WG 129 Deep Ocean Exchange with the Shelf (DOES)

Report on Workshop in Cape Town 5 - 9 October 2008

The workshop was held at the Breakwater Lodge at the Victoria and Alfred Waterfront in Cape Town. It opened with a reception for registering participants at the hotel on **Sunday 5th October**. This was a pleasant way to introduce the young participants from African countries to the experts and delegates from Cape Town and from outside Africa. A friendly atmosphere ensued and many informal conversations were had in both English and French.

Reception including participants from Australia, France, Sweden, Brazil, Canada, USA and UK.

Piers Chapman (co-chair) and young scientists from Togo, Benin, Ghana and Senegal.

The attendance varied from day to day and averaged at about 45 scientists from 18 countries. As part of the outreach and capacity building programmes in Africa, young scientists attended from Benin, Ghana, Namibia, Senegal and Togo as well as from South Africa.

The planned workshop programme was followed with just a few changes due to travel or health problems of expected participants. The programme for **Monday 6th October** was as follows:

Theoretical / Qualitative Aspects of DOES

Session chair - Piers Chapman

0915 The challenge of shelf-ocean exchange - John Johnson (University of East Anglia)
0945 Physical processes of wind-forced upwelling: time and spaced scales - John Middleton (South Australian Research and Development Institute)

1015 **Coffee**

Session chair - Johan Rodhe

1045 The role of Canyons, promontories and topography - Susan Allen (University of British Columbia)
1115 Near-shore natural iron fertilization, distant deep-water carbon flux and benthic communities - Mike Lucas (University of Cape Town), Raymond Pollard (National Oceanography Centre, UK) and the Crozet team
1145 Is the Benguela upwelling system pulling its weight in terms of global carbon sequestration into the deep ocean - Howard Waldron, Pedro Monteiro and Neil Swart (University of Cape Town)
1215 The role of deep eddies in offshore transfers - Isabel Ambar (Universidade de Lisboa)

1245 **Lunch**

Well-studied DOES Systems

Session chair - John Middleton

1400 The Benguela Upwelling system - Frank Shillington (University of Cape Town)
1430 The European North Atlantic shelf - John Huthnance (Proudman Oceanographic Laboratory)
1500 The eastern US and the Gulf of Mexico- Piers Chapman (Texas A&M University)
1530 Shelf export from Western Margin of South Africa: nutrient source to the Southern Ocean - John Compton (University of Cape Town)

1600 **Posters** (including refreshments)

1730 **Close**

These 10 invited lectures set the scene for the working groups later in the week by providing an introduction to the processes observed in Deep Sea Exchange with the Shelf and a description of some well studied DOES systems. Each lecture was well received and generated good discussions.

The working day ended with a poster session in a foyer close to the lecture theatre. Half the posters were put up on each day and remained on display all day. They were available for viewing at the coffee break and over lunchtime. During the poster session, the authors of the posters received much useful discussion about their posters, and this discussion continued beyond the closing time. The poster sessions were certainly a success and enabled everyone from students to experts to participate. A list of the poster titles and authors is given in Appendix 2.

The programme for **Tuesday 7th October** was as follows

Well-studied DOES systems

Session chair - Olga Trusenkova

0845 Antarctic cross-slope exchanges - Alex Orsi (Texas A&M University)
0915 Recurrent slope water intrusions onto the Patagonia continental shelf - Alberto Piola (Servicio de Hidrografía Naval, Argentina)
0945 Influence of the Kuroshio on the current fields in the shelf region of the South and East China Seas - Takeshi Matsuno (Kyushu University)

1015 **Coffee**

1045 **Working Groups**
(1) Exchange rates for heat, salt and fresh water, etc
Leaders: Alex Orsi, Takeshi Matsuno
Rapporteur: Dongliang Yuan
(2) Role of canyon and eddies, etc in DOES
Leaders: Xavier de Madron, Gordon Swaters
Rapporteur: Olga Trusenkova

1245 **Lunch**

1400 **Working Groups**:
(3) Carbon cycles
Leader: Michael Lucas
Rapporteur; Howard Waldron
(4) Internal tides and mixing
Leaders: John Huthnance, Michael Spall
Rapporteur: Susan Allen
1600 **Posters** (including refreshments)

1730 **Close**

Tuesday began with three invited lectures on DOES systems in the Southern Ocean, the South West Atlantic and the North East Pacific, each with its own special features and part of the general introduction to what is already known about DOES systems. Again each lecture generated a good discussion.

The next phase of the meeting used working groups to determine what research needs to be carried out to improve understanding of many features and processes in Deep Ocean Exchange with the Shelf. For each working group session the participants were asked to form into two groups according to their research interests. The larger group (about two-thirds) used the lecture theatre and the smaller group assembly in a smaller committee room.

Each working group was led by one or two selected participants and another person acted as the raconteur/rapporteur to communicate the outcome of the working group to the Wednesday afternoon sessions and to the co-chairs of the SCOR/IAPSO Working Group 129. The smaller size of each working group allowed very full discussions to be held at all the working groups, although often mainly from a small group of people. The leaders tried to bring in more participants. A report of the discussions at each working group is given later in this report as appendix 4.

The working day on Tuesday also ended with a poster session which was again a success. A list of posters is given in appendix 3 to this report.

A workshop dinner was held at the fish restaurant Panama Jacks in the harbour area of Cape Town. Here are a couple of photographs of some of the diners.

The programme for **Wednesday 8Th October** was as follows:

Models and Observational Tools

Session Chair - Gordon Swaters

0845 Fine-scale numerical models applied to high latitude Deep Ocean -Shelf Exchange - John Klinck (Old Dominion University)

0915 Modelling multi-scale ocean dynamics with a new adaptive mesh ocean model- Matthew Piggott (Imperial College London)

0945 The Australian integrated marine observing system - Gary Meyers (University of Tasmania) and John Middleton (South Australian Research and Development Institute)

1015 **Coffee**

1045 **Working Groups**

(5) Future modelling

Leaders: John Johnson, Anne-Marie Treguier

Rapporteur: John Klinck

(6) Future observations

Leaders: Piers Chapman, Christopher Duncombe Rae

Rapporteur: Isabel Ambar

1245 **Lunch**

Session chairs - John Johnson, Piers Chapman

1400 Report back of working group chairs

1500 Closing session (including details of Publications and Montreal meeting)

1530 **Tea**
1600 Meeting for members of SCOR/IAPSO WG 129
1700 Close

Wednesday began with three invited lectures on modelling and observational tools. The models described were two of the latest models being developed which are very useful in dealing with the small time and length scales that are apparent in observations of flows along and over the shelf break between the deep ocean and the shelf. The observational tools described were of the latest hardware that is available for research in the waters over and near the shelf break. The last lecture described the collaborative programme of observations and modelling being set up around Australia.

After coffee, the participants formed into two separate working groups to discuss the future modelling and observational requirements for research into DOES systems in the next five to ten years. Lively discussions were held and many suggestions were made for the future of DOES research. The proposals coming out of these working groups are described later in this report. See Appendix 4 for working group reports.

Wednesday afternoon was used to bring together reports from the working group chairs, and to discuss the proposals to enable the SCOR/IAPSO WG 129 to meet its terms of reference on providing advice on future research needed to improve understanding of Deep Ocean Exchange with the shelf.

After the Cape Town Workshop was closed, the SCOR/IAPSO WG 129 met for a business meeting. The minutes of that meeting are given later in this report as appendix 5.

Some of the participants in the Cape Town Workshop

The special outreach programme for young scientists was held on **Thursday 9th October** at the Old Aquarium at Sea Point, Cape Town. About 25 people attended, mostly students from South Africa but also representatives from Benin, Ghana, Togo and the Ivory Coast. The report provided by Piers Chapman, who organised this special session, is given below as appendix 1.

Summary of Recommendations from the Working Groups

1. To produce a classification of shelves in all oceans, to help with collaboration between groups in different continents. The lowest level of classification would be eastern boundary upwelling, western boundary currents, temperate shelves and polar shelves. More processes could be included in a finer classification. The aim is to produce such a classification during 2009.

2. To propose the setting up of a World Ocean Shelf Group that would assist in coordinating research in different shelf regions around the world. It could lead to a Global Cross Shelf Exchange Experiment as a collaborative project between scientists

from various countries. A similar collaborative project with laboratories all around Australia was set up in 2008.

3. To recommend that over the next 5 to 10 years, the most useful observations for dealing with DOES research are the following:

    - Gliders (even in canyons),
    - HF radar (<150km from coast, which is often well off the shelf),
    - Sediment cores (for research into history of fluxes of material across the shelf including carbon),
    - Better bathymetry using multibeam surveys (in near shore areas, bathymetry has a more dominant effect than offshore - particularly important for tides and internal tides), and
    - Carbon export from shelves (one of the important fluxes for climate studies).

4. To recommend that over the next 5 to 10 years, the following types of numerical modeling would be most useful for DOES applications where short time and lengths scales are very important:

    - Coupling to hydrological models (clearly important in dealing with river and coastal run off or melting in high latitudes),
    - OGCM model development (in the next 5 to 10 years it is believed that adaptive unstructured grids will deliver the detail needed for cross shelf break and along shelf break flows and fluxes),
    - Further development of regional models like ROMS, and
    - It is important that there is open access to model codes in a user-friendly way for the research community use of such models.

5. To note that further process studies are needed on canyons and upwelling filaments.

Sponsors of the Workshop

The principal financial sponsor of the Workshop in Cape Town was the Scientific Committee for Oceanic Research (SCOR) through grants from the US National Science Foundation (NSF) and the U.S. Office of Naval Research (ONR). Some additional financial support was given by the International Association for the Physical Sciences of the Ocean (IAPSO), the International Union for Geodesy and Geophysics (IUGG) and the South African Council for Scientific and Industrial Research (CSIR).

Appendix 1. Report on Meeting on Deep Ocean Hydrographic Cruises – 9 October 2008

On Thursday 9 October, about 25 people, mostly students or members of the South African Department of Marine and Coastal Management, but also including representatives from Benin, Ghana, the Ivory Coast, and Togo, met at the Old Aquarium Building in Sea Point to discuss upcoming deep-sea oceanographic cruises and how they might become involved in them. The discussion was led by Piers Chapman (TAMU), with assistance from Alejandro Orsi (TAMU) and Chris Duncombe Rae (U. Maine).

Chapman began with a discussion of the global carbon repeat hydrography program. This builds on the data collected during WOCE, and aims to repeat a number of the trans-ocean WOCE lines at about 6-8 yearly intervals. The program is described at http://us.hydro.ucsd.edu, and there are berths available both for co-chief scientists and for graduates or junior scientists who would like to take part and learn how to organize such cruises.

Orsi and Mike Roberts (MCM) talked about developments in the Southern Ocean, with particular reference to the SASSI (http://sassi.tamu.edu) and ICED (http://www.iced.ac.uk) programs. SASSI (the Synoptic Antarctic Shelf-Slope Interaction Study) is a multi-national program that concentrates on transfers across the shelf-sle region around Antarctica. ICED (Integrating Climate and Ecosystem Dynamics in the Southern Ocean) is the Southern Ocean version of GLOBEC, and is supported by SCOR and IGBP.

Roberts also talked about the ongoing Agulhas-Somali Large Marine Ecosystem (ASLME) program, which is supported by the UNDP and UNEP as part of the global LME effort. The program concentrates on fisheries management, but also incorporates physical and chemical work to define this part of the western Indian Ocean and assist with reducing pollution and degradation of the coastal environment. Information is available from David Vousden (david.vousden@undp.org), or from the Agulhas and Somali Current LME Project, S. African Institute of Aquatic Biodiversity, Private Bag 1015, Somerset Street, Grahamstown 6140, South Africa.

Another African LME is that in the Gulf of Guinea (see http://preview.eukn.org/susta/themes/Urban_Policy/Urban_environment/Environmental_sustainability/The-Gulf-of-Guinea-Large-Marine-Ecosystem--LME-_1666.html). Emmanuel Lamptey, from Ghana, talked about recent joint cruises with the Norwegians in the region and the desire to find a coastal research vessel for inshore work. There is apparently some uncertainty over who would maintain the vessel if one becomes available.

Following these presentations, there was a general, free-ranging discussion on the methodology of organizing deep-sea cruises and how attendees could become involved. This session covered all aspects of cruises, from finding available ships to equipping them for research and management of data collected.

Thanks are due to Neville Sweijd and his team for organizing the meeting space and refreshments, and to MCM for making the venue available.

Appendix 2: POSTER SESSION - MONDAY, OCTOBER 6

THE TRANSFORMATION OF AN AGULHAS EDDY NEAR THE CONTINENTAL SLOPE
Baker-Yeboah, Sheekela, Georgi Sutyrin, and Glenn R. Flierl

PRIMARY PRODUCTION IN THE BENGUELA AND AGULHAS ECOSYSTEMS
Barlow, R.G., T. Lamont, M. Kyewalyanga, D. Louw, and H. Sessions

A STATISTICAL CONSIDERATION OF THE INTERACTION OF OCEANIC MESOSCALE VARIABILITY WITH THE BENGUELA UPWELLING SYSTEM
Duncombe Rae, Christopher M., Deirdre A. Byrne and Sheekela Baker-Yeboah

EGEE PROGRAM TO ENHANCE UNDERSTANDING COASTAL CONDITIONS IN WEST AFRICA (GULF OF GUINEA)
Gatogo, Etsé and Adoté B. Blivi

SHELFBREAK PROCESSES AND SCALES OF EXCHANGE IN THE MIDDLE ATLANTIC BIGHT
Gawarkiewicz, Glen

OCEAN COLOUR OBSERVATIONS OF THE INTERACTION OF AN AGULHAS CURRENT PULSE WITH THE CYCLONIC CIRCULATION OF THE NATAL BIGHT.
Meyer, Alan A., Roy. C. van Ballegooyen and Marten L. Gründlingh

EFFECTS OF A CYCLONIC EDDY ON THE NORTHERN KWA-ZULU NATAL SHELF.
Morris,T, M.J. Roberts, T. Lamont, L. Hancke, and M.A. van den Berg

EXCHANGE OF NITROGEN AND CARBON BETWEEN NORTH SEA AND NORTH ATLANTIC - COARSE-GRID VERSUS VERTICAL ADAPTIVE-GRID APPROACH
Pätsch, Johannes, Wilfried Kühn and Jan Backhaus

ROLE OF EDDIES AND WIND IN THE VARIABILITY OF THE SLOPE CURRENTS ALONG THE WESTERN AND EASTERN BOUNDARIES OF THE NORTH ATLANTIC IN A HIGH RESOLUTION MODEL.
Roullet, G., A.M. Treguier, C. Guiavarc'h, and A. Le Boyer

CROSS-SHELF WATER EXCHANGE OFF PETER THE GREAT BAY, THE JAPAN SEA
Ladychenko, Svetlana, Olga Trusenkova, and Vyacheslav Lobanov

THE SEASONAL VARIABILITY OF THE NORTHERN BENGUELA UNDERCURRENT AND ITS RELATION TO THE OXYGEN BUDGET ON THE SHELF.
Mohrholz, Volker, Christian H. Bartholomae, Anja K. van der Plas., and H. Ulrich Lass

Appendix 3: POSTER SESSION, TUESDAY, OCTOBER 7

ROMS OCEAN MODEL STUDY OF THE AGULHAS BANK AND ITS RESPONSE TO THE AGULHAS CURRENT
Chang, Nicolette, Pierrick Penven and Frank A. Shillington

SHELF EXPORT FROM THE WESTERN MARGIN OF SOUTH AFRICA: NUTRIENT SOURCE TO THE SOUTHERN OCEAN?
Compton, John, Caren Herbert and Ralph Schneider

EVIDENCE FOR A CROSS SHELF FLUX IN THE SOUTHWESTERN ATLANTIC OCEAN
Jardon, Fernanda

HYDROGRAPHIC AND SATELLITE OBSERVATIONS IN THE DELAGOA BIGHT, SOUTHERN MOZAMBIQUE
Lamont, T., T. Morris, M. Roberts, R.G. Barlow, and M.A. van den Berg

REGIONAL PROGRAM IN PHYSICAL OCEANOGRAPHY IN WEST AFRICA (GULF OF GUINEA)
Lamptey, Emmanuel, Christian Adje, Etsé Gatogo, Shelle Rod, Mayowa Ibitola, Roger Djiman, and Bernard Bourles

PHYSICAL OCEANOGRAPHY OF SODWANA BAY
Morris, T., M.J. Roberts, M.H. Schleyer, and M.A. van den Berg

AUTUMNAL CHLOROPHYLL-*A* DISTRIBUTION IN PETER THE GREAT BAY (SEA OF JAPAN) OVER THE SHELF, SLOPE AND DEEP WATER
Schtraikhert, Elena A. and Sergey P. Zakharkov

SURFACE WINDS SENSITIVITY TO SST ALONG THE SENEGALESE COAST
Sow, Bamol Ali, Patrick Marchesiello and Claude Roy

WESTERN ARCTIC SHELFBREAK EDDIES: FORMATION AND TRANSPORT
Spall, Michael A. and Robert S. Pickart

OBSERVATION OF VOLUME TRANSPORT AND INTERNAL TIDE ENERGY FLUX ACROSS THE LUZON STRAIT
Tian, Jiwei, L. Xie, F. Zhai and Q. Yang

CROSS-SHELF CIRCULATION IN THE YELLOW AND EAST CHINA SEAS
Yuan, Dongliang, Lei He, and Hui Zhou

Appendix 4: Reports from the Working Groups

Working Group (1): **Exchange rates for heat, salt and fresh water, etc.**
Leaders: Alex Orsi and Takeshi Matsuno
Raporteur: Dongliang Yuan

After extensive discussions, the working group has come to a consensus that an international project with a name like World Ocean Shelf Experiment is to be proposed to the SCOR committee for further discussions. The group realized the potential geopolitical obstacles that may be faced by such a programme, but emphasized that the program is unlikely to fail, even if some of the shelf area of the world ocean was not surveyed. The importance of the shelf ocean in regional resource supply and in global issues like carbon and freshwater budgets suggests that an integrated program is timely and necessary. The global program will involve regional research projects in a global scope and will associate the local infrastructure into a coherent and integrated global scientific activity of estimating the fluxes. The final goal of the global program is to come up with a small set of key property flux estimates that scientists of global interdisciplinary studies can incorporate and complement with adjacent regional programs. Partitioning of the world ocean shelf areas based on dynamical similarities has been proposed.

The group has also discussed the issue of mechanism vs. fluxes. The question is whether the observational programs of the DOES research should focus on the key physical mechanisms/dynamics or on estimating fluxes. Discussions also considered what kind of measurements should be made to achieve the goal.

The group believes that the DOES observational program should focus on estimating fluxes, with the dynamics/mechanism study as one of the key element of the research targets. The latter could serve the main objective of estimating the fluxes and could help in the design of the observational arrays.

The group then discussed what we know and do not know about the exchanges between the deep ocean and the shelf. The group suggested that the compilation of an exhaustive list of processes potentially involved in cross-slope exchange is necessary, starting with already published tables to ultimately classify all shelf areas. The group also suggested the development of new tools to better interpret the data. Among them are numerical modelling, data assimilation, interpolation and objective analysis of the observational data, etc.

The group emphasized the usefulness of numerical models in estimating global as well as regional fluxes and in helping with the design of observational arrays. Significant deficiencies exist in current coastal ocean models and the group encouraged their validation with observations.

Working Group (2): Role of canyons and eddies in DOES
Leaders: Xavier de Madron, Gordon Swaters
Raconteur: Olga Trusenkova

Discussion was focused mostly on canyons.

Priorities for canyon study: What regions with canyons are important for DOES at the large scale (e.g. in region of high primary production, like upwelling systems, river-dominated systems, or dense shelf water formation regions, off-shelf export associated with promontories, cape and

canyon)? What is the impact of canyons at the regional scale (identification of active canyons in terms of DOES)? What is the best parameterization of canyon fluxes into larger scale models, including nested models?

What are the predominant processes and their interactions?
E.g. cascading (including turbidity), boundary current, bottom boundary layer dynamics (difference in upwelling and down-welling cases), formation and trapping of eddies, internal tides.

There is a need to build some understanding from process models, to explore the dynamics in and around canyons for different settings (e.g., eastern vs. western shelves, shallow vs. deep shelves, narrow vs. broad shelves), to explore the temporal variability at seasonal and interannual scales), and to identify the role of extreme versus typical events

Some suggestions for new observation methods:

- Use of gliders to explore the 3D distribution of water masses within canyon;
- Use of tracers with different signatures in slope and shelf waters to trace the origin of slope water that intrudes on the shelf;
- Use of seabed structures (furrows, scours) to delimit areas of strong flows.

Working Group (3): Carbon Cycles
Leader: Michael Lucas
Rapporteur: Howard Waldron

Key questions:
What do we need to do in the future to measure and understand carbon export from the shelf to the deep ocean? What are carbon fluxes (DIC) from the deep ocean onto the shelf? What are the important bio-physical processes that control carbon flux? What is the net carbon export from the shelf to the deep ocean?

We recognise the future impacts of ocean warming due to potential changes in AABW and NADW formation, and due to NO_3 flux; ocean acidification; changing thermohaline circulations; changing wind fields (increased dust and iron flux); and ice melt.

The strategic regions of special future interest are upwelling regions, polar shelves and shallow temperate seas. Other important processes and places to be studied are mesoscale eddies, canyons, urban coastal regions (and eutrophication), shallow seas (coral reefs, salt marshes, mangroves).

Future measurements required are:

- In upwelling regions: are these areas net sources or sinks of carbon? what is the vertical export (and burial) into deep sediments; the biological and biogeochemical implications of anoxia and hypoxia.
- On polar shelves (that are sensitive to climate change); exposure of new shelves (following ice melt); export of iron to HNLC environment.

- In shallow temperate seas (including river and atmospheric inputs); long-term moorings (as presently studied by the EU).

Specific recommendations:

- Need for long-term observations (moorings, monitoring lines) to deal with variability (seasonal to decadal);
- Intercalibration exercises - measurement protocols;
- Need for a specific and more representative SCOR-sponsored Carbon Cycling Task Group to explore/expand/tune ideas here, but must link with existing groups (e.g. CMTT).

Working Group (4): Internal tides, mixing (and exchange)
Leaders: John Huthnance, Michael Spall
Rapporteur: Susan Allen

Internal tides' character and propagation (to ocean or shelf) are generally understood and can be measured. However, with speeds O(0.5 m/s) these waves are susceptible to currents, stratification in relation to topography (crucial, subtle); hence they vary according to upwelling, spring/neap cycle etc. They can be generated at various depths, but commonly over seamounts or near the continental shelf break where a critical slope usually occurs, then travel to shelf or ocean.

Effects relating to exchange are

- non-linear forms can carry water on or off the shelf,
- rectified flow (along- or cross-slope; probably local to shelf-break; tricky to estimate),
- sporadic stirring up of bottom sediments if bottom and critical slopes match,
- mixing (effective at maximum stratification; unclear relation to larger modelled scales; favoured by rough topography, trapping in canyons). [Vertical mixing is also caused by long surface waves, directly and via Langmuir circulation].

Development of non-linear forms ("solitons") requires a non-hydrostatic model, but is reasonably understood. 2-D (cross-slope) models tend to under-estimate generation. Once-for-all global modelling of internal tides is of doubtful value owing to variability; shelf-break generation may be more robust with stratification ~ constant at this depth. Good bathymetry, salinity, temperature data and fine resolution are needed for modelling.

Coarser-resolution models need parameterizations of internal waves and their effects on mixing, probably involving measurements of increased mixing (hard to measure; intense along characteristics but variable; also hard to follow internal waves until they break).

Mixing is relevant to exchange:

- it increases volume transport in plumes and downflows; hence importance of mixing at heads of deep channels,
- mixing within a fjord determines the exchange,
- interleaving plus mixing becomes exchange,
- internal wave mixing affects shelf-edge productivity hence organic matter exchange,
- along-slope currents have boundary layers with cross-slope flow (downwelling and upwelling are not "equal and opposite").

Required research includes:

- Measurements for relationship between internal wave field and mixing in varied contexts;
- Application of non-hydrostatic models for internal wave generation in varied contexts and measurements to test them; and
- Parameterisations to represent consequences of internal waves in models that do not resolve them.

Working Group (5): Future Modelling
Leaders: John Johnson, Anne-Marie Treguier
Reporter: John Klinck

Model Studies:

- Encourage process model studies considering situations such as dense plumes, canyons and river outflow;
- Regional studies are useful to answer local questions. ("Small" model efforts are useful);
- Analyze existing global model solutions. Need to work on a mechanism to extract coastal information and deliver to interested parties.

Model Validation:

- Encourage model validation studies;
- Compare results from different models, especially those with different formulations or numerics;
- Identify non-traditional shelf data (e.g., fisheries surveys, commercial coastal activity, ships of opportunity); Encourage sensor calibration of these data;
- Encourage operational use of models which will push an expansion of observations;
- Operational activities can expand funding opportunities.

Future Models:

- Encourage coupling of shelf ocean models to atmospheric or hydrology models;
- Encourage continued model development;
- Insist on open access to model codes and analysis tools;
- Develop user communities for the various models;
- Develop test problems to analyze the behaviour or benefit of existing and newly developed models.

Working Group (6): Future Observations

Leaders: Piers Chapman, Christopher Duncome-Rae
Rapporteur: Isabel Ambar

Regarding the need for a future program on deep ocean exchange with the shelf, the workshop started by considering the following two basic premises. We have to decide what we want to look at in terms of both processes and regions where they occur. We need to identify what particular instruments we have/need and the advantages/ disadvantages of each.

There was considerable discussion about which future processes should be studied, leading to an agreement that:

- We want to know about rates of transfer and variability (seasonal, annual, decadal…);

- Understanding the physics is the key to understanding processes that are important to cross-shelf exchange;
- We have to be able to link the physics to the biology and chemistry, using modeling to couple them together as we can never obtain enough real data points;
- The regions to be studied determine which processes are important; and
- Experimental designs will depend to a large extent on local needs.

As an example, the meeting considered how Africa can be divided into different regions where different processes are important. There are upwelling regions (the Canary, Guinea, and Benguela upwellings), western boundary currents (the Agulhas, Somali, and East Madagascar currents), the Mediterranean region along the north African coast, and an understudied system along the east coast of the continent.

Taking these different regions into account, we may have to consider the effects of: canyons, upwelling/downwelling, mixing processes, tides and internal waves, air-sea interactions, shelf-edge fronts, eddies, filaments, and Lagrangian mean flows. Thus, any process studies may need to account for multiple physical processes.

The WG considered four major regional groups where the important processes are likely to be important, and attempted to identify which processes were most important; the scales at which observations need to be made; and the rationale for these measurements. In some cases, we were able to identify potential experimental sites (see Table 1 below).

Instrumentation

With regard to the likely instrumentation required for any such experiment, it was assumed that all future observations will require the following basic resources:

- Appropriate satellite sensors–temperature, optical, altimeter–although there are problems, particularly related to the cost of future missions, in ensuring continuity in such observations;
- Ship-based resources – again, economic factors influence platform availability;
- HF radar (<150 km from coast);
- Good bathymetry (multibeam survey); and
- Fine-scale modeling.

These resources all exist presently, but their availability in the regions of interest is very variable. Additionally, all experiments will likely require at least some of the following:

- Gliders – from past experience their use will be dependent on local currents (they are not as successful in western boundary currents as elsewhere, for example);
- Moored profilers – these will need to be trawl resistant;
- Lagrangian drifters (surface/deep/nepheloid layers) e.g., Argo;
- Expendable profilers (XBT, CTD, microstructure);
- Sediment traps – although in areas where advection is considerable, such as in strong tidal ields, there are problems in determining the origin of any particles collected;
- Bottom tripods;
- AUVs;
- Towed pack
- Vessels of opportunity.

Proposed workshop products

The group agreed that an important initial product could be map(s) of shelf areas of the world detailing the important processes in each region. These could be used to assist in determining where any such experiments should be carried out.

Table 1. Potential processes, scales and rationales for study during a program on deep ocean exchange with the shelf.

1. Eastern Boundary Upwelling Systems

Process	Area/Scale	Rationale
Filaments	5-30 days	
Internal tides	Potential site: Northern	Carbon transfer
Spin-off eddies	Benguela (Luderitz)	Primary production
Mean flows		
Undercurrents		
Frontal jets		
Gravity currents		

2. Western Boundary Currents

Process	Area/Scale	Rationale
Topographic upwelling	Perennial	Sediment removal
Ekman veering		Nutrient supply
Arrested topographic waves		Ecosystem driving
Intrusions/meanders		
Freshwater		
Eddy formation		
Entrainment		
Inshore countercurrents		

3. Temperate shelves

Process	Area/Scale	Rationale
Tides	Seasonal	Sediment removal
Unstable boundary currents	Potential sites: European shelf,	Nutrient supply
Internal waves	Mid Atlantic Bight	Pollutant transfer
Shelf edge fronts		
Freshwater/estuarine circulation		

4. Polar shelves

Process	Area/Scale	Rationale
Wind forcing	Small Rossby scales	Water mass formation
Ice		
Gravity currents		
Tides		
Freshwater exports (Arctic rivers, ice melt)		

Appendix 5: Minutes of SCOR WG129 Meeting, Cape Town, 8 October, 2008

Members present: J. Johnson (Co-chair), P. Chapman (Co-chair), I. Ambar, X. Durrieu de Madron, T. Matsuno, J. Middleton, A. Orsi, O. Trusenkova.
Guest: S. Allen
Apologies: J.Backhaus, D.Hu, p.Monteiro, W.Naqvi

Johnson called the meeting to order at 16.02. (Note: the meeting was being held immediately following a workshop on Deep Ocean Exchanges with the Shelf.)

Bibliography
Johnson reported that the bibliography is now on the SCOR/IAPSO website and has been updated a couple of times. Members of the WG are asked to send additional references to him for inclusion in the bibliography. It was noted that there are still no references for the Brazil Current region.

Action item:
1. Members to send Johnson additional references for the bibliography.

Montreal meeting
A symposium on the topic of the WG has been convened as part of the IAPSO meeting. To be held in Montreal in August 2009 during the first week of IAPSO. Johnson guaranteed either a talk or a poster to WG members. The final meeting of the WG will take place at the same time and venue.

Action item:
2. We need to decide when to hold the WG meeting, and how many days will be needed.

Cape Town workshop
Johnson will report on the Cape Town workshop at the SCOR 50th Anniversary meeting in Woods Hole later in October. A discussion took place on what still needs to be done; Johnson will collect submissions and send them to all WG members.

It was agreed to produce a map of global shelf types along with a table of processes likely to be important for each type. This will be done with the assistance of outside experts. It was further agreed that a global study of shelves (e.g., Global Integrated Shelf Exchange Program) would be a good idea. Countries should be encouraged to form regional groupings to work on areas such as the East and South China Seas, or the Mediterranean.

Action items:
3. WG members to send suggestions for future work to Johnson for collection and dissemination.
4. WG members (who?) to produce a global map of shelf types and processes.

Publications
The WG agreed that presenters of papers in Cape Town should be encouraged to prepare their papers for publication in a peer-reviewed journal. Johnson suggested a special issue of Ocean Science, a web-based journal of which he is an editor along with David Webb and Bill Jenkins. Individual articles are published in the order in which they are received; once all articles for the special issue have been published, paper versions can be printed. All invited speakers would be

solicited to produce an article for this publication, with a deadline of March 2009 for the initial draft.

It was agreed that canyons appear to be a major unknown area as regards the transfer of material onto and off the shelf. Susan Allen was requested to write an article on this topic for publication in Ocean Science, with assistance from Xavier Durrieu de Madron.

Action items:
5. Johnson to ask all invited speakers to submit an article for publication in a special issue of *Ocean Science* with a deadline of March 2009.
6, Allen and Durrieu de Madron to write an article on the role of canyons on shelf-slope transfer for publication in the special issue.

Terms of reference
The WG agreed that the original terms of reference are being met.

Other business
Middleton asked about funding for the WG. Johnson replied that everybody should receive the required expense forms from Liz Gross.

The meeting was adjourned at 17.05

John Johnson, Piers Chapman 16th January 2009.
