OCEAN

Challenge

The Challenger Society for Marine Science

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OCEAN Challenge

The Magazine of the Challenger Society for Marine Science

SCOPE AND AIMS

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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The cover was designed by Ann Aldred Associates.

Acknowledgements

Going anticlockwise around the spiral, from smallest picure to largest, the images are: (1) A false-colour visible wave-band image based on *SPOT* data showing the mouth of the Gironde Estuary in western France and illustrating the distribution of suspended particulates. Image produced by Ian Robinson from UNESCO educational material provided by P. Castaing and J. Froidefond. (2) *EOSAT* image showing turbidity in the northern Adriatic off the coastal lowlands of Albania. The processed and enhanced image is by courtesy of the British Geological Survey. Reproduced by permission of the Director, BGS, NERC. All rights reserved. (3) Modelled mean lagrangian velocities and long-term trajectories in the Channel, from the EU MAST project Fluxmanche. Reproduced by courtesy of J.C. Salomon, Ifremer, Brest. (4) Part of a global image of sea-surface temperature observed by the Along-Track Scanning Radiometer (ATSR). The data have been extracted from the ASST CD-ROM produced by the Rutherford Appleton Laboratory. Image produced by Ian Robinson. (5) Sea-surface temperature in the North Sea during early summer, showing a coastal fringe of warmer water, derived from data obtained by the NOAA AVHRR sensor. Image produced by Ian Robinson. (6) *ERS-1* ATSR image showing sea-surface temperature of the western Channel. © Rutherford Appleton Laboratory/NERC/ESA/BNSC. The central globe was produced by Tom Van Sant, Geosphere Project, and made available through the Science Photo Library.

News and Views

Henry Charnock: a Champion of Oceanography

Henry Charnock died on 27 November after a short illness. Henry was for many years a champion of physical oceanography in the UK. He was Director of the National Institute of Oceanography (later the Institute of Oceanographic Sciences) in between being twice Professor of Physical Oceanography at Southampton University.

He chaired the UK-WOCE committee in the '90s and long before that he masterminded the Royal Society's JASIN Project in the '70s and '80s. He was influential in setting up and naming the James Rennell Centre for Ocean Circulation. Scientifically, he was much involved in air–sea flux estimation, and with a background as much in meteorology as oceanography, he was as well known in meteorological circles (the Royal Meteorological Society, the UK Meteorological Office) as in oceanographic ones. These are areas in which I was aware of his involvement, but there were many, many others. We shall greatly miss his quiet but penetrating insight, his guidance and his ready wit.

Raymond Pollard

Professor Geoffrey Skirrow

Professor Geoffrey Skirrow died on 9 September at his home at Silverdale, near Carnforth on Morecambe Bay. Best known for his co-editorship with John Riley of the classic two-volume text *Chemical Oceanography*, Skirrow was essentially a chemist with interests in environmental matters, and his principal contribution to marine science was in the field of the CO_2 system and dissolved carbonate equilibria.

Departments to Merge

Plans to amalgamate the Departments of Oceanography and Geology at the University of Southampton took a step forward recently. Following meetings between the Heads of Department, the Dean of Science, and the Director of the Southampton Oceanography Centre, the name 'School of Ocean and Earth Science' (to be proposed formally to the Faculty of Science) has been adopted.

New Port at Southampton

Associated British Ports (ABP) has been awarded a large grant from the EU to develop a new container port at Dibden Bay in the Test Estuary, Southampton. It is believed that the sum involved is the largest award to any UK port.

Plans intended to allay concerns over the environmental impact of the port have recently been released by ABP. At the centre of the proposal is a mile-long creek, some 300 m wide, running along the original foreshore of 50 years ago. It is hoped that its mudflats will provide a haven for wading birds and wildlife. ABP is working closely with English Nature and the RSPB, who have agreed in principle that the creation of a tidal creek is the best way of replacing intertidal habitats lost to the new port.

SANDYDUCK (and CRAB)

A large coastal experiment called SANDYDUCK '97 is underway in Duck, North Carolina, USA. Sponsored by the US Army Corps of Engineers, the Office of Naval Research, and the US Geological Survey, the project aims to monitor waves and currents reaching the shoreline, and will assist with the development of tools to predict the impact of hurricanes, and study long-term coastal evolution. The chosen field site, however, was too shallow for a ship, so the Woods Hole scientists used the US Army's Coastal Research Amphibious Buggy (CRAB), a motorised tripod, 11m high, to deploy their research instruments.

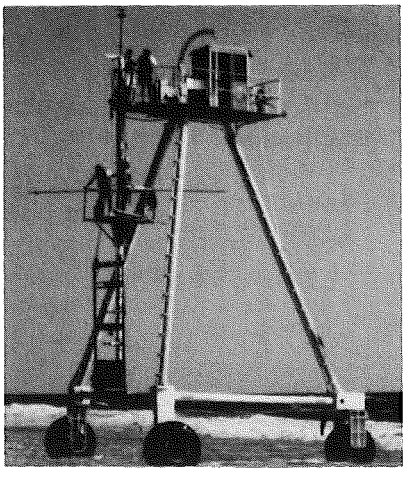

Photo: Rebecca Beavers

Science for Peace Initiative

NATO has recently announced a new programme to encourage cooperation between existing NATO countries and partners from Central and Eastern Europe and Central Asia. Entitled 'Science for Peace', the programme will support projects of 3–5 year duration at an average level of 10–12 million Belgian Francs (~$300 000). Funding will support experts, equipment, computers, software, travel, training and consumables, but not salaries, overheads or office equipment.

Preliminary proposals are to be set out in a simple four-page form describing the cooperating parties, the work, milestones, deliverables and funding requirements. The programme's funding level, project duration and simple procedures for proposal submission are attractive enough to warrant serious attention. The next deadline is 15 May 1998.

Full details are available from the Web: http://www.nato.int/science

PLASMA Trials

One of the exciting areas of research into hydrothermal vents concerns the dispersal of vent animals and the spread of populations between different vent fields. PLASMA is a new instrument that has been developed with the aim of collecting larvae of vent organisms, and preserving them *in situ* for later visual or DNA analysis.

Designed and built at the Southampton Oceanography Centre (SOC), PLASMA (which is based on the stand-alone pump principle) has the capability for time-series measurements, and can be deployed by either a submersible or a surface ship. Its first deployment was from RRS *Discovery* at the Lucky Strike vent field in the North Atlantic.

For more information about PLASMA, visit SOC's Ocean Technology Division home page at: http://www.soc.soton.ac.uk/OTD/otdindex.html, or see the latest *BRIDGE Newsletter* (No.13, for Autumn 1997).

Our thanks to Patrick Friend (SOC) and Alan Weinstein (ONR) for contributions to News and Views.

Shrinking Ship Resources

UK oceanographers (among others) can sometimes – more often these days perhaps – be heard to complain that there are not enough ships and/or insufficient funds for sea-going research. It transpires that they may not be alone. In the *UNOLS Newsletter* for Summer 1997 we read that in the United States, at all Federal Agencies, the ratio of dollars spent on ship operation to dollars spent on ocean science research has declined dramatically in the past decade, and some agencies no longer support ocean-going research at all. The question is whether this trend is deliberate and whether it is good for marine science. More important perhaps, does the marine science community need to use ships as much as heretofore?

The answer seems to be that the declining trend in ship use, while not deliberate, is almost inevitable in light of the growing proportion of research performed in offices and laboratories ashore rather than at sea (rather unkindly dubbed 'cubicle oceanography'). The increasing availability of high quality satellite data has undoubtedly contributed to this trend. So has the fact that two major programmes (JGOFS and WOCE) are simultaneously moving from field programmes to modelling and synthesis phases.

There seems to be a kind of positive feedback at work also. There are fewer requests for ship time in research proposals, because of a (reputedly mistaken) belief that such requests have a low success rate, reinforcing the trend towards less work performed at sea. In the long run, however, while modelling studies may well play a larger part in the oceanographic sciences, they do depend directly upon field data for model validation.

Having identified the trend, no doubt the US oceanographic community can take steps to reverse it, and the newsletter carries another item by D. James Baker of NOAA about an agreement between NOAA and UNOLS relating to mutually beneficial cooperation in the use of each other's vessels. As European unity comes closer, could we aim for similar agreements on this side of the Atlantic? (For more on this topic, see pp.22–5.)

News by courtesy of UNOLS (US University National Oceanography Laboratory System)

Dust and the NAO

The North Atlantic Oscillation – the NAO for short – has been getting quite a bit of publicity lately, not least in *Ocean Challenge*. It figured prominently in Robert Pickart's article in the last issue, and it features several times in this one (see especially pp.40–46). Indeed, the NAO has generally acquired a higher public profile in the last couple of years. Although it still receives nothing like the hype which surrounds El Niño–Southern Oscillation (ENSO) phenomena, it seems to be increasingly implicated in the climatic affairs of north-west Europe.

At first sight, it is not something you'd connect with atmospheric dustiness, but it does seem that the amount of dust exported from northern Africa to the Mediterranean and across the Atlantic is quite well correlated with the size of the NAO Index, which is the pressure difference between the Iceland Low and the Azores High. Quite a lot of statistical processing of meteorological and satellite data were needed but the relationship eventually obtained was a simple one: the greater the NAO, the lower the rainfall over northern Africa, the drier it is there (cf. p.43), and the more dust is lifted into the atmosphere.

The Azores–Iceland pressure difference varies seasonally, being greatest (NAO index highest) in winter, but overall the index has been rising since the mid-1960s, and the atmosphere over Europe has become dustier overall. Until last year, that is. In 1996, the NAO fell to its lowest level since 1968, and so did atmospheric dust concentrations over the North Atlantic region. Interestingly, *The Guardian* picked up on the report of all this in *Nature* (June 12), and was a bit snooty about the way in which increasing dustiness of the atmosphere, hitherto attributed to bad farming practices in lands surrounding (and especially south of) the Mediterranean, actually resulted from the vagaries of atmospheric behaviour – that is, these new results repudiated such a pejorative conclusion But was *The Guardian* right? Surely, more rain means that less dust gets into the atmosphere anyway, whatever its source. Absence of dust does not of itself preclude bad farming practice, because when it rains, eroded topsoil ends up in the rivers which carry it away and dump it somewhere else. The case for or against farming practices in Africa being the main cause of a dustier atmosphere is not resolved by this research.

White Submarines?

In the last issue (pp.11–12) we discussed the idea that decommissioned nuclear subs might find a new lease of life as oceanographic research platforms. Apparently, people with some experience of submarine operations tend to be sceptical of the whole concept, not least because maintanance of a 'white' nuclear submarine would probably be beyond the means of even the most richly endowed research group or consortium, perhaps even of any national research body. Furthermore, equipment on submarines needs frequent overhauling because of the combined corrosive effects of poor air quality (high CO_2 levels) and condensation in confined spaces. Maintenance of the nuclear power plants themselves requires a large technical infrastructure, which would not be viable for fewer than, say, six vessels.

As outlined in the original news item, it would be more sensible not to wait for a nuclear submarine to pass its sell-by date, and instead to persuade the Navy to dedicate one specifically for research. It would give the Navy some 'green' credentials, and help to justify the huge expenditure of taxpayers' money on national defence, especially as people tend to wonder why we need armed forces now that the Cold War has officially ended. But would *any* Defence Ministry agree to that?

Another reason for trying to get a vessel seconded from active service, is that decommissioned submarines will (of course) be old, and in nuclear submarines the power plants become increasingly dodgy with age. What's more, the continual stresses brought on by fluctuating pressures associated with frequent depth changes weakens the hulls.

Alternatively, you can commmission your own submarine from a number of yards in various parts of Europe where a craft can be built to your specification, though it will be of conventional type, that is non-nuclear, powered by diesel–electric or fuel cells. Costs of both construction and maintenance would be a lot less – for one thing the hull need only be strong enough to dive to a few hundred metres, there would be no need to withstand the shock of depth charges; plus which conventional power plants don't need cohorts of nuclear technicians. On the other hand, whatever type of submarine you ended up with, you'd still have to cope with cramped space and warm

damp stale air. Well, at least you don't get those sorts of problems with *AUTOSUB*.

Post Script
As we go to press, we have learnt that for three million bucks, you can buy from a Miami-based entrepreneur a fully equipped Russian nuclear submarine complete with crew, for purposes of drug-running. What a shame the marine science community cannot raise that kind of money for a submarine (complete with crew) that could be used to help their research!

Do Sea-floor Spreading Rates Affect Sea-level?

Most Earth scientists know that sea-levels were higher in the Cretaceous (~100 million years ago), and it is commonly believed that this was a consequence of increased rates of sea-floor spreading associated with break-up of the supercontinent of Pangea and formation of the ocean basins as we know and love them today. The proposed mechanism is simple: Increased sea-floor spreading rates are associated with heating and expansion of ocean ridges, which decreases the average depth of ocean basins and displaces water onto continents. Conversely, if rates of sea-floor spreading were to decline, then sea-level would fall. This is the received wisdom, and it is in (nearly) all the books that discuss this topic.

Well maybe. Is this obvious mechanism for raising and lowering sea-level wholly plausible? Here is an alternative view. Sea-floor spreading must be the chief mechanism by which the Earth loses internal heat. It is a continuous and global process, compared with which the sporadic (albeit occasionally spectacularly large and violent) eruptions of terrestrial volcanoes must surely be a relatively minor player.

If there were greater rates of sea-floor spreading for several million years in the Cretaceous, there must have been correspondingly greater rates of heat loss from the Earth's interior. Although the Earth has been cooling since it formed (as the primordial heat 'leaked' away and the radioactive isotopes in the mantle decayed), there should be no sudden increases (or decreases) in this rate of cooling, as would be implied by increased spreading rates.

Global sea-level did indeed rise dramatically during the Cretaceous, and an alternative suggestion is that this was caused by the localised 'superplumes' which produced great submarine plateaux, especially in the western Pacific (e.g. the Ontong–Java Plateau). Such one-off events can be attributed to localised build-up of heat within the Earth, released rather suddenly by massive eruptions - perhaps akin to continental flood basalts such as the Deccan Traps. And as they occured on the sea-bed, they displaced water onto continents.

Readers' views would be welcomed.

Lake Nyos - a Warning for the Apocalypse?

Remember Lake Nyos? It is one of several crater lakes in the Cameroon volcanic belt, and several years ago it was caused to overturn by an Earth tremor. The underlying dormant volcano(es) had been slowly leaking CO_2 into the bottom of the lake where it dissolved under the prevailing hydrostatic pressure. The tremor set up a seiche, and as the water sloshed back and forth, some of the CO_2-saturated bottom waters came near enough to the surface to de-gas sufficiently vigorously to disrupt the layering in the lake, and de-gassing became catastrophic. A cloud of CO_2 spilled over a low point in the crater wall, rolled down a couple of valleys and suffocated large numbers of people and animals as they slept. Could something comparable happen in the oceans? Did it actually happen at the time of the meteorite impact which is now firmly fixed in the public imagination as having led to extinction of the dinosaurs?

The meteorite that struck the coast of the Yucatan peninsula at the Cretaceous–Tertiary (K–T) boundary penetrated a considerable thickness of limestone, which is believed to have been decomposed by the heat of the impact and liberated vast quantities of CO_2 into the atmosphere, leading to a period of considerable greenhouse warming. This would have followed the 'nuclear winter' produced more or less immediately by the dust and aerosols dispersed throughout the atmosphere by the impact. A large proportion of the aerosols, incidentally, is believed to have come from 'thermal shock' decomposition of evaporitic gypsum deposits, liberating SO_2 to the atmosphere, perhaps in sufficient quantities to produce acid rain on a global scale. It never rains, but it pours – the poor dinosaurs never stood a chance did they?

But how about *oceanic* degassing? We know that the equatorial oceans are a net source of CO_2 to the atmosphere because when cooler water from below the thermocline rises to the surface, pressure falls and CO_2 escapes. Indeed, one of the problems that you don't often hear about in relation to OTEC* is that when it is brought from depth to the surface to cool the condensers, and subsequent use for mariculture, the cold, nutrient-rich water is all cloudy because it's full of CO_2 bubbles (it is also rather acid).

Could the meteorite have released as much or even more CO_2 from solution in seawater as it is alleged to have done from the limestone? It's estimated to have been a body of order 10 km across, and even though it was a coastal impact, the resulting tsunamis could well have been high enough to bring water from quite deep levels to the surface. If catastrophic degassing followed, the Caribbean, perhaps even the equatorial Atlantic, could have been 'turned over', liberating enormous amounts of CO_2 to produce the greenhouse warming. An additional effect might have been to liberate large quantities of methane from gas hydrates that had accumulated near the top of thick sediment accumulations along many continental margins – this would have further added to greenhouse warming.

It's a lovely idea, but there is not a whole lot of evidence that there *was* actually any substantial global warming at the time of the K–T boundary. Perhaps that is not surprising, you'd probably need records with decadal resolution to detect it, and they aren't available that far back in geological time.

An alternative trigger for the turnover of deep ocean waters lies somewhat nearer home in the form of the giant slumps that have been recorded at volcanic islands in the Pacific. Sudden slope failure on a grand scale has caused billions of tonnes of rock literally to fall into the sea and slide several to tens of kilometres along the sea-bed. Ancient (and not so ancient) sedimentary layers in various parts of the world have been attributed to huge tsunamis caused by the 'splash' of such giant collapses. Could there also have been at least some local de-gassing of the deep ocean?

Such ideas migh give brief pause to proponents of the techno-fix solution

*OTEC = Ocean Thermal Energy Conversion.

to greenhouse warming, that involves pumping fossil-fuel CO_2 into the deep ocean. If oceanic degassing by meteorite impact or giant slumps is a possibility, then do we want to risk adding to all that CO_2 already in solution in the ocean depths? On the other hand, those humans who survived the impact and the fires, the tsunamis, and the nuclear winter, might be quite glad of the additional warmth!

Is a Younger Dryas scenario nearer than we think? (An essay in science and politics)

Would you suppose intuitively that global warming is more of a night-time than a daytime phenomenon? No, nor would most people (including me), but climate scientists have evidently been familiar with this for years.

The average daily *maximum* surface temperature has increased by about 0.3 °C in the last 40 years or so, while the average daily *minimum* temperature has increased by much more in the same period: by about 0.8 °C. In other words, the Diurnal Temperature Range (DTR) has actually decreased with the progress of global warming. The explanation is really quite simple – here's how it goes:

Sulphate aerosols increase the Earth's daytime albedo, so warming is less intense than it would otherwise be. Those same aerosols provide cloud condensation nuclei, and the resulting clouds not only help to increase the daytime albedo but also provide a blanket to trap outgoing radiation at night. (An alternative view discounts the 'aerosol effect', suggesting instead that increased cloud cover and precipitation are simply consequences of increased greenhouse gas concentrations.)

If you think that isn't counterintuitive enough, here is more. You might expect evaporation from water surfaces to increase with global warming. It may be true at sea, but measurements using pan evaporimeters on land suggest that in most continental regions evaporation rates have actually been *decreasing* over the past 50 years or so, whereas run-off in streams and rivers has been increasing (how do they know that?). Statistical analysis of huge quantities of data suggest that there are reasonable correlations between decreasing DTR, decreasing evaporation rates, *and* increased cloud cover, over the last half century at least. Increased cloud cover seems to be the common factor in both these phenomena, and it turns out also that decreasing DTR and increased cloud cover are correlated with increasing precipitation.

Most of these changes are recorded in land areas, because although satellite observations are a great help, global synoptic coverage has become available only fairly recently. However, increased cloudiness and precipitation, hand-in-hand with global warming, does suggest that the atmosphere should contain more water vapour. So reduced evaporation on land implies greater evaporation from the sea-surface.

These intriguing relationships came to mind when I saw a short article in a recent issue of *Science* (31 October), concerning the transition from the 'cold, dry, windy Younger Dryas' to the 'warmer, wetter, calmer Holocene', about 11.5 thousand years ago. The authors consider 'significantly increased atmospheric water vapor' to have been a major factor in the change, because it would have 'increased retention of long-wave solar radiation and created a feedback that stabilised the new climate state'. And it all happened on a time-scale of decades.

Has this feedback now reached a limit? Is it now acting to destabilise our 'new climate state', the relatively stable conditions that have characterised the Holocene? Or is it merely a statistical quirk that storms and El Niño events are (according to many climate scientists) both more frequent and more intense now than they once were? How reliable are such conclusions? And how reliable are the allegations that human activities in the twentieth century are in large measure responsible? For instance, there appears to be good archaeological evidence from South America that the El Niños of a millenium or two ago were just as strong as, perhaps stronger than, the 1982–83 event.

These are the kinds of questions that might be raised by persons wishing to delay the implementation of cuts in fossil fuel consumption and hence reduction of carbon dioxide emissions. Among other things, doubts have been expressed about the forecast ferocity of the 1997–98 El Niño by some of the Asian and South American nations likely to be most affected by it. Advocates of 'business as usual' scenarios (i.e. delay any cuts as long as possible) would be heartened by other recent work (coincidentally also appearing in the 31 October issue of *Science*). This suggests that climatic warming can increase microbial activity and nutrient regeneration in soils, encouraging plant growth and drawing down more CO_2 into terrestrial vegetation.

Those seeking cuts in fossil-fuel use already face what has been described as a situation of growing disarray, demonstrated most recently by reports of the outcome of the 'Climate Summit' held at Kyoto in December. Some reductions in CO_2 emissions were agreed, but they were pretty meagre by all accounts. Even so, will they be honoured any more conscientiously than those made at Rio five years ago?

So what has all this to do with 'Return of the Dryas'? At first sight, perhaps, not a lot. After all, the *Science* article is about the transition to our present relatively benign climatic regime. Public, political and commercial concerns are presently focussed on the effects of *continued* warming and wettening, not with reversal to colder and drier conditions.

The point is this, however: the *Science* article is but one among many reminders that global climate can 'flip' from one state to another on a time-scale of decades, i.e. in the span of a human lifetime. Even if those who attended the Kyoto summit knew that, would it have affected their deliberations? I doubt it. If a week is a long time in politics, a decade is an eternity, and the longer the adverse economic effects of curtailing fossil-fuel use can be delayed, the more our comfortable but environmentally unsustainable life-styles can be prolonged.

Anyway, even if the climate did 'flip' from hot to cold in the past, who can guarantee that it will do so in the foreseeable future? Not even the 'forecasting guru' Piers Corbyn (see p.21) can do that (actually, he's gone on record as saying that the idea of anthropogenically assisted global warming is a media scare story).

It looks as though the answer to my question at the top of this essay must be 'No' – but it was fun to write all the same!

John Wright

Challenger Society for Marine Science

UK OCEANOGRAPHY '98

Southampton, 7 - 11 September 1998

Oceanographers throughout the UK and Europe are invited to offer contributions to this, the 8th biennial conference in the UK Oceanography series. Participants from other parts of the world are also warmly welcomed. It is our aim to produce a balanced programme of presentations from established scientists and young researchers. Papers on all aspects of Oceanography including Applied Oceanography and related topics are welcomed and papers emphasising the interdisciplinary nature of the subject are particularly encouraged.

KEYNOTE SPEAKERS

Tony Rice	**Abysmal Biology**
Nick Owens	**Nitrogen Cycling**
Peter Killworth	**Ocean Modelling**
Keith Hiscock	**Sea bed Habitats**
Colin Grant	**Operational Oceanography**
Gwyn Griffiths	**New Technologies**
John Gould	**Acoustic Oceanography**
Julian Priddle	**Polar Oceanography**
Jean-François Minster	**Ocean Forecasting**
Patricia Birnie	**The Law of the Sea**

The Annual Buckland Lecture will take place during the meeting:

Martin Angel "The Deep Ocean - a sustainable option for waste disposal"

All correspondence should be addressed to:

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FURTHER INFORMATION AVAILABLE ON THE WORLD WIDE WEB:
http://www.soc.soton.ac.uk/OTHERS/CSMS/oceans98.html

Southampton Oceanography Centre

The plight of contract researchers

Alison Weeks' report entitled 'Contract research in oceanography' in the last issue of *Ocean Challenge* (Vol.7, No.2) stimulated some heartfelt responses, mostly by Email directly to Alison. The topic is clearly a painful one. A common experience was of tension between doing work one enjoys, is good at, and feels passionately about, and a feeling of great insecurity, often while trying to establish one's reputation. Almost everyone expressed gratitude that the topic was at last being aired and that someone had taken the trouble to put the article together.

Reactions from NERC units were not especially encouraging. Efforts are being made to produce fellowships, but funds are being squeezed; in other words, the will is there, but it is difficult to achieve much in the current financial situation. Moreover, for some time to come, conversion of posts from fixed-term contracts to open-ended appointments will absorb funds that might have been available for new posts.

Readers might be interested to see the letter headed 'NERC maligned' in the 12 June 1997 issue of *Nature*[1]. Here, in reponse to an item in a previous issue of *Nature*[2], Brian Bayne, Director of the NERC Centre for Coastal and Marine Sciences (CCMS), defends his Centre's record in offering open-ended appointments and states that 'young research staff employed on contract have never been viewed by CCMS laboratories as some sort of flexibility buffer'.

Below we reproduce a letter that shows that the current gloomy situation is not confined to the UK.

I read Alison Weeks's article 'Contract Research in Oceanography' with a mixture of delight and despair. Delight, because the problem of fixed-term contracts is apparently now widely recognized. Despair, because it is so widely spread.

Naturally, the situation in Germany differs somewhat from that in the UK: in the 1970s, when contract research came into fashion on a large scale, so did lawsuits by those employed on fixed-term. They argued that they had been given 'Kettenverträge' (i.e. 'chain contracts' – many short-term contracts between the same two parties), which under German law at the time were illegal and were thus automatically extended to open-ended appointments.

However, much to the distress of the universities, more often than not the funds for the new employees' wages had to be taken from the general budget, and many positions originally intended for the support of Ph.D students were henceforth permanently occupied.

From the government's point of view, the solution came in the 1980s when a new law permitted universities to employ scientists on as many fixed-term contracts as they liked, but not for longer than five years altogether – otherwise the employment would again automatically be extended to an open-ended appointment. Thus a principle emerged that has ruled German contract research ever since. Interpretations of the practicalities have varied over time as well as from institute to institute (e.g. Do the five years count afresh after a break? Do Ph.D times count towards the total or not?), but it is generally not possible to stay with one institution for longer than that magic five-year period.

It is easy to imagine what such a regulation does to long-term scientific programmes (just think of WOCE), scientific independence of young researchers (and with it, innovation), and the continuity in an institution's know-how, let alone building up teams of researchers, career plans, or starting a family.

In these respects, the difference from the situation in the UK is marginal, and the basic development is sadly multicultural: as money becomes scarcer and scarcer, it becomes less and less possible for careers in oceanography to lead to a fruitful and interesting life of work.

It is probably mainly scientific reasons that induced the relatively few members of permanent staff (the only ones who, according to EU rules and university regulations, may formally apply for 'soft money') to try and circumvent the strict rules: in Germany these days, scientists very often work in one institution while they are formally employed by another. This is a short-sighted solution, however. One day, the employer who has set up such contracts at various external institutions will retire. His or her successor is very unlikely to take care of these external contract staff (or even accept their existence), and the scientists – now not so young – face the end of an arrangement that was at least semi-secure.

When the contract of one of our colleagues was unexpectedly threatened with termination, rather than extended to an open-ended contract as originally promised (and the news came through while he was on a cruise!), a group of scientists on fixed-term appointments at the Institut für Meereskunde in Hamburg founded the 'Drittmittler-Initiative' (which roughly translates as 'fixed-term employees' initiative') to work on solutions and to convince those in a more secure position, and those in power – professors, but also politicians – that there is indeed a problem, socially as well as scientifically.

The solution is, however, not so easy. As long as increasing amounts of oceanographic research on fixed-term appointments go hand-in-hand with dwindling budgets for permanent staff, efforts like fellowship schemes will at best postpone the problem for the individual. In the long run, I do not see any way out but to try and go back to more open-ended appointments in relation to those on fixed-term, so that after a phase of looking around and seeing the world there is a chance to settle down to more continuity – in work as well as in the private sphere.

Heike Langenberg
GKSS Research Centre, Geesthacht
(and Drittmittler Initiative)
Institut für Meereskunde, Hamburg

A number of articles on this topic have appeared in the *DGM Mitteilungen* and might be interesting for those who can read German (see Nos. 1/1994, 4/1994, 2/1996).

[1] *Nature*, **387**, p.647; [2] *Nature*, **386**, p.754.

Project Darwin 2000

Ray Staines and Jo Hall

The Project

Project Darwin 2000 aims to build the only sailing research vessel in Western Europe. This vessel, the *Darwin 2000*, will provide a readily affordable facility for universities and colleges to conduct hands-on sea-going courses in oceanography and other marine-related sciences, in conjunction with specific marine research activity. The project is intended to meet the increasing need for a practical element within vocational courses in the marine sciences, as well as to provide a viable alternative to conventional expensive, fuel-dependent research vessels.

The *Darwin 2000*, a 24-metre gaff schooner of 65 tonnes displacement, will have the high integrity and stability required to work in adverse sea conditions, enabling her to make ocean voyages in safety, yet be small enough to work inshore and rest at anchorages unsuitable for large motor research vessels. Her crew will thus have access to isolated shores as well as to the open ocean. Two onboard laboratories will be available: one in the deck house for 'wet' work and another in the main accommodation for analytical chemical and biological work. Diving may take place from the stern platform or from the ship's rigid inflatable boat. The *Darwin 2000* will accommodate up to 14 persons, including a crew of three, in cabins fitted with desks and terminals linked to the ship's networked computer. The accommodation plan (*see opposite*) follows a modular approach so that the workspaces are easily modified according to the work in hand, allowing great flexibility of use.

Opportunities offered by Darwin 2000

Students of oceanography undertaking fieldwork on board the *Darwin 2000* will be able to use a range of oceanographic equipment: plankton nets, sediment grabs, conductivity–temperature–depth probes, etc. Courses will be of various lengths, from short coastal cruises of a few days' duration to full-scale open-ocean voyages. For example, a basic four- or five-day cruise might be across the shallow coastal waters, over the continental shelf to the continental slope and back. These shorter cruises will be scheduled to take place at times of year suitable for the attendance of students, and tailored to their needs of low cost, short duration and accommodation all found. Such courses will bring oceanography to life for those with little or no ocean-going experience. They will have the opportunity to examine samples from plankton nets, sediment grabs and so on, and be able to gain first-hand experience in the use of equipment in a ship's laboratories whilst on station, as well as having the chance to observe and learn about basic navigation and the management of a sea-going research vessel.

The work of the *Darwin 2000* will not be limited to higher education. At one end of the scale she will play an important role in helping to raise awareness of the marine environment in youngsters of school age during open days and inshore field trips. One of the many possible spin-offs from this will be to encourage an interest in the marine sciences at secondary and F.E. levels, through the recently developed Marine and Environmental Science GNVQ Unit.

At the other end of the scale she will be available to marine scientists as a well-equipped open-ocean research vessel. As the northern winter advances she will roam further afield, providing opportunities for research and training of a greater depth and scope. During these voyages she will be able to remain on station in remote locations for considerable periods, carrying out continuous real-time studies in areas which may otherwise receive only sporadic visits by research vessels.

Students aren't the only ones who might find a little sea-going experience useful – teachers too could benefit! This was highlighted by Sue Greig in her *Ocean Challenge* article on the USA's Maury Project (Vol. 6, No. 3). Project Darwin 2000 may well be able to provide the practical element for a similar project in this country.

For those scientists and students unable to get to sea, for whatever reason, the creative use of the Internet and global satellite communications technology will enable them to be 'virtually onboard'. The new media will also allow the dissemination of data from the vessel and create collaborative links between disciplines and institutions. This will be especially useful on longer trips and will be a major feature throughout the maiden voyage.

The advantages of sail

As Professor Tim Francis pointed out in *Eos** ten years ago, there are many advantages of sail over engine power. Not the least of these is the fact that there are substantial areas of the oceans which, due to limits on range and endurance, are inaccessible to all but the largest motor research vessels. It is perhaps surprising, therefore, that the small sailing research vessel, along with appropriate techniques and equipment, has not been developed sooner, given the increasing need for cost-effective science in recent years. The endurance advantage of sail over power is unquestionable and the 'pelagic' ability of the *Darwin 2000* will be one of her greatest assets. Indeed, her range will be unlimited, and the length of time she can spend at sea will be largely dictated by the ability of those on board to get on with each other!

Another significant attribute of sail propulsion is its silence. This is an advantage when the vessel is using acoustic devices, and in the study of marine animals. As a working platform, the sailing vessel will be more stable than a motor vessel of similar size, because of the steadying effect of the wind in her sails. This is especially so when the vessel is hove-to in a seaway.

On the horizon

Beginning in the year 2000, the maiden voyage will be a circumnavigation of the world in the wake of Darwin's 'Voyage of the *Beagle*'. The primary purpose of this voyage will be to carry out a study of oceanic and coastal biodiversity and natural history to see how they have changed since Darwin's time,

*Francis, T.J.G. (1988) The use of wingsails on oceanographic ships, *Eos*, **69**, No.31, 2 August, 758–760.

and to inaugurate the vessel in her role in oceanographic and environmental research. With an anticipated 280 days at sea and over 20 destinations worldwide there should be plenty of scope for interesting fieldwork both ashore and afloat. There will be a number of places available on board the vessel during the voyage so that as broad a section of the community as possible may take part in the venture.

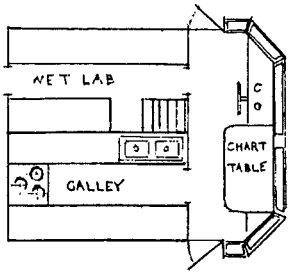
The *Darwin 2000* is not intended to compete with established motor research vessel programmes, rather to fill a niche which they cannot: that is, getting students to sea in reasonable numbers and broadening the range of opportunities for institutions or individuals to undertake projects which would otherwise be impracticable or prohibitively expensive.

We have, as yet, been unable to raise funds for Project Darwin 2000 from the public sector, but once the vessel is in commission it is likely that finance for research projects will be forthcoming from funds such as the Darwin Initiative. We are therefore seeking private sector sponsorship. We intend to generate considerable interest in the project – and publicity for the sponsors – through the maiden voyage. This is by no means inconsistent with our aim of raising the level of awareness of the marine environment amongst the public in general and the young in particular.

We would be glad to hear from those with relevant ideas and those who might like to participate in the project. Indeed, we would welcome questions, ideas, and suggestions in general, from those whom the project is intended to benefit.
Our address is:

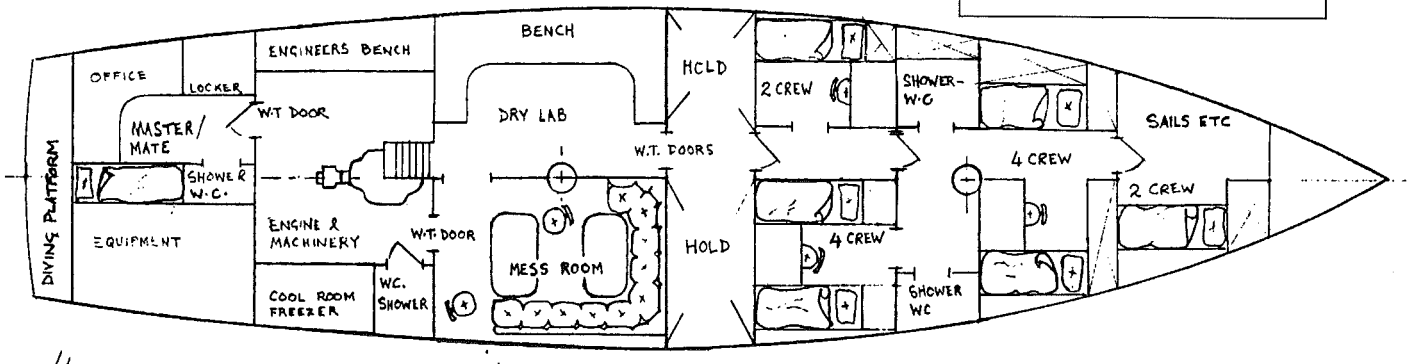
Project Darwin 2000
Carrick Business Centre
Beacon House
Commercial Road
Penryn
Cornwall TR10 8AR
Tel./Fax: +44-(0)1326-313377/-378643
Email:
DARWIN2000@falolccc.demon.co.uk
Web site:
http://www.demon.co.uk/fcms/Darwin2000

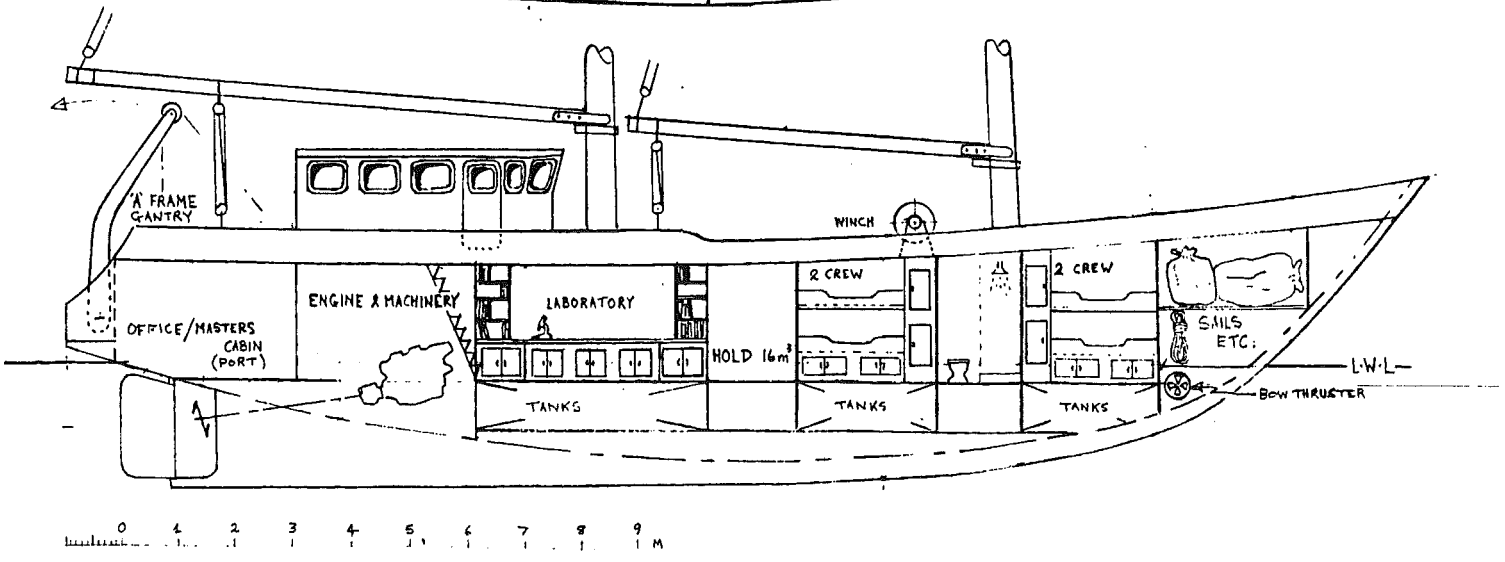
***Layout of accommodation on SRV* Darwin 2000**



Main particulars

LOA	24 m
LWL	20 m
Displacement	65 tonnes
Sail area	255 m²
Draft	2.1 m
Beam	6 m
Construction	steel–chine
Ballast	19.7 tonnes
Auxiliary	175 HP





Education afloat: Exploring the Atlantic Frontier

Patrick Friend

I first became aware of UNESCO's 'Floating University' programme this summer, when I was invited to participate in the seventh annual Training Through Research (TTR) cruise to the north-east Atlantic margin on board the Russian ship, RV *Professor Logachev*. The TTR programme aims to give students and young scientists the opportunity to enhance their education and training by participating in advanced multidisciplinary research projects. Funding is provided by groups with research interests in the area of investigation (this year, the CORSAIRES and European North Atlantic Margins (ENAM) projects of the EC's MAST-III programme) and from Russian, Irish, British and Danish universities, and government organizations. Longer term funding is via UNESCO's Intergovernmental Oceanographic Commission (IOC). Ship hire for this year's cruise was about $10K per day – extremely good value for money, I am told, when compared with the cost of other research platforms.

The success of the TTR programme is due to the spacious accommodation provided by the large Russian research ships (this year there were some 50 scientists and technicians, and 40 crew members), and the wide range of advanced equipment backed up by a high standard of technical support. Site surveys involve underway geophysics, using long-range OKEAN side-scan sonar, short-range, high resolution OREtech side-scan sonar, 6 kHz sub-bottom profiling, and air-gun seismics. Other studies (on themes pursued during previous TTR programmes) use gravity, box and kasten corers, a Preussag TV grab and a bottom TV system (with additional discrete photography) to look at stability and fluid flows at the continental margin, and modern analogues of hydrocarbon reservoirs.

The Floating University programme was launched by an international group of scientists under the auspices of UNESCO in 1990, following an initiative by several universities from Eastern and Western Europe. The main Training Through Research objective is the generation and sharing of advanced knowledge, achieved through the provision of up-to-date education and training in specific geomarine fields, as well as the acquisition of high-quality data during cruises. Where possible, mid-cruise field workshops are held. I joined the *Professor Logachev* in Brest, France, where a mid-cruise workshop on core-processing (incorporated into the CORSAIRES meeting on core-logging techniques) was held at IFREMER, Plouzané. There are post-cruise scientific and training seminars, and fellowships and study grants to process cruise data in leading laboratories. Specialized courses are held at the UNESCO Centre in Moscow State University. Cruise results are published in the UNESCO *Reports in Marine Science* series.

Until 1997, there were annual cruises to the Mediterranean and Black Seas, where significant advances have been made in understanding the structural geology and history of these basins. Of special interest was the discovery, between 1991 and 1993, of approximately twenty mud volcanoes and diapirs at the boundary between the African and Eurasian tectonic plates (i.e. the Mediterranean Ridge). Several young and ancient mud volcanoes, some with a diameter of about 1 km, were identified in the central Black Sea, and sampled for gases and gas hydrates. Mud volcanoes display a variety of different sizes and morphologies; some have well-shaped symmetrical cones with feeder channels and peripheral moats; others, obscured by folded and faulted pelagic sediments, are only discernible after careful analysis of seismic profiles. Detailed studies of the geology and evolution of deep-sea submarine fans associated with major western Mediterranean rivers have been made, and comparisons drawn with analogues on land. The Floating University cruises have contributed to the Ocean Drilling Project by conducting surveys of proposed drilling sites.

This year, the aim of the TTR7 programme was to undertake a comprehensive geological–geophysical investigation of some significant processes occurring at the north-east Atlantic margin, and to investigate some of the potential CORSAIRES drill sites. There has been a recent increase in research activity in this part of the deep sea, led by the hydrocarbon industry's wish to explore the 'Atlantic Frontier' (the name was originally used to describe the deep-water exploration area some 200 km west of Shetland,

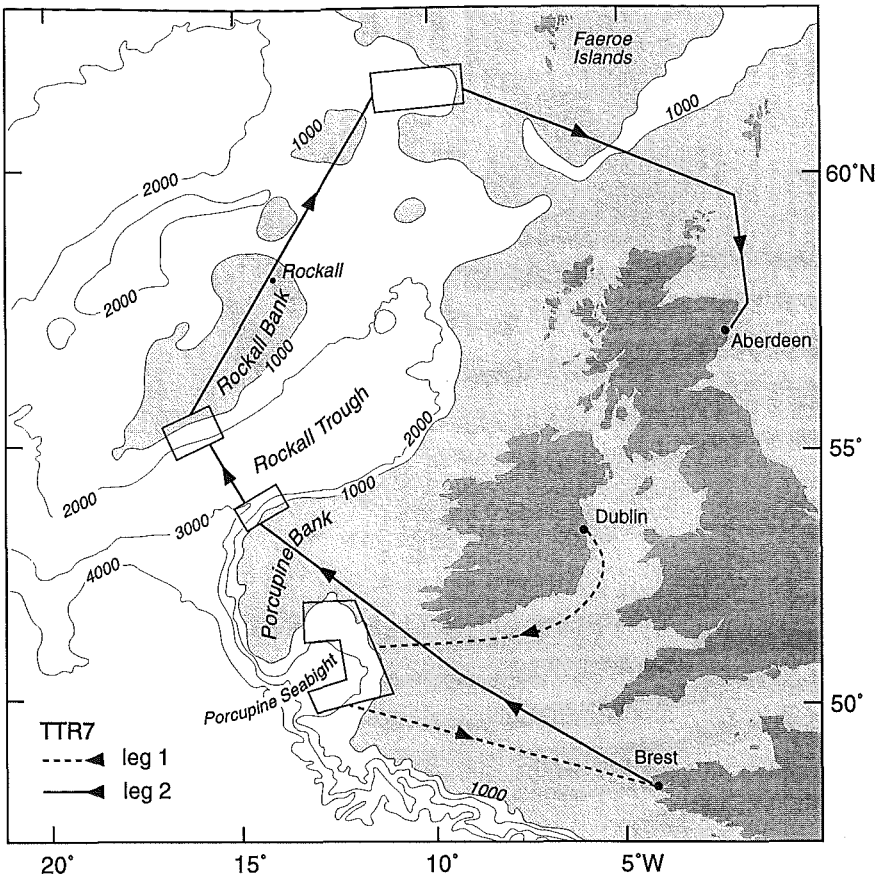
The research vessel Professor Logachev *moored alongside in Brest*

but is now applied to all potential deep-water hydrocarbon exploration areas to the west of Scotland and Ireland; cf. pp.31–33).

Recently, concern has been expressed by environmental groups about the effects of trawling and hydrocarbon exploration on deep-water coral species (especially *Lophelia pertusa*) known to exist on the outer slope and shelf areas of the north-east Atlantic. The potential existed for the TTR7 cruise to use its suite of sophisticated and traditional geological exploration equipment to solve some of the outstanding geological problems associated with processes occurring on a passive continental margin, and to investigate the deep-water coral ecosystems.

In keeping with University practice, daily routine normally began with a morning seminar, well-attended by sleepy students bearing steaming mugs of black coffee! Coring, dredging and sample description followed throughout the day and into the evening, with seismic and side-scan lines generally run at night. The shipboard scientific crew was divided into teams and, although assigned to the sedimentologists, I was able to migrate to other groups if I so wished. The technicians and crew were keen to practise their English. Through them I was able to catch a glimpse of post-communist Russia, and to learn some of their hopes and fears for the future. It struck me that life on this Russian ship was a microcosm of life in mainland Russia: money was tight, and everyone – scientists and crew alike – was in the same boat.

When we joined the ship at Brest, some of the first-leg cruise participants had been somewhat dismissive about the standard of food on board, but I have to say that while the cuisine was somewhat monotonous, I thought it adequate for a working research vessel. The two saunas and swimming pool seemed to make up for the luxuries afforded by ships with a larger budget. I didn't mind too much either, when the hot water system was shut down a couple of days before port to 'save fuel'. After all, if it was not for TTR7's use of the ship, two of the five months' salary owed to the crew would not have been paid.



Cruise tracks for TTR legs 1 and 2 *(Graphics: Kate Davis / John Taylor)*

Publication of the TTR7 cruise report is imminent, but here is a foretaste of some of the exciting results. A previously unknown, northward-flowing current was discovered in the Porcupine Seabight, and other strong currents causing significant sand movement were mapped along the upper slope south-east of Rockall Bank and along the slope west of Porcupine Bank. In the Iceland Basin, channels shaped by the Norwegian Sea Overflow Water (NSOW) were mapped.

In one small area of the Rockall Trough and Porcupine Bank slopes, over 150 carbonate 'mounds' were mapped. Some were very large – up to 400 m high and 5 km in length. Significant advances were made in understanding the origins of these structures through geophysical, biological, geochemical and sedimentological studies. No direct evidence for methane seepage was observed in the vicinity of the mounds, although there appeared to be links between fast-flowing thermohaline currents, deep-water coral growth and mound morphology. Some trawling damage to corals on the upper slope was seen, but coral regeneration appeared to be fairly rapid.

My experience with the Floating University continues to be very rewarding. I have learnt new scientific techniques, and made many new friends and contacts in Eastern and Western Europe. I have to say that Russian hospitality takes an awful lot of beating. To those individuals interested in developing new skills and to those institutions wishing to pursue a very cost-effective method of research, I can thoroughly recommend the Floating University.

For more information about Training Through Research, please contact:

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Ireland takes delivery of *Celtic Voyager*

Michael Orren

***Ireland's brand-new research vessel,* Celtic Voyager** (Photo: Oliver Kazmierczak)

From 1978 to mid-1997, Irish marine research was well served by the 21 m RV *Lough Beltra*, a converted trawler which did sterling work but was too small to operate far offshore in the turbulent waters surrounding Ireland. Acting on technical and financial advice, the Irish National Marine Institute, the national agency set up to promote and co-ordinate marine R&D in Ireland, decided to replace *Lough Beltra* with a custom-built vessel capable of carrying more scientists, with a much wider operational range and greater endurance at sea. Built in the Scheepswerf Visser yards in the Netherlands, the IR£1.75 million vessel was 75% funded by a grant from the EU European Regional Development Fund.

Delivered in July 1997, the 31.4 m long *Celtic Voyager* set out almost immediately on a research cruise carrying scientists from the Martin Ryan Institute at the National University of Ireland, Galway (formerly the University College Galway), home to our Oceanography Department. During July, the Marine Institute Board gathered for their historic 50th meeting aboard *Celtic Voyager* with both pride and delight at the tangible success of their efforts and that of the Executive in acquiring such a modern state-of-the-art vessel for Irish marine research.

The 340 tonne *Celtic Voyager* was officially 'launched' at a ceremony in Dublin on 15 September, 1997 by the wife of the Minister for the Marine and Natural Resources, Dr Michael Woods. This was a great day for Irish oceanography. Capable of carrying eight scientists and with a crew of six skilled in working an oceanographic vessel at sea, the ship has a nominal range of 17 days. Electronics, 'wet' and 'dry' laboratories are available, and there is a clear 25 m^2 deck area aft for handling bulky moorings, nets etc., with a 10-tonne crane to handle gear. She has two 10-tonne pull winches aft, which can spool wire of 8–24 mm diameter and can be coupled together to give an increased pull on a single drum for coring, and an oceanographic winch with 1 000 m of 4 mm wire (1 000 kg pull). She also has space aft for a 10-tonne container laboratory.

Underway acquisition of data is essentially continuous, employing GPS positioning, CCTV for deck surveillance, thermosalinograph, turbidity meter, fluorometer, ADCP, dual-frequency depth sounder and a RoxAnn™ sea-bed classification system with all logged data stored in the National Marine Institute Marine Data Centre.

My scientists report that, with her stabilisation tank and bow thruster, *Celtic Voyager* handles well both on station and at sea, and coped easily with a Force 9 storm off the west coast. The territory of Ireland has been described by our Marine Institute as ' ... 90% undeveloped, undiscovered and underwater', emphasizing Ireland's large area of undersea resources. Indeed, interest in these waters is sufficient to attract the 60–70 surveys carried out by international research vessels annually.

Currently, *Celtic Voyager* operates out of Dublin, but it is possible that in future she may be based at Galway on the westernmost coast of Ireland, adjacent to the active and vigorous north-east Atlantic. The necessary shore support facilities needed for the vessel will then be available for scientific and commercial use by any other specialist research ship operating in the nearby Atlantic Ocean.

The *Celtic Voyager* is open for charter and information regarding availability, detailed technical capabilities, charter rates etc., may be obtained from the vessel manager:

Michael Gillooly
Research Vessel Operations Manager,
Marine Institute, 80 Harcourt Street,
Dublin 2, Ireland
Tel. +353-1-821-01-11; Fax: +353-1-820-50-78; Email: rv@marine.ie

Michael Orren is Head of the Oceanography Department, The National University of Ireland, Galway, Ireland.

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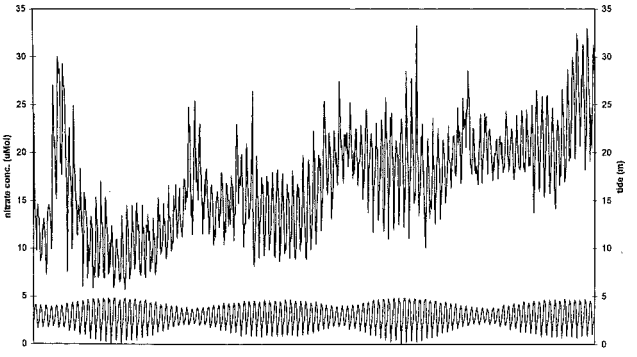
Data courtesy of Southampton Oceanography Centre



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Oceanography in Mainland China

Shu Gao and Neil Wells

Mainland China, with a population of more than 1.2 billion, has around 10 000 people working in ocean science and technology, and there are also approximately 2 500 such people in Taiwan and Hong Kong. Although the percentage of marine scientists and technologists is much smaller than in most western countries, a community of such a size can make an important contribution to international oceanographic research. Here we provide a brief overview of Chinese oceanography, in terms of its history, organization, educational system and research.

History

Before 1950, oceanographic research in China was undertaken on a small scale in some university laboratories, and was concentrated mainly in the area of marine biology: an example is the Laboratory of Oceanography of Shandong University in Qingdao, set up in the 1940s. In 1950, the Laboratory of Marine Biology was established in Qingdao as part of the Chinese Academy of Sciences (CAS); in the same year, the Chinese Society of Oceanology and Limnology was founded. Nine years later, the Qingdao Laboratory was expanded into the Institute of Oceanology. The Institute of Oceanography of the South China Sea (also belonging to the CAS) was established in Guangzhou in 1959.

During the 1950s, oceanographic research was organized mainly by the CAS, through the oceanographic institutes at Qingdao and Guangzhou. A major event of this period was the programme of multidisciplinary investigations into Chinese seas undertaken between 1958 and 1960. More than 600 scientists and 50 vessels were involved in this study, the largest marine project ever seen in China. A number of scientists who played a crucial role in these research activities had been educated in the west. For example, Professor Xi Zhang (cited in western journals as 'Hsi Chang'), a pioneer in research on marine molluscs, obtained his Ph.D in 1931 at the University of Lyon in France. His work is well known to Chinese workers, as is that on marine algae by Professor Chengkui Zeng (C. K. Tseng), who obtained his DSc. at the University of Michigan in 1942. In the area of physical oceanography, Professor Chongben He (C. P. He), who obtained his Ph.D at the California College of Science and Technology in 1948, led the investigations into the origin of bottom water in the South China Sea and the circulation of the Yellow Sea and adjacent seas. Professor Hanli Mao (Han-Lee Mao), who obtained his Ph.D at the Scripps Institution of Oceanography in the USA in 1951, translated many classic oceanographic works into Chinese, including *The Oceans* (by H. U. Sverdrup *et al.*) and *The Gulf Stream* (by H. M. Stommel). He also organized a number of cruises in Chinese seas for systematic study of regional patterns of ocean currents and upwelling.

In July 1964, the National Bureau of Oceanography (NBO, now the State Oceanic Administration, SOA) was formed. Although the purpose of the NBO was initially to organize oceanographic measurements and observations along Chinese coastlines, it rapidly expanded to become a strong research force, parallel with the CAS. The SOA is now responsible for marine management and is a part of the scientific research effort of the country. The Society of Oceanography, which was founded in 1979, is associated mainly with the SOA.

The general trend of oceanographic growth was interrupted by the Cultural Revolution (1966–1976), when research activities ceased almost completely. For example, the journal of the Society of Oceanology and Limnology, *Oceanologia et Limnologia Sinica*, founded in 1957, was not published for 12 years between July 1966 and June 1978. However, oceanographic research resumed in 1978, and in 1980–1983 a large-scale investigation into marine resources, in which 6 000 scientists and technicians were involved, was organized by the Government. Since then, Chinese oceanographers have become increasingly active in both domestic studies and international collaborations.

Organization and education

Today there are around a hundred organizations associated with oceanography in mainland China. Some belong to the Chinese Academy of Sciences (e.g. the Institute of Oceanography of the South China Sea and the Institute of Oceanology), some to the State Oceanic Administration (e.g. the First, Second and Third Institutes of Oceanography), and others to the Universities (e.g. the Department of Oceanography of Amoy University, the Department of Marine Geology of Tongji University (in Shanghai), the Marine Research Centre in Nanjing University, and the Institute of Estuarine and Coastal Research of East China Normal University (in Shanghai)).

Yet others belong to government ministries (e.g. the Institute of Marine Geology in Qingdao, and the Ministry of Geology and Mineral Resources, MGMR). In terms of the size of grants and the personnel involved in research, the coastal city of Qingdao in eastern China is a major oceanographic centre, and is home for more than 60% of China's oceanographers. It is likely that in the near future a National Centre for Oceanographic Research will be established here.

On the basis of the amount of grant awarded during the last decade, the top oceanographic institutions are the Institute of Oceanology (CAS), Qingdao Ocean University, the Institute of South China Sea Oceanography, and the University of Amoy.

In China, there is an education system involving professional schools (i.e. technical colleges), universities and research institutions. The Ningbo Oceanography School (run by the SOA and opened in 1980) is responsible for the training of young students who after graduation will work at the various SOA oceanographic stations, where winds, sea-level, waves, air and seawater temperature, salinity, etc. are measured and recorded. At the higher education level, BSc. courses (which take four years) are taught in universities such as Qingdao Ocean University, the University of Amoy, Tongji University (Shanghai), Nanjing University and the Sun Yat-san University (Guangzhou). Every year, hundreds of students obtain their BSc. degree in oceanography or a related subject.

MSc. and Ph.D studies take place in both universities and research institutes, and MSc. and Ph.D qualifications must be evaluated and approved by the government. Most universities and institutes are given the right to take MSc. students. It normally takes three years for students to obtain the MSc. degree:

they normally do course work for two years and write the thesis in the third year. The viva is usually held in the summer, in the presence of five internal and external examiners.

After the MSc., students can take an entrance examination for admission to a Ph.D programme. Only a limited number of institutions and professors are allowed to supervise Ph.D students, and the institution and professors are reviewed by a central committee in Beijing evey few years for their right to undertake Ph.D supervision. A Ph.D takes three years to complete. The student is required to complete a piece of research independently, but the measurements/observations at sea can be attached to a specific project in which the supervisor is participating. The Ph.D viva is usually organized by ten internal and external examiners, and is open to other staff and students. It is estimated that every year around eighty candidates are awarded a Ph.D degree.

Over the past 15 years, the government has sent many students to study abroad, and others have obtained independent financial support to go abroad. Thus, by 1995 the total number of students who had studied abroad reached 220 000, and of these, hundreds were probably more or less involved in the marine sciences. Some have now returned to China and have started to play an important role in oceanographic research, particularly in the areas of marine environmental studies, marine ecology, biology and biological techniques, marine chemistry, sediment dynamics, estuarine and coastal sedimentology, and geomorphology.

Scientific research

Chinese scientists work in most areas of oceanography, ranging from coastal studies to deep ocean processes, and on subjects ranging from algae to remote sensing. Since the late 1970s, they have undertaken a number of large-scale research projects. Many of these projects are in collaboration with other countries, for example: the investigations into the geology of the Yellow/Bohai Seas (with the USA); sedimentation of the East China Sea continental shelf (with Woods Hole Institution of Oceanography, USA); biogeochemical behaviour of pollutants and nutrients in the Changjiang estuary and its adjacent coastal waters of the East China Sea (with France); and a joint China–Japan research programme on the Kuroshio.

Chinese scientists are now participating in many international projects such as Land–Ocean Interaction in the Coastal Zone (LOICZ), the Joint Global Ocean Flux Study (JGOFS) and the Ocean Drilling Project (ODP). Chinese scientists have made significant contributions to the development of marine biological techniques, and to the understanding of currents and circulation systems in the seas around China, regional marine geology, and the influence of large rivers on continental shelf evolution.

Traditionally, the study on marine life has been the main focus of attention, probably because there are often food shortages in China, and Chinese people enjoy sea food such as edible kelp, prawns and scallops. Since the foundation of the Institute of Oceanology, there have been investigations (under the leadership of Professor C. K. Tseng) into the ecology of algae. The geographic distribution of many edible marine algae has been determined, and much learnt about their life cycles. On the basis of this research, algae farming began in the 1960s. Shortly afterwards, scientists in the Institute focussed upon biotechnology for prawn and scallop farming. Now prawn and scallop culture has become routine along Chinese coastlines. Not surprisingly, the Institute of Oceanology remains a biologically-dominated institution, where more than half of the scientists are either marine biologists or in associated disciplines.

For the past 45 years, Chinese physical oceanographers have been intensively studying the currents and circulation in the seas adjacent to mainland China. On the basis of data collected through numerous programmes and cruises, regional water-mass and circulation patterns have been determined. For the Yellow and East China Seas, for example, seasonal variations of the Yellow Sea Warm Current, the Taiwan Warm Current and the Cold Coastal Current have been described in detail. Numerical models have been constructed to simulate the formation of these current systems and to determine their relationship to the Kuroshio. Another fruitful research area is associated with the tidal currents, tidally-induced residual currents, and sea-level of the shelf seas. Many tide-gauge stations have been set up and the data obtained have aided the construction of numerical models for predicting tides and sea-level. Results of physical oceanographic research provide a solid basis for studies of material fluxes and of the ecological dynamics of the region, both being undertaken at present.

Since the 1960s, marine geologists in China have investigated the geology of the Bohai, Yellow, East China and South China Seas, and have undertaken several cruises to the Okinawa Trough (between Japan and Taiwan). Through the years, a large amount of data has been accumulated; on the basis of analyses of these datasets, sedimentation models for the shelf regions have been established, new processes of mineral formation have been discovered, sources of the sedimentary material have been identified, and the history of regional Quaternary sea-level change has been deduced.

Marine geological research has now begun to focus on sediment transport and deposition, and ongoing projects include the exchange between the Bohai and Yellow Seas, fluxes of material through the various marine boundaries, and the evolution of the Okinawa Trough and adjacent continental shelves.

The physical and ecological environment of the shelf seas to the east of China is deeply influenced by the input from large rivers like the Yangtze (Changjiang), Yellow (Huang-He) and Pearl (Zhujiang) Rivers. For example, at the Yellow River delta, shoreline advancement of up to 1 km yr^{-1} has been observed, and the deposition rate reaches more than 1 m yr^{-1}. Chinese scientists have studied sedimentary, chemical and biological inputs from these rivers to the continental shelf, together with processes associated with these inputs. Research studies now being undertaken in combination with the LOICZ and JGOFS projects include the role played by the Yangtze River in land–sea interaction, the ecological dynamics of Chinese estuaries, and the evolution of the Yellow River delta. This research will be very useful in the evaluation of sea-bed stability, the protection of fragile ecosystems, environmental impact assessment and management for sustainable coastal development.

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Science, superstition ... or just wishful thinking?

Most scientists would probably agree that variations in solar activity can affect the Earth's climate and weather systems, but they would probably also agree that the effects are more likely to be on decadal time-scales or longer than on a time-scale of less than a year. Yet, putting his money where his mouth is, last October one Piers Corbyn 'went public' with his weather-forecasting company, which makes both short- and long-range weather predictions (up to a year ahead) based on observations of sunspots and solar magnetism. The company numbers among its clients gas and electricity companies as well as fashion stores, and is now quoted on the stock market.

We all know that climate models can't give reliable forecasts more than about a week ahead at the outside, at least for the UK. So how does Corbyn do it? The Met Office people don't think he can. He is dismissed as a crank – yet another 'mad professor'. Is that because he claims to make reliable long-range forecasts, which they cannot do? Or simply because he won't publish his methods so that other people can test his method for themselves? But why should he publish? He's making money – if he publishes, he risks either lots of other people getting in on his act, or being exposed as a charlatan. Either way, his market is wrecked.

Further speculation is fruitless, but it is worth wondering whether the sunspots and magnetism story is just a red herring, and that the company is really using fir cones, seaweed and other 'traditional' arcana; or is it a truly sophisticated combination of theory and measurements in a new kind of predictive model that nobody else knows about? Given the vagaries of the British weather, perhaps just looking at the sky, sniffing the wind, glancing at the barometer, and knowing the time of year, you could 'predict' what the weather will be next week, and have a fair chance of getting it right! Apparently Corbyn's company plans to go into forecasting on a Europe-wide scale. The chance of success might be even better over there: weather conditions tend to be more stable in continental interiors than along the margins. *Ocean Challenge* wishes him luck.

On the other hand, our sympathies go out to poor Professor Ian Plimer, geologist of Melbourne University, who failed to win his legal case against the 'creation scientist' Alan Roberts, whom he was in essence accusing of something analogous to contravention of the Trade Description Act. In brief, Roberts claimed to have found Noah's Ark in the mountains of eastern Turkey. On the strength of the 'discovery', Roberts raised funds for further 'research', and to finance more creationist proselytising. Plimer's case was that Roberts was guilty of 'misleading or deceptive commercial conduct'. Plimer pointed out, as any geologist could have done, that the 'Ark' is merely a small doubly plunging synclinal fold in ophiolitic rocks (ancient oceanic crust). Such folds are often described in basic textbooks as being 'boat-shaped', and this one happens to have the appropriate dimensions to fit the biblical measurements (specifically, those in the *Book of Genesis*). The rocks are over 100 million years old, but creationists don't believe in geological time, so that wouldn't affect Roberts' claim.

In retrospect, it is not surprising that Plimer lost the case. After all, Roberts was – indeed is – peddling a belief system, rather than motor cars, second-hand furniture, or time-share villas. If people want to believe Roberts and back their credulity with hard cash, that's their problem and his profit.

It all looks rather like a re-run of the infamous 'Monkey Trial' that took place in the southern USA in the early 1920s, in which a young biology teacher was first sacked and then prosecuted and fined for teaching Darwinian evolution in school. Now here we are, three-quarters of a century on, and creationism can still triumph over science in a court of law.

Science education and the spread of scientific understanding still has a long way to go. Not least in my own case. I have become increasingly puzzled by the many words expended in the literature on the subject of whether or not the oceans are in overall metabolic balance, a topic also discussed by one of the contributors at the symposium held to honour Dennis Burton (pp.28–30). It is my understanding that almost anywhere in the oceans there is an excess of biological production over consumption. Almost any sample of sea-floor sediment contains some organic carbon of marine origin which has sunk to the bottom from the surface waters, where it was fixed by photosynthesising organisms, and remains unconsumed either by animals or bacteria.

Yet distinguished scientists are debating whether the oceans might in fact be a region of excess biological consumption over production. To be sure, even if – as claimed – the excess is but a fraction of one percent, it still represents a surreal scenario. We are taught that it has been the excess of biological production over consumption throughout geological time that has enabled Earth to acquire the atmospheric oxygen without which respiration (and hence most life) is impossible. More sinisterly, if consumption exceeds production in the oceans, how come there is any life left in them at all?

No doubt I have missed something in the small print here. The terrestrial dimension perhaps? If extra organic carbon, either particulate or dissolved, enters the oceans from land, it represents non-marine production and is available for consumption by marine organisms. Then indeed the oceans might be in metabolic deficit. But they cannot have been so until about 400 million years ago, i.e. for about 90 per cent of geological time – because only then did organisms properly start to colonise land areas – and by that time the atmosphere was already quite rich in oxygen.

Or does oceanic production exceed consumption only some of the time? Perhaps we are now in a period when consumption > production. Actually, given all the extra nutrients we dump in the sea, I shall continue to believe that Production Rules OK until persuaded otherwise.

John Wright

What makes a marine disaster?

Martin Angel

Dozing in front of the television, I was abruptly brought to my senses by outrage at a programme in which it was argued that the wreck of the *Sea Empress* was not a disaster. The implication was that the environmental agencies had over-reacted, and that large amounts of public and company money had been squandered as a result of public pressure to take remedial action which was later shown to be unnecessary. I was reminded of the incident in A.G. Macdonell's novel, *England their England,* when the hero, Donald Cameron, sees a hoarding proclaiming 'England overwhelmed with disaster' and another 'Is England doomed?'. Donald (who had just returned from the trenches of World War I), 'almost numb with the cold of sheer panic, took his place in the queue' – only to read that the subject of the headline was the loss of two cheap wickets in a test match against Australia, rather than another World War breaking out. So what *is* a disaster?

Like so many things in life, the definition of a 'disaster' involves a considerable element of subjectivity, and is a matter of scale. If I knock over a cup of coffee on my desk, I might cry out 'What a (expletive deleted) disaster!' But such a trivial event is unlikely to have any impact on anyone else. Moreover, its effects are ephemeral, a few minutes of mopping and tidying up, and most, if not all, traces of the event will be eliminated. If I crash my car into a tree and write it off, the event is a personal disaster for me and maybe the tree, but its impact is unlikely to ripple out beyond my immediate personal circle. In contrast, a major earthquake in Iran is not a disaster for me personally. However, I may consider it sufficiently serious in a global context to agree with the UK Government's decision to send aid (i.e. my taxes) to alleviate the victims' suffering. Similarly, the earthquake in Chiobe affected me personally not a jot, but its effects rippled out much further than might have been expected. The consequent depression of the Japanese economy led via Nick Leeson's activities (a non-linear response?) to the collapse of a bank, with the result that many shareholders, including UK pensioners, lost out very substantially. Remember that mythical butterfly that flapped its wings, and by a series of non-linear responses, triggered a hurricane on the other side of the world!

But are environmental disasters different in some way? Perhaps not. They range in scale from local disasters (all the fish in a stretch of river being killed as a result of illegal discharges of cyanide wastes), through national disasters (the great storm of 1987 and the floods of 1953), to global disasters (possible candidates being the biodiversity crisis, the growing ozone hole, and global climate change). These disasters are often triggered by natural events but are also exacerbated by the activities of humanity. The plummeting cod stocks in the north-west Atlantic may initially have been a result of climate change – perhaps one effect of the 70-year cycle in the North Atlantic Oscillation (see Further Reading), but the situation has been made worse by overfishing.

Similarly, weather conditions were the primary cause of the wreck of the *Braer,* but this 'disaster' could have been avoided if the vessel had taken another route and sensible safety precautions had been taken in the first place. By trying to minimise costs the company had cut corners and taken a (calculated?) gamble, putting the environment and other people's livelihoods and 'quality of life' at risk. Unfortunately, the odds did not work out, although the foul weather conditions that were the original cause of the accident then served to minimise the impacts by dispersing much of the oil that was spilt. Remedial action was taken, because public opinion demanded it, but much proved to be counter-productive.

As always, the costs were assessed in monetary rather than environmental terms. But should such assessments continue to be made almost exclusively on a financial basis, and how else can the impacts be quantified? As any experienced scientist will know, even if the right question is asked, if an inappropriate model or evaluation technique is used, the answer is likely to be gobbledegook. The use of 'environmental' economics to evaluate the seriousness of major oil spills biases the assessment. It comes down to the unanswerable question as to how much a species is worth. The question is only applicable to those few species which have a proven economic value, and even for those it ignores considerations of their ecological role and importance.

But our society is dogged by judgements and decisions based on the economic model. One recommendation of the Donaldson inquiry conducted after the *Braer* incident was that three powerful tugs should be placed permanently at the ready around the UK coastline to deal with such incidents. To save on 'unnecessary' expenditure, the UK Government gambled by financing only two tugs, to be stationed at the sites where the risk was considered to be greatest, one in the Channel, the other in the Shetlands. Were such odds acceptable or not? In the event, when the *Sea Empress* went aground at the entrance to Milford Haven (part of a black comedy of errors) the only tug in the vicinity was a Chinese vessel which did not have the capability to operate effectively in the prevailing conditions. The clean-up teams were reasonably effective in preventing impacts on the scale of the *Torrey Canyon,* and yes, they were successful in cleaning up the tourist beaches so that the economy of the region was not too seriously affected. However, as always in the absence of an adequate baseline survey and a subsequent comprehensive programme monitoring, the full scale and duration of the impacts on the local ecosystems will never be known.

So was the wreck of the *Sea Empress* a disaster? Or, as some commentators would now have us believe, something of a non-event? Should it affect our response to a 'disaster' if the environment is known to be sufficiently resilient for recovery to occur within, say, a year (as seems to be the case for some impacts)? Are we in a position to be able to judge with any degree of confidence whether there will be a recovery and if so, how long it will take? What degree of impact is to be tolerated? According to the television programme, recovery from the *Braer* spill has been rapid – but how do they know? According to some environmental groups there will be some permanent effects. But what constitutes a permanent effect?

Can we expect to have better baseline information in future? The answer to that question appears to be 'No'. In their wisdom (economic, of course), English Nature and the Joint Nature Conservation Committee are closing down the Marine Nature Conservation Review which was achieving some sort of baseline study of inshore and shallow-water environments around the UK. This is despite the strong recommendation in the UK Biodiversity Action Plan that this survey should be completed. A modicum of monitoring is being carried out, mainly by non-governmental organizations (NGOs) such as WWF, and local government, but the problem is what to monitor and where.

There is a need for long-term programmes, but our society is now driven by short-termism and constant and wasteful assessments of accountability. The socio-economic models we use to manage our decision-making often fail to operate at time- and space-scales relevant to environmental problems. An obvious example is the drive to provide cheap energy: the cheaper the energy, the faster national economies will grow, the faster our climate will warm and the faster waste problems will pile up.

The *Sea Empress* incident has other important messages. Prevention is always better than cure. Safety – at all levels – is worth the investment. It takes very few such incidents to increase the economic, let alone environmental, costs to society. Furthermore, the costs do not fall only on the companies whose cost-cutting contributed to the 'disaster', but are spread across society. Local communities in particular are affected by such incidents.

Maybe some sort of Environmental Fund should be established, financed perhaps by levies on insurance premiums which, like motor insurances, would be mandatory for operators. The Fund would finance base-line studies and monitoring programmes, and the coordination of analyses of the impacts caused by major incidents. At present, many environmental organizations are having to divert hard-won funds to boost the efforts made by local and central governmental agencies in assessing impacts and determining what lessons can be learnt. The Fund could contribute to the provision of expertise in coordinating clean-up operations, and to help ensure that longer-term conservation objectives are not lost sight of during the frantic rush to contain the impacts of an incident.

The *Sea Empress* spill affected one of our two marine nature reserves, the island of Skokholm, and highlights concerns that marine reserves (based on a concept borrowed from terrestrial conservation) are not proving an effective way of achieving the aims of conserving species and habitats. There is always considerable and understandable resistance to the establishment of new reserves, usually from local fishermen who see reserves as eroding their ability to make a living. However, in New Zealand it has been demonstrated that in the longer term reserves can actually enhance local catches because they provide a refuge where viable breeding populations of commercial species can be protected.

Models suggest that if 35% of the North Sea were closed to fishing, catches would be increased. For land, it seems that about 10% of the land area should be under protection if species, communities and ecological services are to be maintained. One can imagine the outcry against creating such 'no-take' reserves over 10% of our coastal waters, because of the short-term impact on the freedom of individuals and the erosion of historical rights; however, if we are to operate any sort of stewardship of marine ecosystems, and if we are to be serious in our attempts to conserve marine species and communities, and to ensure that coastal ecosystems continue to cope with the detritus of our society, then short-term sacrifices will be necessary.

I still consider the *Sea Empress* incident to have been a disaster, and an unnecessary one. We would not tolerate an impact of its extent and duration on land, so why should we tolerate it in the sea? We have to find ways of expressing environmental 'values' in quantitative terms more effectively, so that they reflect the qualities and values of the environment and so that we do not have to resort solely to the financial criteria that dominate commercial and industrial activity in and around our coasts. We also have to develop sensible criteria on which to evaluate the acceptability of future industrial developments in the oceans, to decide what precautions must be taken, and to determine what level of response is needed when things still go wrong.

Further Reading

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New Journal on Aquarium Sciences and Conservation

This new quarterly publication is intended to provide up-to-date information to amateur and professional aquarists, including those involved with public aquaria, captive breeding programmes and the ornamental fish industry. It should be of interest to fish biologists as well as those maintaining aquaria for education and research purposes, including taxonomists, toxicologists and those working for river authorities.

Topics that will be covered include:

- Aquaria – enclosed and open systems
- Management of water quality; filtration and sterilization
- Fish – their health and husbandry; reproduction; transportation; collection
- Conservation – captive breeding programmes, impacts of the aquarium trade
- Other aquatic vertebrates, invertebrates and aquatic botany

The Editor is Peter Burgess.

For more information, see:
http://www.thomsonscience.com

NOW There's a FUNNY THING...

More superstition?

I just came across a copy of *The Times* for mid-July, with a short news item about yet another abandoned yacht being found in the Bermuda Triangle – well, actually it said 'on the edge of the Bermuda Triangle'. It was a *Marie Celeste* scenario: no signs of damage, personal effects lying about in the usual comfortable domestic confusion, yet the vessel had been adrift for ten months (so the inside of the fridge was a bit smelly). Then the Royal Navy ship which made the discovery experienced storms and failures of both engines and navigational equipment. The crew is alleged to have 'feared that they too had become victims of the Bermuda Triangle', but to have been reassured when they eventually left the area and things started to work again.

It is high time that a statistically minded sceptic examined the records of lost and abandoned vessels, in relation to frequency of shipping in different areas of ocean. The best explanation I've encountered for at least some of the odd phenomena in the Bermuda Triangle was outlined in an 'Equinox' programme a few years back. It goes like this: Slumps and/or turbidity currents destabilise the top of the sediment pile at the foot of the continental slope where gas hydrates are trapped. A huge volume of methane is released, which turns the sea into a kind of froth as it rises to the surface (like the froth on beer or a fizzy drink). The density of the seawater is reduced by something like half, and any ships in the 'froth zone' just sink. As the froth has probably entrained some deep water, the air gets pretty cold, and fogs are liable to form.

All that at least matches some accounts of people's experiences – but it doesn't explain how mechanical and electronic equipment ceases to function. And anyway, why do these slumps and turbidity currents only liberate methane from gas hydrates in a relatively limited part of the Atlantic margin? Perhaps the slumping idea is all wrong and the stories have more to do with the Atlantis legend than with hard science?

Science and Belief

A recent survey of scientists' religious beliefs established that about 40% of US scientists believe in God, a figure that occasioned some surprise in the UK at least, where the proportion of believers is much lower. The survey perforce concerned the Christian belief system, and the outcome might well be different if scientists were surveyed in countries where other religions prevail. Thus, a Muslim scientist observed, *a propos* the American survey results: 'the surprise is not that so many scientists believe in God, but that so many do not.'

Millenial Giantism (but is Big really that Beautiful?)

The Japanese want to build a jumbo airliner to carry 500–1000 passengers, probably also a supersonic model to match. Makes you wonder if they care either about enhanced greenhouse warming or the ozone hole (the nitrogen oxides that *Concorde* emits in the stratosphere contribute to ozone depletion).

The Welsh want to drive a tunnel from Holyhead to Dublin under the Irish Sea, a distance of the order of 100 km, at an *estimated* cost of £14 billion. It would carry road and rail traffic, and would cut all of an hour off the present crossing time. You'd think that with the lessons of the Channel Tunnel in mind, potential investors would be wary of such a hare-brained scheme.

Forget the Millenium Dome. Book your cruise on any one of three Millenium Colossi, Royal Caribbean's proposed 'Eagle' class liners, each 142 000 tonnes, accommodating 5000 passengers and crew, which will start to sail the seven seas, it is claimed, from the year 2000 onwards. The impact of such a traffic on any kind of local environment, whether historical, cultural or natural, must surely be such as to render it devoid of any attractions in very short order.

It's all right, none of this will happen, there's not enough money around, nor are there enough customers mad enough to want to travel aboard flying or floating towns, let alone break the underground distance record. These grandiose schemes won't get any further than the drawing board. They're like the Arsenal Ship (*Ocean Challenge* Vol. 7, No.1, p.8), which was yet another 'ultimate solution' for war at sea, and is a fantasy in the same vein.

Freebies Galore!

In March this year, there was a real-life version of Compton MacKenzie's famous novel *Whisky Galore* (about a cargo ship loaded with whisky that ran aground in the Hebrides during the War), which was turned into a classic movie. Inhabitants of St Mary's in the Scilly Isles were similarly favoured, not with booze, but with a huge variety of consumer goods, when a container ship ran aground. For several days, newspapers and TV and radio bulletins carried descriptions of the range of merchandise being 'rescued' by the islanders, and there were dark warnings of the fiscal retribution in store when the authorities eventually caught up with the 'salvage' operation. Then it all went quiet.

Now it seems that there is retribution of another kind. Large quantities of plastic film (of the kind used to make audio tapes) are festooning the shore and sea-bed, enveloping benthic organisms (including corals and sea-fans), cutting off water circulation and nutrient supplies. Officially, the film doesn't count as a pollutant, so there was no help from Government agencies. The islanders may be faced with increased local taxes to pay for clearing up the mess, because the ship's owners have not responded to requests for help, nor have the insurers. That's the trouble with windfalls – they often contain worms.

John Wright

Meeresforschung 2000 Oceanography

That bilingual heading was the title of a joint symposium of the Deutsche Gesellschaft für Meeresforschung (DGM) and the Challenger Society, held in Hamburg on 10–11 October, to discuss future perspectives in marine research, including the prospects for research funding. There was also active participation by representatives of France's Union des Océanographes (UOF).

This appears to have been the first official joint meeting of European oceanographic societies. Held at the Geomatikum, University of Hamburg, it was a well-attended event, with a list of participants that included over 100 names. The organizers had arranged an extremely well-paced programme, which did not start until 11 a.m. on the first day and which had thoughtfully planned coffee and lunch breaks; there was also a symposium buffet on the evening of the first day, amid the many fascinating exhibits of the Geological–Palaeontological Museum.

The conference began with an upbeat introduction by the DGM President Thomas Höpner, and the rest of the first day was devoted to two sessions with the themes Marine Technology 2000 (morning) and National and European Research Policy (afternoon). In each session, there were three speakers, representing the countries participating in the symposium.

Marine Technology 2000

Gunther Krause chaired the first session, and began it by reviewing improvements in accuracy, precision and (especially) replicability of marine instrumentation. He emphasized the cruical importance of proper calibration, particularly in the context of the planned global oceanographic observing system, known as GOOS. As he said, it would be a great shame if future generations of oceanographers rejected our measurements because they were not sufficiently well calibrated.

He also remarked on the need for development of more automated instrumentation and new sensors for improved measurement of oceanographic properties, a theme with was taken up by Nick Millard, who spoke chiefly about *AUTOSUB* development at the Southampton Oceanography Centre (SOC), which is funded from both NERC and Navy sources. The present depth and range capability are about 100 m and 100 km respectively, but both should increase tenfold by 1999. With running costs estimated to be in the order of £2000 for a 300 km round trip, *AUTOSUB* would seem to have good prospects at a time of apparently progressive decline in financial support for UK marine science, which is making it difficult to run NERC's three research vessels.

It therefore came as something of a surprise to some participants when Jean-Louis Michel of IFREMER described the prospects for oceanographic research in France, where the research fleet includes *four* deep water ships and *two* large submersibles (*Cyana* and *Nautile*). The title of this contribution was French Large-Scale Equipment for Oceanography, and the underlying philosophy seems to be that increasing coverage of satellite and aircraft observations means that more ships and scientists will be needed, rather than fewer.

One of the recent constructions is *Thalassa*, which was built in cooperation with the Spanish Instituto Español de Oceaografia (IEO); ship time is shared between France and Spain on a 80:20 basis. This cooperative venture was encouraged by the European Commssion, which has also been behind the construction of *L'Europe* a fishing catamaran built jointly by IFREMER and the Italian ICRAM; IFREMER has recieved EU funding to allow easier access to *Cyana* and *Nautile* by young European scientists.

The funds to maintain, renovate and operate the large French fleet appear to be assured until well into the next century, a situation which would seem to contrast sharply with the situation in the UK in particular, and to some extent with that in Germany too.

The afternoon sessions on this opening day were devoted to the ways in which marine science is structured and funded in the three countries represented at the conference, followed by a brief overview of the role of the EU. The contributions were from (in order) Ulrich Schlüter (BundesMinisterium für Bildung, Forschung und Technologie, BMBF), Mike Whitfield (Challenger Society President, Marine Biological Association of the UK), Lucien Laubier (Director, Oceanology Centre of Marseille), and Jean Boissonnas (European Commission).

National and European Marine Policy

It is plain that the systems for organization and funding of marine sciences that have developed in individual countries over the last fifty years are complex. The number of acronyms on overheads displayed by each of the speakers bore eloquent testimony to this. Government agencies, universities and the private sector are all involved in various ways and their interests do not always coincide. A characteristic common factor seems to be that in each country there is some overlap between the research 'providers' of funds and the 'customers' for the products, because in many cases the funding bodies also run their own laboratories.

Below is a summary of the main issues that surfaced during the course of this session.

- There is a general perception that EU support for marine science is declining. European funding for marine research is currently allocated under the MAST (MArine Science and Technology) programme, itself part of the so-called Framework Programme. Funding for projects has been partitioned between three areas: marine science, coastal zone and shelf seas research ('strategic research') and marine technology. MAST-I was adopted as a pilot programme in mid-1989 and ran for three years with a total budget of 50 million ECU. MAST-II lasted from mid-1991 until the end of 1994, with a budget of 118 million ECU, and MAST-III, which will run until 1998, has a budget of 244 million ECU.

The real concern is about funding of marine science and technology under the EU Framework 5 Programme (1998–2002), where there will be important changes in the definition and structuring of marine research and technology, with the result that a smaller proportion of the total will be allocated to these areas than under previous frameworks.

This change has been attributed to national policies in member countries focussing less on marine matters. For example, it is alleged that the new French Minister of Science is not especially interested in space research, and could by extension feel

similarly about the deep sea; recent changes in the UK's principal funding body for research in the Earth Sciences (NERC) now has a dearth of MAST representation in its higher echelons. Jean Boissonas, from the European Commssion, urged marine scientists to be more proactive in dealing with the Commission.

• In Germany, about 450 million DM yr^{-1} (c. £140 million) of public funds are spent on marine and polar research (350 million DM on marine research and 100 DM on polar research). 75% of the 450 million DM comes from the government, and the largest single source is the Federal Ministry of Education, Science, Research and Technology (i.e. the BMBF); 13% comes from the Länder (regional governments), and 3% from the EU.

• The guiding political principles for research support in Germany are set out in the federal programmes for Marine and Polar Research, both of which were developed with long-term perspectives into the next millenium. Both programmes concentrate on 'functional' aspects of the oceans and polar regions, such as their influence on climate, their role as ecosystems and their potential for providing resources.

• France spends about twice as much on marine science as Germany – about 3 billion Fr (over £300 million) of which 2 billion Fr are for investment and 1 billion Fr for running costs.

• In France, the academic (i.e. pure research) community is made up of the universities and CNRS (which is the National Centre for Scientific Research, along with INSU, which includes several large observatories and smaller coastal laboratories, plus some larger academic institutes such as the National Museum of Natural History. These areas are funded by the Ministry of Education, Research and Technology. Applied research is undertaken by IFREMER (French Research Institute for Exploitation of the Sea) at its various large centres. Perhaps because of how it was set up, IFREMER seems to be unique in Europe in combining fisheries science and aquaculture with oceanography, coastal zone management and marine technology; in some ways, its role is similar to that of NOAA in the United States. It obtains funds from three different Ministries: Agriculture and Fisheries; Education, Research and Technology; and Industry, Transport and Housing.

• In the UK, the lead goverment funding agency is the Natural Environment Research Agency (NERC), which is linked to the Department of Trade and Industry. Additional funding is available through contracts with the Ministry of Agriculture, Fisheries and Food, the Scottish Office, the Department of the Environment and the Ministry of Defence.

• Mike Whitfield presented a SWOT analysis (an analysis of Strengths, Weaknesses, Obstacles, Threats – as used by the business community) for marine R&D. This was (perhaps surprisingly) quite illuminating. Top of the list of Strengths was the fact that, although it is diverse, the UK marine science community is well interconnected, partly through NERC-funded Thematic Programmes (previously known as Community Research Programmes) which have enabled 'virtual academies' of scientists from many different institutes to work together with clear objectives on interdisciplinary projects. This trend has been aided considerably by the series of MAST programmes funded by the EC. Top of the list of Threats was the fact that training in marine science is not highly sought by employers, and there is a training imbalance between scientific proirities and national needs.

• There was general agreement that across Europe more effort needs to be made in raising both public and government awareness of the importance of the marine environment in the context of resources, and the role of the oceans in climate regulation.

• In Britain and Germany an increasing proportion of useful work is being done by young scientists on short temporary appointments, which is neither cost-effective nor good for morale (cf. *Ocean Challenge*, Vol. 7, No. 2, and this issue p.9), whereas in France, the majority of marine scientists appear to be tenured civil servants.

• There is a need for more international cooperation, perhaps especially between Britain and other European nations (it was suggested that there is better cooperation, for example, between Germany and France, than between Britain and either of them). MAST proposals must by definition involve scientists from more than one nation, so this is an obvious route forward. There was a somewhat muted observation that the funds go further if the nations selected for involvement in such programmes are 'low-pay' areas; the corollary of this is that German scientists, with relatively high salaries, may be at a disadvantage when international projects are being put together for EU funding.

• As the countries of the European Community grow together, there will inevitably be more cooperation and joint project work in marine science (as in all other fields). There are aleady close ties between individuals in different EU countries, but further links could be forged if more scientists invited colleagues from other countries to join them on cruises.

• The question of whether there was any prospect of procedures for application for EU funds being simplified was raised – but not answered.

• Three types of projects/programmes can be identified: those that involve basic observation and measurement of oceanographic properties and processes, in programmes such as GOOS and EuroGOOS; biotechnological programmes, which involve the search for products that can be obtained/extracted from marine plants and animals; and other commercially relevant programmes, such as the investigation of sediment stability in the Rockall Trough, as a basis for oil exploration in the Atlantic Frontier region. Among the objectives of the EU scientific programmes is one that includes the phrase 'competitive and sustainable growth'. Such programmes may be intended to fulfill that objective.

The second day was devoted to more conventional scientific reviews of research in the marine sciences, with special emphasis on future prospects. They were necessarily wide-ranging, and we hope that at least some of these reviews will appear as articles in *Ocean Challenge*. So we shall confine ourselves to key points that emerged from the various contributions rather than attempt a blow-by-blow account of each. Contributions to the morning session came under the general heading of:

Horizons of Ocean Science and Engineering.

• Because taxonomists are themselves a globally endangered species (Angelika Brandt), it will be difficult to catalogue the full range of marine biodiversity. This is likely to be especially true in the less accessible deep oceans. Here,

biodiversity is encouraged both by sinking of organic detritus from surface water, and by the dispersion of species in deep and bottom water masses. The deep ocean is now well known to be neither as stable nor as quiet as was supposed barely a couple of decades ago, and global change may encourage biodiversity, though that could depend on the time-scale of such change.

• In the Atlantic, the thermohaline 'conveyor belt' has shown evidence of slowing down if not actually being 'switched off' at irregular intervals and on time-scales of centuries or even decades (Stefan Rahmstorf), and there are plenty of models which simulate how that might happen. It is not impossible that the conveyor could be 'switched off', at least partly as a consequence of the environmental modifications caused by human activities. Average annual temperatures in north-west Europe would then fall by several degrees over a matter of decades (or even years). The consequences of that are probably easier to predict for biodiversity in general than for humanity in particular. (See also pp.26–7.)

• The paradox that global warming caused by rising atmospheric CO_2 concentrations could lead to a decrease in surface temperatures locally (cf. previous paragraph) is gradually becoming more widely recognized. There is also growing awareness (Erwin Suess) that the quantity of gas (methane) hydrates stored in sediments of the world's continental rises (and deeper shelves) is roughly twice that of known conventional fossil fuel reserves ($\sim 10^4$ Gtonnes versus 5×10^3 Gtonnes). Methane hydrate is stable at pressures corresponding to depths of about 500 m and temperatures below about 6 °C, but can be explosively released if sea-level falls and/or temperature rises, releasing more gas trapped further down in the sediment pile. Large craters on the floor of the Barents Sea provide evidence that this has happened within the last few tens of thousands of years. Methane is a more potent greenhouse gas than carbon dioxide, and is rapidly becoming the 'preferred' fossil fuel because its calorific value is higher than that of coal or oil – but it burns to form CO_2!

• Deep-sea drilling technology has advanced rapidly in recent decades and continues to do so (Günther Clauss). The size of offshore structures is truly mind-boggling, in many cases greatly exceeding that of all but the tallest buildings on land, and they can weigh more than 100000 tonnes. Oilfields as deep as 1600 m are already being exploited off Brazil and there is every prospect that by early in the new millenium (if not before) extraction at over 2000 m will be a commonplace. By then, however, the size of the installations will probably be somewhat smaller, because floating (moored) rigs are perforce already being developed and deployed for deep-sea hydrocarbon extraction – that should make disposal of redundant structures both easier and less controversial. Gas hydrates do not yet appear to be a primary exploration target, but we can be fairly confident that, if present trends continue, they soon will be.

Marine Resources

• Although the effects of overfishing on recruitment are fairly obvious – i.e. not enough fish survive to breed – it is still useful to try to understand the natural factors controlling recruitment, which can vary widely from year to year, quite independent of any human influence (Rüdiger Berghahn). Flatfish have a two-dimensional distribution – except during dispersal of eggs and juveniles – which should make their populations easier to study, were it not for the fact that they tend not to aggregate in schools (shoals). The Common Fisheries Policy of the EU appears still to concentrate on landed tonnages rather than on available stocks, which must surely be partly because politicians are more concerned with short-term gains than long-term conservation, and partly because large sectors of the fishing industry appear still to have little interest in conserving fish stocks.

• Offshore oil and gas platforms are well known to be sites of enhanced biological production and diversity – they make good artificial reefs (Graham Shimmield and Eric Breuer). Hundreds of thousands of tonnes of drill cuttings have accumulated beneath the longer lived installations, comprising both fragments of reservoir rock and drilling muds, which consist of barite and bentonite, along with a large variety of chemicals (biocides, surfactants, scale inhibitors, etc.), as well as heavy metals and radionuclides, most of which actually come from the black shales which provide the source rocks. Development of anoxic conditions within the accumulations tends to stabilise most (but not all) of the heavy metals as sulphides. One of the objectives of the MIME research programme (Managing Impacts in the Marine Environment, see *Ocean Challenge*, Vol.7, p.15) is to discover whether the drill cuttings should be left *in situ* or removed, and whether it might be preferable in future to collect drill cuttings for disposal on land – a costly proposition, but one that needs to be considered as the rate of offshore hydrocarbon exploitation increases.

• Aquaculture – specifically mariculture – is one of the many ways in which the coastal zone is exploited, but sustainable development of the industry must form part of integrated coastal zone management programmes (Harald Rosenthal). The industry produces in the order of 20 million tonnes of products annually worldwide, including seaweeds and shellfish as well as fin fish. High demand, and potentially large and rapid returns on investment, have often resulted in big projects being started without proper piloting or research, and with scant regard for the requirements or activities of other coastal users. Furthermore, monitoring is often inadequate. Extreme examples are the well-known destruction of mangroves for shrimp farming in Asia and South America, and there are still plenty of cases of local eutrophication (including the formation of 'red tides') and of contamination by pesticides and hormones. Although there are examples of improving practice in several regions, there is a crucial need for co-management of aquaculture with other kinds of activities in the coastal zone, not only industry and shipping, but also conservation, recreation and tourism, agriculture, forestry, and of course the local 'natural' fisheries.

The growth of aquaculture industries has played some part in the global movement of marine species across the oceans, but ballast waters of large, fast modern ships are identified as the principal agent of dispersal. ICES has estimated that at any one time some 3000 marine species may be in transit inter-continentally. The resulting changes in community structure and biodiversity of marine ecosystems (well documented in some regions, e.g. the Black Sea) could be reinforced by changes in global climate. It is difficult to know how this particular global problem can be dealt with.

Along with the global issues raised in this talk, there were some facinating nuggets of information. Did you know, for example, that fish penned in coastal waters can get seasick, because of expansion and contraction of their swimbladders caused by

pressure changes as waves pass through? Or that using OTEC plants for mariculture has its downside, because the cool nutrient-rich water brought up from below the thermocline warms and degasses as it reaches the surface? That an Asian pearl oyster fishery used the quality of pearls as an environmental indicator, and when the quality started to fall, they decreased the density of the farming units?

The last two presentations in this session were on biotechnology (Marinus Meiners), with especial reference to the German research and development programme; and seawater desalination in arid coastal regions round the Red Sea (Thomas Höpner). We plan to have fuller accounts of these topics in future issues of *Ocean Challenge*.

Open Forum Discussion

The meeting concluded with an Open Forum discussion, chaired by Adolf Weber, on future prospects for marine science in a climate of uncertain funding and meagre chances of job security, especially for young scientists.

Two main themes emerged. The first was that the problems that scientists want to address are not necessarily the ones that they are pushed towards by both political pressure and availability of funding; for example, OSPARCOM has had a tendency to ask ICES scientists questions they couldn't answer. One approach might be for European scientists to go to CREST with well formulated ideas about what research is needed. However, because of a natural tendency to ask questions within their own subdisciplines, most scientists currently come up with research ideas that are too specific.

There was a lively discussion about what the task of scientists should be – to work for the resources to do research? To help the right political decisions be made? Or simply to understand Nature?

The second theme was the urgent need for increased intra-European cooperation among marine scientists. One suggestion was that scientists should form pressure groups to bring important issues to the attention of politicians and public, along the lines of the IPCC and the Montreal Protocol (on the ozone layer).

It was pointed out that if the German, French and UK oceanography communities could cooperate effectively, they would constitute a lobby group of 1000–1500 marine scientists, who should be able to make their views heard. In this spirit, it was generally agreed that a steering committee for the establishment of a European Marine Society should be formed as soon as possible.

The overwhelming impression we took away from Hamburg was of a highly successful meeting, an excellent demonstration of the value of intersociety communication and cooperation – definitely an exercise to be repeated.

AMC and JBW (Eds)

Stop Press: DGM Latest

DGM Mitteilungen No. 4 for 1997 contains abstracts of several of the presentations at the Hamburg symposium, especially those given on the first day relating to issues of policy and funding in the marine sciences. They are published in full ***in English!***

In fact, nearly half of this issue of the periodical of the *Deutsch Gesellschaft Meeresforschung* is published in a language intelligible to all UK members of the Society. British readers may well feel embarrassed at this acknowledgement of our indifferent linguistic abilities! Copies can be obtained from the periodical's Editor, Susan Beddig (see end for address).

In addition to the conference abstracts, *DGM Mitteilungen* 4/97 contains several articles on the theme of research into fouling of ships and instruments by marine organisms, and its prevention, and on the related issue of the global distribution of such organisms, both on ships' hulls and in ballast waters. A couple of articles discuss monitoring of the marine environment. One relates to the Oslo–Paris Convention and the forthcoming Quality Status Report (QSR) 2000 for north-eastern Atlantic waters; the other to the CANVAS project (*C*ontaminants *A*nd *N*utrients in *V*ariable sea *Area*s), which involves development of automated techniques for measuring nutrients and trace constituents under a wide range of conditions. There is a short piece on 1998 as the Year of the Oceans, and a somewhat lighthearted account of the joys of leaving the increasingly bureaucratic and (especially) underfunded world of conventional employment and going it alone as an independent freelance scientist.

There are items of interest in earlier numbers of the 1997 *Mitteilungen* too: No.1–2 and No. 3 for 1997 are each largely devoted to contributions on a specific theme, respectively: the handling of marine data in Germany (from a workshop held at Hamburg last December), and a series of articles on new instruments and methods for data acquisition and processing. No.1–2 also contained an interesting discussion by Karsten Reise of the benefits of an interdisciplinary approach to coastal research, with especial reference to the SWAP project (Sylter Wattenmeer Austauschprozesse, i.e. exchange mechanisms in the Sylt Island area of the Waddensea); also included was an overview of BASYS, the Baltic Sea System Study, begun in 1996 as part of MAST-III.

No. 3 carries a fine obituary of the marine biologist Renate Haass, who died earlier this year at the age of only 59. There is also a report of a follow-up to the Workshop on Scientifc Diving (Brussels, early 1996) held on Elba in May 1997.

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MARE: An Unusual New Magazine

On view in Hamburg were copies of the first issue (No. 1, April/May 1997) of a glossy new magazine, called *Mare*, pricey looking, but actually not all that expensive (DM14, a bit over three pounds), perhaps because it is packed with advertisements. There are lots of articles, often lavishly illustrated, on such subjects as: sea-coal gatherers of north-east England; the spread or organisms in ballast waters; the Gulf Stream and the climate of north-west Europe; a short history of cable-laying; and the life history of the eel (do they really go to the Caribbean?).

Most eccentric by a long way is an account of a journey undertaken in the 1830s by a party of explorers who crossed the Atlantic from Mauritania to the Orinoco. Not a big deal until you realise that they went *on foot and by camel* and traversed an arid desert occupying what we know as the floor of the Atlantic. Rock and sand, mainly, and not a lot of pelagic sediments, let alone pillow lavas or relics of hydrothermal vents, and the Mid-Atlantic Ridge seems to have vanished!

That ubiquitous conveyor

Most people interested in oceanography are aware of the concept of a 'thermohaline conveyor belt' – it has appeared in so many textbooks and TV programmes that there is a tendency for people to take it for granted, and not question the ideas it encapsulates, and/or (worse) interpret it too literally.

In his talk at the Meeresforschung 200 Oceanography conference, Stefan Rahmstorf, of the Potsdam Institute for Climate Impact Research,* reviewed the idea, and discussed how it might be refined.

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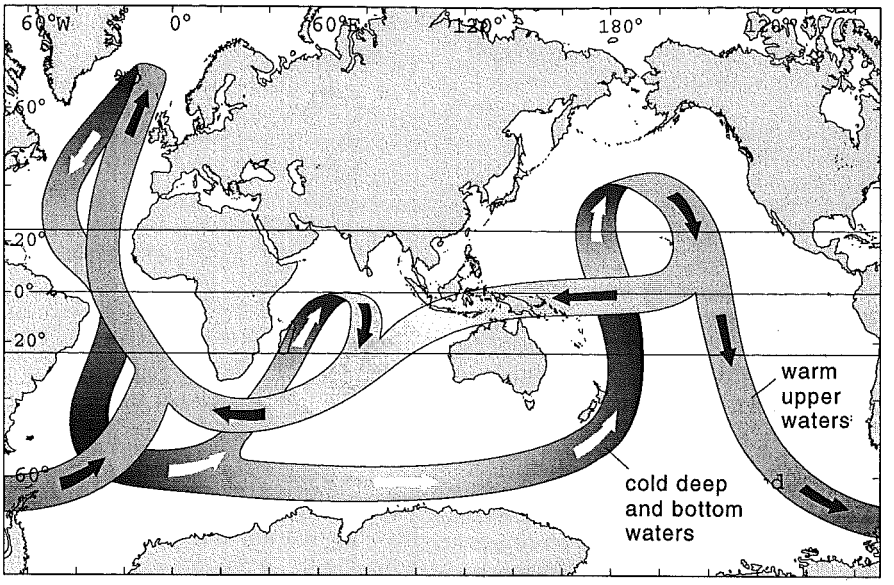
An Atlantic Conveyor – refinement of a Good Idea

by Stefan Rahmstorf

The idea of an oceanic conveyor belt was formulated by Wally Broecker, who thought of it as a global salinity transport system connecting the Atlantic and Pacific, driven by transport of atmospheric vapour transport from the Atlantic to the Pacific. The 'conveyor belt' picture has been scientifically fruitful, even though model studies have shown that it is probably incorrect. There is no simple one-to-one connection between the thermohaline circulations of the Atlantic and the Pacific: in models, one can reverse thermohaline flow in the Atlantic with little change in the Pacific.

The Atlantic Conveyor

Deep-water formation in the North Atlantic seems to be driven not by net evaporation but by cooling, with North Atlantic Deep Water (NADW) flowing out of the southern Atlantic being fresher than the near-surface northward inflow (at least in current models – observations give no clear answer on this point). But even if there is no global 'conveyor belt' as in Broecker's famous diagram, on a more modest scale within the Atlantic there does seem to be a coherent flow system which one might call the 'Atlantic Conveyor Belt'. If high latitudes are diluted by freshwater in models, then the whole system, including the Gulf Stream, Benguela Current and outflow of NADW, slows down together.



Broecker's thermohaline conveyor belt. *(This version, which includes a significant transport of warm upper waters from the Pacific Ocean to the Indian Ocean, is from a recent Open University publication.)*

Its role in climate

The Atlantic Conveyor Belt consists of warm surface water flowing northward and a cold deep branch (NADW) flowing southward; the deep water is formed by convection in the Nordic Seas and the Labrador Sea. This works like a central heating system, bringing some 10^{15} watts towards the northern North Atlantic, raising sea-surface temperatures there by 4–5 °C. Atmospheric temperatures are warmed even more, as the sea-ice margin is pushed north by the warm currents, decreasing the amount of sunlight reflected back into space. Coupled ocean–atmosphere models show that if NADW formation is turned off, there is a drop in annual mean air temperature, reaching a maximum of 10–20 °C near Scandinavia.

Its stability

The stability of the Atlantic thermohaline circulation has been the focus of many systematic model studies in recent years. These have confirmed Stommel's idea of 1961 that there are two states which are stable under present climatic conditions, namely with and without deep-water formation in the North Atlantic. Stommel described the positive salt advection feedback responsible for this strange behaviour: salinity in the high latitudes needs to be high enough for deep water to form, but it is only high enough because the thermohaline circulation continually brings in salty water from the south. The system is therefore self-sustaining. Stommel described this feedback for a simple one-hemisphere system, but it is readily extended to the cross-hemispheric flow of the Atlantic.

We now know that there is a second positive feedback affecting the thermohaline circulation, which involves vertical convection and acts more locally. Correspondingly, there are two distinct mechanisms through which the thermohaline circulation can change state: a fast convective instability, acting within a decade or less, and a slow advective spindown taking centuries.

Its variability

Little is known about the variability of the Atlantic Conveyor Belt in the modern climate. Interdecadal trends in deep-water properties give indirect evidence that the thermohaline circulation must be variable. A recent study of the flow of deep water over the sills between Greenland, Iceland and Scotland, performed by Sheldon Bacon of Southampton, suggests that this overflow has varied by a factor of two over past decades, possibly related to the North Atlantic Oscillation (NAO). Ocean–atmosphere models also tend to show variability of the thermohaline circulation with periods of around twenty years.

Its past

The behaviour of the Atlantic Conveyor Belt during the last Ice Age has been the focus of much research and speculation. Reconstructions from sediment cores show that during the last glacial maximum around 21 000 years ago, NADW formed south of Iceland and sank to intermediate depths only, while Antarctic Bottom Water pushed further northward than today. This picture was confirmed in a coupled ocean–atmosphere model simulation of the last glacial maximum performed by our group in Potsdam. This simulation showed that the change in Atlantic circulation may have significantly enhanced glacial cooling, by as much as 50% over the Northern Hemisphere and 30% globally. Another striking aspect of past thermohaline circulation is its high variability: ice and sediment cores show that surface climate and circulation changed in step throughout the last Ice Age, sometimes making drastic swings within a decade or so. While cause and effect are not clearly established yet, the positive feedbacks and instabilities discussed above are a prime candidate for explaining the sudden changes.

Its future

Given the past instability, the future of the Atlantic circulation in the changing climate of the next century is a natural concern. Model scenarios for a greenhouse world generally show a reduction in thermohaline circulation of between 20% and 50% for a doubling of carbon dioxide in the atmosphere. If carbon dioxide levels rise further after that, the circulation may be halted altogether. This happens on the slow, advective time-scale over one or two centuries in these scenarios; rapid changes as seen during the last glacial have not been forecast so far. However, this does not mean that they are impossible. Due to their poor resolution, present climate models cannot capture the fast convective instability very well, as this process depends on regional details. The 1995 report of the Intergovernmental Panel on Climate Change concluded: "Future climate changes may also involve 'surprises' ... Examples of such non-linear behaviour include rapid circulation changes in the North Atlantic ..."

This is still a valid conclusion today.

Selected Further Reading

Broecker, W.S. (1991) The great ocean conveyor, *Oceanography*, **4**, No.2, 79–89.

Broecker, W.S. (1995) Chaotic climate, *Scientific American* (November), 44–50.

Rahmstorf, S. (1995) Bifurcations of the Atlantic thermohaline conveyor in response to changes in the hydrological cycle, *Nature*, **378**, 145–49.

Rahmstorf, S. (1995) Risk of sea-change in the Atlantic, *Nature*, **388**, 825–26.

Conference tribute to Dennis Burton

To many younger marine scientists, Professor J. Dennis Burton may only be known through benchmark publications such as the book *Estuarine Chemistry*, but to many of the remainder in the field both nationally and internationally, he is a friend and colleague who has been an active and positive force in chemical oceanography for over 30 years.

Amongst his earlier exploits was the initiation with Peter Liss in the early 1970s, of the Marine Chemistry Discussion Group (MCDG) which, despite ups and downs in the intervening period, is still alive and well under the auspices of the Challenger Society, and continues to act as a major forum for marine scientists within the UK with a chemical leaning. With the origins of the MCDG in mind, it is particularly appropriate that this second Progress in Chemical Oceanography MCDG meeting was dedicated to Dennis on his retirement from the Department of Oceanography at the University of Southampton.

Coastal and estuarine biogeochemistry

The theme of the first session was trace metals in coastal and estuarine waters, and environments that were discussed ranged from the heavily contaminated Rio Tinto on the Huelva estuary on the Atlantic seaboard of Spain, where the pH of river water can be below 3 and the dissolved zinc signals can be traced into the adjacent Mediterranean (Eric Achterberg and colleagues), to the pristine Tweed estuary in Scotland.

A common thread running through the session was the role of particles in regulating the balance between dissolved and particulate metals at the interface between river and ocean. Different mechanisms have been inferred for the uptake of radioactive cadmium and manganese tracers from rivers and and from estuaries (Mark Williams), with implications for the distribution coefficients that should be used in models. The impact of biological particles on the distributions of nickel and zinc in the coastal waters of the North Sea (Geoff Millward) indicated similarities between nickel and urea uptake (the two are linked in cellular enzyme systems), which raises the intriguing prospect of a mechanism for this uptake process at the molecular level.

An important ultimate reason for trying to understand the fate and cycling of metals in estuaries and coastal seas is to use this information in numerical models of the behaviour of these constituents. The third version of the estuarine contaminant simulator (ECoS) model for estuaries has been applied to the Tweed estuary and experimentally derived distribution coefficients are being used (Adrian Punt and colleagues). On the larger scale of the North Sea, similar dissolved phase/particle interactions, along with information on inputs and cycling, have been combined with a hydrodynamic model to give good descriptions of the distribution of many elements, and importantly have allowed predictions of the impact of reductions or increases in inputs of metals to be modelled (Alan Tappin and colleagues).

Diagenesis in marine sediments

The session on sediment diagenesis covered changes occurring on timescales ranging from several million years down to very short periods. Work on trace metals in ODP material from the Madeira Abyssal Plain at depths between 130 m and 230 m below the sea floor (John Thomson and colleagues) show that turbidites have relatively high organic carbon contents, except at the top of the turbidite unit. Several redox-sensitive elements are found in localised bands, with little evidence of migration.

Perhaps the most innovative techniques currently in use for studying recent surface sediment diagenesis are diffusive gradient techniques (DGTs) and diffusive equilibrium techniques (DETs), both of which employ gel layers which are inserted as probes into the sediment. Microscale analysis of elements associated with these gel layers give very high resolution profiles of fluxes (DGT) or concentrations (DET) of constituents in porewaters.

Some of the limitations of resolution with DET methods have been studied by numerical modelling (Michael Harper and colleagues): porewater concentration maxima can be underestimated if the gel layers are too thin, with consequent underestimation of fluxes. It therefore follows that as high a resolution as possible of vertical changes in metal concentration in sediments is desirable. An ultra-high resolution DGT/DET technique was described (Gary Fones and colleagues) in which PIXE (Proton Induced X-ray Emission) was used to determine metal distributions at 100 μm resolution; initial results showed the great inhomogeneity of sedimentary systems, and that very rapid changes occurred in surface sediments which could only be observed using this new high resolution technique. Studies using DET methods in lakes (Sarah Shuttleworth) further indicated the potential of the method for process studies, and the problems of heterogeneity in most natural sedimentary systems. The application of the DET method in Loch Duich sediments (Peter Hayes and colleagues) showed an intriguing distinct peak in nitrate which occurred outside the zone anticipated from conventional redox sequences. This may result from a hitherto unidentified process that would not have been detected without the high resolution of the DET method.

The impact of biology on marine chemistry

The links between biological activity and the chemical environment in which organisms find themselves represents an important disciplinary overlap zone. Indeed, Dennis developed marine chemistry at Southampton in a very fruitful partnership with Peter Williams who was developing microbial and phytoplankton process studies. At the meeting, recent suggestions that the oceans are in metabolic imbalance were refuted: improved data suggest that the oceans are almost in metabolic balance (Peter Williams).

Interactions between phytoplankton and bacteria are important (Richard Sanders and Duncan Purdie), particularly as regards the release of

metabolisable organics from phytoplankton, and the role of these compounds as a short-term source or sink for nutrients. In larger scale studies on carbon dioxide in marine systems the focus has been on the open ocean, but estuaries can also show major changes in CO_2 relative to equilibrium values (Duncan Purdie and colleagues), and raises the possibility of measurement of carbon dioxide as an indicator of water quality in estuaries, and the role of such waters in the global scale cycling of carbon.

Trying to estimate new production at regional scales in the ocean is an important objective if its impact on carbon cycling is to be known. Data from the north-west Indian Ocean, in combination with satellite information and a modelling approach, have produced encouraging results on new production during a monsoon period (Louisa Watts and colleagues). Recently available large-scale datasets for nutrients have been used to infer denitrification processes in areas not previously identified. However, it seems that a significant amount of low nitrate outlier data was erroneous, and that while several of the main features are correct, others are not (Toby Tyrrell and Cliff Law). The incorporation of different estimates of denitrification processes into budgets of nitrogen in the North Sea, seem to be leading to convergent values, and helping to provide consistent estimates of the magnitude of different processes (David Hydes).

Air–sea exchange

Exchanges with the atmosphere are key to understanding many aspects of global geochemical cycles. This is obviously the case with carbon, although accurately quantifying the net flux is difficult because in and out fluxes are both very large relative to the difference between them (Peter Liss). Gas exchange across the air–sea interface is clearly a significant process, and factors such as increasing pressure acting on bubbles swept below the surface (particularly under high wind conditions) are important in this gas transfer process (David Woolf and Peter Bowyer). Iron-limitation is amongst the important processes that are currently being considerd in relation to phytoplankton production and carbon drawdown. Iron sources will be expected to be mainly natural background aerosol inputs, but this may be significantly supplemented by events such as volcanic eruptions which produce dust containing iron.

Information on the solubility of metals in particles has been incorporated into studies in the eastern Atlantic, on deposition velocities of atmospheric particles and their impact on surface waters. An important observation is the sporadic but significant input of lead during periods of easterly winds (Lucy Spokes). An understanding of how the atmospheric flux of particles is modified during its passage through the atmosphere and the water column from surface ocean to deeper waters is important if we are to know the impact of such fluxes. Atmospherically derived inputs are modified

RRS Discovery *forms a backdrop for the conference delegates gathered by Empress Dock in the September sunshine. In the front row with Dennis Burton are conference organizers Peter Statham and Rachel Mills.*
(Photo: Mike Conquer)

during transport by air, and subsequent sinking down through the water column; the down-column fluxes, which show seasonal trends, are a function of changing wind systems and of the source of the particles (Tim Jickells).

Moving on to gases, as far as carbon monoxide is concerned, the surface ocean may be a source or a sink. A description of concentration distributions of carbon monoxide from recent measurements was presented (Tristan Sjoberg and colleagues).

Fluxes from crust to ocean

A major area of interest in chemical oceanography is the role of hydrothermal systems in the global cycling of elements in the ocean. Earlier attention was focussed on the 'black smokers', but it is rapidly becoming evident that off-axis flow through ridge flanks can be very significant, particularly where there is an overlying blanket of sediment (Harry Elderfield).

An example of the results of reactions occurring in hydrothermal mounds is the enrichment of rare earth elements and changes in Sr-isotopes in pore fluids (Mark Rudnicki and Rachel Mills). The black smokers with their buoyant particle-rich plumes, represent the obvious major manifestation of ridge hydrothermal processes, but in fact are tiny features on the scale of full ridge systems, and finding them is no trivial task. The towed instrument *BRIDGET* was used to locate the Rainbow site, but the flow of the plume in this particular section of the Mid-Atlantic Ridge is convoluted and a full series of transects, as well as input from physical oceanographers, were required to fully define the path of the plume (Chris German).

The final session brought together a range of topics on fluxes of material from land to ocean. On the grand scale, the role of terrestrial ice masses in global geochemical cycles over the last glacial advance and retreat, may have had an impact on CO_2 concentrations (Martyn Tranter). A key factor is weathering and microbial activity in glacier systems which produce solutes that may stimulate a net release of CO_2 to the atmosphere via reprecipitation of carbonate.

Riverine fluxes of nutrients to coastal waters are not simple to determine, as errors in calculation methods and chemical analyses can lead to large uncertainties in calculated values; improvements needed include better information on waste inputs and continuous monitoring at key points in an estuary (Paul Wright). The dispersion of organic material from rivers, and its fate in coastal and shelf systems during mixing with marine organic matter, is potentially a complex process. However new *in situ* instruments such as ZAPS (Zero Angle Photon Spectrometer) can look at sub-sets of dissolved organic matter in seawater by using selected fluorescence wavelengths (Gary Klinkhammer).

Beyond the coastal waters lies the shelf break with its associated complex water transport and biogeochemical processes. Major transport of metals across the north-west European shelf break is difficult to identify uniquely. The observed distribution of metals appears to result from a range of mixing, scavenging and benthic processes, but a dataset of much higher spatial and temporal resolution is required to effectively unravel the effects of the various processes involved (Anne-Christine LeGall and colleagues).

Sediments of the eastern Mediterranean (Levantine Basin) are made up of Saharan dust and suspended particulates brought down by the Nile. Damming of the Nile has cut off much of its sediment supply to the eastern Mediterranean; isotopic signatures have been used to help distinguish between the aeolian and Mediterranean sources in the sediments (Mike Krom and colleagues).

Tributes and references to Dennis were interspersed throughout the meeting. They ranged from pictures of the intrepid oceanographer at sea to a Zen-inspired view of how his reported water column profiles have a likeness to spaghetti strands that have evolved through various levels of drying to the beautifully symmetrical lines in his most recent work! All of the comments, whether made with tongue in cheek or with deep sincerity, show how much Dennis is appreciated.

The meeting dinner was held at the Dell Football club in Southampton (the venue was chosen with Dennis's sporting interests in mind!) and after the jazz music and the presentations, and good socialising amongst his many friends, Dennis spoke in his 'rabid optimism' mode about how important it is to look to the future in a positive way – very appropriate advice given the presence of a large number of younger scientists, who in many respects could find no better role model than Dennis.

Dennis intends to maintain an active link with chemical oceanography and the Southampton Department, and we are looking forward to his continued and valued contributions at social and scientific occasions in the coming years.

This report was compiled by **Peter Statham**, Southampton Oceanography Centre, with input from those chairing sessions at the PICO II meeting (Chris German, Tim Jickells, Rachel Mills and Martin Preston).

If readers are interested in contacting any of the speakers mentioned, information on how to reach them can be obtained from:
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Dennis (resplendent in Bolton Wanderers scarf) with the Oceanography Head of Department, Mike Collins, and Mike's daughter Samantha who organized the venue for the social event after the conference

Denizens of the deep: Marine life of the Atlantic Frontier

Martin Angel

On the eve of the Rio Convention meeting in New York (on the fifth anniversary of the initial meeting), Greenpeace hosted a gathering at the University of London to discuss whether the Atlantic Frontier – the outer continental slope and shelf areas in the north-eastern Atlantic – should be developed. Billed as a unique opportunity to debate these issues with key players in the field, the meeting was aimed at seeking justification for Greenpeace's campaign against the development of the West of Shetlands Oilfield.

With John Shepherd in the chair, John Gordon addressed the question: 'Deep-sea fish – are we fishing in the dark?' He summarised what is known about the distribution of demersal fish in the Rockall Trough and across the Wyville Thomson Ridge. He pointed out that distributions of demersal fish are far from being uniform, and that our knowledge is restricted to those regions where the sea-bed is flat enough to be trawled. The inadequacy of our knowledge is highlighted by the fact that fish that are rare in scientific collections turn up regularly in French markets. Deep-water fishes are exploited by deep long-lining around the Azores and Madeira. Even so, there are large areas for which we know nothing about the fish faunas, including the Maury Channel which was amongst the original sites considered by Shell for the disposal of *Brent Spar*.

Fish biomass reaches a maximum at 1 000 m and the largest numbers of species are caught at 750 m, but the average size tends to increase with depth – the 'bigger deeper' effect. The top five most abundant species often dominate the catch as far as biomass is concerned. Interestingly, most demersal fish rely on pelagic resources for their food. Exploratory fishing for deep-living species began in the 1970s, but it was not until the late 1980s that exploitation began, because it depended on the creation of new markets. Monkfish, for example, were once discarded but are now ranked the third most valuable fish in Scottish fisheries. There are considerable differences in the dominant fish species between the warm Atlantic water and the cold waters of the Norwegian Sea (as found in the West of Shetlands Oilfield) where the deep-living fish communities have barely been studied; what has been done shows that there are few species living below 1500 m.

John Lambshead of the Natural History Museum then discussed 'Sea-bed life of the deep ocean', concentrating on data from the Rockall Trough. He stressed how little of the deep ocean has been sampled and the technological limitations to being able to make reliable estimates of biodiversity. Taxonomy is enormously difficult in the deep ocean: in one sample of nematodes containing 325 putative species, just 29 could be named, 16 could only be tentatively ascribed to a known species, and the rest were novel. Moreover, 27 of the novel species could not even be ascribed to a known family. Such inadequate taxonomic description of so many of the benthic groups presents overwhelming problems to anyone seeking to monitor in order to detect change and identify the cause of change. If one cannot name a species and recognize it next time around then it is impossible to achieve scientific results in which there can be any confidence.

There is no doubt that benthic communities are much richer in species than was thought to be the case even a decade ago. In their studies of macrobenthos off the eastern seaboard of the United States, Grassle and Maciolek (see Further Reading) estimated that they were finding a new species for every kilometre they extended their survey. However, in this talk we heard how samples of benthic species collected 1000 km apart (from the Porcupine Abyssal Plain and the Tagus Abyssal Plain) had more than 20% of species in common despite being subject to very different productivity regimes. In the Pacific, this change in species composition is even more limited, with 40% of species being common to samples collected 3 000 km apart. However, John put a particular spin on these data, claiming that benthic communities must be as diverse as those of tropical rainforest (a claim later repeated by Greenpeace for *Lophelia* 'reefs'). Even if this is true on a local basis, these limited changes in species composition over large distances suggest to your correspondent that claims that numbers of benthic species are similar to, or even outnumber, those of tropical rainforests are likely to be overstated. As will be revealed below, this is not a trivial argument.

Mark Tasker (Senior Marine Advisor to the Joint Nature Conservation Committee) then described two sets of results, of which the first were from regular boat censuses of the distributions of sea-birds between the Faeroes and north-west Scotland. Bird distributions over the shelf waters between Scotland and the Faeroes show considerable variations with season. During the breeding season the adults are restricted within foraging distances of their nesting sites, which for many seabirds includes St Kilda. Puffins are abundant in these waters in June and August but disperse from the area to overwintering grounds elsewhere in September. The gannet is predominantly a shelf species, but the shelf-break front is clearly a very important foraging ground for it in March and April. Kittiwakes likewise are most abundant over the shelf. Only fulmars are truly oceanic. Interestingly, fulmar populations have increased enormously: a century ago they bred only on St Kilda, but now there are few English cliffs where they do not breed.

The second (and even more interesting) set of results is a consequence of the thawing of the Cold War. The Joint Nature Conservation Committee has now been allowed access to sound recordings from the military hydrophone arrays used to monitor submarine activity in the Atlantic, and these have revealed the presence of cetaceans in quite large numbers to the west of the British Isles. The hydrophone records were played at the meeting (mostly speeded up to render the cetacean calls audible) and illustrated just how mechanical some of the species sounded. Most frequently heard are pilot whales, but minke, sei, fin and sperm whales occur seasonally. Most unexpectedly, up to nine blue whales may be off the UK coast at any one time during the winter. It is possible that acoustic data can give us the best means of

monitoring large cetaceans, and enable us to detect any changes occurring in their populations, especially those caused by exploration for, and exploitation of, oil. Greenpeace can be expected to attribute any changes observed in the ecology of the new oilfields to the industrial activity. It is about time that the petroleum industry woke up to the fact that in the eyes of the conservation bodies they are guilty until they are proven innocent. It is interesting to note that industrial activity does not appear to have deterred cetaceans from straying into the North Sea.

After lunch, Dr Sian Pullen from WWF-UK took the Chair, and in her introduction emphasized that the objective of the afternoon's session was to examine whether human impact in the ocean was innocuous, and to explore the concerns that had been voiced about exploration and exploitation of hydrocarbons from the ocean. The first speaker was Professor Cliff Johnson, an independent consultant for the oil industry. He took the Greenpeace document *Putting the Lid on Fossil Fuels* as his starting point, arguing that it took a very extreme viewpoint and was highly selective in its arguments. The IPCC report still contains many scientific reservations about global warming, and Professor Johnson asked whether it is sensible to panic and abandon exploration and development at this stage. It is still possible, he suggested, that the warming that we have experienced during the last thirty years is no more than normal variability. With the burgeoning human population to feed and house, we cannot afford to lose the planetary gamble.

For example, most of the fossil fuel we have is in the form of coal. Coal produces more carbon dioxide per unit of fuel than any other, so if we abandon hydrocarbons (i.e. oil and gas) without improving the efficiency with which we use and conserve energy then the Greenpeace campaign will result in increases in emissions of carbon dioxide into the atmosphere.

Only three countries have reduced their emissions since the signing of the Rio Convention – Russia (because it has had a recession), the UK and Germany. The UK achieved its reduction by a switch to generation using natural gas. There are many other technologies for achieving further reductions, including capturing the carbon dioxide and sequestering it. And indeed almost at that very moment Tony Blair was committing us to cutting back by 20% (yet now Government has put a freeze on the construction of new gas-fired power stations as a sop to the miners). At present, hydrocarbon production in the UK amounts to 4% of global oil production and our reserves are a meagre 0.4% of global reserves. Stopping the development of the Atlantic Frontier will contribute little to resolving the global problem. The Gulf states holds the majority of the reserves, and export mainly to Japan! To achieve the reduction in emissions needed, we should be switching more to oil and gas for our energy generation.

Professor Johnson then introduced the subject of the cold-water coral *Lophelia pertusa*, which occurs only sparsely in the area of the West of Shetland Oilfield. According to the scientific literature, some 800 species have been found co-occurring with *Lophelia* throughout its range from the Porcupine Seabight to the Norwegian fjords. Not all these species occur throughout this range, and few of them appear to be obligatory associates; to take one example, one of the species reported as being an associate is the abundant and common pelagic copepod *Calanus finmarchicus*. Many of these associated species occur in the dead matrix rather then in living coral, and kelp holdfasts also offer refuge to very high numbers of species. The main cause of damage to the coral is trawling.

Peter Melchett, Director of Greenpeace UK, then took up the theme of the unsustainability of exploiting offshore hydrocarbons. He emphasized that Greenpeace is not against the use of energy: solar power is available and working, but needs development. A 'business as usual' approach spells disaster, and *the debate with science is now over.* Carbon dioxide emissions will lead to an average warming of 2.5–3 °C by 2050. The EU is seeking to keep emissions down to a level where the warming is kept to an average of 2 °C, but is this enough? The need to keep the lid on emissions means that half to three-quarters of oil reserves should remain in the ground and not be used. This can only be achieved by political agreement. When CFCs were identified as creating a problem in the ozone layer, the approach focussed on both the supply-side and the use; the same dualistic approach must be taken with hydrocarbons.

Over the last 20 years, exploration has found two new barrels of oil for every one used. If exploration ceases, the economics of a diminishing resource will soon drive us into more efficient use and greater exploitation of renewables. In the UK, 80% of new reserves are offshore. Just before the election, Tim Eagger (then still at the DTI) released exploration licenses for 27 000 square miles of shelf waters on the Atlantic side of the Wyville Thomson Ridge, without adequate assessments as to the impact of this exploration and exploitation. The Environmental Impact Directive has not been carried out, nor have the requirements of the Habitats Directive been fulfilled. Melchett argued that there are huge gaps in our scientific knowledge of the area and yet there are tantalising glimpses of unexpected richness within this sea of ignorance and lack of understanding.

There was to have been a keynote address by Sylvia Earle, but she was kept away by the imminent birth of a grand-daughter. An emotional letter from her was read out, the gist of which can be found in her recent book on marine diversity. This left considerable time for discussion, and John Wilson led off by trying to put the record straight on *Lophelia*. The day prior to the meeting, *The Sunday Times* had carried a highly erroneous article in which *Lophelia* was shown occurring in a broad band around north-west Scotland, and an analogy was drawn between this mythical reef and the Great Barrier Reef. *Lophelia* is a widespread species in the Atlantic and is particularly abundant off Norway where is forms major reef-like structures tens of metres high. However, in the area to the west of Shetlands it occurs only sporadically.

The discussion then focussed very much on fisheries and not on the main issue of whether the 'Atlantic Frontier' should be exploited. During the discussion, Graham Shimmield, Director of Dunstaffnage Marine Laboratory, revealed that he was the source of the information that had been substantially misquoted by *The Sunday Times*. Peter Melchett sympathised with Graham, saying that the Media are constantly misrepresenting Greenpeace statements. It is worth noting that the Greenpeace News Release produced two days later stated that (I quote verbatim):

'the Government unlawfully issued licenses for oil exploration and production ... as part of the 17th licensing round ... the licenses are unlawful for

two reasons... the Government is failing to protect the cold water coral reef in the Atlantic Frontier ... [and] ... should have given the reef special protection status under the European Habitats Directive. The second is that the Government has not taken relevant steps to protect the Hebridean isles including the island of St Kilda from the impact of oil activities ... The coral at the heart of the case is *Lophelia pertusa* which grows in the very deep, dark waters of the Northeast Atlantic. The reef-forming coral is thought to support around 800 organisms [I assume they mean species] with a biodiversity as rich as a tropical rainforest. Unlike reefs in tropical waters, it is slow growing, has a slow recovery rate and is therefore vulnerable to the impacts of oil exploration.'

I personally feel that this release grossly distorts the scientific facts about *Lophelia*.

Our science is at something of a cross-roads. Up until now, much of what we have had to say has been overlooked. We have not needed to sully our hands by getting involved in political debate about the implications of our data and, more importantly, about the interpretation of these data. Indeed, John Lambshead even went so far as to say that we scientists have invented jargon in order to prevent the general public from understanding our results. Your correspondent pointed out that the function of 'jargon' is to provide words with precise meanings so that pointless semantic arguments are avoided. For example, to say that because large numbers of species have been found co-occurring with *Lophelia* 'they form reefs that are as diverse as tropical rainforest' is to use the terms 'reefs' and 'diverse' misleadingly. The oak tree in Britain is known to have over 600 species of insect associated with it, and many more if accidental species are included, so in the UK much of our woodland could be said to be 'as diverse as rainforest'. This is manifestly untrue, and Greenpeace have recognized this by not taking the UK Government to court over our lack of conservation of oak woodland.

Undoubtedly we will have to become far more proactive in publicising our science, while being warned by Graham Shimmield's experience that communication must be two-way, involving 'speaking' and 'hearing'. We also have to bear in mind that the Media (and others) have a disconcerting way of being very selective about what they 'hear'.

Further Reading

Grassle, J.F. and N.J. Maciolek (1992) Deep-sea richness: regional and local diversity estimates from quantative bottom samples. *The American Naturalist*, **139**, 313–41.

Ormond, R.F.G., J. Gage and M.V. Angel (eds) *Marine biodiversity: patterns and processes,* Cambridge University Press.

Highlights of Seminar on Climate Change and Biodiversity

Greenhouse gas emissions can be expected to warm the globe by about 2 °C over the next 50–100 years, possibly raising sea-level by 44 cm, thereby affecting 70 million people and destroying the habitat of hundreds of species, increasing the occurrences of such diseases as malaria, and changing the economies of most of the world. These were some of the conclusions arising from a seminar entitled 'Climate Change and Biodiversity', held at Imperial College as part of a regular series highlighting important environmental issues. The seminar attracted over 130 scientists, engineers and policy makers, mostly from the UK.

Two of the Seminar's early speakers, Sir John Mason of Imperial College, and Dr Tim Johns, of the UK Meteorological Office, showed impressive examples of agreement between models and observations of average temperature, suggesting ~ 2 °C global warming as a result of the addition of CO_2; this is about 1°C less than earlier estimates, due to the inclusion of direct sulphate effects in the model simulations. These talks, and that of Imperial College Professor, John Harries, described further research on aerosols, clouds (including the indirect effects of sulphate aerosols) and fluxes from vegetation, needed to improve the results still further.

In the first of a series of talks on the biological and economic consequences of global warming, Sir Crispin Tickell reminded the audience that climate change is but one of five factors of 'global change', the others being population increase, land degradation, ocean pollution, and biodiversity decline. Sir Crispin closed by reminding the audience that several of these factors, but not all, played a part when human occupation turned Easter Island from a paradise into a disaster. The analogy with the Earth as a whole did not have to be made for the audience to realise the parallels.

The first afternoon talk, by Imperial College Professor John Lawton, showed that the non-linearity that was so much discussed in the morning's physical papers, applies even more so in biology. Here, intuition is more often wrong than right. As an example of this, he reported how in a controlled laboratory experiment, plant biomass decreased in the presence of increased CO_2. The reason was that as availability of nitrogen – a life staple for insects – declined, the insects needed to consume more plant material to make up for the shortfall in nitrogen.

Mr Ronan Palmer, of the UK Environment Agency, continued the theme of non-linearity, this time in economic models. Here the eventual cost of global warming is highly speculative. One example is the impact of a proposed 'Carbon Tax' whereby fuel consumption taxes replace (or add to) income and sales tax to finance government. There has been little, if any, research on this topic, yet it is being seriously proposed as a method of coping with increased greenhouse gas emissions.

Possibly the most disturbing paper of the day, was the last. This, by Professor Geoffrey Pasvol of Northwick Park Hospital, dealt with disease. Many of the other impacts of global warming can seem remote to people of developed countries who, often smugly, believe that humankind will somehow adapt. The appearance of malaria in New York, following three days of temperatures of ~ 25.8°C in July 1993, shows how vulnerable modern, urban, populations can be to disease.

This report is by courtesy of ***Alan Weinstein****, Associate Director, Environmental Science, Office of Naval Research Europe (Email: aweinstein@onreur.navy.mil).*

It is abridged from his full report which may be found on the Web: http://www.ehis.navy.mil/awnews35.htm

Mark Maslin

The last two decades have seen a dramatic growth in our awareness of humanity's impact on the global environment, the most worrying influence being possible global warming. This concern about future global climate has led scientists to study how climate changes, but since written records of climate only extend back a few centuries, other sources of data are required to reconstruct past climate and how it has changed. An important source of continuous past climate records are deep-sea sediments which have revealed that for the last two and half million years the Earth's climate has varied cyclically between two extremes: cold glacial periods, when massive ice sheets, averaging about 3 km in thickness, covered much of North America and Northern Europe; and interglacial periods, which were climatically similar to the present day, if not slightly warmer. So the next climatic swing toward another glacial period is unlikely to affect us in the foreseeable future. The interesting question now being raised is: how stable is the 'natural climate' within these periods? What has been discovered is that during glacial periods the massive ice-sheets are very unstable, collapsing quasi-periodically approximately every 10 000 years. These so-called 'Heinrich events' lasted between 50 and 200 years and had a huge effect on the global climate. The concern is that global warming could lead to such dramatic surging of the world's ice-sheets.

The last glacial period ended 14 000 years ago, having lasted over 60 000 years. Until fairly recently it was thought that this was a relatively stable climatic period, with slow but continuous accumulation of ice on the continental ice-sheets. In 1988, Dr Hartmut Heinrich of the German Hydrographic Institute in Hamburg was studying the last glacial period using deep-sea sediment cores recovered from the north-east Atlantic. On counting the relative frequency of coarse particles (150 μm to a few mm) in the sediments, he found that during the last glacial there were several short periods when large quantities of these coarse fragments were deposited They are too large to have been transported by wind, and Heinrich concluded that they could only have reached the north-east Atlantic via icebergs, which suggested that during this supposedly stable climatic period there were short periods of very intense iceberg activity. Subsequent work has confirmed that these coarser layers can be found all over the North Atlantic in very different sedimentary environments, which excludes the possibility that they were deposited by turbidity currents.

Professor Wallace Broecker of Columbia University is among those who believe that past perturbations in the climate system can gives us great insight into the mechanisms controlling climate change. He was struck by the important climatic implications of these layers in the deep-sea sediments. In 1992, his group published a short paper confirming Heinrich's results in a core taken close to Heinrich's original study area. It was in this this work that Broecker coined the term 'Heinrich event' – in fact, these coarse layers had been encountered in deep-sea sediments since 1972, but they had remained a puzzle until Heinrich recognized their significance.

Broecker also convened a small conference on Heinrich events in the spring of 1992 at Lamont-Doherty Geological Observatory, just outside New York. At that time, I was investigating these events as part of my PhD research in Cambridge, and through the academic grapevine Wally Broecker heard of my work and invited me to speak at the Lamont conference. The upshot of the conference was a paper published later that year, including the contributions of some of

the scientists who attended the conference. They suggested that Heinrich events had had a profound effect on the surface waters of the North Atlantic, lowering both the salinity and the productivity. They also concluded that the events were extremely rapid. Radiocarbon dating of the calcium carbonate in the shells of microfossils from sediments just above and below the coarse layers showed that their durations were shorter than the limits of error of the radiocarbon dates. It is therefore not possible to determine with any confidence whether the events last two centuries or a decade – either way, they are extremely rapid on a geological time-scale.

The palaeoceanography group at Cambridge decided that it was important to try and understand the causes and effects of these events. Material for our investigations was provided by the Cambridge participants in the Biogeochemical Ocean Flux Study (BOFS), Britain's contribution to the international Joint Global Ocean Flux Study (JGOFS). Our research confirmed that the most recent Heinrich events were represented in our deep sea cores and that they had had a significant effect on the temperature and salinity of the surface waters of the north-east Atlantic Ocean (Figure 1).

It is possible to reconstruct past surface water temperature by counting the relative abundances of different species of planktonic foraminiferan microfossils, whose pin-head sized calcite shells are preserved in the sediment. Each species inhabits a different sea-surface temperature range, so any assemblage of planktonic foraminiferans will indicate a unique temperature. Using this method it was possible to estimate the sea-surface temperature within an error of ± 1 °C for the North Atlantic for the last 40 000 years.

More environmental information can be obtained by analysing the ratio of the different natural isotopes of oxygen in the foraminiferan shells. From the oxygen isotopes and the temperature estimates it is possible to reconstruct the salinity of the surface waters (see the Box overleaf for a more detailed explanation). Figure 1 shows that during the Heinrich events temperature was generally lower than normal and the salinity much lower, consistent with the melting of a great volume of icebergs. This in turn raises two further questions: where did so many icebergs come from, and how did they get to the middle of the Atlantic Ocean?

To answer these questions we first had to investigate how the circulation of the North Atlantic during the last glacial period differed from its present pattern, which is dominated by the warm salty water of the Gulf Stream and its extension, the North Atlantic Drift. This acts as a thermal barrier to the polar and subpolar waters which are confined to the far north-west Atlantic, i.e. north of the Polar Front, where cold northern waters meet warm waters from the south.

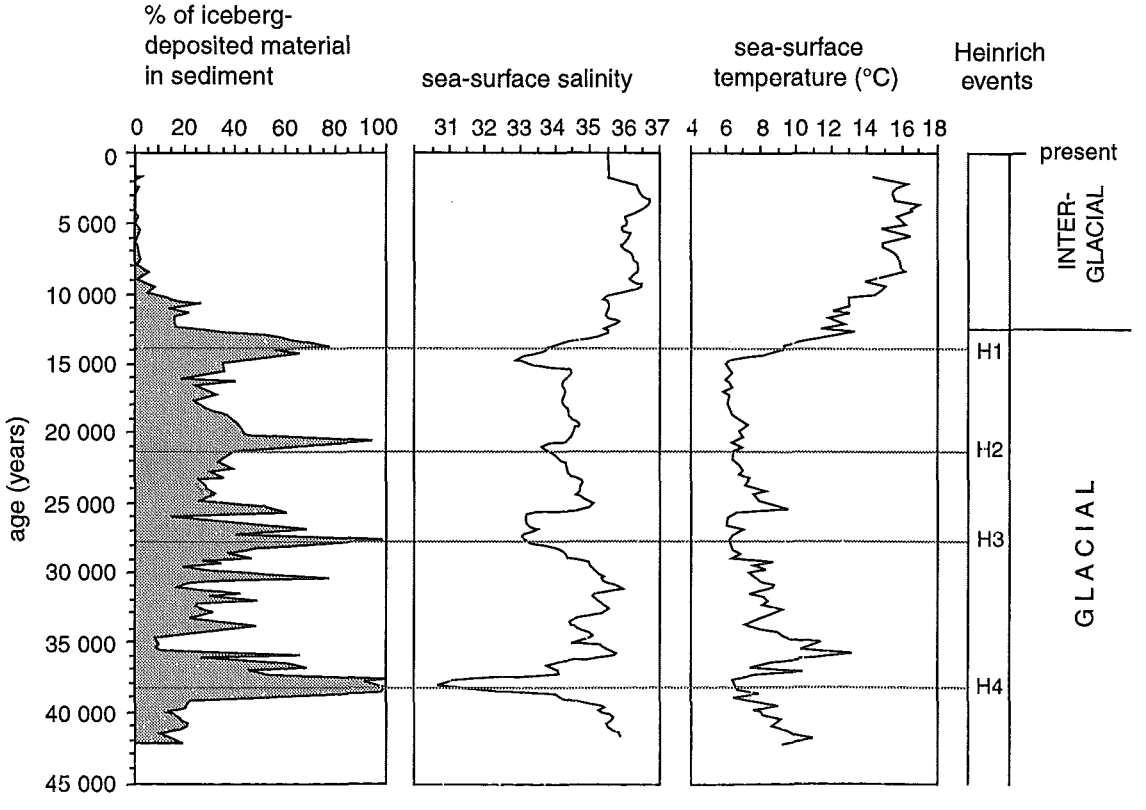


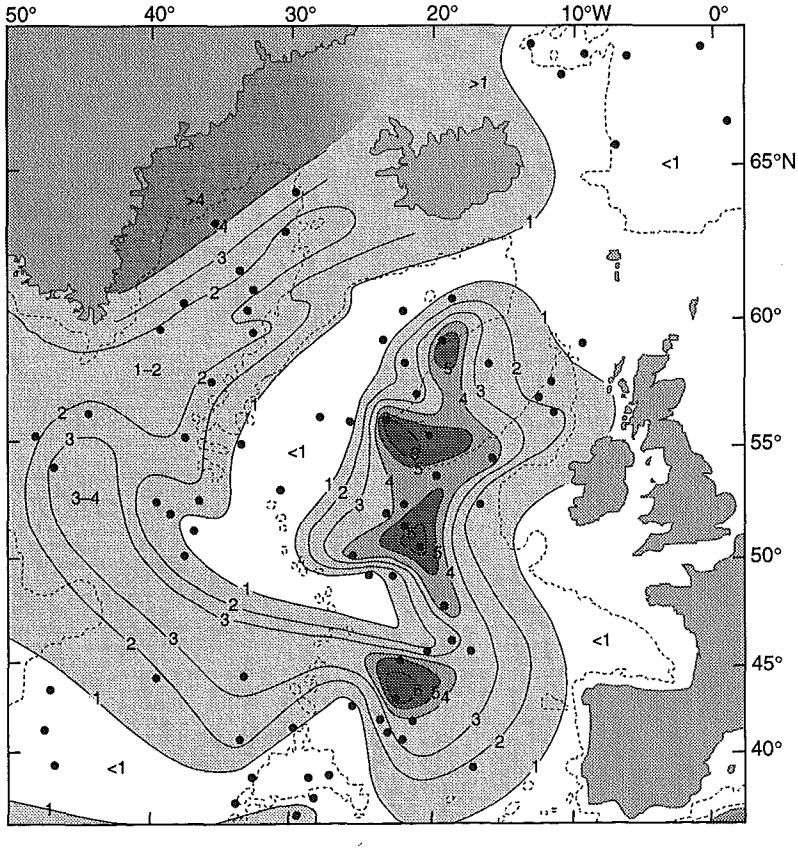
Figure 1 *Reconstruction based on sediment from core BOFS 5K, indicating the amount of coarse material deposited by icebergs, which is related to the volume of melting icebergs in surface waters, and the sea-surface temperature and salinity of the north-east Atlantic Ocean during the last 40 000 years. Note that the error range for sea-surface temperature is ±1 °C and that for sea-surface salinity is ±0.5. For the location of this core, see Figure 3.*

During Heinrich events, both sea-surface temperature and salinity were lower, due to the melting of vast quantities of icebergs

A useful tracer of melt-out from icebergs is the magnetic susceptibility of the sediments. This is a measure of how easily the particles in a sediment can acquire a magnetic field (i.e. become magnetized). In North Atlantic sediments it is primarily a measure of the amounts of rock and soil, which are rich in iron compounds, that have been eroded from the adjacent continents and dumped in the ocean; the other major component, the biogenic material, has a small magnetic susceptibility signal, or none at all. The magnetic susceptibility response increases with increasing grain size, so it is an ideal tool for estimating the amount of ice-rafted debris in the sediment without having to count the grains. We have a large number of deep-sea magnetic susceptibility sediment records which enable us to map the deposition of sediment from melting icebergs in the North Atlantic Ocean during the last glacial period, and thus reconstruct ocean circulation.

Figure 2 shows a broad area of maximum magnetic susceptibility south of Iceland which, with progressively decreasing values of magnetic susceptibility, curves to the west off Iberia and then northwards back towards Iceland. Icebergs are transported by the prevailing surface currents, so the contoured magnetic susceptibility map must reflect the dominant surface circulation at the time, with current flow in the direction of *increasing* susceptibility (see Figure 3 opposite).

Magnetic susceptibility of sediments provides a record of the tracks of melting icebergs



The distribution of magnetic susceptibility values indicates that maximum melt-out occcurred along the broad region south of Iceland. This in turn suggests that during the last glacial period, the polar front and the Gulf Stream were further to the south than they are now (at about the latitude of Iberia, in fact) and that there was anticlockwise circulation in the northern North Atlantic Ocean. The progressive anticlockwise increase in magnetic susceptibility round this circulation going south from Greenland further indicates that the iceberg debris found in the north-east Atlantic sediments was transported from the North American continent, which at that time was covered by an immense ice-sheet. Heinrich events would therefore have been caused by surging of this ice-sheet. For the icebergs to have survived and have had such a significant effect on surface waters of the north-east Atlantic, so far away from their source, they must have been both large and numerous. Icebergs as large as those that broke from the Antarctic Filchner Ice Sheet in 1986 could have been a frequent occurrence.

At the present time, surface water in the North Atlantic Drift flows northwards and is cooled so that its density increases and it sinks forming North Atlantic Deep Water, which then flows southward towards the Antarctic. This 'conveyer belt' for heat (and salt) is an essential part of the mechanism for heat-exchange between high and low latitudes. Broecker has suggested that transport by this conveyor belt was reduced during the last glacial period, so that less heat was released by sinking water, which helped to maintain the cooler climate. He further suggested that during Heinrich events the freshwater input from melting icebergs may have prevented surface water from becoming sufficiently dense to sink, however cold it got, thus further reducing deep-water formation and northwards heat transfer, and promoting still colder conditions in the North Atlantic area. Evidence that supports this proposition has recently been found in Greenland ice cores, which have shown that during Heinrich events air temperatures over Greenland fell by 7 °C, consistent with an increased severity of the Northern Hemisphere climate during these events. It seems that periodic surges of the North American ice-sheet could thus have had a major impact on the global climate.

Figure 2 *Contoured distribution of the ratio of magnetic susceptibility of sediments deposited at the last glacial maximum (20 000 years ago) to the average for sediments deposited during the Holocene (i.e. over the last 10 000 years). The shaded region shows where the predominant deposition of ice-rafted debris occurred, indicating the track of the melting icebergs. The dashed line is the 1000 fathom isobath. Dots indicate deep-sea cores used in the 1995 study by Robinson, Maslin and McCave, from which this figure is taken. (Compare with Figure 3 opposite.)*

Oxygen isotopes and salinity

The two common isotopes of oxygen are oxygen-16 and oxygen-18 (i.e. they have mass numbers of 16 and 18). When foraminiferans build their calcium carbonate ($CaCO_3$) shells, the shells record the relative abundance of ^{16}O and ^{18}O in the surrounding seawater, although the ratio also depends to some extent on temperature. When planktonic foraminiferans die they sink to the sea-bed where their carbonate skeletons may be preserved. We extract the shells from the ocean floor sediment and measure their $^{16}O:^{18}O$ ratio using a mass spectrometer. As we have estimated the sea-surface temperatures at our sites using the relative abundances of different species of planktonic foraminiferans (see text), we can remove the effect of temperature on the oxygen isotope ratio.

Globally, the oxygen isotope ratio varies according to the amount of water contained in the ice-sheets. The water that formed the huge ice-sheets of the last glacial period had evaporated from the surface of the ocean (mainly at low latitudes) and was transported through the atmosphere to high latitudes where it was deposited as snow. Because of the mass difference between the two isotopes, ^{16}O (the lighter isotope) is preferentially removed during evaporation. As the water vapour is transported poleward within the atmosphere, much of it condenses and is precipitated as rain, which contains more ^{18}O (the heavier isotope). The water that eventually reaches polar regions to be precipitated as snow is thus greatly enriched in ^{16}O. When the ice-sheets expand during glacial periods they act as a growing store for ^{16}O, while the ocean becomes enriched in ^{18}O. The oxygen isotope ratio in foraminiferan shells formed during cold glacial periods is thus 'heavier' ($^{18}O/^{16}O$ greater) than the ratio in foraminiferan shells formed during warm interglacial periods

In the north-east Atlantic, the input of meltwater from icebergs would have caused regional variations in the oxygen isotope ratio in the shells of foraminiferans. This is because surface waters would have been variably diluted by melt water originating from the North American ice-sheet, which was highly enriched in ^{16}O. By removing first the known global effect on the oxygen isotope record due to variationsin the total volume of ice-sheets, and then the regional effect caused by temperature variations, and knowing what the oxygen isotope composition of the icebergs was from studies of the North American ice-sheet, we were able to estimate the true salinity of the surface waters from our oxygen isotope record. Figure 1 shows that the salinity of surface waters of the north-east Atlantic decreased considerably during the Heinrich events, which suggests that the events must have produced an enormous amount of meltwater.

What caused these massive surges? It is well established that long-term fluctuations in climate between warm interglacial and cold glacial periods have been controlled externally. Periodic changes in the Earth's orbit affect the total energy received from the Sun, and its regional distribution, sufficiently to force the climate system from one stable state to another. Hartmut Heinrich originally suggested that minor variations in the Earth's orbital parameters decreased the solar energy received by the North American ice-sheet. Lower heat inputs to the ice-sheet would allow it to grow, pushing more ice out into the ocean, thus causing the increase in icebergs that led to Heinrich events. Broecker has called this the 'Denton Model' after George Denton who found that the glaciers of the Chilean Andes in South America also expanded when Heinrich events occurred. In an extensive article in *Science* in 1995, Lowell *et al.* confirmed this finding and suggested a global climate forcing as the cause, on the grounds that it would not be possible for teleconnections to link the North Atlantic and the Southern Andes (see Further Reading). Recent modelling work has shown that there are harmonics of the orbital parameters which correspond approximately with the timing of the Heinrich events.

Reconstruction of the circulation of the North Atlantic 20 000 years ago, during the last glacial period

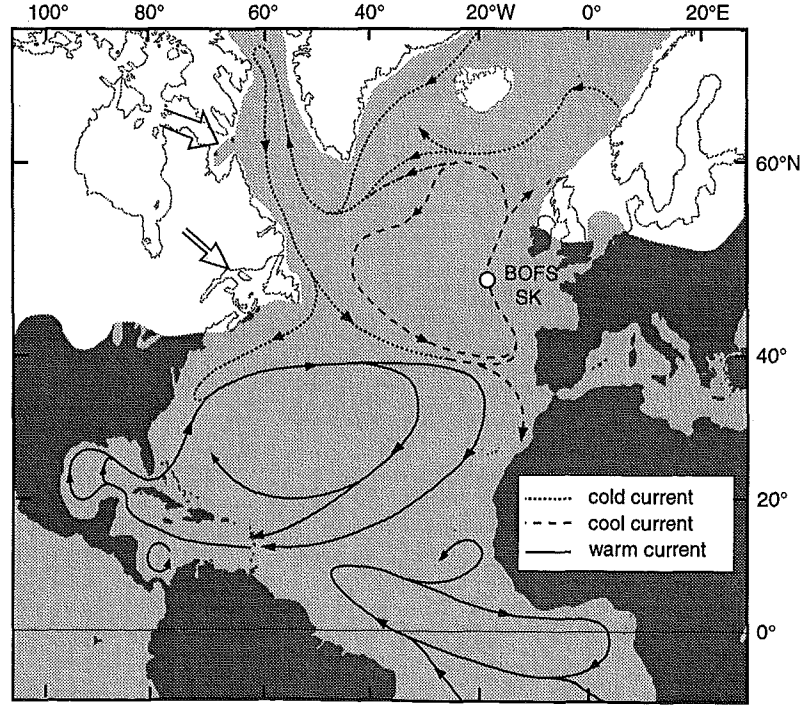


Figure 3 *Reconstruction of the circulation of the North Atlantic during the last glacial period based on the magnetic susceptibility data shown in Figure 2, an extensive literature review of circulation patterns for adjacent areas, and ocean circulation modelling. Note (1) the anticlockwise subpolar gyre above 40°N, (2) the compressed subtropical gyre and (3) the rather limited cross-equatorial transport. The large arrows indicate the possible routes of ice-streams via which the icebergs that gave rise to the Heinrich events were fed into the North Atlantic.*

An alternative theory has been put forward by Dr Douglas MacAyeal (University of Chicago). He suggests that surges of the North American ice-sheet were caused by internal instabilities of the ice-sheet, which rested on a bed of soft unconsolidated sediment. When frozen, the sediment would not deform and would have been able to support the growing ice-sheet. As the ice-sheet expanded, however, geothermal heat from the Earth's crust would have been trapped by the insulating effect of the overlying ice, and the temperature of the sediment increased until a critical point was reached, when it thawed. The sediment became soft, lubricating the base of the ice-sheet and causing a massive outflow of ice through the Hudson Strait into the North Atlantic. Once the thickness of the ice-sheet was sufficiently reduced, the insulating effect declined, the sediment refroze and the outflow ceased. This cycle of natural build-up, melting and surge, followed by renewed build-up, has an approximate periodicity of 7 000 years in McAyeal's theoretical analysis. This is about right for the timing of Heinrich events as recorded in deep sea cores (cf. Figure 1).

My preference is for the second model, as this seems to explain the rapid onset of these events indicated by the sediments. X-ray photographs of deep-sea cores from the North Atlantic show that the uppermost tier of burrows is preserved in the sediment immediately below the Heinrich layers. This suggests that the Heinrich events started very abruptly and that deposition of coarser material from the icebergs was so fast (rates of a few cm per year, ten times greater than normal) that benthic organisms were effectively drowned in sediment.

Two recent geochemical studies have attempted to solve the 'mechanism' problem by locating the source rocks of the ice-rafted fragments. If the source is highly localised, being confined to the Hudson Bay area, then the MacAyeal Model is most likely, but if the source is much wider, including Greenland and areas of North America, then the Denton Model is more plausible. However, the two studies have come to opposite conclusions, so the debate is still wide open.

Figure 4 (*opposite*) is a compilation map showing areas where Heinrich events have been studied and locations where climatic changes in the recent geological past have been linked to Heinrich events. Areas as far apart as the North Pacific and New Zealand seem to have been affected. At first sight, this would seem to strengthen the global climate change model. However, although the deep waters take over a thousand years to circulate around the globe (perhaps even longer during the last glacial), the 'signal' of a change at source can be transmitted throughout the conveyor belt system *within a century*. This is well within the error range of radiocarbon dating used to compare various sites. This argument negates the objection put forward by proponents of the Denton Model, i.e. that teleconnections could not transmit the Heinrich events as a global signal.

I believe our recent knowledge of the global effects of El Niño–Southern Oscillation events indicates that there are very few limits to climate teleconnections. In other words, the 'sheet surge' model of McAyeal remains valid.

Research into Heinrich events may have some interesting implications for the present. It has been suggested that with global warming, there is now a real threat that the Greenland and Antarctic ice-sheets could become unstable. Julian Dowdeswell (of the Scott Polar Research Institute, Cambridge University) suggests that Heinrich events show large ice-sheets to be naturally unstable on time-scales of centuries, which is the time-scale of human history. However, he stresses that the McAyeal mechanism for Heinrich events is unlikely to be applicable to the present day Greenland or Antarctic ice-sheets because, unlike the North American ice-sheet of the last glacial, they do not rest on unconsolidated sediment. Moreover, there is no geological evidence that these ice-sheets have ever surged periodically in the past and thus are unlikely ever to have produced 'Heinrich-type' events.

A simple mechanism which could cause the present ice-sheets to become unstable has been suggested by Geoff Boulton of Edinburgh University. At present, much of the ice discharged from the Greenland and Antarctic ice-sheets is through 'ice-streams', relatively fast moving corridors of ice within the ice sheet (cf. Figure 3). At present they make up only 15% of the total volume of the Antarctic ice-sheet but account for over 85% of the mass of ice discharged into the Southern Ocean. With increased global warming, melting of the ice-sheets will cause sea-level to rise. Many of the ice-streams have tongues of ice which float on the ocean surface, and with rising sea-level more of the ice-stream inshore will be raised up. In each case, that would reduce the amount of friction between the ice-stream and its base, allowing it to move faster and to draw down more ice from its flanks to continue feeding the increased discharge. Geoff Boulton speculates that this could lead to a runaway positive feedback mechanism, with rising sea-level causing greater ice-stream discharge, leading to further rises of sea level, and so on.

From what we have gleaned from our researches into the nature of ice-sheets, it seems that if rapid Heinrich-type surging were to occur, we would have very little warning. Large numbers of melting icebergs in the North Atlantic or the Southern Ocean could reduce deep-water formation, significantly affecting the heat exchange between the tropics and the poles, which would have profound and unpredictable effects on global

climate. Ice-sheet surging could even be countered by cooling at the poles, which could be sufficient to promote the build-up of ice. Further research into the interactions between ice-sheets and the oceans is essential because at the moment we just do not know what might happen in the future.

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Editorial comment

Temperatures in the Arctic have risen by more than the global average in recent decades, and scientists from the Scott Polar Research Institute have found that icebergs moving south from the Arctic Ocean are starting to melt much further north than they used to. This raises the question of whether rapid global warming could produce 'fleets' of icebergs large enough to reduce deep-water formation in the North Atlantic.

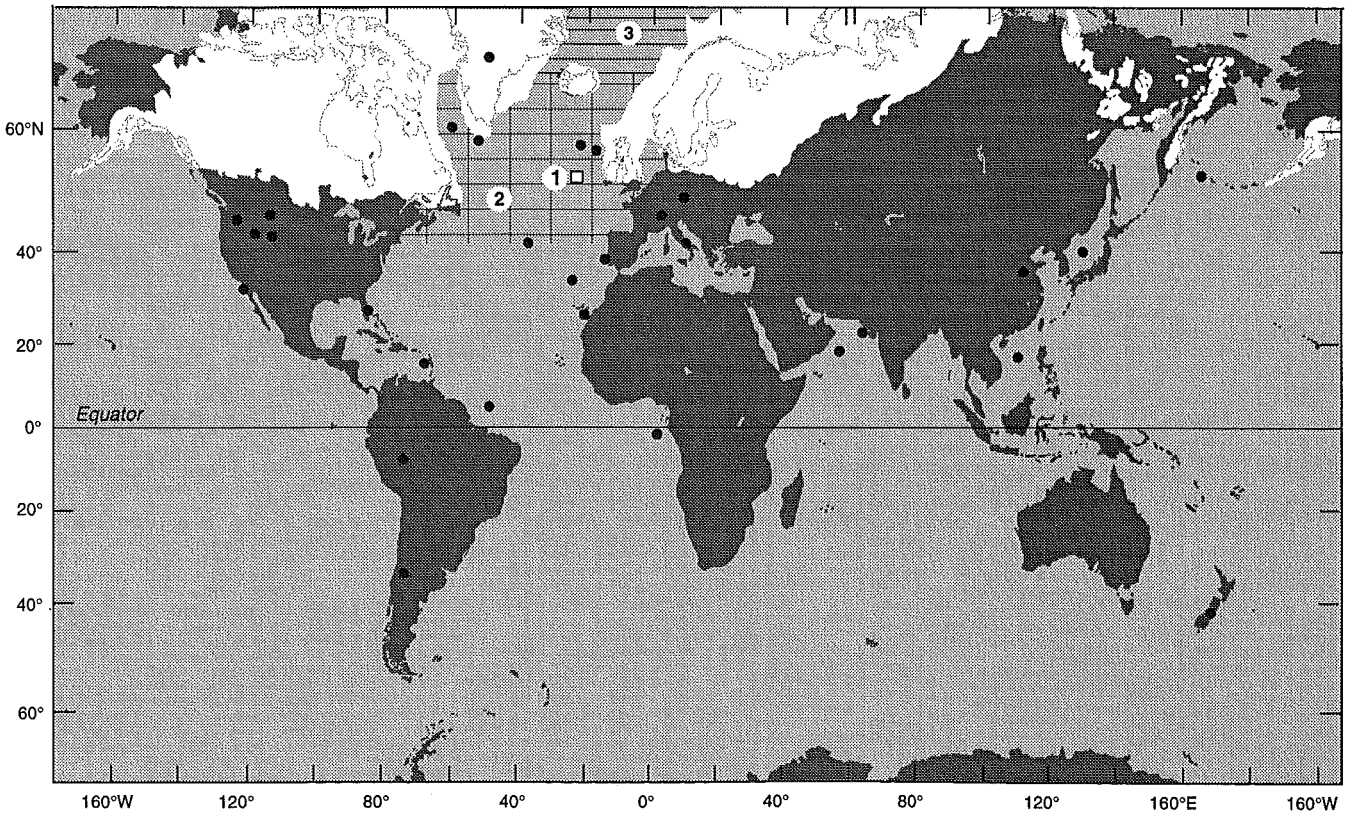
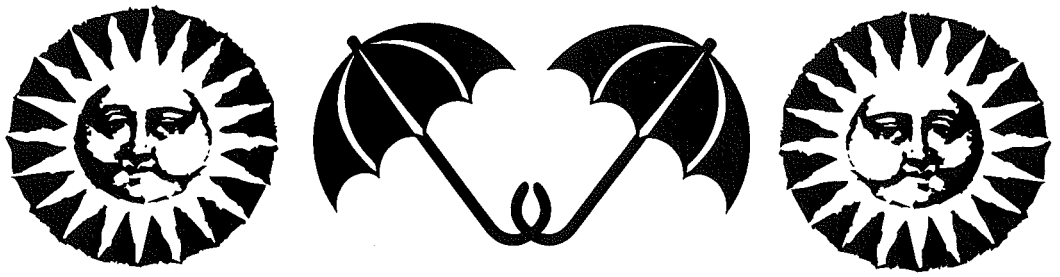
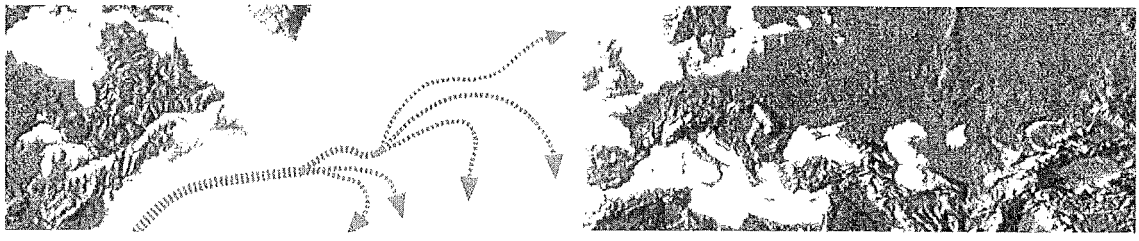


Figure 4 *Compilation map showing study areas and sites (dots) where local climatic and/or environmental change has been linked to Heinrich. events. 1: The location of the original Heinrich study. 2: The North Atlantic, which has been the subject of a number of extensive studies (see also Lehman (1996)) in Further Reading); 3: The polar ocean where an extensive study by Prof. Sarnthein (Kiel University) has shown that the Fenno-Scandinavian ice-sheet seems to have surged at different times from the Heinrich events. (The Southern Hemisphere ice-sheet is not shown.)*



Climate links across the North Atlantic



Brenda Topliss

The desire to 'see' relationships between climate and the environment has itself undergone periodicity in being fashionable. Now, as major changes in weather patterns often result in large financial losses for companies and individuals, the search for patterns in the world's climate has potential monetary benefits as well as satisfying scientific curiosity.

Some have argued that the climate system is far too complex and chaotic to be reduced to a simple series of cycles. This is in part true. External forcing agents (i.e. driving mechanisms) can, of course, influence the Earth's climate, and range from those related to the occurrence of a glacial period to the annual solar heating cycle. But most other cycles are more elusive. For example, the finding of an 11-year cycle in any dataset immediately raises the possibility of links to the 11-year sunspot cycle. Several publications have shown an apparent relationship between sunspot cycles and ocean- and ice-related parameters. However, many such 'climate correlations' have an unfortunate tendency to disappear when a study is extended in either time or space.

A multidisciplinary approach to verifying the occurrence of climate signals in the environment can often help provide supporting evidence for otherwise 'isolated correlations'. More importantly, a multidisciplinary approach offers a better means of identifying causal processes. Also, with increasing electronic access to global databases it is now possible to investigate correlations in time and space.

Oceanographers have a strong interest in the Gulf Stream as the largest surface feature in the North Atlantic. How might such a feature either control or respond to climate changes? This article deals with an exploratory study which looks at climate signals in different parts of the environment, not to firmly prove a distinctive relationship, but to explore ideas and ask questions.

Gulf Stream position as a climatic index

The United Kingdom is at the same latitude as Labrador, on the east coast of Canada. In Labrador, winter temperatures can reach −40 °C, but even non-scientists in Britain have a general understanding that they do not suffer such a climate because the British Isles receive some benefit from the Gulf Stream.

The changing position of the Gulf Stream can be charted from changes in sea-surface temperature contours. Since 1966, a time-series of observations has been built up from a composite of satellite and ship-based observations. From that time-series, annual mean positions of the Gulf Stream can be derived – some years the Gulf Stream may be slightly further north, other years it may be slightly further south. Those mean positions are used to determine a Gulf Stream index (*GS*) which has been used in several climatological studies. The more the Gulf Stream is displaced to the north relative to its long-term average position, the more positive the index; the further the Gulf Stream is displaced to the south relative to its long-term average position, the more negative the index.

Where have correlations been found?

Over the last ten years some striking climatic-signal studies have identified correlations between certain marine parameters, namely zooplankton abundance and *GS* (see later). The best correlations occur in the case of certain regions of the North Sea (see Figure 5).

Recently, land scientists have published correlations between Gulf Stream position and various species of plants growing in controlled plots in Gloucestershire. Possibly the strongest correlation was found between *GS* and annual zooplankton abundance in Lake Windemere in the Lake District, England. A mechanism has ben suggested that relates the two signals through over-turning and stratification of the Lake's water column.

But why this concentration of Gulf Stream work around Britain? Where are the French and Spanish studies? Are not these locations just as likely to be affected by the Gulf Stream? And what about Germany, Norway and Ireland? What and where are the null studies – difficult to publish but sometimes just as important?

The signal was first observed in the North Sea zooplankton population, so why has nothing – either positive or a null result – been published for that signal occurring in the corresponding phytoplankton populations? (Studies by others, completed since this article was submitted, indicate that the trigger for the spring blooms in the Irish Sea may include some influence of the Gulf Stream; but see Discussion.)

Over on the Canadian side the emphasis on Gulf Stream studies has been on whether or not increased Gulf Stream 'ring' and 'streamer' activities impact the fishing banks, pulling off larvae, eggs and/or nutrients, as filaments of the Gulf Stream detach or break away. These studies have often been largely inconclusive, possibly because of the extreme complexity of the problems being investigated.

How do climatic indices behave?

Before we look at the Gulf Stream data, it would help to become familiar with what exactly climatic indices are and how they influence life around the North Atlantic. The major climatic/weather phenomenon influencing the North Atlantic is the North Atlantic Oscillation, or NAO for short. The NAO index is *classically* derived from the pressure difference between Iceland and the Azores for the winter months of December–January–February.

Figure 1 is a spatial probability map. It shows the varying degree of probability of finding a relationship between January air temperatures and the NAO index for the period 1966 to 1993. Different shadings have been used to indicate those areas where the relationship between temperature and the NAO index is likely to be positive and those regions where that relationship is likely to be negative. Hence Figure 1 shows that for a 'stronger' NAO (larger positive values), January is likely to be warmer over the UK but colder over on the Canadian side. This up–down pattern is termed a 'see-saw' in NAO literature. If you, dear European reader, have a mild winter then it is likely that I am busy digging my car out of yet another snow fall.

The stronger the NAO, the warmer winters are in Europe and the colder they are over eastern Canada

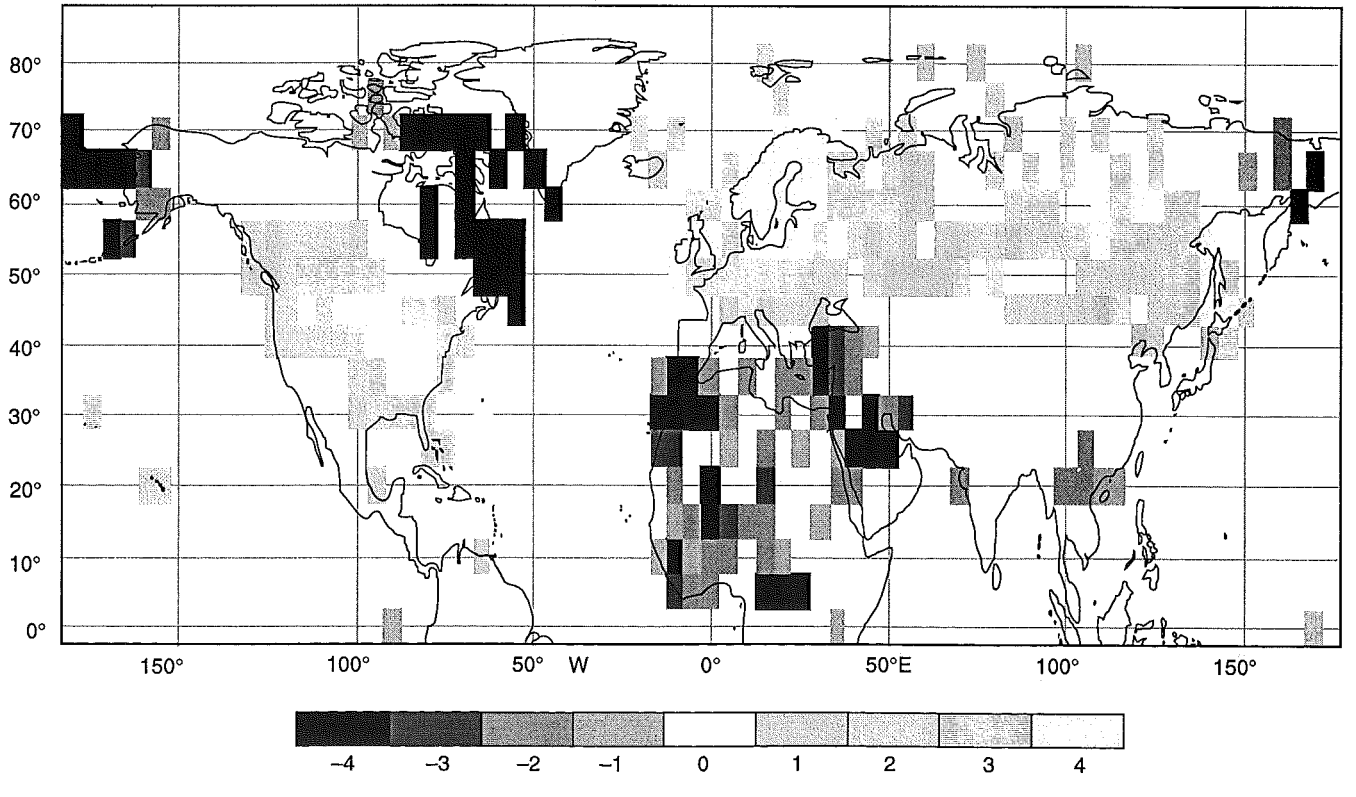


Figure 1 *Spatial variation of the probability of finding an NAO-like correlation in any January air temperature record for the period 1966 to 1993. Areas with a high probability of finding such a relationship in a positive sense (i.e. higher UK temperatures correlating with higher positive values of the NAO index) are shown in light greys, in a negative sense in black/dark greys. These areas result in a sea-saw pattern across the Atlantic, as described in the text.*

There are also apparently similar pairs of 'warm' and 'cold' (up–down) regions over the USA and northern Africa. These regions form part of a counter system to the NAO (sometimes refered to as the 'lower NAO system') as well as being governed by other climate indices centred around the Bermuda High. But this similarity between the UK warm region (influenced by the upper NAO system) and the warm region all long the US eastern seaboard (influenced by the lower NAO system) must raise the question as to how Gulf Stream relationships might occur; from symmetry between the climatic regions? Such links are termed *teleconnections*.

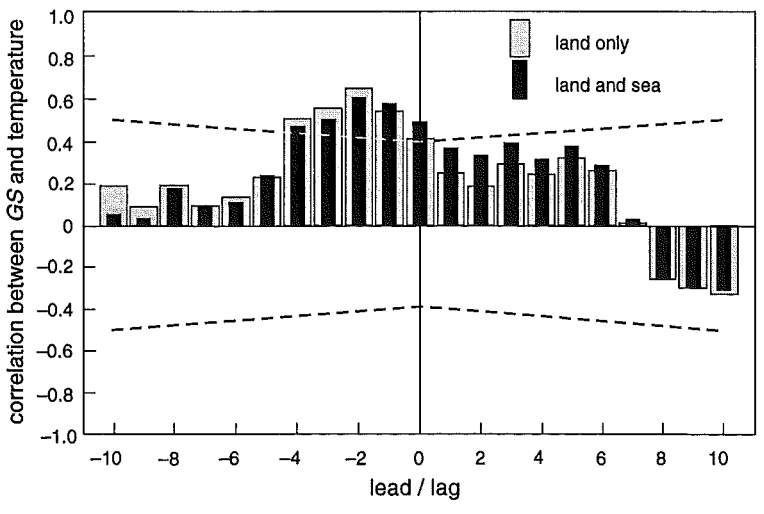
It is worth exploring the possibility that the Gulf Stream might not have to actually reach the UK either by sea or air in order for its position to appear to correlate with regional land and marine parameters. Several mathematical models have been run to try and determine what transport mechanisms – atmospheric or oceanic, would bring that signal into UK waters. However, these are complex processes and strong evidence is still lacking.

Looking for a local *GS*-like index

The possibility raised above starts us searching for locally occurring Gulf Stream-like signals. Figure 2 shows the cross-correlation series between *GS* and the Northern Hemisphere surface temperature time-series, for land only and for the combined land and marine (sea-surface) temperature data. The correlations are shown for leads and lags of up to 10 years.

Figure 2 indicates that the air temperatures in the Northern Hemisphere *lead* the Gulf Stream position by two years! Does the Gulf Stream respond to a climatic signal but take up to three years to do so? Similar lagged correlations exist with the NAO but are not as strong, and there is also evidence of similar lagged behaviour for *GS* with several of the Lamb indices (purely UK indices formed by classifying the daily weather system over the UK).

Changes in Northern Hemisphere air temperatures occur before apparently related changes in the position of the Gulf Stream



All the published findings of *GS* relationships in the environment have indicated direct relationships, not lagged relationships; everything happened in the same year. Therefore, for the rest of this text any proposed explanation of how *GS* is related to any parameter will involve a three year integration of the selected climatic variables.

Simulating a UK-local Gulf Stream

A multiple regression between *GS* and UK Lamb indices can reproduce the *GS* signal to an adjusted variance of 80%. (Adjusted correlations take account of the increasing number of variables added (or reduction in degrees of freedom); if as many variables as data points were used, thereby apparently *explaining* 100% of the variance, the *adjusted* explained variance would be 0%.) The multiple regression can be written:

$$GS = \Sigma_3 (W_{DJF}) - \Sigma_3 (NW_{NDJ}) - 4\Sigma_3 (CW_{FMA})$$

W_{DJF} – days with westerlies in December–February

NW_{NDJ} – days with north-westerlies in November–January

CW_{FMA} – days with cyclonic westerlies in February–April

This regression combines the effects of the winter westerly Lamb indices with north-westerlies and cyclonic westerlies, but for different months in each case; each seasonal component is integrated over three years. Using the winter westerlies alone would only reproduce 47% of the variance of *GS*. This idea of using a combination of influences from different seasons will come up again later with other environmental variables.

Spatial patterns of rain and temperature

Air temperature had the highest single correlation with *GS* so it is logical to turn to that parameter when looking for other Gulf Stream-like signals. What may at first sight be less obvious is to incorporate rainfall into the same analysis. Rainfall itself may have a bearing on land-based studies but it is hard to see what the connection would be for the marine environment. But to cut a long story short, rainfall does play a key role in the following analysis and for the marine environment we presume the connection is through climatic patterns.

Figure 2 *Cross-correlation between the GS index and Northern Hemisphere temperatures for the years when GS has been calculated. The dotted lines represent the upper and lower 95% confidence limits outside which correlations are significant.*

The spatial probability plot, Figure 3, is a little more complex to interpret than the previous map. It combines the winter seasonal rainfall anomaly with the spring seasonal temperature anomaly; both have been integrated over three years and then correlated with the *GS* index. In this map, each type of shading indicates a single high level (95%) of probability of finding a certain combination of warm/cold and/or wet/dry weather correlating with *GS*. The pattern is very clear over Europe where there is a banding pattern of probabilities with *GS*; as the Gulf Stream moves further north (*GS* more positive) the rain/temperature relationships form bands as follows, starting in the north: wetter weather (over the Shetlands); then warmer/wetter weather; then warmer weather, and finally warmer/drier weather (over north Africa and southern Europe).

The only other region (not shown) to exhibit a warmer/wetter relationship with high *GS* is in the US, in the vicinity of Cape Hatteras where the Gulf Stream breaks away from the coastal region and starts its journey across the Atlantic. Over the east coast of Canada (not shown) a positive Gulf Stream signal might be associated with drier winters.

Canadian simulations of *GS* Signals

It now looks as though Gulf Stream-like signals could be 'floating' around Europe in quite a few parameters: in the winds through the Lamb indices, in the spring air temperature, in the winter rainfall, and hence in the associated pressure systems. So what about the Canadian side of the Atlantic? Can we find signs of a *GS*-like index there? Figure 4 compares the original Gulf Stream signal with one simulated solely from east coast Canadian rainfall and temperature data.

From a purely statistical point of view, we have all the *elements* which might relate to a *GS* variation detectable on the Canadian side, that is, on the western side of the upper NAO teleconnection system. If theories or mechanisms are proposed for transferring the Gulf Stream signal to the UK environment, they would also need to accommodate the presence of these potential elements on the Canadian side.

Whether nature ever combines these 'Canadian' elements in the same way as the regression equation is another question. As yet, Canadian data similar to the UK environmental data do not exist. Also, such signals may occur in the Canadian environment, but as secondary signals. For example, the Gulf Stream signal may be masked by effects on

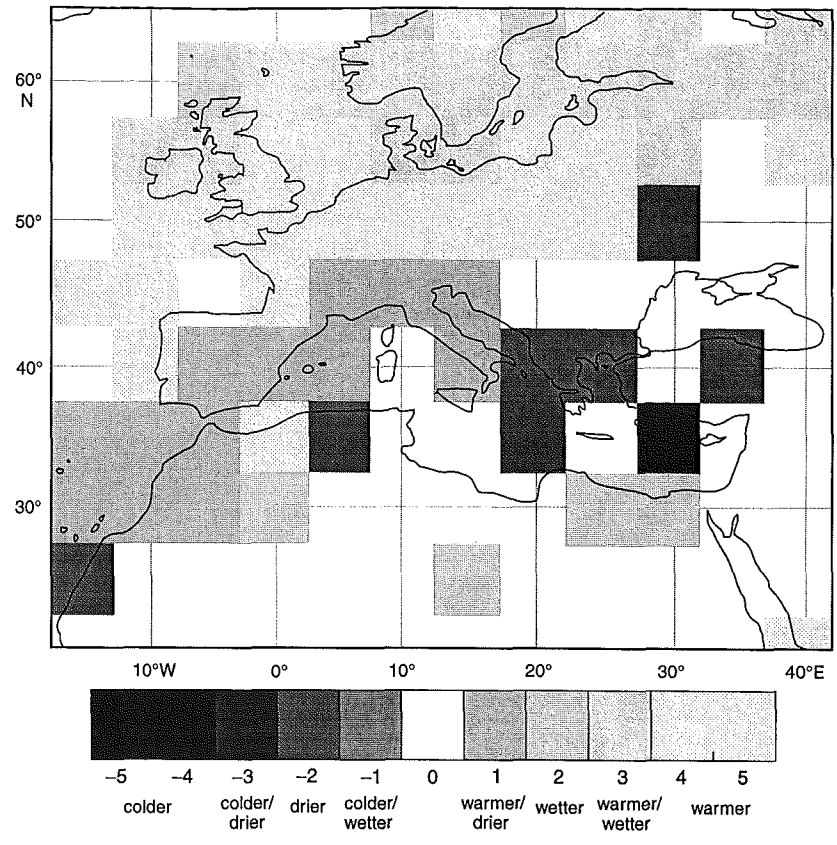


Figure 3 *Spatial probability map of relationships between GS and the three-year integration of winter rainfall and spring air temperatures. Each type of shading represents the influence of one of the factors alone, or a combination of both factors, in either a positive or negative sense (see text).*

The further north the Gulf Stream, the warmer and wetter it is over mainland Britain, and the warmer and drier it is over north Africa

the life-cycle of land plants as a result of being frozen or, conversely, covered by a protective snow layer, at a critical time during the winter.

Regression patterns

If a local Gulf Stream-like signal can be created from regional Lamb, rainfall and temperature data then it is logical to check whether a direct regression between climate and environmental parameters could bypass the *GS* and then explain more of the data. Well, science usually refuses to be that straightforward. Using exactly the same variables that went into those local Gulf Stream indices does not work as well as using

Statistics might lead us to believe that Gulf Stream signals occur over eastern Canada

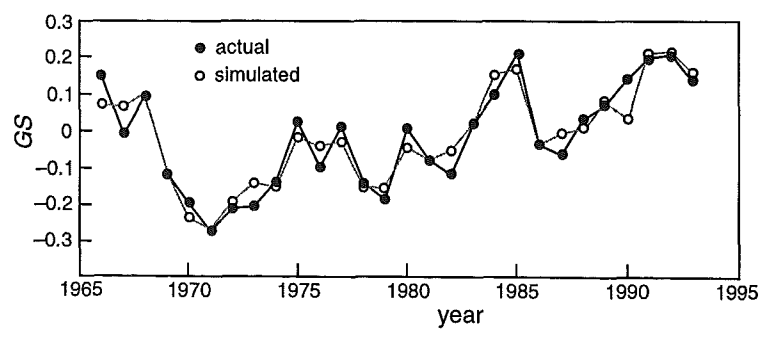


Figure 4 *Comparison of actual GS (filled circles) with a simulated GS (open circles) obtained from a regression against east coast Canadian rainfall and temperature data.*

Both terrestrial and marine observations suggest a 'diagonal' banding of related weather across northern Europe, the North Sea and the NE Atlantic

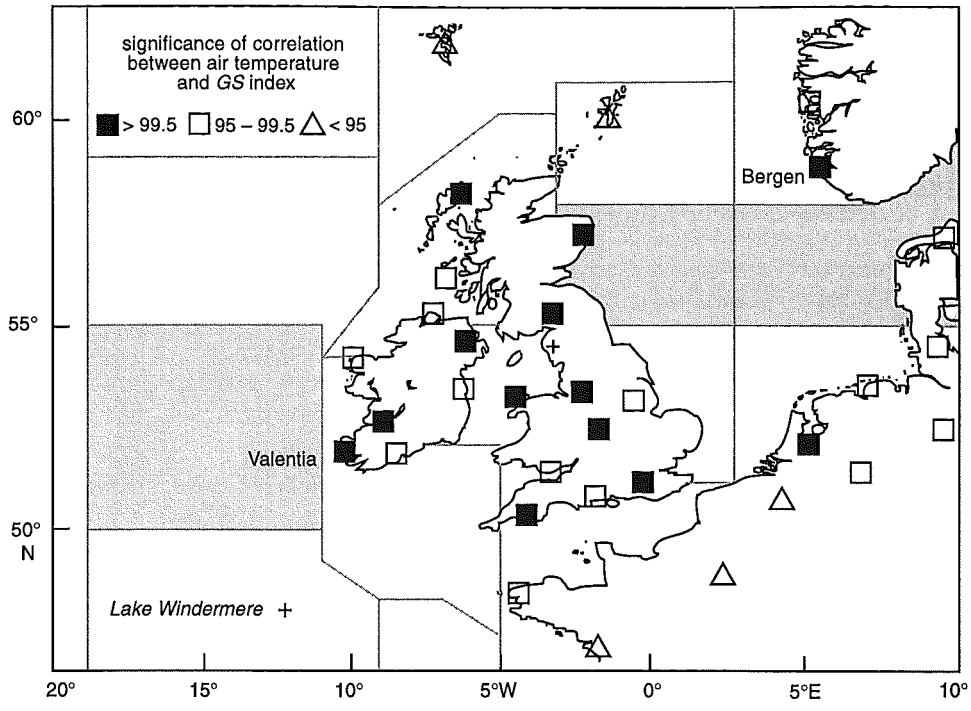


Figure 5 *The atmospheric spatial pattern of significant relationships between March air temperatures and GS along with the marine spatial pattern (toned regions) of greater than 50% explained variance from regressions of total copepod numbers and regional rainfall and temperature (all climate variables summed over three years).*

GS itself. How the Gulf Stream responds to and integrates the Northern Hemisphere climate seems to be part of the puzzle we have not yet fully unlocked.

A biological indicator that has proved to be useful for investigating climatic correlations is 'total copepod abundances', i.e. the sums of various different species of copepods (small crustaceans) as recorded from plankton tows conducted within different marine regions (marked out in Figure 5) by SAHFOS (Sir Alastair Hardy Foundation for Ocean Sciences) at Plymouth. If we give the marine (total copepod) regressions free reign to take any winter rain / spring temperature data from anywhere over the region (limited only by statistical tests on the significance of including yet another variable), we can obtain spatial patterns of maximum explained (adjusted) variance which look similar to published maps of *GS*–copepod correlations. One outer marine region, that to the west of Valentia, would be missing from our results.

Atmospheric and marine patterns

If we square the anomalies before going into the regression we get a slightly different map, but a more interesting one. The missing outer area comes back as significant and now there is an indication that the significant areas may line up into a geographic band (toned areas and black squares in Figure 5).

Why a squared formulation for the marine environment? A tenuous suggestion is that if the climatic variables of temperature, rainfall and frequency of wind-direction (the Lamb indices) all have a Gulf Stream-like signal potentially within them then so presumably would the wind stress (dimensionally the square of wind speed). So is that how a Gulf Stream-like signal has entered the local marine environment?

In order to check out this banding hypothesis, first clearly suggested by Figure 3, we needed to get away from the spatial coarseness of the gridded global data by looking at the individual station data; and for a finer temporal scale we needed to look at the monthly data. The relationship between *GS* and station air temperature peaks in the month of March. Figure 5 superimposes the significance of the correlations between the three-year integration of March air temperatures and *GS* onto the marine regression pattern. As mentioned above, the highest values for the land stations (the black squares in Figure 5) indicate that from Bergen, Norway to Valentia, Eire, there may be a band or region of optimal relationships. So perhaps Norway and Eire would find distinctive *GS*-like signals in their ecology; but for (say) France, perhaps a *GS* search might not be so straightforward.

Note the location of the Lake District with reference to the combined atmospheric–marine analysis of Figure 5. It falls almost in the centre of the band, within the region of highest values for land stations: Belfast, Valley, Manchester and Eskdalemuir. So Lake Windermere should be well situated to experience a really strong, linear relationship!

Is this band the climatological equivalent of the band of coherent wind stress associated with a climatological 'front'?

Discussion

Any statistical 'recreation' of a Gulf Stream-like signal has necessitated integrating variables over three years. Elements of Gulf Stream-like signals can be found in environmental parameters such as air temperature and rainfall on both sides of the North Atlantic.

Can the sign of the correlation between Gulf Stream-like signals and environmental signals provide any clues as to the actual transfer mechanisms? The two major aquatic occurrences of strong Gulf Stream-like signals, Lake Windermere and the northern North Sea, have *opposite* signs. Different signs in a relationship between *GS* and land species might relate to a preferential response for temperature or rainfall. How would a sign difference occur in an aquatic environment?

The spatial banding pattern of Figure 5 might not be quite complete. The Irish Sea lies in the same band as Lake Windermere. Hence by location alone it too ought to exhibit a strong *GS* relationship. The traditional Continuous Plankton Recorder (CPR) transects go from Liverpool to Dublin across both stratified and mixed regions. Could those regions respond to climate signals in different ways so that an overall statistical analysis for this marine 'box' loses the pattern? Or is there some more fundamental, species-related reason? Colleagues at the School of Ocean Sciences, Bangor, are following up those ideas.

Existing theories have only tackled how and where the Gulf Stream separates off from the US coastline. Little theory is available to explain how the passage of the Gulf Stream across the North Atlantic responds to the forces of nature, or if and how long it would take to respond to major climate changes in the Northern Hemisphere. It is assumed that the Gulf Stream would respond, either in parts or as a whole, to the curl – i.e. torque – of the wind stress (that squaring of dimensions again).

The *GS* index only goes back as far as 1966; the SAHFOS zooplankton records go back to 1948. The *GS*–Lamb indices regression equation can be used to provide a *GS*-like time-series for the 1948–1965 period. However, for that early period, no significant relationship is obtained between North Sea total abundance of copepods and such a Gulf Stream-like signal. There is either a sufficient change in the climate regime to invalidate extrapolating the regression equation or to invalidate the *GS*–environment relationship. Some climate publications noted a large-scale change in the climate regime for the upper atmosphere in about 1970.

Because this work has integrated climate variables over three years we must pay some attention to autocorrelation, that is, to the degree to which the value of a variable is related to its previous value (such as this year's weather being similar to last year's weather). However, I want to forget about autocorrelation as a correction factor and instead think of it as a concept which will allow us to ask yet more questions.

The March air temperatures show highest autocorrelation in the same spatial band as Figure 5. So the question is: if parts of the same signal are repeated over three years, do we not increase our chances of seeing that signal in the land and sea systems? More specifically, will we have increased our chances of identifying relationships via very simple linear statistical techniques? Is the ocean, and specifically the Gulf Stream, integrating part of the atmospheric climate signal and then feeding back into and reinforcing that pattern in certain seasons in certain locations?

Are there other climate integrators in the biosphere which could pick up this repeated pattern? Does any part of the marine or terrestrial environment integrate climate in a similar manner, over a similar time-frame or similar seasons to *GS*? To what extent does the fact that Gulf Stream signals were identified first in annual variations in total zooplankton populations, rather than phytoplankton, relate to any population behaviour such as overwintering? Would annual variations in perennial plant growth retain more *GS*-like signals than, say, annual plants? How would the abundance of annuals, perennials, and different moisture-tolerant or drought-tolerant land species respond to the temperature–rainfall *GS* banding pattern indicated over northern Europe in Figure 5? For Europe, this question is complicated by the occurence of an annual NAO pattern very similar to the Gulf Stream pattern; for Canada those two patterns interleave. Has Nature been giving us a 'sporting' chance to pick up a message by repeating that message?

continued

Last parting thoughts

(This article was written during the winter of 96/97)

Finally, I'd like to return to the NAO system which may 'teleconnect' eastern Canada and Europe during the winter. Using winter temperatures for the entire Northern Hemisphere it is possible to manipulate the data until a 'cycle' of periods of anomalous winters appears (Figure 6).

Do anomalous winters occur every 33 years?

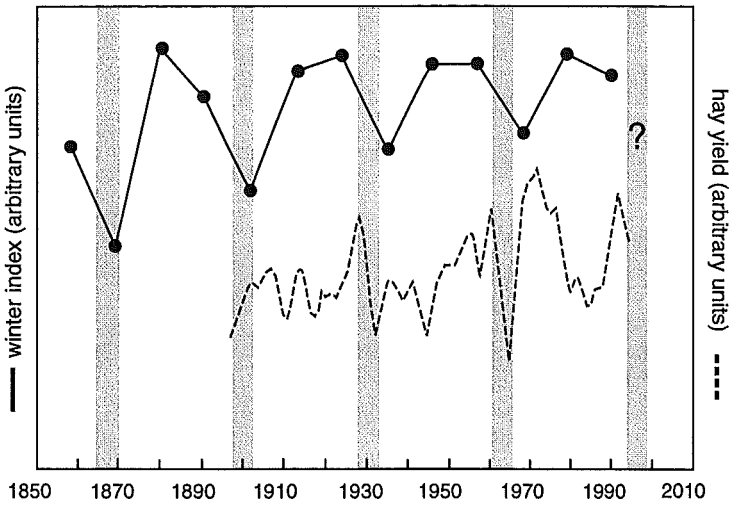


Figure 6 *Variations in winter climate (11-year averages plotted every 11 years) (solid) and smoothed variations in a component of hay yields (dashed) from Cockle Park, UK. A possible cyclicity is indicated by the toned vertical lines. The 'winter index' is a measure of how different winter temperatures are from the annual values.*

The 11-year sections of data analysis dip approximately every 33 years. The 11-year sections centred on 1935 and 1968 start with a period of low NAO: mild winters for eastern Canada and harsher winters for northern Europe. An analysis of hay yields at the Cockle Park Research Station, UK (undertaken to investigate how different crop treatments affected yield), indicated that those same periods may have been associated with underlying changes in the hay yield.

If such a cyclic pattern both existed and persisted, then the next 11-year section, centred on 2001, should include another period of anomalous local winters – starting when? For the winter of 1995/96 the NAO index stopped its rising trend and fell moderately – I only shovelled my car out of a snow drift three times. Was that just a random variation in the NAO or the start of another anomalous period? This 1996/97 winter, we on the Canadian side of the North Atlantic are experiencing what seems to be an even milder winter (at the time of writing – a snow-shovel score of one).

Nature's forces do not act in simple cycles; statistics do not tell us about cause and effect, and speculating from two variables, three numbers and my snow shovel is, of course, not 'good science'. But, dear European reader, just how anomalous was *your* 1996/97 winter?

Acknowledgements

This text is not a review of existing publications. It is in part the text of a talk first given at Oceanography '96 in Bangor and in part a preview of thoughts and work in progress. The present faults are all my own; I must acknowledge SAHFOS for access to the CPR data, Dr Robert Shiel for collaborative efforts with hay yield data, Southampton Oceanography Centre for help with software and Drs Arnold Taylor and Glen George for sharing their own work on this topic.

Further Reading

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Brenda Topliss is a physical oceanographer and works as a research scientist at the Bedford Institute of Oceanography.* Whilst normally working on many aspects of saterllite oceanogrpahy, she still retains a long-term interest in the long term (climate series) – and is always looking for ways of avoiding shovelling snow!

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Book Reviews

Power from the Waves by David Ross (1995). Oxford University Press, 212pp. £19.99 (hard cover, ISBN 0-19-856511-9).

This book incorporates and enlarges upon *Energy from the Waves* by the same author. It is aimed at the general reader rather than the specialist, but would nevertheless form a useful introduction to the science and technology of wave power for undergraduates interested in this area of renewable energy research. It is journalistic in style – which is not surprising since David Ross is a journalist – and relates the story of wave power from the early 1970s to the present. The first decade or so of this period saw the start and finish of the Department of Energy's wave power research and development programme, and throughout the book there is consideration of some of the issues which surround the funding by Government of R&D in difficult and 'unconventional' technologies.

David Ross is a committed advocate of wave power, and readers should not expect a bland or disinterested account of the interaction between the Department of Energy, their agents, the Energy Technology Support Unit who managed the programme, and the 'Device Teams', i.e. the scientists and engineers in universities and commercial organizations who carried out the design and experimental studies.

Government interest in renewable energy was precipitated by the Middle East war of 1973 and the subsequent rise in oil prices. Of the renewables, wave power was considered by many to be the most promising, mainly because of the size of the resource – certainly a substantial fraction of present UK electrical power consumption is available along the coasts of the British Isles. However – and it is a big however – the technology was new and likely to be difficult and expensive. Moreover, the concept itself had a certain lack of credibility: although wave power is more concentrated than wind power, with an average energy flux in deep water off the Scottish and Irish coasts of just 70 kW m^{-1}, it would require an array of structures many kilometres long to generate the 2 GW provided by one large coal-fired power station. Given the long shadow cast by previous hugely expensive Government technology projects it is perhaps not surprising that the Department of Energy trod warily, running a carefully monitored programme with an overriding, and to Ross, misplaced, emphasis on the ultimate cost of power generation.

Then, in the latter half of the 1970s, North Sea gas and then oil came on stream, and by 1982 the Government's interest in wave power had waned to the point where only a small amount of residual funding for some ongoing studies survived. During that time, teams of enthusiatic and talented scientists and engineers were able to develop a number of ideas for wave energy conversion systems into substantially worked-out concept designs. Many laboratory-scale models of varying sophistication were built and some small-scale prototypes were tried out at sea and in a Scottish loch. However, during the currency of the programme not one large-scale demonstration plant was built in the United Kingdom, although the Queen's University 75 kW machine on Islay (built between 1987 and 1991 with Government money) was a direct outcome of the studies which were undertaken as part of the programme. The Norwegians fared rather better with two large demonstration machines each operating on an entirely different principle. In 1995, *OSPREY*, a 2 MW converter utilizing the oscillating water column (built with private and EU money), was lost during its installation off Dounreay; at the time of writing it has not been replaced.

David Ross describes clearly the several principles on which wave power converters (to give them their correct rather pedantic title) are based. He describes in sufficient detail many of the wide variety of devices (some very high-tech, others very simple) which have been proposed, giving along the way some lively insights into the personalities involved. He has a chapter and an appendix on waves, which are as informative as necessary and moreover do not use mathematics. He gives a fascinating account of the difficulties and achievements of installing the Islay machine. There are numerous diagrams and photographs (an index to these would have been useful). There are references at the end of each chapter and also an appendix giving sources for further study. There is an extensive general index.

One might argue that the Department of Energy's programme is now history, but perhaps it is important history. As each year brings its crop of broken meteorological records it is becoming clear that another crisis is in the offing, and it will make the oil crisis of the 1970s look like a minor irritant. In these circumstances we might ask, with David Ross, whether our society, and particularly its decision-makers, have the vision and courage to prepare for long-term challenges. As he says, 'Wave power is about saving the world, not saving money.'

I recommend this book to all who are interested in the science of wave power and the politics of renewable energy.

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Marine Pollution (4th edition) by R.B. Clark, in collaboration with Chris Frid and Martin Attrill (1997). Oxford University Press. 160 pp. £19.50 (flexicover, ISBN 0-19-850069-6) and £40.00 (hard cover, ISBN 0-19-850070-X).

Five years on from the third edition of this important book (reviewed rather late in the day in *Ocean Challenge*, Vol. 5, No.3, pp.20–21), we have the fourth edition. There are now two additional contributing authors, but the basic format of the book resembles that of the previous edition.

A lot has changed in the intervening period, as is made clear in the Preface. Although there is now a much increased public awareness of pollution issues in general, the need to beware of emotive reactions to specific events remains as great as ever. Rather revealingly, the author notes that only a few years ago many students were committed environmentalists for whom dispassionate examination of the data was regarded as irrelevant, even harmful. Nowadays, however, 'younger students are often unaware of the problems associated with waste disposal to the sea, or imagine that governments now have these problems in hand, but the need for a dispassionate review of the subject is no less necessary'. I sometimes wonder what

proportion of younger students even think about waste disposal to the sea, and related matters. If the response of my young cousin is anything to go by, the reaction is likely to be: 'that's geography – 'sboring.'

Although the structure of the book remains essentially the same, there are some significant changes, as summarised in the preface. Eutrophication is now more widely recognized as a major problem than it was only a few years ago, and so receives more attention. The first chapter again deals with definitions of different types of pollution, but incorporates material on pollution control that was previously in the final chapter. A new second chapter 'Measuring Change' introduces statistical treatment of field data and discusses toxicity testing, and in essence replaces the previous final chapter (Assessing Pollution Damage), thus making the book about ten pages shorter.

Although the chapter entitled Conservative Pollutants has gone, the approach has not changed: metals and halogenated hydrocarbons each have a chapter to themselves (as before), and readers are reminded that in the context of pollution, 'conservative' pollutants are those not subject to biodegradation, even though their concentrations in seawater can be changed by processes other than mixing (the 'conventional' definition of the term) – i.e. uptake by organisms, with toxic or lethal consequences. There is more information on dredging and solid wastes, and the construction of artificial islands and reefs, and case studies include recent examples such as the *Braer* and *Brent Spar* controversies. The State of Some Seas, updated from the third edition (of course), is now the final chapter, and deals, as before, with the North Sea, the Mediterranean, the Baltic, the Caribbean and the Caspian. I hardly dare ask why the Black Sea is not included – too far gone, too complicated to summarise, not enough new information?

The blurb on the back cover claims that this edition has 'greater emphasis on tropical seas', but that was not obvious to me. There's not much on pollution in polar seas either, but I wonder whether it matters very much. The basic principles of what constitutes pollution and how it can be measured, monitored and controlled are surely global in their relevance, even if the actual effects vary from place to place, according to variables like temperature, salinity, run-off, nature of sediments, local geology, ecosystem structure and so on.

In my review of the previous edition I described it as 'very readable, well-illustrated and informative', to which I would only add that this edition is also bang up-to-date. It is ideal for anyone who wants to find out more about the subject, and I reckon that even those working as specialists in pollution will find it a useful source of guidance in matters outside their particular field of study.

John Wright

A Field Guide to the Pelagic Invertebrate Larvae of the Maritime Antarctic by Damon Stanwell-Smith, Alison Hood and Lloyd Peck (1997). British Antarctic Survey, 152pp. £35.00 (flexicover, ISBN 0-85665-197-4).

This is an illustrated account of larvae collected in a survey lasting more than two years in depths ranging from 6 m to 28 m near Signy Island in the South Orkneys. Much of the book is taken up by the 173 drawings and 120 photographs (including scanning electron micrographs) of larvae, mostly identified to phylum or class and, in a few cases, to genus or species. The short text describes sampling by diver-towed nets and pump samplers, operated under the ice for much of the year.

The latitude of the South Orkneys is about 61° S, which in the Northern Hemisphere corresponds to the Shetlands rather than the Orkneys. Sea temperatures ranging from +0.78 °C to −1.88 °C are, however, closer to those of Spitsbergen (Svalbard), a further 20° of latitude closer to the nearest pole.

Gunnar Thorson, the great Danish guru of larval ecology, amassed evidence that, at higher latitudes and lower temperatures, animals tend to have fewer larval stages with a greater dependence on internal yolk, or to have lost the larval stage completely. Knowing this, the initiators of the Signy project must have expected a meagre return for their sampling but, in fact, they collected an amazing 131 species of larvae. Ciliated forms make up the bulk of the collection, but a number of tadpoles, nauplii and euphausiid calyptopes are also included. Larger euphausiid and decapod crustacean larvae were unexpectedly absent from the samples, although other crustaceans of similar size and mobility, including many ostracods and amphipods, an isopod and a cumacean (all non-larval), were caught.

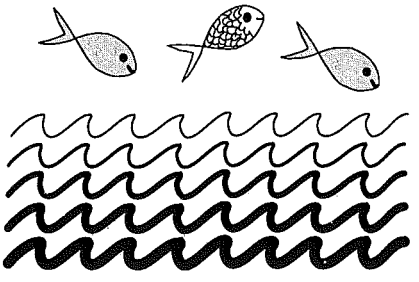
Many Antarctic larvae seem to have stored yolk or oil globules. There is, however, little indication of a shortening of larval development (many of the local starfish apparently hatch as blastulae or gastrulae), and the unexpected number of larval species suggests that comparatively few local animals have lost their larval stage. Thorson's observations came largely from the Northern Hemisphere, and were based on the known breeding methods of adults. Unfortunately there are no surveys of planktonic larvae for the Shetlands or Spitsbergen that are directly comparable with this one from Signy Island.

I question a few of the identifications, like the 'juvenile nemertean' (Figure 27), which is probably a turbellarian, and the segmented 'molluscan trochophore' (Figure 86), which is probably a polychaete. These, however, are minor quibbles. The results of this important project are competently analysed, and the effort and ingenuity of sampling under difficult circumstances were well worthwhile.

The book is of obvious interest to larval ecologists and taxonomists, but those with interests in the evolution of animal development might like to reflect on the implications of the overlapping occurrence of the larva and juvenile of the same animal. There are several examples of juvenile nemerteans within pilidium larvae and of polychaete nectochaetes protruding from trochophores, one of them precociously bearing eggs.

The comparatively few Antarctic zooplanktologists will probably want their own copies of this valuable reference work, but libraries should make it available to a wider readership.

Don Williamson
Port Erin Marine Laboratory



Handbook of Seafloor Sonar Imagery by Phillippe Blondel and Bramley J. Murton (1997). John Wiley & Sons, in association with Praxis Publishing Ltd. 314pp. £65 (hard cover, ISBN 0-471-96217-1).

My first reaction on opening this book was that it is a reference work and not for bedside reading. But then I started looking at the pictures. You could, indeed should, show them to sceptics of your aquaintance, who believe the sea-floor to be a dull and featureless domain of the planet. It is much more varied than most people imagine, even on the abyssal plains – those flat expanses are not as monotonous as the name might imply.

There are *so many* fascinating features on the ocean floor, a huge range of different forms: the variably shaped seamounts, abyssal hills and submarine volcanoes; the intricate topography of ridge crests; the strange eruptions of mud and serpentinite volcanoes above subduction zones; the giant submarine landslides and slumps that crash down continental margins or down the flanks of over-steepened volcanoes, setting off enormous tsunamis; and so on. Illustrations of all these (and other features) are made visually attractive and exciting by the modern data- and image-processing techniques that give us coloured perspective views and the 'fly-by' sequences we see in TV documentaries. Printing costs seem to have restricted colour plates to a handful in the middle of the book – though I'd have thought the publishers could afford a few more, in light of the price they're asking.

The authors state in their preface that there has been no book on side-scan sonar since the 1970s, and the intervening decades have seen great advances in both instrumentation and image processing. Most of us who marvel at the pictures have little notion of how much effort and experience goes into interpretation of the images, even when there are bathymetric data to support them. I should perhaps emphasize that while this book is explicitly about sonar *imagery*, most modern imaging systems can also be used to provide bathymetric information that can be 'laid over' the images to help in making 3D representations.

Nearly all of the images presented here are accompanied by interpretations, analogous to those made by geologists and geographers from aerial photographs and satellite imagery. It might be considered brave of the authors to provide these interpretations. However, while the validity of interpretations in land areas can often be checked by going there, 'ground truth' in the oceans is limited to spot data from drill cores or grab samples, occasionally supplemented by very limited submersible surveys (the nearest anyone can get to 'walking the outcrop'). So the authors probably know that the chances of their interpretations being checked out 'on the ground' are remote for the foreseeable future!

There are three parts to the book. The first introduces us to the latest in side-scan sonar techniques and the problems of interpretation. The authors review the basic methods and problems of acquiring the data. Factors that can affect the quality and reliability of images include: acoustic frequency (which determines the range and the sea-floor response); whether the instrument is towed or hull-mounted; changes of direction; the sonar beam width; and the level of acoustic backscatter, which depends not only on frequency but also on angle and on whether the sea-bed is made of hard rocks or soft sediments. This section gets a bit technical at times, but anyone even slightly familiar with the field will have no difficulty following it.

The middle section, occupying most of the book, is the most interesting for the likes of me, with lots of wonderful pictures. There are descriptions of each of the main ocean-floor 'provinces', with brief geological introductions to set the scene. They are all there: ocean ridges, continental margins, abyssal plains, trenches, coastal environments, and so on, each dealt with in turn, often in considerable detail. It is here that I spent most of the time I'd set aside for writing this review!

The final section deals with computer-assisted techniques of interpretation. As the authors point out, the human eye is subjective and no two people will interpret an image in the same way – as I can testify from my own experience. Artefacts and image anomalies are covered here too, arising from things like variations in speed and attitude of the instrument, the amount of spreading of the sonar beam, and so on, as well as from the imagination. The famous 'Face on Mars' is featured (it was the subject of a whole 'X-Files' episode a year or two back), along with a 'Face on the Seafloor'. The caption tactfully states that such images are 'liable to misinterpretation'.

Because the book is so full of pictures, the authors have thoughtfully provided a list at the front of the book. There's also a Glossary of Abbreviations and Acronyms, a long Bibliography, and an Index.

Advances in technology are now so rapid that one might suppose this book would date quite quickly. I'm not so sure, I reckon it's got a good few years of life in it. After all, the basic principles of sonar imaging don't change, only the sophistication of data collection and processing – and come to think of it, the underlying principles of that don't change much either. The book deserves a wider readership than it is likely to get at the price asked for it.

John Wright

This review first appeared in Progress in Oceanography, *and we would like to thank the editors for allowing us to reproduce it here.*

Introductory Oceanography (8th edn) by Harold V. Thurman (1997). Prentice Hall, 544pp. £22.95 (hard cover, ISBN 0-13-262015-4).

Here you are. Hot off the press. New. Improved. Updated!

Oh really? How much newer, how much improved and updated?

Having bought the 6th edition in light of your review in *Ocean Challenge*, Vol. 4, No. 3, should I fork out another £20-odd for this book?

The 8th edition is 18 pages longer than the 6th, but as the print size is smaller it must have significantly more words in it. But overall I have to say I didn't find it easy to spot more than rather subtle differences from the previous version. All seventeen chapter headings are the same, and their contents have hardly changed apart from: (1) some slight re-arrangement (e.g. short sections on light and sound are shifted from Chapter 7 on Air–Sea Interaction to Chapter 6 on Properties of Water); (2) there are some new pictures, including coloured (almost garish) new versions of earlier more sober illustrations; and (3) as the author notes in his Preface, there is more on instrumentation and technology.

There are some extra case studies too (e.g. early human voyages in the Pacific; WOCE; the Fastnet disaster of 1979, when giant waves overwhelmed several yachts). These case studies have moved to near ends

of chapters, so they don't interrupt the reader's flow as much as they did before. There are now lists of key terms at the ends of chapters, along with references, further reading and questions. Overall, though, the changes are mostly cosmetic, the basics have not altered – nor should they, of course. Perhaps most revealing of all, the end-of-chapter questions are virtually identical to those in the 6th edition, except for minor additions and improved wording here and there. And answers to the questions are *still* not provided.

If you haven't got an earlier edition of this book and you want an introductory multidisciplinary oceanography text, then by all means buy this one. You could do a lot worse at the price. But if you've already got the 6th or 7th editions (I can't comment on earlier ones), then my advice is, don't bother. That verdict won't trouble the publishers, I fancy. This new edition is aimed at new recruits to the marine sciences, not old lags who should by now be past needing introductory texts.

John Wright

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Volume 3, No, 2/3 1992 *Oceanography at Liverpool.* Feature articles: *The Effects of Fishing Disturbance in the Northern North Sea* by Mike Robertson and Steve Hall; *Whaling: the Present Position* by Ray Gambell; *Tracking Wales by Satellite* by Tony Martin; *The Voyage that Changed the World* by Malcolm Walker; *The Politics of Scientific Moves: the transfer of the British Museum scientific collection from Bloomsbury to South Kensington* by Tony Rice. (64pp.)

Volume 4, Nos. 1/2, 1993 James Rennell Special Issue: a collection of articles on the 'Father of Oceanography', by Raymond Pollard,Gwyn Griffiths, John Gould, Michael Bravo, John Phillips and Margaret Deacon. (64pp.)

Volume 4, No. 3, 1993 (pub. 1994) *Marine Science for All?* (marine science education and training). Feature articles: *Something for (almost) Nothing: the Quest of Data Assimilation* by Rebecca Woodgate; *Letter from* Discovery by Jane Read; *Pulling the Plug: the Ocean Floor Revealed* by Anthony S. Laughton; *Krill: the Ecology of Aggregation* by Julian Priddle, John Watkins and Eugene Murphy. (52pp.)

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Volume 5, No.2, 1994 (pub 1995) *Dr John Crossley Swallow FRS: Physical Oceanographer 1923–1994* by John Gould; *Changing Attitudes to Coastal Defence* by Keith Clayton; *The Great Eel Mystery: Is the Solution in Sight at Last?* by Gordon Williamson; *Now, There's a Funny Thing!* (first of new series) *Eating Research Assistants is Wrong* by Martin Angel; UK Oceanography '94; Hydro '94. Feature articles: *The Deepest Depths* by Rear-Admiral

Steve Ritchie; *Stamps of Approval for Edward Forbes* by Tony Rice: *From Dittmar to Diagenesis: 40 Years of Chemistry at IOS* by Sarah Colley and Roger Wilson. (51pp.)

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Volume 6, No.1, 1995 A special Volume consisting of articles arising out of a symposium on 'A century of Hydrographic Work in the Faroe–Shetland Channel', held in Aberdeen in 1993, and involving the ICES Oceanic Hydrography Working Group and the ICES Data-Management Working Group. Among the topics covered are: the history of research in the region, from Danish and Scottish perspectives; the hydrography of the north-east Atlantic; long time-series; tidal oscillations; salinity anomalies; fish migration; and studies of the shelf-edge. (68pp.)

Volume 6, No.2, 1995 (pub. 1996) Feature articles: *The History of Wave Research at Wormley: a personal view* by Laurence Draper; *Dive 3000: A Milestone of Deep Ocean Research* by *Alvin* pilot, Pat Hickey (40pp.)

Volume 6, No.3, 1995 (pub. 1996) *'Sea Bat' Bonanza at Lochinver* by Gordon Williamson'; *The Maury Project* by Sue Greig; *Waves from Westminster* by Stephen King; *Coastal Management in Wales* by Rhoda C. Ballinger and Madeleine S.C. Havard; *Closure of Geevor Tin Mine – Not the Environmental Disaster Once Predicted* by Ben Williamson *et al.*; *Professor Rob Kidd – An Appreciation* by Simon Wakefield; *Professor Ron Currie CBE* by Jack Matthews and Martin Angel; *The Trouble With Imia* by Michael Tsimplis. Feature articles: *Mud Glorious Mud: Morphology and Development of a Coastal Resource* by Keith Dyer; *New Marshes for Old: Saltmarsh Creation in Essex, England* by Laurie Boorman and John Hazelden. (44pp.)

OCEAN Challenge

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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). Manuscripts should be double-spaced and in a clear typeface.

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