OCEAN Challenge

The Challenger Society for Marine Science

Volume 9, No. 1, 1998

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The Magazine of the Challenger Society for Marine Science

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Ocean Challenge aims to keep its readers up to date with what is happening in oceanography in the UK and the rest of Europe. By covering the whole range of marine-related sciences in an accessible style it should be valuable both to specialist oceanographers who wish to broaden their knowledge of marine sciences, and to informed lay persons who are concerned about the oceanic environment.

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CONTENTS

Most of the figures and maps for this issue were drawn by John Taylor of the Cartography Office of the Department of Earth Sciences at the Open University.

The cover and the titles of feature articles were designed by Ann Aldred Associates.

Foundation of the EFMS

The European Federation of Science and Technology Marine Societies was formally created in Paris on 11 December 1998, when delegates from seven European countries signed the 'Act of Creation of EFMS' under statutes of French Law.

This signing ceremony was the culmination of a process which started in 1992 with an informal contact by the Union des Océanographes de France with three other European associations: the Deutsche Gesellschaft für Meeresforschung (DGM), the Challenger Society for Marine Science (CSMS) and the Associazione Italiana di Oceanografia e Limnologia (AIOL), at an annual scientific meeting of the UOF. The participants agreed the importance of developing close working relationships between their societies, and of mutual exchange of information.

Two years later, the Challenger Society proposed to the various associations a charter for European marine science organizations. This was ratified by the UOF during its General Assembly, and the idea of a federation was thus launched. In 1996 the CSMS invited European scientists to its biennial conference in Bangor at which there were discussions between the CSMS and DGM which led to an agreement on supporting the development of a Federation. But in spite of continued regular exchange of information, it was not until September of 1997 at the General Assembly of the DGM in Hamburg, to which the UOF and the Challenger Society were invited, that further progress was made. During that meeting, it was agreed to launch the new European Federation of Marine Science and Technology Societies in 1998, appropriately designated the UN Year of the Ocean. Further meetings to discuss statutes were held in Paris and at Boulogne-sur-Mer, and the concept of a Federation was advertised to the participants of MAST days in Lisbon, in 1998.

At present, eight countries are members of EFMS, either as full members or as observers. They are:

Belgium (Instituut voor Zeewetenschappelijk onderzoek, IZWO)

Finland (Suomen Meriteen Ja Tekniikan Seura Ry, SMTSR)

***Prof. John Simpson (for UK societies) and Prof. Thomas Höpner (for the Deutsche Gesellschaft für Meeresforschung, Germany) signing the* Act of Creation of EFMS.**

The other national representatives were: Dr Amiard (UOF, France), Dr Jaspers (IZWO, Belgium), Dr Kivimaa (SMTSR, Finland), Dr Dassenakis (GOA, Greece), Prof. Albertelli (AIOL, Italy), and Elisabet Fogelqvist (SH, Sweden)

France (Union des Océanographes de France, UOF)

Germany (Deutsche Gesellschaft für Meeresforschung, DGM)

Greece (Greek Oceanographers' Association, GOA)

Italy (Associazione Italiana di Oceanologia e Limnologia, AIOL)

United Kingdom (Challenger Society for Marine Science, CSMS; Society for Underwater Technology, SUT; Marine Biological Association of the UK, MBA; Scottish Association for Marine Sciences, SAMS)

Sweden (Svenska Havsforsknings-föreningen, SH)

The first President of EFMS, for 1999, is Professor Lucien Laubier, and the General Secretary at the French Office is Dr Jean-Francois Pavillon.

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The Objectives of the EFMS

★ *To contribute to the advancement of research and education in Marine Science and Technology.*

★ To disseminate information and to promote the advancement of Marine Science and Technology in Europe.

For these purposes the Federation undertakes:

☆ To address jointly European issues of common interest.

☆ To make known the philosophies and needs of its members.

☆ To promote the development of Marine Science and Technology.

☆ To promote the contribution of Marine Science and Technology to European Union research programmes.

☆ To assist the European Union in obtaining technical advice from members of the Federation.

☆ To provide a permanent network between Marine Science and Technology societies and a common, but not unique, gateway to each of these societies and their national networks.

News and Views

Salinity and the Origin of Life

Could the development of multicellular life have been hindered by high salinity in the primitive ocean? How high would the global average salinity need have been to inhibit evolution in that way? The proposition has been made that all of the salt presently in evaporite deposits was once in the oceans, so they were once much more saline than they are now (*Nature*, **395**, 1998, 564–5).

Globally, there are around 10^{16} tonnes of evaporites, and if all of that went back into the oceans, salinity would go up to 40–45 g l^{-1}, saltier than the Red Sea but much less salty than the Dead Sea. Salts of marine origin are also dissolved in groundwater, of which there is presently about 1.5×10^{16} t – some two order of magnitude less water than in the oceans. If the 'marine' salts in groundwater were returned to the oceans, average salinity could rise by a few more g l^{-1}, to perhaps 50 g l^{-1} (but only if the average salinity of groundwater were several times that of seawater).

Salinity was high in the early ocean, the story goes, because there wasn't enough continental crust to accommodate either evaporite deposits or groundwater, at least until about 2.5 Ga (2.5×10^9 years) ago. Only then could salinity begin to decrease to the levels necessary for development of metazoans (multicellular organisms), modern varieties of which can't tolerate salinities greater than about 50 g l^{-1}.

Can the converse be argued with equal plausibility? Weathering and volcanism continually supply dissolved constituents to seawater, so might salinity be expected to increase gradually over geological time, were it not for removal of salts into evaporites and groundwater? Moreover, both evaporites and saline groundwaters are being recycled back into the oceans all the time, by weathering and seepage, at rates that may or may not balance 'new' supplies of dissolved constituents.

Incidentally, it seems to be assumed in all discussions about Earth history, that the ocean has always been a (mainly) sodium chloride solution. The early Earth had a CO_2-rich atmosphere: could its ocean have been a (mainly) sodium carbonate solution, like today's East African soda lakes?

The Earth has always had an ocean, to be sure, but can we be equally confident that the total quantity of water in the global water inventory has remained more or less constant throught geological time? Perhaps it has been slowly increasing through net additions of juvenile water from the Earth's interior and/or via cometary impacts. Or perhaps any gains have been offset by losses through photolytic dissociation of H_2O, the hydrogen escaping and the oxygen (in part as OH^-) being sequestrated in oxidation reactions.

Meantime, the suggestion that salinity changes could have been implicated in the Cambrian 'explosion' of metazoan life seems to be as good as any of the others that have been proposed, such as changes in nutrient concentrations, growth of shelf sea areas, or increasing O_2:CO_2 ratios in the atmosphere.

Nanobes, Ancient Oil, and the Oldest Living Flatworm

A few years ago there was enormous excitement when minute structures in a meteorite fragment from Mars were interpreted as possible fossilised ancient life-forms. Among the many arguments put forward by scientists sceptical of this interpretation was that the putative Martian 'bugs' were an order of magnitude smaller than any bacteria known on Earth. But only the other day we read of 'submicroscopic fibres' on clay mineral (illite) particles in an Australian oilfield drill core. They've been called 'nanobes' despite uncertainty over their status as life-forms; and they did appear to be composed of C, N, and O (presumably also H), were non-crystalline and apparently showed signs of filamentous growth. There is some question about whether these things were really inside the rocks or whether they infected the core samples in the lab. However, that doesn't really matter, if they *do* turn out to be life-forms. Whatever their provenance, their minute size will provide a boost for those who believe there was once life on Mars.

Those nanobe-bearing rocks are Cretaceous, so the petroleum in them cannot be older than ~150 Ma at most; and oil is pretty rare in rocks older than about Devonian (~400 Ma). The discovery of hydrocarbon-bearing fluid inclusions in Archaean sand-stones (~3 000 Ma old) is therefore both new and interesting (*Nature*, 1998, **395**, 885–7). New, because the oldest rocks previously found to contain traces of oil are about half that age, and interesting because this very ancient fossil oil may contain biomarkers that can provide information about Archaean life-forms, which are – to say the least– not plentiful as fossils.

Indeed, the fossil record remains neither plentiful nor diverse until the Cambrian explosion that heralded the dawn of metazoan life, which may or may have been triggered by a fall in seawater salinity to below some critical value (see previous item). Be that as it may, a 'living fossil' from that event has recently been identified The existence of 'acoels', very primitive marine flatworms, has been known to science for over a hundred years, and scientists have now established just how primitive some of them really are. For example, acoels pass directly from egg to adult without an intervening larval stage, and although (in common with other bilaterally symmetrical animals) they possess a mesoderm, they have no true gut. They were originally classified among the Platyhelminthes, along with virtually all other marine flatworms, but elucidation of their DNA sequences suggests that at least a couple of species of acoels branched off very early indeed from an ancestral animal. They may be one of the closest (and would certainly be the oldest) living representatives of the first bilaterally symmetrical organisms on Earth (much older than the 'oldest living fossil' commonly cited by palaeontologists, the brachiopod *Lingula*). The article reporting these researches (*Science*, 1999, **283**, 1823–4, 1919–23) does not mention the fossil record of acoels, but since they are soft-bodied animals they could only be preserved under special conditions, such as those that provided science with the remarkable Burgess Shale assemblage in British Columbia.

On Coelacanth Migrations and the Perils of being a Living Fossil

The newly discovered Sulawesi population of ceolacanths in the western Pacific (*Ocean Challenge*, Vol. 8, No.3, p.13) is unlikely to be isolated from the much better known Comoros population in the western Indian Ocean. Arnold Gordon and others (e.g. *Nature*, **395**, p.634) have established that there is an oceanographic connection between the two regions via the South Equatorial Current, at least for surface and thermocline water (the upper 400 m of the water column, deep enough for coelacanths). The South Equatorial Current flows westward throughout the year, whereas the eastward flowing Equatorial Countercurrent lies further north, flows only during the North-East Monsoon, and may not always be an ocean-wide feature.

It is tempting to suppose that the western Pacific population could be 'parental' to the Comoros population, but that is too simplistic, because it ignores the long history of this living fossil. The coelacanth (*Latimeria*) was thought to have been extinct since the Cretaceous (which ended c. 65 Ma ago), until a live specimen was caught off the Comoros Islands in 1938.

The distribution of land and sea, and hence of current systems, is nowadays very different from what it was at the time of the coelacanth's supposed extinction. The Mozambique Straits already existed at the end of the Cretaceous and there was probably an embryonic Comoros Island group there. On the other hand, the western Pacific is a complex of micro-continental fragments and island arcs and oceanic crust that is mostly younger than about 50 Ma. Some of the microcontinental rocks are Cretaceous or older, and cannot have been in their present positions at the end of the Cretaceous. Also, at that time there was still a 'Tethyan Ocean', a major seaway north of India and Africa (and a long way north of Madagascar), linking the Pacific to the Atlantic.

In short, the question of where *Latimeria* populations have been hiding for the last 65 Ma – and how they got to be where they are now – remains wide open. However, while the two coelacanth populations may not in principle be isolated from one another, the fact is that they probably separated some tens of thousands of years ago, perhaps more, for they have been assigned to different species: *L. chalumnae* off the Comoros, *L. manadoensis* off Sulawesi (in the Celebes Sea). The Sulawesi population is believed to be both larger and genetically more diverse than the Comoros population, which may number no more than 500 or so individuals. It is thus especially vulnerable to overfishing, not least because of the quaint notion that as the coelacanth has 'cheated extinction' it must possess some ingredient that confers everlasting life (or at least a longer one). Apparently, Comoros fishermen are paid to hunt the coelacanth because a few grams of its spinal fluid sells for thousands of dollars in Japan.

There is something faintly ironic about a living fossil that gets to be classified as an endangered species. But if the coelacanths in the Celebes Sea do prove to be more numerous than those off the Comoros, they may not be so endangered after all – especially as Japan is much closer to Sulawesi than it is to the Comoros!

Global Warming Sets Organisms on the March ...

There was a lot of media and press brouhaha earlier this year about the effects of global warming in Alaska and the Arctic. North of the Arctic Circle, average temperatures have risen something like 3 °C in the last 30 years, and winters have become two weeks shorter over the same period. Glaciers are retreating and Arctic sea-ice cover is 20–30% thinner than it used to be. Less ice means a lower albedo and greater absorption of solar radiation, so the process is likely to accelerate. And since much of the melting ice is land ice, it will contribute to global sea-level rise. Early summers are also adversely affecting terrestrial and marine food chains, to the detriment of both wildlife and the (declining) populations of indigenous peoples who depend upon hunting for survival.

Shorter winters are not occurring only in Arctic regions. Spring now also arrives sooner in northern Europe than it did in the 1960s, with many animal and plant species breeding and flowering 10 days to two weeks earlier on average. Northward migrations of species are also observed. Animals and plants not previously seen in Britain are now establishing footholds here, while large numbers of basking sharks and other relatively warm water marine animals have recently been observed in British waters. Meanwhile, on the other side of the world, Antarctic chinstrap penguins were recently reported to be breeding on Signy Island, well south of their normal breeding grounds in the somewhat warmer latitudes of Chile and Argentina.

Even for those philistines who welcome global warming because it means they'll be able to have the barbecue going on the lawn at Christmas, it isn't all good news. Britain may have had its sunniest winter for ten years and 1998 may have been the hottest year since 1860, but much of the rest of Europe suffered its worst winter since the 1940s. Few of us can have forgotten the harrowing stories of avalanche victims in the French and Austrian Alps for instance – and they were not alone: the trail of winter destruction extended from the Carpathians to the Pyrenees.

There is now also some concern that disease bugs are migrating northwards as the global climate warms, that northern Europeans may soon be afflicted with tropical diseases like malaria. It is worth reminding ourselves that climate change is not new, nor are concomitant species migrations. Organisms have always migrated back and forth across latitude zones, as the Earth's surface has alternately warmed up and cooled down. The difference now is that as we overpopulate the planet we increasingly destroy the habitats of those organisms, with the result that migration may lead to extinction.

... and Unfreezes Cold War Secrets

Hidden in the small print of some of those press accounts of climate change and its effects were brief, almost passing, mentions of strange signals picked up by NATO submarines patrolling Arctic waters. Tantalisingly brief though the reports were they gave the distinct impression that when the signals were processed the messages turned out to be in Russian and related to technology and operational procedures current during the tense Cold

War years of the 1960s. Some readers may recall learning a few years ago of a group of Arctic explorers who reported hearing brief snatches of conversation that seemed to come unbidden out of the surrounding air, and apparently related to an earlier expedition. The explorers could only conclude that they were hearing fragments of speech that had somehow been 'frozen' into the Arctic air, to be released again with the onset of spring. At the time, few people gave this bizarre notion much attention, let alone credence, and some even suggested it was a hoax. But this latest development has given us pause for thought.

Is it not inconceivable that either acoustic or radio signals (or both?) could somehow have become frozen into the ice as it formed during Arctic winters of three or four decades ago, a time when the Cold War was at its most frigid? Now that global warming is causing the ice-edge in the Arctic Ocean to retreat further north each year – and the permanent pack-ice cover to thin progressively – the signals are being released from cold storage, so to speak.

What is perhaps most intriguing about this story is that it got such brief mention in the public prints, suggesting that Govenment and the military establishment are reluctant to release the information. Surely that is nonsense. What possible harm could be done by releasing even military–industrial secrets from what is by now a long bygone age? Still, you can never be sure. Perhaps it is not the messages themselves but the technology behind them that the authorities are reluctant to reveal. Could it be that government scientists are even now investigating a newly discovered field of *cryoacoustics*, with a view to future military advantage?

Stealth Fish

In the last issue of *Ocean Challenge* (Vol. 8, No.3, p.13) we reported on the postulate that the average size of mature cod is decreasing in response to selective pressures caused by overfishing. We have now learned that in certain herring populations, scales in the dorsal area of many individual fishes are finely divided, giving them a fibrous texture, and making them a 'softer target' acoustically, and hence harder to detect and track using sonar. This is a strategy that will be familiar to designers of submarines, and is not unrelated to the idea behind the design of stealth bombers; though the scale of 'roughness' of the surface has to be orders of magnitude smaller to 'foil' radar than to outwit sonar.

For more about these last two items see *J. Acoustic and Defence Studies*, **477**, No. 1, April 1999, pp.42–3 and 66-84.

Coral Bleaching – is Global Warming to blame?

Global warming cannot be responsible for killing off coral reefs all over the world, as press headlines persistently claim. Corals do of course become severely stressed and expel their zooxanthellae (hence the 'bleaching') when water temperatures exceed about 30 °C; and in places like the Seychelles and Australia's Barrier Reef, temperatures recently reached 33 °C. However, it seems inconceivable that in the 400 or so million years of coral evolution surface water temperatures have not fluctuated by several degrees on time-scales of a few years or decades. Data from sediments and ice-cores suggest that such fluctuations were common during the last few tens to hundreds of thousands of years – so they cannot have been all that rare in the preceding hundreds of millions of years. Yet there is no record of global coral wipe-outs other than during the major mass extinction events that decimated the rest of the planet's biota too.

Heat stress by itself surely cannot be new to corals. But when pollution and habitat disruption – not to say destruction – by coastal development, sediment disturbance, industrial fishing, and tourism are added, the combination can prove fatal. A further savage twist to this sorry tale is that the pollution we produce includes not only toxic chemicals, excess nutrients and other substances, but also viruses and bacteria. We are making corals ill, not simply poisoning or smothering them or blowing them up. In light of all this, it is surely disingenuous to finger global warming as the culprit. Humans are certainly to blame for coral extermination, but we aren't doing it by anthropogenic global warming alone.

So ...

... What about El Nino then?

The received wisdom in standard texts is that coral reefs are less common along the low-latitude eastern coasts of major ocean basins because these are regions of upwelling of cold water in eastern boundary currents. It seemed a good enough reason for most people, but at the 1999 Lyell Meeting, Peter Glynn of Miami University suggested that El Niño could be the cause of the 'depauperate coral fauna and meagre reef development in the eastern tropical Pacific'. In essence, his argument is that corals *can* grow in this region despite the upwelling, that coral reefs would become extensive were it not for the hammering they get every few years when El Niño 'heats' the water. Subsequent recovery is hindered because of bio-erosion, as echinoids and bivalves pick over the dead and dying coral in search of food.

One problem with this proposition is an apparent consensus that nutrient-rich upwelling water is bad for corals, partly because it's a bit cold, but chiefly because it can stimulate the growth of benthic algae, which may smother the coral. In addition, it seems that corals themselves can't really cope with sustained high nutrient levels – after all, they've evolved to recycle spare resources efficiently. So normal non-El Niño years wouldn't be all that good for corals anyway, and stronger La Niña years would be even worse. Indeed, it is surprising that there are any coral reefs in the eastern tropical Pacific at all. And what about the eastern tropical Atlantic? Not many coral reefs there either, but surely that can't be ascribed to the influence of ENSO events?

Re-using Old Cables

As long ago as 1991 (Vol. 2, Winter, pp.6–7) we reported on proposals for using redundant under-sea communication cables for deep-sea research. Original ideas covered a range of oceanographic monitoring activities and instruments attached to the cables: sea-bed current meters, pressure gauges, acoustic and seismic sensors, temperature and conductivity sensors, and so on. Seismometers attached to the cable between Hawaii and California are now being used to monitor submarine earthquakes, and it is hoped to extend the coverage by making similar use of other retired cables.

Shoring up Britain's Coasts – Where will it end?

Almost every month – sometimes more often – we learn of yet another sea-side community in peril from the sea along Britain's south and east coasts. The continuing saga of cliff-hanging real estate is occasionally enlivened by tales of expensive house moves (e.g. Bell Tout lighthouse near Beachy Head), but mostly we see pictures of buildings collapsing into the sea (Holbeck Hall near Scarborough is perhaps the best known of recent years).

The sea has been eroding these coasts for centuries and the rate of retreat may well have increased in the last 20–30 years (as many cliff-top residents claim). Erosion rates are likely to increase, as melting ice sheets and glaciers and thermal expansion of the oceans ensure that sea-level goes on rising – and global warming is likely to make winters stormier too, which will exacerbate the problems.

What is to be done? There is a growing body of opinion that it is pointless to continue almost literally pouring money into the sea to rescue that which is already doomed. The more practical solution would seem to be a policy of managed retreat, which allows the sea to invade here and retreat there, as sediment eroded from one stretch of coastline is re-deposited along another. There could even be a net gain of land area, if sediment removed from steep cliffs is re-deposited to form and/or augment salt marshes.

The idea of surrendering land to the sea is understandably not favoured by people living on the edge, and they clamour continuously that Government must *do* something. In times gone by, when villages were self-contained (and perhaps largely self-sufficient) fishing and agricultural communities with relatively simple needs and small populations, people could up sticks and retreat as the sea encroached – an early form of managed retreat! Such an option is no longer possible, now that income accrues more from holiday homes and the tourist trade than from fishing and farming. Only a month or two ago the *Guardian* ran a story about Runswick Bay, a small coastal village near Whitby, where it is proposed to spend nearly £2.5 million on a scheme which will include reinforcing the cliffs with concrete piles and armouring the shoreline with huge blocks of rock brought over from Norway. The taxpayer will foot the bill, but the locals hope the operation itself will be dramatic enough to attract more summer visitors.

They had better also be hoping that the works don't shift wave and tidal current patterns so that they wash away the village's precious beach, the centrepiece of its tourist trade. Perhaps they ought to visit Minehead, where raising the sea-wall and building groynes to prevent future storm damage resulted only in diverting the tidal currents which stripped all the sand from its 'golden' beach ('the jewel in its tourist crown'), leaving an intertidal area consisting mostly of mud.

Further west, people who take boulders from beaches to put in their gardens may face prosecution for theft. So far, it is only the National Trust that threatens such action, with specific reference to the SSSI at Porth Nanven (Cornwall), where the boulders are said of be of glacial origin. It could be the thin end of the wedge, but as we noted in a recent issue (Vol.8, No.2, p.29), it makes sense not to remove boulders, shingle, sand, or even rubbish from beaches – especially not with bulldozers – because it constitutes anthropogenic erosion of natural coastal defences. It places the Scots in a bit of a dilemna, though, because their beaches are said to be the worst in Britain for rubbish. Should they let the rubbish degrade naturally (which could take years) and try to educate people to Take Their Litter Home, or should they send in the bulldozers and increase the local erosion rates? Perhaps they should do both, not least because Scotland's coasts are mostly carved out of hard rocks that are fairly resistant to pummelling by the waves.

Suckers for Satellites – Not so funny after all

It very quickly turned out to too much to hope that the Mad Russian Scientists' plan to put a mirror into space would come to nothing (*Ocean Challenge*, Vol. 8, No. 2, p.29). An attempt to launch the 25 m solar reflector in February failed for technical reasons, but the Russians are evidently determined to keep trying. The idea is to bring light to Arctic regions of winter darkness, which may be fine for humans but is unlikely to benefit ecosystems which have evolved over millions of years to adapt to a day–night cycle that varies over the course of the year.

On the other hand, we may owe America's Vice-President an apology for calling his 'inspirational' satellite a nutty idea. Although it is still intended to be (as we reported) 'a beacon for environmental awareness and science education', it will also carry instruments for monitoring the global radiation budget. Funds for the project (called *Triana*) have been approved, despite scepticism in some circles about its scientific value.

Data-gathering for Improved Management of the Solent

Southampton Institute has begun a long-term tidal and weather monitoring project which will provide information vital for sound management of the Solent region. The Institute's Maritime Faculty has installed a data station at the end of Warsash Jetty, and this automatically logs water and weather conditions every 15 minutes, around the clock. As data continue to flood in, it is hoped that an accurate, long-term picture of local oceanographic and meteorological conditions will be built up.

A recent meeting of the Solent Forum (Hampshire County Council's mouthpiece for those concerned with the day-to-day management of the region) concluded that long-term monitoring of water quality in areas such as Southampton Water was essential for making good scientific sense of the environment, so that sound management decisions could be made. This was a view shared by representatives of the Environment Agency. However, funding for such schemes is hard to obtain, often because of problems in identifying definite research outcomes. By combining a research angle with a valuable teaching resource, the Maritime Faculty has secured funding and installed this first phase of monitoring. It is hoped that the range of parameters can soon be extended to chemical and biological variables.

The station logs tidal height, water temperature and salinity, air temperature and pressure, and wind direction and speed, and weekly samples are taken for phytoplankton abundance and population composition. This station represents one of the first attempts to acquire such long-term, high resolution data in this area. It also links up with more recent similar monitoring stations established further up Southampton Water, by the SOC, and off Littlehampton, as run by Aran District Council.

The information gathered will help research into water movement, pollution, and the ecology of estuaries. For example, it is hoped that the data will help scientists further understand the links between tidal processes and algal growth in the estuary. The movement of nutrients through the estuarine system is also of interest to the people involved in the project. At the same time as providing a research resource it is also returning data, which is of prime importance to the teaching of the Faculty's Marine Environmental Science degree.

Paul Wright
Project Co-ordinator, Southampton Institute

Criteria for Blue Flag Award

It seems that Blue Flag status can only be conferred on a beach when certain criteria have been fulfilled, apart of course from the over-arching requirement that the water be clean enough to swim in. For a Blue Flag award, the following must be available:

- Cafe or restaurant, shop, toilets, public transport, supervision, first aid, and public telephones within easy access (an emergency phone is not enough).
- Adequate life-saving equipment located at 100–200 m intervals along the beach.
- Daily beach supervision by personnel clearly identifiable by a distinctive uniform.

Do you know of a Blue Flag beach and if so, how well does it measure up to these criteria?

A possibly more serious question is this: Can beaches that are nature reserves (or are near a nature reserve and/or SSSI) be awarded Blue Flag, status, if although clean they are otherwise lacking in the facilities listed above. An example of just such a beach is Llandwyn on Anglesey. Is that appropriate? What would happen to the nature reserve/SSSI were all those facilities to become available? Is this something about which the Challenger Society could or should have an opinion?

The Grape Vine

- Professor Stephen Hawkins of the School of Biological Sciences at the University of Southampton has been appointed as the new Director of the Marine Biological Association. He will take up his position at the beginning of October.
- Dr Ed Hill has been appointed as Director of the Centre for Coastal and Marine Sciences Proudman Oceanographic Laboratory. Ed was previously a Senior Lecturer at the School of Ocean Sciences, University of Wales, Bangor.
- Dr Howard Roe has been Acting Director of the Southampton Oceanography Centre since the beginning of April. Howard was previously Deputy Director of SOC, and Head of the George Deacon Divsion. The previous Director, Prof. John Shepherd, has completed his five-year term, and has become the Director of a new Earth System Modelling Initiative at SOC.

Progress with *Autosub*: the Bermuda '98 Expedition

Gwyn Griffiths

Diary entry for 22 Aug. '98

St George's, Bermuda

It is 7.30 a.m. Stepping into the air-conditioned laboratory aboard the RV *Weatherbird II* feels like an instant transportation from the humid heat of Bermuda to the dry cold of the Arctic. I arrived at the Bermuda Biological Station for Research (BBSR) late last night via New York. The safety briefing will be taking place in a moment; the fresh coffee helps to wake me up. I've joined the *Autosub* team for the first leg of an expedition that will take the autonomous underwater vehicle deeper and further than it has ever been before.

The waters around this British colony of Bermuda are particularly well studied. Back in 1954, an American, Henry Stommel from Woods Hole, initiated a programme of ocean observations at a site 24 km offshore, now known as 'Hydrostation S'. This time-series continues to be undertaken by the BBSR and has helped to focus other monitoring activities at Bermuda: the US JGOFS Bermuda Atlantic Time Series stations (since 1988), and the Bermuda Testbed Mooring (since 1994).

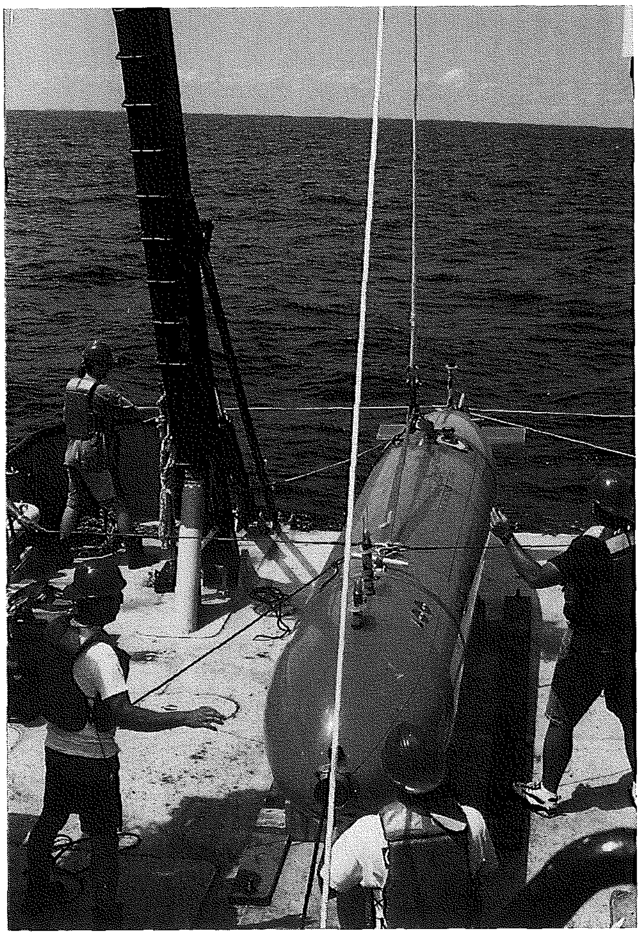
Continuity of observations is critical for long-term research into changes within the ocean. For a number of years, autonomous underwater vehicles – AUVs – have promised to be a cost-efficient way of making routine observations. One of our objectives in taking *Autosub-1* to Bermuda was to show that the promise could now be realized. Working with Dr Tony Knap, Director of BBSR, the *Autosub* team conceived the expedition in January 1997, and with support from the US National Science Foundation, here we are.

There is a swell. Hurricane 'Bonnie' is some 800 km away and just about to deluge North Carolina. There is a local wind too. We set sail at 09.00 and by noon we are in 2000 m of water and ready to deploy the vehicle. *Autosub-1* is nearly 7 m long and weighs over a tonne-and-a-half in air. The crew manage to keep the vehicle from swinging as it is lifted from its cradle and over the stern. Now comes a tricky operation: two associates from Florida Atlantic University need to attach a very sensitive turbulence sensor right on the very nose of *Autosub*. This can only be done when it's in the water. Ken, an accomplished swimmer, dons his lifejacket, and working from a small inflatable, adroitly fixes the small package to the submarine.

Mission 136 is about to start – our first Bermuda mission. It is planned to last an hour, making runs at fixed depths for 10 minutes, in a staircase pattern down to 255 m. All goes exactly to plan. We realize, almost in passing, that the vehicle has been deeper than it has been before. Our previous best was 210 m, off Florida.

The next planned mission is to a depth of 400 m. Mission 137 starts well with a dive to 10 m, but the vehicle rises immediately to the surface. Much scratching of heads. Data are dumped from the vehicle to the *Weatherbird* via a radio link, hypotheses are put forward, argued, and dismissed. Test missions are programmed to find which of the remaining possible problems could be to blame. Two hours later we have the answer. *Autosub-1* uses an acoustic altimeter to sense its height above the sea floor. Here, we were not expecting it to find the sea floor; it is just too deep. But it should indicate 'bottom not found'. Instead, sometimes, it was registering 0.5 m. The vehicle is clever enough not to dive in such ridiculously shallow waters, but not quite clever enough to know that 0.5 m just isn't possible out here!

Problem corrected, missions 141 and 142 proceed according to plan. We achieve 400 m in a succession of dives over tracks of 4 km and 12 km – almost an anticlimax. Not for us the exuberance of a Bob Ballard. In some ways, that is a pity, for our achievement is real and significant, if not particularly televisual. Recovery of the vehicle in the dark at 9 p.m. proves difficult, the sea and swell combine to make it a risky operation. Far safer, we decide, to tow the vehicle to sheltered waters. We dock at 1.30 a.m. I try not to think that it is 5.30 in the morning back home. The sense of achievement helps – the team spirit has been tremendous.



Autosub ***off Bermuda***

Forthcoming *Autosub* Science Missions

Fisheries and plankton acoustics, and oceanographic investigation of impenetrable environments (USIPS: Under Sea-ice and Pelagic Surveys) (June–July, 1999; Oct.–Dec., 2000)
Andrew Brierley and Mark Brandon (British Antarctic Survey) / John Simmonds (Scottish Office)

Antarctic marginal ice zone (MIZ) study • Quantification and comparison of the abundance and distribution of Antarctic krill within the MIZ and outside it, and investigatation of krill behaviour under ice in relation to ice topography.

• Measurements of thickness of Antarctic sea-ice over a scale of tens of kilometres.

• Measurements of downwelling irradiance under Antarctic pack ice.

Fisheries surveys • Increasing the accuracy and precision of the annual North Sea herring acoustic survey.

• Investigating the magnitude of vessel avoidance by herring during the annual North Sea acoustic survey.

• Observing surface schools of herring during the annual North Sea acoustic survey.

Spatial variability of bottom turbulence over a linear sandbank: effects on the vorticity field and the evolution of bottom topography (Aug.–Sept., 1999; Jan.–March, 2000)
Mike Collins and George Voulgaris (SOC)

• Spatial mapping of bottom stress in strong tidal flows over a linear sand bank in the southern North Sea.

• Using the measurements to understand the role of bottom stress in controlling the bedform-scale flow and sediment transport patterns and the processes that maintain the shoal.

Measurement of dissolved and particulate manganese and oxygen, and the relationship to biogeochemical benthic activity, in hypoxic basins of Loch Etive and Loch Fyne (Oct.–Nov., 1999; April, 2000)
Julian Overnall and Kevin Black (Dunstaffnage Marine Laboratory) / Chris German and Peter Statham (SOC)

• Three-dimensional measurements of the distribution of manganese and oxygen concentations, and of light-scattering, as an aid to understanding the Mn cycle at different times during the isolation of the bottom waters of the two sea-lochs.

• Observing the spatial and temporal variability of Mn distributions in relation to physical features and possible anthropogenic and biological activity.

• Correlating the measurements with sediment ground-truth observations and measurements by means of a model.

Analysis of single cells and particles in estuarine waters and in the English Channel (SSCAPA: Subsurface Single Cell and Particle Analysis) (Aug.–Sept., 2000)
Alex Cunningham (University of Strathclyde) / Peter Burkill (Plymouth Marine Laboratory)

• A submersible flow cytometer will be constructed and installed in *Autosub* in order to study the speciation, distribution and dynamic behaviour of organic and inorganic marine particles in the 1–100 μm size range.

Studies of sonar and turbulence in the upper ocean (Jan.–March, 2000)
Steve Thorpe (SOC) and Tom Osborn (Johns Hopkins University, Baltimore, USA)

• Measurement of the horizontal structure, including isotropy, of turbulence dissipation and fine-scale temperature variability, its variation with depth in the upper 10 m of the water column, and its relation to breaking waves and wind speed.

• Establishing the time-history of turbulent dissipation following the generation of turbulence by breaking waves.

• Measurement of the structure of dissipation within bubble bands produced by Langmuir circulation.

• Examining the variation of turbulence in the upper ocean mixed layer in response to internal wave straining.

• Measurement of turbulence in the thermocline and relating it to local features such as internal waves.

Novel measurements in the Straits of Sicily (May–June, 2000) *David Smeed and John Allen (SOC)*

• High-resolution surveys of flows through straits and over sills, using the terrain-following and mission-programming capability of *Autosub*.

• Measurements of the spatial variability of turbulence, both in the upper ocean and over sills.

• Measurement of the overflow of the sill in the Sicilian Channel, allowing a much improved understanding of exchanges between the eastern and western Mediterranean, and contributing to our knowledge of the changing ocean climate in the eastern Mediterranean.

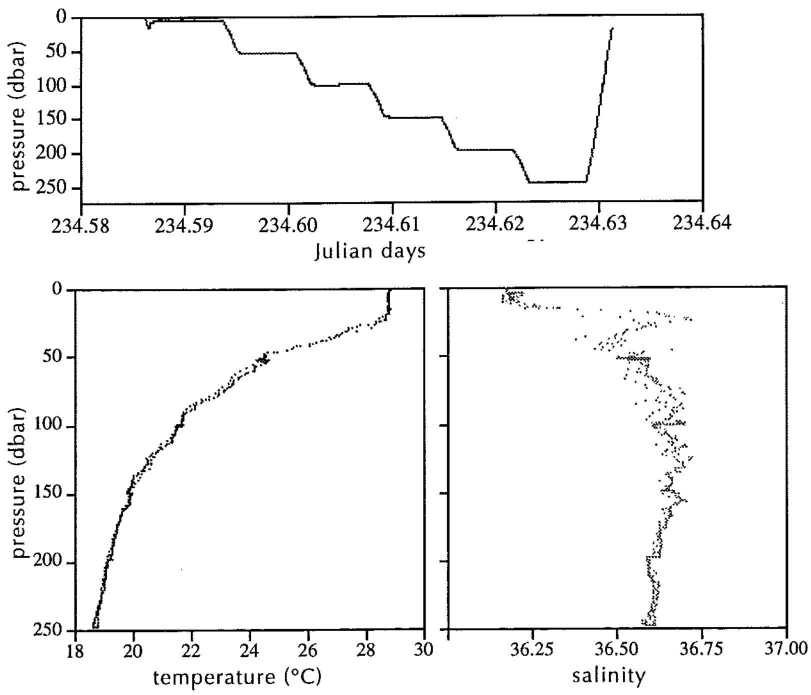
For the Bermuda expedition Steve McPhail led the *Autosub* team which comprised Peter Stevenson, James Perrett, Miles Pebody and Andy Webb. Drs Manhar Dhanak and Ken Holoppa had joined us from Florida Atlantic University. Nick Millard, the team leader, arrived the following day, straight from his summer holiday.

Unfortunately, I had to return to the UK before the final mission. Mission 145 at just over 50 hours, covered 263 km and reached 504 m in a box-and-triangle survey pattern around the Hydrostation S position. To our knowledge, no other self-propelled autonomous underwater vehicle has exceeded that range.

A brief history of *Autosub* missions

Between its launch in May 1996 and the beginning of the Bermuda expedition, *Autosub-1* had completed 135 missions. The first missions were in the safe environs of Empress Dock, immediately adjacent to the Southampton Oceanography Centre. Most of the navigation and control features could be tested in what was, in effect, a 400 m-long by 9 m-deep test tank. Step by step, mission complexity and length were increased during a series of trials within Portland Harbour, before graduating to the open sea off Oban in April 1997. The excercises in the open sea were *Autosub-1*'s formal acceptance trials, which it passed with flying colours. The vehicle ran a number of different missions to demonstrate profiling from the sea-surface to a depth of 195 m, and box-pattern surveys at fixed depths, and showed the feasibility of an AUV leaving harbour under its own control. The longest mission was 34 km. Some 8 months later, the longest mission was up to 110 km – not off Scotland, but off Florida, during the submarine's first venture outside the UK.

The *Autosub* programme has always benefitted from close collaboration with a number of institutions in the UK and abroad. In this case, we were funded by the US Office of Naval Research to run joint missions with our colleagues at Florida Atlantic University and their *Ocean Explorer* underwater vehicle. *Ocean Explorer* does not attempt to match the range or endurance targets of *Autosub* but offers a highly flexible approach to carrying different science payloads for short missions (up to 8 hours). Despite some technical difficulties arising from a circuit-board failure in *Autosub*, the objectives of the programme were nearly all met. Several survey patterns in 'lawnmower' and terrain-following modes were completed in challenging conditions right at the inshore edge of the Florida Current, while gathering data from three CTDs, an acoustic Doppler current profiler and a number of other sensors.



Upper *'Staircase' descent to 255 m during* Autosub *mission 136 off Bermuda.*
Lower *Temperature and salinity profiles obtained during the deployment.*

What next for *Autosub*?

Following *Autosub*'s return to the UK after its triumphant trials in Bermuda, the vehicle has been completely stripped down for a thorough service before a demanding and exciting set of science missions beginning in April 1999 (see box on previous page). The call for proposals in January 1998 for the Natural Environment Research Council's *Autosub* Science Missions thematic programme was oversubscribed, attracting over 20 applications of which six have been funded. The delivery of new carbon-fibre pressure vessels for the battery supply in mid-1999 will enable missions of up to 200 hours or 1000 km to be tackled and the depth-rating to be improved from 500 m to 2500 m. The 'new' vehicle will be known as *Autosub-2*.

AUVs are no longer dreams or engineering curiosities of limited reliability. The quadrupling of the range and endurance of *Autosub-1* each year over the last two years and the quadrupling scheduled for 1999/2000 is just one example of the rapid pace of change in this exciting technology. But, far more important, marine scientists now have a new platform from which to gather much-needed information.

Further reading

Millard, N.W., Griffiths, G., Finnegan, G., McPhail, S.D., Meldrum, D.T., Pebody, M., Perrett, J.R., Stevenson, P. and Webb, A.T. (1998) Versatile autonomous submersibles – the realising and testing of a practical vehicle, *Underwater Technology*, **23**(1), 7–17.

Griffiths, G., Millard, N.W., Pebody, M. and McPhail, S.D. (1997) The end of research ships? *Autosub* – an autonomous underwater vehicle for ocean science, *Proc. Underwater Technology International*, April 1997, Aberdeen, SUT, London, pp.349–62.

Griffiths, G., McPhail, S.D., Rogers, R. and Meldrum, D.T. (1998) Leaving and returning to harbour with an autonomous underwater vehicle, *Proceedings of Oceanology International '98, Brighton*, Vol. 3, pp.75–87, Spearhead Exhibitions Ltd.

For the latest information on *Autosub* please visit our website at:

http://www.soc.soton.ac.uk/OTD/cotdasub/asub.html

Gwyn Griffiths is Head of the Ocean Technology Division at the Southampton Oceanography Centre.

Not too big, not too small ...

Why medium-sized research ships will be the workhorses for shelf-sea oceanography in the coming decades

Ed Hill

From the point of view of humanity's impact on the sea, and the sea's impact on humanity, continental shelf seas are the most important parts of the marine environment. In 1994, 2.1 billion people lived within 100 km of the sea, and coastal populations are the fastest growing. It is estimated that in the UK, £122 billion of trade a year passes through our coastal seas. Although they make up only 8% of the area of the world's oceans, continental shelf seas are responsible for up to 50% of primary (phytoplankton) production and contain most of the world's fisheries. In 1997, Robert Constanza and colleagues (*Nature*, **387**, 253–60) estimated that of the total global cash flow for 'ecosystem services' more than one-third (US$12 trillion a year) derives from coastal seas. Shelves are also the locations of major reserves of minerals, aggregates and hydrocarbons.

International treaty obligations, such as the *UN Convention on Biodiversity*, the *UN Convention on the Law of the Sea, Agenda 21* on sustainable development signed at the Rio Summit, and the *Oslo and Paris Convention*, all place a duty on states to conduct and to document research in, and to manage effectively, the seas within their own Exclusive Economic Zone or EEZ (large parts of which are over the continental shelves). Without concerted programmes of scientific research in shelf seas, we will not be in a position to understand, at a fundamental level, the natural and anthropogenic changes that are occurring in these systems, and such understanding is crucial for underpinning their sustainable development.

New challenges for shelf-sea science

The three key challenges for shelf-sea oceanography in the coming decades and their consequent observational requirements (*given below in italics*) are:

• To understand how the present shelf-sea system functions – e.g. its circulation regimes, ecosystems and biogeochemical cycling – including the internal couplings and feedbacks within the system, and coupling to the deep ocean.

○ *This will require 'process studies' within shelf systems – of, for example, interactions between zooplankton and turbulence, boundary layer dynamics, baroclinic (density-driven) responses, suspended sediment dynamics and diffusion experiments.*

• To understand how the shelf-sea system responds to change at seasonal, annual, decadal and longer time-scales, as well as to identify which parts of the system are most sensitive to change, both natural and anthropogenic.

○ *This will require measurement programmes sustained over long time-scales to provide baseline data and to examine seasonal and inter-annual variability and examine change at longer time-scales (e.g. repeated seasonal hydrographic observations; suspended sediment and plankton surveys; collection of palaeo-shelf records; and long-term measurement with regularly serviced moorings).*

• To test understanding and provide predictive capability through development of new generations of models (e.g. 3-D baroclinic coastal ocean models and ecosystem models) with ultimate applications to water quality and fisheries management, and also for use as research tools in answering complex scientific questions such as those relating to internal couplings in the system (e.g. biophysical and biogeochemical interactions).

○ *This will require systematic measurement programmes designed to provide critical tests of key aspects of the performance of shelf models (e.g. thermocline development, fluxes in channels; also dense water overflows, turbulence fields and coupling to the deep ocean).*

Implications for ship provision

Out of these challenges and requirements there emerge two sharply defined trends that will determine the nature of future shelf-sea measurement programmes. These have direct implications for ship provision (*given below in italics*):

1. As we learn more about how shelf systems work, and our model tests become more specific, there will be a trend towards more highly focussed process studies and measurements, directed at very precise locations or times (e.g. at fronts, on specific sea-bed substrates or habitats, at specific times within the spring–neap cycle, and during post-storm events, algal blooms and spawning periods).

○ *This means that we require a flexibly operated platform to provide access to coastal seas for short durations, for highly targeted sampling in space and/or time and for rapid-response and/or opportunistic access.*

2. There is a move towards sustained, long-term measurement programmes in shelf seas, directed at the detailed investigation of the evolution of shelf systems over seasonal, annual and even decadal time-scales. Such programmes involve long-term monitoring of the shelf environment, and are a reflection of the shift in the shelf-sea scientific agenda to processes acting over longer time-scales (e.g. changes in nutrient loading, interannual variability of density fields and circulation patterns, and shifts in ecosystem regimes). Furthermore, we will continue to need regular access to shelf seas economically, efficiently and flexibly in order to test and develop new observational technologies and to provide training in research methods at sea.

○ *These activities mean that we require platforms to give us access to shelf seas for frequently repeated (but perhaps short duration) experiments and surveys, regular servicing of moored instrumentation, technology development and training.*

These various requirements highlight distinctive elements in the style of measurement required in shelf-sea oceanography. On the continental shelf, spatial changes (in, say the distribution of a plankton bloom) can happen more quickly and over shorter distances than in the open sea. Spatial variability is often large, with distinct dynamical regimes confined to regions with dimensions of just a few tens of kilometres (e.g. regions of freshwater influence) and with events occurring over short-time scales (e.g. pulses of freshwater discharge, tides, storm events).

For logistical reasons, in remote parts of the deep ocean, the emphasis has traditionally been on the large 'one-off' cruise involving long durations away from home with large scientific teams. To some extent, these habits have been adopted in shelf seas, although it is becoming apparent that this style of sampling for shelf waters is less appropriate; nor is it a logistical necessity.

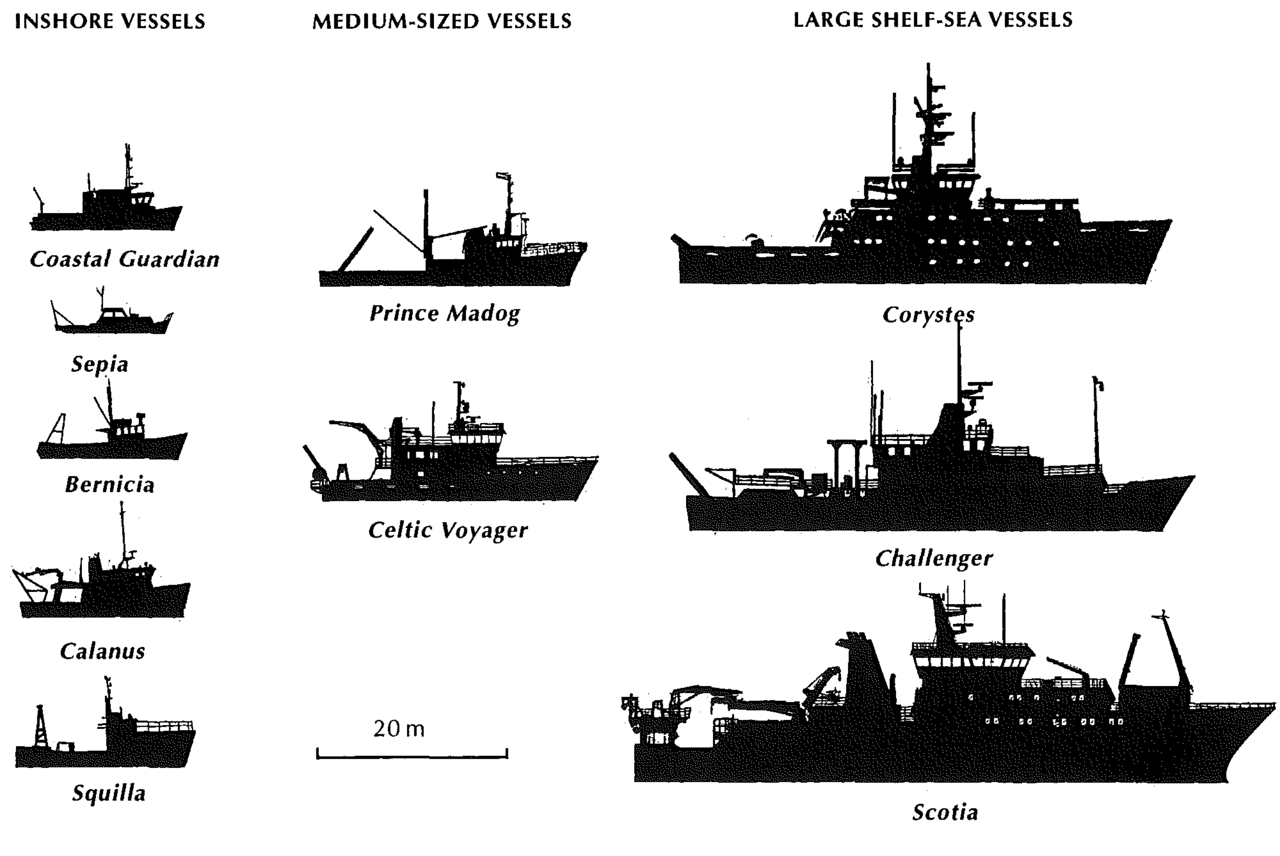
It is true that for certain important aspects of shelf-sea research, large ships (greater than 50 m overall length, with crews of about 20) are essential, particularly in exposed waters such as over the shelf edge, or where very large multidisciplinary teams are needed. However, as discussed above, continental shelf research generates a demand not just for a single class of ship but for an appropriate mix of size classes, from small inshore dayboats to large ocean-going vessels, so that different sampling styles may be matched to a range of regimes, from estuaries to semi-enclosed seas, and out to the continental slope. Within this spectrum, there is a particular need for medium-sized research ships (length 25–40 m overall, with crews of less than ten). These have the unique capacity to meet the above requirements flexibly and economically in inner-shelf and semi-enclosed shelf regions. In particular, it is uneconomical for frequently repeated, short duration cruises to be conducted from large ships, and their use in rapid-response mode is impractical as rigid programming is required if they are to be operated economically. On the other hand, small inshore vessels are also unsuitable for the requirements set out above, because 24-hour working for several days at a time is beyond the sea-going capabilities of such vessels.

Figure 1 shows clearly the contrast between the large shelf-sea ships (capable of working for weeks at a time in the most exposed waters of the shelf and shelf edge) and the small inshore vessels which are confined to sheltered waters within just a few miles of the coast and operate as day boats, returning to port each night. Only the medium-sized ships offer the combination of a robust vessel, capable of working in the open sea for many days at a time, and crew numbers sufficiently small for economic running on a long-term basis.

The present UK research vessel portfolio

Figure 2 (*opposite*) shows that there are a large number of research/ survey vessels operating in the United Kingdom, but in practice many of these (e.g. naval vessels) are not available to the academic research community, and the fisheries vessels (which are almost completely committed to statutory monitoring and other research tasks) cannot take on large volumes of academic research. The most striking feature of Figure 2, however, is the size-polarization it demonstrates, with most vessels being either less than 25 m long, or greater than 50 m. In the crucial medium size range there is very little capacity. There are various reasons for this size-polarization of the UK research vessel portfolio. In some cases, where institutions have

Figure 1 *Only ships like* Prince Madog *and the new* Celtic Voyager *are sufficiently robust to work in the open sea for many days at a time and yet can be sailed with relatively small crews and so can be economically run over the long term.*



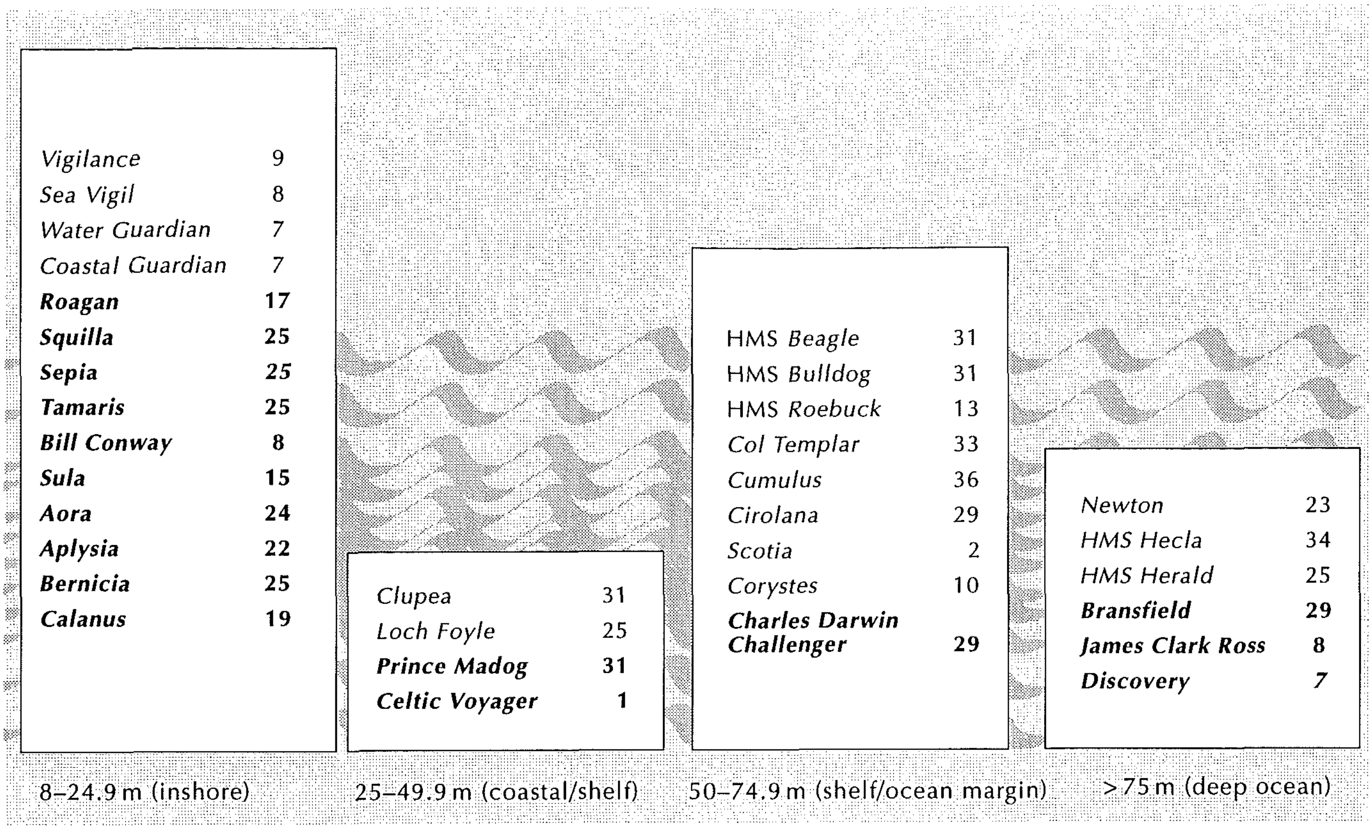


Figure 2 *Histogram showing the size-distribution of UK research and survey vessels.* ***Bold*** *indicates the vessel is primarily available to the academic research community (i.e. operated by a university or research council). The numbers are the ages of the vessels in years as of 1999.*

particular responsibility for exposed waters (around Scotland, for example), the trend towards large vessels is natural. In other cases, however, the drift towards use of larger vessels has been less controlled, often occurring as a means of making the smallest incremental budget cut as resources have tightened over time.

Geographical considerations

Exposure to prevailing weather in the open ocean means that not all areas of the world's coastal seas are suitable for the operation of medium-sized vessels. On the other hand, the semi-enclosed seas of Europe, particularly those west of Britain (the northern Celtic Sea, English Channel, Bristol Channel, Irish Sea, Clyde Sea, Scottish sea-lochs and inner shelf), are ideally suited for the operation of such ships, with short fetches, access to shelter, and short distances for 'weather-window' opportunities. These waters are also served by numerous low-cost ports, small harbours and anchorages not accessible to large research ships. This can greatly enhance operational flexibility, enabling rapid change-over of personnel in combination with a pattern of short-cruise working to allow large multi-disciplinary teams.

Aside from these logistical advantages, the shelf seas west of Britain may be viewed as archetypal shelf systems. For instance, they contain examples of all the major shelf-sea physical domains – seasonally stratified water, tidally mixed, frontal zones, cold pools, regions of fresh water influence, coastal currents, and fjords. They encompass a great variety of surficial sediments and have varied geological histories; they also contain diverse ecosystems and span the present extreme limits of distribution of important indicator species (e.g. *Calanus*), both of which are relevant in the context of climate change. All these aspects of the west-coast shelf system are located within a limited geographical area making them a natural laboratory for shelf science.

Conclusion

This article has highlighted a problem that faces shelf-sea oceanography. Partly by accident and partly by design, the shelf community has been lured into over-dependence on large ships. Whilst these are absolutely central to our science, we cannot afford to lose sight of the fact that what shelf-sea science needs most of all is a balanced mix of ships – small inshore vessels through to very large ocean-margin vessels. The shelf is an integrated system extending from estuaries, lagoons and sea-lochs out across the continental shelf to the shelf edge/slope to the ocean margin, and the absence of any one size-class threatens to compromise shelf-sea oceanography. As far as shelf-sea ships are concerned, bigger does not necessarily mean better.

Acknowledgements

This article is intended to convey to a wider audience the key elements of strategic thinking that underpin a bid to the Joint Infrastructure Fund (submitted in December 1998) for a new medium-sized research vessel for the United Kingdom. I am grateful to many colleagues at Bangor and in the rest of the UK marine science community for their comments and input.

Ed Hill

This article was written while the the author was at the School of Ocean Science, Bangor, University of Wales. Since then, he has moved to the Centre for Coastal and Marine Sciences, Proudman Oceanographic Laboratory, Bidston, where he is the new Director.

The Island Trust: Changing lives for the better

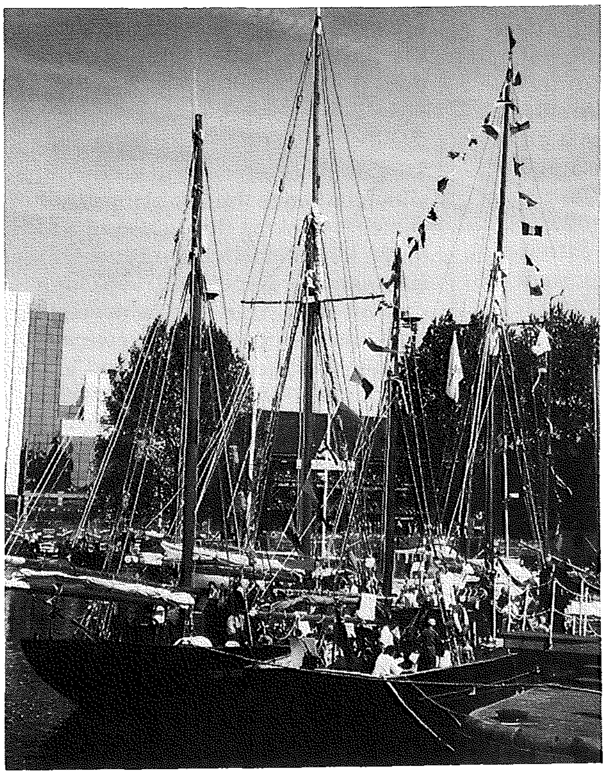
Dick Lloyd

The Island Trust Limited was formed in 1973 to enable disadvantaged children to learn from, and enjoy, sailing. In 1993, the Trust purchased the *Provident* from the Maritime Trust, who had recently carried out a major refit on her. The *Provi*, as she is affectionately known, is one of the last four Brixham trawlers still sailing in UK waters. From this year, three of the trawlers – the *Provi*, the *Leader* and the *Vigilance* – will be based at Brixham, while the other, *Kenya Jacaranda* (formerly *Torbay Lass*), is based on the Thames. It is appropriate that these wonderful old sailing boats should be based at the port where the sailing trawler was born in the early to middle decades of the nineteenth century.

Island Trust beneficiaries sailing a 'Wayfarer' dinghy with an instructor

The tall gaff rig – which gave these fishing boats the power to trawl the sea-bed, and the speed to get them back to land from far out at sea, with the fish in good condition – stands them in good stead as sail-training vessels. When the *Provi* came on the market, the Trustees immediately identified her as an appropriate boat for sail-training purposes, especially suitable for training their beneficiaries, who include the visually and aurally handicapped, youngsters from special needs schools, and those from very deprived backgrounds.

There is plenty of room on deck for the crew to attend to the various tasks, and teamwork is needed if the sails are to be hoisted and lowered successfully. Thus the trainees are kept occupied in activities that require them to cooperate and, once completed, give a sense of achievement to those involved. The crew are also involved in the maintenance and day to day running of the boat. When visually impaired chidren are on board, a specially designed compass is used; this shows the helmsman the course to steer on a large TV-type screen; for those who are not able to see, it emits a clearly audible sound to indicate the error that is being made on the chosen course. However, the Trust has found that if the crew is mixed, some of those with good sight set out to help those who require assistance to see the way ahead.



Provident *and* Leader *at St Katherine's Dock during the Island Trust's Open Day, in May 1998*

For those who are too young to sail on the *Provident,* the Trust provides dinghy sailing courses at appropriate sailing schools, but primarily in Brixham, where the beneficiaries sleep and eat aboard the *Provident.*

Those who come into contact with the *Provident* are keen to learn something of her history. The original boat was sunk in 1916 by a German U-boat, but only after the crew were given time to leave her. She had been involved in saving the lives of about 70 men, when a torpedo struck and sank the battleship *Formidable* off Berry Head in 1915. The present boat was built in 1924 for Captain Pillar, who captained the previous ship of that name. However, in the late 1920s she was bought by Mr R. Howe Lagarde, an American, was converted into a yacht, and passed through a number of hands before coming into the ownership of the Trust.

The *Leader* was built in 1982 by A.W. Gibbs (the same yard that built the *Provident*), in Galmpton Creek on the River Dart. She was in Sweden from 1910 to 1985, continuing under sail alone until 1952. In the 1960s she was bought by the Swedish Cruising Association. In 1985 she returned to Britain and was converted for cruising, and sailed the waters of the west coast of Scotland as *Lorne Leader*, before being brought home to Devon in 1966 and reverting to her original name.

The Trust sends about 250 youngsters sailing each year, and has to raise the money to do so, and it is hoped to add to this number over the next couple of years. As part of this year's fund-raising programme, Harry Sharp, an ardent supporter of the Island Trust, is sailing his small yawl, *Gabrielle II*, round Britain, with crews of volunteers. He leaves London on 2 July and will return on 10 September. He is looking for crews of young people, especially experienced sailors for the Scottish legs. A number of people have indicated that they will be cruising with him, in their own boats. We would love to expand the flotilla if anyone else would like to join.

We are also looking for sailing clubs or individuals at or near the leg ports, to be regional representatives to assist with:

- Logistic support
- Fund raising events
- Local knowledge
- Local contacts

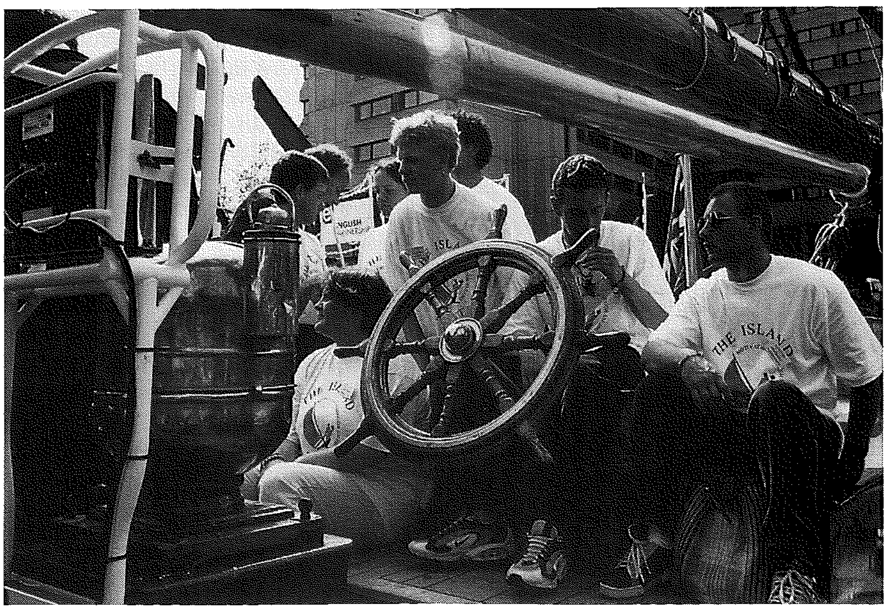
On her passage the *Gabrielle II* will be calling at Grimsby, Dunbar, Wick, Stornoway, Oban, Belfast, Aberystwyth, Plymouth, Portsmouth, and London.

For many years, the *Provident* was the flagship for the Island Cruising Club at Salcombe, but due to financial difficulties the Club terminated the Charter Agreement it had with the Trust. Whilst the trustees appreciated the valuable qualities which she brought to their work, they decided that it was not appropriate to spend the Trust's money on keeping an old wooden boat in commission. Accordingly they have agreed to sell her to a new charitable trust – 'The *Provident* Charitable Trust' – which will be dedicated to looking after her. The two trusts will have common trustees, and will work closely together. In order to pay for the *Provident*, as well as to ensure her future, the new Trust is aiming to raise £200000. All being well, the *Provident* will be participating in the Tall Ships 2000 race, and will be calling at Southampton, Cadiz, Bermuda, Boston, Halifax (Novia Scotia), and, finally, Amsterdam. To make this possible, sponsors and crew will need to be identified.

If anyone would like to know more about either of the trusts, the *Provident*, *Gabrielle II*'s voyage, or the Tall Ships Race, please contact me at 10 Manston Terrace, Exeter, Devon, EX2 4NP; Tel./Fax: 01392-256142.

Pupils from the Royal School for the Deaf, Exeter, with the skipper, mate and cook, on board* Provident *in May 1998.

Children with little or no sight on* Provident*, which was sailed from Salcombe to London by the the youngsters with the aid of a 'talking compass' and a little guidance from the crew.



NOW There's a FUNNY THING...

Fuel from Magma

The 'March of Knowledge' has become so fast that ideas considered plausible barely a generation ago now seem merely quaint, if not outlandish. Consider, for instance, the now well-known fact that hydrogen gas is emitted (along with lots of others) at deep sea hydrothermal vents. In fact, hydrothermal vents were only discovered little more than 20 years ago, and the other day I came across an old cutting from *Nature* (1978), which reads as though the authors were still ignorant of the discovery. The cutting is a short item reporting the results of thermodynamic calculations which suggested that partial reduction of water vapour by reaction with hot basalt (specifically with the ferrous oxide, FeO, in it) could yield small but useful amounts of hydrogen for use as a fuel. Older readers may recall that in 1978 the world was still emerging from the Oil Crisis of the mid-'70s, and alternative sources of energy were much in vogue. It was estimated that 'some two million tonnes of hydrogen could in principle be recovered from water interaction with 1 km^3 of high temperature (1300 °C) magma. The thermal loss arising from the need to heat the requisite amount of steam to the temperature of the magma would only cool the magma by about 50 °C'. The search for suitable sites would be concentrated along mid-ocean ridges (though island arcs were also mentioned), where there was 'geological evidence for large coherent bodies of magma'.

See what I mean about quaint ideas? Yet this was a serious suggestion barely two decades ago. You will not be surprised to learn that the report ends with the message that: 'The practical problems in tapping such bodies, assuring intimate contact of the reagents and recovering the reduced gas mixture are immense ... and require further research.' Yes indeed, especially as addition of biological material was a suggested refinement that would produce methane and/or carbon monoxide as well!

Tell me, someone: Was at least the basic chemistry of this right? Does the hydrogen in hydrothermal vent gases really come from reduction of water in the plumbing system? Or does it have a deeper and more primordial source? Either way, it's not an economically viable source of fuel, is it?

And talking of quaint ideas ...

Remember 'polywater'? Well no, you probably don't, you'd be too young. But back in those same mists of time, to wit the early/mid-1970s, the scientific world was greatly exercised by the discovery of a highly viscous polymer of water. A great many articles and papers appeared (several even in *Nature* itself) about this amazing substance, though it could only be formed in very narrow-bore capillary tubes. With hindsight this fact alone might have caused the scientific community to be a bit sceptical – but hindsight comes a whole lot easier than foresight. At all events, the most exciting thing about polywater was the alarming possibility that seawater might spontaneously polymerize, with interesting consequences not only for shipping (think of all those submarines!) but also for the hydrological cycle.

So what happened? Well it turned out that polywater was just a very concentrated solution of sodium silicate leached from the glass of the narrow capillaries in which this viscous liquid uniquely occurred. The oceans were not going to acquire the consistency of glue after all. (Incidentally, this has nothing to do with so-called amorphous or 'glassy' water that can form when water is strongly supercooled, and can also be very viscous under certain conditions; see *Nature* 1998, **396**, 329–35.)

Few readers will recall that still further back, in the 1950s, there was a rather bigger scare when it was proposed to explode a hydrogen bomb under the sea. Would there be a chain reaction, fusing all the hydrogen in ocean water to helium, and in effect blowing up the world? Edward Teller ('Father of the H-Bomb') performed the necessary calculations to reassure the world that it wouldn't happen. Hydrogen bombs could with impunity be tested under water. Luckily he was right.

Not many people know that ...

... the lost Ancient City of Atlantis is now located on Little Sole Bank about 120 miles south-west of the Scillies, according to a Russian academic, one Viatscheslev Koudriatsev. He bases his claim on a new translation of Plato's original 4th century BC texts (the *Timaeus* and *Critias Dialogues*), describing an ideally run city state that was swallowed up by the sea 9000 years before, a catastrophe in which earthquakes and tsunamis figured prominently. Actually, Plato himself seems to have had the story third-hand, it having been passed on from a philosopher who'd heard it two centuries before from some Egyptian priests. Who did *they* get it from?

Atlantis has been located in all sorts of places over the centuries, including – no doubt among many others – Antarctica, Bolivia, Crete, Caribbean (see below), Central Asia, Libya, Mexico, Nigeria (!), Santorini (the most likely on archaeological and geological grounds), Spain, and Troy.

Not so long ago we reported claims that Atlantean remains had been found on Bimini Island, part of the Bahamas (*Ocean Challenge*, Vol.6, No.3, p.14). Well, now you can enjoy a holday in *modern* Atlantis, built on the same site by Sun International, the people who gave you South Africa's Sun City. Here you are exhorted to 'Live the Legend' and invited to participate in the fantasy that Atlantis has been there for 11 000 years It is a $800 million dollar resort, featuring the largest aquarium in the world (the second largest is in Lisbon, incidentally), the biggest casino in the Caribbean, a shark-infested water park and hugely expensive hotel suites. The place is so vast you need a guide (probably an Indiana Jones look-alike) to find your way through labyrinths of underground passages, past fish tanks containing ruins of the lost city and exhibits of mystical paraphernalia. The huge publicity machine (mis)informs you that, for instance, Atlanteans were the first environmentalists and eschewed gold and riches but valued knowledge (there's even a 'knowledge tank' allegedly guarded by piranhas ... well, if you believe that ...), and that they powered their city by 'crystal energy' (so there's also a Crystal Court). A large fountain with gilt effigies of Pegasus in various leaping and prancing poses no doubt persuades the gullible punters that Atlanteans rode flying horses too. It is scary. In a nation where something like a third of the population believes in Creationism (that's about 100 million people), the majority of 'guests' could well fall for this garbage. They probably see nothing iincongruous about losing their shirts in a place where the original inhabitants, they are told, had no interest in wealth.

Well, the legend is safe in the Bahamas for a while yet, for V. Koudriatsev is most unlikely to get funding for any exploration off Cornwall, given the parlous state of the global (and especially the Russian) ecomomy just now.

or that ...

... under the right conditions, insonfication of bubbles can produce a luminous glow ('sonoluminescence') and huge amounts of heat energy. It is claimed that temperatures inside the bubbles can reach a couple of *million* degrees, possibly enough to initiate nuclear fusion. The best explanation so far is that the bubbles are adiabatically heated by acoustic pressure associated with passage of high frequency sound waves. There are marine scientists who use upward-pointing sonar arrays to monitor bubble formation by surface waves. Might they be unwittingly participating in research into new forms of energy?

or that ...

... you can help Save the Planet by using compressed air to run your car in the same way as a normal internal combustion engine – well, after a bit of modification perhaps – but without the greenhouse gas emissions. The reasoning is plausibly simple. Your car engine is powered by pulses of rapidly expanding gas, so why not put a cyclinder of compressed air into the tank and feed pulses of that to the engine? The concept is said to be the brainchild of a French engineer, and you might ask why nobody has thought of it before. Perhaps they did, and perhaps they saw the catch. The Second Law of Thermodynamics states that 'There Is No Such Thing as a Free Lunch'.

In this case, you need energy to compress the gas. That energy is then released to power the engine and drive the car. Most of the energy would be lost in heat and friction, and we'd end up expending much more energy to compress the gas than we'd ever get back in car mileage. We are back to square one, as the energy used to compress the gas will come from nuclear or fossil fuels. Sorry, can't Save the Planet that way after all.

John Wright

Performance-Related Pay: Lecturers Beware

The thin end of the Performance-Related Pay (PRP) wedge has been inserted into the education system, and anyone who cares about teaching should take note. So far, implementation of the policy is to be confined to schools, but it can be only a matter of time before the university system is similarly afflicted.

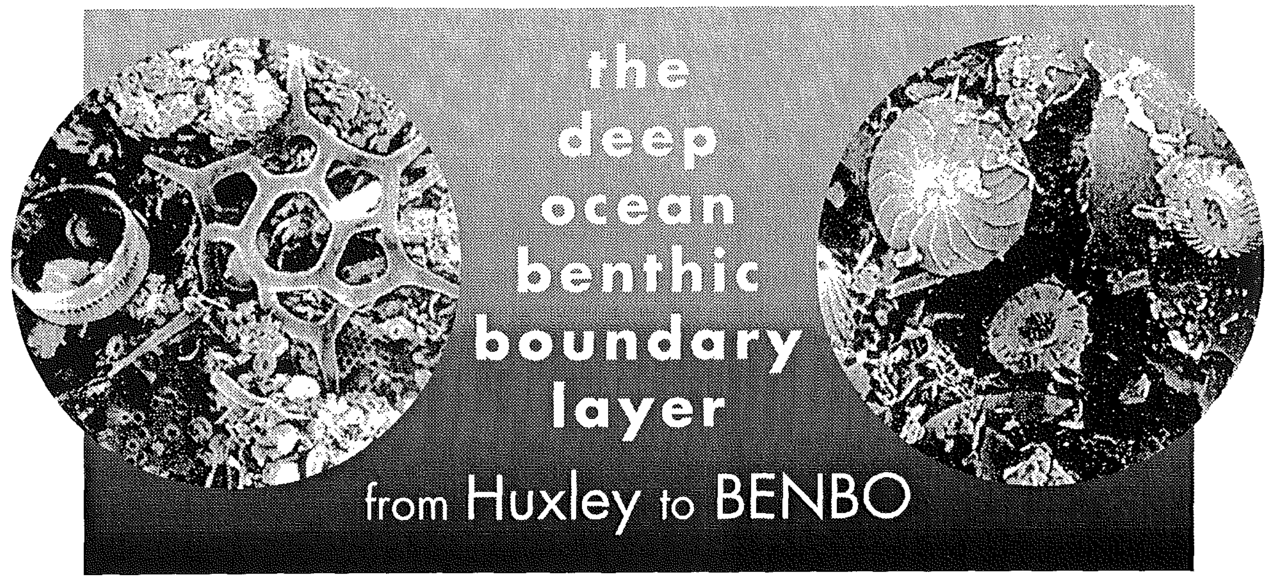
In higher education establishments, the situation is complicated by the often strained relationship between research and teaching. It is sometimes said that excellent researchers make inspiring teachers, but this is not always the case. Most of us probably know people so wedded to their research that teaching comes a poor second, notwithstanding the introduction in recent years of student feedback on teaching effectiveness. Will the number of papers published be an indicator of performance – as they are already for promotion? If so, how is the *quality* of the output to be assessed? If research output is a performance indicator, how will the dedicated teachers be judged, the people who don't want to do research themselves, but nonetheless keep up with developments in their field and pass them on to the students? They already tend to lose out in the promotion stakes, would they also lose out on pay?

Who will assess performance anyway? There must be many institutions where Heads of Department have little idea of who does what or how well, and where preferment can often be based on personal likes or dislikes rather than quality of work. There is already plenty of opportunity for real or fancied injustice to be inflicted, and PRP could make such situations a whole lot worse. Were the criterion of examination results to become a major factor – as it apparently is to be with school teachers – we could look forward to some interesting discussions on standards in future years. That is because school exams are marked externally, whereas in higher education establishments the exam setters can manipulate/alter the results – intentionally or otherwise – by the type of questions that are set, by how strict the marking is, and so on. External examiners do provide checks and balances, of course, but the system is not perfect and there is no guarantee that comparability of standards, or even continuity of standards from year to year, can be maintained.

The Education Secretary (David Blunkett) has in fact denied that school exam results will be a central criterion for PRP. He claims that teachers will be judged on how well they raise the performance level of their students, and thereby invites further questions: Who decides and/or adjudicates on whether or not performance levels have been raised, and what criteria are to be used? It is difficult enough in schools, imagine how much tougher it can get at university level. Of course it is important to weed out lazy and incompetent teachers (both in schools and in universities), but PRP may not be the best way to achieve it.

The majority of school teachers seem to think that PRP is a dodgy proposition. Could it – or should it – be extended to higher education? This is surely an issue upon which many members of the Challenger Society have views. Perhaps they would like to air them in *Ocean Challenge*.

INVESTIGATING



the deep ocean benthic boundary layer from Huxley to BENBO

Kevin Black

The deep ocean has come to the fore of both scientific and public concern only recently. The media interest surrounding the *Brent Spar* controversy and the accidental sinking of the Soviet nuclear submarine *Komsomolets* are prime examples of instances where this distant environment has been thrust into the limelight. From a scientific view, the deep ocean has over the years been of increasing interest: for the disposal of municipal and industrial wastes, and for the exploitation of fisheries and mineral resources (e.g. ferro-manganese nodules, oil, gas). The deep water environment closest to us – the so-called 'Atlantic Frontier' to the west of Scotland and Ireland – has recently attracted the attention of many European governments. Although much of this interest revolves primarily around the potential for oil and gas exploitation, the European Committee for Ocean and Polar Sciences (ECOPS), for instance, recently identified 'Variability in the Deep Sea Environment' as the subject of one of its five Grand Challenges.

As a result, a number of European science programmes have been developed, such as HiBETS (High-Resolution Benthic Exchange and Transformation Studies) and BENGAL (BENthic biology and Geochemistry of a north-eastern Atlantic Abyssal Locality). It is programmes such as these which provide a crucially important environmental baseline (the nature and charactersitics of pristine, undisturbed sediments) against which impacts of future exploitation of the deep sea can be measured, and the value of such studies should not be overlooked. Deep sea environments have also attracted the attention of conservation policy-makers. A recent report from the Australian Commonwealth Scientific Information Research Organization (CSIRO) recommended that 14 seamounts off the Tasmanian coast, with particularly high biological diversity, should be free from trawling and exploitation.

In the spirit of this current wide interest in deep ocean enviroments, the UK Natural Environment Research Council (NERC) has launched a three-year thematic programme to investigate processes occurring at the ocean bed in and around the Rockall Trough to the west of Ireland, an area where the sediments are relatively unaffected by human activity. This programme is called *BENBO – BENthic BOundary study* – and its principal objective is to quantify sediment and solute fluxes and energy flows at this important interface.

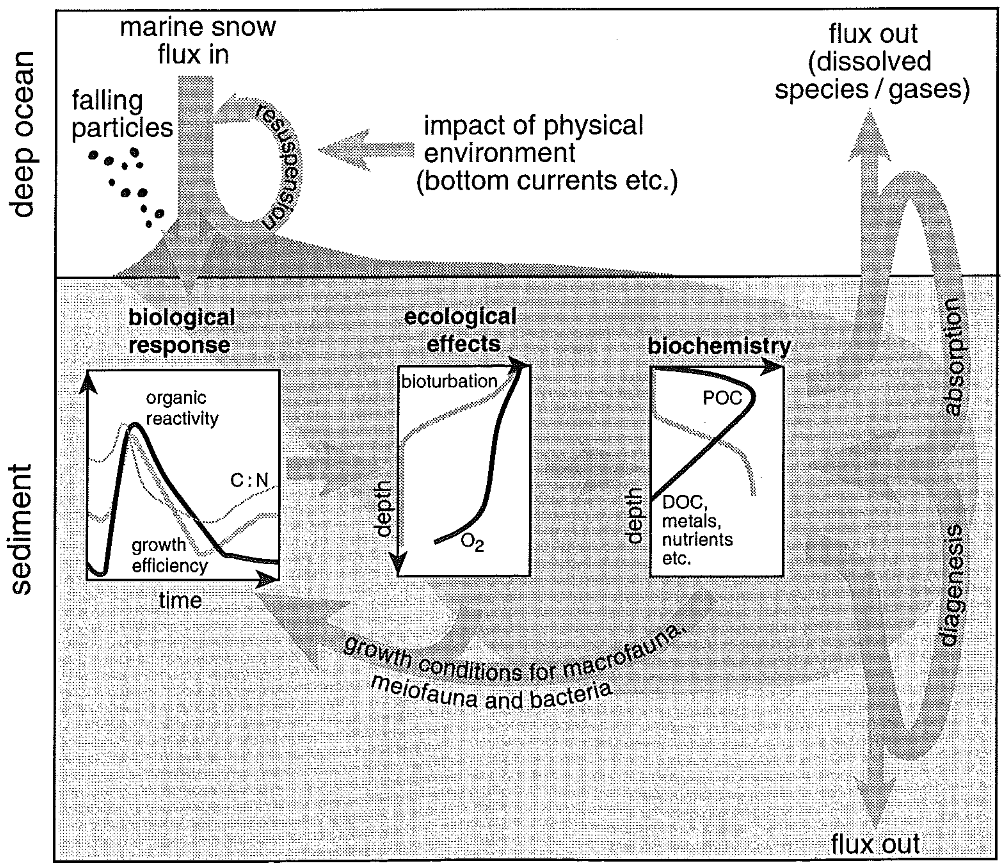
Marine snow and sea-floor fluff

Specifically, the scientists participating in BENBO aim to investigate and quantify the biophysical and biogeochemical processes occurring at the deep ocean bed as a result of the sedimentation of marine snow – the dead and decaying products of algal cells and other microorganisms in a matrix of gelatinous material. Sinking snow particles are micro-niches of enhanced concentrations of nitrogen and carbon, and thus harbour hungry bacteria and plankton. They also act as binding sites for metals and other anthropogenic pollutants introduced into the ocean. Clearly, marine snow has a key role in transferring elements (especially carbon), microbiota and nutrients to the deep ocean, and is therefore of fundamental ecological importance.

Marine snow is the major food source for life in the deep abyss, and its deposition on the sea-bed stimulates benthic biological activity and drives biogeochemical mineralization reactions. Particles arriving at the sea-bed are at the mercy of the biogeophysical dynamics of the boundary layer. Processes such as resuspension, attrition, coagulation, bioturbation and biological ingestion, and exposure to porewater oxidants, can significantly modify the fragile snow aggregates. Of these, it is hypothesised that bacterially-driven biogeochemical reactions in the uppermost sediments are the main factors determining the benthic flux of dissolved organic and inorganic elements from sediment porewater to overlying deep water, so mediating the character of organic material preserved in the sedimentary record. However, our current understanding of these processes in the inhospitable deep sea is, at best, rudimentary. BENBO forms a timely contribution, since its aim is not only to understand, but also to begin to quantify, the biogeochemical processes that contribute to remineralization, cycling and fate of carbon at the benthic boundary layer in the deep sea (Figure 1).

Marine snow is a funny substance, and may have a longer history than you might think. Tony Rice, who recently retired from his position as Head of Benthic Biology at the Southampton Oceanography Centre, reckons that marine scientists have known about marine snow since the middle of the last century, but failed to recognize it or understand its significance. In the summer of 1857, HM frigate *Cyclops*, sounding down to 2 400 fathoms along a transect from Valencia (in southern Ireland) to Newfoundland, brought up some sediment samples which were later sent to the renowned British palaeontologist Professor Thomas Henry Huxley, then at the London School of Mines. Huxley immediately had them preserved in strong alcohol and then apparently forgot about them. Re-examining them eleven years later he found a transparent jelly-like substance and became convinced that this was a living slime which carpeted the deep ocean floor. He gave it the now famous name of *Bathybius haeckelii*, in honour of the German biologist Ernst Haeckel (Figure 2, overleaf). Huxley's discovery provided an impetus to others who dabbled in deep ocean research, and soon everybody seemed to be dredging the stuff up. However, when John Buchanan, the chemist attached to the *Challenger* Expedition,

Figure 1 *Major physical and biogeochemical pathways at the deep ocean sediment–water interface. The diagram illustrates the links between the biological response to sedimented phytodetritus, the ecological repercussions for bottom-dwelling organisms, and the biogeochemical consequences (e.g. solute fluxes, carbon preservation). (In the diagram, C : N is the carbon : nitrogen ratio in particles, and POC and DOC are, respectively, particulate and dissolved organic carbon.)*
This conceptual framework forms the cornerstone of modelling efforts by scientists at Plymouth Marine Laboratory. (Courtesy of G. Ruddy)



Pathways of transfer and regeneration of organic material in deep ocean sediments are complex, and at present are poorly understood

Ernst Haeckel saw* Bathybius *as 'primordial ooze'

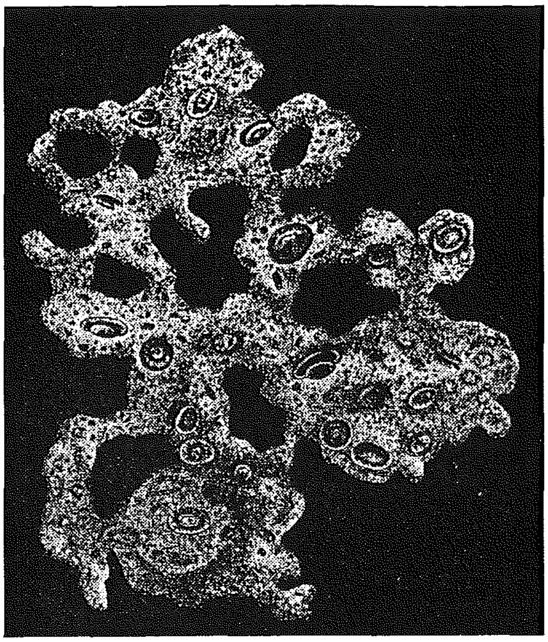


Figure 2 *A woodcut of* Bathybius haeckelii *from a publication by Dr Ernst Haeckel*

Specialised electron microscopy can be used to reveal phytodetritus in great detail

discovered that the famous gelatinous protoplasm was no more than calcium sulphate precipitated while the samples had been preserved in alcohol, Huxley, like a true gentleman, promptly and with great dignity admitted his mistake.

However, Tony Rice contends that Huxley may not have been quite as foolish as many of his contemporaries suggested. The cruise of HM *Cyclops*, through which Huxley obtained his samples, collected the sea-bed sediments during June and July, and other samples which Huxley examined for *Bathybius* were also obtained during the summer months. Rice supports the notion that Huxley may have inadvertently been studying the dead remains of surface-dwelling algal cells which had sunk to the sea-bed. Nowadays, scientists (somewhat unscientifically) refer to this phytodetrital material as 'fluff'. Fluff layers – aggregated masses of cells of a variety of species, bound together by an amorphous matrix (Figure 3) – can carpet the ocean floor, at times to a thickness of some 8–10 cm. They were first reported from the Sargasso Sea in 1980, and since then, direct and indirect observations have revealed a widespread occurrence, including the deep North Atlantic.

Dramatic time-lapse benthic photography, from scientists at the Southampton Oceanography Centre and Dunstaffnage Marine Laboratory in Scotland, has thrown into sharp focus the environment of the deep ocean floor, where phytodetritus survives for only a matter of weeks before consumption and remineralization. As Tony Rice noted, these observations are not consistent with the long-standing perception of the deep sea as a tranquil and quiescent backwater, with a sparse fauna, where nothing ever happens.

Who's involved in BENBO?

Over 30 scientists, including post-graduate students and post-doctoral researchers, are involved in BENBO. Altogether, eight proposals from a pool of 21 were funded by the project. The idea behind Thematic Programmes is to produce a balanced portfolio of research projects within the objectives of the programme. Consequently, whilst each project is free-standing in that it has specific aims and objectives, together the projects address the major issues of BENBO and form a cohesive multidisciplinary, multi-institutional programme of research, governed by a Scientific Steering Committee.

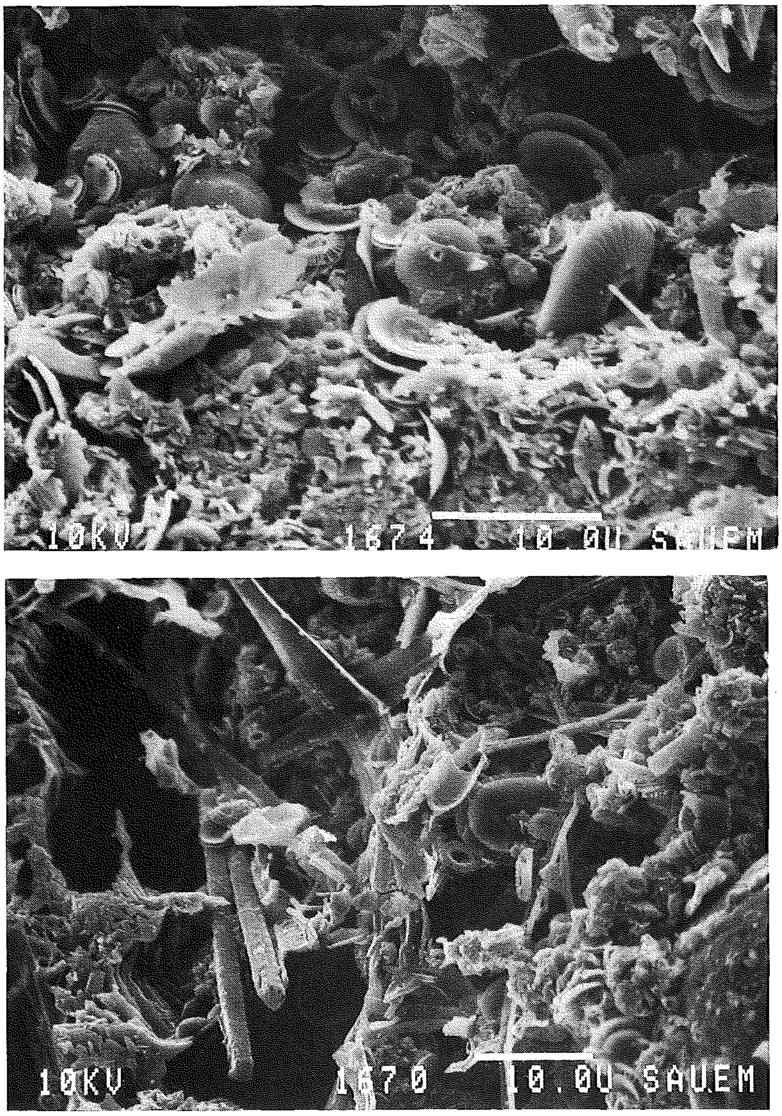


Figure 3 *Two scanning electron micrographs of 'fluff' collected from a site on the Feni Drift (cf. Figure 4). The upper image shows large numbers of coccoliths (the calcium carbonate platelets of coccolithophores) amongst amorphous organic material and some diatom/radiolarian debris; the lower image shows diatoms and (smaller) coccoliths amongst amorphous organic material. The scale bars represent 10 µm.*

BENBO comprises groups from the Centre for Coastal and Marine Sciences (Plymouth Marine Laboratory and Dunstaffnage Marine Laboratory), Southampton Oceanography Centre, the Scottish Universities Research and Reactor Centre (SURRC), and Bangor, Edinburgh, Cambridge, Lancaster and Leeds Universities. Projects range from determination of the time-scales of deposition, mixing and storage within the sediments, to micron-scale *in situ* measurement of concentration gradients and fluxes of trace metals, major ions and nutrients (cf. Figure 1 and box below).

Where's the field study area?

Three areas of sea-bed, around the Rockall Trough region in the north-east Atlantic, were chosen as the field study sites (Figure 4). At sites A and B, the sea-floor sediments comprise calcareous ooze (carbonate content ~75%). Site A is a deep ocean site with a very low organic content. Site B is much shallower, so the time taken for organic debris to sink to the sea-bed is much less than at A.

Site C is on the Feni Drift, an extensive deposit of fine-grained material, formed under energetic current flow during the Plio-Pleistocene. The factors affecting the supply of phytodetritus at this location are expected to be more complex than at A and B, as phytodetritus may be advected towards the site or be swept away from it, and sediment resuspension may change the geochemistry and biology of surficial sediments. (The sea-bed sediment here is a fine-grained marl or calcareous mud, carbonate content ~50%.)

The relatively large separations of the sites, and their positions with respect to natural gradients of surface primary production, should ensure that they represent a range of phytodetrital input at the sea-bed.

Cruise planning

Altogether, three cruises on the *RRS Charles Darwin* have been mounted by BENBO. The first of these (CD 107) took place during August 1997, and was used to obtain 'ground-truth' for each of the sites; activities included acoustic multi-beam swath mapping of the sea-bed topography (single 12 km x 14 km blocks), deployment of moorings comprising sediment traps, transmissometers and current meters, retrieval of bottom sediment samples, and collection of CTD data. In addition, a bottom-mounted ADCP current meter was deployed at site B. To study the benthic processes of interest, two further cruises were undertaken, during 20 April–15 May 1998 (CD 111), and during 28 June–22 July 1998 (CD 113).

The two later cruises were scheduled to be either side of the 1998 spring phytoplankton bloom. In practice, although CD111 managed to sample the bottom sediments when they were free of fluff, towards the end of the cruise there were distinct signs that the bloom

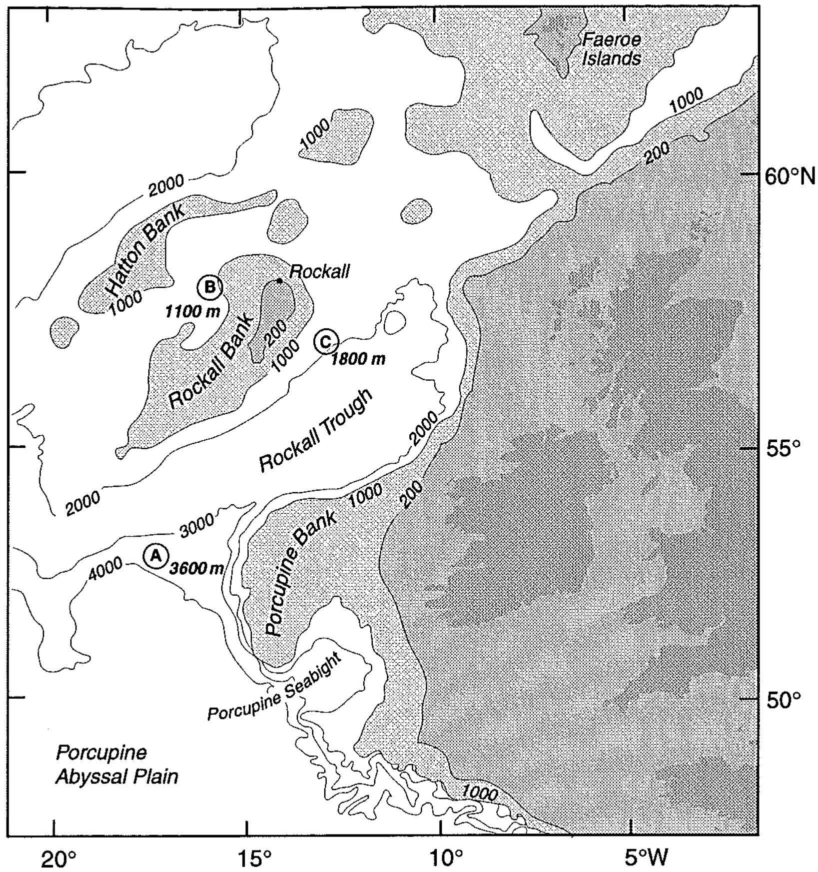


Figure 4 Location of BENBO study sites on the flanks of the Rockall Trough, eastern north Atlantic. For descriptions of sites A, B and C, see text. (Courtesy of Richard Lampitt)

The 'Atlantic frontier' to the west of Ireland and Scotland is the BENBO study area

BENBO Projects from 1997 to 2000

Deposition, mixing and storage time-scales in the benthic boundary layer

The impact of microbially mediated processes on the fate of organic matter in the benthic boundary layer

Biogeochemical studies of the benthic nepheloid layer

High-resolution concentration gradients, and fluxes of trace metals, major ions and nutrients at the benthic boundary

Carbon cycling at the deep ocean boundary layer

Benthic community biomass, and activity in biogeochemical processes at the deep ocean bed

Organic and inorganic transformations at the benthic boundary layer

Foraminiferal shell chemistry and faunal characteristics as proxies for benthic organic matter flux and ocean circulation in the palaeoceanographic record; the role of benthic boundary layer processes

The BENBO lander sinks to the sea floor, then gathers data and returns to the surface when the experiment is completed

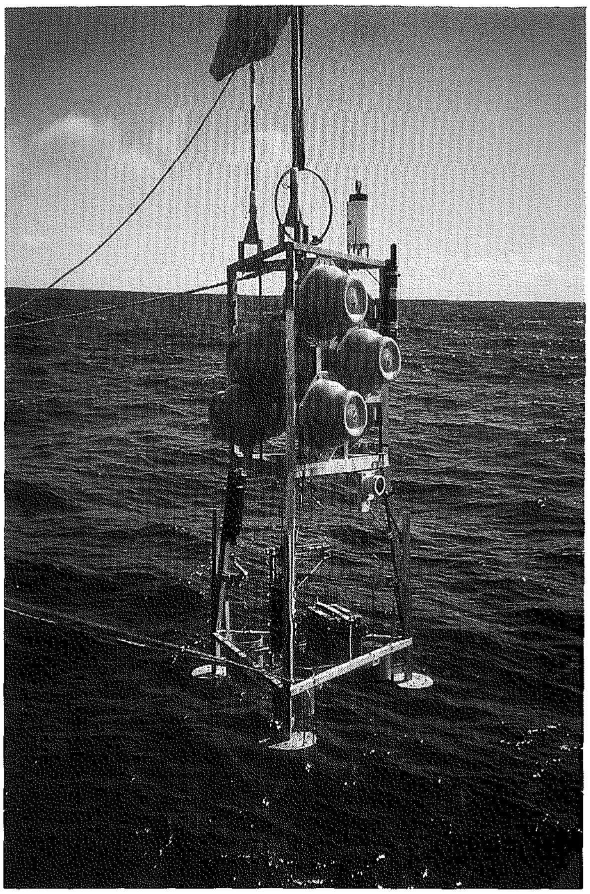


Figure 5 The BENBO benthic lander during deployment of the oxygen micro-profiling module. The rig has 75 kg net buoyancy and descends at approximately 50–60 m per minute. The operational period on the sea-bed varies between several hours and 4–5 days, according to experimental design. (Photo: Kevin Black)

had begun in the upper ocean. Extensive areas of phytoplankton can be seen from space due to their influence on the colour and albedo of the upper layers of the ocean, and BENBO has subscribed, via the Ocean Colour Group at Plymouth Marine Laboratory, to NASA's recently launched SeaWiFS satellite sensor, which can measure the extent of chlorophyll-rich algae over the vast spans of the Earth's major oceans on a daily basis. Satellite data from the eastern North Atlantic will be used by BENBO scientists to examine the timing and intensity of the spring phytoplankton bloom.

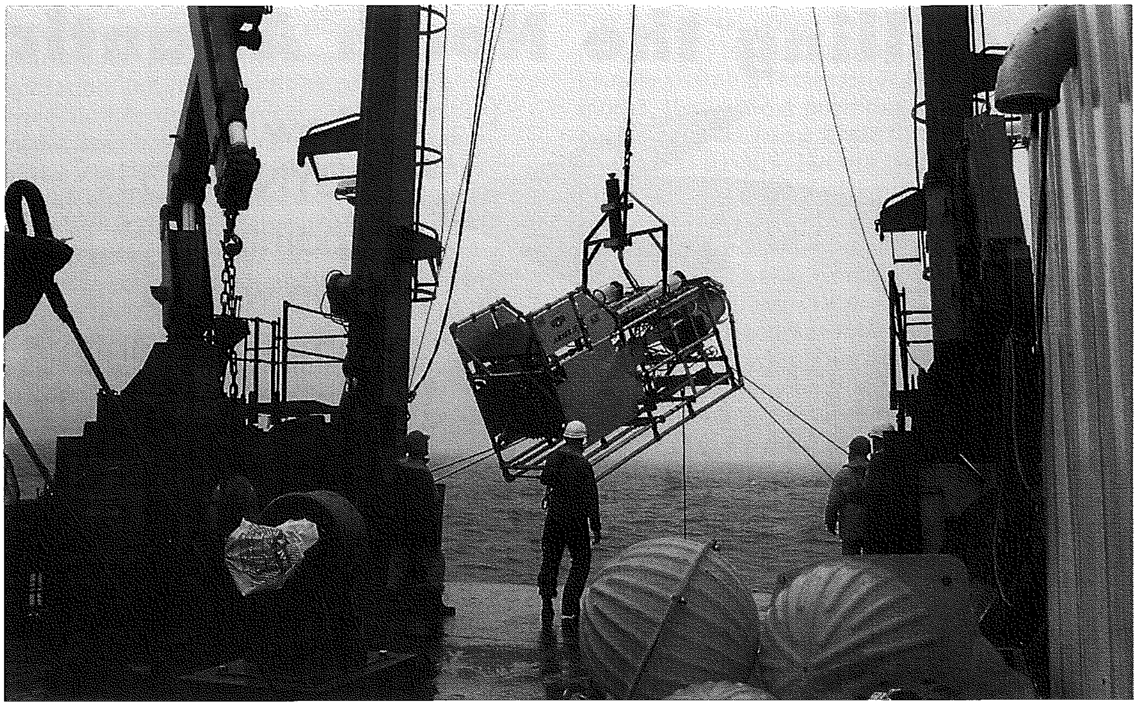
According to scientists on board the *Charles Darwin* during cruise CD 112, working to the north of the BENBO area in the Faeroe–Shetland Channel, the 1998 spring bloom peaked sometime in June. Scientists aboard the ship on CD 113 found only several millimetres to one centimetre of fluff at site C, none at site B, and only trace amounts at site A. Nevertheless, if sites have been recently exposed to the organic detritus, the biogeochemical signal will probably still be in the surface sediments.

New technology

A fascinating component of the work undertaken involves a brand new 'benthic lander', which was constructed by the Danish company KC Denmark, on behalf of BENBO, and recently underwent field trials in the North Atlantic (Figure 5). 'Benthic lander' is a term given to any autonomous, unmanned oceanographic research vehicle which free-falls to the sea-floor. Landers are capable of operating to great depths (as much as 6000 m), and usually have no physical link to the surface. They operate independently on the sea-floor, undertaking pre-programmed experiments, and logging data to an electronics pod *in situ*. On the BENBO lander, several interchangeable modules allow *in situ* measurement and monitoring of: the respiration of the total benthic community; the influence of phytodetrital loads on biogeochemical processes; solute fluxes across the sediment–water interface; micron-scale variability in trace metals, major ions and nutrients; and micron-scale variation in sediment oxygen content and pH (cf. Figure 1). The lander may also be used as a conventional box corer to retrieve mud samples from the ocean floor. Although lander technology is not brand new (and the Danes and Germans are a bit ahead of us in this game), the BENBO lander is the only instrument of its type within the UK marine science sector. The lander is owned and operated by the Dunstaffnage Marine Laboratory, but it is available for use by other members of the marine (and freshwater) research community.

BENBO scientists from the Southampton Oceanography Centre, in conjunction with engineers at the Fisheries Research Station at the Marine Laboratory in Aberdeen, also used a novel instrument (Figure 6, opposite) to assess the size and distribution/variability on kilometre scales of free-swimming mesozooplankton (copepods, amphipods, euphausiids, etc.). This system is called ARIES, standing for Automated Recording Instrumented Environmental Sampler. The ARIES instrument is towed behind the vessel at a pre-determined depth close to the sea-bed and combines netting (200 μm mesh size), remote underway sampling and optical plankton-counter technology, to count, measure and capture zooplankton within and just above the nepheloid layer (the layer of enhanced turbidity due to resuspension of bottom sediment by currents).

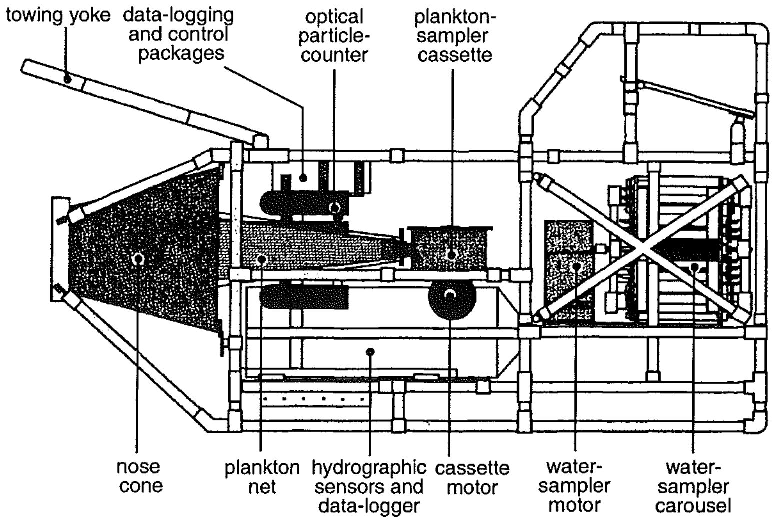
The system can be towed at 3 knots, weather permitting, within 1–2 m of the sea-bed, and provides data on much wider spatial and temporal scales than hitherto possible using conventional techniques. A variety of sensors measure water depth, temperature and salinity, along with fluorescence and turbidity; and a GPS system is integrated into the instrumentation to record the locations of water and plankton samples.



In ARIES, hydrographic instruments and a multiple water sampler are combined with conventional netting technology to characterise the biology and physics of deep ocean water masses

Figure 6 ***Above*** *Launch of the* ARIES *towed instrument over the stern of the RRS* Charles Darwin. *(Photo: Kevin Black)*

Below *Scale drawing of the* ARIES *(Mark III) instrument showing its main components. (J.Dunn)*



What now?

Sometimes it seems as if we have dredged up cubic miles of mud, and have filtered the entire north-east Atlantic! There is little to report at this stage, save for a few exciting snippets which point to a far more interesting set of results in the very near future – for example, the distribution of benthic xeno-phyophores (strange bottom-dwelling protozoans up to 20 cm in diameter), and substantial pulses of phytodetritus during the late autumn of 1997, recorded in sediment traps.

BENBO scientists are busy processing their samples and collating data, and recently all groups came together to present their findings at a preliminary scientific meeting held at the University of Wales conference venue in Gregynog, Powys. Some very interesting data were presented on subjects as diverse as micro-spatial within-site variability in sedi-ment oxygen content, the pressure and temperature dependence of bacterial species, the influence of sponge spicules on sea-bed strength and erosion, and recycling of zinc and cadmium in the fluff layer.

A follow-up meeting will take place next September at the Centre for Coastal and Marine Sciences, Dunstaffnage Marine Laboratory, and you might find many BENBO participants giving presentations and posters at next year's UK Oceanography 2000 at the University of East Anglia.

Relevant Websites

BENBO maintains its own website:
http://www.nerc-oban.ac.uk/dml/projects projects.htm

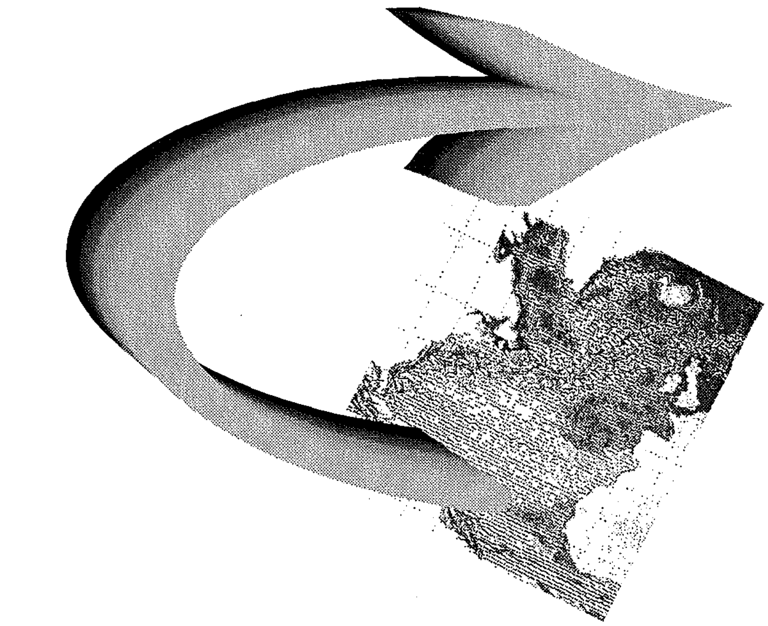
KC Denmark website:
http://www.kc-denmark.dk/

FRS Marine Laboratory, Aberdeen website:
http://www.marlab.ac.uk/MLAHpage.htm

Kevin Black is the Programme Manager for BENBO, at Dunstaffnage Marine Laboratory PO Box 3. Oban, Argyll. He can be contacted on kevb@dml.ac.uk

Acknowledgement *The images of phytodetritus used in the title artwork are based on original photographs produced for IOS Deacon Laboroatory by Ian Joint of Plymouth Marine Laboratory.*

Modelling the North Atlantic



how DYNAMO is pointing the way to improvements in predictive power

Adrian New

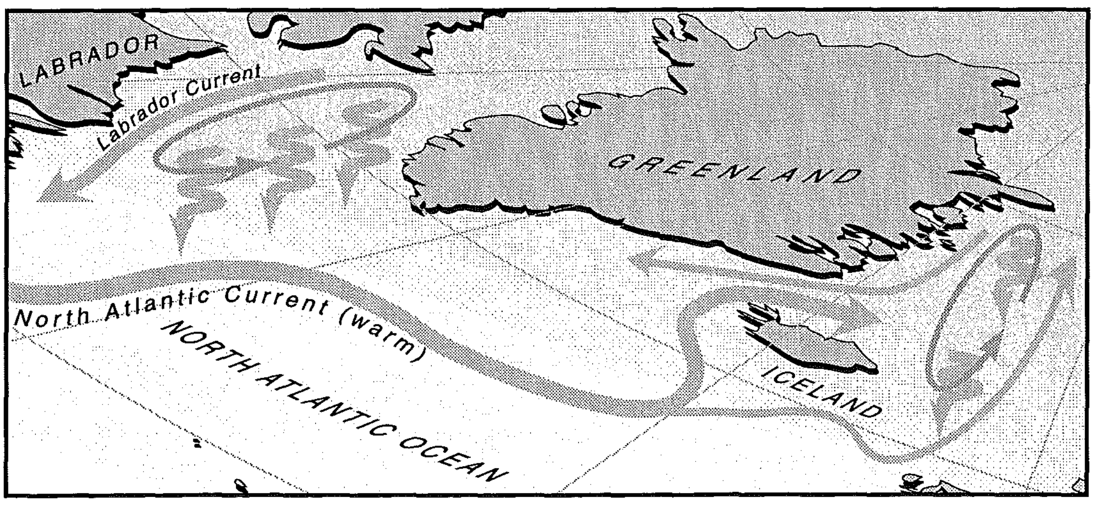
How good are ocean models? What can we do to improve them? And what is the role of the oceans in influencing European climate? These are questions which the Southampton Oceanography Centre is attempting to answer in a quest for increasingly reliable forecasts of climate change.

The North Atlantic transports a huge amount of heat – equivalent to more than 30 000 times the power-generating capacity of the UK – towards high northern latitudes. Here, the heat is released to the atmosphere, and gives Europe its mild climate. This is brought about by a northward flow of warm surface and near-surface waters, and a return southward flow of deep cold waters. These are connected by cooling of the near-surface waters which consequently sink (via deep convection) at high latitudes. The whole process acts as a water mass 'conveyor belt', and is called the thermohaline (or overturning) circulation.

Figure 1 *Schematic diagram to illustrate the role of the northern Atlantic seas in the global thermohaline circulation. The wiggly arrows represent deep convection, resulting in the formation of cold, dense water masses which flow southwards.*

The sinking, often to depths of 1000–2000 m, occurs primarily in two 'convection centres', these being the Greenland–Norwegian (Nordic) Seas, and the Labrador Sea (between Greenland and Canada) (Figure 1). Recent studies are indicating the possibility that the thermohaline circulation will decrease due to global warming, because the input of fresh, less dense water could be sufficient to prevent the surface layers from becoming dense enough in winter to give rise to deep convection. If ice-melt and/or rainfall in the Arctic were high enough, it could collapse altogether. This would result in sea-surface temperatures in the North Atlantic falling by 5–6 °C, and the European landmass would become much colder, with long, harsh winters. Such rapid climate change, occurring over less than a century, would be difficult to cope with.

There may be a 'flip flop' relationship between the intensity of convection in the Nordic Seas and that in the Labrador Sea



There is also pronounced variability on a decadal time-scale in the thermohaline circulation and in the activity of the two convection centres. In recent years, the Nordic Seas have become warmer, and the mixing less deep, and the Labrador Sea has become cooler and the mixing more intense. It seems that there may be a 'flip flop' relationship between these two centres, with deep convection switching between the two, and that their activity could be related to the North Atlantic Oscillation (NAO), a variation in the surface atmospheric pressure difference between Iceland and the Azores, with pronounced variability on the decadal time-scale. The NAO is also known to be correlated with the distribution and intensity of storms impacting upon Europe, with 'high NAO' periods (periods with large pressure differences) corresponding to stronger winds, more frequent storms, higher surface waves, larger transport in North Atlantic current systems, and increased precipitation in Northern Europe leading to greater risk of flooding. Furthermore, there is evidence that global warming will lead to higher states of the NAO, and hence that extreme events will become more common.

The ocean and atmosphere clearly act as a coupled system, but our understanding of the processes involved is far from complete, and the models are far from perfect. We need to be able to model these processes accurately, and then to use the models to make reliable predictions of future changes in the climate system in response to global warming. In particular, we need to address the limitations inherent in present-day ocean models, building improved versions which can be coupled to models of the atmosphere (and other components) to make more accurate predictions of future climate change.

The Southampton Oceanography Centre (SOC) is involved in major programmes of observational and satellite oceanography and so provides a unique interdisciplinary environment for assessing the realism of ocean circulation models, and hence for their continued development. At SOC, we have now developed expertise in two types of state-of-the-art ocean models. These are of basin scale to global scale, are of sufficiently high resolution to resolve ocean eddies (typically 100 km in diameter), and use either 'levels' fixed in the vertical or layers of constant density. The first type of model is referred to as a 'level model' (see Figure 2(b)) and this group includes, for example, OCCAM, the Ocean Circulation and Climate Advanced Model; the second type is known as an 'isopycnic model' (as in AIM and GIM, the Atlantic and Global Isopycnic Models, which are derivatives of the Miami Isopycnic Coordinate Ocean Model, MICOM). In both types of model, the ocean is represented by a grid of points at which the important quantities (such as temperature, salinity and current speed) are known and evolved through time. The horizontal positions of the grid points are not allowed to vary in either model (and usually define a rectangular grid). In a level model, the vertical positions of the grid points are also fixed while the water density is allowed to vary, but the isopycnic models provide an alternative formulation by employing layers of constant density whose thickness and vertical position can change (Figure 2(c)). These models being run at SOC represent two of the major classes of present-day ocean models, and each has relative advantages and disadvantages which we are evaluating. Ultimately, it may be that that one model type will be found to be superior to the other, or it may be that a hybrid model will emerge.

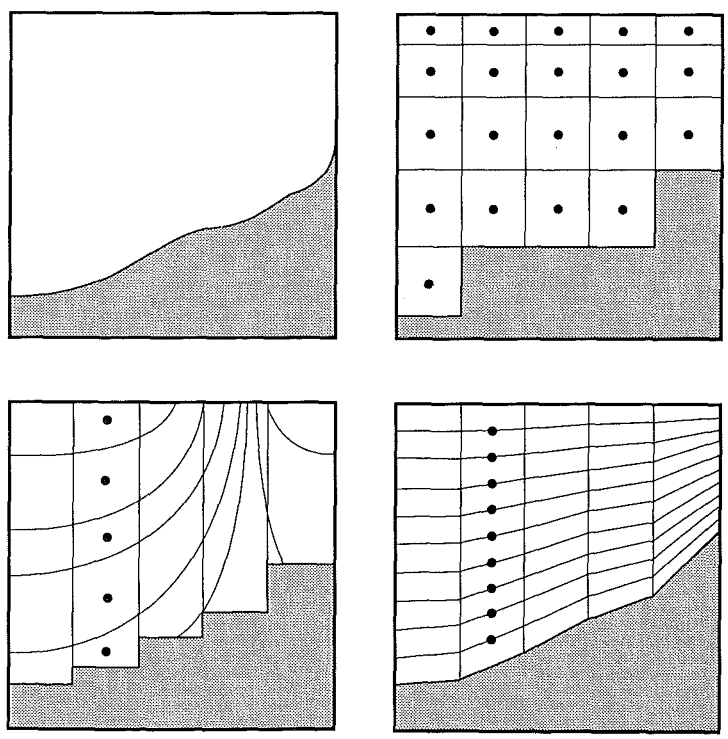
European Collaboration

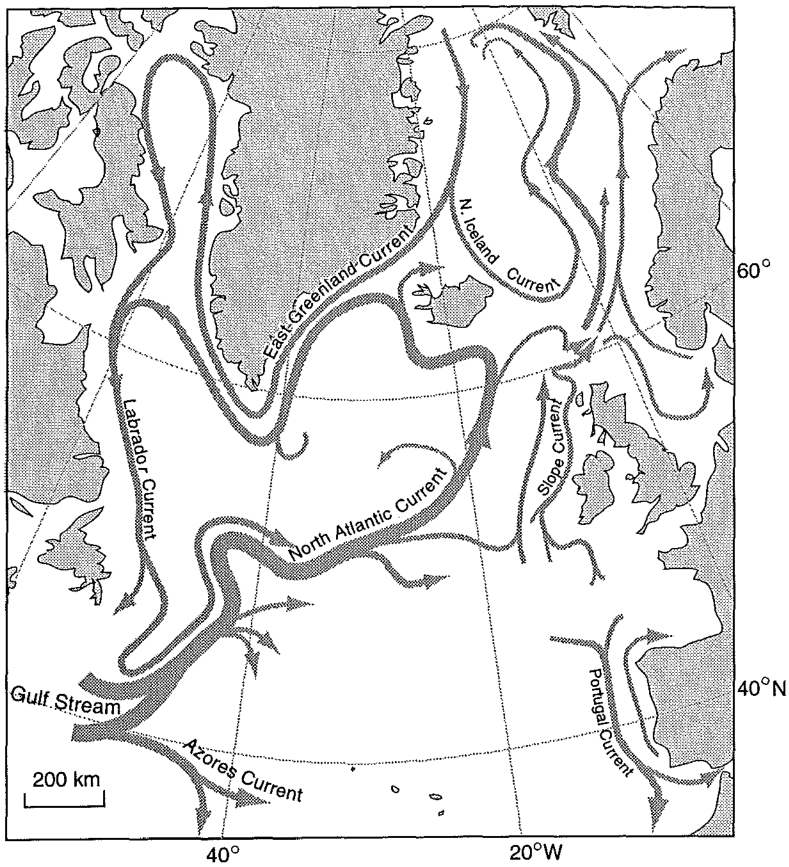
One effective way of learning about the capabilities of ocean models is to compare them both with other models and with observations. DYNAMO (Dynamics of North Atlantic Models) is a model intercomparison project, which was funded by the EU through the MAST-II programme. The project involved a level model run by Kiel University in Germany, an isopycnic model from SOC, and a 'sigma model' (with terrain-following coordinates, such that the vertical positions

Figure 2 *Schematic diagrams to show the differences in the vertical coordinate systems in the model types being compared in DYNAMO.*

(a) *Section showing the bathymetry of the region being modelled;* ***(b)*** *a level model;* ***(c)*** *an isopycnic model; and* ***(d)*** *a sigma model. In (b) to (d) the horizontal model grids are represented by the fine vertical lines, and the vertical coordinates are represented by the horizontal or sloping lines. In (b) the latter are fixed levels, in (c) they are isopycnals, and in (d) they are at a constant proportion of the ocean depth. The dots represent positions at which model variables are known.*

Rather than 'levels' fixed in the vertical, isopycnic and sigma models have layers whose vertical position and thickness can vary





Information about observed current patterns may be used to help interpret the sea-surface temperature distributions generated by the different models

Figure 3 *Schematic map showing a possible average surface current pattern in the North Atlantic, based on inferences derived from observations. (For comparison with Figure 4(a)–(c).) The North Atlantic Current (or North Atlantic Drift) is the downstream continuation of the Gulf Stream.*

of the grid points are proportional to the ocean depth; see Figure 2(d)), implemented by Grenoble University in France. The models were all of the same high horizontal resolution, 1/3° longitude (sufficient to resolve ocean eddies), covered the North Atlantic from 20° S to 70° N, and were all forced (i.e. 'driven') in the same way, using realistic datasets derived from ECMWF* analyses to represent the winds and the exchanges of heat and freshwater at the ocean surface. The models were all started from the 1982 Levitus observations† (representing an observed mean hydrographic state for the ocean) and a state of rest, and integrated forward for 20 years, to allow a near-equilibrium state to be reached.

All three models were successful in simulating the North Atlantic with a considerable degree of realism. For instance, all models show northward heat transports and overturning rates for the thermohaline circulation (i.e. the basin-averaged northward volume transports of upper ocean water masses, balanced by compensating southward transports of deeper water masses) within the range of estimates derived from observations (heat transports between 0.8 and 1.2 PW (1 PW = 10^{15} watts), and overturning rates between 14 and 20 Sv at 30° N). They all also show the northward movement of surface and near-surface water in the North Atlantic Current system, with some of the water going into the Nordic Seas and some around the subpolar gyre and Labrador Sea. In addition, they reveal the cold deep return flows forming into a Deep Western Boundary Current and flowing southwards down the US continental margin, again in line with observations. However, areas where the models disagree or differ from the observations are often the most informative, and may provide direct guidance on what improvements are most crucially needed for the next generation of models. The most important results from the DYNAMO project are described below.

Insights from DYNAMO

The representation in the models of physical mixing, as deep outflows travel southwards through the narrow channels across the Greenland–Scotland ridge, is of major importance in setting the characteristics of the deep waters in the North Atlantic. These waters slowly make their way back to the surface elsewhere, affecting exchanges with the atmosphere, and are an essential part of the global circulation. Their correct representation is therefore crucial if we are to make accurate climate forecasts. In particular, the mixing of the outflows of Iceland–Scotland Overflow Water (ISOW) between Iceland and Scotland, and Denmark Strait Overflow Water (DSOW) between Greenland and Iceland, which together make up the 'lower North Atlantic Deep Water', was found to be over-rapid in the level and sigma models, leading to outflows which were too light and too high in the water column downstream from the sills. In the isopycnic model, the mixing was as specified, but was found to be insufficient (through a lack of knowledge of what to prescribe), so that the outflows were too dense and too deep. This finding is now leading to improved representations of the deep outflows which can be built into the level and sigma models, and is also sending the observational oceanographers the message that we need to know how rapidly these outflows actually mix in the real world, so that correct amounts of mixing can be built into the models.

The total northward heat transport and overturning rate in the 'level' model is low between 20° S and 40° N, compared with deductions from observations and the other two models, possibly because the model assumes that mixing will take place in the horizontal direction, rather than (more realistically) along density surfaces (although this has not yet been unequivocally determined). This assumption of horizontal mixing is probably particularly unrealistic near the

*ECMWF = the European Centre for Medium-range Weather Forecasting.

†That is, data from the *Climatological Atlas of the World Ocean* by Levitus, S. (1982) (NOAA Professional Paper 13, US Dept of Commerce, NOAA.)

western side of the Atlantic, where strong current systems (i.e. the Gulf Stream) make surfaces of constant density slope significantly away from the horizontal, with the result that water mass properties are being incorrectly mixed across the sloping density surfaces. This results in a heat flux from the warm to the cold side of the sloping isopycnals, which must be balanced by the upwelling of cooler deeper water. In turn, this upwelling in the western boundary current system would be likely to reduce the flow rate of the deep southward flows, the overturning rate itself, and the heat transport which is intimately linked to it. New specifications for level ocean models, replacing the horizontal mixing by more realistic mixing along density surfaces, have recently been developed, and can now be implemented in high-resolution ocean models.

Antarctic Bottom Water (AABW, another deep water mass important in the global circulation) cannot be correctly represented by the present isopycnic model, which uses density referenced to the sea-surface. The problem is essentially that, in the real world, compared with NADW, AABW has a lower value of density referenced to the sea-surface, and yet it lies beneath the NADW. (Of course, AABW has a higher value of *in situ* density than NADW, and this is because it is colder, fresher, and hence more compressible. Consequently, even though AABW is less dense than the NADW at the surface, as it sinks to depth it compresses more, and becomes heavier than, NADW.) In the isopycnic model, the density coordinate must increase monotonically downwards, and so cannot represent this state of affairs. Essentially, the water masses are mixed together. However, recent work at Miami University has enabled the compressibility of seawater to be included in the model and has largely rectified this problem.

All the models show that after leaving the Straits of Gibraltar, high salinity Mediterranean Water (MW) moves south-westwards, as well as northwards. The northward spreading around the European margins is, however, only as far as the southern Rockall Trough in the isopycnic and level models, and reaches the northern Rockall Trough in the sigma model. In none of the models does MW move northwards into the Nordic Seas. This had previously been thought to be possible, although recent observational results are confirming that it is unlikely. Since all three models agree, this is seen as a strong result, and it means that the salty MW is unlikely to affect the production in the Nordic Seas of deep water masses important for the global circulation. It also means that changes in MW characteristics are not likely to play an important role in driving changes in this component of the thermohaline circulation. Instead, the models show that the salty water observed in the Nordic Seas is likely to derive partly from a branch of the North Atlantic Current (NAC) which sweeps into the Rockall Trough, and

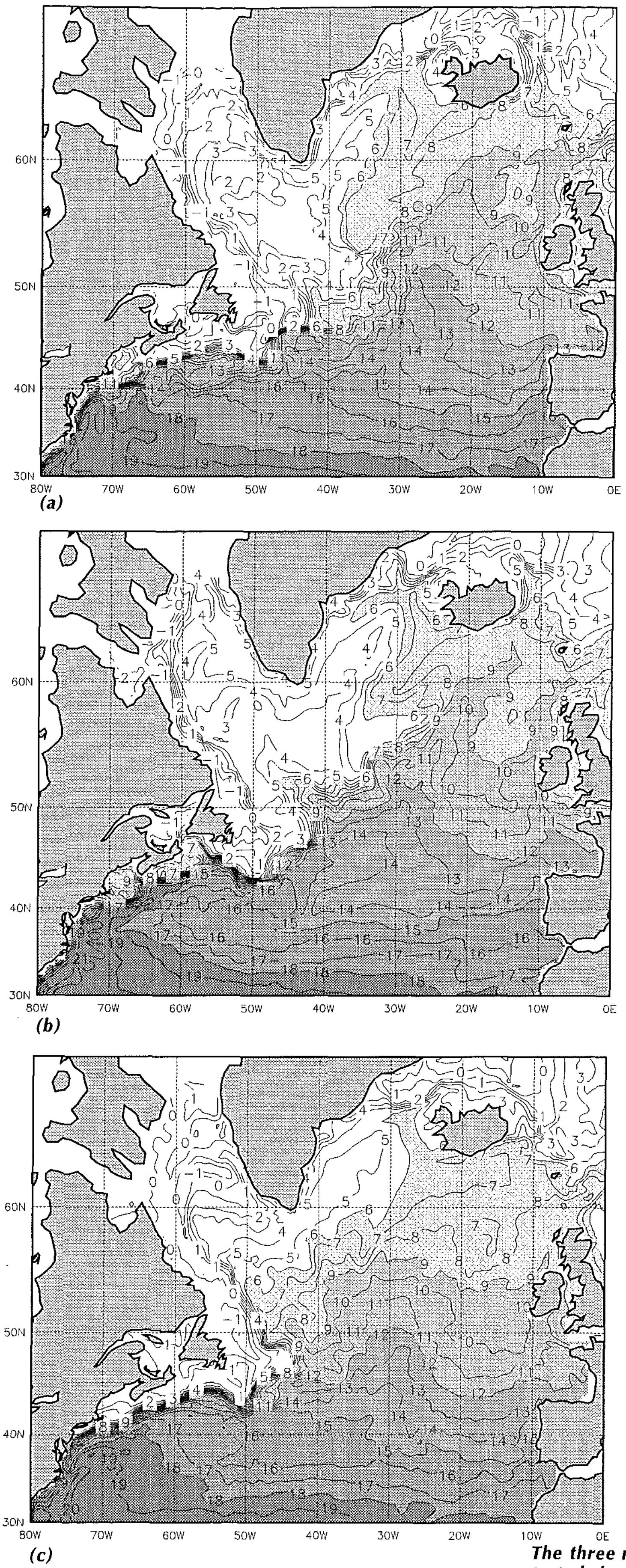


Figure 4 *Winter sea-surface temperatures (°C) predicted by the three ocean models tested in the DYNAMO project:* ***(a)*** *level model,* ***(b)*** *isopycnic model, and* ***(c)*** *sigma model.*

The three models tested show broadly similar SST patterns, but some interesting differences

partly from a near-surface current which flows northwards around the European margins. Again, this both supports and adds to recent deductions from observations which suggested that the saline pathway was derived principally from the NAC. Consequently, the models are providing insights into the observations.

The presence of the Azores Current – a major feature in the central Atlantic (Figure 3) – provides a controlling influence on the circulation and dynamics of upper ocean water masses over much of the mid-latitude regions. A feature resembling the Azores Current, which flows eastwards near 34 °N in the western North Atlantic, is strongly present only in the isopycnic model (Figure 4(b)). This acts as a barrier to the southward movement of water masses – collectively known as Eastern North Atlantic Water (ENAW) – which are drawn down from the ocean surface ('subducted') in the Bay of Biscay region to 'ventilate' the ocean interior. In the isopycnic model, the ENAW is therefore confined to the region north of the Azores Current, and is forced to penetrate too far westwards into the subtropical gyre. In the other models, with weaker or non-existent Azores Currents, the ENAW ventilates almost directly to the south. The situation in the real world is between these two scenarios, with the Azores Current acting as a partial barrier, and ENAW being transferred across the Azores Current by large eddies. It is now apparent that in the isopycnic model these eddies are not present in sufficient numbers to represent this process fully.

There are significant differences in the pathway of the North Atlantic Current between the three DYNAMO models. These lead to different patterns of sea-surface temperature (Figure 4), and would give rise to different heat exchanges with the atmosphere in coupled climate models. Observations show that the NAC pathway should follow around the Grand Banks (off Newfoundland) to about 50° N before moving eastwards across the North Atlantic (Figure 3). In particular, the NAC is thought to pass through 40° W and 50° N and move eastwards to the Mid-Atlantic Ridge near 30°W before breaking up into a series of branches which sweep into the eastern North Atlantic. In the level model, the pathway is too far to the south until it reaches the Mid-Atlantic Ridge (see the 9 °C contour between 30° and 45° N); that in the isopycnic model is reasonably realistic; but that in the sigma model is too far north to the west of the Mid-Atlantic Ridge (turning too strongly into the Labrador Sea, as evinced by the position of the 6°C isotherm). The reasons for these differences are still under investigation, although coarser resolution level models in other comparisons have placed their NAC too far to the south because of over-active mixing of the Nordic Sea outflows. The turning of the NAC into the Labrador Sea in the sigma model might be a reflection of the strong bottom-following currents seen elsewhere in this model.

Acknowledgements
The DYNAMO project was supported by the EU MAST Programme under contract No. MAS2-CT93-0060. This was a collaborative programme involving principally J. Willebrand, C.W. Böning, P. Herrmann, A. Oschlies, R. Redler, C. le Provost, B. Barrier, J.-M. Molines, T. Reynaud, P.D. Killworth, Y. Jia and S. Barnard, as well as the author.

A Final Word

The global ocean forms a key component of the climate system, and specific improvements in ocean models are resulting from careful intercomparison exercises such as DYNAMO. Furthermore, the models are not only providing guidance as to what key aspects require further observation and measurement, they are also giving important new insights into the way in which the ocean works. In the near future, the improved ocean models will be used to provide increasingly reliable predictions of the state of the ocean around the European margins, and to assess the role of the oceans in the coupled climate system and the possible consequences for Europe of global warming.

Suggested Further Reading

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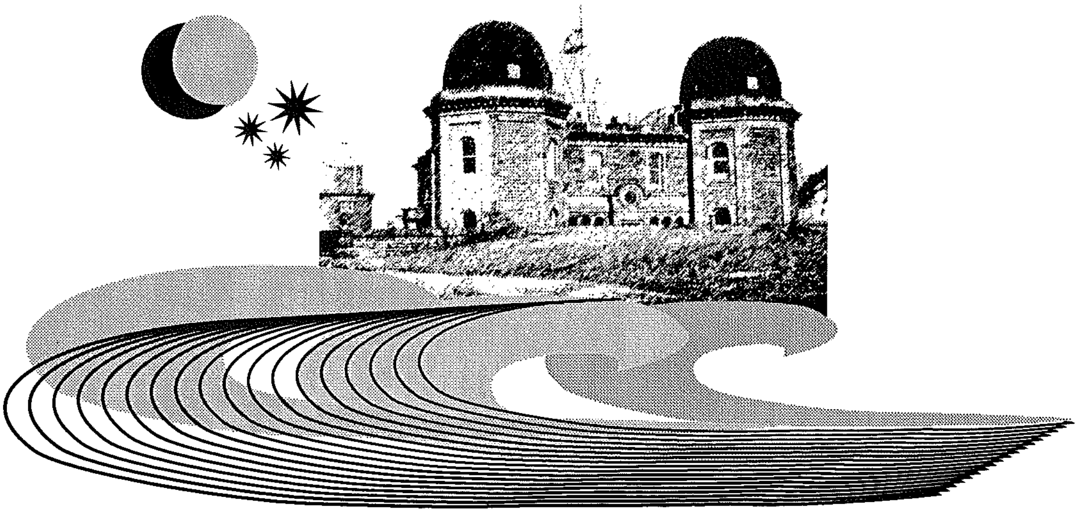
From Astronomy to Oceanography –
a brief history of Bidston Observatory



J. Eric Jones

Bidston Observatory has a remarkable history. It was built 134 years ago to replace and carry on the work of the Port of Liverpool Observatory. Since then it has been involved in the pursuit of scientific knowledge in many fields, and has changed its function a number of times in response to the national need. Several anniversaries of these changes fall in 1999, so it is timely to record briefly the events that have profoundly affected the Observatory's activities, and some of the people whose scientific work have contributed to its exceptional heritage.

Bidston Hill is the northernmost point of the sandstone ridge forming the backbone of the Wirral Peninsula which lies between the Dee and Mersey estuaries opposite Liverpool. From the top on a clear day there are splendid views of Liverpool Bay, the mountains of North Wales as far as Snowdonia, and even the Lake District.

Being such a prominent feature, Bidston Hill has been a focus for human activity for many centuries. It bears rock carvings of a horse, a Sun goddess, and a cat-faced Moon goddess, all of which date back to Norse settlement 1000 years ago. There is a windmill, the remains of a cock-fighting pit, and the post holes which used to hold the flag masts employed in an ingenious semaphore telegraph system that brought messages in minutes from Anglesey to shipping owners in Liverpool. This existed for several decades before it was superseded by the electric telegraph. However the most prominent feature is the cluster of three buildings which presently house the Centre for Coastal and Marine Sciences, Proudman Oceanographic Laboratory. The oldest of the three buildings, constructed in 1866, is Bidston Observatory itself, a large square building faced with the very sandstone quarried for its foundations. It is topped by two prominent domes which can be seen over a wide area. The next oldest building is a lighthouse (replacing an earlier lighthouse of 1771), with a lantern topped by a green conical roof, and some associated keeper's cottages which were built in 1873. Almost exactly a century later, in 1975, these were joined by the large square white Joseph Proudman Building which, with its many small windows like so many portholes, resembles a beached ocean liner straddling the hill top.

The first Liverpool Observatory, 1843–66

In the early 19th century it was a necessity for every major port to have an observatory to ascertain the longitude of the port and to keep accurate time. In 1834 a Lieut. Jones RN recommended to the Liverpool Town Council the establishment of an astronomical observatory. They deliberated the question but postponed any decision. Over the next few years the Council was bombarded with a series of similar recommendations from the British Association for the Advancement of Science, William Lassell (a local astronomer who, though strictly an amateur, was pre-eminent in British astronomical circles), and the Liverpool Literary and Philosophical Society. In addition, Captain (later Admiral) Denham FRS, the Port Hydrographer, published 'proposals for a better port' which became the basis for the Mersey Conservancy Act of 1842, and which stressed the need for an astronomical and meteorological observatory and a permanent tide-gauge. Although a special committee was set up, no action was taken until 1839 when permission was granted to erect an observatory and dwelling house at Waterloo Dock in Liverpool. Funding out of dock dues was obtained by the 1841 Liverpool Dock Act and in 1843 Mr John Hartnup, Assistant Secretary to the Royal Astronomical Society, was appointed as Director. Systematic observations then began in 1845.

Apart from obtaining and preserving Greenwich time and securing the longitude of Liverpool, a further duty was to test chronometers so that, in the words of the British Association, 'a captain when he sails may receive his chronometer sure both of its error and its rate'. As part of these duties, the Observatory took part in a series of chronometer exchanges to determine the longitude difference between Greenwich and Valentia in Ireland, and subsequently between Greenwich and the Harvard College Observatory in the USA. A 'time ball'* was fitted to the Observatory, and meteorological observations were started to provide local forecasts for shipping. In 1857 the Mersey Docks and Harbour Board took over the running of the Observatory.

The move to Bidston in 1866

In 1864, extension of the Waterloo Dock required the removal of the Observatory. Bidston Hill, which had been in the service of the port through its telegraph system, was selected as the site of the new Observatory and the land was purchased from the local landowner, Mr Vyner. Having acquired this site, the Docks and Harbour Board spared no expense in construction of the new Observatory. Built from stone excavated at the site, it covers an area of about 500 square yards. Above ground it has two storeys over which are the two domes as well as a meteorological hut. Below ground there are cellars 12 feet deep, and below these another cellar 24 feet deep, which has a very steady temperature and is nowadays is used for gravity measurements. There are many notable architectural details – for example, the decorative carved arches flanking the entrance corridor supposedly represent the mathematical function known as a cycloid.

Observations began in 1867. As the new building was now about three miles from the river the time ball was replaced by the remote electrical firing of a cannon, a veteran of the Crimean and earlier wars, situated in Birkenhead Docks. The work continued as before. Two large warm air chambers were set up for the rating of chronometers, each chamber capable of holding one hundred instruments. Astronomical observations continued, with a transit telescope in the east dome and a massively-mounted 9-inch refracting telescope in the west dome.

*A 'time ball' was a sphere which could move up and down a mast. Each day, the ball was raised and then abruptly dropped at a specific time, usually 1 p.m., so that shipping etc. within sight could obtain the correct time.

In 1885, after 40 years as Director, John Hartnup retired and was succeeded by his son, John Hartnup Jr. The young John Hartnup continued much of the work of his father and wrote many papers on chronometrical management, but tragically on 21 April 1892 he was killed by falling from the roof of the Observatory, where he had mounted to make meteorological observations.

He was succeeded by another astronomer, Mr William Plummer, who recognized the value of the meteorological work and oversaw an increase in its importance. Perhaps ironically, William Plummer was also forced to oversee a decline in astronomical work as the increasing use of photographic methods in astronomy implied that considerable expenditure would be required to renovate and modernise the astronomical equipment. However, a new activity commenced in 1897 with the installation in the cellars of a seismograph. This was the first of a series of seismographs of different designs that followed. In 1910, observations were made using instruments designed by Sir George Darwin, Sir Horace Darwin and others to determine the yielding of the land to the load of tidal water, now called the 'ocean loading effect'.

The Liverpool Tidal Institute, 1919

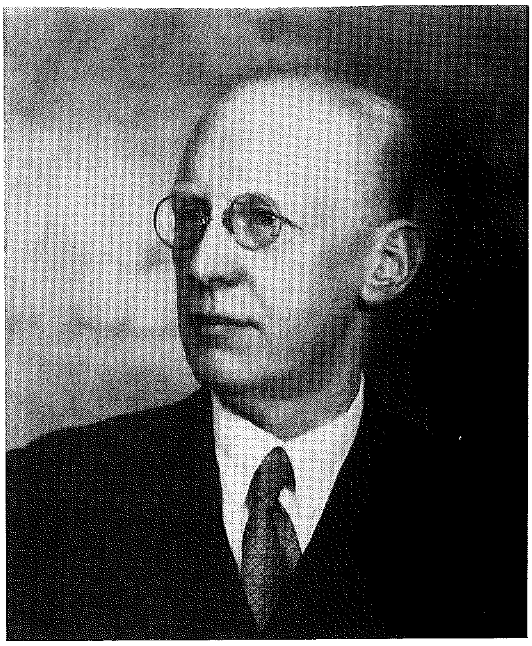
In 1919, an important step took place with the establishment of the University of Liverpool Tidal Institute, located in Liverpool, with Professor Joseph Proudman as Director and Dr Arthur Doodson as Secretary. Although it was a separate body, separately governed and funded, there was a very early association with Bidston Observatory. It was intended to be a research institution with both theoretical and practical aspects of tidal dynamics as topics of study. In 1923, a major achievement was the award by Cambridge University of the Adams Prize to Joseph Proudman for an 'Essay on the Tides'. The effects of this were far-reaching, one result being to convince the Hydrographic Department that accurate cotidal charts could be drawn for the North Sea. The association between the Institute and Bidston gradually strengthened, with William Plummer joining the governing board of the Institute. Significantly a tide-predicting machine was installed at Bidston at the end of 1924. Tide-predicting machines are devices that can be 'programmed' with the harmonic tidal constants for a particular port and then proceed to provide predictions or hindcasts for any desired date. As they required very high precision engineering, very few were in existence and several foreign governments asked the Institute to supervise the construction of machines for their own use.

The Liverpool Observatory and Tidal Institute, 1929

In 1928, William Plummer died and this may have been the catalyst for the amalgamation of the Observatory and the Tidal Institute, which took place on the 1 January 1929. This was a pivotal moment as the next decade brought a considerable increase in oceanographic research to Bidston. With Joseph Proudman as Director and Arthur Doodson as Associate Director, the Liverpool Observatory and Tidal Institute developed new methods for the analysis of tides and their prediction, and a second tide-predicting machine was acquired. This second machine meant that Bidston had the only two machines in the entire British Empire, apart from perhaps an old one in India. Bidston rapidly acquired a world-wide reputation for the analysis and prediction of tides and was soon providing predictions for many British territories overseas as well as foreign countries. It has been estimated that from 1924 up to the 1950s the Institute was responsible for predicting tides for two-thirds of the world. The provision of tidal predictions was a valuable source of funding.

Apart from the prediction of tides at particular ports, interest now extended to offshore tidal elevations and currents and to the idea of drawing cotidal charts showing the distribution of the tide throughout areas such as the North Sea. Apart from theoretical studies in several pioneering papers by Joseph Proudman, this also led to actual oceanographic observation. In association with the University of Liverpool Department of Oceanography, and with grants from the Royal Society, instruments were purchased or developed. In particular, mention must be made of the Favé offshore tide gauge and a current meter developed by Doodson. These were deployed on four expeditions south of the Isle of Man. An additional interest was the effect of meteorological forcing on the tides. This had become particularly important following disastrous flooding in the Thames estuary in 1928.

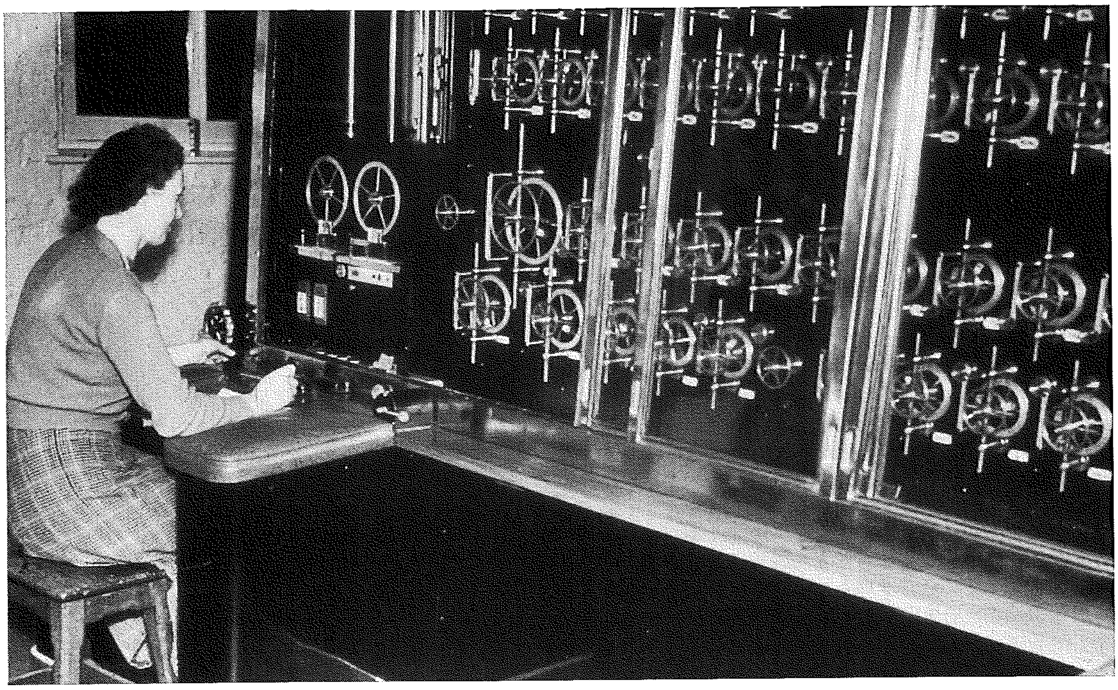
Naturally the expertise built up at Bidston became invaluable during the Second World War. It was vital to be able to predict tides for the many theatres of war, such as Burma and the D-Day landings. One of the tide-predicting machines was placed in a separate semi-underground room in the Observatory grounds. Indeed, the door to this room suffered blast damage from a bomb and the Observatory building itself lost a hundred panes of glass as well as suffering damage to doors, interior walls and ceilings in six different incidents. Remains of some of the necessary building reinforcements can still be seen. The scientific work itself was speeded up so that predictions were advanced by a year, and they were photographically recorded against loss – a wise precaution as some were lost at sea. The staff at this time were mostly female 'computors' and some volunteered for war service. However, various authorities such as the Ministry of Labour recognized the national importance of their work, so most were allowed to remain in post. Nevertheless, a few others such as the 'junior male assistant', Mr Jack Rossiter (see below), were called to active service.



Joseph Proudman, first Director of the amalgamated Observatory and Tidal Institute

This was also a period of close cooperation with the Admiralty Hydrographic Department. One of the fruits of this collaboration was the *Admiralty Manual of Tides* written jointly by Arthur Doodson and Commander H. Warburg and published in 1941. This cooperation continues up to the present in the production of the annual *Admiralty Tide Tables*. In 1946, Joseph Proudman retired as Director and was succeeded by Doodson.

Arthur Doodson, Proudman's Associate Director and successor



The 1949 Doodson–Légé tide-predicting machine

The tide-prediction service expanded and was augmented by the construction of a large 42-constituent Doodson–Légé tide-predicting machine in 1949 (see above).

In 1953 there was a catastrophic storm surge in the southern North Sea, with the loss of about 2000 lives in the Netherlands and along the east coast of England, and damage running into many tens of millions of pounds. That disaster provided a new impetus for research in the meteorological perturbation of tides and this became a dominant area of study at Bidston. Interest in long-term sea-level change had been a by-product of the tidal work, and led in 1933 to the establishment of the Committee on Mean Sea Level and its Variations, of the International Association of Physical Oceanography (the predecessor of the International Association for the Physical Sciences of the Ocean), under Proudman's direction. After the International Geophysical Year of 1956–57 the Committee was renamed the Permanent Service for Mean Sea Level (PSMSL) of the International Union of Geodesy and Geophysics (IUGG), with Doodson as Chairman and Rossiter as Secretary. This event was marked by a large International Symposium held in Liverpool in 1959. Over the next decade Rossiter carried out a major reorganization of the PSMSL, and today's service is essentially a modern computerized version. Investigations into Earth tides also continued with instruments situated in the cellars. In 1960, Arthur Doodson retired and was succeeded by Jack Rossiter, who simultaneously obtained the degree of DSc.

The University of Liverpool Tidal Institute and Observatory, 1961

The increasing interest in oceanographic research was recognized in 1961 when Bidston became a full department of the Faculty of Science of Liverpool University. Various services still continued, such as meteorological observations and the firing of the one o'clock gun (replaced by a Hotchkiss naval gun in 1946). However, this move was important because being a university department underpinned the expansion in oceanographic research. There was a gradual transition from tide-prediction machines to computers.

It was during this period in 1962 that Mr Norman S. Heaps joined the staff. It looked as if the relatively new field of computer-based numerical modelling might be a key to understanding meteorological influences on water level additional to the tides. Norman Heaps' work culminated (in 1978) in what was perhaps the world's first operational storm-surge prediction scheme based on a numerical model. Having access to the University computers was a vital facility for the development of modelling techniques. Modelling also commenced in studies for tidal barriers and in particular a proposed storm surge barrier for the Thames. At the same time, interests continued to expand in other fields. In 1968 Earth tide measurements were moved to a disused mine in North Wales to provide a quieter background.

The Institute of Coastal Oceanography and Tides, 1969

With the Natural Environment Research Council taking over responsibility for a large part of oceanographic research in the UK, Bidston Observatory changed its name yet again and joined the Natural Environment Research Council on 1 April 1969. This was a time of great change. The telescopes were removed from the domes and sent to the Liverpool Museum, and the one o'clock gun was fired for the last time on 18 July 1969. Even the domes changed colour from white to black! There followed a very rapid increase in staff from 26 to 66, requiring the use of temporary accommodation at Moreton, about three miles distant. The first computer at Bidston, an IBM 1130, was installed in the basement of the Observatory. With a connection to an IBM 360 at the London Data Centre, this allowed a great expansion in the modelling of coastal and shelf seas by Norman Heaps and others. Sadly, in 1972 Rossiter died suddenly and Mr Geoffrey W. Lennon took over as acting Director.

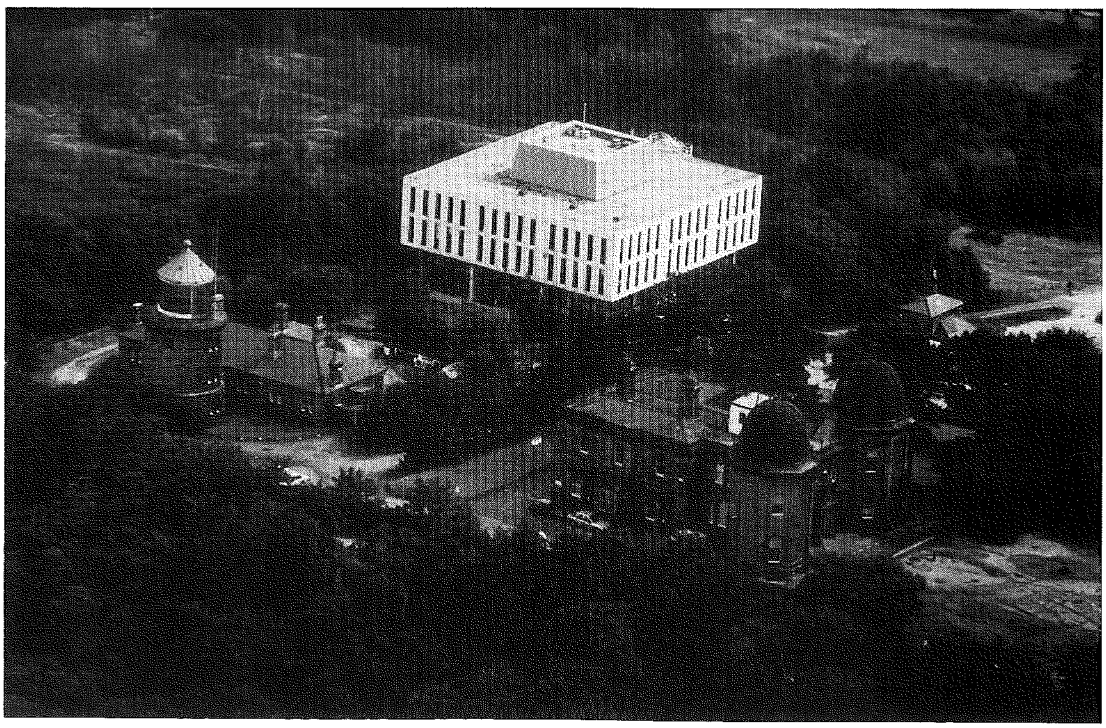
The Institute of Oceanographic Sciences (Bidston), 1973

Once again the death of the Director seemed to be a catalyst for change, as in 1973 the Institute of Oceanographic Sciences (IOS) was formed by initially combining Bidston with the National Institute of Oceanography (Wormley, Surrey), the Unit of Coastal Sedimentation (Taunton, Somerset) and some of the Research Vessel Services (Barry, South Wales). In 1975 staff occupied the new Joseph Proudman building. With the expansion in the numbers of staff, there were great advances in the type of work being carried out at Bidston. A much larger Honeywell 66/20 computer was installed which, after several upgrades, in effect became the main NERC computer. The Marine Information and Advisory Service (MIAS) came into existence, the forerunner of the British Oceanographic Data Centre (BODC), which is the national data centre based at Bidston.

Instrumentation and technical support services expanded greatly and existing fields of study such as sea-level change, Earth tides and numerical modelling, were strengthened. With hindsight, this was a period which laid the groundwork for much that was achieved in succeeding years. For example, there was a demonstration of how a model scheme could be used successfully to estimate the distribution of radioactive caesium emitted from the nuclear reprocessing plant in Cumbria. In 1978, based on the work by Norman Heaps and Roger Flather, the east coast storm-surge forecasting scheme went into operation at the Meteorological Office. This model has been continually upgraded. The tides were not ignored, however, as the renowned tidal theoretician, Dr David Cartwright, was appointed Assistant Director in overall charge of Bidston. He expanded tidal and sea-level research into the new fields of bottom pressure recorder measurements and satellite radar altimetry.
It was also during this period that Bidston became the centre for a unified 'A Class' national tide-gauge network. Inevitably, with time there was internal reorganization within IOS which resulted in the closure of the Taunton laboratory and the move of some members of staff, which brought sedimentary studies to Bidston. In 1986 Norman Heaps died after a long illness. He is honoured by a memorial prize awarded for the best paper by a young researcher at each UK Oceanography conference.

The Proudman Oceanographic Laboratory (POL) 1987

After the retirement of David Cartwright, the Directorship was taken up briefly by Dr Keith Dyer who moved from IOS (Taunton). There was a brief period of reorganization, following which Bidston attained a period of autonomy within NERC and a new Director – Dr Brian McCartney – was appointed. It was at this time that the laboratory was given its present name in honour of Joseph Proudman. The following decade built on the experience of earlier years but new key activities



The Proudman Oceanographic Laboratory photographed from the air in 1986, when the domes (lower right) were still painted black

commenced. During 1987–92, POL was the host laboratory for the North Sea Project, the first large 'community research project', involving many other UK institutes and university research departments. One main aspect of this project was that it established strong links with researchers in fields other than the physical sciences. This continued with increasing participation in many other collaborative projects in the UK and elsewhere, especially under the auspices of the European Union.

There were continuing advances in many kinds of instrumentation, for example the use of radar to measure surface currents and waves, the use of ADCPs in many observational programmes, the development of the sea-bed STABLE and MYRTLE platforms, the latter achieving a four-year deep ocean record from the sea-bed in the Drake Passage. Tidal measurements were made at stations such as Tristan da Cunha and Signy Island in Antarctica. There were a number of observational and modelling efforts examining processes along the UK shelf edge, which now included microplankton distribution as well as the usual physical variables. By now, shelf-sea models were addressing various time- and space-scales, three-dimensional baroclinic systems, temperature and salinity, and different turbulence and advection schemes, as well as ocean–shelf coupling. Sedimentary and biological processes were also included. The national need was also recognized when models were set up, in collaboration with other laboratories, to look at the major oil spill during the Gulf War as well as those from several tanker groundings. Models were even used as part of the Olympic Yachting effort. In Earth tides, the measurements became increasingly part of inter-national collaboration across Europe as well as in China. In addition, instruments were deployed near a pumped water storage scheme in North Wales to detect possible variation in the Universal Constant of Gravitation.

Table 1 *Important Bidston anniversaries falling in 1999*

160th	Permission granted to construct an Observatory at Waterloo Dock (1839)
80th	Establishment of the Liverpool Tidal Institute with Proudman as Director (1919)
70th	Amalgamation of the Tidal Institute with Bidston Observatory (1929)
50th	Construction of the 42-constituent Doodson–Légé tide-predicting machine (1949)
40th	Symposium marking the setting up of the Permanent Service for Mean Sea-Level (1959)
30th	The Tidal Institute enters NERC (1969)

This increasing collaboration with other institutes resulted in the recognition of common interests with two other major UK Laboratories, which led to the incorporation of POL within the Centre for Coastal and Marine Sciences (CCMS).

The Centre for Coastal and Marine Sciences, Proudman Laboratory, 1994

In 1994 the CCMS was formed from the Plymouth Marine Laboratory, Dunstaffnage Marine Laboratory and Proudman Oceanographic Laboratory, under the overall Directorship of, at first, Dr Brian Bayne (1994–98), and then Professor Jacqueline McGlade. After the retirement of Brian McCartney (now Professor), Professor John Huthnance became acting Director at Bidston until the appointment of Dr Ed (A.E.) Hill, with effect from April 1999. This also marked the start of six new core-strategic CCMS projects extending until 2004. These science programmes are linked through all three CCMS laboratories.

The formation of the Centre for Coastal and Marine Sciences now provides the setting for integrating the scientific effort in an interdisciplinary way, drawing on the strengths of each laboratory and affording the prospect of bright new opportunities for innovative research by the Centre as a whole. Even the domes are back to their original white!

Table 1 shows the various anniversaries that Bidston will be marking in 1999. Even astronomically there is an 'anniversary' to celebrate. A feature of total solar eclipses is that they repeat under almost exactly similar conditions – called the 'Saros' – every 18 years 11.3 days. On 29 June 1927 Bidston Observatory was surrounded by 50 000 people observing the last total solar eclipse on the UK mainland. Four Saroses later we reach 11 August 1999, when once again a total solar eclipse will cross the UK, passing over our sister CCMS Laboratory at Plymouth!

Bidston Observatory has had a remarkable history in so many ways. It has even had its 'show business' connections – the Director Jack Rossiter was brother to the comic actor Leonard Rossiter, particularly known for such television series as 'Rising Damp'. Also it must be a proud distinction, particularly for a Merseyside-based institute, to have had both Lennon and McCartney as Directors (Table 2)!

Bidston Observatory has evolved in many ways over the years in response to waxing and waning interests in various scientific fields, and has achieved great distinction in each of these. In its present form as a component of the CCMS it continues to play a major role in UK Science, and on past performance will undoubtedly continue to build on its existing expertise, and will evolve to meet new challenges as required by both national and international needs.

Further Reading

'William Hutchinson – Local Hero' by Philip Woodworth (1998), *Ocean Challenge*, Vol. 8, No. 3, pp.47–51.

'Modelling the Tides for the 1988 Olympic Games' by Roger Proctor and Judith Wolf (1990) *Ocean Challenge*, Vol.1, Spring, pp.10–14.

For more information about work undertaken at Bidston, see the Annual Reports of the Proudman Oceanographic Laboratory (or its predecessors), or see the web site at: http://www.pol.ac.uk

J. Eric Jones is a Senior Scientific Officer working as a numerical modeller at the CCMS* Proudman Oceanographic Laboratory; he also observes total solar eclipses and tidal river bores.

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Table 2 *Changing names, changing Directors*

The Liverpool Observatory
J. Hartnup 1843–85
J. Hartnup (Jr) 1885–92
W. E. Plummer 1892–1928

University of Liverpool Tidal Institute
Joseph Proudman 1919–1928

Liverpool Observatory and Tidal Institute
Joseph Proudman 1929–46
Arthur (A.T.) Doodson 1946–60

University of Liverpool Tidal Institute and Observatory
Jack (J.R.) Rossiter 1961–69

Institute of Coastal Oceanography and Tides
Jack (J.R.) Rossiter 1969–72
Geoffrey (G.W.) Lennon (Acting Director) 1972–73

Institute of Oceanographic Sciences
David (D.E.) Cartwright (Assistant Director) 1973–86
Keith (K.R.) Dyer (Acting Assistant Director) 1986
John (J.M.) Huthnance (Officer-in-Charge) 1987

Proudman Oceanographic Laboratory (CCMS–POL after 1994)
Brian (B.S.) McCartney 1987–98
John (J.M.) Huthnance (Acting Director) 1998–99
Ed (A.E.) Hill 1999–

Book Reviews

The Sea Surface and Global Change edited by Peter Liss and Robert A. Duce (1997). Cambridge University Press, £65 (hard cover, ISBN 0-521-56273-2).

Three things struck me rather forcibly when I came to write this review. The first was how long it has been since the book was sent out to me. The second, the rather high proportion of this time that it subsequently spent away from my desk and in the offices and homes of various colleagues. The latter probably gives a better idea of how well the book has been received by fellow researchers than can be conveyed by my review. The final jolt was the number of times I encountered statements similar to 'almost nothing is known about the role of X in the sea-surface microlayer', or 'few (or no) *in situ* measurements of X have been made', or 'the analytical techniques have yet to be developed'. This should be music to the ears of any scientists searching for new, challenging and 'relevant' areas of research where real impacts can still be made.

This book grew out of a scientific workshop on 'The role of the sea-surface microlayer and its potential role in global change' held in Rhode Island, USA, in 1994. It consists of three group reports produced as a result of the meeting, and thirteen individually authored chapters. The reports review the state of knowledge about the microlayer, highlight areas of uncertainty in our current understanding and speculate on the role of the sea-surface in climate change (and *vice versa*). The authors also suggest areas where future research should be concentrated. The reports are grouped rather roughly into three areas covering in turn the physics, biology and photochemistry of the microlayer.

The list of authors for the first report is really a line-up of who's who in air–sea gas exchange and the physics of the microlayer. As would be expected, it is well written, up-to-date and an excellent summary of almost 40 years of research. Nevertheless, the chapter does leave the reader with the impression that, in spite of a great deal of effort, relatively little progress has been made in successfully transferring knowledge gleaned from theoretical and laboratory studies into the oceans.

The second group report chapter deals with the possible effects of chemical and radiative change on the biology in the sea-surface layer. As a simple chemist I had no idea of the importance of the microlayer in ocean biology and found this a fascinating read. I highly recommend it. Having, I hope, whetted appetites, I leave readers to discover for themselves the material contained within this chapter. The final group report deals with the role of photochemistry in the microlayer. It discusses the potential effect of photochemistry on air–sea fluxes of gases, aerosols and trace metals. The section on photochemical processes operating in the microlayer is brief and speculative for the simple reason that few *in situ* measurements have been made.

The second and third group reports came as real revelations. It is clear that the microlayer is of great importance to both the ocean and atmosphere (and hence climate) but we know so little about it. We have even less idea of how the sea-surface might respond to climate change.

The single-authored chapters deal in considerable detail with different aspects of the sea-surface microlayer and are essentially peer-reviewed research articles. Five of these chapters are based around air–sea gas exchange. The first of these, Chapter 4, is written by Lutz Hasse and covers transport processes in the sea-surface

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The single-authored chapters deal in considerable detail with different aspects of the sea-surface microlayer and are essentially peer-reviewed research articles. Five of these chapters are based around air–sea gas exchange. The first of these, Chapter 4, is written by Lutz Hasse and covers transport processes in the sea-surface microlayer. As the microlayer is so difficult to access in the oceans, the author sifts through laboratory and theoretical studies of typical modes of fluid motion and assesses which transport mechanisms are dominant in the transfer of gases and materials in the ocean. It is blissfully free of Greek characters and a relatively simple read.

Chapter 5, by Nelson Frew is perhaps the best (and longest) chapter in the book. It discusses the role of organic films in air–sea gas exchange and contains a wealth of material accumulated by the Woods Hole group, of which very little has been published in regular journals. That surface films have the potential to inhibit the exchange of gases (and momentum) in the oceans has been suspected for a long time. Laboratory studies have confirmed this but extrapolation of results to the field has proved impossible. Here Frew reports on laboratory measurements of gas exchange using 'natural' seawater samples and shows that the inhibition of gas exchange is well correlated with the levels of dissolved organic carbon and chlorophyll-*a* in the sample. Frew shows that gas exchange is related rather poorly to wind speed in these experiments but that it is well correlated with the mean square wave slope. However, these findings cast serious doubt on whether a good parameter-isation of gas exchange in the oceans can be developed, particularly as the degree of inhibition was found to vary with time.

Chapter 6 by David Woolf reviews the probable role of bubbles in air–sea gas exchange and summarizes his previous papers on this topic. Again, it is clear, well written and relatively simple to follow. Woolf proposes a model for gas exchange that includes bubble enhancements to air–sea fluxes and shows that it agrees rather well with other global estimates of air–sea exchange. He notes that further progress is hindered by the lack of good field measurements of bubble spectra and surface-active material.

The next chapter is on physical chemistry of air–sea gas exchange and is written by Leon Phillips. The author has tried to make this paper accessible to the non-specialist, but do not be fooled by the title. It is based around irreversible thermodynamics and is, I suspect, only for the dedicated physical chemist. It argues strongly for a coup-ling between heat and matter fluxes in air–sea exchange, but although I tried several times to get beyond the deceptively simple introduction I could not negotiate the finer points of the argument.

A model for the effect of surfactants on air–sea gas exchange is presented by Bill Asher in Chapter 8. It is an interesting study in that it focusses on the exchange of ammonia, a compound whose air–sea exchange is often overlooked but which is important in cloud formation, and also in carbon dioxide exchange. Asher proposes that surface films can increase or decrease the net uptake of CO_2 by the ocean depending on whether regions covered by films are sources or sinks of CO_2. Clearly, this topic warrants further investigation and a priority must be the application of *in situ* measurement techniques.

Chapter 9 is a well written review of the chemistry of the microlayer by Keith Hunter. He describes existing and new sampling techniques. Data suggest that the sea-surface is significantly enriched in particulate species. Inevitably, in a book containing single authored papers, there is some overlap but it is not too significant. Chapter 10 by Mikhail Gladyshev, detailing the biophysics of surface films, suffers from this more than most, in that effects of surface films and air–water temperature gradients are also described in earlier chapters.

Chapter 11 is intriguing. John Hardy reviews information on organisms that live in the sea-surface layer (the neuston). He describes the enrichment of anthropogenic organic compounds and metals in the microlayer and discusses their potential effect on neuston. Hardy proceeds to speculate on the effect of increases in global sea-surface contamination and UV radiation on this layer, not only on neuston but also on fish eggs and larvae. It is clear that many questions remain unresolved. Chapter 12 by Yuvenaly Zaitsev is a short but detailed review of neuston species.

Photochemistry in the microlayer is the subject of Chapters 13 and 14 by Neil Blough and Manfred Ehrhardt respectively. The first of these is a thorough review that should be of interest to atmospheric chemists but which requires the reader to have some background in chemistry to be read in detail. Although significant progress has been made through laboratory-based kinetic studies, assessment of the importance of photochemical reactions within the microlayer are hindered by a lack of data on its spectral and photochemical properties. Chapter 14 discusses the sources and sinks of hydrocarbons and concentrates on photochemical breakdown of these compounds.

Chapter 15 by Gerald Korenowski describes the application of laser technology and laser spectroscopy to measurements of the sea-surface. Parameters that can presently be determined include wave slope and near surface turbulence. In the near future lasers could be used to characterize chemical species in the microlayer. The arrival of these types of non-intrusive instruments suggest that we may soon make more progress with understanding processes in the sea-surface layer.

Finally, remote sensing of the microlayer is reviewed by Ian Robinson. The chapter covers satellite measurement of sea-surface temperature, height and slope, skin temperature, wind speed and direction and chlorophyll. Despite the advances made over the last 20 years, there is still a need for accurate and rapid *in situ* measurements with which to calibrate satellite data.

What are my general opinions of the book? The cover states that it is an authoritative work, aimed at the graduate and research level and likely to be welcomed by environmental scientists, oceanographers and atmospheric scientists interested in global change. The first statement is undoubtedly true. The group reports are by top scientists drawn from throughout the international community and are excellent summaries of our current (lack of) understanding of the microlayer. Most of the single-author chapters are high quality research articles and well worth dipping into. The strength of the book is that it has successfully managed to bring together marine physicists, chemists and biologists, and consequently it really is interdisciplinary. Its regular absence from my desk has shown that it is indeed in great demand by environmental scientists and oceanographers. It ought to stimulate research in this area.

However, the book is not always a simple read and unless oceanography courses in the UK have suddenly taken a turn for the worse, my experience of students suggests that some sections would defeat all but the most zealous of undergraduates. As for encouraging more than the occasional enlightened atmospheric scientist to get their metaphorical toes wet, that would be great but would seem most unlikely!

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Dispersion in Estuaries and Coastal Waters by Roy Lewis (1997). John Wiley, 311pp. £60.00 (hardback, ISBN 0-471-96162-0).

This book is a timely addition to the literature on marine processes, and fills a long-empty niche by specifically addressing the physical mechanisms responsible for the dispersion of solutes and fine suspended material in coastal waters.

Its readership will be predominantly postgraduate students, research workers and professionals working in coastal hydraulics. It summarizes current knowledge, drawing on the author's thirty years of practical experience in solving mixing problems and providing a platform for the future work of others. It aims to give the reader a good understanding of fundamental physical processes, their mathematical formulation and, importantly, their limitations. The style is clear and simple, each chapter beginning with an introduction of the material to come and finishing with a summary. There are several interesting anecdotes relating the experiences of the author and those of other key workers in the field, such as Richardson.

In the Introduction, the author introduces the idea that only a small amount of knowledge is required to estimate the concentration of a substance in the marine environment, namely the distribution and magnitude of the fluid velocity and information about the turbulence in the fluid. That this is a deceptively simple idea is confirmed by the following 300 or so pages! This is a recurrent style of the book – ideas are introduced in simple terms and then, later, the complexities of dealing with the real world and all its variability are gradually brought to bear on the original concept.

Chapter 1 introduces some of the key concepts involved in the dispersion of a dissolved substance in a fluid, for example molecular and turbulent diffusion, mass and momentum transfer, shear dispersion and dilution rates. These (and many more ideas) are developed more fully in later chapters. This chapter declares the principal aim of the book to be '... to describe the present understanding of dispersion processes in the marine environment in relatively simple terms in the hope that it will be helpful to oceanographers and scientists from other disciplines.' An additional aim is '... to gather together those studies which either represent significant steps in understanding dispersion processes or those which describe particularly useful experimental results'. The chapter finishes with a summary of the structure of succeeding chapters.

Chapter 2 covers fluid dynamics relevant to the description of currents in well mixed flows in estuaries and coastal regions. Features of steady flows, boundary layers, unsteady flows (including waves), velocity shear and mixing by turbulence are discussed at length – the main interest of the chapter being on how velocity, velocity shear and turbulent mixing affect the movement and dilution of material. Chapter 3 discusses the influence of density stratification on the ideas introduced in the previous chapter, with attention now focussed on the dispersion of solutes in stratified estuaries and coastal waters. Particular attention is paid to vertical mixing, sources of turbulent mixing, and the stability of the water column.

Chapter 4 deals with turbulent diffusion and its mathematical representation. It begins with turbulent averaging and mixing-length theories before turning to statistical treatments of turbulent mixing. Particular reference is made to the diffusion of discrete patches, with lucid treatments of the contributions of Richardson, Kolmogoroff and Batchelor. Chapter 5 covers shear dispersion in steady and unsteady (principally oscillatory) flow. The role of velocity profiles and the time-scale of vertical mixing are discussed at length.

Chapter 6 covers mathematical modelling of dispersion in the marine environment. It begins with the initial dilution of buoyant discharges at the sea-bed before moving on to simple analytical techniques for the dispersion of patches and plumes, followed by a description of the random-walk approach. The chapter then covers regional rather than local phenomena, turning attention to one-dimensional estuary models using both simple approaches (tidal flushing and the concept of the tidal prism) and more sophisticated ones (finite difference techniques), for steady state and unsteady state conditions. The emphasis is on modelling salinity distributions but there is also a brief mention of dissolved oxygen modelling. The chapter finishes with an introduction to the fundamental aspects of two- and three-dimensional models. There is little here for the dedicated numerical modeller and disappointingly there are few references to important works on relevant numerical methods and their problems.

Chapter 7 covers the principles of the measurement of dispersion parameters. Attention focusses on techniques appropriate to introduced tracers (e.g. fluorescent dyes) and natural tracers (e.g. salinity). The chapter contains several numerical examples of how measurements are used to evaluate the required dispersion rates. The final section is a description of some key ancillary observational techniques such as position-fixing, remote sensing and Eulerian and Lagrangian velocity measurement.

Chapter 8 examines dispersion with reference to experiments in well-mixed estuaries and coastal waters, with an emphasis on the dispersion of patches and plumes. The chapter begins with a useful reminder of the key features of shear dispersion followed by a summary of estuary-classification techniques. It then moves on to consider dispersion at three different time-scales. Short time-scale dispersion is relevant to conditions controlled entirely by turbulent diffusion (i.e. the influence of velocity shear is negligible), and hence is concerned with experimental data for horizontal dispersion. Intermediate time-scale dispersion is relevant to situations controlled by intra-tidal shear, and this section contains useful reproductions of tables of horizontal, lateral and longitudinal dispersion coefficients from estuarine and coastal waters. Long time-scale dispersion involves tidally averaged (or should this be steady state or even residual?) conditions. At the end of the chapter there are a few useful caveats about the difficulty of predicting coefficient values.

Chapter 9 is similar to Chapter 8 but considers dispersion in stratified marine waters. Discussion focusses on salt-wedge estuaries and fjords, the interaction of estuary outflows with coastal waters and fronts. Chapter 10 considers dispersion in partially stratified systems, calling on both laboratory and field experiments to show the effects on dispersion of variations in shear and turbulent mixing. The use of observations in identifying the roles of different transport mechanisms in maintaining salt budgets is also described, and values of mixing coefficients from the literature are quoted. The Chapter finishes with a brief look forward to future research and an overall summary consisting of five main findings drawn from the previous chapters.

continued overleaf

Overall, I like the book and think it will become one of the standard texts on marine processes. The price may deter all individuals except professional marine scientists from buying it, but institutional librarians should be encouraged to acquire it.

Steve Wallis
Department of Civil and Offshore Engineering
Heriot-Watt University, Edinburgh

Ocean Waves: the Stochastic Approach by Michel K. Ochi (1998) Cambridge University Press. £65. (hard cover, ISBN 0-521-56378 -X)

Michel Ochi's name is well known and he has published many papers in the field of wave studies. A book by him is therefore welcome, and your reviewer has read it with interest and found it thought-provoking. All the other books on waves which your reviewer has seen are based on physics/hydrodynamics, though most contain the stochastic – i.e. statistical – treatment as well, of course. Ochi's book is wholly about the stochastics of waves, as one would expect from the title, but this is taken to the extreme, and there are several places where a brief discussion of the physical basis of the aspects being treated would shed light on them, and indeed, prevent one or two misconceptions which have crept into the book. One of the best parts of the book is his treatment of the theory of extreme wave prediction, which is elegantly set out.

The most serious criticism of the book is that it is out of touch with the thinking, practices, and problems of engineers and applied oceanographers who have to interpret wave data. A basic illustration of this is that the first part of the book (to p.104, in fact) is entirely devoted to the study of crest-to-trough waves, which are rarely, if ever, used by applied oceanographers. The most fundamental reason for this is that for all the standard spectral formulations, the mean crest-to-trough period is zero. In practice, it is critically sensitive to the high frequency response of the wave-measuring system. Usually, other period parameters depending on lower-order moments of the spectrum are used (or sometimes the period corresponding to the peak of the spectrum), and these longer periods are more relevant to the calculation of forces on offshore structures.

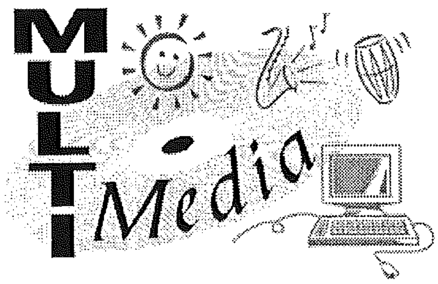
To give an example of the detail, Ochi defines the significant waveheight as the average height of the highest one-third of the waves. This parameter went out of general use long ago because it has no simple theoretical relationship to any other wave parameter. Nowadays we use $H_{m_0} = 4\sqrt{m_0}$ where m_0 is the variance of the surface elevation about its mean. One result of using $H_{1/3}$ is that in some cases he has to say that his results are approximate, whereas using H_{m_0} they would be exact.

One of the first things your reviewer did on getting the book was to look at what Ochi has to say about the three most recent problems he has been concerned with. The first is the limiting height of waves in water of intermediate depths, which is an important design input for some North Sea offshore platforms. There is nothing helpful on this. The second problem concerns the wave kinematics factor, defined as the proportion by which wave-spreading reduces the r.m.s. amplitude of that component of the wave particle velocity which is in-line with the mean wave direction. At first sight this may appear to be just another of the nearly 20 different measures of wave-spreading which are to be found in the literature, but it is the one which the American Petroleum Institute's *Recommended Practice for the Design of Offshore Structures* says should be used when calculating the reduction in wave force resulting from the directional spreading of waves. Ochi does not mention it.

One might consider these two problems to be in the realms of physics, but the third one is definitely stochastic in nature. It is to do with the period and wavelength of extreme waves. For some years, it has been known that for a linear wave system, the time-history of extreme waves tends to the shape of the temporal autocorrelation function, with an equivalent result for the spatial cross-section. Some elegant and well-publicised work by a group of workers at Shell in the Hague exploits this result to produce methods which can be used by design engineers. This development is called 'The Shell New-Wave Theory'. Ochi appears to be unaware of this work, and in so far as he treats the problem, he quotes Longuet-Higgins (1983) who, surprising though it may seem, reached an incorrect conclusion.

To sum up, Ochi has done us a service by collecting together the statistical theory relevant to the interpretation of wave data, but, as one of your reviewer's colleagues put it, it is a book which you will want on your shelves but not permanently beside you on your working desk.

Tom (M. J.) Tucker
Taunton, Somerset



Invitation to Oceanography* (Web-Enhanced Edition) by Paul Pinet

In my review of this book in the last *Ocean Challenge* I complained that when I tried to open two of the Oceanlink web components (the Key Topics and the Science Boxes) I only got blank pages. I am glad to report that the problem has now been solved. It turned out that I was using Netscape browser system that cannot cope with 'frames' versions of these web pages. The publishers (Jones & Bartlett) have now added 'no(n)-frames' versions, and the other day I was able to get into all the web components.

John Wright

*ISBN 0-7637-0614-0.

G^3: A New Cyber Journal

G^3 – standing for 'Geochemistry, Geophysics, Geosystems' – is an international multidisciplinary electronic journal that publishes contributions investigating Earth as a dynamic chemical system on all time-scales. It is completely electronic (i.e. no hard copy is involved, though high quality reprints can be downloaded and printed). and is presented by the Geochemical Society and the AGU, and has been founded with the support of Scripps Institution of Oceanography, Harvard University, and Lamont-Doherty Earth Observatory. It will be possible to submit articles, rapid publication research letters, reviews, data briefs and technical briefs (e.g. analytical methods), as well as models, movies etc.

At present, there is no subscription charge for individuals or institutions. For further information, see the web site: http://g-cubed.org/

Letters to the Editor

Storm Surge Modelling

I was interested to read the article by John Wright reviewing UK Oceanography '98 ('A curmudgeon writes ...', *Ocean Challenge*, Volume 8, No. 3) in which he makes the point that 'much of what was presented was a case of dotting i's and crossing t's', which he illustrates with reference to a storm surge paper. Later on, he also comments about the 'relevance' of various lines of work. Although in some cases 'dotting i's and crossing t's' may not be particularly relevant, with regard to small improvements in surge elevation prediction, it should be pointed out that the final few centimetres can be very important indeed. If we regularly and needlessly evacuated people from their homes each time a potential storm surge of whatever magnitude occurred, apart from anything else this would be very costly and very inconvenient. At the same time a small difference could be the trigger to start evacuation when a surge actually does occur. This is recognized by the various surge forecast authorities, and standards for surge prediction have been laid down.

I would fully agree with John Wright that a law of diminishing returns can arise as models attempt to deal with the last few percent of discrepancies with observations, especially as models become limited by their inputs. However for currents associated with major surges (which I thought was the main thrust of the storm surge presentation) we are certainly not 'dotting i's and crossing t's', as observations are rather sparse and models very poor, which is the reason for the existence of a ` research topic of 'relevance' in understanding the movements of pollutants which are mobilized during major storm events.

J. Eric Jones
Centre for Coastal and Marine Studies, Proudman Oceanographic Laboratory

The curmudgeon replies:
I am suitably chastened. I stick to my general point about crossing t's and dotting i's, but have to admit that in choosing this example I was being slightly impish. Although half-expecting a riposte, I did not anticipate one that would be so full and so courteously worded.

Noah's Waterfall

'Noah and the Black Sea Waterfall' (Volume 8, No.3, p.9) made me sit up and take notice, not because of the Noah connection but because of the presumption that the Black Sea basin had a very low water level during the last glacial maximum until rising sea level in the Mediterranean topped the Bosphorus 'ridge' and poured catastrophically into the basin to produce the so-called Bosphorus waterfall.

Some years ago I interested a graduate student, Richard S. Anderson, in taking a preliminary look at the water budget and circulation of the Mediterranean during the last glacial epoch. To do this, a water budget for the Black Sea was also needed. Working together we deduced that precipitation (estimatd at 15 200 m^3s^{-1}) plus runoff (20 800 m^3s^{-1}) exceeded evaporation (8 600 m^3s^{-1}) from the Black Sea at that time so that the basin was full, with one-way flow out through the Bosphorus. In fact our estimates suggest that the outflow (27 400 $m^3 s^{-1}$) exceeded the sum of today's combined surface inflow and subsurface outflow through the Bosphorus (18 700 $m^3 s^{-1}$, from Sverdrup *et al.*).

Your article presumes the water level in the Black Sea basin was well below the Bosphorus sill depth which would have to result from an evaporation excess over precipitation and runoff, but doesn't hint at geological or recent water-budget evidence for that condition. I confess I have not followed Black Sea research studies in recent decades but I remain interested in the conditions that prevailed in the region during the last glaciation. Accordingly, if you can steer me to evidence of a sub-Bosphorus water level during that time I would be grateful.

Anderson presented the results of his investigation in his MS Thesis titled 'Paleo-Oceanography of the Mediterranean Sea: Some Consequences of the Wurm Glaciation', May 1965, written at the Naval Postgraduate School, Monterey, California. We subsequently co-authored a paper titled 'Water Budget of the Mediterranean Sea During the Last (Wurm) Glacial Epoch', and an abstract is contained in the Proceedings of the Second International Oceanographic Congress, Moscow, 1966. (These obscure references would not easily be found by an interested person.)

Now back to Noah ...

Warren C. Thompson
Department of Oceanography
Naval Postgraduate School
Monterey, California 93940

(Challenger Society member since 1960)

The Editors reply:
The story evolved from a short item in *Science* (**279**, 22 Feb. 1998, p.1132), a press cutting (*Observer,* 1 March 1998) and a TV documentary. We, however, are solely responsible for the speculations and the flights of fancy. The water budget calculations are plainly at variance with conclusions drawn from the Black Sea sediments. We would not presume to adjudicate between the alternative hypotheses, noting only that it might be difficult to reconcile two such radically different conclusions! If any reader can help solve this conundrum, please let us know.

Forthcoming Events

Events in 1999

Education: Weather, Ocean, Climate (EWOC99) (Fifth International Conference on School and Popular Meteorological and Oceanographic Education). 5–9 July. The conference is intended for teachers, educationalists, meteorologists, oceanographers, equipment manufacturers and science communicators. Three venues will be used: the University of Ballarat (5, 6 July), the Bureau of Meteorology, Melbourne (7 July) and the Glen Waverley Secondary College, Melbourne (8, 9 July). *Contact* DWOC99, Cooperative Research Centre for Southern Hemisphere Meteorology, Monash University, Clayton, Victoria 3168, Australia.

National Open Forum on Education and Training in Marine Sciences 10 June, Royal Society, London. *Contact* Sylvia Allison, Administrative Secretary, IACMST Secretariat, Southampton Oceanography Centre, Empress Dock, Southampton SO14 3ZH. Tel. +44-(0)1703-596612; Fax: +44-(0)1703-596395; Website: www. marine.gov.uk01703-596395; Email: saea@mail.soc.soton.ac.uk

Vessels and Structures – Technologies and Trends 16 June, City Conference Centre, London. Workshop organized by IACMST and sponsored by Lloyd's Register of Shipping. Topics covered include risk, safety and the environment. *Contact as for previous meeting.*

Impact of Climate Change on the Coastal Zone (ECSA 30). 9–13 August, Zentrum für Meeres- und Klimaforschung (ZMK), Hamburg, Germany. *Contact* Prof. Dr Jürgen Sündermann, ZMK, Bundestrasse 55, 20146 Hamburg, Germany; Fax: +49-40-4123-5235; Email: suendermann@ifm.uni-hamburg.de

Primary Productivity of Planet Earth: Biological Determinants and Physical Constraints in Terrestrial and Aquatic Habitats (MBA, British Phycological Society, BES, Challenger Society, SEB). 6–11 September, Plymouth. Topics include: Plant form and function; carbon metabolism and primary productivity; ecological constraints; regional and global assessments; photosynthesis/plant productivity in transition. **Nos. restricted to 100.** Fee: £100. *For further details contact* Dr Richard Geider, Marine Biological Association, The Laboratory, Citadel Hill, Plymouth, PL1 2PB, UK. Tel.+44-(0)1752-633100; Fax: +44-(0)1752-633102; Email: rdg@wpo.nerc.ac.uk

Using Marine Biological Information in the Electronic Age 19–21 July, University of Plymouth This conference is being organized by the MBA to encourage the marine community to realise the potential of electronic media. Emphasis will be on identifying and exploring the new tools made available through advances in IT for biological recording, education and networking to support research and decision-making in marine environmental management and protection. *For more information, see* the MarLIN web page at http:/www.marlin.ac.uk *or contact*: Bob Earll (CMS) Candle Cottage, Kempley, Gloucestershire, Tel./Fax: +44(0)1531-890415; Email: bob.earll@dial.pipex.com *or* Keith Hiscock: MarLIN Office, MBA, The Laboratory, Citadel Hill, Plymouth PL1 2PB; Tel. +44-(0)1752-633336; Email: k.hiscock@mba.ac.uk

Progress in Chemical Oceanography (PICO) August/September, Plymouth. *Contact* Eric Achterberg, University of Plymouth; Email: e.achterberg@plymouth.ac.uk

Offshore Europe '99: Oil and Gas Exhibition and Conference 7–10 September, Aberdeen, Scotland. *For further information contact* The Offshore Europe Partnership, Ocean House, 50 Kingston Rd, New Marlden. Fax: +44-(0)181-949-8193/8186; Email: oe99@spearhead.co.uk *or* see the website: http://www.offshore-europe.co.uk

The Deep Subsurface Biosphere (Joint Meeting of the Society for General Microbiology Environmental Microbiology Group, the Challenger Society and the Geological Society Marine Studies Group). 9–10 September, University of Leeds. *For further information contact* Rachel Mills, SOC, Southampton, SO14 3ZH; Email: ram1@soc.soton.ac.uk.

34th European Marine Biology Symposium 13-17 September, Ponta Delgada, Azores. The main themes will be: ecology and evolution on island shores; the open ocean; and the deep ocean. *For more information see* website: http://www.uac.pt/db/embs34 *or contact:* 34th EMBS Secretariat, Dept of Biology, Marine Biology Section, University of the Azores, Rua da Mãe de Deus, 58, 9502 Ponta Delgada CODEX, Azores, Portugal; Tel. +351-96-653044 (extn 1237); Fax: +351-96-653455; Email: embs34@alf.uac.pt

Events in 2000

North Sea 2000 (13th International Senckenberg Conference on Burning Issues of North Sea Ecology) 8–12 May, Wilhelmshaven, Germany. Topics will include biodiversity in North Sea ecosystems, ecological barriers and gradients and modelling; structure and functioning; influx/effects of alien organisms, pelagic–benthic coupling. *Contact* Dr I. Kroncke, Seckenberg Institute; Tel. +49-4421-947532; Fax: +49-4421-947550; Email: kroencke@sam-terranare.fh-wilhelmshaven.de *or* Dr M. Turkay, Senckenberg Institute, Senckenberganlage 25, Germany; Tel./Fax: +49-69-7542240 / 746238; Email mtuerkay@sng.uni-frankfurt.de. Web: http://senckenburg.uni-frankfurt.de/fis/sngc13.htm

Meteorology at the Millenium: Its Relationship to other Sciences and Technology, and to Society 10–14 July, St John's College, Cambrdge. For more information contact The Royal Meteorological Society, 104 Oxford Rd, Reading RG1 7LL, UK. Email: execsec@royal-met-soc.org.uk

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Remember If you are organizing a conference or meeting on any aspect of oceanography, you can publicize it through *Ocean Challenge*. Details should be sent to the Editor (for address see inside back cover)

IYO Recollected

There were over 100 activities related to maritime affairs and marine conservation in UK waters during 1998. *International Year of the Ocean 1998: Ocean Policy and Activities in the United Kingdom*, compiled by Martin Angel and David Pugh, summarises some of these, as well as reproducing the texts of keynote speeches on these issues by John Prescott and Michael Meacher. We hope to feature a longer account in the next issue of *Ocean Challenge*. Meantime, the 60-page document can be obtained from: IACMST, Southampton Oceanography Centre, Empress Dock, Southampton, SO14 3ZH. Web: www.marine.gov.uk

OCEAN Challenge

The Magazine of the Challenger Society for Marine Science

SOME INFORMATION ABOUT THE CHALLENGER SOCIETY

The Society's objectives are:

To advance the study of Marine Science through research and education.

To disseminate knowledge of Marine Science with a view to encouraging a wider interest in the study of the seas and an awareness of the need for their proper management.

To contribute to public debate on the development of Marine Science.

The Society aims to achieve these objectives through a range of activities:

Holding regular scientific meetings covering all aspects of Marine Science.

Supporting specialist groups to provide a forum for discussion.

Publication of a range of documents dealing with aspects of Marine Science and the programme of meetings of the Society.

Membership provides the following benefits:

An opportunity to attend, at reduced rates, the biennial four-day UK Oceanography Conference and a range of other scientific meetings supported by the Society.

Regular bulletins providing details of Society activities, news of conferences, meetings and seminars (in addition to those in *Ocean Challenge* itself).

MEMBERSHIP SUBSCRIPTIONS

The subscription for 1999 costs £30.00 (£12 for students, in the UK only). If you would like to join the Society or obtain further information, contact the Executive Secretary, Challenger Society for Marine Science, Room 251/20, Ocean Technology Division, Southampton Oceanography Centre, European Way, Southampton SO14 3ZH, UK.

ADVICE TO AUTHORS

Articles for *Ocean Challenge* can be on any aspect of oceanography. They should be written in an accessible style with a minimum of jargon and avoiding the use of references. If at all possible, they should be well illustrated (please supply clear artwork roughs or good-contrast black and white glossy prints). Copy may be sent electronically.

For further information, please contact the Editor:

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