oceans as a complementary and more inclusive pathway into a career in the marine sciences

Participation in offshore fieldwork is a frequent pathway into a successful career in marine science. However, this experience can present a considerable barrier to individuals from diverse backgrounds, including those with physical disabilities or caring responsibilities, and those from minority groups who may perceive the limited confines of a research ship as a hostile or unwelcoming environment. Imagery used to represent the discipline also emphasises outdoor and ship-based content, however the actual skills and activities involved in the field require a much broader skill set that encompasses non-field-based roles. With the developing possibilities of remote data collection and transmission through virtual representations of the ocean, an emergent area of work known as 'digital twinning', careers in the field are becoming more diverse and less likely to require first-hand fieldwork. The aim of this work was to explore the perceptions of both incoming and established scientists about the skills required in the discipline and the importance of fieldwork and digital capabilities. A mixed-method approach of online questionnaires and focus groups was used to collect views from undergraduate and postgraduate students enrolled in UK marine science programmes and scientists working at key research and academic organisations across the UK. Responses from both groups indicated an emphasis on field experiences, however both groups also acknowledged the importance of transferable skills, particularly related to programming and communication. In summary, an opportunity exists to encourage diversity in the field through digital twinning, however more focus is needed to expand general awareness of it as a career option.

McQuaid C[1]

[1]Dept of Zoology and Entomology, Rhodes University, South Africa.
Talk: Abstract #21 / Session T10 - Micro to macro: linking bottom-up and top-down approaches that investigate the function, resilience and conservation of polar ecosystems

Top-down and bottom-up drivers of Southern Ocean ecosystems

Understanding the future of Southern Ocean ecosystems requires approaches at both the micro and the macro levels. The Southern Ocean has experienced two dramatic perturbations driven by man, one top-down and one bottom-up. The removal of whales and finfish was a disruption of top-down effects through the removal of enormous levels of consumer biomass, with subsequent competitive release for many other predators. In contrast, climate change is altering physical conditions within the system in complex, interacting ways likely to change primary producer community structure, with bottom-up consequences for the nature and quantity of primary production. These systems depend heavily on small numbers of key species of animals and primary producers. The taxa driving primary production dictate the efficiency of energy transfer to top predators, and the efficiency of the biological pump. The vulnerability of the animals to sublethal effects on their demography will have important consequences before conditions reach lethal levels, but the physiological effects of increasing temperatures are likely to be less important than loss of the sea-ice habitat and changes to water column stability, which will affect krill abundances and primary producer community structure respectively. Given the strong physical forcing of Southern Ocean ecosystems, many of the initial consequences of climate change will operate through direct physiological effects on the primary producers and indirect effects on the larger organisms. All this will disrupt existing species interactions and drive new relationships. Critically, the Southern Ocean is vast and different regions already exhibit different patterns of physical and biological change.

McQuaid K[1]; Bridges AEH; Howell KL; Gandra TBR; Souza Vd; Currie JC; Hogg OT; Pearman TRR; Bell JB; Atkinson LJ; Baum D; Bonetti J; Carranza A; Defeo O; Furey T; Gasalla MA; Golding N; Hampton SL; Horta S; Jones DOB; Lombard AT; Manca E; Marin Y; Martin S; Mortensen P; Passdore C; Piechaud N; Sink KJ; Yool A
[1]University of Plymouth.
Talk: Abstract #246 / Session T14 - A decade of deep ocean science for sustainable development

Broad-scale benthic habitat classification of the South Atlantic

Marine Spatial Planning (MSP) has become a priority for many states wanting to develop national blue economy plans and meet international obligations in response to the increasing cumulative impacts of human activities and climate change. In areas beyond national jurisdiction (ABNJ), MSP is proposed as part of a package of solutions for multi-sectoral management at the ocean-basin scale. To facilitate planning, maps showing the spatial distribution of marine biological diversity are required. In areas lacking data, like the South Atlantic, environmental proxies can be used to predict these distributions. We undertook broad-scale benthic habitat classification of the South Atlantic, employing two top-down approaches spanning from national waters to ABNJ. The first was non-hierarchical and clustered groups of environmental variables prior to combination; the second was hierarchical and clustered Principal Components of environmental variables. Areas of agreement between the two approaches were identified and results compared with existing national and global classifications and published biodiversity patterns. We highlight several habitat classes we can be cautiously confident represent variation in biological diversity, such as topographic features, frontal systems and some abyssal basins. We also identify critical gaps in our knowledge of regional biogeography and advocate for collaborative effort to compile benthic species records and promote further exploration of the region to address these gaps. These insights into the distribution of habitats have the potential to support sustainable use and conservation of biodiversity beyond national jurisdiction, enable transboundary and ocean-basin scale management, and empower nations to make progress towards achieving Sustainable Development Goals.

Meagher J[1]; Huvenne V
[1]University of Southampton.
Poster: Abstract #282 / Session T14 - A decade of deep ocean science for sustainable development

Community structure and environmental drivers of benthic megafauna in the deep waters of the SW Greenland margin

Cold water coral reefs take a key role in the distribution and density of other benthic megafauna in the deep sea. This project aims to describe the relationship of the colonial scleractinian coral Lophelia pertusa and other benthic individuals in the phylum Cnidaria in the Labrador Sea. The remotely operated vehicle (ROV), Isis, image data utilized in this study was collected in July 2017, on the Isotope CYcling in the LABrador Sea (ICY-LAB) expedition, DY081, from depths of 840 meters to 1340 meters. Image data was annotated using the online platform "Biigle", and using a label tree already designed for DY081, with a few additional observed morphospecies added to the label tree. Identification of Cnidarians was made possible by sampling, images, videos and taxonomists. Image data were also combined with CTD and other sensory equipment data to determine abiotic factors such as depth, temperature, salinity and position data. These variables were used to determine if any observable community gradients were a result of abiotic factors, rather than the presence of L. pertusa. Other relationships are considered, such as substrate types, overall species densities and diversities unrelated to the colonial scleractinian corals, and relief of the substrate upon which the benthic organisms are located. Analyzing these possible reasons for species diversity and density gradients will aid in determination of any community gradients observed being a result of the presence of the colonial scleractinian coral Lophelia pertusa.

Meng X[1]
[1]University of Liverpool.
Poster: Abstract #170 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

Analysis of the physical and biogeochemical drivers of dissolved oxygen (DO) decrease in Celtic Sea under climate change

Dissolved oxygen (DO) decline is an important global issue. Low oxygen can result in dramatic changes to marine ecosystems, ocean productivity and fisheries. The rate of reduction of oxygen in the highly productive shelf seas is often found to exceed that of the open ocean. The DO concentration in seasonally stratified seas is controlled by the interplay of physical and biogeochemical processes: vertical mixing, horizontal advection, photosynthesis and respiration. Environmental change, including global warming and nutrient enrichment, results in DO decline by reducing the solubility of oxygen, enhancing the intensity and duration of stratification, and increasing rates of respiration and degradation, but the relative contribution of the different processes driving DO changes is currently unclear. This work explores the processes controlling the DO in the Celtic Sea, using CTD data from UK Shelf-Sea Biogeochemistry Research Programme and focused on the stratified period (2014 Mar – 2015 Sep). The potential processes affecting the oxygen inventory in the central Celtic Sea are explored, allowing an estimated budget of oxygen in the bottom mixed layer (BML) during the stratified period. It is found that respiration and vertical mixing are the most important processes. It is shown that episodic strong wind events and internal wave mixing could also be important in the supply of oxygen into the BML.

Meng Y[1]**; Sheen K; Ashton I; Gunn K; Menesguen C**
[1]CLES, University of Exeter.
Poster: Abstract #105 / Session T25 - Physical Oceanography Open Session - Ocean Eddies

Investigating mesoscale eddies and submesoscale Ocean Dynamics in the Mozambique Channel with Seismic and Simulation Datasets

Oceanic processes that occur on scales around 10 km (i.e. submesoscale) play a key role in the energy path toward, transport of heat and momentum, air-sea interaction and biological productivity. Despite their importance, knowledge of submesoscale processes is severely hampered by a lack of in situ observations with appropriate resolution. One potential solution is a technique known as seismic oceanography that uses acoustic reflections from temperature and salinity changes in the water column. With horizontal and vertical spatial resolutions that span 10 m to 100 km, seismic oceanography is well suited to capturing submesoscale variability throughout the water column. Here we present a unique seismic data set collected in the Mozambique Channel, a highly energetic boundary current where eddies and instabilities are active. The seismic sections were collected between Jan-March in 2016 and show the evolution of several submesoscale features associated with the passage both an anti-cyclonic and cyclonic mesoscale eddy and their interaction with the continental shelf. The ultimate goal is to compare these data with results from a high-resolution numerical model in order to have new advances in the understanding of energy paths and mechanisms in the creation and dissipation of mesoscale eddies and submesoscales.

Methou P[1]; Chen C; Watanabe HK; Cambon M; Pradillon F
[1]JAMSTEC.
Talk: Abstract #204 / Session T14 - A decade of deep ocean science for sustainable development

Reproduction in deep-sea vent shrimps is influenced by diet, with rhythms apparently unlinked to surface production

Variations in offspring production according to feeding strategies or food supply have been recognized in many animals from various ecosystems. With a trophic structure based on non-photosynthetic derived carbon, chemosynthetic ecosystems constitute an ideal natural laboratory to study these processes. Here, we use alvinocaridid shrimps as a study case to explore relationships between reproduction, diets and food supply in these environments. For this we compared reproductive outputs of ten species from the family differing by their diets and with a global distribution in the Atlantic, Indian and Pacific oceans covering distinct latitudes and both hemispheres. We also used both our original data and a compilation of published observations on the presence of ovigerous females covering various seasons, up to 35 years of sampling records for some species. Our results show distinct egg production trends between species relying solely on chemosymbiosis and those relying on mixotrophy. Besides, our data suggest a reproductive periodicity that does not correspond to seasonal variations in surface production, with substantial proportions of brooding females during the same months despite those months corresponding to either boreal winter or austral summer depending on the hemisphere. These observations contrast with the long-standing paradigm in deep-sea species for which periodic reproductive patterns have always been attributed to seasonal variations of photosynthetic production sinking from surface. Our results suggest the presence of intrinsic basis for biological rhythms in the deep sea, and bring to light the importance of having year-round observations in order to understand life history of vent animals.

Meuriot O[1]; Plancherel Y; Lique C
[1]Imperial College London.
Talk: Abstract #210 / Session T26 - Physical Oceanography Open Session - Water Masses

Antarctic Intermediate Water's response to climate change in CMIP6 models

Antarctic Intermediate Water (AAIW) forms in the Southern Ocean and spreads northward in the Atlantic, Pacific and Indian oceans. It plays a key role in the global overturning circulation and global water cycle. It can be clearly identified by its low salinity signature, however how it forms, how it is modelled and its sensitivity to climate change are not well understood. Properties of AAIW are investigated in 17 CMIP6 models. The CMIP6 multi-model mean shows that the AAIW core (the salinity minimum) presents a shallow, light and warm bias when compared to observations. Zonal differences exist; the multi-model mean core AAIW salinity is too salty in the Atlantic and too fresh in the Pacific and Indian basins. In future scenarios, AAIW core properties get shallower, warmer and lighter in all CMIP6 models. The AAIW core in the Pacific and Indian basins freshens under radiative forcing whereas in the Atlantic basin, no clear changes in salinity can be observed. Although all CMIP6 models show that the Antarctic Circumpolar Current (ACC) remains stable in future scenarios, the response of the position of the outcrop of the AAIW is not consistent across models. Changes in AAIW properties can impact the heat and carbon storage capacity of the water mass, assessing the impact of these changes is therefore key and will be investigated in future works.

Middleton F[1]
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Poster: Abstract #283 / Session T16 - How Art-Science Collaborations can Inspire Societal Change

Designing participatory creative processes for ocean literacy

The term 'ocean literacy', posed by the UN Ocean Decade as an important tool to achieve an 'inspiring and engaging ocean', suggests ways of connecting with the ocean based on read and written knowledge. To complement this knowledge, intimate and subjective forms of communicating with the ocean allow the learnings and lessons from 150 years of marine science to percolate through society in touching and impactful ways. Art

opens a space for transdisciplinary speculation about human–ocean relations. It also offers diverse methodologies for observing, recording and interpreting the world around us. Collaboratively assembling living artefacts, like maps and manifestos, can blend lived and scientific understandings of the ocean. In this way, participatory creative processes can expand the possibilities for different groups to share and co-create knowledge that is multi-dimensional and reflective of societal values and needs of the ocean.

Miller CG[1]; Stukins S; Rickaby R; Zarkogiannis S
[1]Science Group, Natural History Museum, London.
Talk: Abstract #243 / Session T18 - HMS Challenger collections as a benchmark for oceanographic studies

Making the most of a collection that illuminates the debate on anthropogenic climate change: The HMS Challenger and Ocean Bottom Deposits Collection at The Natural History Museum

The Challenger Collection of Ocean Sediments is the nucleus of a larger collection of Ocean Bottom Deposits at the Natural History Museum that consists of samples from over 30,000 sites from collections made over the last 150 years. The collection is digitised (https://data.nhm.ac.uk/dataset/ocean-bottom-deposits-collection). Two recent publications highlighted pilot studies that encourage further use of these sediments as a baseline for oceanic conditions almost 150 years ago. Fox et al. (2020) compared Challenger plankton tow collected planktonic Foraminifera with material from the recent Tara Oceans expedition that visited the same region of the Pacific Ocean. Using nano-CT scans, comparison of multiple species present in both collections showed that modern examples may have thinner shells to conclude that Foraminifera calcification is impacted by anthropogenic carbon emissions. Rillo et al. (2019) assessed the planktonic foraminiferal content of the bottom sediments, comparing other datasets from core top samples and the Last Glacial Maximum. It concluded that some of these sediments from an early age of seafloor exploration can provide a late 19th Century baseline of the marine environment and Challenger and other early cruises sampling methods render collected sediments as indicators of a specific and measurable time-period. Here we show some early results from a CT scanning method that provides a further assessment of these sediments so that specific samples can be identified as best representing the preindustrial oceanic conditions at the time of the Challenger Expedition.

Fox et al. (2020). Scientific Reports, doi:10.1038/s41598-020-58501-w
Rillo et al. (2019). Frontiers of Marine Science, doi:10.3389/fmars.2018.00517

Millette N[1]; Costa Md; Gast R; Grattepanche J
[1]William & Mary, Virginia Institute of Marine Science.
Talk: Abstract #23 / Session T5 - The role of mixoplankton and mixotrophy in the global carbon cycle

Estimating the proportion of mixoplankton in existing phytoplankton samples

There are numerous long-term monitoring programs that track the abundance of phytoplankton species via microscopy; for example, the Continuous Plankton Recorder Survey has collected decades of phytoplankton data. However, many species identified as phytoplankton are actually mixoplankton, cells that obtain nutrients through a combination of photosynthesis and prey ingestion. Understanding the global biogeographical distribution of mixoplankton is a major research gap. Existing phytoplankton datasets are potentially useful for examining under what conditions mixoplankton may dominate, but identifying mixoplankton in a system is necessary. We demonstrate how a combination of bromodeoxyuridine (BrdU) experiments and microscopy data can be used to identify mixoplankton present in a given sample and translate that to abundances. In these experiments, bacterial prey are labeled with BrdU, an analog of thymidine, which is incorporated into their DNA. These prey are fed to the in situ grazer population and the BrdU is transferred to the grazer genome during DNA replication. Immunoprecipitation is then used to isolate grazer DNA labeled with BrdU, followed by eukaryotic ribosomal amplicon sequencing. Amplicon sequence variants (ASVs) that consume bacteria and are associated with chloroplast containing taxa are identified as mixoplankton. The mixoplankton ASV taxonomic identifications are compared to the microscopy taxa; qualitative identification of microscopy taxa as mixoplankton is made if there are matches at the genus and/or species level. In systems with robust phytoplankton community data, this approach could be used to quickly develop and study a large dataset on mixoplankton abundance for analysis.

Monteiro F[1]; Vries Jd; Poulton A; Wheeler G
[1]University of Bristol.
Talk: Abstract #219 / Session T21 - Trait-based approaches to improve conservation, management, and restoration of our oceans

Revealing the ecological impact of coccolithophore diversity through mechanistic and statistical modelling

While most coccolithophore studies rely on the fast-growing Emiliania huxleyi species, observations suggest that other species are more important for the ocean calcium carbonate production as larger and more heavily calcified. Including diversity is then fundamental to understanding coccolithophore's ecological and climatic impact. Here, I present the development of two modelling techniques, mechanistic and statistical, to explore the impact of coccolithophore diversity on the global ocean. The mechanistic model relies on the promising trait-based approaches, where biodiversity is captured by functional diversity, which defines functional groups of similar traits (e.g., size, calcification) and trade-offs (costs and benefits of a particular trait). We apply trait-based approaches to coccolithophore and review the costs and benefits of coccolithophore's main trait of calcification. We find that calcification has multiple benefits explaining their high diversity and broad ecological niches. We also find that trait-based knowledge is limited to modelling coccolithophore functional diversity accurately. Without more knowledge, an alternative approach is to use statistical modelling, where we model coccolithophore species distributions by combining global datasets of coccolithophore abundance of the top 160 species and environmental conditions (e.g., temperature, nutrients, light). The resulting species distribution model shows that a handful of species contribute to the total coccolithophore organic carbon biomass with E. huxleyi dominating by ~66% and Umbellosphaera species like U. tenuis and U. irregularis accounting for ~26%.

Moore M[1]; Presented on behalf of all involved in the DY149 trials cruise and associated OCEANIDS sensor projects
[1]University of Southampton.
Talk: Abstract #165 / Session T6 - Towards a Net Zero Oceanographic Capability

Towards net zero hollistic observational biogeochemistry: preliminary overview of the DY149 trials cruise

Deployment of state of the art biogeochemical sensors on autonomous platforms has the potential to revolutionise observational oceanography. Through both reducing reliance on shipboard measurements and providing new observational modes, such integrated sensor / platform systems offer the potential to simultaneously increase scientific capabilities, while reducing carbon emissions. The recent DY149 cruise on the RRS Discovery, which formed a key component of the OCEANIDS programme, provided an opportunity to simultaneously trial 11 new biogeochemical sensors, covering multiple nutrient, carbonate chemistry and microbiological rate measurements, on the Autosub Long Range platform. Here we will present a preliminary overview of the achievements of this trial from both technical and scientific perspectives, emphasising key lessons learnt and the exciting possibilities such hollistic autonmous biogeochemical data represent for a Net Zero Oceanographic Capacity.

Moore O[1]; Moore O; Curti L; Woulds C; Bradley J; Mills B; Homoky WB; Xiao K; Babakhani P; Fisher B; Peacock C
[1]University of Leeds.
Talk: Abstract #116 / Session T4 - Shackleton Session: Marine Sedimentary Carbon

The transformation and preservation of mineral-associated organic carbon within marine sediments

The balance between the preservation and degradation of organic carbon (OC) within marine sediments is of primary importance to the Earth's carbon and oxygen cycles over geologic timescales (Lenton et al., 2018). The main control on preservation is thought to be the exposure time of OC to oxygen (Hartnett et al., 1998), but in continental margins where >90% of OC preservation occurs, this relationship is weak (Arndt et al., 2013), suggesting that other mechanisms must play a role in these environments. One mechanism that has received little attention is the geopolymerisation of small labile OC molecules, into complex and stable forms via reactions such as the Maillard reaction (Hedges, 1978). However, the contribution of these types of reactions to OC preservation were previously thought to be minor due to slow reaction kinetics (Alperin et al., 1994). Here we show that iron and manganese (oxy)hydroxide minerals catalyse the Maillard reaction by up to two orders of magnitude at

temperatures, OC concentrations and mineral concentrations similar to continental margins. Furthermore, using STXM-NEXAFS we show that the chemical structures of these geopolymerised substances are consistent with OC in continental margin sediments from around the globe. Our results indicate that the catalysed geopolymerisation of simple OC molecules into complex macromolecules accounts for 3-17% of global OC preservation in marine sediments.

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Hedges, J., Geochim.Cosmochim.Acta 1978, 42(1),69-76. Alperin, M., et al., Geochim.Cosmochim.Acta 1994, 58(22),4909-4930.

Morgan C[1]; Wånggren L; Woolf D; Magill C; Fernandes T; Watson F; Sang K
[1]Heriot-Watt University.
Talk: Abstract #29 / Session T22 - Strengthening Equality, Diversity, Inclusivity and Accessibility in Marine Science

Enabling Neurodiversity-Inclusive Marine Science Careers – A Way Forward

Inequalities in science careers are well-established, particularly concerning the under-representation of women. However, other strands of inequality, including disability, remain poorly understood. Based on a qualitative multidisciplinary UK research project bringing together social and natural scientists and humanities scholars, this paper examines disability inclusion in the marine and wider environmental sciences, focusing on neurodiversity. This paper describes the challenges faced by neurodivergent environmental scientists and presents a co-designed set of strategies for more inclusive and equitable research careers within the field. Persons with so-called hidden impairments and health conditions, such as autism [associated with the lowest levels of employment in countries including UK (Office for National Statistics, 2021)], are particularly marginalised groups that face additional, intersectional barriers in the workplace. Neurodiversity encompasses a range of experiences, identities and diagnoses, including autism spectrum disorder (ASD), attention deficit hyperactivity disorder (ADHD or ADD), dyslexia, dyscalculia, and dyspraxia. Evidence shows an overwhelmingly negative workplace experience for neurodivergent workers, unless managers had a good understanding of neurodiversity. Anxiety and fear due to stigma, negative attitudes, fear of discrimination, and due to neurotypical workplace processes, are key to hindering inclusion at work. Based on extant literature and recent fieldwork (qualitative surveys and interviews) with neurodivergent environmental scientists, we present specific strategies to attract and retain neurodivergent staff. These include increasing understanding by awareness training for staff, clear and flexible management styles, and planning fieldwork around different needs. It is clear that specific actions within recruitment, workspaces, and work cultures are needed.

Morley S[1]; Souster TA; Barnes DK; Sands CJ; Vause BJ; Gerrish L; Peck L
[1]British Antarctic Survey.
Talk: Abstract #1 / Session T15 - Carbon cycling in the global ocean and the role of blue carbon in climate mitigation

Valuing intact marine benthic biodiversity to help mitigate against climate and biodiversity crises.

Seafloor biodiversity can provide key regulating ecosystem services, these include an efficient pathway for carbon to be removed from the atmosphere and become buried (long-term) in marine sediments. Protecting near intact ecosystems, particularly those that are hotspots of species- and carbon-rich biodiversity is increasingly being recognized as a strong method to protect and maximise blue carbon pathways. The current study attempts to quantify benthic blue carbon in the South Atlantic (Tristan da Cunha) and Southern Ocean (Antarctic Peninsula and South Georgia) coastal shallows. Along the Antarctic Peninsula we estimate a benthic standing stock of 253k t C at 20 m depth along the seasonally ice free shores, with a potential sequestration of 4.5k t C year-1. 54% of the shore along the Antarctic Peninsula is still permanently ice covered, and so blue carbon ecosystem services are expected to more than double with continued ice loss mediated by climate warming; one of the few increasing negative feedbacks against climate change. Our research highlights the importance of protecting diversity to blue carbon ecosystem services, emphasizing the importance of considering blue carbon in marine management plans in order to help tackle the biodiversity and climate crises together. We strongly advocate that carbon credit

systems need to value the protection of existing ecosystem services, not just regeneration of new habitat (additionality).

Mostert W[1]; Deike L; Boswell H; Popinet S; Yan G
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Talk: Abstract #255 / Session T17 - Physical and chemical drivers of air-sea exchange processes: waves, bubbles, aerosols and surface chemistry

Dimensional and depth dependencies in energy dissipation of breaking waves

Not only do the energy dissipation rates of breaking coastal and ocean waves provide a mechanism for energy transfer from atmosphere to ocean, they are also closely linked to mass transfer phenomena via cavity entrainment and bubble generation, to sediment and pollutant transport in coastal regions, and to momentum considerations in the upper ocean. Breaking dissipation has however been historically difficult to estimate consistently, especially with regard to the different properties of deep and shallow water breakers. We present data from high-resolution direct numerical simulation of breaking waves in deep and shallow water in two (2D) and three dimensions (3D). First, we compare detailed 2D and 3D dissipation rates in deep water, and find that 2D simulations provide a reasonable first estimate for turbulent dissipation in breaking waves, consistent with literature. Second, we present 2D results in shallow water for breaking solitary waves in a variety of shoaling configurations, along with a simple predictive physical model. Finally, we discuss the possibilities in finding a universal breaking dissipation function, valid at any depth, using simple measurements of local parameters.

Mowlem M[1]; TechOceanS consortium
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Talk: Abstract #247 / Session T6 - Towards a Net Zero Oceanographic Capability

Technologies for Ocean Sensing (TechOceanS project)

Covering over 70% of our planet, the health of our oceans is vital for the survival and well-being of all life. TechOceanS is an EU-funded project that will create new remote ocean sensing technology to support ocean conservation and monitoring. The project will deliver 5 new sensor classes for biogeochemistry, biology and ecosystems addressing 10 of 19 EOVs, 31 of 73 subvariables, 6 of 9 MSFD targets together with microplastics and a range of biotoxins and contaminants. It will also develop a new image processing workflow for extracting EOVs (9) and MSFD (6) and litter measurements from images. These innovations concentrate on key capability gaps in ocean observing from non-ship systems with a focus on low-cost per measurement through minimised instrument and deployment costs. These innovative technologies move significantly beyond the state of the art and have potential for innovation in instrument manufacturing (manufacture and sale of products) and associated service industries (e.g. monitoring services) as well as delivering capability and data for information products for offshore industries, aquaculture and fisheries.

Munday D[1]; Jones D; Boland E; Blaker A; Meijers A
[1]BAS.
Talk: Abstract #120 / Session T26 - Physical Oceanography Open Session - Water Masses

Semi-optimal perturbations to South Atlantic heat content in an eddy-resolving Southern Ocean model and a global state estimate

The South Atlantic stores a large amount of heat and is a region where multiple current systems, e.g. the Antarctic Circumpolar Current, the Agulhas Current and the Brazil Current, interact. In the ORCHESTRA fieldwork region, these currents all influence the circulation and heat storage, which may be modified by both local and remote forcing. The ECCOv4r3 state estimate is used to design specific zonal wind stress perturbations that influence the South Atlantic heat content based on adjoint sensitivity maps. These perturbations are applied in a 1/12 degree, eddy-resolving model of the Southern Ocean and the forwards model of the ECCOv4r3 state estimate. Results show that both models demonstrate comparable changes in heat content/mean temperature, primarily driven by advection of heat through the 30oE section. The distribution in space of the temperature change, both inside and

outside of the ORCHESTRA box, is very similar. The increase/decrease in mean temperature of the ORCHESTRA box is largely offset by changes elsewhere; the heat content change is a redistribution of current heat, rather than the addition/removal of new/old heat. Additional experiments with the ECCOv4r3 forwards model show that the heat content change saturates within 20-30 years. Beyond this point, the change in mean temperature leads to a change in the advection of heat past 30oE such as to balance the change driven by the wind stress. Removal of the zonal wind stress perturbation reverses it's impact within 20-30 years as the perturbed heat content is advected out of the 30oE section back into the rest of the ocean.

Murray L[1]; Chin J; McGrath J
[1]Queens University Belfast.
Talk: Abstract #77 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

A flair for phosphonates; Roseovarius nubinhibens obtains phosphorus from diverse substrates by expanding old pathways

Marine microorganisms regulate the Earth's climate and drive vast global-ocean biogeochemical cycles. It has long been established that phosphorus (P) availability is fundamental to these processes by controlling productivity in the oceans. However, vast oceanic regions are oligotrophic with inorganic phosphate concentrations as low as <10 nmol L-1. As such, microorganisms are reliant upon the catabolism of dissolved organic phosphorus compounds including organophosphonates, molecules characterised by a direct carbon-phosphorus bond to meet their P requirements. Inhabitants of oligotrophic surface waters that significantly contribute to biogeochemical cycling include the Roseobacteraceae, a major clade of marine bacteria. Yet, how these important marine bacteria tolerate low P is poorly explored. A bioinformatic examination revealed the presence of phosphonate metabolism genes in Roseovarius nubinhibens, including phnWYA, C-P lyase with an adjacent LysR transcriptional regulator, and the newly discovered phosphonate breakdown factor gene pbfA. We tested R. nubinhibens' ability to utilise phosphonates as a P source through growth on various phosphonates, protein quantification, and phosphate release. Cell-free extracts were used to test enzyme activity by assaying organic end products. Results shows that R. nubinhibens metabolises 2-aminoethylphosphonate, its derivatives (R)-1-hydroxy-2-aminoethylphosphonate and N-methyl-2-aminoethylphosphonate, and methylphosphonate. The aminophosphonate metabolism appears to be via a novel PbfA-PhnWYA pathway, the first time this has been demonstrated, and suggesting a novel flexible approach to metabolising several phosphonates via PhnA. The regulation of these pathways, and their control by P, will be further explored to determine how important this metabolism is for the marine environment. The versatility of phosphonate metabolism pathways in R. nubinhibens suggests that phosphonates represent an important source of P for these abundant marine bacteria.

Murton B[1]
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Talk: Abstract #350 / Session T1 - Deep Sea Mining 1 - geology, resource, legal, technical and societal aspects

Giant seafloor massive sulphide deposits forming at dying ocean core complexes.

Paradoxically, there is an apparent paucity of hydrothermal systems and their associated mineral deposits on the mid-ocean ridges when considering the availability of magmatic heat and circulating seawater. The reasons for this discrepancy are unknown but there are three particularly likely ones: active hydrothermal systems are relatively easy to locate but greatly underrepresent the totality of seafloor massive sulphides within the mid-ocean ridge crest; the conditions that favour the largest accumulations of sulphide are relatively rare and easily missed; and the sub-seafloor structure and volume of sulphide accumulations is notoriously hard to determine. Here, we report on a study of a number of hydrothermal accumulations from the 13°30'N oceanic core complex on the Mid-Atlantic Ridge. The deposits. which are collectively known as the Semyenov hydrothermal fields, are all hydrothermally inactive except for one. Some are associated with late-stage volcanism that has erupted lavas through the core complex. By far the most dramatic deposits are found on the hanging wall, where they form the largest seafloor accumulations known. Their location on the hanging wall, relative to the plunging detachment fault and to nearby propagating volcanic rifts, yield clues as to their formation. We propose that the availability of magmatic heat at depth from the approaching neovolcanic axes of the axial combines with the constant

extension on the detachment fault maintains pathways for deep circulating hydrothermal fluids and the subsequent development of large sulphide deposits.

Ni Q[1]; Zhai X; Chen D
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Talk: Abstract #7 / Session T25 - Physical Oceanography Open Session - Ocean Eddies

Impact of mesoscale eddies on near-inertial energy in the global ocean

Near-inertial waves are a dominant mode of high-frequency variability in the ocean and are one of the most important energy sources for generating turbulent ocean mixing. Mesoscale eddies are long thought to play a significant role in regulating the distribution, propagation and dissipation of near-inertial energy. However, observational evidence on a global scale is still lacking. Using satellite altimeter and surface drifter data, here we show that anticyclonic eddies (AEs) and cyclonic eddies (CEs) systematically trap and expel near-inertial energy in the global ocean, respectively. Composite analysis using Argo float profiles further reveals that turbulent energy dissipation associated with wind-driven near-inertial waves is much stronger and more deep-reaching in AEs that in CEs. Given the importance of mesoscale eddies in modulating near-inertial waves in the global ocean, such processes need to be properly taken into account in future development of parameterizations of near-inertial wave-induced mixing in ocean and climate models.

Nickells N[1]; Cavan E; Belcher A; Atkinson A
[1]Imperial College London.
Talk: Abstract #182 / Session T10 - Micro to macro: linking bottom-up and top-down approaches that investigate the function, resilience and conservation of polar ecosystems

Quantifying the role of Antarctic krill and salps on carbon flux to depth in the Southern Ocean

Euphausia superba (Antarctic krill) and salps (Salpidae) make significant contributions to the Biological Carbon Pump, through their faecal pellets, moults and carcasses sinking to the deep ocean. Despite their importance, little is known of the relative roles of the two taxa in carbon export, with the majority of work focusing on Antarctic krill only. Furthermore, there has been little focus on the processes that attenuate particulate organic carbon flux (POC) before it reaches sequestration depths. I present maps of both krill and salp particulate organic carbon (POC) flux in the Atlantic sector of the Southern Ocean, from the epipelagic to the deep ocean (1000m) and to the seabed. These POC estimates use observed Atlantic sector values (eg. for water temperature, pellet carbon contents and sinking rates) in attenuation equations, to provide an estimate of whole-area scale carbon flux to depth. POC flux to depth is simulated using the z* exponential equation, in which I vary the exponent as a factor of temperature. This changing exponent represents the response of microbial respiration to temperature: in warmer water, microbial respiration is greater and POC attenuation is likely to be greater, resulting in reduced carbon flux to depth. I will include an uncertainty analysis to discuss which processes are most key but poorly constrained, and thus should be prioritised for further research. The presentation will conclude with analyses of the implications for increases in water temperature and of potential shift from krill to salp dominance, with consequences for blue carbon budgeting.

Nightingale A[1]; Beaton, AD; Birchill AJ; Coleman S; Evans GWH; Hassan S; Zhu J; Mowlem MC; Niu X
[1]University of Southampton.
Talk: Abstract #72 / Session T7 - Pushing the limits in autonomous oceanography in a net zero carbon world

Anti-fouling copper surfaces interfere with wet chemical nitrate sensors and Griess-based nitrate assays

Biofouling is the rapid and undesirable accumulation of microorganisms, algae and animals on structures submerged in natural waters. It can be a serious problem for oceanographic sensors, most notably in warm nutrient-rich waters. In situ sensors allow continuous monitoring of the aquatic environment with much increased temporal resolution compared to traditional spot-sampling and lab analysis. Left unchecked, biofouling can perturb sensor data and hence is an important consideration when planning sensor deployments. Our two groups

have separately developed microfluidic sensors to measure nitrate and nitrite concentrations in situ using the spectrophotometric Griess assay. While they use slightly different flow regimes (single-phase stop flow versus continuous droplet flow) they both operate in a broadly similar fashion – drawing in water from the external environment through a filter, flowing it onwards into narrow channels where it mixes with reagents to generate a quantifiable colour which is automatically recorded. Biofouling within the device is not a problem, due to the harsh chemical environment, however the sample intake and filter are still susceptible to biofouling, hence we have trialled copper to prevent fouling at the intake. Here we detail field trials of filters featuring antifouling copper surfaces which produced an unexpected and notable reduction in measured nitrate. We will show how the interference was subsequently replicated in laboratory testing, and the mechanism successfully characterised. This interference has a wider implication beyond these sensors, with potential impact on any aquatic samples that are acquired near copper surfaces and subsequently analysed using the highly common Griess assay.

Nole Eduardo L[1]; Lucena-Frédou F; Mincarone MM; Aparecido K; Bertrand A
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Talk: Abstract #232 / Session T14 - A decade of deep ocean science for sustainable development

The crucial role of international cooperation in deep-sea science: a case study of a 7-year French-Brazilian partnership

Mesopelagic organisms are increasingly threatened, and there is a significant lack of knowledge on all aspects of their ecology, especially in tropical areas where most countries lack funding for deep-sea research. International partnerships therefore can be a powerful tool to foster such critical research. Here we compile the results of a 7-year French-Brazilian partnership to study the mesopelagic region in Brazil and discuss its importance on a regional and global scale. Three oceanographic campaigns aboard French oceanographic vessels have been carried out so far. More than 50 researchers from different scientific areas are involved in mesopelagics, of which 70% are Brazilian and 30% French. Of these, 60% are students, representing a significant investment in human resources for the next generation of deep-sea scientists. At least 10.000 specimens and 300 species of mesopelagic organisms were recorded, including at least ten new species (4%) and 80 (27%) new records for Brazilian waters. This international cooperation (see www.tapioca.fr) allowed us to tackle essential questions, such as (i)which are the main species, (ii)what are the features of their diel vertical migration, (iii) what are their trophic relationships, (iv) how are they related to oceanographic conditions, (v) what are their functional roles, and (vi) what are their main threats? Despite these efforts, the deep waters of Brazil and other developing economies remain mostly unknown. The results of the cooperation presented here show that strengthing international collaboration is an essential path to smooth asymmetries among countries and provide the deep-sea knowledge necessary to achieve global sustainability.

Nole Eduardo L[1]; Lucena-Frédou F; Frédou T; Lanco-Bertrand S; Tavares G; Mincarone MM; Lira AS; Soares A; Loc'h FL; Pelage L; Schwamborn R; Travassos P; Martins K; Lira S; Figueiredo G; Vaske T; Aparecido K; Bertrand A
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Talk: Abstract #233 / Session T14 - A decade of deep ocean science for sustainable development

From the light blue sky to the dark deep sea: the food web structure of a tropical island revealed by stable isotope analyses

For a better understanding of marine ecosystems, a comprehensive trophic characterization of pelagic ecosystems is still needed, mainly including classically lesser-known regions such as the deep-ocean and tropical environments. Here we take advantage of a comprehensive set of data from the Southwestern Tropical Atlantic Ocean (vicinity of the Fernando de Noronha Archipelago) and propose an integrative study on the food web dynamics of a tropical oceanic system. We explore the main trophic links of epipelagic and mesopelagic species through stable isotope composition (carbon and nitrogen) on seabirds, zooplankton, cephalopods, crustaceans, and fishes. Cluster analysis based on the log-transformed dataset of 55 species exhibited five significant groups (I-POM; II- Zooplankton; III-Mesopelagic organisms; IV-Epipelagic organisms; and V- others), showing a tendency of increasing nitrogen with depth and differences between epipelagic and mesopelagic organisms. It provides evidence that changes in the isotopic composition of higher-order consumers reflect not only changes in trophic status but also variation at the base of the food web. This pattern is likely related to microbial degradation, indicating that several species obtain energy from the highly altered organic matter source within the ocean's

deep layers. Regarding interspecific competition, a relatively high niche overlap was observed for the epipelagic groups (>40%). However, for mesopelagic groups, a relatively low niche overlap was observed (<30%). Additionally, it was noted that vertical migrators are feeding in many depth layers, which may alleviate competition. Through these finds we expand our knowledge of the interaction, connection, and energy flow between pelagic ecosystems.

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Talk: Abstract #157 / Session T27 - Physical Oceanography Open Session - Physics-Biology Interactions

Upwelling statistics around seven Atolls in the Pacific Ocean

Upwelling of cold, nutrient rich water to the upper layers of the ocean increase primary productivity and provide a thermal refugia for organisms, such as corals, which live in the area. This mechanism has the potential to mitigate effects of global warming, however, our current knowledge is not comprehensive. Upwelling or cold pulses detected around Pacific Ocean islands and atolls, such as Palmyra Atoll, are assumed to be caused by the internal tide. The temperature stratification index method is applied to in-situ temperature data, from 2004-present, to compute cold pulse statistics around Pacific Ocean islands and atolls. Multiple logger locations around Palmyra Atoll allow investigation into statistics around the Atoll, along with inter-island statistics. Palmyra Atoll receives a maximum of 1511 Degree Cooling Hours (DCH) in a month between 2009 and 2017, considerably more than both Wake and Johnson which both receive less than 1.5 DCH/month, 1,451km and 3,697km away from Palmyra respectively. Howland and Baker are 70km apart and show a difference in maximum DCH/month >650. Jarvis showed the maximum DCH/month recorded at any island investigated to be 3707. Temperature drop during the cold pulse also varies with location. Jarvis and Johnson show a maximum of 4°C and 0.5°C decrease in temperature respectively. Palmyra Atoll, with a maximum temperature drop of 2.2°C, differs from its closest neighbour Kingman by 0.7°C. We conclude that a single location cannot be used to represent another, and the underlying drivers of the cold pulses at each location needs to be determined independently.

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Talk: Abstract #108 / Session T25 - Physical Oceanography Open Session - Ocean Eddies

Stirring Across the Antarctic Circumpolar Current's Southern Boundary at the Greenwich Meridian

The Southern Boundary of the Antarctic Circumpolar Current (ACC) describes the closest connection of warm ACC waters to colder waters within the marginal seas of Antarctica. It is established that eddies cross the fronts of the ACC and are advected downstream, but how does an eddy interact with the Southern Boundary of the ACC? How does it impact the frontal structure, the intensity of the frontal jet and mixing across the Southern Boundary? These are questions that we aim to address. As part of the ROAM-MIZ project, ocean glider observations at the Greenwich Meridian between 54-57°S from October 2019 to February 2020 provide a unique data set of 5 highly resolved hydrographic transects that cross the Southern Boundary repeatedly. Water mass properties, maps from satellite altimetry (AVISO) data and dive average currents are used to identify the location, properties and rotational direction of eddies crossing the Greenwich Meridian. We demonstrate that a cyclonic eddy crossing the Greenwich Meridian south of the Southern Boundary impacts the boundary's frontal structure and frontal jet intensity. Mixing length scales (MLS, the length at which a water parcel can move before mixing laterally) present near zero values across the frontal jet while the eddy is crossing and values near 25 km after the eddy has crossed the Greenwich Meridian. The MLS indicate increased water parcel exchange between ACC waters and waters further south after the eddy has crossed the Greenwich Meridian, which further implies that 'barrier' properties of the Southern Boundary are reduced.

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Talk: Abstract #35 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

Lead concentrations and isotope compositions of surface waters from the western South Atlantic Ocean

Anthropogenic emissions mainly enter the ocean from the atmosphere and have severely perturbed the natural lead (Pb) signal in the ocean. Their origin and impact can be revealed by analysing the Pb isotope composition of seawater. Here, we present new data on Pb concentrations and isotope compositions of surface seawater samples collected from a GEOTRACES section (GA02) in the western South Atlantic in 2011. Considering our results in the context of backward particle trajectories in the atmosphere and known Pb isotope compositions of natural and anthropogenic sources, it reveals that the major source of Pb to the equatorial zone (0 – 20°S) is "inherited" Pb transported via surface currents. In the subtropical zone (20 – 40°S) Pb from urban and industrial emissions sources in coastal South American cities is predominant and the subantarctic zone (40 – 60°S) displays more diverse Pb isotope compositions, suggesting that both urban areas and natural dust from Patagonia are potential sources. Our results furthermore show that the mean Pb concentration (16.8 ± 4.0 pM) of southwest Atlantic surface waters was 30% lower than observed in the 1990s (24.0 ± 15.0 pM). The mean Pb isotope composition of samples collected in the equatorial and subtropical zone has a signal closer to that of natural mineral dust from Patagonia and northern Africa than in 1996, but it still remains dominated by anthropogenic sources. Overall, the decrease in Pb concentration and shift in isotope composition likely reflects the global effort to reduce anthropogenic Pb emissions.

Oliver S[1]
[1]National Oceanography Centre.
Talk: Abstract #59 / Session T10 - Micro to macro: linking bottom-up and top-down approaches that investigate the function, resilience and conservation of polar ecosystems

When and where can't you balance the mesopelagic budget in the Southern Ocean?

When measuring carbon fluxes, observationalists often try to balance the attenuation of organic matter in the mesopelagic with the mesopelagic community metabolism. This should be feasible for a system in steady state, however, on the short timescales considered by a station occupied over only a few days to weeks, steady state may not be observed. Here we use the global ocean biogeochemical model MEDUSA-2.0 (Yool et al., 2013) coupled with the ECCO general circulation model (Stammer et al., 2004) via the transport matrix method (Khatiwala, 2007) to show how the monthly mesopelagic budget is non-balanced in the subtropics and polar regions throughout most of the year. We attribute this to the method of calculating flux attenuation, whereby it is considered the difference between the flux into the top of the mesopelagic and out of the base. The time lag between these two depths leads to overestimates/underestimates of flux attenuation during time periods of increasing/decreasing surface primary production. Additionally, we found internal mesopelagic detritus creation poses a significant problem to balancing the mesopelagic budget in areas of deep winter mixing, such as the northern North Atlantic and the Southern Ocean. We provide global maps of seasonal mesopelagic budgets to help observationalists explain why they may have been unable to close their observed budgets in the Southern Ocean.

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Ouala S[1]**; Chapron B; Collard F; Gaultier L; Fablet R**
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Talk: Abstract #353 / Session T19 - Mathematics of Satellite Oceanography

Analysis of ocean heat wave dynamics and predictability

When considering the modeling of dynamical systems, the increasing interest in machine learning, artificial intelligence and more generally, data-driven representations, as well as the increasing availability of data, motivated the exploration and definition of new identification techniques. These new data-driven representations aim at solving modern questions regarding the modeling, the prediction and ultimately, the understanding of complex systems such as the ocean, the atmosphere and the climate. In this work, we explore the ability of using recent machine learning techniques [1] to capture complex ocean heat wave dynamics. These events are

characterized by an extreme increase of the temperature anomaly [2] making their characterization and prediction relevant and challenging. Our analysis suggest that these extremes emerge due to the non-linear interaction of slow and fast variables.

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Ouled-Cheikh J[1]; Coll M; Cardona L; Steenbeek J; Ramírez F
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Talk: Abstract #175 / Session T20 - Evidence to support international oceans policy

Stronger together: fisheries enhance pressure on Mediterranean regions and pelagic species already impacted by climate change

Marine species are widely threatened by anthropogenic activities, including fishing and human-induced climate change. Here, we analysed a 26-year (1993-2018) time series of highly-resolved remotely sensed environmental data to evaluate changes in optimal habitat availability (i.e., extent of marine areas encompassing optimal environmental conditions) for 15 species representative of small, medium and large pelagic fish inhabiting the Mediterranean Sea Large Marine Ecosystem. We then combined spatial and temporal data on fishing pressure and changes in optimal habitats to identify areas of high risk of cumulative impacts. Overall, results showed how most of the studied Mediterranean pelagic species went through a reduction of optimal habitat availability over the past decades. The few species that showed positive trends in optimal habitat availability did not expand largely and hence were unlikely to compensate for the loss of key functional roles at the group level. Habitat loss concentrated in the western and central basins. Similarly, fishing pressure was found to be the higher in both basins, thus overlapping with the areas experiencing a higher reduction of optimal habitat. Small and large pelagic fish were the most impacted groups, having a larger proportion of their distribution in highly, cumulative impacted areas. Redistributing fishing pressure and reducing it in highly impacted areas may alleviate the overall cumulative pressure on pelagic stocks, contributing to the necessary shift to sustainable and resilient fisheries that allow ensuring food security and achieving a healthy ecosystem in this highly impacted basin.

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Poster: Abstract #307 / Session T7 - Pushing the limits in autonomous oceanography in a net zero carbon world

High-resolution pH measurements using a USV deployed from an autonomous docking station (Robodock).

The uptake of anthropogenic carbon dioxide (CO2) changes the ocean's chemistry and properties such as the pH. To monitor this impact, sustained, accurate and high-resolution pH measurements are required to detect pH trends and variability, especially in complex systems, such as the North Sea. Uncrewed surface vehicles (USVs) equipped with biogeochemical sensors allow high spatio-temporal resolution monitoring. However, operating range and duration of USVs are limited by power and communication requirements. To meet this challenge, our industrial project partners (Fugro) are developing the Robodock platform. This autonomous floating platform will provide a safe docking station for USV, allowing automated refuelling and communication with an onshore control station. Here, we describe the deployment of an automated pH measuring system on the USV and Robodock platform. The USV is fitted with an optode pH sensor that measures at high temporal resolution, but may drift through deployments, requiring regular calibration. Thus, the use of pH modelled from satellite and model reanalysis for the optode calibration is considered. We also plan to deploy a more accurate and stable spectrophotometric pH sensor on the Robodock platform, which allows direct calibration of the optode each time the USV returns to the platform. However, this spectrophotometric system measures at lower resolution. Combining the optode and the spectrophotometric systems enables high frequency, high accuracy time series along the USV tracks. Here, we will show preliminary results from the first field campaign in which sensor and calibration were tested during the summer of 2022 in the Dutch North Sea.

Palmer M[1]; Palmer MR; Shagude YW; Roberts MJ; Popova E; Wihsgott JU; Aswani S; Coupland J; Howe JA; Bett BJ; Osuka KE; Abernethy C; Alexiou S; Painter SC; Kamau JN; Nyandwi N; Sekadende B
[1]National Oceanography Centre, UK.
Talk: Abstract #214 / Session T20 - Evidence to support international oceans policy

Building capacity for using marine autonomy in the Western Indian Ocean (WIO) region

Autonomous and robotic technologies are often proposed to hold the key to global enhancement of ocean research capacity by bypassing the requirement for expensive infrastructure, such as large research vessels. We test this hypothesis using a range of analyses from a marine robots case study undertaken in coastal waters in the Western Indian Ocean in 2019. The campaign formed part of a multinational project focused on increasing WIO capacity to meet food security and ocean sustainability challenges in line with UN SDGs 2, 13 & 14. A coastal community engagement programme resulted in positive changes in attitudes towards these new technologies but benefits were perceived to come at a high cost that is difficult to achieve using current levels of national or regional funding. WIO marine institutes received a significant uplift in perceived capacity during the study, particularly related to access to infrastructure and expertise as well as support and opportunities for funding at each level. This study demonstrates that taking early steps towards adopting new technologies has increased WIO regional marine research capacity and increased the confidence and willingness of local researchers to seek alternative solutions to ongoing marine research challenges. Recommendations are provided for future action that will continue to increase the capacity and readiness for regional adoption of autonomous technology. Further information is available here: https://www.sciencedirect.com/science/article/pii/S096456912100288X

Panneels I[1]
[1]Edinburgh Napier University.
Talk: Abstract #158 / Session T16 - How Art-Science Collaborations can Inspire Societal Change

Ocean ARTic: cultural ecosystem services connect society to marine ecosystem services

The Ecosystem Services (ES) framework posits that four types of ES (provisioning, regulating, supporting and cultural ecosystem services) are critical to the benefit of society. The provisioning, regulating and supporting ecosystem services are routinely degraded and can often be measured quantitatively. In contrast, cultural ecosystem services (CES) are mostly analysed qualitatively. Yet, human cultures, and thus CES, are as much at stake when ecosystems breakdown. CES are considered a useful tool to bridge gaps between disciplines, giving broader human relevance to fostering alternative logics that connect societal and ecological issues. This cultural lens on a hitherto primarily scientific problem has becoming increasingly relevant in the climate emergency. Through case studies of two art projects that engage with climate data, we demonstrate that attention to CES offer ways to bridge gaps between scientific climate data and an embodied understanding of climate change. Light Water, Black Water, Michael Begg's musical composition, is derived directly from UK Earth Modelling project, a climate science project that contributes directly to the IPCC reports. With Holding the Ocean Eve Mosher uses chatbot technology to enable a dialogue about the lived experience of climate scientists and coastal communities taking climate action. We argue that creative engagement through art-science collaborations can leverage synergies from enmeshed ecosystem services fostering societal attitudes in support of climate action. Keywords: climate change, marine science, data, art-science collaboration

Parker R[1]; Aldridge J; Bullimore R; Mynott F; Proctor W; Lamb P; Mason C; Bradley K; Chaniotis P; Cook D; Cook H
[1]CEFAS.
Talk: Abstract #75 / Session T15 - Carbon cycling in the global ocean and the role of blue carbon in climate mitigation

Shelf seabed blue carbon: What is the potential of the English seabed sediment for climate mitigation under future marine management?

The seabed is an integrated system which provides many ecosystem services. Awareness of the ecosystem service of carbon sequestration and storage provided by the seabed marine system and its potential in the mitigation of climate change is growing rapidly. While the focus of Blue Carbon has been on vegetated coastal systems, recent publications at European and global levels have illustrated the significance of the stocks in the offshore seabed system. However, many seabed C stocks are under pressure from human activities and climate forcing itself which can lead disturbance of C pools and potential degradation. Their protection or restoration, including using management of activities in and around MPAs (Marine Protected Areas), may act as significant nature-based solutions (NBS) for climate change mitigation, including emission avoidance or savings. This presentation draws together the evidence components required to provide understanding on the significance of carbon stocks in English waters and how they may be managed in future, to protect or maximize the potential climate regulation or mitigation potential they perform. Key components are:

- Carbon provision: stock, sequestration and characteristics
- Carbon change and fate under pressure / recovery (including biodiversity)
- Understanding of carbon dynamics, recoverability including timescales
- A framework to assess carbon manageability, including predictive tools to investigate scenarios at appropriate scales

This presentation will illustrate these key components using English seabed as an example and identifying where key evidence gaps exist which will need addressing to allow carbon management strategies and trade-off decisions to be made in future with increased confidence levels.

Patmore R[1]; Ferreira D; Marshall D
[1]University of Reading.
Talk: Abstract #76 / Session T7 - Pushing the limits in autonomous oceanography in a net zero carbon world

Investigating glider sampling strategies by emulation

The transect sampling of autonomous underwater vehicles produce unrivalled two-dimensional depth-transect datasets. The flexibility of these instruments leaves a large scope for the choice of sampling patterns. In many ways, this is beneficial but the evidence base for sampling choices is relatively weak. Observational programmes have converged on a very particular bow-tie pattern of sampling. This study quantifies the performance of this bow-tie pattern in representing fundamental ocean variables. Using high-resolution ocean simulations (1/48°), we emulate gliders within the model and quantify their representation of the patches that they sample. The advantage of this method is that the model provides a `truth' on which to make a comparison. Within this framework, we test a range of metrics from bow-tie orientation to dive-climb sequencing.

Peach J[1]; Callaghan A; Bergamasco F; Benetazzo A; Barberiol F; Pistellato M
[1]Imperial College London.
Talk: Abstract #254 / Session T17 - Physical and chemical drivers of air-sea exchange processes: waves, bubbles, aerosols and surface chemistry

Statistical distributions of whitecap variables using a novel remote sensing technique to detect and track individual whitecaps in digital sea surface images

Sea surface wave breaking is the dominant process that results in dissipation of ocean surface wave energy. During the breaking process, wave energy is converted into turbulent kinetic energy, asnd if significantly energetic, entrains air which facilitates air-sea gas transfer and scatters light to create the signature whitecap. Exploiting the broadband scattering of light by the surface whitecaps, this study uses a fixed stereo video system to detect and track individual air-entraining surface breaking waves at wind speeds of up to 16 m/s. The sea surface foam (whitecap) from a breaking event is detected in grayscale images using a brightness thresholding technique based on the image pixel intensity histogram. The movement of individual whitecaps is estimated with optical flow and is used to track whitecaps between consecutive frames. Once breaking events have been tracked through their lifetime, fundamental properties of the whitecap such as the time-evolving foam area [m2], breaking speed [m/s], average crest length [m] and foam area growth and decay timescales [s] are extracted and subsequently aggregated into whitecap statistics. The geometric, kinematic and dynamic quantities obtained for individual whitecaps via this tracking method are used in conjunction with the volume-time-integral method developed in Callaghan et al 2016 to estimate the energy dissipated by each individual whitecap and to then develop an empirical frequency-dependent whitecap energy dissipation source term.

Pereira R[1]; Norouzi S; Bischoff J; Walker K; Cowling B
[1]Lyell Centre, Heriot-Watt University.
Talk: Abstract #275 / Session T17 - Physical and chemical drivers of air-sea exchange processes: waves, bubbles, aerosols and surface chemistry

Breathing Oceans: understanding the role of surface-active organic matter composition in the ocean skin layer to modulate gas exchange between the atmosphere and ocean (BOOGIE)

Oceans are a global reservoir of greenhouse gases estimated to account for 20–40% of the post-industrial sink for anthropogenic carbon dioxide (CO2). However, quantifying the exchange of key greenhouse gases across the air-water interface of the ocean is a major challenge. The oceanic uptake of greenhouse gases is determined by relative differences in gas concentrations of water and air and its transfer velocity (kw), which is controlled by variability of near surface turbulence in the sea surface microlayer (SML). The SML is a physically and biogeochemically distinct ocean-atmosphere interface covering the entire ocean surface, containing enrichments in surface-active organic matter (surfactants). Gas exchange suppression by surfactants in the SML, has been shown to reduce the estimated amount of CO2 annually stored by ~9% in the Atlantic Ocean. Surfactants are derived from multiple sources along the land-ocean continuum including in-situ primary production, allochthonous inputs of terrestrial material of either natural or anthropogenic origin, and the photochemical and/or microbial reworking of higher molecular weight material. However, the role of surfactants in the SML is obscured by our current (in)ability to characterise OM. Here we outline a new 5-year European Research Council funded project (BOOGIE) that builds on our previous work that will further resolve how the dynamic OM composition in the SML impacts gas exchange over space and through time to improve estimates of oceanic sinks and sources of key greenhouse gases.

Phillips A[1]; Templeton R; Bagley P; the MARS Group
[1]National Oceanography Centre.
Talk: Abstract #89 / Session T6 - Towards a Net Zero Oceanographic Capability

Autosub Long Range: towards a shore launch shore recover AUV capability

Long range Marine Autonomous Systems (MAS) such as underwater gliders and Long Range Autonomous Underwater Vehicles (LRAUVs) have the potential to be a critical element of the future net zero oceanographic capability. The Autosub Long Range (ALR) class of ultra-endurance Autonomous Underwater Vehicles (AUVs) has been developed to provide a multi-week to multi-month observational capability suitable for operations both on the shelf and in deep water. In the first six months of 2022 individual ALR vehicles have undertaken campaigns in: Antarctica conducting missions under the Dotson ice shelf supporting the TARSAN project, been equipped with a suite of eleven novel biogeochemical sensors for the Oceanids Sensors trial in the Southwest Approaches and been deployed from Plymouth for a long-distance trial intending to demonstrate the long endurance capability of the platforms to traverse from shore to offshore locations in this case the Canyons MPA in the far south-west corner of the UK's continental shelf. These provide clear examples of how LRAUVs can be used to either augment ship-based operations or provide alternatives to more conventional ship-based observations. The transition from near ship to over the horizon operations requires an alternative approach to AUV operations in particular: the longer nature of the missions generates increased uncertainty over the length of the deployment which needs to be captured in mission planning, the remote nature of the pilots necessitates further thought on near real time data transfer. The current programme of ALR deployments are informing our understanding of how we may address these issues.

Phillips A[1]; Furlong M
[1]National Oceanography Centre.
Poster: Abstract #91 / Session T7 - Pushing the limits in autonomous oceanography in a net zero carbon world

Marine Autonomous and Robotic Systems (MARS): Current and Future Capabilities

Oceanographers have driven the widespread use and acceptance of robotic and autonomous systems in the marine environment. These platforms have transformed our monitoring capability through autonomous, adaptive and persistent observations from the sea surface to the deepest depths and furthest reaches of the oceans. To ensure the scientific community have broad access to Marine Autonomous Systems platforms, sensors and networks, the Natural Environment Research Council (NERC) supports the Marine Autonomous and Robotic Systems (MARS) fleet at the National Oceanography Centre. The MARS fleet is one of the largest and most advanced in the world, comprising of over 40 vehicles including: underwater gliders, uncrewed surface vehicles, remotely operated vehicles and the autonomous underwater vehicles. Supporting the fleet are a team of 50 engineers who: deliver operational support at sea and develop new capabilities. Recent developments have focussed on updating the Autosub AUVs and developing the piloting and data infrastructure required to manage vehicles operating over the horizon. MARS' aspirations for future development are described in the National Marine Facilities (NMF) Technology Roadmap.

Phillips A[1]; Kingsland M; Roper D; The MARS Group
[1]National Oceanography Centre.
Talk: Abstract #88 / Session T7 - Pushing the limits in autonomous oceanography in a net zero carbon world

Autosub5 the UK's new Workclass AUV for Deep Water and Under Ice: Introducing the Platform, Early Science Deployments and Development Roadmap

Autosub5 is the latest high-power work class AUV to enter the National Marine Equipment Pool (NMEP) the largest centralised marine scientific equipment pool in Europe providing scientific instruments and equipment capable of sampling from the sea surface to the deep ocean. Developed under the Oceanids Programme Autosub5 is replacing the under-ice capability of Autosub3 and the deep-water survey capability of Autosub6000. Autosub5 is 5.8m long, displaces 2.8 tonnes and is designed for operation at water depths down to 6000m. The design of the vehicle is modular allowing her to be equipped with a range of science payloads depending on the science requirements. As standard she is equipped with a downwards 400-700kHz multibeam echosounder, a 600kHz ADCP, a dual CTD, a dual frequency side scan sonar, a sub bottom profiler and two still cameras. The AUV has completed a series of three commissioning trials in Loch Ness to characterise the performance of the navigation system, vehicle control and payload configuration. At sea commissioning is being undertaken as part of the NMEP trials expedition DY152 in July 2022, which will see Autosub5 conduct benthic surveys in and around Greater Haig Fras and Whittard Canyon. Ongoing developments include: integration of optional payloads for midwater and benthic survey, porting of under ice autonomy developed for Autosub Long Range to enable Autosub5 to conduct sonar surveys under ice and release of a backseat interface to enable scientists to co-develop onboard adaptive sampling strategies.

Pickup D[1]; Bakker DCE; Heywood KJ; Lee GA; Loucaides S; Hammermeister E
[1]University of East Anglia.
Poster: Abstract #163 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

Drivers of surface pH gradients in the Amundsen Sea Polynya, Antarctica

The Amundsen Sea Polynya is one of the most productive coastal systems in the Southern Ocean. Seasonal ice-free conditions allow for enhanced primary production during spring and summer, affecting surface ocean carbonate chemistry parameters. A variable of particular interest is pH, due to its role in ocean acidification, which is also influenced by factors such as temperature, primary production and sea-ice coverage on seasonal scales. Two datasets of pH were collected in front of Dotson Ice Shelf and within the Amundsen Sea Polynya, between January and February 2022. Both datasets used novel pH sensors: a Lab-on-Chip sensor integrated into a Seaglider and a self-calibrating ANB sensor on the underway seawater supply of the RV Nathaniel B Palmer. The Seaglider was also equipped with temperature, conductivity, chlorophyll fluorescence and optical backscatter sensors. The Seaglider completed 204 dives containing pH data, whilst the ANB sensor ran continuously. Preliminary pH values are presented for the surface ocean, offering a comparison between the two sensor measurements. Drivers of spatial gradients are assessed using corresponding underway measurements of temperature, salinity and chlorophyll fluorescence, as well as the additional sensors on the Seaglider. Gradients in pH are observed between Dotson Ice Shelf and the Amundsen Sea Polynya due to changes in surface CO2 uptake through primary production. Gradients are also observed in areas of sea-ice coverage. We show that the

use of high-resolution pH data is valuable for understanding seasonal changes to carbonate chemistry in remote, productive regions.

Piechaud N[1]; Howell KL
[1]University of Plymouth (U.K.).
Talk: Abstract #299 / Session T14 - A decade of deep ocean science for sustainable development

Can Artificial Intelligence help deep-sea ecologists support sustainable development?

Ecologists and policymakers need considerably more data than they presently have to understand and preserve deep-sea benthic ecosystems. Digital imaging has become a popular way to sample and study benthic megafauna. However, manual annotation of these images, to extract biological information, is a slow and tedious task. Ecologists are thus collecting images at orders of magnitude higher than they can currently process. Artificial Intelligence (AI) applied to image analysis - or Computer Vision (CV) - could help bypass this bottleneck. To investigate how well CV algorithms can perform in practical applications, we trained YOLO (V4 & V5) Convolutional Neural Networks (CNNs) to detect benthic species (including sea-pens, bamboo corals and xenophyophores) in images and videos of the seabed. The results were encouraging as hundreds of thousands of images could be analysed in a matter of hours, with accuracy metrics (recall, precision and F1 scores) as high as 0.9 in some instances and correlations above 95%, between manual and automated counting of VME indicator species. Consequently, high resolution distribution maps could be drawn within a much shorter time scale, than with conventional manual analysis methods. Therefore, by making large datasets easier to acquire and by making better use of available data, future applications of CV could make marine research more efficient and, ultimately, help progress towards sustainable development. AI has a great potential, but its use is not without caveats. A community effort is needed to better understand its behaviour and use it appropriately along other existing methods.

Pimm C[1]; Williams R; Meijers A; Jones D
[1]University of Liverpool.
Talk: Abstract #27 / Session T26 - Physical Oceanography Open Session - Water Masses

Quantifying the relative importance of external forcing in determining Subantarctic mode water properties across the south Pacific.

Subantarctic mode water (SAMW) is a subsurface water mass which is formed through surface heat loss. This leads to thick winter mixed layers which are then subducted resulting in low stratification water-masses. In the South Pacific mode water formation region, central and eastern pools of mode water have been found to have wintertime thicknesses that vary strongly interannually and out of phase across the basin. This thickness variability is associated with changes in atmospheric forcing, as evident in peaks in variability in sea level pressure between the central and eastern pools. However, the mechanisms by which the external forcing drives this thickness variability has not been quantified explicitly. To investigate how external forcing affects the properties of SAMW in the central and eastern mode water pools, two separate adjoint sensitivity experiments are conducted. The traditional adjoint approach uses a vertical mask that is fixed at all times, however here a density following mask is developed. This more closely reflects how water masses preferentially spread along density surfaces. The objective function is the yearly averaged potential temperature over the pool and the density surfaces. The analysis compares the effect of local versus remote forcing, identifying the separate effects of wind stress, heat flux, and freshwater flux, using the impact of sensitivities. The analysis reveals the dominant control of the thickness variability from local and far field surface heat fluxes, as well as a smaller effect of freshwater surface fluxes and wind stress.

Pitchford J[1]; Law R; Plank M; Pyramids of Life project (https://pyramidsoflife.york.ac.uk/home)
[1]Departments of Mathematics and Biology, University of York.
Talk: Abstract #257 / Session T20 - Evidence to support international oceans policy

Pyramids of life – fishing for biodiversity and conservation

Commercial fisheries are essential to global food security and central to the health of our coastal communities. However, current fishing practice may unintentionally deplete target stocks or result in bycatch of threatened species. It also imposes rules which remove opportunities for more productive and more sustainable yields. We propose that, by aligning fishery activity with established size-based scaling laws, fishing which respects "Pyramids of Life" can both deliver enhanced yields and promote marine biodiversity. New fisheries paradigms are meaningless unless they are practical, legal, and generate a valuable product. We can learn from other "pyramids" describing consumer and retailer decisions, governance, nutrition and economic value in order to translate theory into new ways of sustainable management.

Portlock G[1]; Gazeau F; Bonnet S; Guieu C; Whitby H; Salaun P
[1]University of Liverpool.
Talk: Abstract #98 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

Distribution of thiol and humic substances during the 2019 TONGA cruise

Trace element bioavailability shapes phytoplankton communities, with primary productivity being limited by iron (Fe) in large areas of the ocean. Understanding the processes that affect this bioavailability requires a prior understanding of the biogeochemical cycling of the ligands, those molecules that have a high affinity for the metal. Two important groups of ligands involved in metal complexation are thiols and humic substances (HS), the former being involved in the speciation of both Fe and copper (Cu), while thiols have been shown to complex Cu. Here, we present the concentration of dissolved eHS and thiols measured in samples from the 2019 GEOTRACES GPpr14 cruise in the Western Tropical South Pacific Ocean (https://doi.org/10.17600/18000884). Samples were collected along a transect crossing the TONGA arc and from on-board minicosms experiments where water collected from 2 shallow hydrothermal vents (PANAMAX and SIMONE) was mixed at different ratios with surface waters. Our aim was to assess if hydrothermal vents are a direct or indirect source of thiols and eHS. We found no direct input of eHS from either hydrothermal sites. A Thiol-like compound was found to be released from PANAMAX. For the minicoms, the data suggests that the input of hydrothermal vents in surface waters promotes the increase of both eHS and thiols, possibly through increased biological production and bacterial activity (remineralisation).

Poulton A[1]; Stinchcombe MC; McClay SL; Ainsworth J; Carvalho F; Painter SC; Moore CM
[1]Heriot-Watt University.
Talk: Abstract #304 / Session T10 - Micro to macro: linking bottom-up and top-down approaches that investigate the function, resilience and conservation of polar ecosystems

Upper ocean carbon, nitrogen and silica cycling in the South Georgia bloom

The South Georgia phytoplankton bloom is one of the largest sustained productivity features in the High-Nutrient-Low-Chlorophyll Southern Ocean. On an annual scale it provides essential organic material for local marine ecosystems, as well as being a key source of material exported to the deep-sea. During November to December 2017, we conducted a multidisciplinary examination of the bloom in terms of composition, productivity and elemental cycling – with a focus on the (de-)coupling of the production and loss of carbon, nitrogen and silica from the upper-ocean (<100 m). During our month-long sampling period there was a shift in bloom dynamics, with a loss of particulate material and a change in the cycling of nitrogen and silica. Diatoms dominated bloom biomass and productivity, with the change in dynamics associated with the loss of the whole community rather than selective losses. Uptake rates of nitrogen and silica declined as the community was lost from the upper-ocean, with a shift from reliance on 'new' sources of nitrogen and silica to increased recycling. In the case of silica, dissolution in the upper-ocean was rapid and increasingly supported the silica-demand of the community. Rather than iron-limitation or zooplankton grazing, the loss of material and shift to a recycling system appears linked to the onset of persistent silica-limitation as the silica-pump removed this element from the upper-ocean. Mesopelagic (100-1000 m) observations imply that silica was preferentially exported over carbon, with shallow remineralisation of nitrogen supporting continued bloom productivity and deep-export of silica terminating the diatom dominated early-spring phase.

Powell C[1]; Graves C; Austin B; Brabben E; Brown N; Dal-Molin F; Garcia C; Hynes C; I'Anson K; Limpenny C; Mason C; Nelson P; Smeaton C; Wexler S; Parker R
[1]Cefas.
Poster: Abstract #84 / Session T15 - Carbon cycling in the global ocean and the role of blue carbon in climate mitigation

Opportunistic blue carbon observations in the North Sea: a toolbox case study

In February 2021 a total of 14 sediment cores were taken opportunistically from sites across the North Sea, with the dual aims of testing a toolbox approach to carbon source and lability observations, and to improve the carbon stock, sequestration and condition evidence base across the English shelf seabed. Understanding the capacity of marine sediments to store and sequester atmospheric carbon is an essential first step in assessing the possibilities for the management of these stores and exploring their potential as nature-based solutions to climate change. However, the evidence base for sequestration is poor, with very few observations of the source and lability of regional carbon stocks and little understanding of how these characteristics interact to control sequestration. We present here the results from our toolbox approach, measuring the carbon stock and sequestration for the 14 cores using a suite of complimentary analyses: from novel techniques such as alkane biomarkers and thermogravimetric analysis (TGA), to radiometric determination of sedimentation rates by lead-210 and stable carbon isotopes (δ13C) in bulk organic carbon, to the more routine techniques such as particle size distribution (PSA), organic & inorganic carbon and nitrogen, porosity, chlorophyll/phaeopigment, and black carbon. We demonstrate that together the results increase the understanding of how carbon is processed in the seabed at a regional scale, and how this can help us assess the climate mitigation role of shelf sediments.

Publicover L[1]
[1]University of Bristol.
Talk: Abstract #20 / Session T16 - How Art-Science Collaborations can Inspire Societal Change

Arts, Sciences, and the Seafloor: Teaching and Research Challenges and Possibilities

In 2015, Kate Hendry, a geochemist, and Laurence Publicover, a literature scholar, were two of several participants in 'The Invisibility of the Sea', a project in which scholars from across the arts, sciences and social sciences discussed their perspectives on and fears for the global ocean and which resulted in a series of works by the artist Rodney Harris. Building on this collaboration, Hendry and Publicover subsequently wrote a short piece for The Conversation on the probable advent of deep-sea mining, as well as a longer piece on how both artists and scientists struggle to grapple with the seafloor. In addition, they launched a Masters by Research degree within the Cabot Institute for the Environment at Bristol University which asked students to devise a research project combining perspectives from the arts and sciences. This programme has recruited four students, whose topics are: the intermingling of science and literary fantasy in Hollow Earth Theory; the cultural invisibility and consequences of metal pollution in the ocean; social attitudes towards and effects of trawling; and the history of Nautilus Minerals' attempts to mine within the territorial waters of Papua New Guinea. In this paper, Hendry and Publicover will use their experiences to illustrate and discuss the challenges and rewards of interdisciplinary approaches to the oceans, and more specifically the deep ocean and seafloor. Publicover will also outline the aims of his forthcoming book The Seabed: A Human History, whose second chapter, 'Messengers', explores histories of dredging and fathoming – including, of course, the Challenger voyage of 1872-6.

Puglia M[1]; Bibby T; Ward B
[1]University of Southampton.
Talk: Abstract #135 / Session T5 - The role of mixoplankton and mixotrophy in the global carbon cycle

Modelling the 21st century response of a mixotrophic marine ecosystem

The mixotrophic use of light, inorganic nutrients and prey is increasingly recognized as an important process in ocean plankton food webs. Mixotrophy has been shown to increase simulated trophic transfer efficiency and export production at the global scale and has the potential to impact the marine ecosystem's response to environmental change over the 21st century. In this study we use a coupled ecosystem and Earth system model to explore the impacts of mixotrophy on the ocean's capacity to sequester carbon away from the atmosphere and

the sensitivity of this capacity to projected climate change throughout the 21st century. We show that mixotrophy may play a key role through its response to increased stratification and through a differential sensitivity of autotrophic and heterotrophic processes to increasing temperatures

Rabone M[1]; Simon-Lledo E; Jones D; Dahlgren TG; Horton T; Wiklund H; Glover AG
[1]NHM.
Talk: Abstract #315 / Session T2 - Deep Sea Mining 2 - environmental aspects: baselines, impacts, monitoring

Current state of metazoan biodiversity knowledge in the world's largest mineral exploration frontier

The predicted global surge in demand for metals such as cobalt and nickel has created unprecedented interest in mineral exploration in the deep sea. The largest area of activity is a 6 million km2 region known as the Clarion-Clipperton Zone (CCZ) in the central Pacific, with 17 contracts for mineral exploration covering 1.2 million km2, an area roughly twice the size of France, regulated by the International Seabed Authority. The CCZ is composed of abyssal seafloor at depths of 4000-6000m, characterised by muddy sediments overlain by polymetallic nodules rich in useful minerals. Despite the dark and low food-availability both the mud and nodules contain a diverse assemblage of benthic invertebrate animals, albeit at low densities compared to shallower benthic habitats. Critical to informed policy on the environmental management of deep-sea mining is baseline knowledge of the biodiversity of the potentially impacted regions, which until recently has been completely lacking. Here we have compiled the first comprehensive synthesis of CCZ benthic metazoan biodiversity, for all faunal size classes. We identified 642 named benthic species in the region of a total 5077 recorded species, an estimated 87% new to science. These data are incorporated into the first CCZ regional checklist. Significant undescribed diversity is present in all size classes, with species richness estimates ranging from >5000 in macrofauna to >7000 in meiofauna. Recent growth in taxonomic work and data availability is welcome, and as comparable datasets accumulate, regional syntheses become possible, critical to understanding ecological processes and species extinction risks in the region.

Radziejewska T[1]
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Talk: Abstract #93 / Session T2 - Deep Sea Mining 2 - environmental aspects: baselines, impacts, monitoring

Reiterating the importance of and the need for environmental monitoring in impact studies related to deep-sea mining

Considering the seriousness and costs of deep-sea mining (DSM), it should be successful (providing the benefits intended), sustainable (providing the benefits in a long term), and responsible (causing the least possible disruption of the deep-sea environment and its communities). The success, sustainability and responsibility of DSM require knowledge of conditions under which it is to be carried out. This necessitates appropriate environmental baseline datasets pertinent to the area(s) targeted for mining. Particularly important is the knowledge on the status and natural variability of benthic communities and ecosystem services they provide. Polymetallic nodule deposits in the NE Pacific's Clarion-Clipperton Fracture Zone (CCFZ) have been drawing a particularly critical international attention. The anticipated mining, and the uncertainties regarding the impact of mining activities on the CCFZ benthic communities, make it imperative to collect baseline data and to predict the severity of mining effects as well as the extent and rate of recovery. From the sustainability standpoint, important is the understanding of, and the ability to predict/assess, potential environmental consequences of DSM. One of the approaches to prediction involves test impact studies. Of a key value is to follow the aftermath of an impact test at an appropriate temporal resolution, since extended time intervals (a coarse temporal resolution) will likely be a source of uncertainty regarding the relative importance of natural and test-induced variability in the system tested, and hence render the assessments and predictions problematic.

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Talk: Abstract #273 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

Linking high-resolution dissolved organic matter characterisation to prokaryotic metabolism in the Benguela upwelling

Despite being a key biogeochemical variable and an important component of the marine carbon cycle, little is known about marine dissolved organic matter (DOM) composition or about its mechanisms of production and transformation. Additionally, there is a close relationship between DOM composition and the microbial community, with microbes regulating most of the production and consumption of DOM in the ocean. We compared DOM composition to its rates of consumption by prokaryotes in the mixed layer and upper mesopelagic of the Benguela upwelling system, as part of the COMICS (Controls over Ocean Mesopelagic Interior Carbon Storage) programme. We sampled using both niskins and marine snow catchers (MSCs) and employed high-resolution DOM characterisation by FT-ICR-MS taken alongside prokaryotic metabolism measurements using leucine radiotracers. We assessed the influence of sinking marine particles on the DOM composition and prokaryotic metabolism in the mesopelagic ocean; clearly observing the signal of particle derived DOM leaching into surrounding water. We identified the components of the DOM pool that correspond to our observations of changes in prokaryotic metabolism between different MSC fractions. We see clear labile DOM signals from fast-sinking particles, highlighting that fast-sinking particles are a source of labile DOM to the mesopelagic that supply substrate with similar DOM composition to the mixed layer. Linking DOM composition to biogeochemically relevant measurements of organic matter utilisation by prokaryotes in this way is an important step in improving our understanding of the role of DOM in the marine carbon cycle.

Reed B[1]; Green M; Gudmundsson H; Jenkins A
[1]Bangor University.
Talk: Abstract #178 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

Recent irreversible retreat of Pine Island Glacier

Pine Island Glacier (PIG), in West Antarctica, has undergone dramatic changes in the last few decades, where flow speeds have increased by 75% and grounding lines have retreated over 30km. These recent changes are part of a long term trend of mass loss, believed to have been initiated following climate anomalies in the 1940s and 1970s. Observational records show that intermittent cool periods likely slowed the retreat of PIG but were not enough to reverse its progress. Here we use the ice-flow model Úa to study the recent transient evolution of PIG over the last several decades, with the aim of identifying the drivers of observed changes in geometry and grounding line position. We demonstrate the first observationally constrained example of the marine ice sheet instability, as PIG rapidly retreats across a retrograde bedrock slope. The retreat becomes irreversible once an ocean cavity opens upstream of a submarine bedrock ridge beneath the ice shelf.

Reeve K[1]; Hoppema M; Kanzow T; Boebel O; Geibert W; Strass V
[1]Alfred Wegener Institute for polar and marine research, Bremerhaven, Germany.
Talk: Abstract #212 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

East versus West: the influence of Weddell Gyre circulation on long-term trends in surface nutrient concentrations

The Weddell Gyre supplies heat towards the Antarctic ice shelves and regulates the density of water masses that feed the deepest limb of the global overturning circulation. It also plays a role in connecting the deep circulation to the surface circulation through upwelling. A fleet of Argo floats drifting throughout the entire Weddell Gyre were used to determine the large-scale horizontal circulation and distribution of heat throughout the Weddell Sea region. We found an elongated double-gyre system whereby circulation is intensified in the east in comparison to the west, which impacts the distribution of properties throughout the Weddell Gyre. This complements findings that inferred upwelling rates from radionuclide concentrations are stronger in the eastern sub-gyre region than in the western sub-gyre. However, while a long-term increase in sub-surface nutrients

observed in the central western sub-gyre has been associated with increased upwelling, a weaker long-term increase in sub-surface nutrients was found in the eastern sub-gyre south of Maud Rise only. This implies there are different dynamical causes of the nutrient trends in the east versus the west, which are investigated accordingly.

Reynard N[1]; Mashayek A
[1]Imperial College London.
Talk: Abstract #286 / Session T24 - The Atlantic Meridional Overturning Circulation: Observations, Simulations and Equations

The role of ocean interior turbulent mixing in climate change induced internal variability

The meridional ocean circulation (MOC) plays a key role in modulating the climate through the transport of tracers such as heat and carbon. Diapycnal mixing is integral for the upwelling of abyssal waters, thereby sustaining the deep branch of the MOC. Here we use a low complexity climate model in which tidal power and mixing efficiency both evolve with stratification. We investigate the impact of such changes on the MOC as well as on meridional heat transport and atmospheric pCO2. We do so by running simulations from pre-industrial times to the year 2100by applying changes to the surface forcings in line with multi-model means from CMIP6 models. We report three primary findings: (I) changes to wave generation and mixing efficiency both have leading order impacts on the MOC, (II) consideration of their covariance is essential; otherwise changes to either in isolation can lead to gross inaccuracy in the MOC prediction, (III) allowing both will add two degrees of freedom to the model and give rise to a strong internal variability signal with frequencies ranging from inter-annual to decadal and centennial. Such variability is entirely absent from any ocean/climate model and may very well contribute to MOC variability as inferred from various proxy records.

Richards A[1]; Johnson H; Lique C
[1]University of Oxford.
Poster: Abstract #324 / Session T24 - The Atlantic Meridional Overturning Circulation: Observations, Simulations and Equations

Using the CESM Large Ensemble to study Atlantic Water heat in the Arctic

Atlantic Water is the most significant source of oceanic heat in the Arctic Ocean. It sits a few hundred meters beneath the surface, isolated from sea-ice by a strong halocline. Understanding how Atlantic Water heat may change in the future Arctic, in terms of its quantity and distribution in the water column, is an important part of understanding changes in both the Arctic climate and global ocean circulation. Here we use the CESM Large Ensemble to investigate forced trends and natural variability in Atlantic Water within the Arctic throughout the 21st century under an RCP8.5 emissions scenario. We also look at what this means for Arctic stratification and sea-ice to determine the role of Atlantic Water in future Arctic changes.

Rickaby R[1]; Zhang Q; Zhou Y; Barton S; Liu F; Shafiee R; Yin K; Bouman H; Tagliabue A; Rickaby REM
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Talk: Abstract #12 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

Global patterns of trace metal limitation shape the distribution of dominant phytoplankton in the ocean

Nutrient availability determines the productivity of phytoplankton in different ocean regions, with implications for deep carbon sequestration, yet the current conceptual view of nutrient limitation overlooks the contrasting requirements and growth responses of phytoplankton groups to a single set of environment variables, i.e., those of trace metals. Here we elucidate the patterns of trace metal limitation of phytoplankton species spanning across different functional groups using a combined data synthesis and diagnostic modelling approach. Representative species of diatoms, cyanobacteria, and dinoflagellates are found to be iron limited in over 60%, 38%, and 5% of the global ocean. In comparison, diatoms are manganese limited in ~20% and dinoflagellates zinc limited in over 60% of the ocean. Trace metal limitation has greater impact on the distribution of diatoms and dinoflagellates than on coccolithophores. Our analysis highlights that copper and zinc are more important in controlling

phytoplankton distribution than previously assumed, challenging the notion that marine Cu concentrations are frequently toxic to phytoplankton. Using projections of how trace metal chemistry may alter, we show that the future changes in patterns of species-specific metal limitation are a potential driver of change in the phytoplankton community structure in the ocean which will feedback on carbon sequestration.

Roberts C[1]; Bird K; Chrismas N; Baker C; Pabortsava K; Blackbird S; Venables H; Moigne FL; Martin A; Cunliffe M
[1]Marine Biological Association and University of Plymouth.
Poster: Abstract #166 / Session T10 - Micro to macro: linking bottom-up and top-down approaches that investigate the function, resilience and conservation of polar ecosystems

Environmental DNA (eDNA) and RNA (eRNA) based assessment of the Biological Carbon Pump in the Southern Ocean.

Production and remineralisation through the Biological Carbon Pump (BCP) influences the transport and storage of organic carbon in pelagic ecosystems in the Southern Ocean (SO), however knowledge of the diversity and activity of these ecosystems remains limited. Environmental DNA (eDNA) provides an opportunity to assess the diversity of the BCP in the SO, whilst environmental RNA (eRNA) offers a complementary view of the active diversity. Using samples collected on transects across a key junction of the global ocean circulation in the SO as part of the NERC Carbon Uptake and Seasonal Traits in Antarctic Remineralisation Depth (CUSTARD) project in austral summer 2019/2020, we combined eDNA- and eRNA-based assessments of pelagic eukaryote diversity. The SO pelagic ecosystems were dominated by radiolarians (a plankton group also studied by Ernst Haeckel during the Challenger Expedition), diatoms and copepods, with diversity distinct across stations and depths. Comparison of epipelagic and mesopelagic ecosystems showed increasing dissimilarity between eDNA and eRNA with depth suggesting eDNA at depth may represent sinking material whilst eRNA captures active diversity. Our eDNA/eRNA-based approach revealed fine-scale population-level dynamics in the major players of the SO BCP (e.g. radiolarians) suggesting niche separation corresponding to specific water masses and concurrent biogeochemical cycling (e.g. Particulate Organic Carbon vertical flux). Our study adds biological and ecological diversity detail to understanding the ecosystems underpinning the BCP in the SO, and contributes to an improved view of ecosystem processes in this globally significant region.

Roberts E[1]; Lenn Y; Johnson H
[1]Bangor University, School of Ocean Sciences.
Talk: Abstract #53 / Session T25 - Physical Oceanography Open Session - Ocean Eddies

Changing the layer cake: Stratification trends in the Barents-Kara Seas (BKS)

The Barents-Kara region is an Arctic warming hotspot. It has experienced increased water column and lower troposphere temperatures, pronounced sea ice loss, and ecosystem change. Ocean stratification here is a pertinent focus for study: the strength of density stratification controls vertical mixing and the fluxes of quantities, including heat and salt, which determine the properties (temperature, salinity, and density) of water throughout the water column. At the surface, these properties influence sea ice processes and heat loss to the atmosphere in a region ostensibly linked to Northern Hemisphere mid-latitude weather. More generally, they govern the characteristics and behaviour of water masses, undergoing transformation in the BKS, that participate in Arctic and North Atlantic circulation. We use the potential energy anomaly (PEA), a metric of density stratification, to investigate changes in the region from 1993 to present day. Representing the energy required to hypothetically mix stratified water to vertical homogeneity (strongly stratified water columns require more energy to mix), PEA is calculated spatio-temporally from the ARMOR-3D reanalysis product. The rate of change of PEA with time can be expressed as the sum of contributions from physical processes that increase stratification (e.g., surface heating and sea ice melting) or decrease it (e.g., wind-driven mixing and tidal stirring), each of which can be computed from reanalysis products or model outputs. We thus determine the processes dominating BKS stratification and identify those driving long-term trends in parts of the region. Implications for ocean-atmosphere coupled interactions, water masses, and broader circulation are discussed.

Roberts S[1]

[1]University of Southampton.
Talk: Abstract #343 / Session T1 - Deep Sea Mining 1 - geology, resource, legal, technical and societal aspects

What lies beneath? Using scientific ocean drilling to investigate the subsurface below actively forming sea-floor massive sulphide deposits.

A wealth of data has been collected over the past 40 years from active hydrothermal vent sites on the sea floor, many precipitating massive sulphides rich in Cu, Pb, and Zn. However, the subsurface architecture of these hydrothermal systems is relatively poorly understood and our understanding is largely underpinned by the results of a series of expeditions of the ODP/IODP including: Leg 158, Transatlantic Geotraverse (TAG); Legs 139 and 169, Middle Valley, Juan de Fuca Ridge; 193 PACMANUS, Manus Basin; and Expedition 376, Brothers Volcano, Kermadec Arc. Each of these legs has made a substantive contribution to our understanding of these hydrothermal systems. For example, ODP Leg 158 TAG, for the first time, penetrated a sulphide mound and drilled down into the underlying alteration system. Despite the relatively low core recovery rate, this Leg reported an abundance of anhydrite within the mound and though stable (δ34S) and radiogenic (87/86Sr) strontium analyses of the anhydrite, provided new insights into the subsurface circulation and mixing of seawater with hydrothermal fluid. Leg 169 demonstrated that a key element in creating massive sulphide deposits, as large as drilled in Middle Valley, is the extended focusing of intense hydrothermal discharge. PACMANUS illustrated the complexity of the subsurface hydrothermal systems within a single vent field, and the recent drilling of hydrothermal systems on the Brothers Volcano provided new stratigraphic, lithologic, and geochemical constraints on the development and evolution of a volcano and its hydrothermal systems. This contribution will further explore the key findings of these pioneering investigations.

Robinson E[1]; Hosegood P; Eager D; Embling C; Harris J
[1]University of Plymouth.
Talk: Abstract #150 / Session T27 - Physical Oceanography Open Session - Physics-Biology Interactions

Internal waves: Ecosystem impacts from localised oceanographic processes at a tropical seamount

The role of high frequency oceanographic processes as key drivers of ecosystem variability is being increasingly recognised at multiple trophic levels but particularly in providing localised bottom-up support within highly dynamical habitats. By flushing areas near to and close to slopes with cold water at tidal and shorter periods, internal waves generate large changes in environmental parameters. In the example presented here, a temperature change of >4 oC over <5 minutes, generates turbulent mixing at the thermocline and drives vertical advection of the deep chlorophyll maximum into shallower water. Here we focus on internal waves at a steep sloped seamount in the Central Indian Ocean which have been tentatively linked to the schooling of fish and aggregation of large marine predators at the site. We examine how these processes evolve as they encounter the summit, in addition to the influence of basin scale processes in controlling the thermocline depth act and acting as on-off switches by modulating the background stratification. We also discuss the potential wider impact of these processes by demonstrating their prevalence at a nearby atoll and a secondary site in the Western Indian Ocean where coral health differs between the north and south face of a remote island.

Robinson S[1]
[1]University of Southampton.
Talk: Abstract #265 / Session T1 - Deep Sea Mining 1 - geology, resource, legal, technical and societal aspects

Challenging the Manganese: HMS Challenger, John Mero, and the Extractive Ocean Imaginary.

In 1965, John L. Mero a mining engineer working in California published a monograph: The Mineral Resources of the Sea. In this work, he pointed to the immense potential of the deep-sea mineral deposits discovered during the Challenger expedition; noting that these cannonball-like spheres contained a vast wealth of manganese, nickel, cobalt, and copper amongst other metals. Whilst many scientists have subsequently argued that Mero's numbers where wildly optimistic, they nonetheless sparked an oceans arms race to be the first to exploit this 'wealth' under the sea. Ultimately creating what international legal scholar Surabhi Ranganathan (2019) terms the 'extractive imaginary' of modern ocean regime. Utilising archival sources this paper will argue that the 'potential' of deep-seabed resources has proved very useful to marine scientists. Not because of any belief that

deep-sea mining would emerge but because of the subsequent boost to scientific capabilities that have been enabled by maintaining what might well be a disingenuous future vision for the ocean. Demonstrating that ocean science is always geopolitical and entwined within capitalist exploitative realities of global industries, this paper argues that manganese nodules, whilst rather overshadowed in the Challenger reports compared to the zoological collections have done rather more for ocean science than merely provided an interesting novelty. Leaning on the potential riches has enabled vast non-military funding sources, enabling the acquisition of large-scale research platforms, and bringing about a different kind of "wealth" than Mero ever imagined.

Rochner A[1]; Ford D; Sheen K; Watson A
[1]University of Exeter.
Talk: Abstract #238 / Session T7 - Pushing the limits in autonomous oceanography in a net zero carbon world

Can assimilating Biogeochemical-Argo data improve carbon flux estimates?

Analysing the observations from a growing number of biogeochemical (BGC) Argo floats has greatly improved our understanding of BGC processes. But these observations can yield additional value when combined with model simulations. For example, Ford (2021) showed improvements in the BGC simulation when assimilating synthetic BGC profiles, i.e. profiles mimicking BGC-Argo floats in a model simulation. Here, we test the impact of assimilating actual BGC-Argo float observations into a physical-biogeochemical model using the same 3D-Variational data assimilation method as Ford (2021). The analysis focusses on the Southern Ocean, where most BGC-Argo floats have been deployed due to the dedicated effort by the SOCCOM programme. We evaluate the influence of the assimilation on the air-sea flux of carbon dioxide. Assimilating BGC profiles adds valuable information about the vertical distribution of BGC properties, especially in combination with satellite observations with global surface coverage. The model-based results of the data assimilation can be used to investigate drivers of carbon fluxes, globally and on a regular grid, and therefore help to better understand the underlying processes. The results also highlight biases in the biogeochemical model which can inform model development, e.g., for the ocean components of Earth System Models used for future projections.

Ford, D.: Assimilating synthetic Biogeochemical-Argo and ocean colour observations into a global ocean model to inform observing system design, Biogeosciences, 18, 509–534, https://doi.org/10.5194/bg-18-509-2021, 2021.

Ross J[1]; Bigg G; Zhao Y
[1]University of Sheffield.
Poster: Abstract #22 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

Assessing Current and Future Trends in the Iceberg Season off Newfoundland, Canada, using a control systems model, a machine learning approach and the NEMO ocean model

The Greenland Ice Sheet loses mass through two main processes: ice sheet melt and subsequent runoff, and iceberg calving. Icebergs have been a known threat to shipping in the North Atlantic for centuries, but came to public attention after the sinking of the Titanic in 1912. They also have a physical effect on the surface ocean, inputting cold, freshwater as they melt. An existing control systems model has been combined with a machine learning approach to forecast the iceberg season in the region off Newfoundland, Canada. The control systems model produces a yearly total number of icebergs south of the 48th parallel, while the machine learning aspect addresses iceberg behaviour. This is achieved by predicting a 'low', 'medium' or 'high' year for iceberg numbers and the rate of iceberg change during the season, as well as an assessment of the peak month in which icebergs will be found off Newfoundland, and whether there will be one or multiple peaks. The 2022 forecast is analysed, and an early look at the 2023 season is included. Additionally, a long-term prediction of iceberg numbers in the North Atlantic is presented, using a high-emission scenario from NEMO, the Nucleus for European Modelling of the Ocean, model. Iceberg numbers are shown to decrease by 2050 in this scenario, while runoff increases. The International Ice Patrol (IIP) produces daily charts of iceberg activity in the region, as well as a yearly total (I48N). It is suggested that I48N may have peaked in the 1990's.

Rosser J[1]; Meijers A; Haynes P; Webb M

[1]British Antarctic Survey, University of Cambridge.
Talk: Abstract #87 / Session T26 - Physical Oceanography Open Session - Water Masses

Southern Ocean Centennial Oscillations in CMIP6 Models

Centennial scale oscillations in the Southern Ocean have been observed in many climate models. These oscillations involve significant changes in the Antarctic Circumpolar Current and the subsurface heat. The potential for these oscillations to influence future climate trajectories makes understanding their drivers and dynamics critical for future climate predictions and our understanding of the Southern Ocean as a whole. This study analyses these oscillations across an ensemble of CMIP6 model pre-Industrial Control runs. Oscillations are evident in the Antarctic Circumpolar Current (ACC) and have magnitudes of up to 15Sv or roughly 10-15% of the mean strength with a periodicity of around 100 years. This is a similar magnitude to changes in ACC strength predicted under strong climate forcing scenarios. However, the oscillations are only clearly present in a fraction of the ensemble, with 5 models showing clear oscillations and 6 models showing none. The reasons for this difference are a key focus of this study, with a particular emphasis on open ocean deep convection around Antarctica. Oscillations are characterised to assess the relationship between the primary large scale physical features of the Southern Ocean as well as potential causal factors. These features included the Antarctic Circumpolar Current, the subpolar gyres, open ocean polynya activity, subsurface heat, surface winds, buoyancy flux and meridional transport among others. The behaviour of these variables across the ensemble was analysed to determine the features of oscillating models compared to non-oscillating models. This enabled us to compare the dynamical states of the different groups.

Rowlands E[1]; Galloway T; Blackbird S; Cole M; Lewis C; Peck V; Thorpe S; Wolff G; Manno C
[1]British Antarctic Survey.
Talk: Abstract #17 / Session T12 - Interactions between plastics and marine ecosystem

Scoping intergenerational effects of nanoplastic on Antarctic krill embryos

Antarctic krill (*Euphausia superba*) plays a central role in the Antarctic marine food web and biogeochemical cycles and has been identified as a potentially vulnerable species to plastic pollution. Whilst plastic pollution has been acknowledged as a potential threat to Southern Ocean marine ecosystems, the effect of nanoplastics (<1 μm) are poorly elucidated. Deleterious consequences are predicted to be higher due to the small size of nanoplastics which enables permeation of cell membranes and provokes toxicity. Here, we investigated the intergenerational effects of Antarctic krill exposure to nanoplastics. We focused on whether embryonic energy resources were affected when gravid female krill were exposed to nanoplastic by analysing lipid and fatty acid compositions of embryos produced in incubation. Maternally exposed versus control embryos were exposed to polystyrene nanoplastic (50 nm) for 36-42 h. Nanoplastic did not impact lipid metabolism (total lipid, or fatty acid composition) across maternal treatments or direct embryo treatments, and no interactive effects were observed. The provision of a food source during maternal exposure had a positive effect on fatty acids, which are identified to be important during embryogenesis, including higher total polyunsaturated fatty acids (PUFA), eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA) and EPA/DHA ratio when compared to the control. Whilst the short exposure time was ample for digested material of the algae to be incorporated into embryos, we discuss why the nanoplastic/fatty acid relationship may be more complex, addressing species breeding strategy and nanoplastic surface properties, among other factors. Our study is the first to scope intergeneration effects of nanoplastic on Antarctic krill and their potential to disrupt lipid and fatty acid reserves. From this, we suggest directions for future research including long term exposures and exploring other critical energy reserves such as proteins and multi-stress scenarios.

Rufas A[1]
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Poster: Abstract #327 / Session T15 - Carbon cycling in the global ocean and the role of blue carbon in climate mitigation

Data is not everything –A modeller's perspective on making sense and use of global marine particle data collected without a joint plan.

The increasing availability of marine particle data from sediment traps, radionuclides and UVPs should make the life of (data-thirsty) biogeochemical modellers easier. Still, using particle flux data to optimise or validate a global biogeochemical model is a challenge due to the dysfunctionalities of those particular data. For instance, the collection in time periods that remain unsynchronised between locations (e.g., in some locations, sampling is before the bloom peak; in others, it is after) or the differing methodologies across sampling projects, even when using the same technology (e.g., choice of the set of depths where sediment traps will be deployed). With data collection biased towards certain periods and depths, it is difficult to aggregate (statistically treat) those data to produce quantities representative of the annual particle flux mean. Even the methods section of modelling papers are quite cryptic regarding the choice of the statistical treatment of particle flux data, with no unique way of doing it. Here, I present a compilation of particle flux data from five well-sampled and biogeochemically distinct ocean locations that suffer from spatial and temporal heterogeneity. A thoughtful visualisation of the particle flux data shows how the data set characteristics complicate the choice of the correct aggregation method to produce relevant oceanographic metrics. Setting global, joint strategies to sample particle fluxes in the water column is essential to elaborate data sets that can be meaningfully interpreted in broader contexts, like biogeochemical models. Achieving that does not require large expenditures of money but agreement.

Rulent J[1]; Artioli Y; Partridge D; Jardine J; Holt J
[1]National Oceanography Centre (NOC).
Talk: Abstract #73 / Session T28 - Physical Oceanography Open Session - Coastal Physics

Simulation of pollutants dispersal from XPP disaster

Following the X-Press Pearl shipwreck in May 2021, hundreds of tons of pollutants, including plastic nurdles and urea, have been released into the ocean along with other pollutants off the coast of Sri Lanka. This is causing damage to the local ecosystem and fishing industry, with great socioeconomic and ecological damage. Understanding how these pollutants are spreading and where is essential in understanding the impact of the event, plan responses and preparing responses to similar events more promptly in future. Using the new relocatable NEMO system, a subdomain of the South Asian Nitrogen Hub (SANH) model was built at a 1/60th degree resolution (aprox. 1-2 km) over the Sri Lankan region to simulate the dispersal of pollutants after the shipwreck. Coupling this model to the Framework for Aquatic Biogeochemical Models (FABM) and the marine ecosystem model ERSEM allows the simulation of tracer dispersal under different scenarios of release rates. The aim is to understand how far these pollutants could spread in each scenario, and which regions are likely to be affected. Here we show the latest development in this assessment of the pollution footprint between the south coast of India and the Sri Lankan region.

Rydzy M[1]; Davies S
[1]International Ocean Discovery Program, School of Geography, Geology and the Environment, University of Leicester, UK.
Talk: Abstract #244 / Session T23 - Unlocking Climate Histories from Marine Sediments

Lessons Learned about Natural Gas Hydrates from 50 Years of Scientific Ocean Drilling Expeditions within DSDP/ODP/IODP Programs – A Review

During the 1979 DSDP 66 Expedition off the coast of southwestern Mexico, the first physical marine gas hydrate sample was recovered, unequivocally proving the existence of gas hydrates in nature which had first been hypothesized just 14 years earlier. Since 1970, direct and indirect evidence for the presence of natural gas hydrates has been discovered in 53 legs drilled internationally during 23 scientific ocean drilling expeditions within the DSDP/ODP/IODP Program (Zhong et al. 2021). Owing to the abundance of geophysical, petrophysical, geological, geochemical, and biological data collected on these expeditions, great strides have been made towards a better comprehension of marine gas hydrate systems (e.g. Becker, 2014), most notably with respect to gas hydrate formation/accumulation, their link to bottom-simulating reflectors, and their role in past warming and events and submarine landslides. As the world moves away from fossil fuel energy sources, understanding marine gas hydrates remains important given their contribution to the global carbon cycle and their vulnerability to changes in sea level and water temperature. Continued mining of the vast DSDP/ODP/IODP data repositories that have been generated over the last 50+ years will be extremely valuable in further developing that understanding. We highlight key datasets, the information they reveal, and the potential for further study.

Becker, K. (2014). Developments in Marine Geology, 7, 1-36. Zhong, G., Zhang, D., & Zhao, L. (2021). Natural Gas Industry B, 8(2), 128-145.

Saavedra-Pellitero M[1]; Hernández-Almeida I; Cabarcos E; Baumann K; Dunkley-Jones T; Sierro FJ; Flores J
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Talk: Abstract #360 / Session T23 - Unlocking Climate Histories from Marine Sediments

Coccolithophores: the art of Equatorial Pacific SST and productivity reconstructions during lockdown

Here, we developed a new high-resolution reconstruction of annual sea-surface temperature (SST) and net primary productivity in the Eastern Equatorial Pacific (EEP) based on novel coccolithophore-based models. The addition of coccolithophore assemblage data from new surface sediment samples located in the EEP improved previous SST-calibrations, and resulted in higher confidence reconstruction of temperatures higher than 20°C. Our study sheds light on conflicting (palaeo-) temperature and productivity reconstructions for the last 20 kyr available in the EEP. We also reconstructed processes related to export production in response to rapid climatic variability from the late last Glacial to recent times at ODP Site 1240. We propose a change in the plankton ecosystem structure at the end of Termination I, from calcareous to siliceous plankton, and a concomitant reduction in the carbonate pump. This research inspired artwork, a comic-book story and an exhibition, with the aim of promoting science as well mental health issues during lockdown.

Salavasidis G[1]; Kamarudzaman I; Saeharaseelan T; Lorenzo A; Harris C; Phillips A
[1]National Oceanography Centre.
Talk: Abstract #122 / Session T6 - Towards a Net Zero Oceanographic Capability

Automated Piloting Framework for Efficient Use of Marine Autonomous Robotic Systems

Marine Autonomous Robotic Systems (MARS), such as Autonomous Underwater Vehicles (AUVs) and underwater gliders, are becoming increasingly popular, creating unprecedented opportunities for oceanographic data collection and improved composite picture of marine environments by operating them for extended periods of time. AUVs are now routinely used simultaneously in single or multi-vehicle campaigns around the globe. However, the scalability of such vehicle operations is limited by several factors; while remote piloting is possible via satellite services, pilots need to be trained for each individual vehicle technology to interpret the operational data coming from the vehicles and then manually take control decisions to maximize the operational efficiency without compromising the vehicle's safety. To avoid these time-consuming manual processes and ensure the MARS fleet is used to its full potential, an Automated Piloting Framework (APF) that resides within the NOC's unified Command and Control (C2) system has been developed, providing piloting tools and data services to streamline MARS over-the-horizon operations. The APF enables the integration of advanced algorithms to provide automated data interpretation/fusion, automated health/condition monitoring, and data-driven decision making for generating optimal control commands for a single vehicle or fleets of collaborative vehicles. Recent application examples of the APF include the use of a low-cost AUV for acoustic harvesting of data from a smart network of underwater sensors (HUDSON project, EPSRC ORCA Hub) and the use of heterogeneous fleets of AUVs with complementary sensing for efficient spatial and temporal area coverage and detection of underwater features of interest (SoAR project, Innovate UK).

Sanchez-Franks A[1]; Holliday P
[1]National Oceanography Centre.
Poster: Abstract #225 / Session T24 - The Atlantic Meridional Overturning Circulation: Observations, Simulations and Equations

Estimates of the boundary currents and water masses associated with the AMOC from a continuous mooring array in the subpolar North Atlantic

The Atlantic meridional overturning circulation (AMOC) is key in regulating the global climate system through a large-scale system of currents transporting warm waters northward and cooler waters southward. The subpolar North Atlantic, in particular, is a key region for the Atlantic meridional overturning circulation (AMOC) as it is

the location where northwards flowing warm waters from the subtropical gyre get transformed into denser waters, sinking to recirculate back equatorward as the AMOC's lower limb. The Overturning in the Subpolar North Atlantic Program (OSNAP) is a mooring array extending across the North Atlantic from Scotland to Greenland to Labrador which has been continuously measuring the AMOC directly since 2014. Using 6 years of available OSNAP data, we give a comprehensive overview of the boundary currents and the water masses that make up the subpolar north Atlantic circulation system across the Labrador, Irminger and Iceland basins and explore the interconnectivity of the boundary currents between basins.
One of the highlights shows that the North Atlantic Current (NAC) accounts for over 72% of the variability in the upper limb of the AMOC. The easternmost branches of the NAC (over the Rockall Plateau and Trough) account for the majority of the AMOC variability (~38%), even though the westernmost branches account for more than half the mean transport (~10 Sv).

Sanders R[1]; Jones D; Josey S; Sinha B; Forget G
[1]British Antarctic Survey.
Talk: Abstract #106 / Session T24 - The Atlantic Meridional Overturning Circulation: Observations, Simulations and Equations

Causes of the 2015 North Atlantic cold anomaly in the ECCOv4 state estimate

While most of the global ocean exhibited higher than average surface temperatures in 2015, the subpolar North Atlantic instead experienced record low temperatures. To better understand the processes driving this cold anomaly, we computed mixed layer temperature budgets in the ECCO Version 4 ocean state estimate. We show that strong surface cooling was responsible for approximately 75% of the initial anomalous cooling of the mixed layer during December 2013, while the remaining 25% was driven by advection. The cold anomaly was then sequestered beneath the mixed layer. Re-emergence of the cold anomaly the following summer/autumn was primarily the result of a strong temperature gradient across the base of the mixed layer, with vertical diffusion accounting for around 70% of the re-emergence. Weaker surface warming of the mixed layer during the summer of 2015 enhanced the anomaly, causing a temperature minimum. Spatial patterns in the budgets show significant differences between the north and south of the region, with particularly strong initial surface cooling in the south related to the positive phase of the East Atlantic Pattern.

Sands C[1]; Sands CJ; Moreau C; Bax N; Barnes DKA; Souster T; Downey R; Zwerschke N; Moreno B; Held C; Lund M
[1]British Antarctic Survey.
Talk: Abstract #241 / Session T15 - Carbon cycling in the global ocean and the role of blue carbon in climate mitigation

Who's Blue Washing? Nature based solutions are not just economic targets but ecological processes that can help balance out a profound anthropogenically inflicted problem

Atmospheric carbon dioxide levels are rapidly increasing and resulting climate aberrations are strongly affecting quality of life and threatening natural ecosystems. Commercial capture and sequestration of carbon is proving grossly inadequate and hugely expensive. Nature-based solutions capture and store carbon effectively and many natural systems are highly efficient at sequestering carbon out of the carbon cycle for hundreds, thousands or millions of years. The ocean is the most effective carbon capture and store system planet earth has, and there are associated pathways to further remove carbon out of the ocean carbon storage flux and into long term sequestration. The best known of these marine paths to sequestration are mangrove forests, seagrass beds and salt marshes. These are globally small in area, have been severely degraded over the years and are in ongoing decline. There are, however, other pathways to sequestration that require attention and understanding. In particular the shallow shelf regions of some polar and sub-polar seas have been shown to be increasing in primary productivity directly contributing to increasing growth-rates in benthos and subsequent burial and sequestration of carbon. The amounts of carbon sequestered may be small, but the regions involved are huge. What's more, these regions are increasing in area as winter sea-ice extent decreases, ice-shelves break off and marine terminating glaciers retreat. Many of these regions are currently considered of low economic value. A strong, evidence based conservation approach to these areas now will protect a Blue Carbon sequestration pathway that is increasing in potential.

Savage G[1]; Porter A; Simpson S

[1]University of Exeter.
Talk: Abstract #328 / Session T12 - Interactions between plastics and marine ecosystem

*Microplastic uptake by the snakelocks anemone (*Anemonia viridis*): investigating environmental and physical factors that alter uptake*

Microplastics (<1 mm) are ubiquitous in marine ecosystems, exerting multi-faceted threats – including microplastic uptake – on marine organisms. Anthozoans, comprising sea anemones and corals, are especially at risk of microplastic uptake as a result of their coastal habitats, sedentary life stages and non-selective feeding strategies. Here, we examine microplastic uptake in the relatively understudied anthozoans class, through a series of microplastic exposures and multi-stressor studies performed using the temperate snakelocks anemone (*Anemonia viridis*). All exposed *A. viridis* readily took up microplastics (mean 142.1 ± 83.4 particles per gram of tissue) but demonstrated limited particle shape and size selectivity (n = 32). Further investigation concluded that microplastic uptake in *A. viridis* involved both ingestion and external tissue adhesion, with microplastics trapped by mucus accumulation. Additionally, prey availability and elevated seawater temperature did not affect *A. virid*is uptake (n = 40). Finally, microplastic uptake by *A. virid*is (n = 8) on the coast of southwest England was accessed, with a mean of 15.8 ± 4.0 particles taken up per individual. Clear, blue and black fibres were the dominant particles identified (87%). FTIR spectroscopy confirmed that 70% of particles were anthropogenic cellulosic or plastic polymers. Thus, here we document microplastic uptake by *A. viridis* in both laboratory experiments and in the marine environment. We discuss how our findings support recent literature proposing that external adhesion may be the primary mechanism in which anthozoans capture microplastics from the water column, and we highlight the potential role anemones can play as environmental microplastic bioindicators.

Savage J[1]; Chamberlain A; Fellows M; Jones R; Letessier TB; Llewellyn F; Morritt D; Rowcliffe M; Koldewey H
[1]Royal Holloway University of London; Institute of Zoology; Zoological Society of London.
Poster: Abstract #190 / Session T12 - Interactions between plastics and marine ecosystem

Insights into the origins of beached plastic bottles in the Chagos Archipelago, a remote Marine Protected Area

Plastic is ubiquitous in the environment and has negative impacts on marine ecosystems. The Chagos Archipelago is an isolated Marine Protected Area (MPA), which supports important marine biodiversity, including coral reefs, turtles, seabirds, and large pelagic wildlife, such as reef manta rays (Mobula alfredi). Despite its remote setting, Chagos is a major sink for plastic pollution, the origins of which are unclear. It is important to understand the sources and pathways of plastic pollution in this location, to recognise the risks to the biodiversity that the MPA supports.
The aim of this study is to examine the origins, geographical distribution, and temporal trends of plastic bottles in BIOT. During two expeditions, in 2021 and 2022, we performed beach transects of plastic debris composition around the archipelago. We collected plastic bottle lids and labels to determine their brands and countries of origin. We also performed a full clean of a beach previously cleared in 2019, to understand temporal variation and accumulation patterns. We hypothesised that the plastic bottles would mainly originate from Indonesia, the largest polluter in the region, and the Maldives, the closest touristic location to Chagos. Our results confirmed this hypothesis. Furthermore, the main brands found on the Chagos beaches were Aqua Danone, Life and the Coca Cola Company. The limited human influence and remote setting make Chagos an important scientific reference point for global anthropogenic change. By identifying the main origins of the plastic pollution in Chagos and the central Indian Ocean, mitigation can be targeted accordingly.

Savineau E[1]; Cook KB; Blackbird SJ; Stowasser G; Tarling G; Fielding S; Belcher AC; Wolff G; Mayor DJ
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Poster: Abstract #161 / Session T10 - Micro to macro: linking bottom-up and top-down approaches that investigate the function, resilience and conservation of polar ecosystems

Investigating the physiological- and trophic ecology of zooplankton in the Scotia Sea using lipid profiles.

Zooplankton have a central role in controlling the strength of the biological carbon pump, yet little is known about mesozooplankton physiological- and trophic ecology, hindering our understanding of the routes through which energy and organic matter cycle. In this study, the lipid profiles of zooplankton and suspended material

were used to investigate the physiology and trophic interactions between 8 of the most common mesozooplankton species found throughout the meso- and epipelagic waters around South Georgia. Multivariate statistical analysis demonstrated that species identity explained 72.5 % of the variability in the fatty acid data. The calanoid copepods, *Calanoides acutus*, *Rhincalanus gigas* and *Paraeuchaeta* spp., were characterised by different fatty acid profiles and each formed a distinct cluster, reflecting differences in their underlying physiology and diet (diapausing herbivore, non-diapausing herbivore/omnivore and non-diapausing carnivore respectively). In contrast, chaetognaths, amphipods (*Themisto gaudichaudii*), salps and euphausiids (*Euphausia triacantha* and *Thysanoessa* spp.) formed a single, large cluster, suggesting they may share similar generalist strategies. Characteristic herbivorous calanoid biomarkers, whilst present in *C. acutus*, were lacking in *Rhincalanus gigas*. These differences support the idea that *C. acutus* and *R. gigas* have different life-histories, with only the former overwintering in the deep ocean by subsisting off long-chained wax esters. The presence of the herbivorous calanoid biomarkers in chaetognaths, amphipods and euphausiids suggests predation on *C. acutus*, advancing our understanding of trophic interactions. We provide suggestions for how future studies may benefit from combining the lipid biomarker approach with other, complementary techniques, to advance our understanding of mesopelagic ecology.

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[1]National Oceanography Centre.
Poster: Abstract #297 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

In situ analysis of pore water nitrate concentrations in estuarine sediments

Estuaries exhibit dynamic temporal and spatial variability and are under pressures from anthropogenic nutrient inputs. Estuarine sediments play an important role in nutrient recycling, often leading to strong vertical gradients in the upper centimetres of the sediments. To understand these processes it is necessary to monitor the nutrient concentrations in the porewaters of estuarine sediments. However the traditional process of collecting sediment cores and extracting and analysing porewater in a laboratory often cannot resolve the temporal development of nutrient gradients. Here, we present a new method for autonomous measurements of nitrate concentrations in estuarine sediments over several tidal cycles, using a spectrophotometric lab-on-chip sensor. A Rhizon filter inserted horizontally into the sediment allowed the sensor to autonomously collect pore water for in situ analysis. The nitrate concentration in the overlying water was measured with the same sensor and the temperature, pressure and salinity was measured with a CTD. The data (124 measurements over 5 days) showed a strong variability of the pore water nitrate concentration with tides: at 2.5 cm depth the pore water nitrate concentrations ranged from 0-30 µM and peak concentrations in the porewater were recorded half a tidal cycle later than peak concentrations in the water column.
These results demonstrate that this new technique can resolve the temporal variation of nutrients within sediments. This approach could be extended to examine time series of any parameter which can be measured with lab-on-chip sensor technology (e.g. phosphate, silicate, pH, total alkalinity), including in coastal and deep sea settings.

Schmidt K[1]; Graeve M; Lebreton B; Atkinson A; Niehoff B; Hagen W; Flores H; MOSAiC community
[1]University of Plymouth.
Talk: Abstract #333 / Session T15 - Carbon cycling in the global ocean and the role of blue carbon in climate mitigation

Do ice algae fuel the lipid pump in the central Arctic Ocean?

The seasonal 'lipid pump' is an important pathway of Carbon sequestration into the deep ocean. It involves the vertical transport and metabolism of carbon rich lipids by zooplankton that overwinter below the permanent pycnocline. It has been suggested that in the North Atlantic the 'lipid pump' sequesters more carbon in the deep ocean than any other process in the Biological carbon pump. However, key aspects of the lipid pump still lack our understanding, for instances what determines when and how deep copepods descend. Here we studied the lipid composition of the largest Arctic copepod, Calanus hyperboreus, alongside a suit of trophic markers including bulk stable isotopes, compound-specific stable isotopes, fatty acids, sterols and highly branched isoprenoids. The samples derived from the MOSAiC expedition to the Central Arctic Ocean, and cover 5 depth

horizons between the surface and 2000m, adult and juvenile developmental stages. The data show that C. hyperboreus which migrate to great depth have been feeding on ice-associated algae, including the diatom Melosira arctica. We reason why the lipid pump might slow in a future ice-free Arctic.

Schumacher M[1]; Brix S; Taylor J
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Poster: Abstract #228 / Session T14 - A decade of deep ocean science for sustainable development

Mapping deep trash - An illustration from expedition observations about global oceanic litter

The deep sea is the final destination for human trash. This type of pollution has even reached the deepest and remotest parts of the world's oceans. Due to extremely little currents and turbidity, it is potentially trapped there forever. Depending on the kind of litter, it does not dissolve, but slowly decays into microscopic pieces and is thus able to enter the food chain. A very common type, microplastic, has drawn public attention recently. It is presently found everywhere across the ocean, on its surface, in the water column, and even in sediments (Van Cauwenberghe et al. 2013). We would like to present our interactive Trashmap, locating deep sea trash on underwater footage that we found during many dives with remotely operating vehicles (ROVs) and towed camera systems. With the map, we would like to raise awareness to this special problem as, unlike in shallow waters or on land, marine litter cannot be retrieved easily. Our trash map adds to the existing AWI Litterbase (Tekman et al.), a global collection of literature-based findings of trash in the sea, with a focus on deep sea litter. Meant as a public accessible map, we would like to give a push to reduce waste production and reconsider human habits, being the main source of this major threat. The Trashmap is meant as a living document that is constantly updated with imagery and samples from ongoing expeditions, and at the same time it is a huge data call to all scientists in the community to contribute.

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Tekman, M.B., Gutow, L., Macario, A., Haas, A., Walter, A., Bergmann, M.: Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung. Litterbase. (URL: https://litterbase.awi.de/)

Schwarz-Schampera U[1]
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Talk: Abstract #74 / Session T1 - Deep Sea Mining 1 - geology, resource, legal, technical and societal aspects

Resource prospects of seabed minerals of the Area

Recent interest in deep-sea minerals including polymetallic nodules, polymetallic sulphides and cobalt-rich ferromanganese crusts is driven by a substantial increase in commodity prices due to forecasts of future demands for metal resources. Factors behind this increase include population growth, the rapidly expanding economies of countries with large populations, market concentrations and the development of low-carbon footprint technologies such as wind turbines, photovoltaic cells, and batteries for electric cars as possible answers to climate change. These new technologies require a wider range of base and trace metals, which are considered economically strategic to meet current and future demand and which are concentrated in seabed minerals. Currently, ISA signed 31 contracts for resource exploration in the Area. The enrichment of seabed minerals to deposit scales requires very specific conditions including stable plate tectonics, limited sedimentation rates, specific water column redox characteristics, temporary intraplate and ridge-related volcanism, slow spreading rates, tectonic phases with limited magmatic activities. Cobalt-rich ferromanganese crusts and polymetallic massive sulphides form local, 3-dimensional deposits extending for 100 to 1,000m whereas polymetallic nodule deposits may occupy few thousands of sq.km for feasible operations. Similar to land-based deposits, seabed mineral resources need to occur in such form, grade, quality, quantity that definition of well-defined prospects for eventual economic extraction is possible. Their characteristics are measured with confidence to support detailed mine planning, and proven mineral reserves require innovative approaches towards intelligent and remotely operated mining technology, infrastructure, legal, economic, environmental and other factors to represent valuable resource prospects.

Scott W[1]; Vallot D; Kramer S; Holland P; Nicholls K; Siegert M; Piggott M
[1]Department of Earth Science and Engineering, Imperial College London.
Poster: Abstract #250 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

Unstructured modelling of ocean flow in ice shelf basal crevasses

Basal crevasses are common features under ice shelves. They are important for the mass-balance, and indeed stability, of an ice shelf as they play a role in calving events. As they offer additional roughness to the ice-ocean interface they may also have an impact on ocean flow within the ice shelf cavity and, hence, on basal melt rates. It remains unclear how basal ice shelf crevasses evolve from initiation to calving episode, however. Theoretically, viscous deformation of the ice shelf acts to smooth out basal crevasses in time. Similarly, idealised modelling studies of ocean flow predicts that in both freezing and melting regimes crevasses are eroded, again reducing their impact on roughness. During freezing, the dominant mechanism is frazil ice formation which fills the crevasse space. During melting, ocean stratification effects, in conjunction with the depth-dependent freezing point, lead to lower melts within the crevasse than outside, again reducing roughness. Here, we present preliminary work investigating ocean flow in basal crevasses using the Firedrake finite element framework. The model is capable of running on fully unstructured meshes and the model physics are valid at a range of aspect ratios. In particular, we examine the importance of rotation and basal slope which has been neglected in previous modelling studies on the ocean side.

Segabinazzi Dotto T[1]; Hall R; Heywood K; TARSAN Team
[1]University of East Anglia.
Talk: Abstract #28 / Session T26 - Physical Oceanography Open Session - Water Masses

Ocean Circulation and Heat Fluxes in Front of the Dotson Ice Shelf, Antarctica

The West Antarctic Ice Sheet retreat in the Amundsen Sea is driven by decadal oceanic variability. High ocean temperatures in the mid-2000s are thought to have induced a fast thinning of the Dotson Ice Shelf in recent years, which accelerated the undergrounding of a series of pinning points, with the potential for accelerating the ice discharge of adjacent glaciers. Here we present the hydrographic conditions measured in front of the Dotson Ice Shelf between January and March 2022. A strong and narrow jet (~5 km width) brings large amounts of modified Circumpolar Deep Water into the sub-ice shelf cavity, which has the potential to induce basal melting. After interacting with the base of the ice shelf, a glacially modified plume leaves the cavity as a ~2 km jet between 200-500 m depth on the western Dotson Ice Shelf. Strong turbulent processes mix the freshwater-enrich plume with adjacent waters, increasing its buoyancy and shallowing the plume just a few kilometres away from the ice front. The shallowing of the plume after leaving the cavity imports heat to the upper ocean. The narrow outflow jet follows the 500 m isobath and contours the Martin Peninsula in direction of the Getz Ice Shelf. The connections between these two ice shelves will be further discussed. Studying the ocean processes in detail in front of the Dotson Ice Shelf is key to understanding its evolution and its sensitivity to changing ocean forcings.

Serdy A[1]
[1]University of Southampton.
Talk: Abstract #348 / Session T1 - Deep Sea Mining 1 - geology, resource, legal, technical and societal aspects

The common heritage regime for deep seabed minerals: a legal product of its time

Designed for a primarily non-legal audience, this paper begins with an overview of the "common heritage of mankind" principle governing exploration and exploitation of the minerals of the deep seabed beyond national jurisdiction in Part XI of the UN Convention on the Law of the Sea and its 1994 Implementing Agreement, explaining how they make the International Seabed Authority a legally unique body, designed to be the antithesis of the unregulated exploitation that would have prevailed under the former high seas status of this area. Central to the model is State sponsorship of contractors, and the second half of the paper traverses two related issues tackled by the 2011 advisory opinion of the International Tribunal for the Law of the Sea. One is the tension or

trade-off between equity and the rigour of environmental regulation: should developing countries by virtue of their status have less onerous duties of supervision of the contractors they sponsor? (The tribunal answered no, as this would have created a risk of "sponsors of convenience" and a race to the bottom.) The other is a possible flaw in the system's design, namely the potential chilling effect of environmental liability: any State party can sponsor a contractor, but will poorer ones be inequitably frightened off doing so by the spectre of huge environmental damages awards, and how can they avoid this?

Sheehan P[1]; Heywood K; Thompson A; Flexas M; Schodlok M
[1]University of East Anglia.
Talk: Abstract #11 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

Sources and transport of glacial meltwater in the Bellingshausen Sea, Antarctica

Determining meltwater content and describing transport pathways is important for understanding the impact of a warming, melting Antarctica on ocean circulation and climate. Using ocean glider transects, we quantify meltwater distribution and fluxes within the Bellingshausen Sea's Belgica Trough. A northward-flowing meltwater flux (0.37 mSv) is observed in the western trough; a newly identified meltwater re-circulation (0.85 mSv) flows southward in the eastern Trough. Meltwater is present in two layers: one at 27.4 kg/m3 and one at 27.6 kg/m3. Model simulations of ice-shelf cavity-water circulation agree well with the observations. In the eastern Bellingshausen, meltwater is confined to the narrow Antarctic Coastal Current, but penetrates northward into the southwestern Belgica Trough. Meltwater also enter the Trough from the west, having spread over the entire shelf of the western Bellingshausen. Meltwater from eastern ice shelves equilibrates at densities approximately 0.1 to 0.2 kg/m3 lighter than meltwater from southern ice shelves. These observations and model results demonstrate the potential for feedbacks between meltwater input and: the strength of the shelf circulation; the stratification in front of ice shelves; and the heat flux into ice-shelf cavities. Moreover, an accurate assessment of the impact of meltwater should account for the different densities of meltwater plumes originating from different ice shelves.

Sheen K[1]; Polzin BLK; Meredith M; Retallick K; Scourse J; Landeghem KV; Rippeth T; Lenn Y
[1]University of Exeter.
Talk: Abstract #38 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

Bathymetric sills, turbulent mixing and glacier retreat in the west Antarctic Peninsula

Oceanic turbulent mixing proximal to glacial fronts plays a key role in distributing heat, freshwater and nutrients, and hence in de-stabilising ice-shelves and mediating meltwater outflows and marine productivity. Quantifying turbulent mixing on the Antarctic shelves, alongside assessing its driving processes, is therefore key for predicting the future trajectory of Antarctic coastal systems and wider scale environmental change in the coming century. This talk will present hydrographic and turbulence measurements collected in three embayments along the West Antarctic Peninsula. The data were collected close to glacier marine termini that have shown rapid retreat in recent decades. In particular, the role of bathymetric sills in acting as both a barrier and blender to the exchange between waters that impinge on the glacial edge and the ocean open is discussed: such sills are characteristic features in all three bays. Hydrographic data imply a distinct difference in water characteristics on each side of the sill, whilst observations from vertical microstructure profiles indicate that the tidal flow over the sill enhances mixing in the bay, impacting the vertical exchange of properties such as heat, salt, oxygen and nutrients. The data presented were collected as part of the BAS-funded project OCTONAUT, on the NERC-CONICYT funded ICEBERGS research cruise.

Shelley R[1]; Baker A
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Talk: Abstract #104 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

Is aerosol trace element fractional solubility a function of total atmospheric loading?

The availability of iron (Fe), and other trace elements (TEs), is central in controlling biological activity and CO2 sequestration in many ocean regions. Atmospheric deposition provides an external source of TEs to the ocean, but most fluxes are currently poorly understood and have large uncertainties associated with them. Therefore, determining the factors which control aerosol TE solubility are a current research priority. Sholkovitz et al. (2012) presented a global dataset for aerosol Fe which demonstrated an inverse relationship between Fe fractional solubility and its atmospheric loading. This relationship appeared to be robust across diverse ocean regions. However, recent studies of Fe solubility in remote regions and of other TEs (e.g., manganese, cobalt and thorium, Th) have challenged this assumption. This is significant as atmospheric deposition flux calculations which use atmospheric deposition tracers (most frequently aluminium, Al) often assume uniform solubility and/or residence time of dissolved species. In this study, we report fractional solubility data for Th in bulk and size segregated aerosols and compare them to other TEs. For example, Th solubility in Saharan dust (5.8 +/- 1.9%) was significantly less variable than Al solubility (4.0 +/- 2.7%). Consequently, we propose the stability of Th solubility during transport may make it a more suitable tracer for dust inputs and reduce uncertainties in atmospheric deposition flux estimates.

Sholkovitz, E.R., Sedwick, P.N., Church, T.M., Baker, A.R., and Powell, C.F. (2012). Fractional solubility of aerosol iron: Synthesis of a global-scale data set. Geochimica et Cosmochimica Acta, 89, 173-189.

Siddle E[1]; Heywood KJ; Webber BGM
[1]University of East Anglia.
Poster: Abstract #136 / Session T26 - Physical Oceanography Open Session - Water Masses

Combining uncrewed oceanographic observing systems for observational ocean heat budget determination.

Quantifying the heat absorbed and released by the ocean is important in understanding the role of air-sea interactions in global climate. Here we demonstrate the use of uncrewed autonomous platforms to investigate ocean heat content, attempting to close the heat budget on a scale of days in a 10 km x 10 km region. In January – February 2020, we deployed four autonomous platforms east of Barbados as part of the Eurec4a campaign. 3 Seagliders undertook 581 dives and our 5 m wave-powered surface vessel, Caravela, travelled more than 1000 km over ground.
We present high resolution upper ocean observations throughout the 4-week campaign. Seaglider profiles of temperature and salinity give insight into variations in the surface mixed layer properties. For example, the mixed layer depth varies over days to weeks between 11 m and 45 m. Turbulent microstructure from one glider allows an estimate of the contribution of vertical mixing to the heat budget. Variations in upper ocean heat and freshwater content are derived, and we test the extent to which changes in heat content can be accounted for by local air-sea fluxes. These fluxes are derived from Caravela's in-situ measurements, including down-welling long-wave and short-wave radiation (long-wave observations varying from 378.3 W/m2 to 495.4 W/m2, with a peak solar radiation of 1441 W/m2), supplemented by fluxes from the ERA5 reanalysis. We discuss the potential of these surface and subsurface platforms to derive an observationally-based heat budget.

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Poster: Abstract #42 / Session T28 - Physical Oceanography Open Session - Coastal Physics

Impact of tidal mixing on shelf sea flushing times in a global climate model

Whilst accounting for only 7% of the global ocean surface area, shelf seas are major sinks for tidal energy, responsible for 75% of global tidal dissipation (~ 2.6 TW). The resulting intense tidal currents act to mix the water column in shallow regions. Shelf seas are greatly influenced by seasonal variations in solar heating and freshwater influxes, acting as buoyancy forcing which can overcome the impact of tidal mixing, resulting in the formation of stratification. This stratification tends to be seasonal, developing in spring and summer in deeper regions. Areas of seasonal stratification are separated from areas which remain well mixed year round by tidal mixing fronts. Despite their importance, shelf seas are generally poorly represented in global climate models due to coarse resolution, with the neglect of shallow water dissipation leading to the under-representation of mixed regions. Here, we examine the accuracy of shelf sea representation within the intermediate-complexity UVic Earth System

Climate Model. Due to a lack of shallow water dissipation in regions less than 500m deep, TPXO9v4 data are used to introduce dissipation into the 'mixed' and 'stratified' regions of the modelled shelf seas, via internal wave dissipation and bed friction. Through a series of simulations with differing levels of tidal mixing, we investigate the impact of varying dissipation on the predicted extent of seasonal stratification for several shelf seas and the associated impact on the shelf sea flushing times.

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Poster: Abstract #69 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

Prolonged deep mixing explains surprisingly persistent oxygen disequilibrium in surface waters of the Labrador Sea

The Labrador Sea shows an unexpected persistent surface O2 disequilibrium which contradicts theoretical expectations of gas exchange rapidly counteracting air-sea disequilibria (Vachon et al., 2020). The long-lasting disequilibrium is caused by intense deep convection in autumn, winter and spring, outcompeting air-sea gas exchange. Investigations were carried out by comparing deviations of surface O2 and CO2 concentrations from atmospheric equilibrium (Wu et al., 2022), based on time series observations, global and regional datasets and a biogeochemical model. According to the results, supersaturation of O2 caused by spring blooms is quickly restored to saturation by air-sea gas exchange. However, this equilibrium lasts for only two months before convection of O2-poor deep waters pushes O2 towards undersaturation. Thus, continuous deep mixing is found (confirming Kortzinger et al., 2008) to be the factor preventing re-establishment of air-sea equilibrium of O2 for much of the year.

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Vachon, D., Sadro, S., Bogard, M. J., Lapierre, J., Baulch, H. M., Rusak, J. A., Denfeld, B. A., Laas, A., Klaus, M., Karlsson, J., Weyhenmeyer, G. A., & Giorgio, P. A. (2020). Paired O2 – CO2 measurements provide emergent insights into aquatic ecosystem function. Limnology and Oceanography Letters, 5(4).
Wu, Y., Bakker, D. C. E., Achterberg, E. P., Silva, A. N., Pickup, D. D., Li, X., Hartman, S., Stappard, D., Qi, D., & Tyrrell, T. (2022). Integrated analysis of carbon dioxide and oxygen concentrations as a quality control of ocean float data. Communications Earth & Environment, 3(1).

Silva T[1]; Fernand L; Bell E; Lawler A; Stott S
[1]Centre for Environment, Fisheries & Aquaculture Science.
Talk: Abstract #285 / Session T20 - Evidence to support international oceans policy

Assessing resilience of King Scallop (Pecten maximus) populations through larval dispersal

In 2020 an infrequently exploited population of King Scallops in the North Sea saw a great increase in catches prompting questions on its sustainability. These beds, in the North Dogger region, are located offshore unlike the regular fishing grounds off Scarborough and Eastern Scotland. After talks with the fishing industry, the fishing was suspended to allow assessing its resilience. This depends on, among other factors, the inflow and settling or larvae which will then contribute to population recruitment. Effect of fishing the offshore ground would depend on the following questions: i) Are the offshore grounds self-sustaining i.e. not supplied from other sources? ii) Do they export larvae to other scallop populations? In this study the larval transport, behaviour and settlement were simulated using the GETM hydrodynamic model for the North West European Shelf and a lagrangian particle tracking model (GITM), where larvae growth, mortality and behaviour are represented by an Individual Based Model (IBM). A set of simulations including tides, realistic meteorological forcing (including inter annual variability) and the effect of vertical density structure were performed. The results describe the Western North Sea as a metapopulation with a strong connectivity along the Scottish and the NE English coast. The offshore populations were shown to be weakly linked to the coastal populations. The Northern part of the offshore population has a low rate of larval retention and low imports giving it low resilience to overfishing. The Offshore South area has a higher rate of retention than other established coastal beds, but as it has lower import rates,

resilience may also be lower than the coastal beds. These results were combined with assessment of the biomass and age structure of the population, ultimately leading to a temporary closure of the region for scallop dredging.

Silvano A[1]; Holland PR; Naughten KA; Dragomir O; Dutrieux P; Jenkins A; Si Y; Stewart A; Molino BP; Janzing J; Dotto T; Garabato ACN
[1]University of Southampton.
Talk: Abstract #312 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

Simulated warm water access to the Amundsen Sea continental shelf

The West Antarctic Ice Sheet is losing mass at an accelerating rate, contributing to sea level rise. Ocean forcing is considered to be the main driver of this mass loss, associated with warm intrusions of Circumpolar Deep Water onto the continental shelf. Here we describe these intrusions, focussing on the role of the Amundsen Undercurrent. The Amundsen Undercurrent is an eastward, bottom-intensified current located at the shelf break/upper slope that transports warm Circumpolar Deep Water. This current enters the continental shelf through deep canyons that connect the shelf break with ice shelf cavities, bringing oceanic heat to the base of the ice shelves. We use a regional ocean model to introduce the forcing mechanisms of the Amundsen Undercurrent and the drivers of its temporal variability. We conclude by discussing how this variability ultimately influences melting of ice shelves in the Amundsen Sea.

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Poster: Abstract #234 / Session T7 - Pushing the limits in autonomous oceanography in a net zero carbon world

Cytochip: a portable system for rapid detection of Harmful Algal Blooms

At certain times of year, naturally occurring marine algae can proliferate and pose a threat to human health from the production of potent bio-toxins. These "Harmful Algal Blooms" (HABs) are particularly damaging when algal bio-toxins become concentrated in the bodies of filter feeding bi-valve shellfish, posing a risk to human health when consumed. The current method for the monitoring of HABs involves the delivery of water samples to a centralised lab and analysis for certain algal species by microscopy. This incurs a severe time delay between the detection of a HAB event and the enation of the necessary intervention. The aim of this project is to improve early warning and event forecasting of harmful algal blooms within and around shellfisheries by developing existing, state of the art, lab-on-chip technology into a new, portable tool that will enable end-users (i.e., shellfish producers, and statutory monitoring authorities) to undertake HAB surveillance in the field. This technology takes the form of a micro-cytometer, a device that measures the properties of cells as they pass through a narrow channel. While conventional cytometers only measure the optical properties of cells, our system (CYTOCHIP) measures multiple optical and electrical properties simultaneously, providing excellent discrimination of cell types and differentiation of toxin-producing and non-toxic species. These capabilities are being exploited to help shellfish producers and authorities to protect consumers and public health, and reduce the costs associated with the existing, delayed analysis methods.

Skliris N[1]; Marsh R; Addo KA; Oxenford H
[1]University of Southampton.
Talk: Abstract #205 / Session T27 - Physical Oceanography Open Session - Physics-Biology Interactions

Physical drivers of post-2011 inter-annual variability in Sargassum blooms in the Central West Atlantic

Since 2011, pelagic Sargassum macroalgae has proliferated across the tropical North Atlantic, evident in Floating Algae Index (AFAI) images for the Central West Atlantic (CWA) over 2010-2021. Sargassum blooms are mainly initiated each year in CWA in late winter with Sargassum biomass peaking there in early summer. Large quantities of Sargassum inundate beaches across the CWA and the Caribbean, typically from spring to autumn, especially impacting ecosystems, fishing, and tourism, with severe socio-economic implications for local communities. To

investigate the role of physical drivers in the inter-annual variability of post-2011 Sargassum blooms, conditions are examined across the wider tropical Atlantic. Of particular consequence for the growth and drift of Sargassum are patterns and seasonality of winds and ocean currents, which, in turn, are strongly regulated by natural tropical climate variability, especially by variations in the Atlantic Meridional Mode (AMM). In years when AMM was strongly negative (2015, 2018, 2021) massive Sargassum blooms were observed across the Tropical Atlantic. Negative AMM is associated with a southward shift of the Intertropical Convergence Zone (where Sargassum naturally accumulates), towards nutrient-rich waters of the Amazon and Orinoco river plumes and the equatorial upwelling zone, further enhancing Sargassum blooms. Negative AMM is also associated with stronger trade winds and enhanced northwest Africa upwelling, resulting in stronger southwestward nutrient transport into the eastern part of CWA. Moreover, important secondary winter blooms took place in both 2015 and 2018, attributed to excessive wind-driven equatorial upwelling and anomalously strong northwestward nutrient transport, feeding the northern CWA.

Smith A[1]; Callaghan AH; Bidlot J
[1]Imperial College London.
Talk: Abstract #251 / Session T17 - Physical and chemical drivers of air-sea exchange processes: waves, bubbles, aerosols and surface chemistry

Parameterising CO2 air-sea gas transfer with wave breaking energy dissipation rate, sea state, and wind speed

Although carbon dioxide gas (CO2) constitutes only 1.4 percent of the gas composition of sea-water at equilibrium, air-sea flux of CO2 has up-scale ramifications for global climate and ocean biogeochemistry. Measurements of the gas transfer velocity (k) are required to quantify and predict the fluxes of CO2 by linking gas transfer rates to chemical and physical processes. Such linkages have been difficult to properly characterise where data are scarce, or in challenging and complex environments (e.g., high winds and complex seas). Consequently, there is considerable scatter in predicted values of k from existing parameterisations. To address this, we use measurements of the gas transfer velocity of CO2 (kCO2) from 9 cruises undertaken between 2007-2019 in the North Atlantic, Southern, Indian, and Pacific Ocean and Norwegian Sea. Coastal and open ocean were sampled during these cruises, with wind speeds U10N = 0.3 – 25.2 m s-1, SST of -1.8 – 29.7 degrees Celsius, and wave ages cpU10N-1 = 0.18 – 43.35. We use these data to validate a novel gas transfer velocity parameterization constructed using output from a wave hindcast obtained with the spectral wave model (ecWAM) forced with the European Centre for Medium-Range Weather Forecasts (ECMWF) 5th Generation Reanalysis (ERA5). Our parameterisation combines diffusive flux based on wind speed and Schmidt number Sc, and bubble-mediated flux using bubble size-dependent exchange efficiency, solubility, sea state, and wave breaking energy dissipation rate to capture gas transfer velocity. We compare our results to common wind-speed-only parameterisations and more recent sea-state based relationships.

Smith EL[1]; White M; Huvenne V; Wolff G; **Kiriakoulakis K (presenting author)[1]**
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Talk. Session T21 - Trait-based approaches to improve conservation, management, and restoration of our oceans

Tracing particulate organic matter pathways in deep-sea ecosystems: Food supply and partitioning in Whittard canyon vulnerable marine ecosystems dominated by filter feeders.

Near bottom (<15 m above bottom) suspended Particulate Organic Matter (POM_{susp}), *Acesta excavata* mussels and two species of Scleractinian cold water corals (CWCs), *Madrepora oculata* and *Lophelia pertusa*, were collected during two surveys in June 2014 and August-September 2015 from several depths and branches of the Whittard Canyon System (WCS) in the Celtic Sea. The work aimed to investigate trophic dynamics and resource partitioning between overlapping filter feeding phyla in vulnerable deep-sea ecosystems. Specifically elemental (OC, N), bulk isotopic ($\delta^{13}C$, $\delta^{15}N$), and lipid analyses from selected locations were carried out to a) characterise the nutritional quality and quantity of POM_{susp} and b) trace the organic matter signal to biological tissues. OC and molar C/N ratios of POM_{susp} were similar to previous studies for WCS, showing a typically marine signal. However $\delta^{13}C$ and $\delta^{15}N$ bulk isotopes of POM_{susp} were -27.5±1.8 ‰ and 11.9±3.4 ‰ respectively, showing an unusually 'light' signal. Additionally, the nutritional quality of POM_{susp}, approximated by relative amounts of polyunsaturated fatty acids, was low (PUFAs; 0.32±0.23%total lipids). PCA with Simprof clustering showed distinct grouping between the lipid profiles of $POM_{susp,}$ and *A. excavata* and CWCs tissues. Significant differences were detected between isotope signatures of POM_{susp}, *A. excavata* and CWCs. Several explanations are discussed, related to timing of sampling, potential internal recycling and trophic upgrading of the investigated filter feeders

and/or the degrading impact of the complex and occasionally anthropogenically induced hydrodynamics of the areas sampled.

Smith C[1]
[1]University of Hawai'i at Manoa, Honolulu, HI, USA.
Talk: Abstract #83 / Session T2 - Deep Sea Mining 2 - environmental aspects: baselines, impacts, monitoring

FROM SCIENCE TO POLICY: THE DESIGN, IMPLEMENTATION, AND REVISION OF NO-MINING AREAS TO CONSERVE BIODIVERSITY DURING NODULE MINING IN THE CLARION-CLIPPERTON ZONE

The Clarion-Clipperton Zone (CCZ) is a vast region targeted for polymetallic-nodule mining. To safeguard seafloor biodiversity across the CCZ, a 2004 Pew Fellowship in Marine Conservation supported design of a network of nine 400x400 km no-mining areas. The design used environmental correlates of biodiversity to help protect the full range of seafloor habitats and communities potentially impacted by nodule mining. In 2012, the International Seabed Authority (ISA) partially followed our recommendations and designated nine no-mining areas, now called Areas of Particular Environmental Interest (APEIs). From 2012- 2019, many new biodiversity studies occurred in the CCZ, leading to the convening of 47 scientific experts at the Deep CCZ Biodiversity Synthesis Workshop to review biodiversity data from the CCZ and to evaluate the representivity of APEIs relative to mining exploration areas. I synthesize results from 17 workshop-related publications to show that: (1) Biodiversity is high and still poorly sampled across the CCZ, with thousands of new species to be collected/described; (2) Key biodiversity drivers include POC flux, nodule abundance, and bottom topography; (3) Connectivity patterns vary across the CCZ and across taxa, with some species occurring widely while most have been collected only at single sites; (4) The original APEI network captured substantial habitat variability, but nodule-rich habitats were poorly represented and needed protection in additional APEIs. Our synthesis and other studies led the ISA to implement 4 new APEIs to capture nodule-rich habitats. This provides an important case study of scientist/policy-maker cooperation to institute environmental protections before extractive activities begin.

Smith H[1]**; Rabe B; Holah H; Clayton L; Clarke L; Watret R; Holah H; Grewar G**
[1]Marine Scotland Science.
Poster: Abstract #211 / Session T22 - Strengthening Equality, Diversity, Inclusivity and Accessibility in Marine Science

Developing a Scientist-in-Charge (SIC) Pathway for Marine Scotland Science's research vessels as part of an Athena-SWAN action to create a gender balanced SIC pool

Historically, successors for Scientist-in-Charge (SIC) roles on Marine Scotland Science's (MSS) research vessels were chosen by existing SICs and contingency planning was usually lacking. The Athena-SWAN bronze award action plan included an Action Point (AP) to develop a structured, open and fair approach to SIC succession planning and training (the "SIC Pathway") within MSS. The AP was created in response to the low numbers of female SICs on MSS cruises, ~10% (2015-19), while the % of female sea-goers was ~32%. In other international institutions the proportion of female SICs is ~20-30%. The overall aim of this AP was to achieve a 100% increase in female SICs, from 3 (2019) to 6 by 2022. The training role of co-SIC was created, whereby a prospective SIC could shadow an existing SIC for a selected number of tasks per cruise, over time gaining enough experience to become an SIC. The co-SIC concept was tested on a small number of cruises in 2020/2021, with feedback gathered from the co-SIC and SIC to help refine the Pathway. Buy-in from senior staff has proved vital in getting the co-SIC Pathway off the ground and influencing late adopters. We have successfully developed resources and implemented the Pathway, with two co-SICs progressing to SICs in 2021, and at least two more on track for 2022. Originally gender-driven, the main aim is to benefit everyone by making the path for development and training consistent, transparent and fair, creating a more diverse and larger pool of SICs.

Søreide F[1]
[1]Promare , Norwegian University of Science and Technology.
Talk: Abstract #58 / Session T7 - Pushing the limits in autonomous oceanography in a net zero carbon world

Towards the Unmanned Research Vessel

The last few years have seen a drive towards unmanned and autonomous ships. Small drones have been used for marine research and oceanography, but there are now several full size ships in operation or under development. This talk will present the Mayflower Autonomous Ship, the first full-sized unmanned and autonomous research vessel in operation. It will also present the planned activities of the Ocean Infinity adjunct science program, which will do ocean science from a fleet of commercial unmanned ships up to 78 meters in length. Unmanned research vessels will likely constitute a paradigm shift for ocean research going forward, much the same way the Challenger expedition defined the field 150 years ago.

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Talk: Abstract #15 / Session T15 - Carbon cycling in the global ocean and the role of blue carbon in climate mitigation

Barents Sea Benthic Blue Carbon with respect to different habitats and its role as nature based solution to climate change

Sustained intense warming has led to massive Arctic seasonal sea ice losses. This has caused new and longer phytoplankton algal blooms, and responsive growth increases of benthos, driving increases in zoobenthic blue carbon (carbon held within marine animals). This is important because it is a powerful negative feedback on climate change (warming decreases marine ice, which increases algal bloom duration, benthic growth, immobilization of seabed carbon and removal of carbon from cycling). The first aim is to quantify Barents Sea blue carbon and functional groups with respect to different habitats – feed into management plans for protection of high blue carbon areas which could offer a nature based solution to climate change mitigation The second aim is to test a multi stressor approach on the quantity of benthic blue carbon and functional groups with respect to trawling intensity and frequency alongside climate change. Calibrated vertical camera deployments were made to get accurate replicate seabed images across 17 sites to calculate densities of epi-benthic functional groups. Three replicate Agassiz trawls were towed to collect specimens of zoobenthos which were also identified before measuring morphometrics, drying, weighing and ashing and reweighing. Size spectra and carbon content of functional zoobenthic groups were calculated and analysed against physical factors measured at the time of collection.

Spingys C[1]; Naveira-Garabato A; Polzin K; Voet G; Wynne-Cattanach B; Alford M
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Talk: Abstract #306 / Session T15 - Physical Oceanography Open Session – Energetics and Mixing

Observations of turbulence, temperature variance and mixing on a sloping bottom boundary

Recent theoretical work proposes that the bulk of deep-ocean upwelling may be focused on turbulent bottom boundary layers along the ocean's sloping side walls driven by diapycnal mixing. This requires a reduction in the buoyancy flux as one approaches the boundary, opposite to the bottom enhanced mixing typically seen in observations. In the Boundary Layer Turbulence and Abyssal Recipes project we set out to observe this process on the sloping sides of the Rockall Trough. Here we present data from two moorings deployed from July to October 2021 as part of this project. These moorings include Modular Acoustic Velocity Sensors capturing high temporal resolution (5 Hz) velocities and temperature at 8 depths through the bottom 300 m of the water column alongside approximately 80 temperature loggers at up to 1m vertical resolution. These data allow us to calculate the buoyancy flux using an eddy covariance approach, construct a temperature variance budget, and estimate more typical turbulence parameters such as the turbulent kinetic energy (TKE) dissipation and temperature variance dissipation rates. In combination these allow us to explore a series of vital questions about the turbulence and mixing underpinning the boundary driven upwelling idea. Is the bottom boundary well mixed? Is the buoyancy flux down the mean gradient? Does the buoyancy flux reduce towards the boundary? Does the buoyancy gradient and flux vary on both short and long timescales? Can we assume a local production-dissipation balance for temperature variance? How efficient is the boundary mixing?

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Talk: Abstract #361 / Session T23 - Unlocking Climate Histories from Marine Sediments

The Maldivian archipelago marine sediment archives: Exploring the last ~500 kyr

The South Asian Monsoon (SAM) is one of the most dynamic climatic systems on earth and considering its vast extent and impact, understanding how it has responded to past climatic perturbations is vital. In this regard, multi-species foraminiferal studies are the ideal tool to interpret and track past oceanic conditions and its link with climatic variability. We have analysed samples from International Ocean Discovery Program (IODP) Expedition 359, Site U1467 drilled in the Inner Sea of the Maldivian archipelago in the northern Indian Ocean. In conjunction to our high-resolution, long-term (δ18O, δ13C and Mg/Ca) records, spanning the last ~500 kyr, we use multi-species analyses to reconstruct the vertical structure of the water column (thermal, δ18Osw and salinity) and its link to SAM and northern Indian Ocean circulation variability. Furthermore, the utilisation of Individual Foraminiferal Analysis (IFA), allows past interglacial temperature maxima to be explored in relation to transgressions in bleaching thresholds. IFA studies are particularly insightful as they provide a means to extract information on the frequency and magnitude of bleaching threshold transgressions, which is a primary threat to global tropical reefs.

Funding for this research is provided by the Swiss National Science Foundation (SNSF) projects 200021_165852 / 1 and 200020_201106 / 1.

Stappard D[1]; Tyrrell T
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Poster: Abstract #253 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

A new technique of identify upwelling in the Southern Ocean from BGC-Argo floats.

The Southern Ocean surrounds the continent of Antarctica, linking the southern sections of the Atlantic, Indian and Pacific Oceans. It plays a fundamental role in the global overturning circulation and is the site of upwelling of deep water. The ability to identify upwelling is important as it supplies nutrient-rich water to the surface but also for the role it plays in water-mass formation dynamics. The deep water is depleted in oxygen (O2) and enriched in carbon dioxide (CO2) after supporting extensive remineralisation of organic matter. Enhanced ability to identify upwelling in the Southern Ocean will improve the understanding of Earth's carbon cycle and assist in predicting the impact of anthropogenic perturbations. The Southern Ocean Carbon and Climate Observations and Modeling project have deployed a network of autonomous Argo floats throughout the Southern Ocean. Here we propose a method of identifying upwelling that utilises the biogeochemical data from Argo floats. Argo float data was analysed and segregated temporally by season, and spatially by zone. Biogeochemical data has facilitated the examination of [CO2] and [O2] Relative to Saturation (CORS). This research has supported the value of the CORS methodology in identifying biogeochemical processes and their influence on surface waters. It has also shown that identification of upwelling using in-situ measurements by autonomous Argo floats is feasible.

Stewart E[1]; Bribiesca-Contreras G; Wiklund H; Dahlgren T; Glover AG
[1]Natural History Museum.
Poster: Abstract #131 / Session T14 - A decade of deep ocean science for sustainable development

Deep-sea parasite-host relationships: A new genus of Myzostomida from the Pacific abyss

The Myzostomida von Graff, 1887 are a small order of parasitic marine annelids, with only around 170 species described to date. This specialised group is associated with echinoderms and anthozoans, with most species living on or inside crinoids, and very few on asteroids and ophiuroids. Co-evolutionary analyses have indicated a strong phylogenetic relationship between myzostomids and their hosts, however there is limited data available on the relationships been these parasites and asteroid hosts. There are currently seven described families within the order, of which two – Asteriomyzostomidae and Asteromyzostomidae – are characterised by being endo- and ectoparasitic on asteroids respectively. Here we describe a new genus and species of Asteromyzostomidae, the first species of Myzostomida described from abyssal depths. Specimens were found infecting the dorsal surface

of the starfish Styracaster paucispinus Ludwig, 1907, at 4500 m deep in the equatorial Pacific Ocean. An integrative taxonomic approach was undertaken, including microCT scanning of individual myzostomids, and specimens attached to a host, allowing for a complete understanding of the species morphology.

Stewart E[1]; Bribiesca-Contreras G; Wiklund H; Taboada S; Ravara A; Pape E; Smet Bd; Neal L; Cunha MR; Jones DOB; Smith CR; Glover AG; Dahlgren T
[1]Natural History Museum.
Talk: Abstract #130 / Session T2 - Deep Sea Mining 2 - environmental aspects: baselines, impacts, monitoring

Biodiversity, biogeography, and connectivity of polychaetes in the world's largest marine minerals exploration frontier

The Clarion-Clipperton Zone (CCZ), equatorial Pacific Ocean, has become an area of commercial importance owing to the growing interest in mining high-grade polymetallic nodules at the seafloor. Nodule mining is expected to have a significant impact on the vulnerable and diverse abyssal fauna found in the CCZ. However, spatial patterns of faunal diversity and community composition are still largely unknown. Here, a DNA taxonomy approach is used to investigate patterns of taxonomic and phylogenetic alpha and beta diversity, and genetic connectivity, of polychaetes (Annelida) across the abyssal seafloor. Connectivity analyses were based on haplotype distribution data for a subset of the studied taxa. DNA taxonomy identified 280 – 289 polychaete species from the COI and 16S datasets respectively, with remarkably high alpha diversity across the CCZ. Both taxonomic and phylogenetic beta diversity were high between sites, and were mostly explained by lineage turnover. Comparison against a null model found that over half of pairwise comparisons were more phylogenetically distinct than expected based on their taxonomic diversity. The connectivity analyses indicate absence of population structuring at the spatial scale studied. These results suggest that environmental filtering, rather than dispersal limitation, plays a greater role in regulating spatial patterns of biodiversity in the CCZ. This represents the first insight into both taxonomic and phylogenetic beta diversity for macrofauna at a regional scale inhabiting a potential deep-sea mining zone and provides new insights into the processes driving diversity on abyssal seafloors.

Stratmann T[1]
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Talk: Abstract #227 / Session T2 - Deep Sea Mining 2 - environmental aspects: baselines, impacts, monitoring

Role of polymetallic-nodule dependent fauna on carbon cycling in the eastern Clarion-Clipperton Fracture Zone (Pacific)

The seafloor in the Clarion-Clipperton Fracture Zone (CCZ) is covered with large densities of polymetallic nodules. These nodules are of economic interested and considered potential future resources for said metals, but they also host a variety deep-sea fauna. Recently, it was estimated that the removal of these nodules would lead to a loss of up to 18% of all taxa in the CCZ. Here, I assess the impact of removing these nodule-dependent taxa on carbon cycling in the Belgian license area in the eastern CCZ. For this purpose, I developed two highly-resolved carbon-based food web models consisting of different detritus pools, bacteria, metazoan meiobenthos, macrobenthic isopods, polychaetes and other macrobenthos, megabenthic cnidarians, crustaceans, poriferans, holothurians and other invertebrate megabenthos, and fish. These compartments were connected with 304 to 331 links which were reduced by 5% when nodule-dependent faunal compartments were removed. The models estimated the total system throughput T.., i.e., the sum of all carbon flows in the food webs, in intact food webs as 1.20 mmol C m-2 d-1 to 1.24 mmol C m-2 d-1, whereupon 67.7% to 69.8% of T.. flowed through the microbial loop. A removal of the nodule-dependent fauna did not affect this microbial loop, but reduced the scavenger loop by 49.7% to 67.9%. Overall, nodule-dependent fauna is responsible for only small fraction of total carbon cycling at the eastern CCZ. Therefore, when the effect of prospective deep-seabed mining on carbon cycling is investigated, its impact on benthic prokaryotes and the microbial loop should be addressed.

Street O[1]; Holm DD; Hu R
[1]Imperial College London.
Talk: Abstract #223 / Session T19 - Mathematics of Satellite Oceanography

Coupling of waves to sea surface currents via horizontal density gradients

Capabilities in sea surface observation have been improving rapidly during the past two decades, revealing rich submesoscale dynamics on the ocean surface. These new higher-resolution observations will present a formidable array of challenges for the next generation in data management, computational simulation and mathematical modelling. The assimilation of this data requires principle-driven deterministic modelling and data-driven stochastic parameterisations. We will discuss new deterministic models, designed to investigate the responses of the ocean upper layer to the effects of global warming. Specifically, this involves the interactions of thermal fronts with ocean waves and currents, for which satellite observations reveal high emergent coordination.

Sweetman A[1]; Smith A; Jonge Dd; Hahn T; Schroedl P; Silverstein M; Allen KM; Edwards RL; Marlow J
[1]The Lyell Centre for Earth and Marine Science and Technology, Heriot-Watt University, Edinburgh, UK.
Talk: Abstract #303 / Session T2 - Deep Sea Mining 2 - environmental aspects: baselines, impacts, monitoring

Unique oxygen dynamics at the abyssal seafloor of the Clarion-Clipperton Fracture Zone points to a previously uncharacterized biogeochemical process

Numerous deep-sea studies have demonstrated clear oxygen (O2) consumption at the seabed in the presence of organic material exported from the pelagic zone. The O2 consumed at the seafloor has long been thought to be supplied by air-sea gas exchange and photosynthesis, which releases O2 into the atmosphere and surface ocean; oxygen-perfused surface waters sink into the deep sea and circulate around the world providing oxygen for deep-sea life. We performed 16 benthic incubations to measure benthic O2 consumption at 4200m depth at 2 locations separated by >100km in the eastern Clarion-Clipperton Zone (CCZ) of the abyssal Pacific Ocean using a seafloor respirometer. Optode measurements made every 10 seconds in the chambers revealed that O2 concentrations increased to 309% above background levels over 48 hr, indicating unprecedented benthic oxygenic activity over large spatial scales. Oxygen production reached 16.51 mmol O2 mmol m-2 d-1, equivalent to 14% of the gross primary production rate in the euphotic equatorial Pacific. Optode data was supported by Winkler analysis on water samples collected periodically from the chambers, and seafloor micro-profiles pointed to oxygenic activity occurring within the surface sediments. A re-evaluation of optode data from other seafloor locations in the western and eastern CCZ also indicated oxygenic activity, indicating its widespread occurrence. It is unclear which process(es) are responsible for the O2 production, but our data show that net O2 consumption is not a universal property of the deep seafloor; rather, O2 production occurs and may help oxygenate the deep sea with widespread ecosystem effects.

Tagliabue A[1]; Buck K; Sofen L; Twining B; Aumont O; Caprara S; Homoky WB; Johnson R; Ohnemus D; Sohst B; Sedwick P
[1]University of Liverpool.
Talk: Abstract #186 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

Escaping the ligand trap: authigenic mineral phases control the ocean iron cycle

Via its control on upper ocean primary production, dissolved iron (DFe) is a key regulator of the ocean carbon cycle. Although many different dissolved and particulate iron species participate in the ocean iron cycle, our current understanding emphasises the importance of organic ligand complexation of ferric ions in modulating oceanic dFe distributions. Here we show that the cycling of iron through authigenic mineral phases, independently of organic ligands, is an essential process regulating the distribution of iron in the ocean. A unique seasonal data set comprising DFe, ligands and particulate iron phases from the Bermuda Atlantic Time-series Study region reveals marked seasonal changes in the upper ocean DFe inventory despite year-round excesses in organic ligands. Our observations can be explained by colloidal iron (oxyhydr)oxides cycling out of equilibrium with ligands, resulting in a significant upper-ocean reservoir of authigenic particulate iron that settles through the ocean interior. When implemented in a global-scale biogeochemical model, this new paradigm reproduces the observed data where previous models have failed. Overall, our results demonstrate that the formation, sinking and solubilisation of iron (oxyhydr)oxides play a hitherto underappreciated role in shaping the distribution and residence time of iron in the ocean across multiple timescales.

Takeuchi M[1]
[1]National Oceanography Centre.
Talk: Abstract #266 / Session Session T15 - Carbon cycling in the global ocean and the role of blue carbon in climate mitigation

Size distribution of aggregates in coastal and pelagic waters: potential roles of aggregates in the oligotrophic wood webs.

Marine aggregates are ubiquitous particles formed through the accretion of smaller biogenic and non-biogenic components. Visible aggregates, known as marine snow, are typically larger than 0.5 cm and important pathway for transferring materials from the surface to the deep ocean (Busseler & Boyd, 2009). Previous studies have also shown that some zooplankton and fish larvae feed on aggregates (Larson & Shanks, 1996, Möller et al., 2012, Tsukamoto & Miller, 2020), suggesting the importance of aggregates in the ecosystems as nutrient input to food webs. The Kuroshio current off the coast of Japan transports warm and high salinity water, but oligotrophic, from south to north.Various pelagic fish utilizes the Kuroshio as spawning and nursery grounds (Nagai et al., 2019, Sogawa et al., 2019), despite the low productivity in the region. Aggregates may be the key food source to support high trophic level in such oligotrophic waters, however, our understanding of aggregate properties, such as abundance and size distribution, in the Kuroshio is still limited due to insufficient field observations. In this study, we will present size distribution and abundance of aggregates that are measured by an optical instrument in the Kuroshio and coastal region of Japan. By comparing biological and physical variables are measured simultaneously with aggregates, we investigate the interaction between biological and physical variables with aggregate properties. We will also discuss the potential roles of aggregates in the oligotrophic food webs.

Tambre G[1]**; Woulds C**
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Poster: Abstract #140 / Session T12 - Interactions between plastics and marine ecosystem

A Systematic review on Microplastics pollution in Marine Sediment; from coastal to the deep-sea habitat around the globe.

The prevalence of microplastics (MP) has been continuously raised by many researchers all over the world since their first discovery in the marine environment in 2004. Marine sediments are considered to be a major global sink for microplastics in the marine ecosystem with potential threats to benthic communities. However, we are still suffering from data scarcity on MP abundance in marine benthic sediments. Published studies on the abundance of MPs in marine sediments vary in their sampling techniques, extraction protocols, interpretations, and use of diverse measuring units, which makes existing data complex and challenging to compare. To address this challenge, we have reviewed a total of 107 published articles in this field, including 75 studies on microplastics pollution in marine sediments, and 32 on their effect on benthic communities in natural and controlled environments around the globe. Our review revealed that 39 studies are available on coastal/intertidal (52%) and 31 on shelf/subtidal sediment (41%), which receive the most attention, compared to deep-sea sediment with only 10 articles (13%) for all geographic regions. These numbers illustrate a major gap in this field of deep-sea research. Moreover, 17 and 15 different studies have reported on the biological effects of MP pollution on the marine benthic community in controlled and natural environments respectively. Based on this literature review, we strongly recommend the adoption of standard laboratory protocols and using a common unit of measurement which would aid the comparability of data sets in the future.

Tate A[1]
[1]British Antarctic Survey.
Poster: Abstract #331 / Session T6 - Towards a Net Zero Oceanographic Capability

Continued development of a data management system for the new UK polar research vessel, the RRS Sir David Attenborough

The new UK polar research vessel, RRS Sir David Attenborough, hosts a wide array of scientific instrumentation and as a marine platform will deploy a range of remotely-operated data gathering equipment, both marine and airborne. The resulting datasets are both complex and voluminous and their management and availability need to fulfil the requirements of a wide range of end users from cruise participants to global data archiving facilities. The UK Polar Data Centre, based at the British Antarctic Survey, is leading on the development of the scientific data management systems aboard the new vessel. Major areas of focus include; data and event logging, data visualisation and access, automated quality control routines and sensor metadata. The presentation will provide an update on these major focus areas as well as an up-to-date overview of the scientific instrumentation currently being commissioned on the vessel and the types of data that are now being routinely collected.

Tate K[1]; Copley J
[1]University of Southampton.
Poster: Abstract #268 / Session T2 - Deep Sea Mining 2 - environmental aspects: baselines, impacts, monitoring

Deep-sea reducing ecosystems under a future worst-case scenario: Combining anthropogenic impacts

Hydrothermal vent communities are expected to be impacted significantly by future exploitation and climate activities. The level of protection and regulation afforded to these unique ecosystems against deep sea mining could greatly influence the level of impact they will face. However, a lack of anthropogenic disturbance studies on hydrothermal vent systems hinders informed regulation. Current research on the cumulative loss of ecosystem structure from all anthropogenic activities are spatially limited and based on expert opinion rather than the results of anthropogenic disturbance studies. In multiple locations worldwide, cold seeps are found in geological settings close to that of hydrothermal vents and could encounter some second-hand impacts from deep sea mining activity. This study presents new examples of: - Evidence based semi-quantitative analysis of the impacts of seafloor massive sulphide mining on hydrothermal vent and cold seep community structure. - Combining the impacts of SMS mining and climate change on hydrothermal vent and cold seep community structure. - Predictions of the resulting community structure for all biogeographic hydrothermal vent and cold seep regions. Using a hydrothermal eruption as a proxy for mining activity, in combination with ordination techniques, this project will predict which species are likely to recover after the combined impacts of anthropogenic disturbance and climate change based on the traits of lost and recovered species after disturbance. This study should not be considered a reliable estimation of community composition post-disturbance, but a stepping-stone towards more reliable predictions of community composition under anthropogenic impacts.

Tatkiewicz W[1]; Schuster U; Watson A
[1]University of Exeter.
Talk: Abstract #308 / Session T7 - Pushing the limits in autonomous oceanography in a net zero carbon world

Autonomous oceanography for improved estimates of sea-air CO2 exchange

The identification of the ocean uptake of atmospheric CO2 is crucially important for the estimation of the ocean capacity to mitigate climate change. In addition, regular, low-cost measurements are required to capture spatial and temporal variability. At the University of Exeter, we are developing a small instrument for the deployment on a number of different autonomous surface vehicles (ASVs) for the measurement of upper ocean and lower atmosphere parameters required for the determination of the sea-air CO2 exchange. This has the potential of deployment and retrieval on from the coast, i.e. significantly reducing the carbon-footprint of oceanographic measurements, compared to system requiring deployment from research vessels. We will present the instrument and its initial trials on different ASVs.

Taylor A[1]; Green M; Wilmes S; Way M
[1]Bangor University.
Poster: Abstract #222 / Session T28 - Physical Oceanography Open Session - Coastal Physics

Impact of tidal mixing changes on future deep time Earth's ocean circulation and climate

The pursuit to find a habitable extrasolar planet is at the forefront of exoplanet research and benefits from collaborations with Earth scientists, e.g., by using deep time Earth climate modelling as a proxy for Earth-like exoplanets. For Earth's oceans, vertical mixing is a key controller of the meridional overturning circulation, and therefore on large-scale ocean heat transport and surface climate. Its magnitude is in part controlled by the continental configuration and its effect on tidally driven mixing, so we have used two possible future supercontinents – Amasia and Aurica - to investigate the influence of vertical diffusivity on the climate of deep time Earth with land distributions very different from today. We use ROCKE-3D - a fully coupled ocean-atmosphere GCM - to simulate the climate of Amasia and Aurica with varying vertical diffusivity coefficients: one with tidally driven mixing removed, and another with a realistic tidal coefficient obtained from tidal model simulations. We find that reduced vertical diffusivity led to stronger global ocean stream functions in both supercontinent simulations, whereas in the preindustrial control run it weakened, suggesting that ocean circulation in both supercontinent scenarios responds counterintuitively to reduced ocean mixing. Initial results here indicate that present day Earth's continental configuration, and therefore its ocean mixing regime and circulation, may be highly unusual and therefore not the best proxy for Earth-like habitable exoplanets. This work further highlights the importance of incorporating an accurate ocean mixing scheme into deep time Earth and exoplanet climate models to more accurately assess habitability.

Taylor J[1]
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Talk: Abstract #362 / Session T28 - Physical Oceanography Open Session - Coastal Physics

Submesoscales under near-resonant inertial shear experiment (SUNRISE)

Wind-driven near-inertial waves form a major component of the internal wave field. Mesoscale and submesoscale eddies play an important role in generating downward propagating near-inertial waves, but the physics involved are not fully understood. Wind forcing excites inertial oscillations (IOs), predominately at large scales. IOs are known to be modified by the vorticity associated with mesoscale eddies, decreasing the associated horizontal length scales and permitting more rapid downward energy propagation. Most of the existing theories for this process rest on an assumption that the eddy Rossby number is small. Submesoscale eddies are characterized by a Rossby number of order unity. Although submesoscales are expected to influence the generation of near-inertial waves, observations and theory of this process is lacking. The joint NSF-NERC funded SUNRISE project aims to study the influence of submesoscale fronts and eddies on near-inertial waves. The project involves two field campaigns in the northern Gulf of Mexico. Here, close to the critical latitude, a diurnal sea breeze resonantly forces near-inertial oscillations. These IOs interact with a vigorous field of submesoscale eddies and fronts associated with the Mississippi/Atchafalaya river plume. In this talk, I will summarize recent combined theory/modelling/observational results from the SUNRISE project.

Taylor J[1]**; Kamyab E; George KH; Kieneke A; Linse K; Arbizu PM; Neuhaus J; Schumacher M; Brix S**
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Talk: Abstract #220 / Session T14 - A decade of deep ocean science for sustainable development

What is the IceDivA project? Research expeditions and science in the face of Covid-19

During the Covid-19 pandemic research fleets were docked the World over. To keep their research fleet running, Germany issued emergency "Pandemia calls" for research expeditions to embark and disembark in Emden, Germany. As an answer to these calls the "Icelandic marine Animals meets Diversity along latitudinal gradients in the deep sea of the Atlantic Ocean" (IceDivA) project was born. Flying under the Challenger 150 banner, this project focuses on abyssal plain communities east and west of the Mid-Atlantic Ridge, as well as planktonic communities throughout the water column. By sampling Northwest and Northeast Atlantic deep-sea basins, IceDivA aims to extend the previous Northeast Atlantic deep-sea program, IceAGE (Icelandic marine Animals: Genetics and Ecology), also linking with the South Atlantic deep-sea programme DIVA (Latitudinal Gradients in BioDIVersity in the deep Atlantic), as well as those in the Southern Ocean, providing pan-Atlantic deep-sea samples to investigate topics regarding species richness and evolution. To map the species diversity, and answer questions on the connectivity of deep-sea fauna along latitudinal gradients in the pan-Atlantic Ocean, we sampled in 3,000 m to 5,500 m water depths bridging the Atlantic knowledge gap between prior expeditions. Here we will present an overview of the IceDivA project, including: the narrative of two research cruises; IceDivA1 (08.01-

07.02.2021) and IceDivA2 (05.11-09.12.2021), participation in the UN Ocean Decade, ongoing research, preliminary results, our mapping of marine litter, and the outlook for the project.

Taylor M[1]; Henson S; Sahu S; Cael B; Hammond M
[1]National Oceanography Centre (Southampton).
Poster: Abstract #216 / Session T7 - Pushing the limits in autonomous oceanography in a net zero carbon world

Spatio-temporal modelling of subsurface chlorophyll maxima using BGC-Argo profiles

Often the highest concentration of chlorophyll a (Chl-a) is not found at the top of the water column, but instead in the ocean interior, resulting from limitations in nutrients and light from above and below respectively. This phenomenon is called a subsurface chlorophyll maximum (SCM) and it is a common feature across much of the global ocean. Properties of SCMs, such as depth and concentration, vary seasonally and between regions, depending on the local availability of light and nutrients. Chl-a profiles from biogeochemical (BGC) Argo floats have previously been used to identify differences in vertical Chl-a structure across space and time, although formal geostatistical modelling has not been attempted. We have developed a novel approach to assess the spatio-temporal variability of SCM depth (Z_SCM) and concentration (Chl_SCM) of over 30 000 BGC-Argo profiles in the Atlantic Ocean. We present Bayesian hierarchical models containing a Gaussian predictive process (GPP) to incorporate correlation between neighbouring observations. GPPs are used because they account for the movement of floats between observations as well as the variable number of observations on any given day. We fit univariate models for Z_SCM and Chl_SCM and a bivariate model for both response variables using biogeochemical and physical predictors. Markov chain Monte Carlo sampling is used to estimate parameter values and quantify uncertainty in predictions. This work provides a framework for both univariate and multivariate spatio-temporal modelling using the BGC-Argo float network.

Tedesco P[1]; Mashayek A; Naveira-Garabato A; Mazloff M; Caulfield C; Gille S; Cornuelle B; Baker L
[1]Imperial College London, London, United Kingdom.
Talk: Abstract #141 / Session T25 - Physical Oceanography Open Session - Ocean Eddies

Mixed layer energetic dynamics across scales in the Drake Passage

The mixed layer (ML) is a key component of the global climate system, as it contributes to momentum, heat and gas exchanges between the ocean and the atmosphere. These exchanges are controlled by the ML dynamics, which is characterized by strong scale interactions between mesoscale eddies, submesoscale currents and waves. Submesoscale currents are, in particular, a key component as they can have contrasted contributions to the ML dynamics. Understanding the contribution of scales, in the meso and submesoscale ranges, to the ML dynamics represents a fundamental issue and a technical one in view of numerical models. We focus on the Drake Passage — a region of the Southern Ocean of highly energetic and deep ML — at the end of winter. Here we show that the contribution of the submesoscale currents to the ML dynamics (energy source or sink for the mesoscale range) is driven by the currents' dynamical regime. We found that balanced (coupled balanced-unbalanced) part of submesoscale currents transfer energy toward larger (smaller) scales. The transition scale between balanced- to unbalanced-dominated dynamical regimes occurs at O(10)km. It indicates that submesoscale currents represents an energy source for the mesoscale range down to O(10)km and an energy sink below. Our results emphasize the impact of small scales onto larger ones and the need to resolve or parameterise them to accurately simulate the ML dynamics. It calls for further analysis to complete our understanding of the ML dynamics in this region, such as assessing the energy sources and sinks for the submesoscale range and their sensitivity to the ML seasonal cycle.

Tedesco P[1]; Gula J; Penven P; Ménesguen C; Jamet Q; Vic C
[1]Imperial College London.
Poster: Abstract #194 / Session T24 - The Atlantic Meridional Overturning Circulation: Observations, Simulations and Equations

Can mesoscale eddy kinetic energy sources and sinks be inferred from sea surface height in the Agulhas Current ?

Mesoscale eddies are a key component of the ocean energy budget. Although their generation are largely documented, how their energy is dissipated remains uncertain. A closure to their lifecycle — decay at western boundaries — has been suggested using an eddy kinetic energy (EKE)-fluxes divergence based on sea surface height (SSH). However, the SSH-based diagnostic requires several approximations, including geostrophic velocities. Understanding to what extent, mesoscale EKE-fluxes divergence (EKE sources and sinks) can be inferred from SSH is a fundamental issue for ocean dynamics and study strategy. We investigate the impacts of the approximations on the EKE-fluxes divergence using a numerical simulation of the Agulhas Current. Here we show that both components of EKE-fluxes divergence indicate net mesoscale EKE sources that are not reliably accounted by both SSH-based diagnostics. Advection of EKE (nonlinear component) mainly accounts for geostrophic fluxes. Eddy-pressure work (linear component) mainly accounts for ageostrophic fluxes. The dominating-ageostrophic eddy-pressure work can be explained by the scale of mesoscale eddies falling below the scale of Ro f/beta (Ro : Rossby number; f : Coriolis parameter; beta : latitudinal variations of f). The EKE-fluxes divergence is dominated by the advection of EKE, therefore enabling its qualitative estimation using SSH (up to 46% of the net mesoscale EKE source). Our results in the Agulhas Current show a mesoscale eddy dynamics contrasted with the lifecycle´s closure at western boundaries. It calls for analysis in other western boundaries to complete our understanding of mesoscale eddies lifecycle.

ten Hoopen P[1]; Novellino A; Alba M; Hancock A
[1]British Antarctic Survey.
Poster: Abstract #133 / Session T6 - Towards a Net Zero Oceanographic Capability

A data system for the Southern Ocean

The Southern Ocean connects the world's ocean basins and acts as a sensitive indicator of oceans' health. Researchers and data professionals from more than 40 countries are part of the Southern Ocean Observing System (SOOS), which facilitates the collection and delivery of essential observations on dynamics of Southern Ocean systems. This collaborative community aims to develop an interoperable data ecosystem that serves a multitude of scientific disciplines and, with a minimum of centralised funding, depends on the generosity and cooperation of a broad community. At the centre of the Southern Ocean data system is SOOSmap - a portal for well curated and standardised datasets of key circumpolar interest, which draws on the infrastructure of EMODnet Physics. It provides not just access to datasets but also a very visible way to identify gaps in observing and data sharing efforts in the Southern Ocean. SOOS is also working with international colleagues to develop a federated metadata search based on Schema.org, as an attempt to bridge the seemingly intractable differences in metadata standards across scientific communities, to enable access to data coming from the wide variety of process studies that cannot be made available in a unified way. Here we present a new version of the portal, SOOSmap version 2, developed by the EMODnet Physics and supported by the SO-CHIC project. We will highlight key features designed for better discoverability of datasets and for improved usability of this tool that strives to get research data 'on the map'.

Thorpe S[1]; Young E; Murphy E
[1]British Antarctic Survey.
Poster: Abstract #47 / Session T10 - Micro to macro: linking bottom-up and top-down approaches that investigate the function, resilience and conservation of polar ecosystems

Modelling Antarctic krill distribution at South Georgia: from physics to fisheries management

South Georgia, a subantarctic island in the southwest Atlantic sector of the Southern Ocean, is a biological hotspot. The marine ecosystem is highly productive, supporting large numbers of higher predators that breed on South Georgia. For many of these predators, their main prey is Antarctic krill (*Euphausia superba*). In addition to demand for krill from the predators, a winter-only fishery for krill operates in localised areas of the northern continental shelf of the island. The distribution of krill on the shelf around South Georgia is spatially and temporally variable, relying on influx of krill from upstream of the island. Understanding the influx of krill to the shelf, their subsequent movement and retention, and the potential impacts of fishing on regional krill availability and ecosystem processes, is key to the management of the krill fishery at South Georgia. Here we present results from a modelling study that aims to understand the processes driving the retention and dispersal of Antarctic krill

on the northern shelf of South Georgia. The use of oceanographic models allows investigation of such processes throughout the year, with consistent spatial and temporal coverage. We use output from a 20-year run of a high resolution (~ 3 km) regional ocean model to provide quantitative information on the connections (pathways and timescales), retention (rates and spatial variability) and fluxes in the main areas of fishing and predator demand around South Georgia that will contribute to the development of the management framework for the krill fishery.

Tooth O[1]; Johnson H; Wilson C
[1]University of Oxford.
Talk: Abstract #97 / Session T24 - The Atlantic Meridional Overturning Circulation: Observations, Simulations and Equations

Seasonal overturning variability in the eastern subpolar North Atlantic Ocean: A Lagrangian perspective.

The strength and variability of the Atlantic Meridional Overturning Circulation (AMOC) at subpolar latitudes is dominated by water mass transformation in the eastern subpolar North Atlantic. Both observations and reanalyses find a pronounced seasonal cycle in the AMOC within this region, however, the distribution of overturning variability across the individual circulation pathways of the Subpolar Gyre (SPG) remains poorly understood. Here, we use a recently developed Lagrangian measure of the density-space overturning to identify the dominant pathways of overturning seasonality within an eddy-permitting ocean model hindcast. By evaluating the trajectories of water parcels released from the northward inflows across the OSNAP East section, we find a clear distinction between the advection times of pathways which contribute substantially to the mean strength of the AMOC and those responsible for its variability on seasonal timescales. Seasonality in our Lagrangian overturning metric results from water parcels which are transformed by seasonal heating/cooling during rapid recirculation (3-9 months) in the upper 250m of the Irminger and Iceland Basins. The recirculation time of water parcels circulating in the upper Irminger Sea also exhibits a strong seasonal cycle: parcels advected northwards in winter typically require an additional 1.5 months to return to OSNAP East compared with those released during summer. The decrease in upper Irminger Sea recirculation times through spring leads to increasing convergence of southward transport within the density classes of the upper limb in the East Greenland Current during autumn, and thus explains the simulated seasonal minimum in the Eulerian overturning at OSNAP East.

Veloy C[1]; Coll M; Penino MG; Garcia E; Esteban A; Ruiz CG; Certain G; Vaz S; Jadaud A; Hidalgo M
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Talk: Abstract #139 / Session T20 - Evidence to support international oceans policy

UNDERSTANDING THE RISE OF CEPHALOPODS IN THE WESTERN MEDITERRANEAN USING BIODIVERSITY INDICATORS

Increasing impacts of both fisheries and climate change have resulted in changes in the structure, functioning and related ecological metrics of marine communities. A recurrent observation is the rise of cephalopods as fish communities recede. The reason behind this phenomenon is most likely linked with the removal of main predators and competitors by fishing. However, the consequences of climate change (variations in primary production, changes in stratification, and sea warming, among others) may also have an influence due to the high environmental sensitivity and plasticity of cephalopods. Here we aim to unveil the effects of different drivers in the cephalopod community of the Western Mediterranean Sea as well as its differential role in space. We combine several ecological indicators offering a wide range of information about biodiversity, production, trophic structure and relative contribution of prey and predators and relate them with environmental and fisheries drivers of change. The ecological indicators are calculated using data from the MEDITS trawling survey in the region (from the Alboran Sea to the Gulf of Lion) from 2013 to 2019. Our results highlight the response of ecological indicators to several drivers of change and the spatial differences in cephalopod communities with, for instance, higher richness and trophic level of cephalopods in areas associated to higher SST and fishing effort. Overall, the effect of the environment is greater than the effect of other variables; such results may highlight that under foreseen scenarios of climate change cephalopods could continue to increase due to increases in sea warming.

Anderson, S. C., Flemming, J. M., Watson, R., & Lotze, H. K. (2011). Rapid global expansion of invertebrate fisheries: Trends, drivers, and ecosystem effects. PLoS ONE, 6(3), 1–9. https://doi.org/10.1371/journal.pone.0014735

Doubleday, Z. A., Prowse, T. A. A., Arkhipkin, A., Pierce, G. J., Semmens, J., Steer, M., Leporati, S. C., Lourenço, S., Quetglas, A., Sauer, W., & Gillanders, B. M. (2016). Global proliferation of cephalopods. Current Biology, 26(10), R406–R407. https://doi.org/10.1016/j.cub.2016.04.002

Venables H[1]; Meredith M; Brearley A; Abrahamsen P; Droste E; Bakker D
[1]British Antarctic Survey.
Poster: Abstract #289 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

Heat and carbon changes driven by winter sea ice variability on the West Antarctic Peninsula

Winter sea-ice variability through the Rothera Time Series drives considerable changes in winter and summer in heat content, phytoplankton and CO2 uptake and release. Sampling has been done through the year since 1998, with carbon samples taken since 2011. Low sea-ice years have deep mixing, driven by increased wind stress, bringing warmer and carbon-rich waters to the surface. This leads to rapid heat loss and further hinders sea-ice formation. Carbon outgassing is inherently slower, but enhanced over years with more sea-ice cover, due to extra carbon at the surface and lack of sea-ice as a physical barrier to gas exchange. The reduced stratification from the extra surface mixing is followed by a reduction in stratification in summers following deep mixing. This leads to a greater extent of surface mixing and increased heat uptake in the summer. For heat content this leads to a much greater seasonality as summer warming counteracts or even exceeds winter cooling in the top 100m. Deployments of ocean gliders in the wider area show that the surface changes are propagated to depth where water flows down after sills across the channel leading towards Ryder Bay. Summer carbon uptake is however reduced, due to the lower stratification leading to a weaker phytoplankton bloom. The summer shift in CO2 gas exchange therefore consolidates winter changes, with more outgassing in winter followed by less uptake in summer. Reduced sea-ice therefore, at least in the short-term response leads to a shift towards the ocean being a source of CO2.

Ward B[1]
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Talk: Abstract #123 / Session T5 - The role of mixoplankton and mixotrophy in the global carbon cycle

The ecological and biogeochemical role of mixotrophy: addressing a false dichotomy in the foundation of ocean food-webs

Marine ecology frequently assumes that microscopic plankton can be neatly divided into two mutually exclusive guilds - phytoplankton and zooplankton. Over the past decade or so, it has become clear that a great number of plankton are in fact mixotrophic - combining the use of light and inorganic resources with the ingestion of prey. These mixotrophs frequently dominate marine ecosystems and appear to have a significant impact on community structure and ecosystem function. While laboratory cultures and global surveys suggest a broad range of mixotrophic strategies, each associated with distinct environmental conditions, global models of marine ecology and biogeochemistry have however been slow to reflect this complex biological reality. In this talk I will discuss strategies by which the observed diversity of marine mixotrophs is being incorporated into conceptual and numerical models of the marine ecosystem. By developing models that represent mixotrophic strategies as emergent properties, we can simplify and improve our representation of marine ecosystems and increase our understanding of their role in the Earth system.

Ward J[1]
[1]National Oceanography Centre.
Talk: Abstract #203 / Session T6 - Towards a Net Zero Oceanographic Capability

Making the most of data

The NZOC report (Storey & et al, 2021) recommends (KR6.3) that we: "…Further develop the data flow architecture that allows data to flow from planning (MFP website) through capture, processing, storage and use with the aim of delivering FAIR data to multiple users across science, government, defence and business." The

research ships are sources for some of these data flows, and the onboard data acquisition and metadata management is a key part of preparing the data products for their journey along the pipeline to consumers. Good data management at source decreases the workload downstream. In the short term, upholding FAIR principles aims to deliver the best value in terms of 'data per carbon'. In the longer term, more complex sensor ecosystems and increasing automation requires robust and adaptable acquisition and metadata management. This talk will look at: the challenge of onboard data acquisition and metadata management; how this has been dealt with historically; how the teams at the National Oceanography Centre and the British Antarctic Survey are working together solving them today to uphold FAIR data principles; and our plans for medium-to-longer term as we address ever more complex sensor ecosystems.

Storey, L., & et al. (2021). NZOC: Net Zero Oceanographic Capability (Summary Report). Retrieved from https://noc.ac.uk/files/documents/nzoc_summary_report.pdf

Ward S[1]; Robins P; Jenkins S
[1]Bangor University.
Talk: Abstract #260 / Session T20 - Evidence to support international oceans policy

How offshore renewable energy installations and climate change may alter marine population connectivity in the Irish Sea

The introduction, spread and establishment of marine non-native species, facilitated by species' dispersal capabilities and enhanced by the continued expansion of global trade and transportation networks, presents a global threat to marine biodiversity and ecosystem functioning. Increases in hard structures such as offshore renewable energy devices or coastal defences, built partly as a response to climate change, potentially facilitate the secondary spread of non-native species by providing stepping-stones of suitable habitat for fouling organisms. Along with additional devices being installed in the Irish Sea in the future, projections are for sea water temperatures to continue rise in the Irish Sea (>2°C warmer for annual mean sea water temperature in the region for the period 1989-2019 vs. 2069-2099), which has the effect of reducing the time taken for pelagic larvae to mature and become competent to settle. Within the ECOSTRUCTURE project we use larval dispersal modelling to simulate how offshore renewable energy installations and climate change (using UKCP18 projections) may affect the background spread of marine populations, through provision of artificial habitats and through decreasing the pelagic larval duration in warming waters. This is the first study to consider how anthropogenic structures and climate change in the Irish Sea can alter interconnection of natural coastal populations or may facilitate the spread of marine non-native species in the region. Understanding how anthropogenic climate change or man-made structures change the geographic extent and connectivity of marine species is important for future policy decisions regarding marine resources and for marine spatial planning.

Ward S[1]; Webb J; Winterbourn B; Robins P; Malham S; Le Vay L
[1]Bangor University.
Poster: Abstract #261 / Session T20 - Evidence to support international oceans policy

Physical and operational constraints mapping for offshore expansion of the UK shellfish industry

There is widely recognised potential for sustainable expansion of the aquaculture industry, across all UK Nations. For example, the Welsh Seafood Strategy sets goals of establishing a robust evidence-base to ensure the sustainability and growth of existing - and development of new - fisheries and aquaculture activities. The Shellfish Centre and the MOSSS projects (Menai Offshore Subsurface Shellfish Systems) are two research and innovation initiatives supporting this development of the shellfish sector in Wales, with research outcomes applicable to aquaculture industries worldwide. Using a questionnaire approach, we have surveyed shellfish producers globally to quantify key physical constraints to installation and operation of commercial production in exposed and offshore conditions, using sub-surface suspended long-line systems. Based on our new understanding and quantification of physical hydrodynamic constraints (e.g., water depth, tidal currents, wave conditions), combined with key operational constraints, we have identified and mapped potentially suitable areas for shellfish culture around the UK coast. Identification of these areas with suitable conditions for offshore shellfish farming can inform refinement of marine spatial plans including identification of strategic resource areas, as well as informing investment decisions as producers seek optimal areas for expansion offshore.

Weatherley A[1]
[1]University of Bristol.
Poster: Abstract #63 / Session T1 - Deep Sea Mining 1 - geology, resource, legal, technical and societal aspects

Contextualising contemporary deep-sea mining debates through an analysis of a failed project located in Papua New Guinea waters.

Rising metal and mineral demands are set to outpace global production, partly due to a move towards renewable technologies. Mining seafloor resources, residing in the form of seafloor massive sulphides (SMS) and manganese nodules, could be the solution to the growing supply gap, although exploitation is yet to reach commercial levels. New seafloor mining proposals are therefore at the centre of public scrutiny and will set the precedent for future projects within the emerging industry. My research aims to contextualise contemporary debates over the shape deep-sea mining (DSM) should take -- if any -- through an analysis of Solwara 1: the project, run by Nautilus Minerals, that was set to become the first example of commercial mining for SMS, but which ended in failure. In examining the reasons for its failure, my research explores the geopolitical history of Papua New Guinea (PNG), whose territorial waters were to be mined, the environmental concerns voiced regarding the venture from both within and without PNG, and the ways in which the project exposes Western conceptions of the deep ocean that may sit in conflict with those held by non-Western peoples. Considering the project's evolution and legacy, I argue, is important in understanding the emergence of similar projects and to recognise gaps in knowledge or legislation: including those likely to arise from the recent shift in focus towards mining manganese nodules on international seabed areas governed by the International Seabed Authority (ISA).

Weaver P[1]
[1]retired.
Poster: Abstract #252 / Session T2 - Deep Sea Mining 2 - environmental aspects: baselines, impacts, monitoring

Comparison of the environmental impacts of deep-sea mining for manganese nodules, cobalt crusts and polymetallic sulphides.

Deep-sea mining covers three resources manganese nodules, cobalt crusts and polymetallic sulphides. They are located in different deep-sea environments and each has a different set of environmental issues. Manganese nodules are located on deep abyssal plains especially the Pacific and Indian Oceans. Here the ecosystems are poorly understood and although biomass is low, biodiversity is high with large proportions of newly discovered species. The nodules are potato sized and lie on the seabed, producing a very thin layer of resource. Mining 1Mt of nodules will destroy about 90 km2 of seabed and each contractor will mine 2-9Mt per annum. So far the International Seabed Authority has signed 19 contracts for exploration for manganese nodules. Not only will large areas be destroyed but recovery of the ecosystem is expected to be very slow and non-existent for the animals that live on and in the nodules. Cobalt crust deposits are located between 800-2500 metres water depth on seamounts particularly in the North Pacific. Attached fauna such as corals and sponges may be common and provide structural habitat for a wide range of species. Crusts may form a continuous layer up to 30 cm thick and mining 1Mt of ore will destroy approximately 25km2 of seabed with each contractor expected to mine 2Mt per annum. The ecosystems will take many tens of years to recover. Polymetallic sulphides are 3-dimensional ore bodies formed at hydrothermal vents on ocean ridges. If locations with vent faunas and other vulnerable ecosystems are avoided impacts may be small.

Weaver P[1]
[1]Retired.
Talk: Abstract #221 / Session T2 - Deep Sea Mining 2 - environmental aspects: baselines, impacts, monitoring

Progress in developing a Regional Environmental Management Plan for the Polymetallic sulphide deposits of the North Atlantic

The International Seabed Authority has recently developed a draft Regional Environmental Management Plan (REMP) to manage mining activities on the mid-Atlantic ridge of the North Atlantic, south of the Azores. The area includes exploration blocks for polymetallic sulphides that are part of three contracts signed by the ISA. Exploration is concentrated within a few kilometres of the ridge axis where the sulphides can be located. Mine sites will occupy areas probably less than 1 km^2 and could be in place for years to decades.

The REMP will establish conservation and management measures and tools to ensure effective protection of the marine environment from harmful effects of mining. It should maintain regional biodiversity and ecosystem structure, function and processes across the region; enable conservation of representative habitats and vulnerable marine ecosystems; ensure environmental sustainability and functionality during and after exploitation.

Particular attention needs to be given to specialised hydrothermal vent fauna that have very limited distributions but live in association with the metal rich deposits. In addition, the rocky nature of the ridge axis provides anchorage for attached animals such as corals and sponges amongst others and colonies of such animals are regarded as Vulnerable Marine Ecosystems by fisheries bodies.

The REMP will also need to address plumes generated by the mining process that may have impacts over much wider areas including in the water column. The talk will outline the process leading to the development of the draft REMP, summarise its main components and discuss its progress towards implementation.

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[1]Northumbria University.
Poster: Abstract #34 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

Ocean Circulation and Ice Shelf Melting in the Bellingshausen Sea

A modified version of warm Circumpolar Deep Water (mCDW) is able to flow onto the continental shelf in the Bellingshausen Sea, leading to high melt rates beneath the floating ice shelves. Data are presented from a 2007 research cruise to the Bellingshausen Sea, during which temperature, salinity and dissolved oxygen measurements were made at 253 stations. These observations provide detailed insights into the physical oceanographic regime of the region and its impact on the ice shelves, particularly in the western Bellingshausen Sea where few other ship-based observations exist. In particular, we focus on the sources of mCDW on the continental shelf and the transport of meltwater away from the ice shelves. Key water masses on the continental shelf include mCDW, Winter Water, Antarctic Surface Water and glacial meltwater. The properties and spatial variability seen in these water masses are used to infer the circulation in the region and the concentration of meltwater in the water column. We observe two types of mCDW on the continental shelf, sourced from Marguerite Trough and Belgica Trough, respectively, with the former being 0.1oC warmer than the latter, despite similar offshore temperatures. This could be due to a shallower thermocline, or steeper continental slope bringing warm water closer to the shelf break at Marguerite Trough. The distinctive properties allow mCDW on the shelf to be traced back to the two source regions at the shelf break, revealing that the slightly cooler mCDW from Belgica Trough appears to drive most of the ice shelf melting.

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Talk: Abstract #102 / Session T16 - How Art-Science Collaborations can Inspire Societal Change

Creating space for something more? Reflections on measuring the Success of Art Science Collaborations.

One of the challenges set out by the UN Ocean Decade (2021-2030) is to confront 'Humanity's relationship with the ocean' by identifying and overcoming 'barriers to behaviour change required for a step change'. They go on to state that to do this, one of the Ocean Decade outcomes is to create an 'inspiring' and 'engaging' ocean for all society. Thus, art-science collaborations are increasingly being valued as fundamental to the communication strategies of making the ocean meaningful and accessible to all, in the hope that this inspires people to care enough to change their behaviours and relationships with the sea. But how can we measure this? As we enter a decade where art-science collaborations are becoming more important then, a difficult question to answer will

be, what will success look like by 2030, or even how instructive is this question to begin with anyway? Is the fact that something is produced from a collaboration between an artist and a scientist by itself a success, or must we measure the ways in which the public respond? This paper will explore these questions and discuss how creating meaningful legacy through art-science collaborations can be possible.

Wicks R[1]; Gunning H
[1]BBC Natural History Unit – BLUE PLANET III
Poster/video loop in Exhibition Centre

Breaking box office records worldwide, Blue Planet II's legacy had a profound impact on the global conservation of our oceans. Now, with ground-breaking new technology, Blue Planet III will dive deeper than ever, to reveal phenomenal creatures and untold stories from magical underwater worlds. We would love to hear about recent discoveries and exciting new research underway which may lead to featured stories and collaborations. To discuss ideas further please find us here, or contact us: Rachel.wicks@bbc.co.uk | Harry.gunning@bbc.co.uk

Wienkers A[1]; Taylor JR
[1]University of Cambridge.
Talk: Abstract #16 / Session T25 - Physical Oceanography Open Session - Ocean Eddies

Vertical transport and mixing driven by symmetric instability in strong ocean fronts

Fronts with large horizontal density gradients and O(1) Rossby numbers are common in the upper ocean. Such fronts develop through a variety of mechanisms including by mesoscale eddy strains, coastal upwelling, or the input of freshwater via river discharge. These fronts may be unstable to symmetric instability --- a form of convective-inertial instability which occurs when the potential vorticity is of opposite sign to the Coriolis parameter. Symmetric instability is characterised by growing slantwise convection cells aligned with isopycnals and which encourage vertical transport of important biogeochemical tracers in addition to geostrophic momentum. This momentum transport destabilises the balanced thermal wind and can prompt geostrophic adjustment which often leaves remnant inertial oscillations. Here, we consider the equilibration of an initially balanced but symmetrically unstable front and explore the parameter space of front strength and Rossby number using nonlinear numerical simulations. While fronts with Ro > 2.6 collapse to a self-similar profile dependent only on the deformation radius, we find that for small enough Ro ~ 1, self-similar frontlets form during equilibration. These frontlets increase the energy of the equilibrated state and can interact with the near-surface currents to further enhance mixing. We finally propose a scaling model for the incurred diabatic mixing and to describe the ultimate state of the front.

Wilkie Johnston L[1]; Rowlands E; Bergami E; Manno C
[1]University of St Andrews, British Antarctic Survey.
Poster: Abstract #41 / Session T12 - Interactions between plastics and marine ecosystem

Quantifying the in-situ abundance and type of microplastic within Southern Ocean keystone species

Plastic production has increased exponentially in the last 50 years, with outputs into the marine environment percolating into the most remote regions, such as the Southern Ocean (SO). A category of particular concern are microplastics (particles <5mm), which can be ingested by zooplankton and incorporated into the food web. Antarctic Krill (*Euphausia superba*) and Salp (*Salpa thompsoni*), two keystone species of the SO ecosystem, have already been seen to ingest microplastic under laboratory simulation. This study investigates the abundance and type of microplastic (>100µm) found within *E. superba* and *S. thompsoni* collected in the Atlantic sector of the SO. Microplastic polymers were identified using a novel oxidative-enzymatic digestion protocol coupled with optical analysis using a Fourier-Transform Infrared Spectrometer (FT-IR). Preliminary results suggest a presence of microplastic in both salp and krill, with krill having relatively larger abundances contained within them. We observe a positive correlation between organisms' size and microplastic concentration with high presence of microplastic in largest organisms. The most common synthetic polymer found is polyamide, followed by polyethylene. These results suggest a potential important incorporation of microplastic into the SO food web, raising concerns about further impacts on higher trophic levels.

Williams C[1]; Hull T; Toberman M; Mahaffey C; Palmer M; Greenwood N; Kaiser J
[1]National Oceanography Centre.
Talk: Abstract #57 / Session T27 - Physical Oceanography Open Session – Physical Drivers of Ocean Productivity

Autumnal Diapycnal Oxygen Fluxes in the North Sea

Due to their highly dynamic nature, quantifying and understanding the oxygenation status of seasonally stratified shelf seas is a vital, albeit non-trivial, challenge. The stratified regions of the North Sea have been undergoing a trend of reducing dissolved oxygen concentrations for several decades (Mahaffey, 2020). The central North Sea, with both strong seasonal stratification and a small sub-thermocline volume, is considered most at risk. In these regions the thermocline acts as a physical barrier between the warmer, oxygenated, nutrient-depleted surface mixed layer (SML) and the cooler, dark, nutrient-rich bottom mixed layer (BML). In the BML, oxygen concentrations decrease due to this restricted ventilation and respiration of organic matter and nitrification. Transient periods of increased vertical mixing during the stratified period have been observed in the Celtic Sea to simultaneously supply nutrients and promote biological production within the thermocline while also ventilating the bottom waters (Wihsgott et al., 2019). This can also increase the amount of sinking organic matter, increasing BML oxygen consumption. The net result on bottom oxygen concentrations from these processes can be difficult to determine without sustained observations. Using high-resolution ocean glider observations of both turbulent kinetic energy dissipation rates and dissolved oxygen concentrations, we quantify the autumnal diapycnal oxygen flux in parts of the central North Sea. We demonstrated a new methodology which provides estimates of the vertical oxygen concentration gradient across the pycnocline despite the slow response time of the oxygen optode. Our results show that weak diapycnal mixing provides a small but steady flux of oxygen into the BML that is comparable to prior spring and summer vertical flux estimates (Rovelli et al 2016, Queste et al, 2016). We will also see evidence for diurnal variation in the mixing, suggesting that the vertical fluxes are tidally modulated. Our work demonstrates the potential of autonomous glider platforms for quantifying vertical oxygen fluxes and underpins the role of ocean gliders as a biogeochemical monitoring tool that can aid sustainable management of shelf sea ecosystems.

Williams J[1]; Giering S
[1]University of Southampton, National Oceanography Centre.
Talk: Abstract #127 / Session T15 - Carbon cycling in the global ocean and the role of blue carbon in climate mitigation

In situ Particle Measurements Deemphasize the Role of Size in Governing Particle Sinking Velocity

Sinking particles are important in delivering carbon to the deep ocean where it may be stored out of contact with the atmosphere. Particle sinking velocity strongly influences the amount of carbon reaching the deep ocean, and is thought to be strongly affected by particle size. Here we carried out an extensive literature review (62 datasets) into the size-sinking velocity relationship, and find the relationship is much weaker for studies examining particles in situ (median R2 = 0.03) compared with ex situ studies (median R2 = 0.35). This may be because particles examined in the laboratory have more uniform properties than those studied in situ, and represent only a subset of particles from the natural environment. Our findings suggest a simple relationship between size and sinking velocity may be insufficient when calculating sinking particulate fluxes in the ocean, with immediate implications for the use of particle image datasets in determining particulate fluxes. When deriving estimates of particulate fluxes from particle size spectra, considering individual size-scaling relationships for different particle types will enable more accurate calculations of particulate fluxes.

Wilmes S[1]; Green M; Schmittner A
[1]Bangor University.
Talk: Abstract #48 / Session T24 - The Atlantic Meridional Overturning Circulation: Observations, Simulations and Equations

Was tidal mixing in the glacial ocean enhanced?

The global mean sea-level decrease of 120 – 130 m and increased ice sheet extent during the Last Glacial Maximum (LGM; 26 – 19 kyr BP) are thought to have substantially altered tidal dynamics in the glacial North Atlantic. These factors enhanced global open ocean tidal dissipation in comparison to present day by a factor of 2 – 3, thus increasing the amount of energy available to diapycnal mixing which drives the global meridional overturning circulation. Reconstructions of the glacial ocean have generally suggested a more sluggish Atlantic meridional overturning circulation (AMOC) during the LGM and suggested weaker mixing as a driver. Here, we investigate the impact of tidal dissipation changes on the LGM AMOC and the carbon cycle using the intermediate complexity ocean model UVic coupled to the biogeochemistry model MOBI forced with three different LGM tidal dissipation estimates. The simulations are constrained with LGM δ13C and radiocarbon sediment data which suggest that our simulations, as previously inferred, most closely agree with a weakened LGM AMOC (8 – 9 Sv); but importantly, that the best agreement is found with increased LGM tidal mixing. These results, firstly, imply that a weakened AMOC state can occur with stronger tidal mixing without hampering the agreement with the sediment isotope data. Secondly, it implies that vertical mixing was probably not reduced during the LGM, and, thirdly, this work highlights the importance of considering tidal dissipation changes when modelling the paleo-ocean.

Wilson D[1]; Sheen K; Clark J; Thorpe S; Young E
[1]University of Exeter.
Talk: Abstract #80 / Session T12 - Interactions between plastics and marine ecosystem

Modelling the transport of microplastic pollution in the Southern Ocean

Microplastic pollution is widely accepted to be a ubiquitous environmental contaminant, with microplastics recorded in a range of marine environments across the world. The Southern Ocean is no different, with a number of studies reporting microplastic pollution in the region, including south of the Antarctic Circumpolar Current (ACC). However, given the expense and difficulty associated with collecting data on microplastic abundance in the Southern Ocean, combined with the majority of previous research focusing on the Antarctic Peninsula, there are large areas of the Southern Ocean where plastic concentrations are unknown. The transport pathways and processes that drive transport of microplastic pollution across the ACC are similarly unknown. To tackle these knowledge gaps, we use a modelling approach to simulate transport pathways of plastic debris in the Southern Ocean, with a focus on the cross-ACC transport of microplastics. Specifically, we use the Lagrangian particle tracking framework Ocean Parcels, forced with ocean velocity fields from a Southern Ocean configuration of NEMO-LIM3 with 1/12 degree horizontal resolution. By including Stokes drift, sub-grid scale diffusion and sea ice drift alongside the ocean currents, we aim to better understand how and where microplastics may cross the ACC and identify regions of the Southern Ocean where microplastic pollution may accumulate. This will allow improved targeting of future research into microplastic pollution impacts in the Southern Ocean.

Wilson E[1]; Arundell M; Schaap A; Cardwell C; Walk J; Mowlem M
[1]National Oceanography Centre.
Poster: Abstract #199 / Session T7 - Pushing the limits in autonomous oceanography in a net zero carbon world

A combined Total Alkalinity-Dissolved Inorganic Carbon (TADIC) sensor for autonomous deep water oceanography

Following recent successful field testing of NOC Wetchem Total Alkalinity (TA) and Dissolved Inorganic Carbon (DIC) sensors, development of the newly-designed combined "TADIC" sensor is underway. This device incorporates a revised fluid handling system to increase reliability, electronics, software, and bespoke electrochemical sensor. Reductions in size and power usage compared with the previous separate sensor approach allows TADIC to be used more flexibly with autonomous underwater vehicles. Simultaneous measurement of TA and DIC will produce valuable data on ocean acidification and other marine biogeochemical processes while functioning as a test bed for future improvements for other NOC Wetchem sensors.

Wilson S[1]
[1]Newcastle University.

Talk: Abstract #101 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

Oceanic nitrogen fixation in a changing climate

Biological dinitrogen (N2) fixation is the metabolic capability of certain microorganisms to convert N2 into bioavailable nitrogen. N2 fixation plays a critical role in carbon capture and export of marine ecosystems and can support up to 50% of new production in oligotrophic gyres. However, our ability to resolve the physical, chemical, and biological parameters that regulate N2 fixation is hindered by the difficulty of conducting high resolution measurements that yield comparable datasets across oceanic basins. The currently favoured technique to measure N2 fixation in real time is the acetylene reduction assay. An alternative technique, known as the Argon Induced Hydrogen Production (AIHP) method, exploits the production of H2 as a side product of N2 fixation to determine real time rate measurements. Progress on using the AIHP method to obtain high resolution measurements of N2 fixation is presented along recent discoveries using this method on novel microorganisms.

Wise A[1]; Polton J
[1]National Oceanography Centre.
Talk: Abstract #71 / Session T28 - Physical Oceanography Open Session - Coastal Physics

A simple conceptual model to connect coastal sea level variability with the continental slope current and deep ocean circulation

Data-driven reconstructions suggest that open ocean density variability acts as a good predictor of coastal sea level variability on interannual-to-decadel timescales. This is despite the local density driven (steric) component of coastal sea level tending to zero as the coast is approached. Physically understanding the link between deep and coastal ocean sea level variability is required to interpret experiments investigating drivers of coastal sea level. We introduce a conceptual model to physically explain the mechanism. It is based on an analysis of the momentum budgets of a stratified, realistically forced ocean model of the north west European shelf. We target the dynamics along specific isobaths on the continental margin and demonstrate their connection with sea level variability on the shelf and at the coast. By doing this we show: 1) how monthly variability in along-isobath wind stress is responsible for driving common modes of variability along the coasts of the north west European shelf; 2) how off-shelf density variability is connected to sea level variability on the shelf via the slope current.

Wong T[1]; Copley J
[1]University of Southampton.
Poster: Abstract #281 / Session T2 - Deep Sea Mining 2 - environmental aspects: baselines, impacts, monitoring

Predicting the life history and key traits conferring vulnerability to mining impacts for abyssal marine invertebrates in the Clarion-Clipperton Zone

The Clarion-Clipperton Zone (CCZ) is an abyssal plain rich in polymetallic nodules, which contain metal resources such as manganese, nickel and cobalt. With deep-sea mining being viewed as technically feasible in the future century, it is important for us to understand the biodiversity and ecosystem of the CCZ. This project is compiling a taxonomic database of fauna in the CCZ for analysis of life-history traits that may confer vulnerabilities to mining impacts, using analysis of potential links between reproductive traits and phylogeny to enable the possible prediction of traits not yet confirmed specifically in CCZ taxa.

Wood G[1]; Karimi K
[1]University of Illinois, Urbana-Champaign.
Talk: Abstract #342 / Session T18 - HMS Challenger collections as a benchmark for oceanographic studies

The Oceans 1876 Project: An Introduction

This talk introduces ongoing Challenger research that marries traditional archival research with Big Data. The goal of the Oceans 1876 Project, funded by the Carnegie Foundation and based at the University of Illinois, is to extract and modernize marine data from the Challenger's 50-volume reports, and to make that data better accessible to researchers and the general public. The Carnegie Foundation is also supporting publication of a book on the Challenger voyage that will incorporate the newly standardized data. The Oceans 1876 team has nearly completed the enormous task of extracting and standardizing the published Challenger data. The priority moving forward is the mapping of marine species to their modern names, as many have gone through multiple taxomonic changes in the past 150 years. The final deliverable of the project will be a web application (with interactive global map) that allows users to search Challenger species and temperature data, and to compare the state of the oceans in the 1870s with today. For scientists, the digital re-packaging of Challenger data through a web service API will enable a range of comparative marine research not currently possible. For historians, in turn, this includes new narratives of the Challenger voyage itself. The Oceans 1876 book, published by Princeton University Press, will spotlight threats to charismatic marine species first described by Challenger, and draws on newly discovered journals from the Challenger archive at the Natural History Museum.

Woolf D[1]
[1]Heriot-Watt University.
Talk: Abstract #113 / Session T17 - Physical and chemical drivers of air-sea exchange processes: waves, bubbles, aerosols and surface chemistry

A categorical framework for the modelling of air-sea exchange at a broken surface

A standard air-sea gas exchange equation, or bulk formula, dominates discourse on air-sea gas fluxes and budgets. However, early studies of air-sea exchange adopted paradigms from chemical engineering that are poorly suited to gas exchange at a broken sea surface. In particular, the "two-layer model" allows an understanding of the control of air-sea exchange by diffusive processes on one or both sides of the intact sea surface, and a working understanding of "direct" air-sea transfer has been achieved. A useful description of some aspects of broken surface exchange can also be incorporated, for example, by representing bubble-mediated transfer as a parallel process on the liquid side of the interface that enhances the transfer of poorly soluble gases. However, the fit is "a square peg in a round hole" and representations of air-sea exchange by a set of serial and parallel diffusive processes can be inadequate. Two key omissions severely limit the general applicability of the standard air-sea gas equation. Firstly, static pressures diverge from the sea surface pressure away from the sea surface and these affect the partial pressures in the air surrounding aerosol and within bubbles. Secondly, the behaviour of a particle or bubble depends on a "carrier"; primarily nitrogen for a bubble and water for a droplet. The transfer of a trace gas by bubble-mediated exchange is affected by the growth or shrinkage of the bubble. In aerosol-mediated exchange, the evaporation of the droplets may be the key process.

Woolf D[1]; Dominicis MD; Barton B; Porter J; Want A; Bell M; Elliot M; Mazik K; Franco A; Gormley K; Waeschenbach A; Miller R; Davies G; Clarke D
[1]Heriot-Watt University.
Talk: Abstract #112 / Session T28 - Physical Oceanography Open Session - Coastal Physics

CHASANS – Dispersion and connectivity of hard-substrate organisms in the central North Sea and their interaction with offshore energy infrastructure

Changes in the energy system in the twenty-first century are having a major effect on the North Sea, notably as oil and gas infrastructure is dismantled and very large arrays of offshore wind turbines are commissioned. One consequence will be the availability of hard substrates within the North Sea, which will affect the connectivity of both natural and invasive species that are dispersed by currents in their larval stage and settle on hard surfaces. The overall effect of changes in infrastructure are not obvious in part because the connectivity of various locations within the North Sea are unknown. CHASANS is an "INSITE" project building the necessary knowledge of connectivity by a combination of methods. Dispersion within the North Sea is investigated by numerical modelling based on the Scottish Shelf Model with tracking of simple representations of larvae. A novel apparatus for deployment of settling panels has been adapted for the energetic seas of the northern North Sea and siting of these close to various oil and offshore-wind sites. The panels will be collected and replaced each season. Analysis will include coverage, identification at a species level and genetic analysis to establish the genetic similarity of populations of the same species at different locations. The modelling and experimental data will be combined

firstly to understand at a basic scientific level the connectivity within the northern North Sea. Secondly, the implications of that connectivity and changes to the connectivity will be communicated to a diverse audience.

https://storymaps.arcgis.com/stories/5d556fa2a4c94ceeac63c5f3be16da6d

Wyatt N[1]; Birchill A; Ussher S; Milne A; Bouman H; Shoenfelt-Troein E; Porpatsava K; Wright A; Flannigan O; Bibby T; Martin A; Moore CM
[1]University of Plymouth.
Talk: Abstract #174 / Session T3 - Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans

Phytoplankton responses to dust addition in the Fe(Mn) co-limited Eastern Pacific sub-Antarctic differ by source region

Iron (Fe) availability strongly regulates productivity in the Southern Ocean. Manganese (Mn) also has an essential role in phytoplankton photophysiology and has recently been shown to co-limit growth in Southern Ocean surface waters. Mineral dust flux is a key supply route of both Fe and Mn to the ocean and a critical mediator of millennial-scale atmospheric CO2 oscillations. As part of the Carbon Uptake and Seasonal Traits in Antarctic Remineralisation Depth programme, we present results from 15 nutrient amendment experiments along a north-south transect in the largely under-sampled eastern Pacific Sub-Antarctic Zone (SAZ). All experiments indicated widespread increased photochemical efficiency following Fe addition, leading to enhanced growth rates. Interestingly, we found further enhancements of photochemical efficiency with Mn addition at southerly stations, supporting recent work suggesting an important role for Fe(Mn) co-limitation in the Southern Ocean. Moreover, addition of different Patagonian dusts resulted in significantly enhanced photochemical efficiency with the differential response linked to both source region dust characteristics and relative Fe/Mn solubility. Changes in both the relative magnitude of dust deposition and source region mineralogy could hence determine whether Fe or Mn limitation play the most prominent roles in defining the productivity and biological carbon uptake potential of the Southern Ocean under future as well as past climate states.

Yamazaki K[1]; Aoki S; Mizobata K
[1]National Institute of Polar Research.
Poster: Abstract #26 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

Diffusion of Circumpolar Deep Water Towards Antarctica

Previous studies have long regarded warm, salty Circumpolar Deep Water (CDW) as the climatological driver for Antarctica, but the mechanism of how it can reach the continental shelf remains unsettled. Motivated by the absence of observational eddy flux estimation in the Antarctic margin, we quantify isopycnal diffusivity of CDW by hydrographic records and satellite altimetry under the mixing length framework. For comparison, spiciness and thickness are used as the isopycnal tracer. Over the extent of the Antarctic Circumpolar Current (ACC), we find a general agreement with the mixing suppression theory and its exception in the lee of the topography as previously reported. In contrast, mixing length does not depend on mean flow to the pole, reflecting a calm flow regime in the Antarctic margin. Estimated isopycnal diffusivity ranges 100–500 m2 s-1 to the south of the ACC. Eddy diffusion tends to be enhanced where the CDW intrusion is localized by the recirculating gyres, primarily attributable to the small gradient of isopycnal thickness. Volume transport is then estimated by the layer thickness gradient. Associated onshore heat flux across the continental slope by CDW is calculated as ~3.6 TW and ~1.2 TW in the eastern and western Indian sectors, respectively. The estimates are quantitatively consistent with cryospheric heat sinks by sea ice formation and ice shelf basal melt, suggesting that the isopycnal eddy diffusion is the leading cause of the onshore CDW intrusion. We emphasize that the thickness field is essential for determining the eddy fluxes in the Antarctic margin.

Yang J[1]; Cavan E; Plancherel Y
[1]Imperial College London.

Talk: Abstract #215 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

CMIP6 climate change projections for the Southern Ocean sea ice and biological carbon sink

The Southern Ocean plays a central role in the global carbon cycle and is responsible for 40% of the carbon uptake by the ocean. However, climate change is expected to have a profound impact on the Southern Ocean biological carbon pump, the biological pathway of carbon sequestration, by altering the ocean biogeochemistry. Of particular importance is the dynamics of sea ice, which regulates the timing and location of iron supply and light availability for phytoplankton growth that drives the biological pump. However, it remains unclear how future changes in the Southern Ocean sea ice dynamics will affect the behaviour of carbon sink. Here, we used the Coupled Model Intercomparison Project Phase 6 (CMIP6) to investigate how the Southern Ocean carbon sink changes with retreating sea ice by analysing primary production and exports under different climate change scenarios. Sea-ice-related environmental factors (light, nutrient, stratifications) will also be examined to determine their relative importance to the biological pump. I will finish with a discussion on the implications of our findings on the global scale, including nutrient distribution and productivity.

Yao L[1]; Taylor JR; Jones DC; Bachman SD
[1]Department of Applied Mathematics and Theoretical Physics, University of Cambridge, UK.
Poster: Abstract #132 / Session T25 - Physical Oceanography Open Session - Ocean Eddies

Identifying Ocean Submesoscale Activity from Vertical Density Profiles Using Machine Learning

Submesoscale eddies are important features in the upper ocean where they mediate air-sea exchanges, convey heat and tracer fluxes into ocean interior, and enhance biological production. However, due to their small size (0.1-10 km) and short lifetime (hours to days), directly observing submesoscales in the field generally requires targeted high-resolution surveys. Submesoscales increase the vertical density stratification of the upper ocean and qualitatively modify the vertical density profile. We propose an unsupervised machine learning algorithm to identify submesoscale activity using vertical density profiles. The algorithm, based on the profile classification model (PCM) approach, is trained and tested on two model-based datasets with vastly different resolutions. One dataset is extracted from a large-eddy simulation (LES) in a 4 km by 4 km domain and the other from a regional model for a sector in the Southern Ocean. We show that the adapted PCM can identify regions with high submesoscale activity, as characterized by the vorticity field (i.e., where surface vertical vorticity ζ is similar to Coriolis frequency f and Rossby number $Ro=\zeta/f \sim O(1)$), using solely the vertical density profiles, without any additional information on the velocity, the profile location, or horizontal density gradients. The results show that the adapted PCM can be applied to datasets from different sources and provides a method to study submesoscales using global datasets (e.g., CTD profiles collected from ships, gliders, and Argo floats).

Zaencker B[1]; Bird K; Harley J; Flores H; Krumpen T; Cunliffe M
[1]The Marine Biological Association of the UK.
Talk: Abstract #164 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

Fungal communities across Greenland's shelf sea ice ecosystems and the wider Central Arctic Ocean.

Sea ice provides a unique and productive substrate for microbial life in polar regions. Once enough light becomes available in the spring, diatoms can grow in high abundances at the underside of the ice, supporting a variety of other organisms that can parasitize, feed on or take advantage of diatom exudates. Fungi have emerged also as important components of sea ice ecosystems. In sea ice, fungi can either live a saprotrophic or a parasitic lifestyle, and as parasites, can influence sea ice diatom community composition by selectively parasitizing specific groups. During the Synoptic Arctic Survey (SAS) expedition onboard the ice breaker Oden (July-September 2021) we sampled different sea ice ecosystems (e.g. melt ponds, brines, surface and bottom ice) along a transect from the second year ice (SYI) on Greenland's shelf to the first year ice (FYI) at the North Pole and around Svalbard. From the various sea ice ecosystems, we used environmental DNA (eDNA) and RNA (eRNA) to assess fungal abundance and diversity. We show that Greenland's shelf older SYI contains distinct fungal communities compared to the younger FYI in other regions. The surface SYI was dominated by unicellular yeasts, making up

a major proportion of the total community. Chytrids (a group of parasitic fungi) dominated the fungal communities in the bottom ice and showed diatom host specificity. We set this work in the context of the rapidly changing Arctic and developing a better understanding of the sea ice ecosystems that are being lost because of global climate change.

Zampollo A[1]; Murray RO; Tweddle TCJF; Scott B
[1]University of Aberdeen.
Talk: Abstract #300 / Session T15 - Carbon cycling in the global ocean and the role of blue carbon in climate mitigation

The potential effecs of wind farms on primary production

The rapid growth of renewable energy development in the shelf seas has raised the need of assessing the indirect impacts of new infrastructures in the marine ecosystem. Very large-scale windfarms (fixed and floating) are planned to be deployed in shelf seas and are likely to change hydrodynamic and biological processes. Shelf seas are resilient productive environments that rely upon phytoplankton communities. To investigate the effects of wind energy extraction, we need to start exploring areas with good long-term baseline data. The region of Firth of Forth and Tay Bay (Scotland) has extensive wildlife and physical surveys and exemplifies an ecological and economic area of interest for top predators (seabirds, mammals) and the fishing industry. The area is targeted for future floating and static wind farm deployments. Seasonal variations occurring at and around windfarms were investigated by comparing two modelled scenarios, with and without windfarms, using FVCOM coupled to ERSEM. A first parametrization of the effects of windfarms on primary production is here reported, showing an overall decrease in primary production from March to June 2003, and patches with increasing/decreasing producers in the proximity of the windfarms. Shallow and highly concentrated patches develop in coastal waters (< 25 km), while the primary productivity decreases over banks (< 54 m). The resulting change in the vertical distribution of food resources is likely to affect the distribution of upper trophic layers, influencing their vulnerability or sensitivity to turbines (e.g. seabirds and fish).

Zanker J[1]; Young E; Haigh I; Brickle P; Holland P
[1]British Antarctic Survey.
Talk: Abstract #33 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

Variability in circulation and exchange in a sub-Antarctic island fjord

South Georgia is a heavily glaciated sub-Antarctic island in the Southern Ocean in the path of the Antarctic Circumpolar Current. The island hosts a rich ecosystem supported by krill and fish and is a target area for important commercial fisheries. Cumberland Bay is the largest fjord on the island, split into two arms, Cumberland East and West Bay, with a large marine terminating glacier at the head of each arm. Water circulation in such fjords, and associated transport and exchange of heat, directly governs the stability of glaciers at the ice-ocean interface and the subsequent glacier dynamics. Cumberland Bay is an important spawning ground for the commercially fished mackerel icefish, with the transport and retention of icefish larvae controlled by fjord circulation and shelf exchange. Fjord circulation patterns are complex with influencing factors including winds, freshwater input, bathymetry, and coastal current systems. Understanding of the variability in circulation and exchange in Cumberland Bay cannot be derived from limited observational data alone. A new high-resolution simulation of the fjord water circulation in Cumberland Bay is built using the NEMO4 modelling framework. The model will help determine the dominant physical drivers of variability and elucidate the role of such variability on glacier dynamics and rate of retreat. Model flow fields will drive an Individual Based Model to investigate the transport and retention of mackerel icefish larvae, aiding fisheries management.

Zarkogiannis S[1]
[1]Department of Earth Sciences , University of Oxford.
Talk: Abstract #43 / Session T4 - Shackleton Session: Marine Sedimentary Carbon

The role of oceanic density on planktonic calcification

Non-motile calcifying planktonic organisms remain buoyant at their optimum depths by maintaining equilibrium with the upthrust force exerted to them by the medium in which they are immersed. Changes in the physical properties (i.e. temperature and salinity) of the ambient seawater mass during climatic shifts should cause changes in the oceanic upthrust force applied to floating organisms. In order to counteract physical forcing changes and remain at optimum depths these organisms may adjust their degree of biomineral production. There is evidence to suggest that the degree of plankton calcification is more sensitive to changes in the physical properties of the water column rather than its acidity. Considering changes in oceanic density opens a new window in the understanding of the marine carbon sedimentation and the response of marine calcifiers in the ongoing oceanic change.

Zazueta-Lopez A[1]; Woulds C; Maerz C; Cowie G; Jilbert T; Watson G; Devlin M; Best M
[1]University of Leeds.
Talk: Abstract #154 / Session T15 - Carbon cycling in the global ocean and the role of blue carbon in climate mitigation

Influence of macroalgae mats on sediment carbon storage in coastal environments

There has been an increasing interest in studying blue carbon ecosystems. Although most of the quantifications of carbon stocks have been done in coastal vegetated wetlands, estimations show that macroalgae can contribute up to 173 Tg C y-1 to carbon sequestration. Nonetheless, macroalgae carbon derived characterisation still a challenge. The proliferation of opportunistic macroalgae is a clear sign of eutrophication affecting many coastal areas in England and these mats cover a significant area of intertidal sediments. Understanding the influence of macroalgae mats on sediment carbon storage on these production areas is a key step for more precise estimations of macroalgae C export and storage. Recently, the use of biomarkers in combination to bulk isotopic signatures have been suggested as promising tools to identify macroalgae derived carbon. In order to assess the influence of green ephemeral macroalgae on sediment carbon stocks, a group of three estuaries with various levels of eutrophication and presence of macroalgae (Portsmouth, Langstone and Poole Harbours) on the south coast of England were sampled to assess differences in sediment carbon storage. CuO oxidation products and bulk isotopes (C, N and H) alongside sediment properties, organic C content, and porewater chemistry will be presented, and discussed in relation to the impact of macroalgal mats on sediment C storage.

Zhang K[1]; Kunkelova T; Wilson P; Xuan C; Crocker A
[1]University of Southampton, School of Ocean and Earth Science.
Poster: Abstract #288 / Session T23 - Unlocking Climate Histories from Marine Sediments

What don't we understand about past rainfall changes in Africa and Arabia during the Pliocene?

Past hydroclimate change in Africa and the Arabian Peninsula plays a vital role in early human evolution and dispersal. Although arid today, North Africa and the Arabian Peninsula experienced periodic humid intervals, during which strengthened rainfall driven by astronomical forcing (chiefly eccentricity-modulated precessional cycles) transformed the Saharo-Arabian desert into a vegetated landscape cross-cut by rivers and lakes. The relationship between hydroclimate variability and hominid evolution is strongly debated and continuous palaeoclimate reconstructions are required to provide a context for understanding evolutionary outcomes on land. However, there are major discrepancies between different types of proxy data and between these reconstructions and those generated by numerical models as to the spatial and temporal occurrence of humid events and to the seasonality of the rainfall responsible. Two major contributing problems concern (i) the incontinuous nature of palaeo records from terrestrial archives (palaeolake sediments and stalagmites) and (ii) the challenges of attribution associated with records from marine sediment cores. Here, we report geochemical and stable isotope data from the Arabian Sea to reconstruct past environmental changes in a multi-proxy approach, which will help us to understand the relationship between palaeoclimate change and hominid evolution, reveal how the West Asian monsoon responded to a period of increased global warmth and furthermore, provide a reliable data set for model simulations in the future.

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Talk: Abstract #144 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

Intense upper-ocean cooling and salinification in the Amundsen Sea Polynya in austral autumn

Amundsen Sea Polynya is the most productive polynya in Antarctica and is an essential component of global marine productivity and carbon uptake. Its high productivity has been attributed to the abundant nutrient brought to the upper ocean (~ 200 m) from the water beneath. However, sea ice covering this region for ten months a year limits the amount of high-resolution and long-period observations in the upper ocean, so as our understanding of its processes. Here we present a high-frequency (1-Hz) full-depth hydrographic dataset in a small region (within a ~ 15-km-radius circle) in the eastern side of the Amundsen Sea Polynya in austral autumn (mid-February to mid-April 2014) collected by a recovered seal's tag. Our seal-tag data reveal a mixed layer with rapid cooling, salinification and deepening in the Amundsen Sea Polynya, in contrast with a mixed layer with relatively slow cooling, salinification and deepening outside the polynya where sea-ice concentration is high. The thick mixed layer and the associated convection might contribute to the nutrients moving upwards. We use a 1-D model with and without sea-ice coverage, to show that sea ice reducing the air-sea heat exchange plays a key role in impeding the cooling, salinification and deepening of the mixed layer in ice-covered regions.

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Talk: Abstract #70 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

A multidecadal decline in the densest water exported from the Weddell Sea, Antarctica, forced by wind-driven sea ice changes

Antarctic Bottom Water (AABW) is a key water mass in the global overturning circulation; it floods most of the abyss of the world's ocean and plays a critical role in deep ocean ventilation and oceanic heat/carbon exchanges on multidecadal to millennial timescales. Half of the global AABW supply originates from Weddell Sea sector of the Southern Ocean. In this region, the densest version of AABW are called Weddell Sea Bottom Water (WSBW) and are formed on the Antarctic continental shelf in winter, as a result of intense air-sea-ice interaction. Here we report a distinct long-term decline in the volume of WSBW, as revealed by data collected along repeat occupations of hydrographic sections. We estimate a >20% reduction of WSBW volume since the early 1990s and a resultant widespread deep Weddell Sea warming associated with a basin-scale deepening of density surfaces. The most significant volume reduction is concentrated within the densest classes of WSBW and is concurrent with a decline of sea ice formation rate (>40%) over the southwestern Weddell Sea continental shelf, close to the Filchner-Ronne Ice Shelf. We find that the observed WSBW volume reduction is thus likely driven by a multidecadal weakening of dense shelf water production, primarily driven by the impacts on sea ice of a northerly wind trend associated with a vigorous Amundsen Sea Low deepening from 1992 to 2020.

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Talk: Abstract #13 / Session T13 - Where ice meets ocean: the unique ocean environments of Antarctica and Greenland's shelf seas, ice shelf cavities and tidewater glaciers

Blue Carbon Potential of Polar Region Fjords

The oceans take up 30% of human annual CO2 production and are thus incredibly important at combating climate change. The role of benthos in carbon pathways from drawdown to burial has so far focused on coastal vegetated habitats such as seagrasses and mangroves. However, during interglacial periods, like we are experiencing right now, the polar regions (which do not have these habitats) are becoming more important for carbon storage. This is partly because of marine ice losses extending primary productivity. Fjord systems which characterize polar coasts are particularly promising as carbon sinks. Along the West Antarctic Peninsula (WAP) we found that the retreat of marine terminating glaciers is opening up novel fjordic seafloor habitats to be rapidly and densely colonised by benthic organisms and enhances the capture of organic matter by sedimentation.

Benthos in polar regions are often long-lived, allowing for the storage of up to 56,900 t Carbon/yr in fjords along the WAP while proximity to glacier termini and thus increased sedimentation increases the potential of burial and likely sequestration of such organic matter. Greenland is another hot-spot of climate change and with over 200 marine terminating glaciers and a fjordic coastline has huge potential to become another important area for additional carbon drawdown to sequestration in the coming years. Here, we aim to use data collected from a long-term monitoring series to generate a first time estimate of potential benthic carbon storage along the Greenland Shelf.

List of Organisations in Attendance

For privacy reasons we cannot provide personal details of all delegates attending the conference.

Alfred Wegener Institute for Polar and Marine Research (AWI) / The Helmholtz Institute for Functional Marine Biodiversity (HIFMB)
Bangor University
BBC Natural History Unit
British Geological Survey
Cape Eleuthera Institute
CEFAS
Centre for Ocean and Atmospheric Sciences, School of Environmental Sciences, University of East Anglia
CESAM
Chief Compliance and Management Regulatory Unit
CIC
CLES, University of Exeter
CNRS
CTG
Deep Seas Environmental Solutions Ltd
DEFRA
DSTL
DZMB - Senckenberg am Meer
Edinburgh Napier University
Environmental Analyst
GEOMAR Helmholtz Centre for Ocean Research
Greenland Climate Research Centre
Heriot-Watt University
HKUST
Hull Marine Laboratory
Hull University
Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER)
IICM - Okeanos (UAC)
Imperial College London
Institut Ciències del Mar - CSIC
Institute of Oceanology Polish Academy of Sciences
Institute of Zoology
Integrated Statistics (NOAA)/Cornell University
International Seabed Authority
JAMSTEC
Japan Fisheries Research and Education Agency; Tokyo University of Marine Science and Technology
KTH - Royal Institute of Technology, Sweden
Liverpool John Moores
Marine Biological Association and University of Plymouth Marine Scotland Science
McGill University
National Institute of Polar Research
National Oceanography Centre
Natural History Museum
Nature Porfolio
Newcastle University
NIOZ Royal Netherlands Institute for Sea Research
NORCE Norwegian Research Centre, Bjerknes Centre for Climate Research Northumbria University
Ocean Challenge
Okinawa Institute of Science and Technology
Open University
Oxford University
Plymouth Marine Laboratory
Promare
Queen's University Belfast
Rhodes University

Royal Museums Greenwich, National Maritime Museum
School of Natural and Environmental Sciences, Newcastle University
Scottish Association for Marine Science
Senckenberg/DZMB
Technical University Dresden, UFZ Leipzig
The Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research The Arctic University (UIT), Norway
The Hong Kong University of Science and Technology
The Marine Biological Association of the UK
The Nerherlands Royal Institute for Sea Research
The Pew Charitable Trusts
TMC
United Kingdom Hydrographic Office
Universitat de Barcelona (UB) & Institut de Ciències del Mar (ICM-CSIC) University College London
University Federal Rural of Pernambuco/ IRD
University of Aberdeen
University of Bath
University of Bristol
University of California, Los Angeles (UCLA)
University of Cambridge
University of East Anglia
University of Edinburgh
University of Essex
University of Exeter
University of Glasgow
University of Hawaii
University of Hull
University of Illinois - Urbana - Champaign
University of Leeds
University of Leicester
University of Liverpool
University of Manchester
University of Oxford
University of Plymouth
University of Portsmouth
University of Reading University of Sheffield University of Southampton University of St. Andrews University of Stirling
University of Strathclyde University of Sussex University of Szczecin University of Western Australia University of York
Unversity of Montpellier / Rural Federal University of Pernambuco William & Mary, Virginia Institute of Marine Science
Zoological Society of London