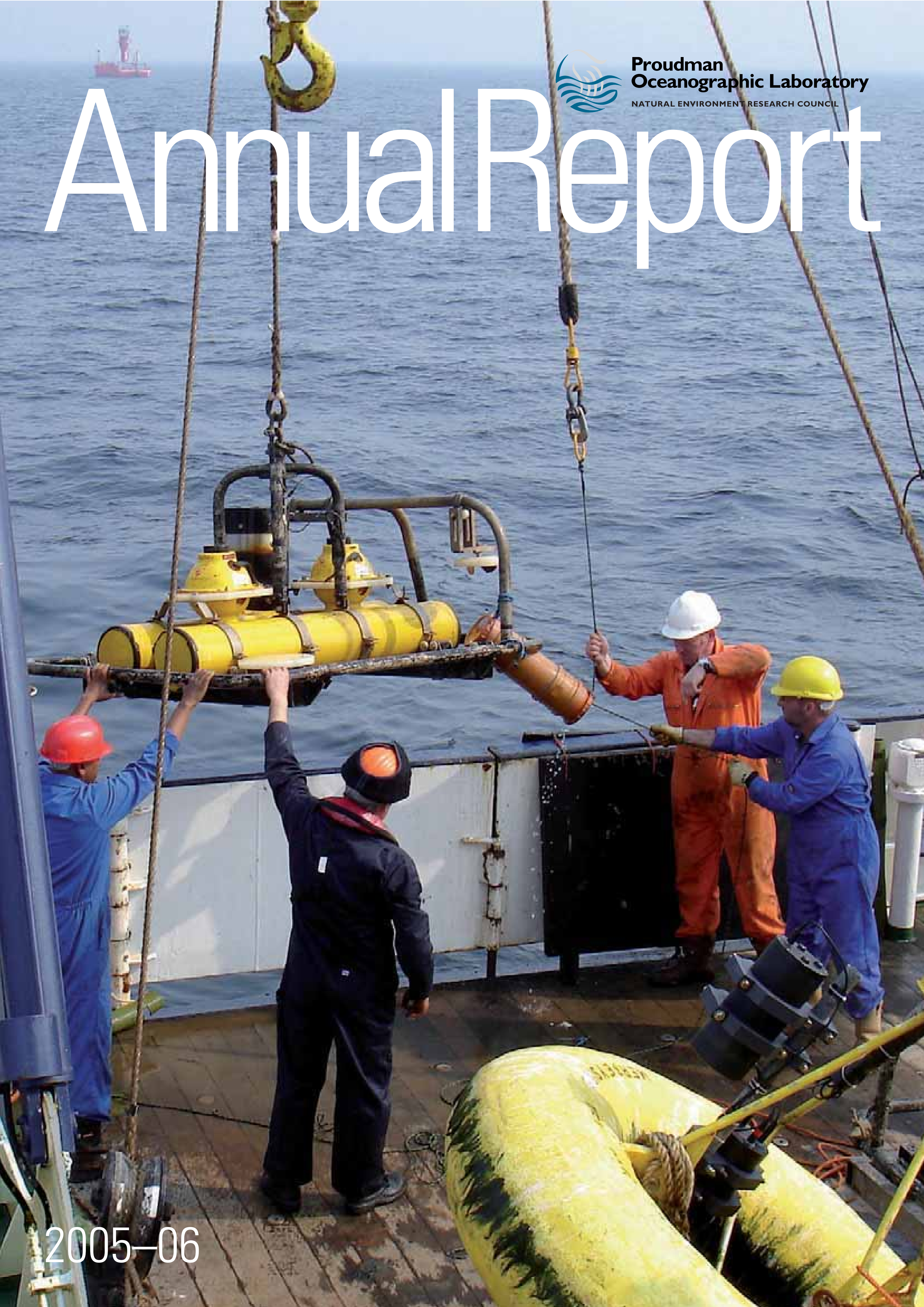
Proudman Oceanographic Laboratory
NATURAL ENVIRONMENT RESEARCH COUNCIL

Annual Report

2005–06



The Proudman Oceanographic Laboratory (POL) is a research centre wholly owned by the Natural Environment Research Council (NERC). Its main areas of research are sea-level and allied science, the physics of the shelf and slope seas, marine observation and modelling systems, and data management in POL-hosted data centres: the British Oceanographic Data Centre (BODC) and the Permanent Service for Mean Sea Level (PSMSL).

MERSEY MARITIME

pogo

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Cover: Recovery of a nutrient analyser at site A near the Mersey Bar Light Vessel.
Photo: Andrew Willmott.

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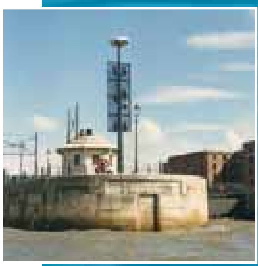
Director's introduction



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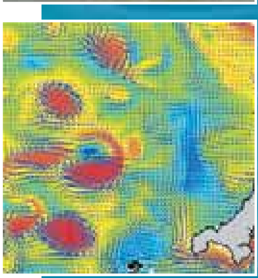
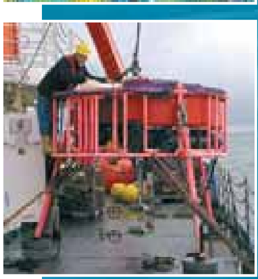
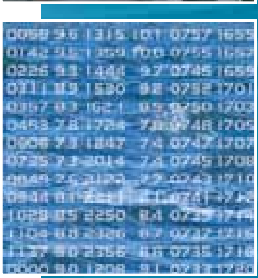






Following my appointment as the Director of POL from 1 July 2005 it gives me great pleasure to introduce this year's annual report. A change of laboratory Director is often accompanied by a change in its direction. POL is already recognised internationally for its excellent research in sea level, geodesy, shelf sea dynamics, sediment transport processes and hosting the British Oceanographic Data Centre (BODC); and my challenge to staff in the laboratory is to make POL the leading institution of its type internationally. In working towards this goal we will organise and host more conferences and workshops, helped along by our new location in a purpose-built home on the campus of the University of Liverpool. During September 2005 we hosted an international workshop on 'Sediment and coastal processes' with support from the US Army Engineering Research and Development Centre and the US Office of Naval Research.

Our new home is paying dividends through increased collaboration with our colleagues at the University of Liverpool. For example, we recently received funding for two projects involving colleagues in engineering. The LEACOAST2 project is studying sediment transport around the coast of Norfolk. Renewable energy is high on the political agenda, and POL scientists were delighted to have the opportunity to study the feasibility of deploying tidal turbines in the estuaries of the Mersey and Ribble. Moreover, during the year, three students started research co-supervised with University colleagues in Earth and Ocean Sciences.

2

With six other UK marine laboratories, POL has been involved in preparing proposals for *Oceans 2025*, the NERC marine strategic programme due to be launched in April 2007. It is the first time that the seven marine laboratories have come together to develop an ambitious collaborative programme of this type. Within Oceans 2025, we have exciting plans to use our long-standing expertise in shelf sea modelling to address climate-change impacts on Arctic shelf waters. Nowhere on the planet are the signals of global warming as dramatic as in the Arctic. The retreat of summer sea ice will have a major impact on the biogeochemistry of the Arctic and the climate of North-western Europe, as well as creating a new sea route between China and Europe via the Northeast Passage. With the launch of the International Polar Year (IPY, 2007–08) in April 2007, it is a good time for POL to launch a new research initiative on the impact of global warming on the shelf seas of the Arctic Ocean.

With the launch of Oceans 2025 the laboratory will be restructuring its science management.

Also, in response to the 2004 Science and Management Audit of POL, we have created an External Science Advisory Board comprising key stakeholders and leading national and international researchers. We expect that the board will challenge and test our research, ensuring that it meets the very highest standards. Part of POL's research contributes sound scientific data to the formulation of government policy and we expect the board to challenge our record in these areas.

The well established shelf sea circulation model POLCOMS continues to be applied to a range of strategic 'big science' questions. These include studying the uptake of carbon in the global shelf seas and its subsequent export into the deep ocean, through working with the Centre for observation of Air-Sea Interactions and fluXes (CASIX) and the QUEST (Quantifying and Understanding the Earth System) programme. Our sea level research plays an ever more important role, focusing on delivering real-time data for flood forecasting predictions in collaboration with the Environment Agency, and on unravelling the processes that control regional sea-level variability. These topics, with our other major achievements during the past year, are described in the following pages.

The Coastal Observatory and BODC have improved their websites, including a facility to enable users to search more data types via interactive maps, and to get the data delivered via the internet. We welcome feedback from members of the public and stakeholders, whether funders or users of our work, about how useful these new websites are.

Meeting the needs of our stakeholders is central to our work at POL. We greatly appreciate your continued support as our stakeholders, and we welcome your feedback about the achievements described in this annual report.

Andrew Willmott

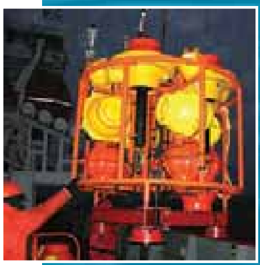
1. *We have excellence in four distinct areas: sea level science; numerical modelling of ocean margins; science, engineering, and technology for in situ ocean observation; marine data management.*
2. *Prof Andrew Willmott.*

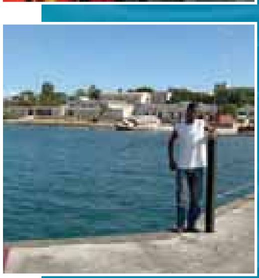
Science

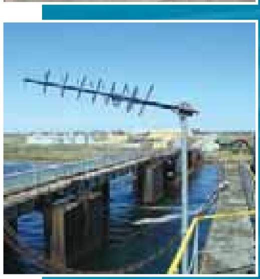
Since 1933, the Permanent Service for Mean Sea Level at POL has collected and published sea-level data from an international network of tide gauges (page 23). From the 1990s, POL and the Institute of Engineering Surveying and Space Geodesy at the University of Nottingham have been measuring changes in UK land levels. We use this information to predict the effects of climate change on sea levels.

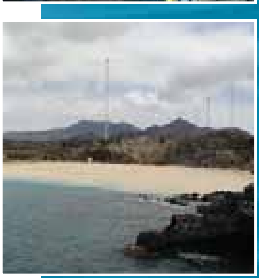
On the LEVEL?

Changes in global and regional sea and land levels









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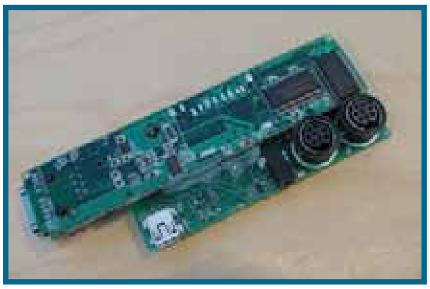
gumstix™ development and deployment

The demand for real-time data after the Asian tsunami of December 2004 has led us to develop new methods for sending sea-level data to POL. We have been working on two systems, both of which allow near real-time data to display immediately on the POL website. The first simply returns the data as emails using ORBCOMM satellites. The second uses a tiny Linux-based computer, the 'gumstix'. About the size of a stick of chewing gum, the internet-connected gumstix allows us to communicate with it as if it were in the laboratory, even though it may be many thousands of miles away. Both the gumstix and ORBCOMM systems use an OTT 'Kalesto' radar gauge for making measurements. The gumstix returns five one-minute averages of tidal height every five minutes by e-mail and the ORBCOMM returns four 15-minute averages every hour.
Two ORBCOMM systems are now in use in Mozambique with two more installed near English Bay, Ascension Island and at Port Stanley, Falkland Islands. Developmental gumstix units are at Holyhead and Liverpool.

The British Antarctic Survey Rothera base will have an operational unit installed later this year.



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Papers from the Royal Society Sea Level Science Conference held in February 2004 have now been published in Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences. You can read them at http://www.pubs.royalsoc.ac.uk/index.cfm?page=1266

Port Stanley and the South Atlantic

Time-series of sea-level changes at Port Stanley present a spectrum of variability from seiches, tides and storm surges through to the seasonal, year-to-year and longer-timescale changes that are of interest to ocean circulation and climate change studies. In a recent paper, Philip Woodworth and colleagues described this spectrum in detail and highlighted the strategic importance of Port Stanley within a global sea-level network. Port Stanley has one of the longest records from a southern hemisphere island, and shows a trend of sea levels rising by about 1mm a year since 1964.

During the year Peter Foden and colleagues in our Ocean Engineering and Technology Group have contributed to developing the global sea-level network in British dependent territories and developing countries. This work includes:

- installing radar gauges with satellite telemetry (remote measurement) at two sites in Mozambique
- buying five new gauges for use in Africa and Pakistan
- delivering a new gauge for the Vernadsky base in Antarctica
- upgrading stations at Ascension, Port Stanley and the Rothera Antarctic base.

In addition, they have made detailed studies of alternative telemetry systems. Steve Mack, Geoff Hargreaves and Simon Holgate deployed an advanced deep-sea tide gauge – Multi-Year Return Tidal Level Equipment (MYRTLE 3) – in the Drake Passage, which will provide tidal measurements for the next five years.

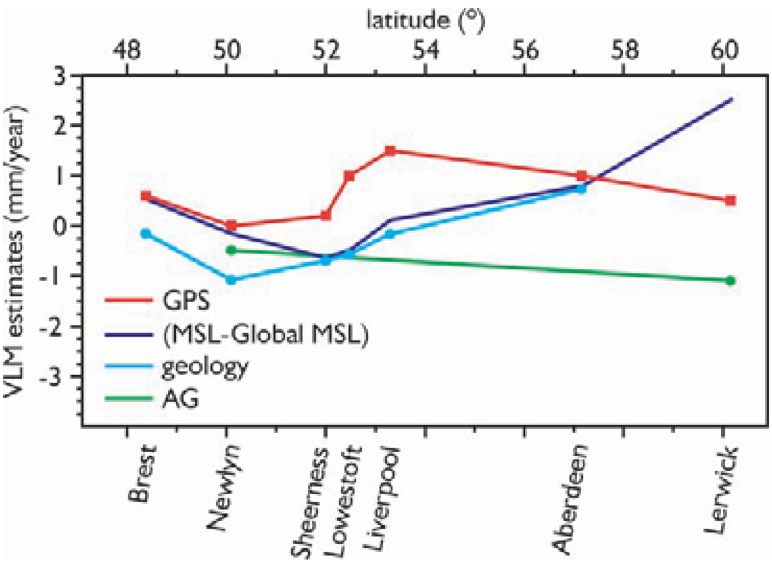
3

Separating changes in sea level from changes in land level

Researchers studying climate change have used historical tide-gauge measurements from all over the world to study sea-level change over the last century. However, such estimates combine true sea-level variations and vertical land movements at any specific tide gauge. Using a tide-gauge record to identify the changes in sea level that are related to climate makes it necessary to correct for vertical land movement. Since 1990, we have been working with the Institute of Engineering Surveying and Space Geodesy (Nottingham University) to develop techniques to do this. These techniques are based on the Global Positioning System (GPS) and Absolute Gravity (AG) for measuring vertical land movements (VLM) at tide gauges in the UK.

We compared data from GPS and AG with independent evidence for vertical land movements in the UK. This evidence includes mean sea-level records from tide gauges, geological evidence, and results from post-glacial rebound models. We found a consistent variation between the GPS estimates and the AG estimates. This suggests that while GPS produces good results in a relative sense it needs a complementary technique such as AG to provide a stable measure for estimating absolute changes in sea and land levels.

A first comparison between these 'AG-aligned GPS estimates of VLM' and relative mean sea-level change recorded by tide gauges suggests a sea-level rise around the British Isles of 0.6–1.9mm a year. Using GPS and AG on a national scale to record land-level changes at tide gauges enables us to estimate sea-level changes separately from land-level changes.



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1. MYRTLE being deployed in the Drake Passage on 12 December 2006; Pemba, Mozambique; ORBCOMM transmitter, Port Stanley; English Bay, Ascension Island.

2. gumstix – the tiny Linux computer.

3. Dave Jones installing the OTT 'Kalesto' gauge at Port Stanley.

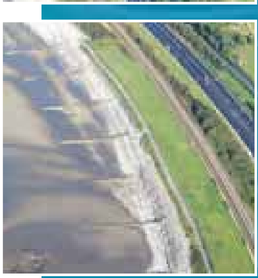
4. Vertical land movement estimates for seven continuous GPS stations close to or at tide-gauge sites in the UK and northern France, compared to alternative evidence for land movements.

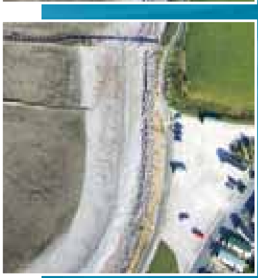
Science

To design effective coastal defences, or identify places likely to flood, we need to predict areas at risk from occasional but unusually high sea levels. Engineers often design coastal defences to withstand extreme sea levels that occur only once every hundred years on average, when the surge caused by a major storm coincides with the high water of a large spring tide. We are finding out which areas of the UK could be most at risk in the future.

The ever-changing SEA

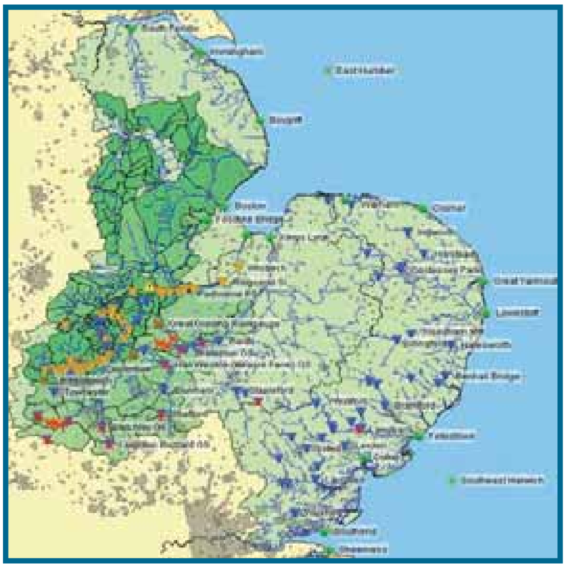
Sea-level variability and extremes





Flood warning improves

Storm surges are an important cause of coastal flooding, and POL is responsible for providing the best available computer models to predict surges for the Environment Agency (EA). Jane Williams and Kevin Horsburgh have linked the POL tide-surge models with a new North Atlantic atmospheric model. This provides better coverage of wind speeds and sea-level pressures over a wider domain to improve surge forecasts. Forecasts are provided four times a day, up to 48 hours ahead. The new model ensures that any meteorological disturbances in the Bay of Biscay are correctly input to the predictions, giving great improvements.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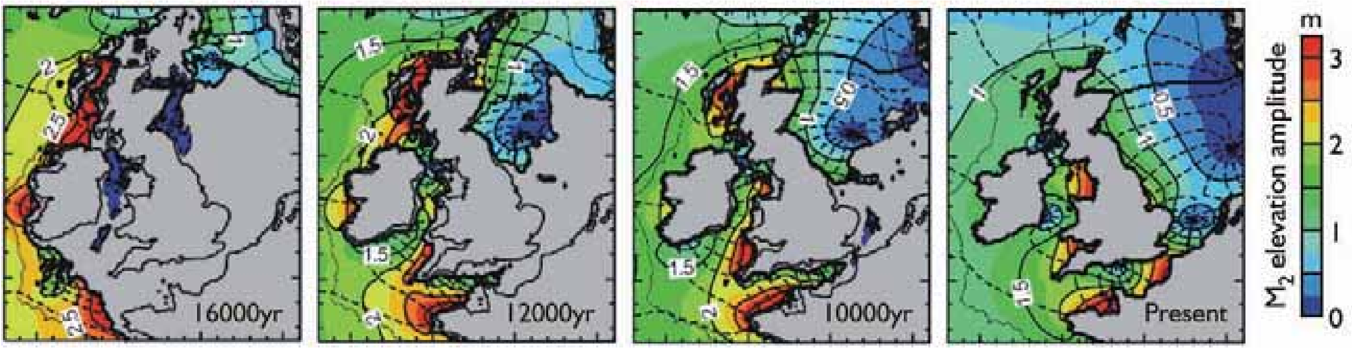
Further developments have led to a stand-alone surge model of the North Sea for the team at the Thames Barrier. This model receives meteorological data directly from the Met Office and uses a simple assimilation scheme to correct the surge arriving in the North Sea. The model is part of the National Flood Forecasting Scheme (NFFS) package used by the EA. The NFFS assembles all rainfall, river flow and coastal sea-level data from all sources and combines the measurements with the outputs from several computer prediction models.

1. Integrated forecasting from the National Flood Forecasting System showing data sources for south-east England.

2. Tidal elevation throughout the interglacial period from 16000 years ago to the present.

Higher tides following the last ice age

There are large changes to the tides over shelf seas when viewed over glacial-interglacial timescales. Kevin Horsburgh has been working with colleagues at the University of Wales, Bangor and the Australian National University. They have conducted model experiments to examine the effect of post-glacial rebound (as the Earth relaxes from ice loading), and changes to tides in the North Atlantic ocean as the basin readjusts. They found that before 10,000 years ago, twice-daily (semi-diurnal) tides were significantly larger than now because of a greater resonant response of the ocean. This had a large effect on seasonal stratification (vertical layering of water) and energy dissipation. The way in which the shallow shelf rebounds following the ice loading was less important but did affect the precise timing of emerging tidal patterns. This work makes it clear that changes to the oceanic tide are the most important driver for any tide-dependent processes on the continental shelf. Hence, any geological evidence for a changing tidal regime lends strong support to the theory of a changing ocean tide.



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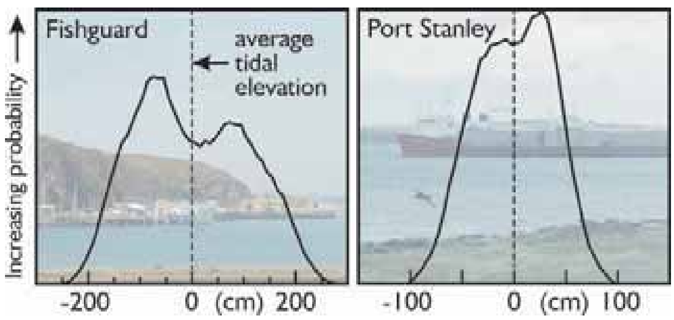
Understanding tides



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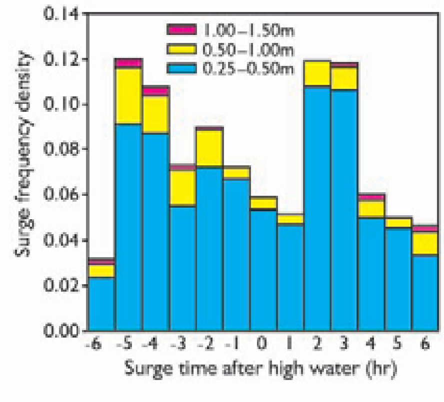
To plan coastal defences, engineers need to be able to estimate future extreme water levels. To do this they use probability distribution functions (PDFs) of tidal elevations. These are histograms of tidal levels sampled regularly (for example, hourly) for months or years. A proper understanding of tidal PDFs is important and we are finding out more about what they can tell us.

All tides have once-daily (diurnal) and twice-daily (semi-diurnal) components. In areas where the tide is mainly semi-diurnal, the PDFs are normally symmetric, having two peaks that reflect high- and low-water neap levels. However, some locations have asymmetric PDFs. Often this is because of shallow-water effects, yet such asymmetries can also be observed on narrow shelves and around ocean islands. Philip Woodworth and David Blackman have added to the understanding of tidal elevation PDFs by showing that at these locations it is the diurnal component of the tide that is responsible for the asymmetry.

Thames Estuary 2100 – assessing the risks

The densely populated flood plain of the Thames is critical to the UK's economic well-being. We are contributing to the flood risk management plan for the Thames Estuary over the next hundred years. Chris Wilson has made a detailed historical analysis of surge heights and their chance of happening over a tidal cycle. Histograms like that in Fig. 4 use the best quality-controlled tide gauge data from the British Oceanographic Data Centre and provide statistics for evaluating the behaviour of surges and their interaction with the tide. The analysis also sets a benchmark for sea levels predicted by coupled climate-surge models that we are developing with the Hadley Centre for Climate Research. The project will provide engineers with worst-case storm-surge predictions for engineering design that best characterise historical events and include consideration of long-term changes in the North Sea.



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3. Asymmetric probability distribution functions showing the likelihood of a tide being above or below the average tidal level.

4. Surge frequency relative to time of high water at Immingham. The data are from 3,037 surges; colours show the surge height.

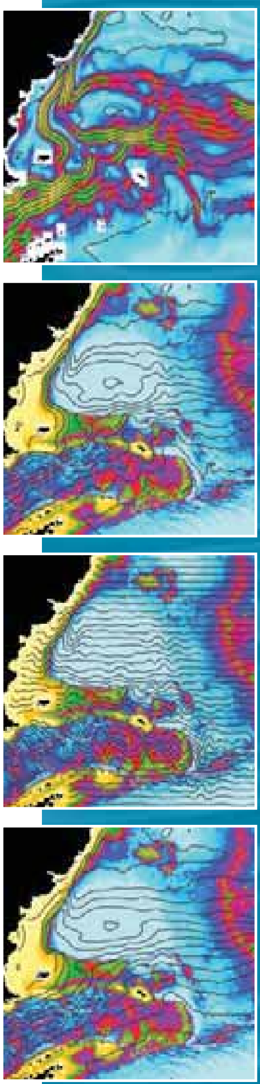
Science

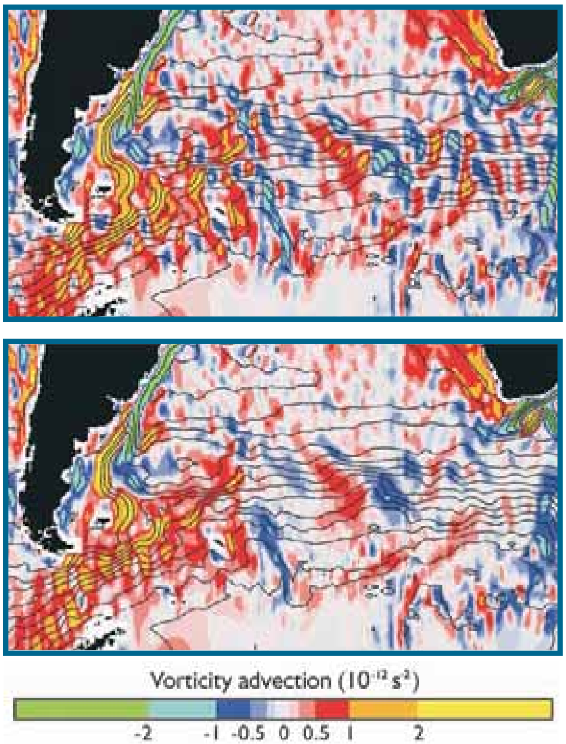
It is difficult to find out about the ocean beneath its surface, where satellites cannot see and sampling is only occasionally possible. POL scientists, led by Chris Hughes, are using continuous measurements from carefully chosen sites to better our understanding of the deep. POL technologists, led by Peter Foden, are using novel instruments to make these measurements, with new equipment being designed to meet evolving needs.

Measuring UP

Continuous ocean measurement methods

Getting to the bottom of it





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As water flows around Antarctica in the vast Antarctic Circumpolar Current, it meanders to the north and south. There are two possible reasons for this. Either (i) the flow penetrates right down to the sea floor, steering the current to avoid climbing over ridges and mountains; or (ii) long waves are being held stationary, as the eastward-flowing current stops them travelling westwards. Using new information about ocean currents from drifting buoys, satellite measurements of gravity, and satellite sea-level data, Chris Hughes has been finding out where the meanders are acting like stationary waves. It turns out that most of the meandering of currents is the result of stationary waves. Removing the effect of these waves shows the places where the flow reaches the bottom and is steered by the topography. As well as teaching us about how the Circumpolar Current works, this verifies the accuracy of the new maps of global currents.

1. Total northward flow of the Antarctic Circumpolar Current (top) and with the effect of stationary waves removed (bottom). The black contours – equivalent to isobars on a weather map – show mean currents.

2. Satellite measurement of the forcing of the flow by ocean eddies within an ocean storm track. The black contours – equivalent to isobars on a weather map – show mean currents.

Ocean storms

In Britain we live beneath an atmospheric storm track. This region, where high and low-pressure systems are generated and swept to the east, controls our day-to-day weather. We know a great deal about these storm tracks, and how the storms reinforce the mean eastward wind they feed off. In principle, the same ought to happen in the ocean. But the properties of sea water mean that everything in the ocean happens at much smaller scales – about ten times smaller. This means that it is much more difficult to assess how the ocean equivalent of pressure systems – known as eddies – grow and decay, and interact with the mean currents. Using new ocean current data, Chris Wilson and Chris Hughes, with Ric Williams of the University of Liverpool, have shown that ocean eddies indeed act like atmospheric pressure systems in storm tracks. In the ocean, topographic steering complicates the picture almost everywhere. In contrast, in the atmosphere there are large regions where topography is absent – over the oceans – or on too small a scale to interact strongly with the storm track.

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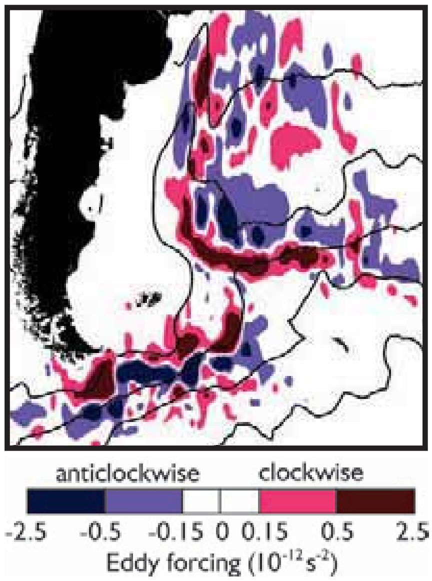
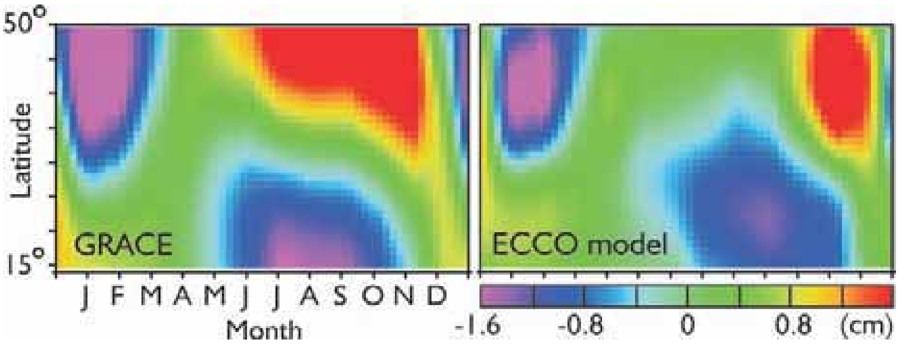


Seeing deeper

The GRACE mission consists of twin satellites orbiting the earth and measuring their separation to a precision of better than a millionth of a metre (micron). As they orbit the earth the gravitational attraction of a mass near the earth's surface causes first one satellite then the other to accelerate and decelerate as they pass over the mass. This allows them to detect changes in mass distribution around the earth. Changes in mass over the ocean are the result of movements of air and water. If the satellites are working correctly, it should be possible to use them to calculate large-scale averages of ocean-bottom pressure changes. As the technology is new and ocean signals are small, it is important to test whether the satellite is providing what is expected. Rory Bingham has been using the satellite data to calculate east-west averages of ocean-bottom pressure in the North Pacific. The patterns seen in the observations are similar to the predictions, confirming the satellites are measuring large-scale ocean-bottom pressure changes with accuracy close to 1cm of water.

3



3. Comparison of ocean-bottom pressure changes measured by satellite (left) and predicted by an ocean climate circulation model (right).

4. Correlation of bottom pressure at each point in the model ocean, with bottom pressure averaged over the Southern Ocean.

Tipping the scales

Since global observations of large-scale ocean-bottom pressure signals are new, we are still feeling our way for what we should expect to see. Vladimir Stepanov and Chris Hughes have been studying these signals in a global ocean model to find out how mass moves between ocean basins. At the longest time scales, the main exchange is between the Southern Ocean and the Pacific. They found this is due to winds in the Southern Ocean. Stronger eastward winds produce a stronger eastward current, which means lower pressure to the south of the current and higher pressure further north. At the same time, the current pushes to the east on the sea-floor topography, especially in the Drake Passage between the Pacific and Atlantic. This results in higher pressure in the Pacific than in the Atlantic. Combining these two effects means that, as pressure decreases to the south, it increases to the north in the Pacific Ocean, but not in the Atlantic. Experimentally removing the Drake Passage topography reverses this effect, as topography elsewhere becomes important instead.

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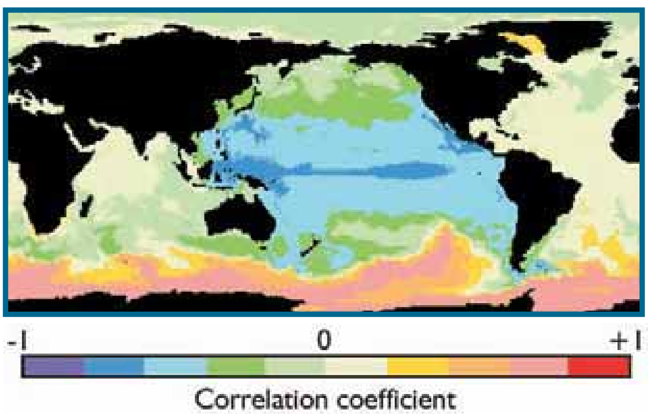

Science

We are finding out how shallow continental-shelf seas respond to effects of climate and human activity such as pollution and increased nutrients. We are researching how the open ocean affects shelf seas and how shelf seas exchange water and its contents with the ocean.

In the MIX

Water movement in shelf seas

Mixing in Loch Etive

In the ocean a thermocline (region of rapidly changing temperature) usually separates a warm surface layer from the colder, deeper water. It is possible for this thermocline to oscillate up and down, producing waves that move along the thermocline. These 'internal' waves are widespread in the ocean. The breaking of these waves is an important source of mixing, which can affect pollutant dispersal, the growth of marine plants and animals, ocean circulation and the global climate. In the coastal ocean, tidal currents flowing over sharp bumps in the seabed (for example, the sill at the entrance to a sea loch) often create internal waves.

Using a sophisticated computer model of the sill at the entrance to Loch Etive on the west coast of Scotland, Jiuxing Xing and Alan Davies have looked at how the internal waves cause mixing near the sill. They found the waves formed during the flood tide. As the tide changed direction the waves broke up against the sill, causing strong mixing. They also found that adding 'roughness' to the seabed near the sill (for example, large ripples in the seabed) led to an increase in the mixing. The success of the model will allow its use in the more complicated environment of the open shelf sea.

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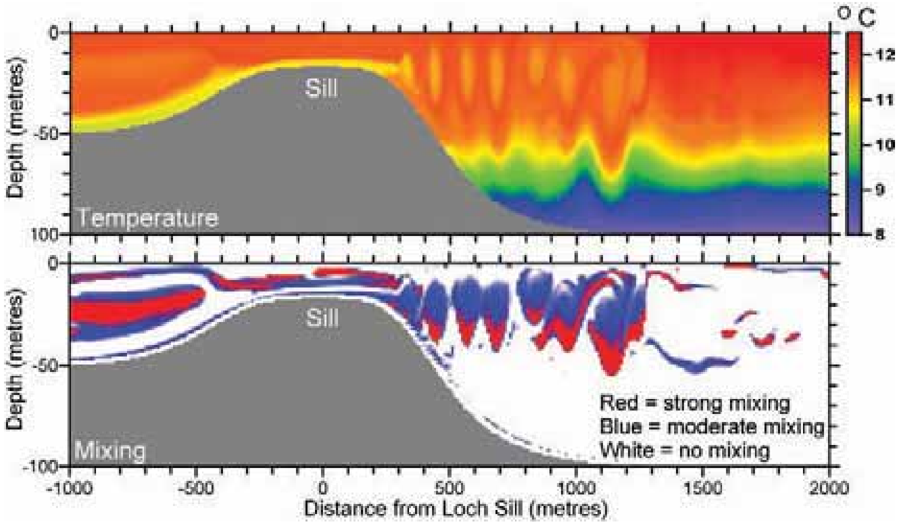


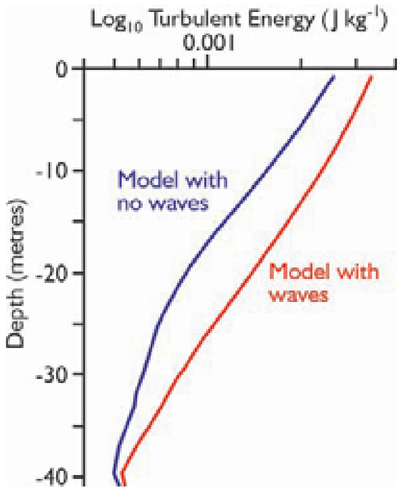
1. A life on the ocean wave.

2. Model results showing the mixing caused by internal waves at the sill of Loch Etive. The upper panel shows water temperature, with large oscillations inside the Loch between 500 and 1,200m from the sill, caused by internal waves. The lower panel shows how strong the mixing is, with patches of strong mixing inside the internal waves.

Waves and sunlight

Waves in coastal seas affect the way turbulence mixes up sediments from the seabed. The sediments affect absorption of sunlight into the sea, and marine algae need sunlight for photosynthesis. So getting our computer models to simulate this wave-driven turbulence is important if we want to predict biological growth. With data from a site west of Anglesey, Sarah Wakelin and Pedro Osuna have been using a computer model that includes tidal currents and surface waves to study how waves caused by strong winds produce turbulence and mix up sediments. The model results agree well with measurements. Compared to tidal currents alone, waves during storms can produce large increases in turbulence, even near the seabed. This work will improve our model's ability to reproduce observations of sediments, and the resulting distribution of sunlight in the water.

3



Why do seabed bumps attract fish?

Phytoplankton, single-celled plants in the ocean, are the base of the marine food chain; understanding phytoplankton distribution is fundamental to our knowledge of marine fisheries. Jonathan Sharples, in collaboration with scientists at the Universities of Southampton and Wales, Bangor, has identified a previously unrecognised, but seemingly predictable, patchiness in phytoplankton distributions in shelf seas. Banks in the seabed, typically 10–30km in size and 10–15m high, cause internal waves to develop on the thermocline above them. These internal waves break, mixing water between the surface and bottom layers at the edges of the banks. There are higher concentrations of phytoplankton where this mixing occurs, both within the thermocline and in the bottom water. In summer the growth of phytoplankton in the thermocline is critical to providing food to the rest of the food chain. The scientists saw many fishing vessels over these seabed banks. This suggests that internal mixing could be the physical start to a chain of events that eventually provides more fish over the banks. Research continues into the details of the physics, and how the chain of biological interactions might lead to more fish. This work is part of the basic understanding that scientists need to be able to manage sustainable fisheries.

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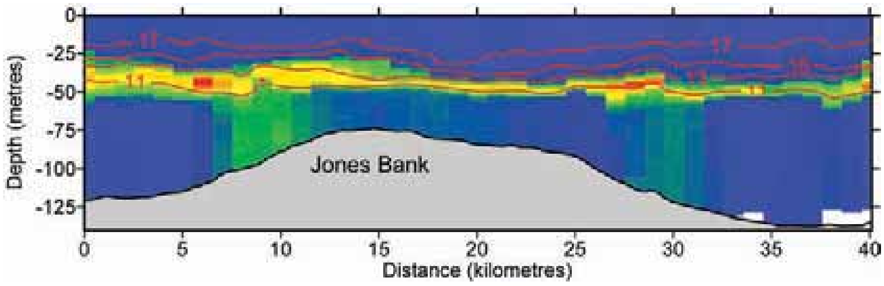


At the ocean's edge

Mixing determines the exchanges of water and its contents between the continental shelf and open ocean; the ocean's water properties; and its circulation. But we still need to find all the mixing to explain our observations of these aspects of the ocean. One contributor may be the way internal waves on the sloping seabed steepen and even break when approaching the shallow water of the continental shelf – like surface waves approaching a beach.
John Huthnance led a cruise with POL colleagues, scientists from the Scottish Association for Marine Science, the Netherlands Institute for Sea Research and the University of Plymouth. They studied mixing over the sloping seabed north of Scotland. Intensive current and temperature measurements showed strong tidal flows in the colder, deeper water and the presence of many steep internal waves.
They expect to be able to estimate the strength of the associated mixing by comparing changes in water properties across the slope.
They also saw changes in the internal waves as the waves travelled along the slope, and carried out measurements of turbulence near the bed. This work should lead to better descriptions of mixing for use in ocean-circulation computer models.

3. The graph compares how much turbulence the model calculates without and with the effect of surface waves during a storm. The waves increase the turbulence through the whole depth of the water.

4. Temperature and phytoplankton data collected over Jones Bank in the Celtic Sea. The red lines illustrate the thermocline, lying between a warm (greater than 17°C) surface layer and a cold (less than 11°C) bottom layer. The colours show where the phytoplankton were seen in the lower part of the thermocline and in the bottom layer over the bank. The numbers of phytoplankton are low in the blue regions, moderate in the green/yellow regions, and high in the red regions.

Science

Increasingly, for economic, environmental and aesthetic reasons, managers and engineers are choosing to let our coastlines evolve naturally. To do this effectively, we have to be able to predict future changes to the coastline.

Shifting SANDS

Predicting sediment movement around our coasts

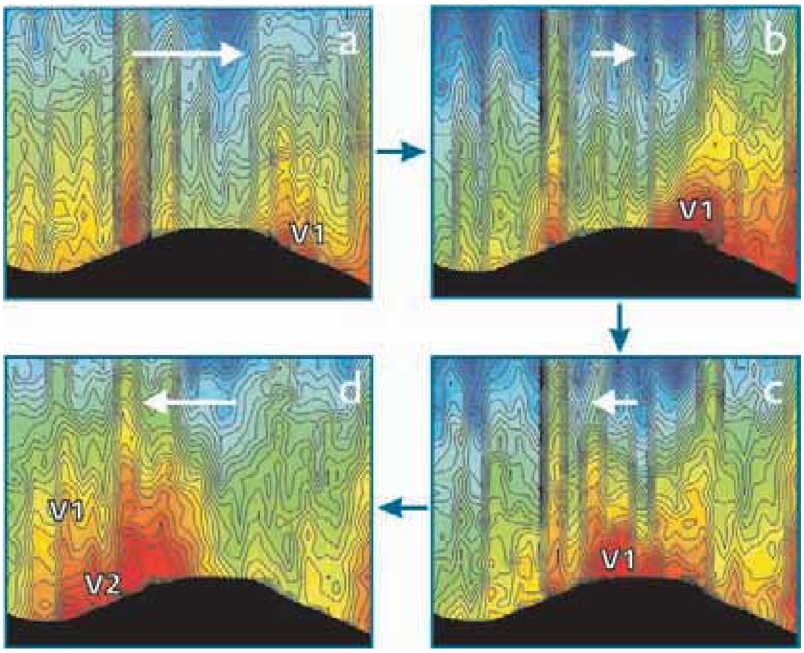
Predicting the seabed

Tides and currents continuously erode and deposit sand and mud over the boundary between the land and the sea. Predicting this is a challenging and essential task. Using one of the world's largest constructed water channels and exploiting new imaging techniques from sound, we have tested some of the latest mathematical predictions on sediment transport processes.

The results obtained by Peter Thorne, collaborating with WL Delft Hydraulics (Netherlands) and Alan Davies of the University of Wales, Bangor, show in detail how sand lifts into the water as a wave passes over a rippled seabed.

The figure below shows the measurements. At maximum wave speed, a small spinning parcel of water laden with sediment, vortex V1, forms on the lee-side of the ripple. As the flow lessens, this sediment parcel grows and travels up the lee-slope, travelling over the crest at flow reversal. As the reversed flow increases, another sediment parcel (vortex V2) begins to grow, while V1 expands and is carried away from the bed up into the water. Using the outcome from this detailed work in large-area models of sediment transport will help predict the way nearshore seabeds and coastlines evolve.

1



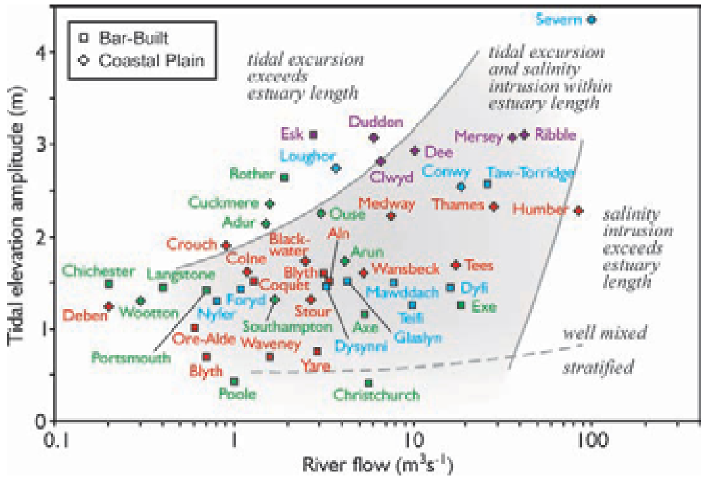
1. Acoustic imaging of how sand is lifted up into the water during the passage of a wave over a rippled sandy bed. The white arrows show the direction and speed of the wave. Red is large concentrations of sand in suspension and blue is small.

Estuaries and climate change

Estuaries are important for supporting a rich and healthy ecology, and also necessary for navigation, recreation and industry. To support these activities we need accurate forecasts of bathymetry. Future climate-change impacts, including sea-level rise, will alter estuary processes, in which tidal currents mix sea water and sediments with those from rivers. Past studies traditionally predict bathymetric evolution from existing patterns of sediment movements.

New theories developed by David Prandle suggest the dynamics and mixing of tides and river flows control estuarine bathymetries – the prevailing sediment regime is a result rather than a cause. David Prandle and Andy Lane (collaborating with HR Wallingford and the University of Plymouth), tested this by using data (depth, length, sediment concentrations and rates of axial and vertical mixing) from estuaries around the UK. The relation of these data to tidal amplitude and river flow support the new theories; the close correspondence allows assessments of how sensitively estuaries are likely to respond to individual components of climate change.

2



Watching the sea with radar

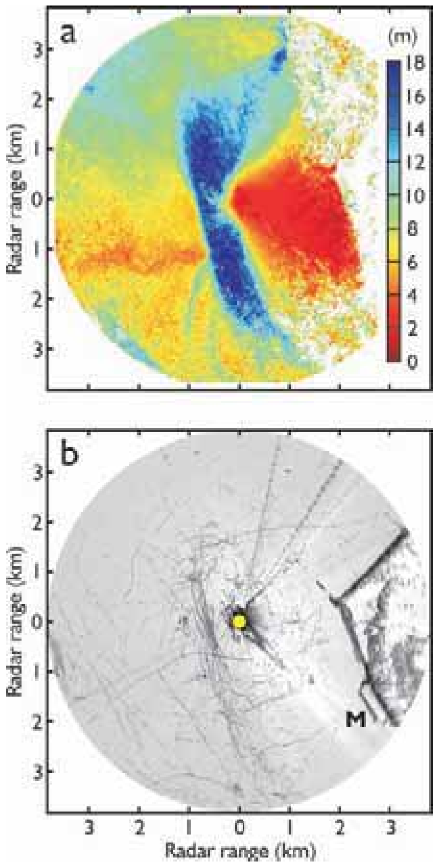
Over the last few years Paul Bell has been developing a technique to use marine radars to measure waves and water depth. This has been so successful that it has gained national and international contracts. The Centre for Environment, Fisheries & Aquaculture Science commissioned POL to survey the wave climate around Great Yarmouth before and after the construction of an offshore wind farm. The work was funded for its importance in assessing the environmental impact of offshore wind farms. The US Office of Naval Research sponsored Jon Williams and Paul Bell to study the interaction of suspended mud and waves over a nearshore mud bank as part of the MUDEX experiment at Cassino Beach in southern Brazil.

The radar records coastal and bathymetric changes over long periods (months, years) at high frequency (minutes) so we can distinguish the continuous change caused by tides from rapid change due to storms. It improves our ability to predict evolving mud and sand banks and is an important step towards real-time surveying of coastal seas.

Following studies of evolving bathymetry around a migrating tidal inlet off Faro in the Algarve in Portugal (1999, 2002 and 2003) a further radar survey began in December 2005. Bathymetric maps of 2km radius produced from wave data collected in previous years have given new insights into the mechanisms of inlet migration.

The Hilbre Island radar station developed by Paul Bell has 'gone live'. It records sequences of 256 radar images over a 10-minute period every hour to almost 4km range. Images from each record appear on the Coastal Observatory website within one hour. Detailed analysis of the radar data – using a wave inversion technique developed by Paul – will allow regular mapping of bathymetry and possibly currents around the mouth of the Dee Estuary. Long time-series of these data will allow remote observation of evolving sandbanks and associated waves and currents. Early tests on the data show promising results. An unexpected outcome is the possible use of radar to track the flight paths of feeding and migrating birds around the estuary, and so pinpoint areas that may need increased protection.

3



2. *Characteristics of English and Welsh estuaries. North-western estuaries are purple; eastern ones are red; blue indicates those in the west; and green shows the southern ones.*

3. *(a) Water depth around Hilbre Island derived from a single five-minute record of 128 radar images. (b) Birds' flight paths for the same area. The Wirral coast and West Kirby marine lake (M) are easily identified. The radar location on Hilbre Island is marked with a yellow dot.*

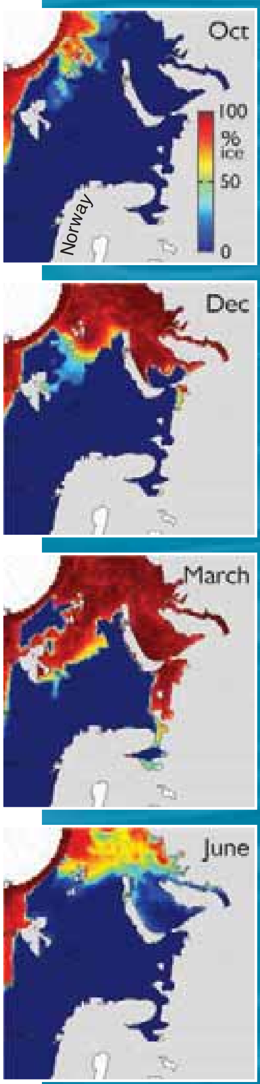
Science

Computer modelling is a core activity for us, both in the development of models for use in coastal seas and neighbouring oceans, and in their increasingly multi-disciplinary use. POLCOMS (Proudman Oceanographic Laboratory Coastal Ocean Modelling System) continues to be the framework on which these models are developed. New advances keep this system at the forefront of European modelling.

The NUMBERS game

Advanced numerical modelling

1



Step by step

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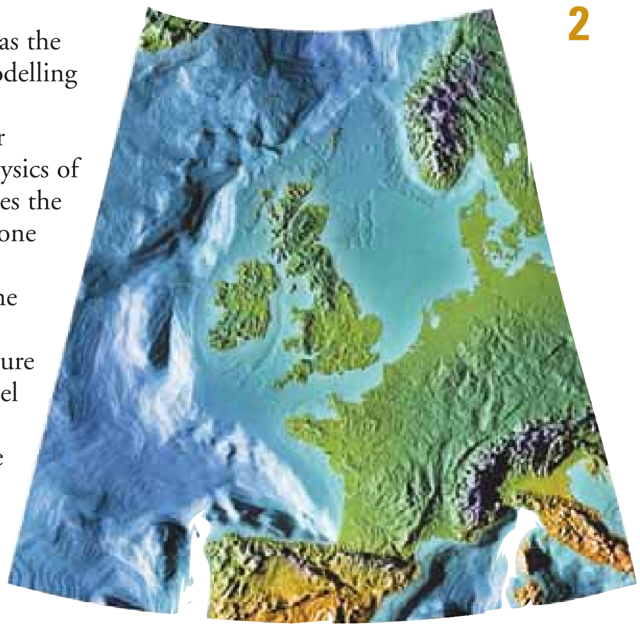
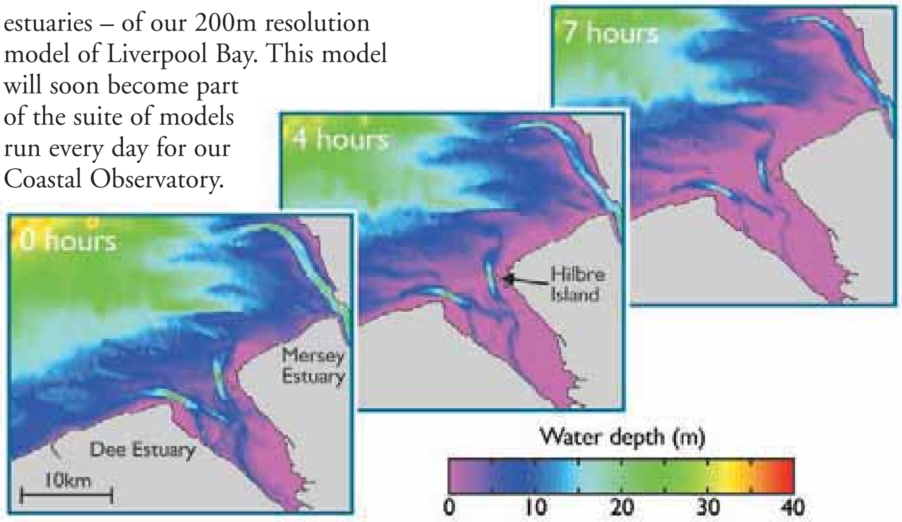


Computer models such as the POL Coastal-Ocean Modelling System (POLCOMS) incorporate much of our understanding of the physics of the sea. POLCOMS takes the conditions in the sea at one instant and steps them forward a short time. The conditions may include currents, tides, temperature and salinity. As the model repeats this process we build up a picture of the changing state of the seas, which may range from days (showing the tides), to years (showing heating and cooling with the seasons), to decades (showing climate change). Alongside physical properties we also study biological and chemical properties, including suspended mud and sand.

1. *Seasonal distribution of sea ice in the Barents and Kara Seas from the POLCOMS/CICE model.*
2. *POLCOMS covering the entire north-west European continental shelf and the open ocean as far as Iceland.*

What do we do when the tide goes out?

A particular feature of our coastline is that many regions dry out at low tide. Examples in the eastern Irish Sea include the Dee and Mersey estuaries and Morecambe Bay. This presents a particular problem for modelling on a fixed grid, since the question of which points are land and which are sea changes with the tide. Ian James has developed a new method of approaching this problem, which allows the water depth to become close to zero but never negative, just as in the real sea. This is useful for modelling constituents in the water such as sediment and plankton. The new approach has been applied to a section – from the Dee to the Ribble estuaries – of our 200m resolution model of Liverpool Bay. This model will soon become part of the suite of models run every day for our Coastal Observatory.



3

POLCOMS in icy seas

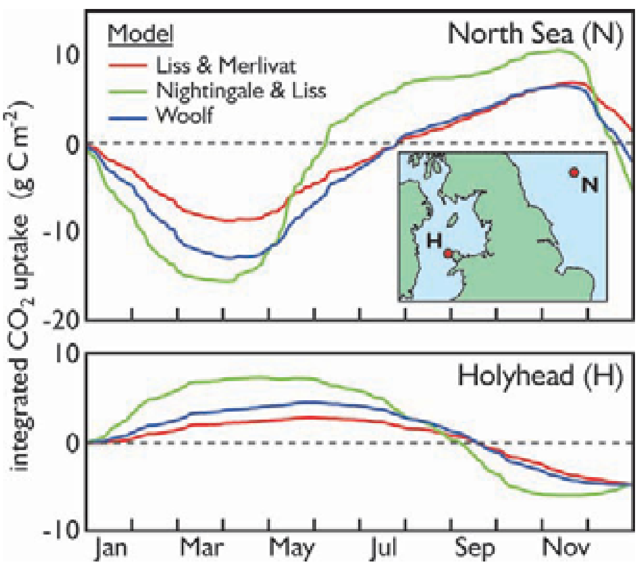
POLCOMS has a new ability. It now includes a sea-ice component for studying Arctic shelf seas, using the Los Alamos Sea Ice Model (CICE). When the wind blows from the shore across ice-covered seas it can create ice-free regions, known as polynyas. In a polynya the surface water is exposed to rapid cooling, and as it freezes it ejects salt into the water below (ice is made of fresh water). This cold, saltier, dense water sinks, flows to the edge of the continental shelf and can cascade into the deep ocean. This dense-water formation plays an essential part in maintaining the circulation of the world's oceans. However, current global climate models cannot represent these important small-scale processes. Using the POLCOMS/CICE model Clare Postlethwaite and Graham Tattersall are developing a simple and efficient method for including the effect of polynyas in global climate models. This work is part of the RAPID programme and will improve our knowledge of global circulation and how it may change.

3. Time-series of water depth from POLCOMS Mersea and Dee model (200m resolution) showing the drying out at low water. Times are from high water at Hibre.

4. Integrated CO_2 uptake for three one-dimensional water column models in the North Sea (N) and at Holyhead (H). At N, the choice of algorithm affects whether the model predicts a positive or negative net air-sea flux (absorption or release) of CO_2 over the year. At Holyhead, the model predicts a net out-gassing (release out of the sea) over the year.

Exploring the shelf-sea carbon pump

Carbon dioxide (CO_2) is an important greenhouse gas that affects our climate. What is less well-known is that shelf seas are regions of such high biological productivity that they can contribute to the permanent removal of CO_2 from the carbon cycle. This may play an important role in the global climate. As a partner in the Centre for observation of Air-Sea Interactions & fluXes (CASIX), we are studying this 'carbon pump'. Sarah Wakelin and Jason Holt are using POLCOMS, with an added air-sea exchange algorithm for CO_2. One factor that influences how much gas passes between the air-sea boundary is the roughness of the sea surface, particularly wave heights. So a key part of the work uses POLCOMS coupled with the wave model WAM. Also, working jointly with Plymouth Marine Laboratory, we are using the European Regional Seas Ecosystem Model (ERSEM) to quantify the effects that changes in the ecosystem may be having on the CO_2 budget.



4

Science

Our Coastal Observatory – in the Liverpool Bay area of the Irish Sea – is set up to investigate the environment of a typical coastal sea. We are developing and testing our combined new system that gathers, forecasts and displays measurements in real time.

An eye on the OCEAN

The Coastal Observatory

enquiries to mjh@pol.ac.uk or visit: http://coastobs.pol.ac.uk

New web viewer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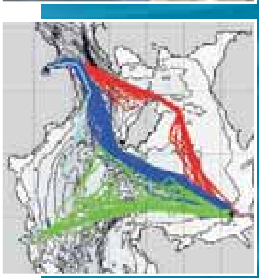
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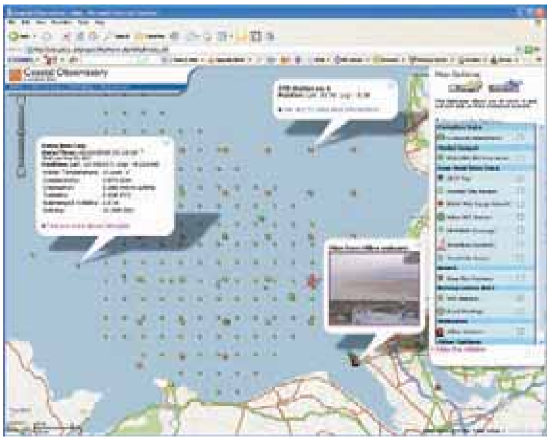
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Viewing Coastal Observatory information is now easier using the new and improved MapViewer. This software, developed using the Google Application Program Interface (API), allows access to Google maps and satellite images. If you click on locations where the Coastal Observatory takes measurements, results are displayed in a small bubble, with links to more information. For example, if you want to know where the ferry is with our instruments and what the sea temperatures are, all you have to do is click the relevant box and the track will appear on the screen. Clicking one of the track marks gives you the information from that point. As well as measurements you can also access model forecasts (temperature, salinity, currents, etc) for selected points within the Irish Sea.

1. *(a) Glider tracks shown in blue for 26 October to 17 November 2005. Exclusion areas are shown in red. (b and c) Launching the glider.*
2. *Liverpool Viking ferry tracks showing Irish Sea crossings.*
3. *New web viewer for Coastal Observatory measurements.*

Collecting measurements

The Liverpool Bay Coastal Observatory consists of measurements, numerical modelling, and a web display. The four main measurement elements are: in situ time series; a ferry carrying our instruments; shore-based high-frequency (HF) radar for surface currents, waves and winds; and spatial surveys of water column properties nine times a year.

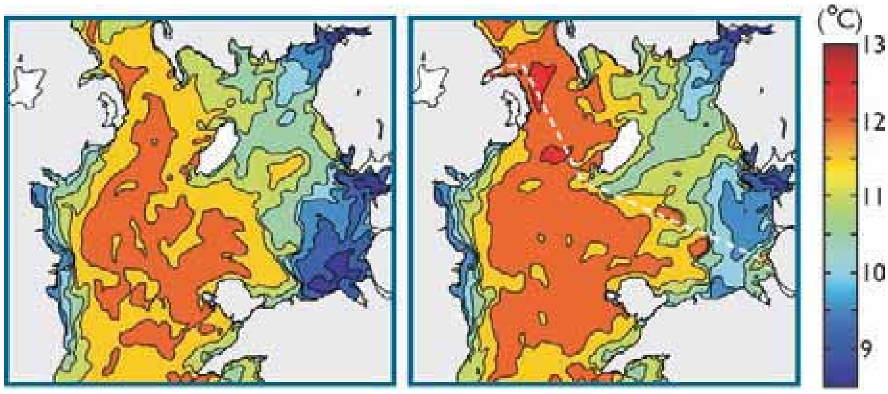
This year we present results from the ferry and the second mooring site, the use of a novel technology – an underwater glider – and developments to the website.

Cruising for data

We have been measuring near-surface temperature, salinity, turbidity and chlorophyll fluorescence on the *Liverpool Viking* since December 2003. The ferry, owned by Norfolkline, uses two routes depending on commercial requirements – from Birkenhead to either Belfast or Dublin. On both routes the return journey takes a day. Birkenhead to Belfast is 135 miles and takes about 7 hours, at an average speed of just under 20 knots. Initially the ferry almost always passed to the south and west of the Isle of Man but more recently it has often gone to the east and north. For both routes the distances and passage times are almost identical. Birkenhead to Dublin (115 miles) takes on average 6.25 hours.

All crossings pass close to the Coastal Observatory mooring site (A) by the Mersey Bar Light, enabling a check on the ferry-measured temperatures.

4



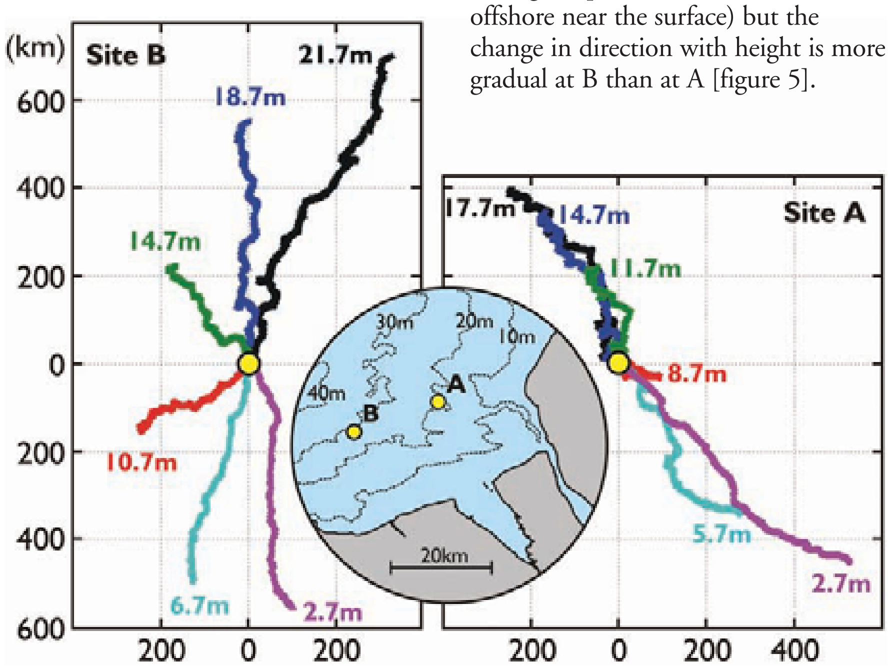
The values – obtained within 1km east-west and 20 minutes in time – show excellent agreement. The mean difference (ferry minus buoy) of 0.11°C suggests there is little warming of the water within the ferry. This comparison is one of the few ways of checking the ferry temperature sensor, although ideally it should be carried out in a region where the gradients are smaller.

Isabel Andreu-Burillo explored the added value of assimilating ferry temperature data into numerical models in comparison with assimilating satellite infrared data alone. Adding the ferry data gives better results, showing finer-scale structures in the areas surrounding the ferry track [figure 4]. The improvement is due to the high resolution and accuracy of the data.

Second mooring site

The first mooring site (A) was established in August 2002 close to the Mersey Bar Light. A second site (B), situated 21km WSW of the first and consisting of a seabed frame and a surface buoy, was started in April 2005 to estimate horizontal (and vertical) differences. The current profile throughout the water column is being measured along with near-bed and near-surface temperature and salinity. The results are similar to the first mooring. The mean current varies through depth (onshore near the bed, offshore near the surface) but the change in direction with height is more gradual at B than at A [figure 5].

5



4. *POLCOMS sea surface temperature model forecast at 0hrs on 11 November 2004. Left: with assimilation of satellite data; right: with assimilation of both satellite and FerryBox data. The white dashed line is the ferry track.*

5. *Current measurements at six heights above the seabed, 5 April–27 October 2005.*

Gliding along

Underwater gliders are vehicles without propulsion that gain their forward movement by varying their buoyancy. Wings convert their vertical velocity into a forward velocity of about 0.4ms (just under a knot). They glide downward when heavier than water and upward when buoyant. Navigation is by dead reckoning (charting course and speed from the previous position) for several hours until the glider surfaces to obtain a GPS position update. It then transmits collected data via the Iridium satellite mobile phone system (providing the data in near real time), receives any updated instructions and continues on its journey.

On 26 October 2005 during a Coastal Observatory cruise, Mike Burke launched a glider – on loan to us from Rutgers University, USA – between the Isle of Man and Anglesey. For 22 days the glider shuttled east and west covering 1,000km and collecting 4,235 temperature and salinity profiles [figure 1]. The glider performed well during this trial in an area of strong tidal currents, proving its ability to maintain its course and position.

National and international facilities

POL monitors sea level and tides in the UK and at sites in the South Atlantic and Southern Ocean. The National Tidal and Sea Level Facility (NTSLF) at POL brings all this work together with the aim of making information about British sea levels more easily available.

The National Tidal and Sea Level Facility

www.pol.ac.uk/ntslf

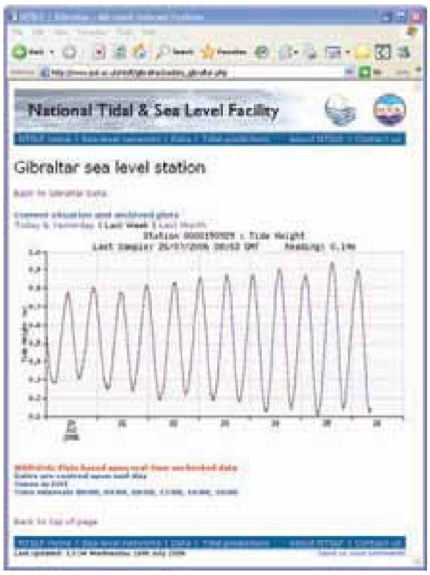
1

Role of the NTSLF

The NTSLF provides technical expertise to a wide community and supplies quality-controlled data with a range of practical and scientific applications, including:

- tidal prediction
- flood warning
- navigation
- extreme sea levels for coastal engineering
- climate-change studies.

The establishment of the NTSLF in 2002 reflected the importance of national sea-level monitoring to the public and government, as well as the academic community. It comprises the UK National Tide Gauge Network, geodetic networks for monitoring vertical land movements, and gauges in the South Atlantic and Gibraltar. From January 2005 responsibility for funding the UK National Tide Gauge Network transferred to the Environment Agency from the Department for Environment,

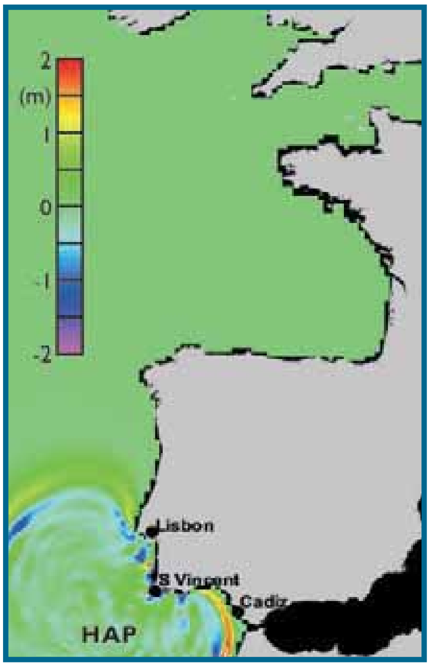


2

Food and Rural Affairs (Defra). This reflects the fact that the network is an important tool for flood forecasting and for research into the effects of sea-level change on coastal defences.

1. Sites of the UK National Tide Gauge Network: Lerwick; the new tide gauge building at Leith; Milford Haven; and St Mary's on the Isles of Scilly.
2. Real-time tide-gauge data from Gibraltar.
3. Computed tsunami elevation 40 minutes after an earthquake of magnitude 8.7Mw in the Horseshoe Abyssal Plain (HAP) about 330km from Lisbon.
4. Lowest modelled tidal surface from the 12km resolution model.

Tsunamis – low risk for UK



Following a first tsunami report in 2005, Defra commissioned more detailed work involving POL, the British Geological Survey and HR Wallingford. Here at POL, Kevin Horsburgh and Chris Wilson used a computer model to simulate possible tsunamis emanating from an earthquake off the Portuguese coastline, similar to that which destroyed the city of Lisbon in November 1755. The aim was to experiment with several orientations of the earthquake fault and estimate the height of any wave reaching the coastline of Britain.

Travel times for the wave's journey towards the Portuguese coastline agreed well with accounts of the 1755 event. The most credible simulation saw most of the wave energy directed immediately towards the Portuguese coast. Spreading of the wave resulted in lower amplitudes by the time any tsunami reached the continental shelf break to the south-west of the Celtic Sea. Here, even the largest possible seismic disturbance resulted in heights of only 50cm.

The rapid change of depth at the shelf break means the wave slows down as it crosses the Celtic Sea. This gives at least three hours' warning, so well-positioned instrumentation would allow an effective emergency response time.

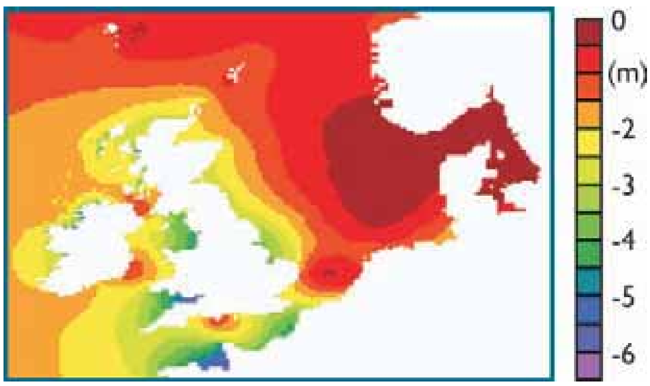
UK tide-gauge network

Throughout the year the Tide Gauge Inspectorate (TGI) staff – Dave Smith, Les Bradley and Darryn Gaudie – continued the programme of refurbishment, maintenance and development of the 44 sites of the National Tide Gauge Network. This included refurbishments at three Scottish sites: Ullapool, Kinlochbervie and Leith. Ullapool and Kinlochbervie now have new underwater steelwork and mid-tide sensors. Leith has a new building – on the original site – with a bubbler system replacing the float gauge chart recorder. All 44 sites were visited, with geodetic levelling completed at 14. As well as their work at Ullapool and Kinlochbervie, the POL diving team – Les Bradley, Ray Cramer, John Mackinnon and Danny McLaughlin – also inspected measuring systems at Milford Haven and Fishguard. The OTT 'Kalesto' radar gauge at Gibraltar (in the commercial port) was serviced and calibrated; geodetic levelling between this gauge and the tide-gauge benchmark at the old float-driven chart recorder in the Royal Naval base was checked.

The TGI continue to develop data collection systems which link to all existing network sensors and the new radar sensor. They are also improving site communications, testing both the Global System for Mobile Communications (GSM) and broadband.

Significant aid to marine safety

Kevin Horsburgh and Chris Wilson are working with colleagues at University College London (UCL) to combine satellite altimetry with tidal modelling. The aim is to produce seamless Vertical Offshore Reference Frames (VORF) that may eventually replace Chart Datum for practical maritime applications. Chart Datum, the level below which the tide rarely falls, is defined at over 500 points around the coasts of Britain and Ireland. The UCL team will fix a mean sea level by merging offshore satellite altimetry observations from TOPEX/POSEIDON with onshore measurements from the 44 stations of the UK National Tide Gauge Network. They will also use secondary measurements from 400 other locations. The new reference surface will help mariners, offshore surveyors, and others in the marine environment to fix their positions.



Our contribution is to provide modelled tidal surfaces for the highest- and lowest-possible water levels. Using the tide-surge model suite we calculate the highest and lowest tides by performing 20-year simulations centred on years when the tides are extreme. Adding these surfaces to the mean surface deduced from altimetry produces the VORF. Using model grids of 12, 3.5 and 1km shows the improvement in potential accuracy that comes with higher resolution.

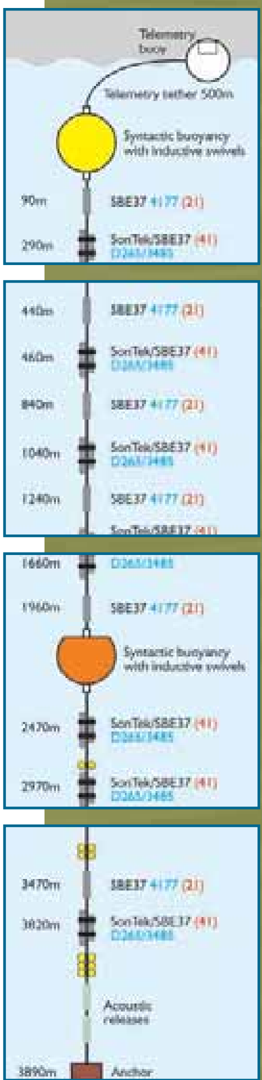
National and international facilities

The British Oceanographic Data Centre (BODC) is a national facility for storing and distributing data concerning the marine environment. We are part of the Intergovernmental Oceanographic Commission's network of data centres. The centre provides a resource for science, education and industry, as well as for the wider public.

The British Oceanographic Data Centre

British Oceanographic Data Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

www.bodc.ac.uk



1

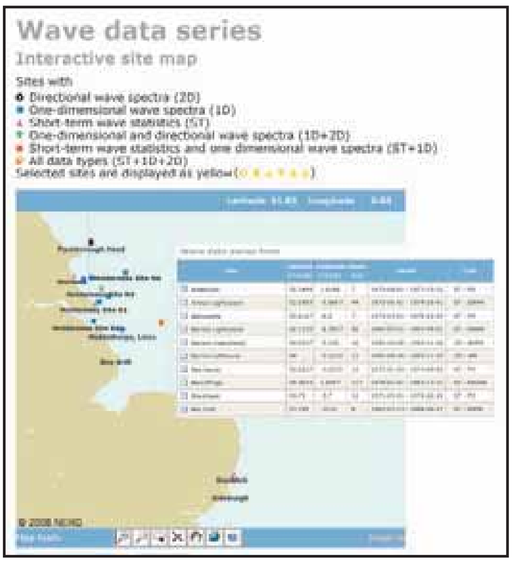
Working for the marine community

Making information and knowledge available to the marine community is a key element of BODC's role. We have pioneered a proactive approach to managing complex multi-disciplinary oceanographic data. Rather than just storing information, our staff collect, calibrate, compile and check the quality of data, from major research programmes to information from individual sampling stations. Much of the data has been paid for by public funds. BODC stores the information securely and promotes its continued use.

In 2005–06, BODC:

- handled 42,828 enquiries
- received 180 sets of data from 41 organisations in nine countries
- published the National Tidal and Sea Level Facility annual report for 2004 (www.pol.ac.uk/ntslf/reports.html)
- made data freely available from the UK's National Tide Gauge Network of 44 sites (following an initial period of three months to ensure data quality; see www.bodc.ac.uk/data)
- continued to improve the website content, incorporating a facility to allow an increasing number of data types to be searched via an interactive map.

We have answered enquiries from organisations and private individuals engaged in leading-edge science, students working on research projects in universities and schools, offshore industry impact studies and wealth creation, as well as requests for information to help central and local government meet statutory responsibilities.



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Monitoring our climate

The transport of warm water in the Gulf Stream means that north-west Europe enjoys a mild climate for its latitude. However, climate models and palaeoclimate records show that an abrupt change in the major currents in the Atlantic may cause the European climate to cool by 5–10°C. A principal objective of NERC's RAPID climate-change programme is to develop a system to continuously observe the strength and structure of the major elements of the current system that move heat around the North Atlantic. See www.soc.soton.ac.uk/rapid/rapid.php.

This northward flow of a warm Gulf Stream and a southward flow of cooler thermocline and cold North Atlantic deep water is termed the Meridional Overturning Circulation. It is being monitored by teams of scientists at the National Oceanography Centre, Southampton, the University of Miami's Rosenstiel School of Marine and Atmospheric Science and the Atlantic Oceanographic and Meteorological Laboratory, Miami. They are collecting data using arrays of instruments at key locations in the North Atlantic. BODC is making the data available as they are collected and delivered via satellite. See www.bodc.ac.uk/rapidmoc.

3

1. *The western boundary mooring from the RAPID monitoring array.*
2. *Part of our increasing interactive map search facility.*
3. *RAPID instrument deployment.*
4. *Gas platform in the North Sea. Copyright of SIMORC participating company*

The management challenge

Recently, NERC began the UK Surface-Ocean/Lower Atmosphere Study. This five-year programme aims to advance our understanding of environmentally significant interactions between atmosphere and ocean. The main areas of research consider processes that involve ocean productivity, atmospheric composition and climate. With a strong international focus, the knowledge gained will improve the predictability of climate change and give insights into the distribution and fate of persistent pollutants and other future environmental conditions. See www.nerc.ac.uk/funding/thematics/solas.

With our sister organisation, the British Atmospheric Data Centre (www.badc.co.uk), we will provide the data management to promote data sharing and collaboration between projects and to ensure safe storage of the data for long-term use. We will be directly involved with project scientists; helping with the working up, calibration and quality control of the data; compiling the data documentation and assembling the project database for use within and beyond the project.

Working with industry

Large quantities of marine data, comprising measurements of ocean currents, waves, sea level and meteorological data, are collected for the use of major oil and gas companies. These companies have many offshore oil and gas fields scattered worldwide in seas and on continental shelves, often in remote areas. The information is expensive to collect and frequently forms the sole source of data.

4

As a national facility BODC works with the entire marine community to make the data more widely available. We are collaborating with the International Association of Oil & Gas Producers (OGP), Mariene Informatie Service 'MARIS' BV (MARIS) and the Intergovernmental Oceanographic Commission of UNESCO (IOC-IODE), co-funded by the European Commission. BODC will quality control the data and unify their formats.
Details of the SIMORC (System of Industry Metocean data for the Offshore and Research Communities) can be found at www.simorc.org

5. *The UK National Tide Gauge Network. Source of requests for UK National Tide Gauge Network data for 2005–06. Number of manually/automatically serviced requests for 2000–06. The tide gauge at Wick.*
6. *RRS James Cook, the replacement for RRS Charles Darwin.*

National and international facilities

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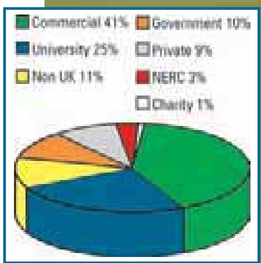
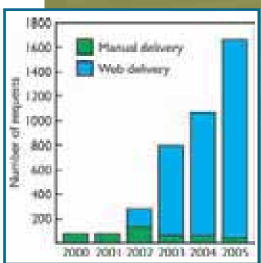
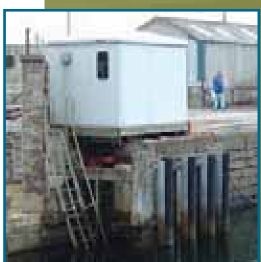






A rising tide of free information

Through Defra and latterly Environment Agency funding, all data from the UK National Tide Gauge Network of 44 coastal tide gauges (see page 18) are freely available from our website. They are accessible following an initial period of three months to ensure data quality. There are 1,276 site years of data, with the longest record at Newlyn stretching back to 1915. Further information about the UK National Tide Gauge Network and related sea-level science is in the NTSLF 2004 annual report. See www.pol.ac.uk/ntslf/pdf/annual_reports.

Free web-based access has led to a 30-fold increase in data supplied to users compared with previous years, benefiting industry, schools, universities, scientific research and the public.

A gateway to marine data and information

Enormous investments are made in collecting marine data, yet the full benefits are not always realised. Often this is because of: lack of awareness of existing data; incompatibility and disparity between data sets; differences in quality assurance standards; differences or even lack of data management methods. BODC is a leading partner in several national and international initiatives to resolve this:

1) SEA-SEARCH is a pan-European network of 33 national oceanographic data centres and marine information services from 30 coastal states. This provides a central overview of marine data and information in the countries bordering the European seas. See www.bodc.ac.uk/projects/european/seasearch.

2) Through two complementary working groups of the Inter-Agency Committee on Marine Science and Technology (IACMST):

   - Marine Environmental Data Action Group (MEDAG) – coordinating the accessibility and availability of UK marine environmental data
   - Marine Data and Information Partnership (MDIP) – providing a framework for data management in the UK.

   See www.oceannet.org.

Did you know?

You can access a catalogue of UK research vessel activities dating from 1960 to the present day. Currently, it contains entries for 7,355 cruises from 658 individual ships, with 4,112 cruise reports and track charts available.
See www.bodc.ac.uk/data/information_and_inventories/cruise_inventory.

6

The Permanent Service for Mean Sea Level

PSMSL

www.pol.ac.uk/psmsl

Sea level in the news

Two recent events highlight the need for sharing information on sea-level changes internationally: the Sumatra tsunami of December 2004 and the hurricane Katrina floods of August 2005. There are also scientific and public concerns about climate change and sea-level rise. The PSMSL is the global data bank for long-term sea-level information from tide gauges. It operates with the support of the International Council for Science. PSMSL's data holdings now total more than 54,000 station-years from around 2,000 stations, an increase of over 1,600 station-years during 2005–06.

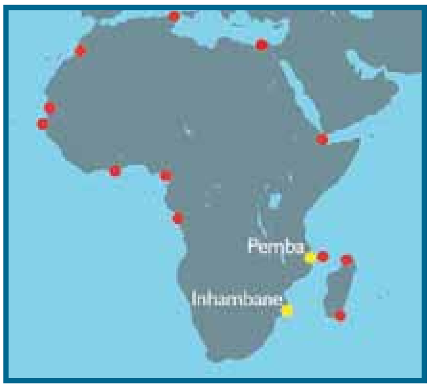
International Polar Year

The International Polar Year (IPY, 2007–08) is focusing attention on making and using more measurements in the polar regions to better understand our current global climate and what may happen in the future. As part of the IPY, the PSMSL took the lead in 2005 in a proposal for sea-level measurements in the Arctic and Antarctic. The proposal was enthusiastically endorsed by our international partners and accepted by the IPY Committee.

1

PSMSL and Africa

2



There are major gaps in the global sea-level network in Africa, which need filling. PSMSL and the Inter-governmental Oceanographic Commission (IOC) have co-operated in installing two new tide gauges at Pemba and Inhambane in Mozambique (see the 2004–05 POL Annual Report). They have also bought hardware for the first four of 12 new stations in Africa. These, based on radar and pressure gauge technology, will be part of the ODINAFRICA programme.

1. The tide gauge at Vernadsky on the Antarctic Peninsula, operated by POL and Ukraine partners – this gauge has a 45-year record, the longest from Antarctica.

2. New tide gauges at Pemba and Inhambane in Mozambique and the 12 new African stations, to be installed under ODINAFRICA.

New tidal software

A version of the PSMSL Tidal Analysis Software Kit (TASK) which can run under Windows has been developed jointly with colleagues in Israel. It has been renamed TIDE TASKS for WINDOWS and is available free of charge to sea-level researchers. For details see: http://medgloss.ocean.org.il/

4th edition IOC Tide Gauge Manual

A fourth edition of the IOC Manual on Sea Level Measurement and Interpretation has been produced by the PSMSL and international colleagues with the help of consultant Dr Ian Vassie.

GLOSS CD

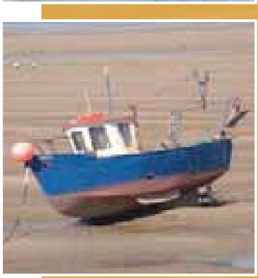
PSMSL plays a large part in managing the Global Sea Level Observing System (GLOSS). A demonstration CD, produced for PSMSL by the POL Applications Team, is now available. It contains PowerPoint presentations from several recent GLOSS training courses and reports of recent meetings. Over 500 copies are in circulation.

Putting science to work

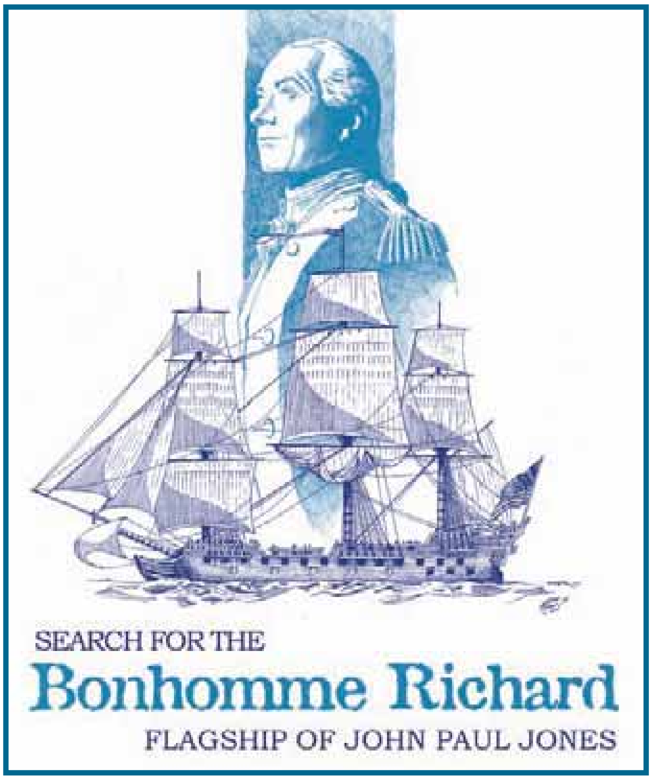
Our Applications Team are at the front line for dealing with all enquiries to POL, from large commercial companies through to members of the public. A wide range of products and services will help you get the most from our science.

The Applications Team

www.pol.ac.uk/appl



Search for sunken treasure?



We don't know whether there will be any treasure on board, but when the flagship of John Paul Jones sank, a ship of major historic significance was lost. In 1779, the *Bonhomme Richard* engaged HMS *Serapis* in a three-and-a-half-hour point-blank battle. Jones finally won and captured the *Serapis*, only to watch the *Bonhomme Richard* be consumed by the sea 36 hours later.

The Ocean Technology Foundation is coordinating the search for the *Bonhomme Richard*, and eventually her raising. They have enlisted the help of experts in many fields to help achieve this. As the precise whereabouts of the ship are unknown, POL provided maps showing the tidal currents in September 1779 – not something readily found at your local chandlers.

It is satisfying to see scientists and historians co-operating in the same quest.

Serving new markets

This year has seen increased interest from certain industries – in particular marine renewable energy. Large tides around the UK give us prime potential to exploit the energy available from this movement of water. Over the next ten years this could grow into a very profitable market. In the early stages of this industry, identifying prime locations is high on the agenda. This is where POL's numerical models and our POLPRED software can give companies the upper hand.

Driven by feedback from our existing POLPRED users, we have improved the software to provide a non-interactive mode, running the software direct from the parameters stored in a file rather than controlled by the user. Tidally correcting large data sets – never possible before – is now achieved in minutes.

Tidal harmonic analysis is another area in which we have been busy. This is a service we offer to complement our production of tide tables. In particular we have used clients' own data to provide improved tide tables for the UK Environment Agency and the Isle of Man Met Office.

When Airbus needed to float the wings of their A380 Superjumbo from their factory in Broughton, North Wales, to Mostyn Dock on the River Dee, they came to us for help. The route, along a complex stretch of water, passes under some low bridges. We carried out tidal analyses, incorporating the results into POLTIPS, so they are now able to plan the best time to transport the wings.

1

1. Airbus use a traffic light system – when the tide level is within the green range the wings can be floated safely down the river.

Disc duplication and distribution

The Applications Team has set up a CD/DVD duplication and distribution service. We offer this as a service to POL, the British Oceanographic Data Centre and the wider NERC community. For small runs of up to about 500 discs, our robotic disc publisher – which copies and prints the disc – means we can provide a fast turnaround. We also offer design work and front-end development.

Statistics

In 2005–2006 the Applications Team:

- answered around 4,500 enquiries
- issued 40 licences for offshore data – over 20% increase on last year
- served over 300 customers with tide tables and POLTIPS software
- provided support for over 25 users of POLPRED software and 10 hydro-DLL users.

Low flying over rough seas

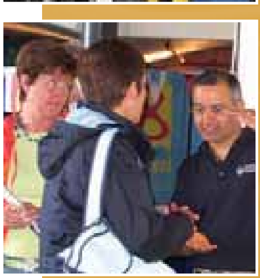
Military helicopters need to align their navigation systems over water without GPS. This is done by comparing onboard data with measurements of the aircraft's motion over the sea surface using Doppler radar. The Doppler measurements are then corrected for the motion of the water beneath the helicopter.

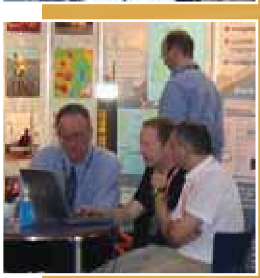
We were able to provide AgustaWestland UK (navigation systems section) with our POLPRED software configured for POL's new high-resolution Continental Shelf model. AgustaWestland UK will use this as a tool to predict the sea surface over the Bristol Channel, east of Swansea – a complex tidal area.

Putting science to work

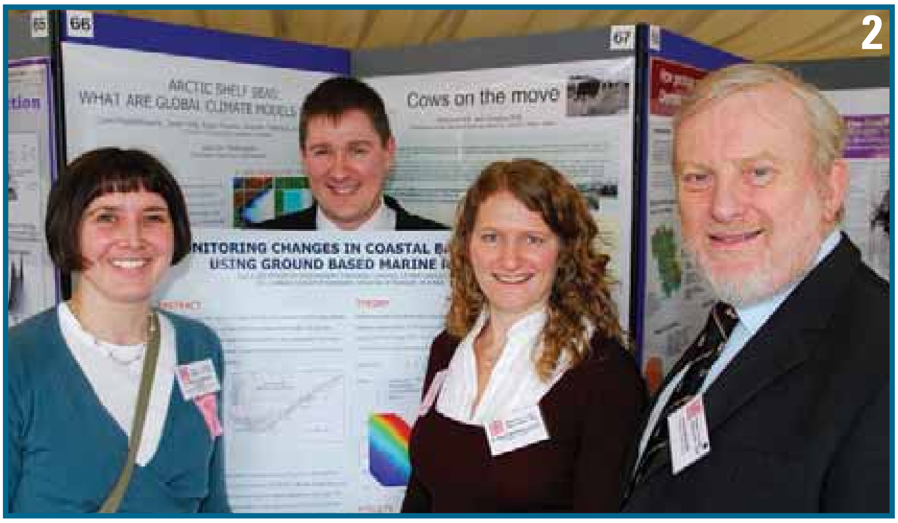
Science and Society

Top scientists meet MPs





Clare Postlethwaite and Paul Bell were selected to display posters about their research at the 'Annual Presentations by Britain's Top Younger Scientists, Engineers and Technologists'. On 13 March Clare and Paul joined other young researchers as they descended on the House of Commons. The event, organised by Eric Wharton of SET for BRITAIN, aims to inform decision-makers about ground-breaking research carried out by top young scientists, engineers and technologists in the UK. Clare's poster 'Arctic Shelf Seas: What are Global Climate Models Missing?' and Paul's 'Monitoring Changes in Coastal Bathymetry Using Ground-Based Marine Radar' created much discussion. Over 250 young scientists were able to network with peers from diverse scientific back-grounds as well as their parliamentary representatives. The busy lunchtime and evening poster sessions created a relaxed but energetic forum. About 120 MPs were able to meet the researchers and find out all about their work.



1. Photos from the Mersey River Festival, Blue Planet Aquarium and Oceanology International 06.
2. Clare Postlethwaite and Paul Bell with Susan Robinson from the University of Liverpool Faculty of Veterinary Science and Andrew Miller MP at the reception for younger scientists, engineers and technologists at the House of Commons. Photo: Frank Dumbleton/SET for Britain.
3. Andrew Manning, University of Plymouth, with Nuffield students Kate Welch and David Balmford.

Students test new theory

Two Nuffield-funded students came to work at POL for four weeks in July-August 2005. Kate Welch (Notre Dame High School) and David Balmford (Carmel College; both schools near Liverpool) worked on a project with POL's David Prandle and Andrew Manning from the University of Plymouth. They aimed to assess the validity of new theoretical formulae for the shape of estuaries. Kate and David assembled data on the length, breadth and depth of 96 UK estuaries, and related them to river flow and tidal range. The results supporting the new theories are published as a POL Report and confirm the relationships reported in 'Shifting SANDS' on page 13.

4. Sean Gaffney, Geoffrey Williams, Frances Kellie, and Stephanie Contardo.

5. Chris Wilson, Chris Balfour, Jingbo He, Sylvain Michel, and Darryn Gaudie.

New faces

We are pleased to have recruited many new staff at POL. Rory Bingham, Miguel Morales-Maqueda and Chris Wilson have joined our sea-level research team. Kathy Gordon has joined the Permanent Service for Mean Sea Level. Sylvain Michel has joined the modelling team. Chris Balfour looks after instrumentation for the Coastal Observatory. Darryn Gaudie has joined the Tide Gauge Inspectorate. Jingbo He works in finance. BODC also welcome new data and IT specialist staff: Mark Charlesworth, Stephanie Contardo, Stephen Emsley, Frances Kellie, Adam Leadbetter, Sean Gaffney and Geoffrey Williams.

Oceanology International

This biennial exhibition and conference, held in March, not only enables us to publicise our research but also get up to date on the latest emerging technologies. Most of our Ocean Engineering and Technology Group and some POL scientists – including Andrew Willmott and John Huthnance – attended the event at ExCel in London. All took a turn on the POL stand, but were also able to take part in various workshops, meetings and conferences during the week. One of these was the third in a series of meetings held by the UK Moorings Group. John Humphery arranged the speakers for this gathering of practical oceanographers to discuss specialist techniques of mooring deployments and recoveries. All the delegates thought the meeting, organised jointly by POL and the Institute of Marine Engineering, Science and Technology, a great success.

Presenting our observatory

During the year we have been busy promoting our Liverpool Bay Coastal Observatory to audiences in the UK and abroad. Roger Proctor presented in Daresbury, Exeter, Southampton, Vienna, Charleston, Salt Lake City, and Seoul. John Howarth presented in Plymouth, Southampton, Paris, and San Fransisco. Andy Lane presented in Brest. At the most recent event in London, during March, John presented to three international and national audiences. The first of these, at the World Maritime Technology Conference, were mainly scientists. The other two were at Oceanology International 06 – first a workshop on Coastal Ocean Benthic Observatories, and then a meeting on 'Emerging technologies for monitoring the coastal zone' (organised by the Institute of Civil Engineers), which was well attended by coastal engineers.

Blue Planet

and River Festival

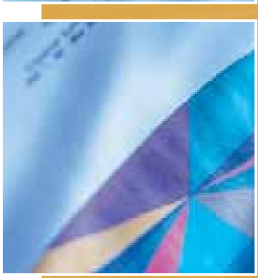
As part of communicating our science, we take part in events where we meet the public. In June we had a stand at the Mersey River Festival held at the Albert Dock in Liverpool. In August we were at the Blue Planet Aquarium 'Ocean Awareness Weekend' at Ellesmere Port, Wirral. Our eye-catching deep-sea and shallow-water landers [figure 1, page 4 and cover] attracted many people to the stands. Displays explaining our research on sea-level rise, our Coastal Observatory, and our Ocean Engineering and Technology Group proved popular. Our scientists and technologists enjoy these events, answering many questions and promoting the research of POL and NERC.

Putting science to work

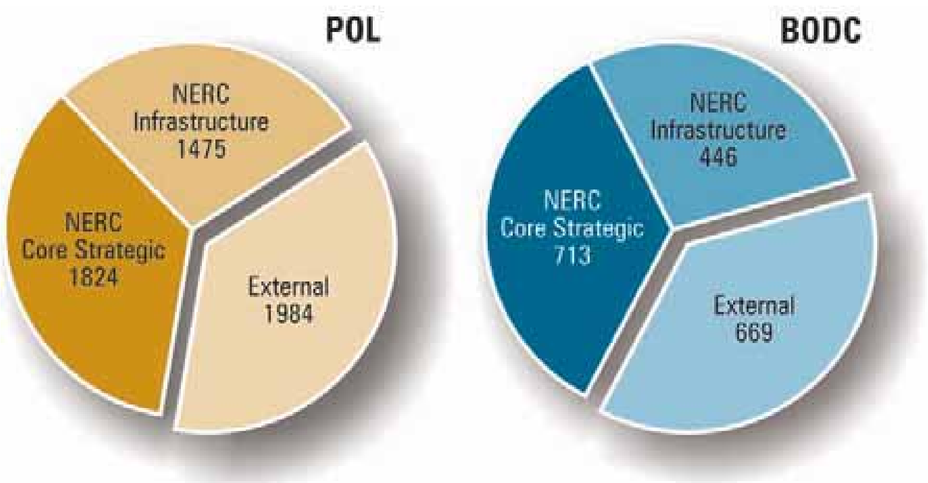
Finance

Where we get our funding

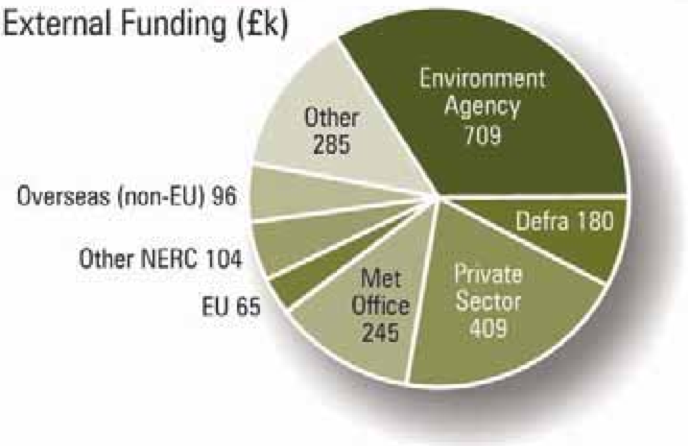





From NERC (£k)



External Funding (£k)



Where we spend our funding

	Science including the NTSLF and PSMSL	British Oceanograhic Data Centre	POL Applications Team	Infrastructure	Total
Staff	2367	1243	123	898	4631
Recurrent expenditure	926	119	6	1080	2131
Capital expenditure	103	0	0	128	231
Indirect costs	1451	590	65	-2106	0
Total	**4847**	**1952**	**194**	**0**	**6993**

Commissioned research

Much of our work is commissioned by other organizations. Here, we list all the commissioned work we undertake within our main science themes.

Commission projects

Changes in global and regional sea and land levels

Permanent Service for Mean Sea Level	Federation of Astronomical & Geophysical Data Analysis Services, International Oceanographic Commission, UNESCO and NERC
UK tide-gauge network	Environment Agency
Absolute Gravity, GPS & MSL	Defra
European Sea-Level Service Research Infrastructure	EU
Absolute Fixing of Tide Gauge Benchmarks	Defra

Sea level variability and extremes

Climate and Sea Level Change in the Indian sub-continent	DFID
Threat posed by tsunami-type events for north-west Europe	NERC/Met Office/Defra
Tsunami threat study	Defra/Private sector
EPSRC Floods	EU
Advanced Global Barotropic Ocean Model	NERC
Thames Estuary 2100 for a Phase 2 review of storm surge scenarios	Environment Agency

Continuous ocean measurement methods

Attribution of ocean climate change signals in the Atlantic	NERC
Western Atlantic Variability Experiment (WAVE)	NERC(RAPID)

Shelf and coastal ocean processes

Geophysical Oceanography – a new tool to understand the thermal structure of dynamic oceans	University of Durham/EU
Turbulence and plankton	NERC

Measuring how sediments move around our coasts

Inshore wave (Scrobie Sands)	Cefas
Larger-scale Morphodynamic Impacts of Segmented Shore-Parallel Breakwaters on Coast and Beaches	University of Liverpool/EPSRC
Mine burial prediction	ONR
Estuary Process Research	Defra/Private sector
Estuarine Morphology	Defra
Tracers	NERC

Advanced numerical modelling

Pre-operational model development	Met Office
Marine Environment and Security for the European Area	EU/NERC
Processes controlling dense water formation on Arctic continental shelves	NERC(RAPID)
Global Coastal-Ocean Modelling	NERC
Palaeo-tide and wave modelling	Private sector
Centre for observation of Air-Sea Interactions & fluXes	NERC
Exotic disease research – virus transport	Defra
Marine Biogeochemistry and Ecosystem Initiative in QUEST	NERC

Progress to operational oceanography

Ferrybox – modelling based on ship-borne monitoring instrumentation	EU/NERC
International Network of Coastal Observing Systems	NERC
Predictive Irish Sea Models	EU/NERC
Optimal Design of Observational Networks	EU/NERC

Publications list 2005–06

ISI®-listed publications
ISI®: Institute for Scientific Information www.isinet.com/isi/

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