Liverpool Marine Science Symposium

January 10th 2007

Foresight Centre, University of Liverpool.

"Signals of Climate Change in Coastal and Shelf Seas"

Acknowledgements: Our thanks to Prof. Brian Tomsett (Dean of Science, University of Liverpool) and Prof. Andrew Willmott (Director, Proudman Oceanographic Laboratory) for providing the financial support for this meeting.

Presentations and Timetable:

Time	Speaker	Title
0900	**Welcome**	
	Session Chair: Jonathan Sharples	
0915	**Keynote**: Jason Lowe, Met Office Hadley Centre	Modelling changes in sea level.
1000	Simon Holgate, Proudman Oceanographic Lab	Decadal rates of sea level change during the twentieth century.
1015	Phil Woodworth, Proudman Oceanographic Lab	Evidence for Changes in Extreme Sea Levels and Waves in the Recent Past
1030	**Tea/Coffee Break**	***Posters put up.***
	Session Chair: Ric Williams	
1100	Miguel Maqueda, Proudman Oceanographic Lab	Modelling ocean climate change in the Arctic
1115	George Wolff, University of Liverpool (Earth & Ocean Science)	Cold-water corals and climate change – a study of the Tisler Reef (Sweden)
1130	Fabienne Marret, University of Liverpool (Geography)	The onset of seasonal stratification in the Celtic Sea during the Holocene from a benthos-phytoplankton perspective
1145	Roger Proctor, Proudman Oceanographic Lab	Ecosystem function in shelf-wide models.
1200	Graham Tattersall, Proudman Oceanographic Lab	Temperature and salinity trends in the NW European shelf seas
1215	**Lunch**	
1245	**Poster Session**	
	Session Chair: George Wolff	
1400	**Keynote**: Nova Mieszkowska, Marine Biological Association.	Responses to global environmental change: the need for an ecosystem approach to long-term coastal observing.

1445	Andy Plater, University of Liverpool (Geography)	Temporal and spatial controls on tidal signal preservation in late-Holocene tidal rhythmites, Romney Marsh, Southeast England.
1500	Alex Souza, Proudman Oceanographic Lab	Anomalous Coastal Upwelling in the California Current Region.
1515	**Tea/Coffee Break**	
	Session Chair: Roger Proctor	
1545	Jonathan Sharples, Proudman Oceanographic Lab	Climate variability and change in the northern North Sea.
1600	Rob Hall, Proudman Oceanographic Lab/University of Liverpool	Seasonal and inter-annual variability in the Faroe-Shetland Channel
1615	Heidi Tillin, University of Liverpool (Biological Sciences)	Predicting the Effects of Change using Models of Species' Habitat
1630	Leonie Robinson, University of Liverpool (Biological Sciences)	Grabbing soft bottoms: What can we learn from 33 years of North Sea benthic studies?
1645	**Symposium Close – wine & nibbles**	

Posters:

Gualtiero Badin (UoL, Earth & Ocean Science): Are eddies important in the coastal ocean?

Rachel Bearon (UoL, Maths): Swimming phytoplankton in turbulence.

Richard Burrows (UoL, Engineering): Tapping the tidal power potential of the eastern Irish Sea.

Christopher Cesar (UoL, Biological Sciences): Ecosystem functioning: commercial cockle bed dynamics.

Jennifer Edwards (UoL, Biological Sciences): Metaproteomic and metagenomic analysis of marine polysaccharide-degrading micro-organisms.

John Howarth (POL): The POL Coastal Observatory.

Diane Jones (UoL, Biological Sciences): Does topography alter nutrient regeneration?

Sylvain Michel (POL): Towards modelling the global coastal ocean for earth systems science.

Eleanor O'Rourke (POL/UoL): The potential of coastal trapped waves as signals of climate change.

Alex Souza (POL): Observations of turbulence and suspended sediment in the Dee Estuary.

Graham Tattersall (POL): What are climate models missing from Arctic shelf seas?

Sarah Wakelin (POL): Sensitivity of carbon dioxide drawdown to optical conditions in the NE Atlantic.

Phil Woodworth (POL): Understanding long term sea level change.

Talk Abstracts:

Modelling Changes in Sea Level.

Jason Lowe, Met Office Hadley Centre

The potential impacts from changes in time-mean and extreme sea levels are large. Here we discuss a range of model simulations and highlight some of the obstacles to making a robust projection of future sea level rise for the UK coastline. The current generation of extreme
sea level projections suggest large increases in the frequency of flood events during the 21st century at some locations.

Decadal rates of sea level change during the twentieth century.

Simon Holgate, Proudman Oceanographic Laboratory.

Nine long and nearly continuous sea level records were chosen from around the world to explore rates of change in sea level for 1904-2003. These records were found to capture the variability found in a larger number of stations over the last half century studied previously.

Extending the sea level record back over the entire century suggests that the high variability in the rates of sea level change observed over the past 20 years were not particularly unusual. The rate of sea level change was found to be larger in the early part of last century (2.03+/-0.35 mm/yr 1904-1953), in comparison with the latter part (1.45+/-0.34 mm/yr 1954-2003).

The highest decadal rate of rise occurred in the decade centred on 1980 (5.31 mm/yr) with the lowest rate of rise occurring in the decade centred on 1964 (-1.49 mm/yr). Over the entire century the mean rate of change was 1.74+/-0.16 mm/yr.

Evidence for Changes in Extreme Sea Levels and Waves in the Recent Past

P.L. Woodworth
Permanent Service for Mean Sea Level, Proudman Oceanographic Laboratory

This talk will examine the evidence for changes in extreme sea level and waves worldwide during the latter part of the 20th century from both observational data and model information. It will also discuss the sensitivity of UK storm surges and extreme sea levels to changes in the westerly winds, the strength of which is often represented by the North Atlantic Oscillation index, and will speculate on how UK extreme sea levels might change in the future.

Modelling Ocean Climate Variability in the Arctic

Miguel Maqueda, Proudman Oceanographic Laboratory.

During the past 30 years, the Arctic region has been warming at twice the global rate. The Arctic Ocean and the Arctic sea ice cover, which has decreased by 10-15% since the 1970s, are crucial players in this enhanced climatic response. The complexity of the physical, chemical and biological processes

operating in the Arctic makes it difficult to calculate projections of future impacts. Nevertheless, a warming ocean surface and a retreating sea ice cover are expected to impact on sea level, atmosphere and ocean circulations, oceanic intake of greenhouse gases, marine and coastal ecosystems, shoreline vulnerability and economic activities, e.g., oil and gas exploitation, fisheries and navigation. Evaluation of these impacts requires coupled ocean-sea ice models capable of representing key physical processes, such as coastal polynyas, dense water formation over the Arctic shelves, and downslope ocean currents. Unfortunately, present day models are ill equipped to either resolve or properly parameterise these processes. This presentation provides an overview of the problems and challenges of current Arctic ocean-sea ice modelling.

Cold-water corals and climate change – a study of the Tisler Reef (Sweden)

George A. Wolff, Kostas Kiriakoulakis, Tomas Lundalf[1] and Martin White[2]

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Coral reefs are usually associated with warm, tropical waters and exotic fish, but not with the cold, deep and dark waters of the North Atlantic where corals were regarded as oddities on the seafloor. It is now known that cold-water coral species also produce reefs, which may rival their tropical cousins in terms of the species richness of associated marine life. Increasing commercial operations in deep waters, and the use of advanced offshore technology have slowly revealed the true extent of Europe's hidden coral ecosystems. The discovery of extraordinary, 10 km-long chains of the reef-building scleractarian corals *Lophelia pertusa* and *Madrepora oculata* on the Norwegian and Irish Shelves have deeply challenged conventional views. The immediate threat to the cold-water corals is fishing, but climate change and ocean acidification will very likely have a significant impact on these important ecosystems. *L. pertusa* is very sensitive to temperature having an optimal range of 4 – 12°C. Warmer shelf sea waters will definitely impact shallow reefs, as will increased soil erosion arising from desiccation of the Artic tundra and resulting in elevated coastal sediment loads. Ocean acidification will have a greater impact on cold-water corals than their tropical counterparts as the former need to work harder to precipitate carbonate against the concentration gradient in cold water.

In this talk, we will discuss issues of climate change and cold-water corals and present the results of initial experiments at the Tissler Reef, Norway. Our initial objectives are to assess the temporal and spatial variability in environmental parameters there (currents, turbidity, organic matter), so that we can provide gross estimates of biogeochemical fluxes and biomass at the reef.

The onset of seasonal stratification in the Celtic Sea during the Holocene from a benthos-phytoplankton perspective

Fabienne Marret (UoL), James Scourse (UoWales-Bangor), Bill Austin (UoSt Andrews)

"Published records of the Holocene evolution of seasonal stratification in the Celtic Sea (NW European shelf) have been based on benthic proxies, notably benthic foraminifera and associated stable isotopic data. We have investigated organic-walled dinoflagellate cyst assemblages from a well-dated Holocene sequence from the central Celtic Sea in order to assess the signal from this planktonic proxy and to

reconstruct paired bottom and surface water conditions through time. This sequence has, on the basis of the benthic proxies, been interpreted previously as a record of the replacement of tidally mixed water by stratified water associated with tidal front migration during the early Holocene. Interpretation of the dinocyst record has been facilitated by a parallel study of the distribution of cysts from Celtic Sea surface sediments and their relationship with seasonal water masses. The dinocyst stratigraphy indicates mixed water conditions during the early Holocene consistent with reduced water depths (hence lowered sea-level) over the core site. The first significant change in the dinocyst assemblages is recorded at around 6650 cal years BP and indicates a transition from mixed-frontal conditions to seasonal stratification. This interpretation of frontal migration is consistent with changes in the benthic foraminiferal assemblages and associated stable isotopes at the same depth. From 6650 to 3600 cal years BP, the significant occurrence of *Bitectatodinium tepikiense* accompanied by *Spiniferites elongatus* is attributed to strong seasonality, with winter sea-surface temperatures possibly below 5ºC. Another transition at 3600 cal years BP is attributed to a reduction in seasonality generated by milder winter conditions linked to a stronger influence of the thermohaline circulation over the studied area. This transition is not recorded by the benthic proxies and is attributed to climatic forcing rather then to any change in tidal dynamics. It is notable that many mires in western Britain record distinct wet-shifts contemporary with this change."

Abstract from the paper "Holocene shelf-sea seasonal stratification dynamics: a dinoflagellate cyst record from the Celtic Sea, NW European shelf", in the Holocene (2004, vol 14(5), 689-696)

Temperature and salinity trends in the NW European shelf seas

Graham Tattersall, Jason Holt, Roger Proctor, Sarah Wakelin & Ben Ward*
Proudman Oceanographic Laboratory, Liverpool.
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Insights into recent climate change can be derived from long time series measurements or by collating large datasets within a specific area; however, these methods have limitations, either temporal, spatial or both. Using the POL Coastal-Ocean Modelling System (POLCOMS) we have examined the recent trends and variability in temperature and salinity of the NW European shelf seas over the period 1960-1999, compared with some *in-situ* time series data and the ICES temperature-salinity database. Observations show a general warming of the UK coastal waters over the period 1980-1999 with a more pronounced increase in the Irish and southern North Seas, whilst salinity decreased in these regions during this time. Temperature and salinity budgets were calculated for the UK shelf seas to investigate the relative contribution of surface forcing and horizontal transport to the observed changes.

Responses to global environmental change: an ecosystem approach to long-term coastal observing.

Nova Mieszkowska, Marine Biodiversity and Climate Change, Marine Biological Association of the U.K.

The effects of global climate change are already being detected in the coastal waters of the British Isles. Long-term physical and biological data series collected by the Marine Biological Association from periods dating back to the start of the 1900s have been re-analysed to detect species, community and ecosystem changes that have occurred over the last century. The Marine Biodiversity and Climate Change Project: MarClim analysed data on rocky intertidal species collected during the 1950s, 1970s

and 1980s in conjunction with resurvey data from 2001-2005. Polewards extensions in distributional limits of southern species of warm water origin and retreats in the range limits of northern species of cold water origin had occurred since climate warming began to accelerate in the mid-1908s. This data concurs with the offshore demersal fish records from the MBA archives, which show massive changes in fish assemblages in the English Channel. A shift in dominance from species with northern to those with more southerly distributions has occurred as SST have increased. These changes occur in both commercial and non-commercial species, suggesting that the shifts are not solely due to fishing pressure. Long-term records of fish, squid and plankton collected by the MBA and the Sir Alister Hardy Foundation for Ocean Science both show shifts in the phenology of species across a wide range of benthic and pelagic taxa in the English Channel and the North Sea, with earlier migration and spawning times in response to warming coastal waters.

Whilst comparisons of baselines from cooler periods with current surveys provide an initial assessment of changes to marine ecosystems, it is imperative that we accurately determine the temporal and spatial resolution of responses to climate change and determine the underlying causal mechanisms. Modelling of species, assemblage and ecosystem responses is already underway, and the continuation of long-term data collection is paramount to the degree of confidence with which hindcast, nowcast and forecast predictions can be made. In tandem, research into the biological mechanisms by which species are responding to climate change and the environmental drivers impacting on the physiology of marine species is required for a more holistic approach to the assessment of ecosystem responses to global environmental change.

Temporal and spatial controls on tidal signal preservation in late-Holocene tidal rhythmites, Romney Marsh, Southeast England.

Andy Plater and Paul Stupples
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A hierarchical series of tidal periodicities is preserved in laminated tidal flat deposits at the barrier/back-barrier interface of Romney Marsh and Dungeness Foreland in southeast England. The sedimentary record of the tidal signature, extracted from variations in sand layer thickness, was found to be severely truncated with neap-spring periods typically represented by five or less sand layers and possibly only alternate neap-spring periods present. Despite the low number of sand layers deposited in these higher frequency tidal cycles, semi-annual periods are clearly preserved but tend to contain less than the expected six months of sedimentation. Annual accumulation rates of around 0.2 to 0.3 m/year are indicated. Local emplacement of storm beaches is considered to have created the protected conditions suitable for tidal rhythmite preservation. Ongoing foreland progradation and infilling eventually restricted tidal inundation to the point where distinct sand laminae were no longer deposited. Accommodation space is not considered to be limiting, instead tidal flat elevation operates as a more subtle control in recording the tidal signature.

Anomalous Coastal Upwelling in California Current Region.

Alejandro J. Souza[1], Victor Camacho[2], Reginaldo Durazo[2] and Adan Mejia[2]
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The timing of the onset of the coastal upwelling in spring and its intensity over the upwelling season are critical factors for the productivity and structure of the California Current ecosystem. While the onset of coastal in 2005 was delayed by 2 or 3 months in the Northern California Current Region; it was about 2 month earlier and stronger in the Southern California Current region. The effect in the north was devastating to sea birds, but beneficial to grey whales which stay feeding until late in the summer in the California Coast. The effect in the south of the stronger upwelling was the enhanced primary productivity during the spring months; this was observed in San Quintin Bay, Baja California, Mexico. San Quintin Bay is a lagoon, which is entirely dependent of the adjacent ocean for the nutrient renewal; the observations nutrients and Chlorophyll at the mouth of the bay show a remarkable higher concentration in spring-summer 2005 when compared with other years. The position, strength and timing of the North Pacific High appears to be responsible for this anomalous behaviour.

Climate variability and change in the northern North Sea.

Jonathan Sharples, Proudman Oceanographic Laboratory
Beth Scott, University of Aberdeen

Observations from the International Bottom Trawl Survey since 1973 show quasi-regular, inter-annual variability in winter sea temperatures in the northern North Sea, superimposed on a 0.4 °C decade^{-1} warming trend. A 1-D (vertical) model of the region over the Marr Bank in the northwestern North Sea shows that this temperature variability is almost entirely driven by local processes; i.e. the warming sea is caused by the warmer air above it, and not by influences of flows from the North Atlantic. Using the model to investigate the impacts of the climate on the timing of spring stratification shows that since the 1990s the increasing winter air temperature as become the most important control. We also use the model to speculate about how the timing of spring stratification might change over the next century, and suggest possible consequences of the gradual warming for components of the ecosystem.

Seasonal and inter-annual variability in the Faroe-Shetland Channel

Rob Hall, John Huthnance, Proudman Oceanographic Laboratory
Ric Williams, University of Liverpool

Fifteen CTD stations across the Faroe-Shetland Channel have been occupied by the Fisheries Research Service Marine Laboratory and the Faroese Fisheries Laboratory between four and eight times annually for the past twelve years. In total there have been 72 occupations between September 1994 and May 2005 although not all stations were occupied during each cruise. The hydrography of the channel is dominated by a permanent thermocline that separates high salinity North Atlantic Water, flowing northward against the West Shetland slope, and typically southward flowing intermediate and deep waters that originate in the Arctic basin. The strength of the thermocline varies seasonally, being the most diffuse in spring and summer. The local slope and height of the thermocline varies significantly between cruises, suggesting that the recirculation of intermediate watermasses changes on short time scales. Integrated heat and salt contents of the channel show a significant increase in the salt content of

the surface layer (defined as the layer above the 6°C isotherm), equivalent to an average increase of 0.1 psu per decade. The heat content of the surface lay has also increased, equivalent to 0.5°C per decade, although it is masked by a strong seasonal signal. Below the 6°C isotherm there is quasi-seasonal variability in the integrated heat and salt contents, with amplitudes of the same order as in the surface layer, but the long term trends are negligible. Empirical orthogonal functions of the temperature and salinity anomalies show most of the variability can be accounted for by heterogeneous vertical movement of the pycnocline on time scales shorter than the seasonal cycle. The high variability of temperature and salinity evident in this dataset shows that the stratification was not in a typical mode during the shelf mixing cruise (*F. S. Poseidon* cruise 328) to the Channel in September 2005.

Predicting the Effects of Change using Models of Species' Habitat

H.M. Tillin, S.I. Rogers and C.L.J. Frid

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Marine benthic invertebrates carry out important ecological roles within marine ecosystems: they underpin food webs as prey items, stimulate nutrient regeneration through burrowing activities and add physical complexity by forming structures. Changes within the composition of the benthos are therefore the subject of management and conservation concern. Early studies of the marine benthos described species assemblages which occur with certain environmental conditions. While it is recognized that chemical, physical and biological variables interact to determine species distributions little is known about the habitat requirements of individual species. This means that the ways that populations will respond to environmental changes are uncertain.

The use of statistical models to assess the suitability of habitats for species and predict the likely occurrence or distribution of populations is an increasingly important tool in conservation planning and wildlife management in terrestrial ecosystems. Recent models of benthic species distributions in relation to estuarine gradients have demonstrated a high degree of predictivity; however such statistical models have rarely been developed and tested in fully marine environments.

Using data from the North Sea, we selected a number of environmental variables which influence the distribution of a range of common invertebrate species from different functional groups. We developed statistical models to determine which of these variables were the most important in influencing habitat choice for these species. The predictive power of the models was tested using different benthic data sets to identify areas where the species should occur. These were compared to the actual distribution of the species. We comment on the similarities and differences between the model output and the actual data and the implications of this for predicting the effects of environmental change on the marine benthos.

Grabbing soft bottoms: What can we learn from 33 years of North Sea benthic studies?

Leonnie Robinson & Chris Frid, School of Biological Sciences, The University, Crown Street, Liverpool L69 7ZB, UK

Since 1972 the macro-benthic infauna at station M1, 10.5 km off the Northumberland coast (central western North Sea), have been sampled by grabbing each March and September. The data series now

includes over 500 taxa from 327 genera. During the 1970's the system showed a regular alternation of high and low abundance years and this was interpreted as evidence of density dependence, when this broke down in the 1980s winter temperature appeared to be involved. After 20 years of data collection analysis of the time series, showed that variability had increased and that there was a very strong link to phytoplankton production in the overlying water. The latest analyses show that this relationship has now also disappeared. The number of genera represented in the system has increased over time while total productivity has not altered significantly. Multivariate ordinations also show changes through time with breakpoints occurring in the early 1980s and early 1990s. The coastal benthos of this region shows decadal scale and longer term changes in biological composition and ecological function. The system is certainly influenced by climatic variation, environmental conditions (winter temperature) and carbon flux to the benthos. Over the 33 year time series none these appears to have a dominant effect, rather different factors seem to dominate at different times. The extent to which this is due to a biological 'system memory' imposed by good recruitments of long lived taxa would warrant further study.

Poster Abstracts:

Are eddies important in the coastal ocean?

Gualtiero Badin (1), Ric Williams (1), Jason Holt (2)
(1) Department of Earth and Ocean Sciences, Liverpool University
(2) Proudman Oceanographic Laboratories

In shallow seas, the competitive effect of tidal and mixing from one side, and of buoyancy forcing from the other sides, creates regions of stably stratified waters and regions where instead the water column is well-mixed. These two regions are separated by fronts.
While the problem of cross-frontal transfer has been extensively studied for the open ocean, we still have indeed limited understanding on the transfer in the coastal environment: while in the open-ocean case diabatic mixing is restricted to a surface mixed layer, in the shallow seas it is possible to observe that one side of the front is stratified and the other side is vertically homogeneous from tidal mixing.
One of the key-features in this cross-frontal transfer is given by baroclinic eddies. Signals of geostrophic eddies are rarely seen clearly in the coastal ocean. The absence of a clear signal may be due to a variety of reasons: surface signals are eroded by air-sea interaction; features have a small spatial scale of a few kilometers; and during winter eddies are destroyed by mixing. This eddy-driven exchange, together with the dynamics setting the different dynamical regimes in the coastal ocean, is here studied through the use of observations and of numerical modelling.
Both the methodologies show patches of freshwater advected laterally inside the thermocline from a well-mixed region, where tidal mixing is important throughout the entire water column. Their associated potential vorticity signals, and spatial scales comparable with the Rossby radius of deformation, suggest that these freshwater patches are associated with eddies.
These eddies can be important for defining the stratification structure of the coastal ocean and hence for the climate.

Swimming phytoplankton in turbulence

Rachel Bearon, Department of Methematics, University of Liverpool

Many phytoplankton are motile, but can this ever be important in the turbulent marine environment? Furthermore, how does the fluid environment alter population-level models describing the dispersion of swimming cells in still fluid?

I shall present work based on laboratory studies and mathematical models which suggests how swimming behaviour can interact with salinity stratification & turbulence to generate algal blooms in surface water.
I shall also outline the scientific case for a new EPSRC-funded project looking at mathematical models for swimming phytoplankton in turbulence. Specific objectives of this project include: development of numerical model which describes the flow field at appropriate scales; incorporation of individual-based data on swimming phytoplankton; development of population-level model to be tested against the individual-based simulation.

Tapping the tidal power potential of the eastern Irish Sea.

Richard Burrows T Hedges, M Li, S Pan, D Chen, J Zhou (University of Liverpool, Departmant of Engineering) & J Wolf, J Holt, R Proctor (Proudman Oceanographic Laboratory).

The Joule Project Objectives

1. To evaluate the realisable tidal energy potential of the coastal waters of the North West of England, stretching from the Dee estuary to the Solway, with regard to the installation of estuary barrages, tidal lagoons, tidal fence structures or tidal stream rotor arrays, or combinations thereof.
2. To establish the potential daily generation window from optimal conjunctive operation of such devices, taking account of the different possible modes of operation (ebb, flood or dual phase generation) in the case of barrages.
3. To evaluate (using POLCOMS) any impact on the overall tidal dynamics of the Irish Sea as a consequence of this energy extraction and the associated modifications by time lag in estuary momentum exchange.
4. To assess (using POLCOMS) the implications, if any, of biophysical coupling in the marine ecosystem, manifesting water quality or ecological consequences.
5. To ascertain the scale of flood protection benefit likely to accrue from proactive operation of barrages, fully accounting for the worsening effects of sea level rise (SLR) and change in catchment rainfall regimes as a consequence of climate change, so affecting fluvial flood magnitudes and frequencies.

Ecosystem functioning: commercial cockle bed dynamics

Christopher P. Cesar, Chris L. J. Frid

Marine & Freshwater Biology Research Group, School of Biological Sciences, University of Liverpool.

Since the introduction of the 2002 European Union Common Fisheries Policy, the management of fisheries has moved towards an ecosystem-based approach, aiming to ensure the extended functioning of exploited systems. The functioning of intertidal benthic systems is of particular interest to ecologists, due to their role in the regeneration and re-supply of nutrients to the water column. The intertidal zone also houses a number of economically-important species, including the common cockle, *Cerastoderma edule* L. Cockles are common to sand/mud habitats on all British coasts and have been the target of fisheries for over 100 years. There is increasing concern with regards to the degree that cockle stocks are being exploited. In recent years, diminishing cockle stocks have resulted in many commercial beds within the UK to be closed to fishing; there is a need therefore to consider the impacts of fishing activity upon the functioning of cockle bed systems.

The aim of this investigation was to compare the macrofaunal community compositions and ecosystem functioning at 4 geographically-distinct commercial cockle grounds at Thurstaston and West Kirby, Dee estuary, Traeth Lafan, Conwy and Wharton Sands, Morecambe Bay. Community compositions differed between sites, hence Biological Traits Analysis (BTA) was carried out to enable the comparison of ecosystem functioning between areas consisting of different species: that is, do the functional roles carried out within a cockle-bed system remain the same even when the species comprising the system differ? Subsequent investigations will involve the manipulation of macrofaunal communities and will consider whether the biological diversity of the benthos influences the degree to which the system is affected: do species-rich systems provide a greater ‘insurance’ against impact?

Metaproteomic and metagenomic analysis of marine polysaccharide-degrading micro-organisms

Jennifer L. Edwards[1], Michael J. Cox[1], Ian R. Joint [2], Jon R. Saunders[1], Clive Edwards[1] and Alan J. McCarthy[1]

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The insoluble polysaccharides, chitin and cellulose, are an important source of organic carbon in the marine environment. Conversion of these substrates to soluble oligo- and mono-saccharides releases labile carbon from the particulate organic carbon pool, making it available for heterotrophic microorganisms. Although many types of cultured bacteria are known to degrade chitin and cellulose, little is known of the polysaccharide hydrolases expressed by microorganisms *in situ*, particularly in the marine environment

Here we are utilising a range of molecular biological and biochemical approaches to analyse the microbial communities that colonise and degrade insoluble polysaccharides in marine systems. Chitin and cellulose baits are tethered at marine sites to act as a matrix for colonising biomass and provide source material for metaproteomic and metagenomic analysis of the biofilm communities responsible for polysaccharide degradation in the water column. Techniques include: the preparation of metagenomic libraries that will screened for both polysaccharide hydrolase activity and the presence of the encoding genes; metaproteomic techniques in which the activity of cellulases and chitinases and their identification is directly addressed in environmental samples; stable isotope probing with ^{13}C labelled cellulose to demonstrate *in situ* activity; isolation of polysaccharide-degrading microorganisms from marine samples.

Our sampling sites include the coastal observatory buoys maintained in Liverpool Bay by Proudman Oceanographic Laboratory and a mesocosm facility in Bergen, Norway where, in May, we participated in an Aquatic Microbial Metagenomics Consortium experiment looking at changes in oceanic pH levels due to increased atmospheric CO_2 levels.

The POL Coastal Observatory

John Howarth[1], Jason Holt[1], Martin Holt[2], Phil Knight[1], Andrew Lane[1], David Mills[3], Roger Proctor[1], Alejandro Souza[1], Duncan Stirling[1]

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[3.] CEFAS Lowestoft Laboratory, Pakefield Road, Lowestoft, Suffolk NR33 0HT, UK.

The pilot Coastal Observatory (http://cobs.pol.ac.uk) was established in Liverpool Bay (Eastern Irish Sea) in 2002 with an anticipated lifespan of at least 10 years. In an evolving process, near real-time measurements are integrated with coupled models in a pre-operational coastal prediction system. In this highly tidal energetic region (tidal range 10 m, tidal currents up to 1 m s^{-1}) the aim is to understand a coastal sea's response to natural forcing and the consequences of human activity - the goal to provide a scientific underpinning for coastal management. The foci are the impacts of storms,

seasonality, and variations in river discharge (freshwater and nutrients) on the functioning of Liverpool Bay. A range of parameters are measured by a variety of platforms for example: *in-situ* surface waves, and vertical profiles of current, temperature, salinity, turbidity, nutrients and chlorophyll; shore-based HF radar measuring waves and surface currents out to a range of 50 km; instrumented ferries measuring surface properties; coastal tide gauges; satellite data – infra-red (for sea surface temperature) and visible (for chlorophyll and suspended sediment). In cooperation with the UK Met Office, a suite of nested 3-dimensional models (the Proudman Oceanographic Laboratory Coastal Ocean Modelling System - POLCOMS) is run daily, focusing on the Observatory area by covering the ocean/shelf of northwest Europe (at 12 km resolution), the Irish Sea (at 1.8 km) and Liverpool Bay (at ~ 200m resolution). These models simulate the physical environment, nutrient and plankton dynamics, and the processes influencing sediment suspension and transport. After more than 4 years of operation we are beginning to build up a picture, which only continuous monitoring provides, of the interaction between the coastal sea of Liverpool Bay and the three estuaries (Dee, Mersey and Ribble) which connect with it.

Does topography alter nutrient regeneration?

Diane Jones, Chris Frid

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Regeneration of nutrients within marine benthic sediments is of considerable importance in maintaining ecosystem functioning. Nutrient regeneration processes are of particular interest in intertidal estuarine mudflats as these regions act as 'traps' for detritus much of which is produced allochthonously by marine macrophytes and terrestrial plants. This material supports high secondary production which in turn often supports large aggregations of birds and nursery areas for marine fish. The system, however, shows a high degree of spatial patchiness of habitat types. While the exchange of nutrients across the sediment-water interface, and the role of porewater movement through estuarine sediments, has been documented, these studies have often focussed on a single nutrient. Recent interest in ecosystem functioning means that the influence of the fauna and/or topographical features of the sediments upon nutrient flux have become a topic of concern.

The present study focuses on the influence of patches of varying topographical complexity on nutrient regeneration within the sediment and the changes, if any, to the associated fauna. The physical nature of the study units was altered from a smooth mud surface to mimic the 'rough' surface of bivalve crumble (a matrix of shell debris binding the mud) using plastic netting to which empty shells had been attached. Three treatments were considered, shelled nets, plain nets (net controls), and un-manipulated control plots. Each plot was $1m^2$ and porewater was collected from four depths (3, 5, 9 and 12cm) within each plot using a novel porewater collection technique on the neap tide stage of the tidal cycle. The water was analysed for $NH4^+$, NO_3^-, NO_2^-, PO_4^{3-} and SiO using an autoanalyser to observe changes in nutrients levels over time. Sediment particle size analysis, porosity analysis and faunal composition analysis (from the area under the nets and any attached fauna) were also conducted.

Towards modelling the global coastal ocean for earth systems science

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Shelf seas are usually omitted or at best poorly resolved in global ocean climate simulations. However, these seas are a disproportionately important part of the earth system: 37% of the Earth's population live within 100km of the coast; shelf seas occupy 7% of global ocean area but account for 14-30% of primary production; they modify and transport terrestrial inputs (freshwater, nutrient, pollutants); and have a role in water mass transformation. For these reasons, these seas cannot be excluded from any model of the Earth System. In this poster we present the first steps towards setting up a system for including the shelf seas around the globe in climate simulations, focusing on their role in CO2 transport. Based on the POLCOMS-ERSEM model system, which has been extensively tested on the North West European shelf, the Global Coastal Ocean Modelling System (GCOMS) aims to simulate the shelf sea around the world using a multi-domain nested approach drawing on e-science technology (Grid computing). The system concept is described and preliminary results from a prototype system for the tidal constituents are presented.

The Potential of Coastal Trapped Waves as Signals of Climate Change

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Climate change signals, in terms of a change in the Meridional Overturning Circulation (MOC), have been detected in changing heat and salinity water characteristics along 26°N (Bryden et al, 2005) but this advective signal takes place over a decadal timescale. Johnson & Marshall (2002) suggested that a coastal-trapped wave travelling down the western boundary of the North Atlantic may be an alternative, and much more rapid, signal of change.

However, the effect of realistic topography and stratification along the boundary was not included. Therefore, to determine whether coastal-trapped waves are a realistic signal the wave behaviour and structure over realistic topographic profiles has been initially analysed in a barotropic model. The study will then be extended to a more complete baroclinic model incorporating both realistic topography and stratification.

Observations of turbulence and suspended sediment in the Dee Estuary

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Measurements of Reynolds stresses, turbulence production, water column density structure and suspended sediment concentrations were carried out over 2 spring-neap tidal cycles, between February and March 2005, in the Dee Estuary in the eastern Irish Sea. The measurements were carried out using a moored fast sampling ADCP, LISST-100, LISST-ST, OBS, conductivity and temperature sensors. The moored observations were supplemented by 2 intense periods of observations, in which vertical profiles were carried out, for at least a tidal cycle, using a CTD, equipped with transmissometers, LISST-25 and LISST-100 systems, as well as obtaining water samples.

The observations indicate a strong correlation between suspended sediment concentrations and levels of turbulent kinetic energy (TKE), mainly related to the tidal flow. The variations of SPM concentration appear to be a complex balance between resuspension and settling, on one hand and aggregation dissagregation on the other. There are clear monthly, spring-neap and M_4 variability in both suspended sediment and TKE, with a time lag increasing with height. One of the most striking results is that the freshwater from the Dee appear to have low concentrations, there are also striking differences in the behaviour of the two channels at the mouth of the Dee.

What are Global Climate Models missing from Arctic Shelf Seas?

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The Arctic shelf seas are important sites of dense water formation, driven by surface cooling and brine rejection, which contribute to the maintenance of the global thermohaline circulation. Significant quantities of sea ice are formed in recurrent polynyas and leads, where ice cover is patchy and ice free areas are opened and closed by mechanisms such as strong winds and tidal currents. The concept of ice concentration is often used in models to deal with this patchiness, i.e. the fraction of ice cover within a grid cell. Thus, the representation of sea ice processes is dependent on grid size, which can lead to an underestimation of the intensity of dense water formation in coarse resolution models, such as global climate models. We present results from a dynamic/thermodynamic sea ice model coupled to a baroclinic coastal ocean model. We have investigated the effect of grid resolution (2km, 10km & 25km) on polynyas size and dense water production, using three identical domains with uniform topography. In addition, a 25km resolution domain with realistic topography was used to examine the role that tidal stresses play in exposing areas of open water in the Barents and Kara Seas.

Sensitivity of carbon dioxide drawdown to optical conditions in the NE Atlantic

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Carbon dioxide is an important greenhouse gas with a significant influence on the Earth's heat budget and climate change. Numerical models provide a useful tool for calculating CO_2 budgets and for quantifying their uncertainty. We examine the sensitivity of a modelled ecosystem to optical properties in the water column and how this impacts on the air-sea flux of CO_2.

An air-sea exchange algorithm for CO_2 is included in the European Regional Seas Ecosystem Model (ERSEM) coupled to the Proudman Oceanographic Laboratory Coastal Ocean Modelling System (POLCOMS). Optical conditions in the water column have an affect on the biological growth rates, which in turn impact on the air-sea exchange of CO_2. The optical conditions are currently represented by modelling suspended particulate matter (spm) but there are large uncertainties in the composition of the sediment field and its sources and sinks. The possibility of using observations of attenuation to replace the spm model is investigated. Sensitivity studies are carried out using a 1D water column model located at test sites at Holyhead, the Southern Bight in the North Sea and the Rockall Trough northwest of Ireland.

Understanding Long Term Sea Level Cange

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One of the clearest indicators of climate change is the fact that global sea level is rising. Almost all tide gauge records around the world show increases in level during the 20th century of approximately 18 cm. However, there remains considerable uncertainty as to the individual contributions of each part of the climate system. Ocean warming, melting glaciers, wastage from Greenland and Antarctica, and changes in hydrological practices are all known to contribute, but at rates which undoubtedly change with time and have historically been measured imperfectly. In addition, there could even be very long term 'baseline' contributions following for example the Little Ice Age. This poster will explore some of the many uncertainties associated with sea level measurements.

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