Integrated Marine Biogeochemistry and Ecosystem Research

Issue n°19 - December 2011

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1 - Welcome to SIBER!

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Integrated Marine Biogeochemistry and Ecosystem Research

GLOBAL OCEAN OBSERVING SYSTEM FOR INDIAN OCEAN

Eileen E. Hofmann (IMBER Chair), Center for Coastal Physical Oceanograph, Norfolk, VA, USA

Nick D'Adamo, Perth Regional Programme Office of the IOC, Perth, Australia

*The **Sustained Indian Ocean Biogeochemical and Ecological Research (SIBER)** initiative is the most recent regional programme of IMBER. The importance of this programme to Indian Ocean research is underscored by its co-sponsorship by the Indian Ocean Global Ocean Observing System (IOGOOS). Also, the UNESCO Intergovernmental Oceanographic Commission (IOC) through its Regional Programme Office in Perth, Australia is a sponsor and facilitator of IOGOOS and, in turn, of SIBER.*

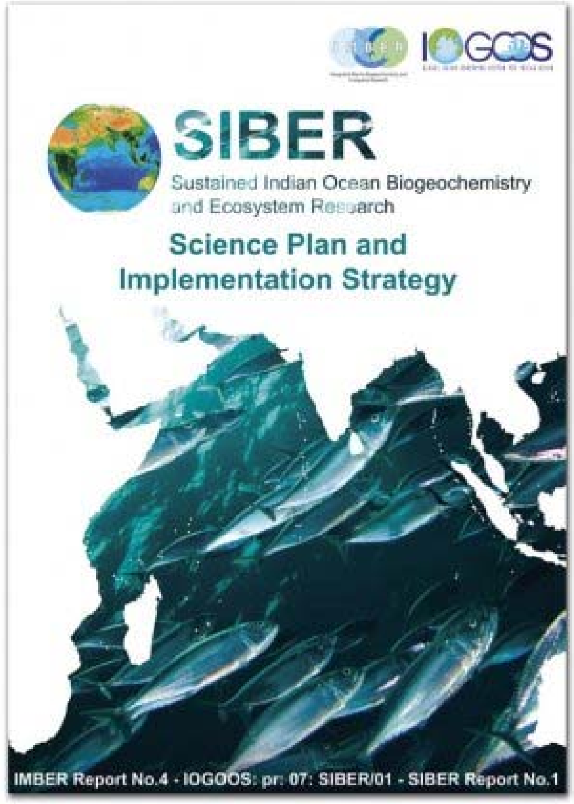
The scientific basis for SIBER arose from large multi-disciplinary gatherings of marine scientists interested in the biogeochemical cycling and ecology of the Indian Ocean held in Goa, India during 2006, and then again in 2007. These community-wide meetings resulted in development of the SIBER Science Plan and Implementation

Strategy (SPIS), which provides a blueprint for a comprehensive science meme to study biogeochemical cycles, ecosystem dynamics, and their interactions in the Indian Ocean. The SIBER SPIS, recently published as IMBER Report 4, was developed under the guidance of the SIBER Scientific Steering Committee, co-chaired by Raleigh Hood (USA) and Wajih Naqvi (India).

The articles in this newsletter illustrate that SIBER is already a robust and active programme. The science highlights focus on results from studies of oxygen minimum zones and boundary current dynamics; both important to understanding the role of Indian Ocean in biogeochemical cycling and ecosystem dynamics. The infrastructure and partnerships that will support a sustained research programme in the Indian Ocean are being developed. A SIBER International Programme Office, hosted by the Indian National Centre for Ocean Information Services (INCOIS), has been established. Important partnerships are being developed with the Agulhas and Somali Current Large Marine Ecosystems (ASCLME) project, the Bay of Bengal Large Marine Ecosystem (BOBLME) project, and the Indian Ocean Panel (IOP) of GOOS-CLIVAR. Each of these partnerships provides the ability for long-term sustained measurements and research in the Indian Ocean, a primary goal of SIBER.

The partnership with the IOP provides a unique opportunity for SIBER in that this group has established 30 mooring sites spanning the Indian Ocean since 2000, with the intention of sustaining them in the long term. These sites afford SIBER the opportunity to enhance the moorings with biological instrumentation and efficiently establish a unique observing capability. This will greatly enhance the combined biological and physical understanding of the Indian Ocean across deep ocean and continental margin scales.

Another important partnership for SIBER is provided by the IndOOS Resources Forum (IRF), recently developed under the auspices of IOGOOS with the support of the UNESCO IOC Perth Office. The IRF is intended to help leading oceanographic agencies of the world come together under a spirit of mutual cooperation and interest, to facilitate the alignment or allocation of operational resources in support of the operational missions of SIBER and IOP.



SIBER SPIS sept 2011.pdf 3.88 MB

2 - SIBER: A New Basin-wide, international programme in the Indian Ocean

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Raleigh Hood (SIBER co-chair), University of Maryland, Cambridge, USA
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2.1 - Introduction to SIBER

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Although there have been significant advances in our ability to describe and model the oceanic environment, our understanding of the physical, biogeochemical and ecological dynamics of the Indian Ocean is still rudimentary in many respects. This is partly due to the fact that the Indian Ocean remains substantially under-sampled in both space and time, especially compared with the Atlantic and Pacific Oceans. The situation is compounded by the Indian Ocean being a dynamically complex and highly variable system under monsoonal influence. The biogeochemical and ecological impacts of this complex physical forcing are not yet fully understood. Indeed, the Indian Ocean is truly one of the last great frontiers of oceanographic research.

The Indian Ocean is also warming rapidly, but the impacts of this warming on the biota, carbon uptake, and nitrogen cycling are largely unknown. The increasing population density and rapid economic growth of many of the countries surrounding the Indian Ocean make the coastal environments particularly vulnerable to anthropogenic influences. Warming and anthropogenic effects are also impacting valuable fish species. These influences and their socio-economic impacts need to be quantified. Understanding the processes that drive biogeochemical and ecological responses to anthropogenic effects is necessary to provide a sound basis for the sustainable management of this globally important ocean. An understanding of these processes is also necessary to predict the impacts and feedbacks of the Indian Ocean as part of the Earth System.

The Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER) programme is an emerging basin-wide, international research initiative sponsored jointly by IMBER and IOGOOS with close ties to CLIVAR's Indian Ocean Panel (IOP). Financial and logistical support of SIBER activities is provided by IMBER and the IOC Perth Office.

The long-term goal of SIBER is to understand the role of the Indian Ocean in global biogeochemical cycles and the interaction between these cycles and marine ecosystem dynamics. This understanding will be required in order to predict the impacts of climate change, eutrophication and harvesting on the global oceans and the Earth System and it is fundamental to policy makers in the development of management strategies for the Indian Ocean.

SIBER has been motivated by the deployment of new coastal and open-ocean observing systems in the Indian Ocean that have created new opportunities for carrying out biogeochemical and ecological research. The IOP is coordinating the deployment of a basin-wide observing system in the Indian Ocean (the Indian Ocean Observing System, IndOOS, which includes the Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction, RAMA) (International CLIVAR Project Office, 2006; McPhaden *et al.*, 2009 and McPhaden *et al.,* 2010). Although there are significant challenges (see the piracy article in this issue), deployment of an array of more than 30 buoys is planned in the open ocean between 20°N and 30°S spanning the entire basin. These deployments, which are already well underway, are accompanied by efforts to maintain the Argo float network and a variety of physical oceanographic survey and mooring support cruises. In addition, several nations in the Indian Ocean are deploying coastal observing systems. These observatories, which are focused primarily on physical measurements, provide foundational infrastructure that could support a wide variety of biogeochemical and ecological studies in both coastal waters and the open ocean. SIBER is a decade-long (Figure 1), multidisciplinary international effort that is designed to leverage these observing systems and other international programmes in order to advance our understanding of biogeochemical cycles and ecosystem dynamics of the Indian Ocean in the context of climate and human-driven changes.

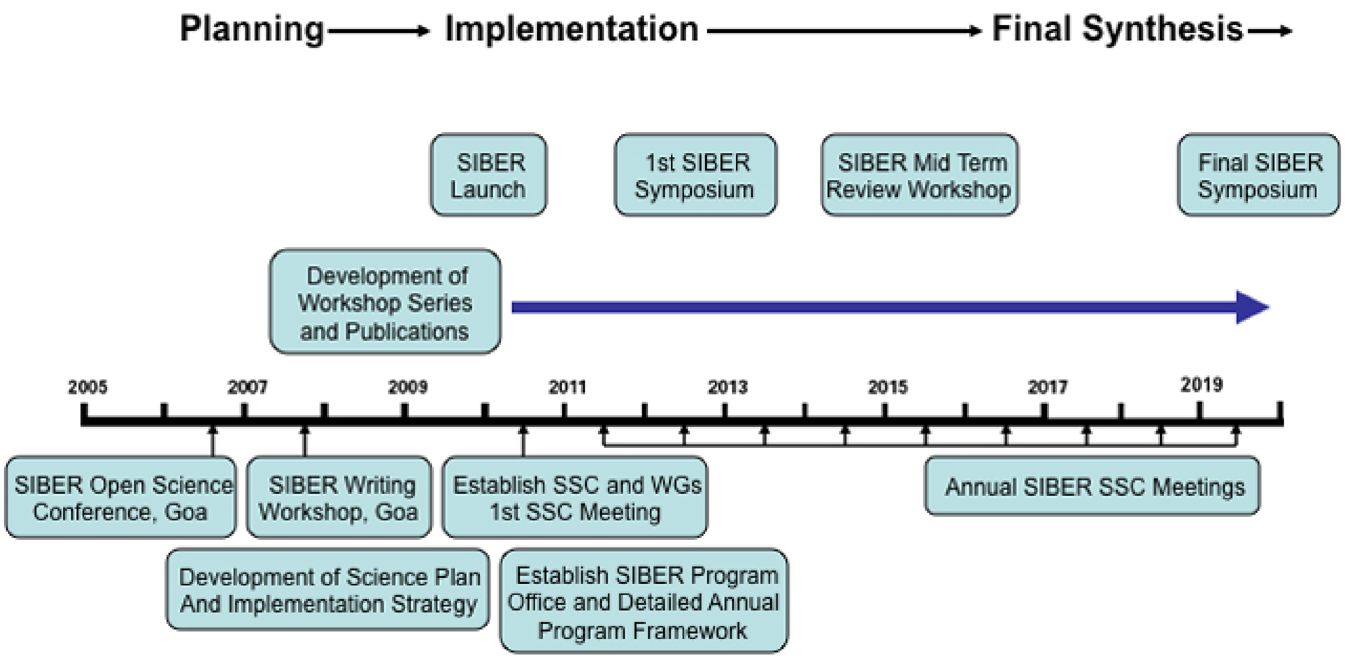

Figure 1: SIBER Programme timeline (from Hood *et al.*, 2011)

2.2 - Legacy

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SIBER reflects the importance placed on these issues by the International Geosphere-Biosphere Programme (IGBP), the Scientific Committee on Oceanic Research (SCOR) and the Global Earth Observing System of Systems (GEOSS). SIBER, which has been developed with the guidance and endorsement of IMBER and IOGOOS, is ambitious and very broad. It is basin-wide, encompasses biogeochemical research from the continental margins to the deep sea and tropic levels ranging from phytoplankton to top predators including fish and humans. SIBER is intended to provide scientific guidance and potential research foci to accommodate the broad (and often regional) interests of many countries that are interested in pursuing research in the Indian Ocean.

It is important to emphasize that SIBER is a fusion of IMBER and IOGOOS with specific focus on major Indian Ocean research questions. SIBER embraces the complementary IOGOOS and IMBER goals of developing a monitoring and predictive capacity for detecting and predicting ocean responses to accelerating global change and consequent effects on the Earth System and human society. Informed decisions require an understanding of which parts of the Earth System are most sensitive to change, and the nature and extent of anticipated impacts. This requirement is a major motivation for SIBER, i.e., there is evidence to

In this special 'SIBER' issue of the IMBER newsletter we highlight some recent programmatic and research activities associated with SIBER and some of the challenges we face as well. It is our hope that the coordination and integration of Indian Ocean biogeochemical and ecosystem research through SIBER will advance our knowledge of this under-sampled basin and provide a major contribution to the understanding of how regional and global change may impact biogeochemical cycles and ecosystem function, not only in the Indian Ocean, but in the Earth System, creating a lasting legacy on which future research can build. We encourage scientists from all relevant fields to collaborate and participate in SIBER to ensure that major questions about the Indian Ocean and Earth System are addressed in a fully integrated manner.

suggest that the Indian Ocean is particularly sensitive to global change, yet it is one of the most poorly understood basins in terms of its physical, biogeochemical and ecological dynamics.

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Hood, R.R., S.W.A. Naqvi, J.D. Wiggert, M.R. Landry, T. Rixen, L.E. Beckley, C. Goyet and G.L. Cowie (2011) SIBER Science Plan and Implementation Strategy, Vol. IMBER Report No. 4, IOGOOS Report No. 7, SIBER Report No. 1. More info...

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International CLIVAR Project Office (2006) Understanding the role of the Indian Ocean in the climate system - Implementation plan for sustained observations. January. International CLIVAR Project Office, CLIVAR Publication Series No.100. More info...

McPhaden, M., K. Ando, B. Bourles, H. Freitag, R. Lumpkin, Y. Masumoto, V. Murty, P. Nobre, M. Ravichandran, J. Vialard, D. Vousden and W. Yu (2010) The Global Tropical Moored Buoy Array. In: Hall J, Harrison DE, Stammer D (eds) OceanObs'09: Sustanied Ocean Observations and Information for Society ESA Publication WPP-306, Venice, Italy, p doi:10.5270/OceanObs5209.cwp.5261.

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3 - SIBER International Programme Office at INCOIS

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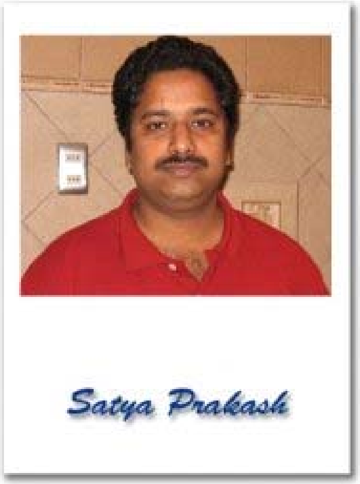

SIBER is a basin-scale international programme that is making a concerted effort to develop an enhanced understanding of the Indian Ocean and its role in the global biogeochemical cycle. This programme is intended to provide scientific guidance and potential research focus to many countries, including Indian Ocean rim countries, interested in pursuing research activities in the Indian Ocean. Coordination of such a basin-wide research programme requires well-organized guidance and oversight by a governing body that is well-informed about the scientific questions to address in the Indian Ocean. SIBER Scientific Steering Committee (SIBER SSC) members are tasked with providing this guidance. To facilitate information sharing among various international programmes and to co-ordinate the activities pertaining to SIBER in different Indian Ocean rim countries, an International Programme Office (IPO) has been established at the Indian National Centre for Ocean Information Services (INCOIS) in Hyderabad, India as a part of IOGOOS secretariat on the advice and guidance of the SIBER SSC. The decision was made at the SIBER SSC meeting held during 12-15 July 2010 in Perth, Australia.

The primary responsibilities of the SIBER IPO are:

- to provide logistical support for convening SIBER SSC meetings, symposia and workshops;
- to develop and maintain the SIBER website;
- to develop and distribute the SIBER Newsletter.

Since its inception, the SIBER IPO has made significant contributions to the SIBER community. The SIBER IPO provided the logistical support for convening SIBER SSC meetings, conferences and workshops including on-sight meeting support. The SIBER IPO coordinated the SIBER-2 meeting, concurrent with the IOP-8 and IRF-2 meetings during 25-29 July 2011 at the MGM Beach Resort, Chennai.SIBER IPO also created a new SIBER website which was launched prior to SIBER-2. This new web portal replaced the temporary website, that was hosted by IMBER. The new website gives a glimpse of SIBER and its activities. The website contains a brief description of SIBER, its scientific goals, objectives and themes. The list of SSC members and their contact details and lists of participants from the various SIBER workshops and meetings is also available. Various SIBER-related publications/reports, including the science implementation plan, are also available and can be downloaded from the website. Additional content will be added over time, including meeting reports, working group activities, overview presentations and links to other relevant websites.

It is planned to bring out a SIBER Newsletter - to be published and distributed semi-annually to communicate the SIBER activities and other relevant information about Indian Ocean research and monitoring programmes to the researchers having SIBER-related interests. SSC members will act as the editorial team. The first newsletter is expected in mid 2012.

The INCOIS campus at Hyderabad, India where the SIBER IPO is located

4 - The Agulhas and Somali Current Large Marine Ecosystems (ASCLME) Project

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4.1 - ASCLME contributions to SIBER - partnering to build ocean observing systems in the western Indian Ocean

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James Stapley (IT and Communications Coordinator) and David Vousden (Regional Director), ASCLME, Grahamstown, South Africa

The UNDP supported GEF financed ASCLME Project strongly supports the objectives of SIBER in understanding the biogeochemical cycles and marine ecosystems of the Indian Ocean. The Project's research cruises will undoubtedly provide a rich dataset to the marine science community of the region. We are particularly pleased with the dynamic partnerships we have established with

The Agulhas Current Time-Series (ACT) experiment has just finished its second research cruise, and will help to understand in more detail the variation of the Agulhas Current over a longer time-period, adding yet more data, and another important partnership, to ASCLME.

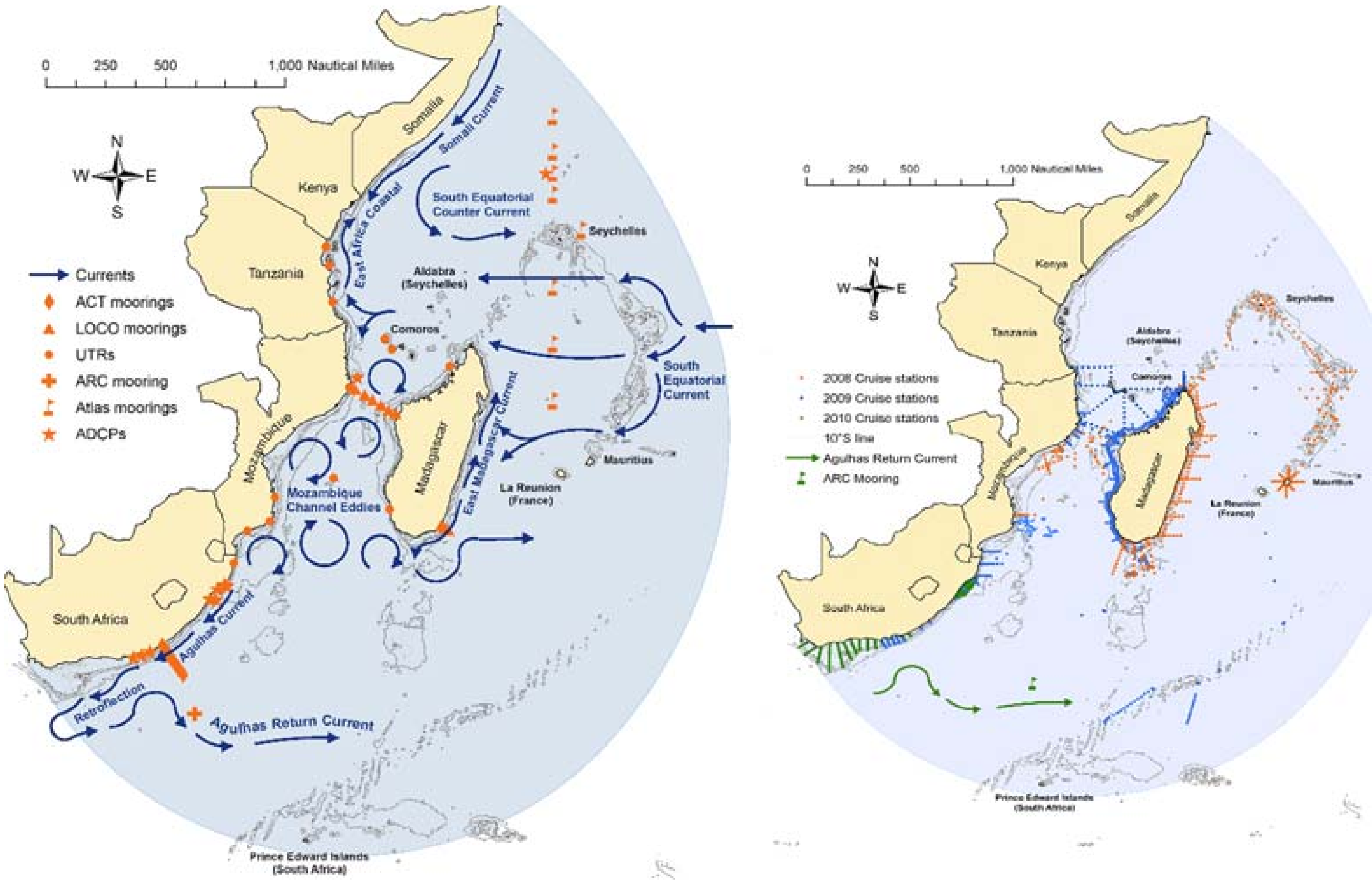
The African Coelacanth Ecosystem Programme (ACEP) and its host institution, national, regional and international organisations who are jointly creating a long-term ocean observing system in the western Indian Ocean, which will continue to provide data and fill in gaps in our knowledge far into the future.

A particularly strong partnership has been forged with the National Oceanic and Atmospheric Administration (NOAA), which has resulted in the deployment of several ATLAS moorings as part of the RAMA array, along with contributions of satellite drifters and Argo floats. NOAA is also working with the Project to ensure the countries of the region are able to use such data, notably through the Data Buoy Cooperation Panel (DBCP). Another joint project is trying to better establish the flow and ocean/atmosphere interactions of the Agulhas Return Current (ARC); unfortunately, the deep currents in the region were stronger than expected and caused the mooring line to snap. The French research vessel *Marion Dufresne* ultimately rescued the mooring, which we hope to reconfigure and redeploy in due course.

The Royal Netherlands Institute for Sea Research (NIOZ) is another important partner; their willingness to share, maintain and extend the Long-term Ocean Climate Observations (LOCO) array in the Mozambique Channel and now the East Madagascar Current will help unlock the secrets of the dynamic, but poorly understood, currents of this region. Research is indicating that the eddy systems in the Mozambique Channel are potentially extremely important in driving productivity, and their interaction with the landmasses either side of the channel has interesting implications not only for productivity, but also larval dispersal and recruitment.

the South African Institute for Aquatic Biodiversity (SAIAB) have been one of our strongest supporters, particularly in their willingness to arrange cruise logistics, align their research programmes with ours (essentially covering most of the Agulhas Current research) and of course, in providing a "home" for the Project Coordination Unit.

Although space precludes a full list of the many, many institutions that give selflessly of their time and data and help to make ASCLME a success, we recognise and acknowledge the importance of these partnerships, and the limitations that a short-term project has in sustaining them. For this reason, the project is engaged in a process to create a self-sustaining Western Indian Ocean Sustainable Ecosystem Alliance (WIOSEA), which ultimately aims to maintain existing partnerships, create new ones and assist in the achievement of Strategic Action Programme (SAP) targets which will ultimately be identified by ASCLME, along with the sustainable development of the region and adaptive management of its marine and coastal resources. This process recognises the importance of working together and creating more tightly integrated research projects throughout the region.



The ASCLME Project and its partners have conducted a comprehensive cruise programme since 2008. The chart to the right shows the cruise stations. The chart to the left indicates the positions of the longer term, often near real-time instrumentation the Project and its partners have deployed during those cruises, along with an indication of the prevailing currents. The dotted line on the right hand chart indicates the piracy exclusion zone at 10°S in 2009; this is slowly extending further south, currently at 12°S; this has affected the ability of the Project to work in the northern part of the region, and threatens its ability to maintain the more northerly equipment. *Image courtesy Tommy Bornman.*

4.2 - The Bay of Bengal Large Marine Ecosystem (BOBLME) Project and potential linkages with RAMA and SIBER

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Rudi Hermes, Chief Technical Advisor, BOBLME, Phuket, Thailand

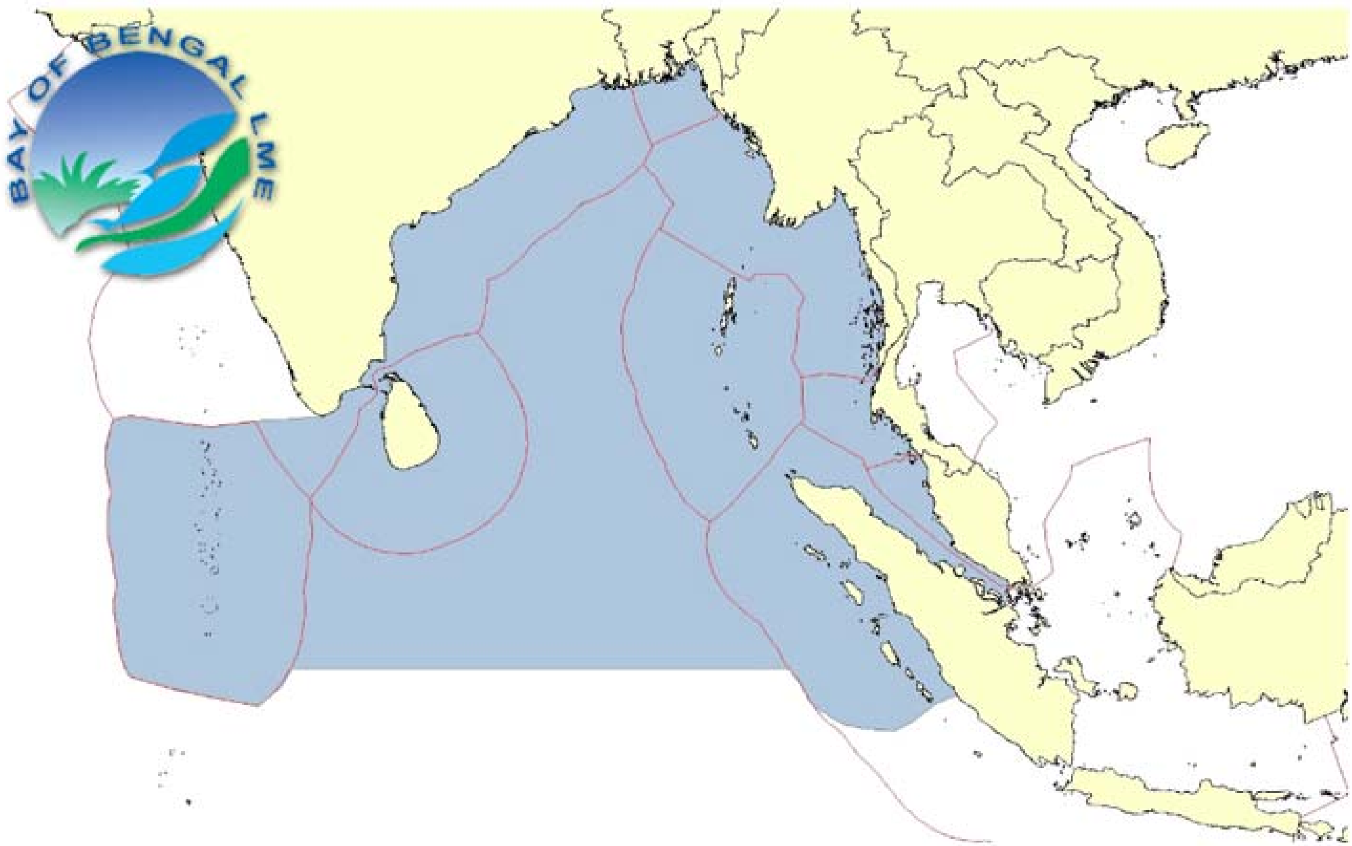
In line with this objective, BOBLME has become an associate member of

In the northeastern basin of the Indian Ocean, diagonally opposite the ASCLME, another LME project become operational in mid-2009. The Bay of Bengal Large Marine Ecosystem (BOBLME) Project is a five-year (until 2014), $31 million collaboration involving eight coastal states: Bangladesh, India, Indonesia, Malaysia, Maldives, Myanmar, Sri Lanka and Thailand. These countries are working together to develop a coordinated programme of action designed to improve the lives of the coastal populations through improved regional management of the Bay of Bengal environment and its fisheries. The major implementation partners are the Fisheries and Environment Departments of each country. BOBLME is funded principally by the Global Environment Facility (GEF), Norway, Sweden, Food and Agriculture Organization of the United Nations (FAO) and NOAA of the USA. FAO is the executing agency. According to the standard design of all GEF-funded LME projects, the BOBLME has two major expected outputs. The first is a Transboundary Diagnostic Analysis (TDA) which identifies, ranks and prioritizes water-related environmental transboundary issues (overexploitation of fish stocks, habitat degradation and land based pollution), and their causes, according to the severity of environmental and/or socio-economic impacts. It provides the scientific basis for the development of the Strategic Action Programme (SAP) that will formulate nationally and regionally coordinated activities to address the issues and their causes. The SAP is the prerequisite for a second phase of the Project, beyond 2014 and towards 2020, which will be tasked with implementing the SAP.

BOBLME follows the modular assessment approach for sustainable development, with indicators for five interconnected modules: fish and fisheries, productivity, pollution and ecosystem health, socio-economics and governance. Oceanographic variability, together with photosynthetic activity, zooplankton and ichthyoplankton biodiversity, and zooplankton biomass are the relevant indicators for the productivity module. Among a range of project objectives, dealing with fisheries resources management and habitat conservation, the objective of sub-component 3.1 aims to "*contribute to an improved understanding of large-scale oceanographic and ecological processes controlling the BOBLME living resources*".

IOGOOS and has formed working groups on oceanography, climate change and ecosystem health, promoting capacity building, adaptation to climate change, generation and exchange of oceanographic data and information, and ecosystem mapping and monitoring of indicators of ecosystem health. Working group members are usually oceanographers from the partner countries and BOBLME is also promoting the IOGOOS membership of their agencies and institutes.

SIBER, in its Science Plan and Implementation Strategy, has underlined the need for deployment of biogeochemical sensors on RAMA moorings, with the Bay of Bengal identified as a priority location. The SIBER objectives for deployment of biogeochemical sensors, for example, to provide data for defining biogeochemical variability in key regions of the Indian Ocean (in this case, the Bay of Bengal) and for understanding the physical, biological and chemical processes that govern it, are very much in line with the corresponding BOBLME objective. BOBLME is therefore, prepared to contribute to the SIBER objectives by providing a set of sensors for the Bay of Bengal RAMA mooring (e.g. for CO_2, chlorophyll [fluorescence], oxygen, turbidity and pH). Planning for purchase and deployment is done jointly with the BOBLME partner NOAA. BOBLME wants to ensure that data and information gathered as part of this activity will be freely available e.g. via the internet. Through its involvement in IOGOOS and SIBER, BOBLME also promotes regional collaboration amongst scientists and related capacity development; e.g. participation in regional training events or oceanographic survey work, allowing reciprocal access to the EEZ of partner countries.



Map of the Bay of Bengal Large Marine Ecosystem indicating EEZ boundaries (Source: SAUP Project, UBC)

5 - SIBER and the Indian Ocean Panel (IOP): a unique interdisciplinary partnership

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Raleigh R. Hood, University of Maryland Center for Environmental Science, Cambridge, MD, USA

Weidong Yu, First Institute of Oceanography, SOA, Qingdao, China

Yukio Masumoto, Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan

Introduction

Developing the ability to predict the impacts of climate change is an inherently interdisciplinary endeavour. Global warming-induced changes in circulation, air-sea exchange and climate variability, drive changes in biogeochemical cycles and ecological responses. Similarly, biogeochemical and ecological responses to climate change may result in feedbacks that impact physical processes. For example, if biological production and export increase in response to ocean warming, it could provide a negative feedback that slows the accumulation of CO_2 in the atmosphere and the ocean. This, in turn, would slow the rate of warming and its impacts on atmosphere and ocean circulation and air-sea exchange (Sarmiento and Le Quéré, 1996). In contrast, if biological production and export decrease in response to ocean warming, the opposite might occur, i.e., there could be a positive feedback that accelerates CO_2 accumulation, warming and its physical, biogeochemical and ecological impacts (Sarmiento and Le Quéré, 1996). It is still unclear which of these two scenarios is more likely to materialize or how they might be manifested in time and space.

Yet, with the possible exception of the biogeochemical modeling community, oceanographic research is still carried out largely along traditional disciplinary lines. This happens because our traditional research infrastructure separates physical, chemical and biological oceanographic research planning and funding at both national and international levels.

For example, under the World Climate Research Programme (WCRP), physical studies of the ocean and atmosphere system are planned under the Climate Variability and Exchange (CLIVAR) programme, whereas biological and chemical studies are directed under the International Geosphere Biosphere Programme (IGBP). Similarly, for example, at the U.S. National Science Foundation (NSF), physical, chemical and biological oceanographic research is reviewed and funded separately, with substantial overlap only between chemical and biological studies. These "pipeline" structures create real barriers to interdisciplinary research, especially between physical oceanographers and other oceanographic disciplines. To overcome these barriers scientists and research programme leaders need to actively seek out opportunities for carrying out interdisciplinary research. The connection between the CLIVAR-GOOS IOP and SIBER is an example of how these barriers to interdisciplinary research can be overcome.

Background

CLIVAR formed the IOP in 2004 as an international committee charged with guiding sustainable ocean observing and climate research in the Indian Ocean, focusing primarily on physical processes, e.g., atmosphere and ocean circulation and air-sea exchange at intraseasonal, interannual and multi-decadal time scales. The overarching goal of the IOP is to improve our understanding of the physical dynamics of the Indian Ocean and its teleconnections with the other ocean basins, with a view toward improving models and prediction. The IOP leadership recognized from its start the importance of establishing meaningful interdisciplinary ties and collaborations aimed at understanding how physical processes impact biogeochemical cycles and particularly air-sea CO_2 exchange and carbon export.

Toward this end, they established a tradition of inviting biogeochemists and ecologists to attend their annual panel meetings. The lead author of this article was invited to attend the 2006 IOP meeting in Hawaii. At that time the IOP was planning the Indian Ocean Observing System (IndOOS) (International CLIVAR Project Office, 2006), where the Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA) is the critical component (McPhaden et al., 2009), with the intent to deploy moorings throughout the

These deployments are now well underway (Figure 1) and are being accompanied by deployment of Argo floats and a variety of physical oceanographic survey and mooring support cruises. In addition, several nations in the Indian Ocean (most notably India, Oman and Australia) are deploying coastal observing systems. These efforts represent an important opportunity to carry out interdisciplinary research, with the observatories collecting the physical measurements that can provide a foundation for a wide variety of biogeochemical and ecological studies in both coastal waters and the open ocean.

However, in 2006 there was no equivalent panel or committee to act as a compliment to the IOP for guiding biogeochemical and ecological research in the Indian Ocean. The identification of this gap was the motivation for developing SIBER, i.e., to address the need for an international committee/programme that can guide biogeochemical and ecological research in the Indian Ocean and capitalize on this opportunity to "piggy back" biogeochemical and ecological research on emerging physical oceanographic studies.

tropical and subtropical Indian Ocean that would result in a Global Tropical Moored Buoy Array (McPhaden *et al.*, 2010).

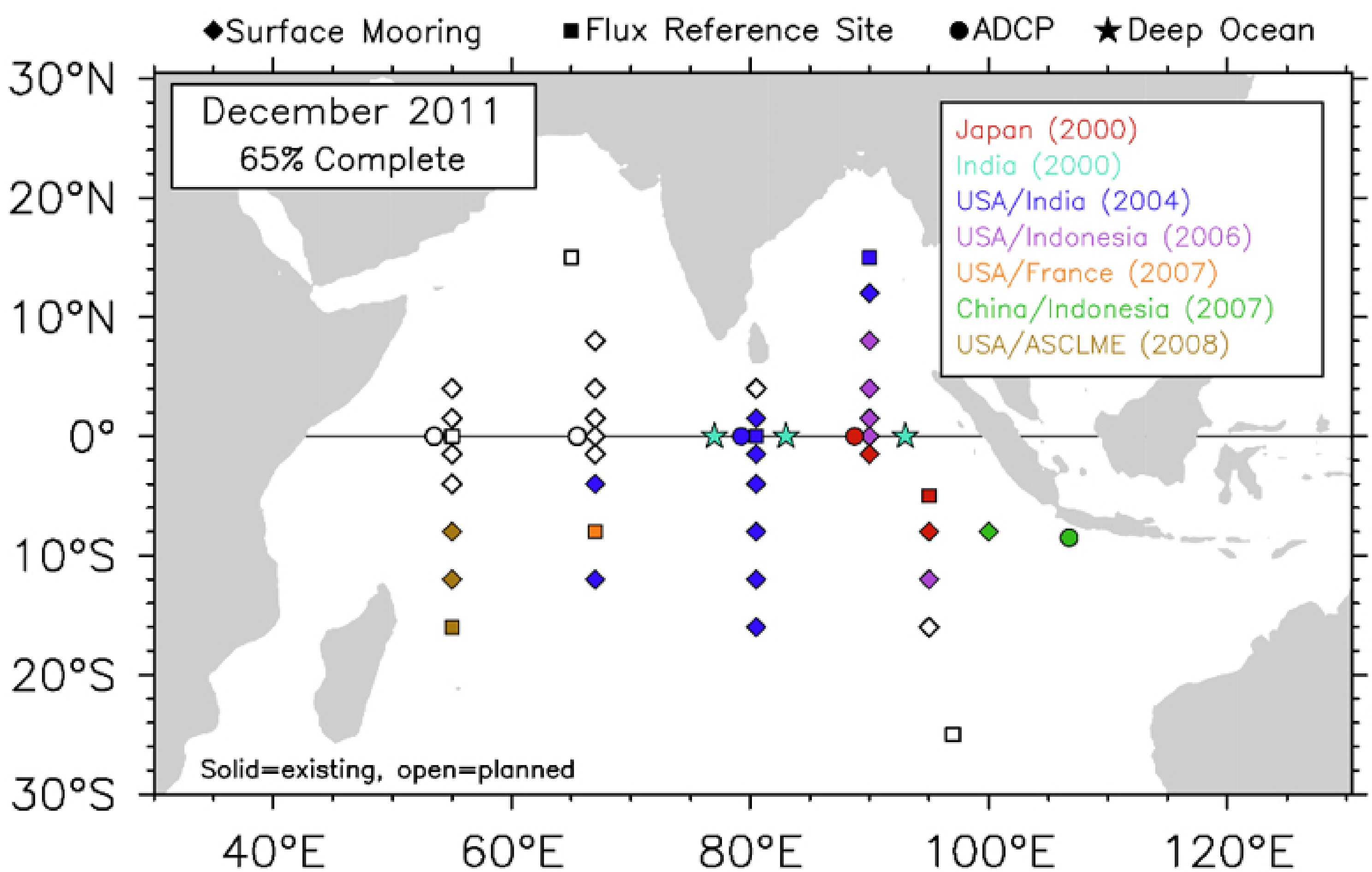

Figure 1: Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA). Note that the filled symbols represent buoys/moorings deployed as of December 2011.

Benefits and promise of the SIBER and IOP linkage

After several years of meetings, planning and negotiation the SIBER programme emerged as an international effort under IMBER and Indian Ocean Global Ocean Observing System (IOGOOS), with close ties to the IOP. The connection to the IOP is maintained in two ways. First, cross membership between IOP and SIBER

1. Defining biogeochemical variability in key regions of the Indian Ocean and for understanding the physical, biological and chemical processes that govern it;

Scientific Steering Committee (SSC) is arranged to promote continuous communication and exchange between the two groups. Second, the SIBER SSC and the IOP convene back-to-back meetings every year, which include a joint session to explicitly discuss ongoing and potential new interdisciplinary collaborations. Typically, several members of the SIBER SSC (mostly biological and chemical oceanographers) attend the entire IOP (mostly physical oceanographers) meeting and vice versa. This co-convening of annual meetings provides an important forum for an interdisciplinary group of scientists to learn about ongoing and planned research in the Indian Ocean in disciplines outside their own. Though, perhaps, the most important function of these meetings is to provide an opportunity to get to know one another, which helps to foster long-term interdisciplinary collaborations.At present, SIBER and IOP efforts are focused on finding the resources needed to deploy biogeochemical sensors on IndOOS/RAMA moorings (see SIBER SPIS, Appendix IV). The overarching objectives of this effort are to provide data for:

2. Developing and validating models of ocean-atmosphere-biosphere interactions;
3. Assessing the impacts of climate change on oceanic primary productivity and air-sea CO_2 exchange.

Some preliminary attempts to deploy biogeochemical sensors on RAMA buoys have been carried out. NOAA instrumented a fluorometer at 25m depth on one of its buoys deployed on 22 May 2010 at location (80.5°E, 0°N) to measure the chlorophyll concentrations. The First Institute of Oceanography (FIO, SOA, China) recently deployed its Bailong Buoy equipped with a pCO_2 system to measure the air-sea CO_2 flux at location (100°E, 8°S) on 28 Feb. 2011. Further plans and funding are now in place to deploy multiple biogeochemical sensor packages on RAMA and Indian moorings in the Bay of Bengal with the generous support from BOBLME.

Summary

Collaboration between SIBER and IOP offers a unique opportunity to mobilize the multidisciplinary, international research effort that will be required to develop a new level of understanding of the physical, biogeochemical and ecological dynamics of the Indian Ocean in the context of the global ocean and the Earth System. This understanding will be required to predict the impacts of climate change. It also provides an important new model for carrying out basin-scale interdisciplinary research that can lead to the long-term collaborations needed to achieve this goal. This model can and should be applied in the other ocean basins.

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6 - The impact of maritime piracy on Indian Ocean observing and climate research

Return to TOC

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A survey of scientists involved in the Indian Ocean Panel (IOP), Sustained Indian

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In the past decade piracy has re-emerged as a security concern for international shipping, particularly in southeast Asia. According to the ICC International Maritime Bureau, there have been 409 attacks worldwide so far this year, and 230 of these occurred off the coast of Somalia, mostly in the northwestern Indian Ocean (Figure 1). Marauding gangs routinely attack large ocean-going vessels and have shown to be able to operate as far as 1000 nautical miles from shore, using hijacked vessels as the 'mothership'. There has also been a discernable increase in hostage-taking.

This scourge of piracy, besides endangering the crews and driving up the costs of shipping, is also having a very detrimental impact on climate change science in the region. Merchant ships that previously plied these waters, often carrying instruments for recording wind and other weather and oceanic conditions, are now being diverted from the area, resulting in a void of information for an area of approximately 2.5 million square kilometres.

It is now virtually impossible to organise research cruises in the northwestern region of the Indian Ocean basin. The cost of additional security measures is prohibitive, often amounting to the equivalent of several sea days aboard a research vessel in a non high risk area. Many planned cruises were cancelled, diverted to other regions or had to be adapted due to the piracy problem, thus preventing scientists from deploying equipment to gather critical data. Indian Ocean climate research, observations, modelling and consequently the ability to address the impacts of climate variability and climate change are being very adversely affected. There have been several reports in the international media in this regard, for example:

"Pirates Scupper Monsoon Research - *Piracy is stopping oceanographers and meteorologists from collecting data vital to understanding the Indian monsoon…"* (Jones, 2011. Nature. doi:10.1038/news.2011.402. More info...).

"Navy to Help Climate Scientists in Pirate-Infested Waters - *About a quarter of the Indian Ocean is now off limits to climate scientists trying to complete a global network of deep ocean devices that gather data crucial to climate change studies and weather forecasts."* (New York Times, 14 July 2011. More info...).

In the western Indian Ocean, in response to numerous incidents, Lloyds of London declared a high risk exclusion zone within which additional risk insurance premiums are required for both merchant and research vessels. Earlier this year the eastern boundary of this zone was extended from 65^{o}E to 78^{o}E, so that it now covers almost the entire northwestern Indian Ocean (Figure 2).

Ocean Biogeochemical and Ecological Research (SIBER) and the Indian Ocean Observing System (IndOOS) Resource Forum (IRF) showed that piracy is proving to be a major impediment to establishing and maintaining the IndOOS Research Moored Array for the African-Asian-Australian Monsoon Analysis and Prediction (RAMA) and to carrying out research in many parts of the Indian Ocean. The RAMA array is an observational network that aims to answer several scientific questions relating to Indian Ocean variability and the monsoons. It comprises complimentary satellite and *in situ* observational platforms for climate research and forecasting. During the past six years, 30 of the planned 46 buoys were installed. However, many of these, as well as 13 of the remaining planned sites, are located within the high risk exclusion zone (Figure 2).

This has motivated identification of alternative sampling methods that could be adopted to cover the observational gaps that would otherwise result in the array. Glider technologies are capable of sampling remotely over large areas. It has recently been demonstrated that trans-basin glider deployments, collecting physical measurements (temperature and salinity) covering 1000s of kilometres are possible (see http://rucool.marine.rutgers.edu/atlantic/). Such devices could potentially be deployed to provide subsurface measurements of physical and biogeochemical properties. The latter include chlorophyll fluorescence/pigments, transmittance/carbon, oxygen and even nutrient concentrations.

Discussions amongst high-level representatives from many world-leading institutions/agencies are needed to consider ways of dealing with the piracy issue. Additional resources and effort are required to provide the necessary security measures for research cruises that need to enter the exclusion zone to deploy and service buoys. It was suggested that affected research communities should lobby their national and intergovernmental representatives/agencies in order to highlight the plight of scientific research and the implications of expanding maritime piracy for the region and ultimately for society.*See also Appendix V of the SIBER SPIS:*

SIBER SPIS sept 2011.pdf 3.88 MB

Figure 1: Map indicating all the piracy and armed robbery incidents reported to the International Maritime Bureau (IMB) Piracy Reporting Centre in Indian Ocean during 2011.

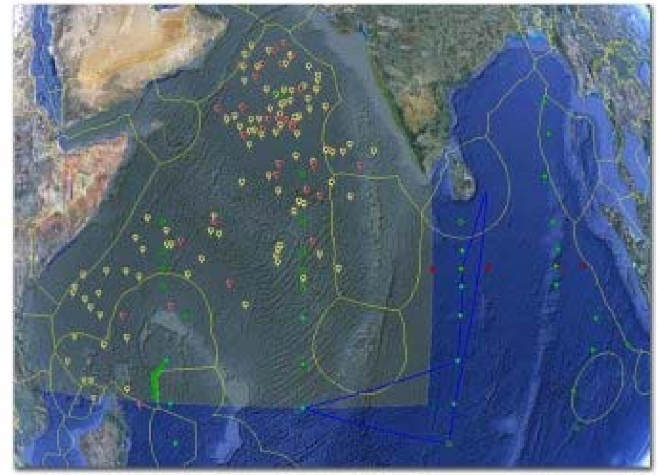

Figure 2: Map of the western Indian Ocean showing the 2011 Lloyds of London Piracy Exclusion Zone (yellow line). The red symbols indicate pirate attacks and the yellow symbols attempted, but thwarted, attacks near the RAMA sites (green circles) from January 2010 - May 2011. Green open circles are RAMA sites still to be installed.

7 - SIBER science highlights

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7.1 - Modelling the Arabian Sea Oxygen Minimum Zone (ASOMZ)

Return to TOC

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The Arabian Sea Oxygen Minimum Zone (ASOMZ) is the second-most intense OMZ in the world's tropical oceans, with near-total depletion of oxygen at depths from 200 to 1000m (e.g. Morrison et al., 1998). Indeed, oxygen in the Arabian Sea can reach suboxic levels (O_2<~5µM), allowing denitrification to occur in the upper part of the ASOMZ. Yet, the physical and biological factors that determine the location and intensity of the ASOMZ have not been quantified and few, if any, models have successfully reproduced it. In this article, we report solutions to a coupled biological/physical Indian Ocean model designed to investigate the processes that determine the strength and structure, particularly concerning the location of the upper ASOMZ in the central and eastern basins.

Background

Figure 1 maps the horizontal distribution of the ASOMZ at a depth near 200m using the secondary nitrite maximum as an indication of the suboxic level where denitrification occurs (Naqvi, 1991 and 2006). It is clearly detached from the

Other sources of subsurface oxygen in the Arabian Sea are Red Sea water (RSW), Persian Gulf water (PGW), and possibly water from the lower portion of the Indonesian throughflow (ITF), but their contributions are not expected to be western and northern boundaries. This "eastward shift" of the (upper) ASOMZ into the central and eastern basins is surprising, since biological production is the largest in the western basin due to upwelling off Somalia and Oman. Figure 2 plots along-track oxygen (top) and nitrite (bottom) sections across the northern Arabian Sea. It shows that the ASOMZ is absent near the western boundary above 400m, confirming the eastward shift seen in Figure 1. It also shows that the ASOMZ is present near the Omani coast at depths greater than 400m. For this reason, we have found it useful to divide the ASOMZ into upper and lower parts, with the dividing depth being roughly 400m.

Without a source of subsurface oxygen, the continual remineralization of sinking detritus would eventually deplete all oxygen from subsurface waters. The major source of subsurface oxygen for the Arabian Sea is from the southern hemisphere. Figure 3 (top panel) plots oxygen concentrations on the 26.6-σ_θ density surface (World Ocean Atlas, 2005; WOA05): It shows that highly oxygenated, intermediate water is formed along the northern edge of the Antarctic Circumpolar Current (ACC), and subsequently spreads throughout the Indian Ocean.

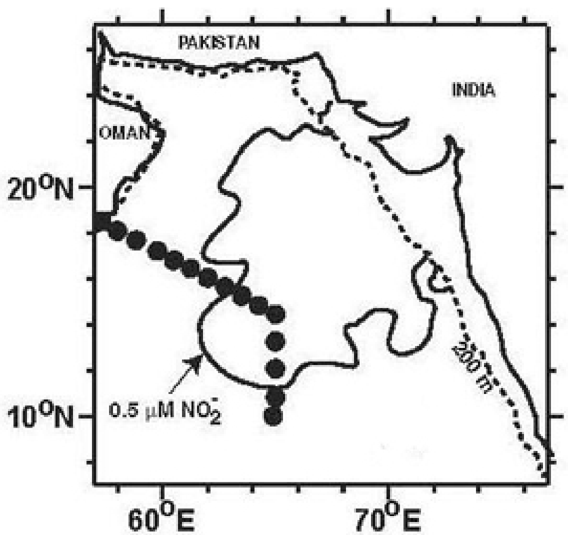

Figure 1: A map of upper ASOMZ as demarcated by the 0.5μM nitrite contour. Low nitrite concentrations are an indication of active denitrification, which only occurs under anoxic condition (After Naqvi *et al.*, 2006).

large (Swallow, 1984).

The physical and biological processes that determine the strength and location of the ASOMZ have not been fully determined, largely because ocean models fail to reproduce its basic properties (e.g., Oschlies *et al.*, 2008). Several hypotheses have been put forward to explain the eastward shift of upper ASOMZ. Biological hypotheses include: slow detrital sinking rates in the western Arabian Sea which allow detritus to be advected considerably northward and eastward before it is remineralized (Naqvi, pers. comm.); conversely, it is possible that sinking rates in the western ocean are so rapid that detritus cannot be significantly remineralized above 400m. Physical hypotheses include: advection of oxygen by the swift coastal currents off Somalia and Oman, and intensified mixing of near-surface oxygen downward by the strong, mesoscale eddy field in the western and northern Arabian Sea (Kim *et al.*, 2001).

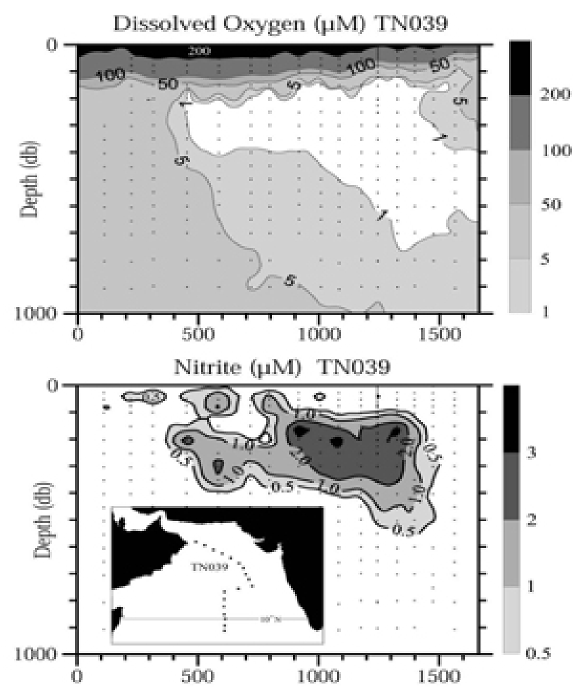

Figure 2: Vertical section of oxygen (top) and nitrite (bottom) concentrations from cruise TN039 of the Joint Global Ocean Flux Study (JGOFS) Arabian Sea Process Study (ASPS). The *x*-axis runs along the indicated cruise track, extending from

8°N in the central Arabian Sea (origin of the *x*-axis) to about 1675km near the coast of Oman (After Codispoti *et al.*, 2001).

Coupled model

Our coupled model is an extension of the 4½-layer (*NPZD*) system used by Hood *et al.* (2003). Key differences are that it has two more active layers at depth (a 6½-layer model), more realistic coastlines (including ports that allow for exchanges with the Red Sea and Persian Gulf), an additional detrital class, and an oxygen compartment that does not feed back to the ecosystem model. The model grid has a spatial resolution of 0.5°, which is not eddy resolving, so effects of mesoscale eddies are parameterized by enhanced mixing coefficients.Each active layer of the model corresponds to a distinct dynamic regime or water-mass type: the surface mixed layer (layer 1; Kraus and Turner, 1976), a diurnal thermocline that allows the system to "remember" physical and biological variables when the mixed layer thins during the day (layer 2; McCreary *et al.*, 2001), the seasonal thermocline (layer 3), the main thermocline that encompasses the depth range of the upper ASOMZ (layer 4), a subthermocline layer for the lower ASOMZ (layer 5), and a deeper layer below the ASOMZ (layer 6). In equilibrium solutions, the depth ranges of the layers are roughly 0-150m for layers 1-3, 150-500m for layer 4, 500-1000m for layer 5, and 1000-1500m for layer 6. At greater depths (the "½" layer), the ocean is quiescent.

The model domain is a representation of the Indian Ocean north of 30°S and west of 115°E. Closed boundary conditions are imposed everywhere, except for *i)* the Indonesian, Red Sea, and Persian Gulf ports and *ii)* the southwest corner of the basin where any net water that is added (say, due to precipitation, river runoff, and the ITF) to the system is removed. Regarding *i)*, values of variables that are advected into the basin (via boundary conditions) are determined from WOA05 data in the depth range of the layers. There is a sponge layer along the southern boundary, where model variables are relaxed to WOA05 values in layers 4-6. Finally, there is upward diffusion of nitrogen and oxygen from the deep ocean into layer 6 with N_7=36μmolN/kg and O_7 set to its annual-mean WOA05 value at 1500m.

During the course of this research, we found it necessary to expand the detritus compartment of our previous model (Hood *et al.*, 2003) to include two size classes: a small class with e=333day^{-1} and a slow sinking rate of w_s=0.18m/day, and a large class with e'=400day^{-1} and w_s'=3.33m/day. The small detritus allows for a microbial-remineralization loop that maintains layer 1 phytoplankton concentrations (P_1) at reasonable levels, and accounts for the

The equation (1) for layer 4 oxygen (O_4) determines the upper OMZ in the model. Subscripts on the biological variables and h are layer indices, $h_{ij}=(h_i+h_j)/2$ and φ=8.625 is a factor that relates detrital remineralization to oxygen consumption. According to (1), O_4 is affected by advection, vertical mixing (κ), horizontal mixing (κ_2 and κ_4); it only retains the sink terms due to remineralization (e and e'), as the other source/sink terms are negligible in the depth range of layer 4. Equation (1) provides a succinct statement of the need for physical processes: In an equilibrium state, the loss of O_4 due to remineralization can only be balanced by advection or mixing. In our initial runs, (1) was dominated by the remineralization term. A key model development was thus to decrease both e and e' until the physical processes (horizontal advection in particular) had a significant impact.

Values of vertical and Laplacian mixing coefficients in layers 5 and 6 are κ=1.0cm^2/s (Lumpkin and Speer, 2007) and κ_2=2×10^{7}cm^2/s, respectively; biharmonic mixing of κ_4=10^{21}cm^4/s is used in all layers. In layers 1-4, κ=0.75cm^2/s and κ_2 is modified to simulate the impact of mesoscale eddies in the upper ocean. Specifically, we set $\kappa_2=\kappa_{2b}+aE$, where κ_{2b}=2×10^{7}cm^2/s, and a=3.7cm^2/s for the main run. Variable E is the eddy kinetic energy field determined from the AVISO data, capped at a value E=30cm^2/s^2 and normalized by E so that $E\leq1$.

The wind stress in the model is determined from QuikSCAT daily winds for the period from 16 April 2004 to 15 April 2005, a normal year for the Indian Ocean. These winds are looped annually with smoothing during April to form a repeating cycle. All other forcings are climatological fields from the Comprehensive Ocean-Atmosphere Data Set prepared at the University of Wisconsin-Milwaukee (COADS/UWM). Diurnal variability is introduced by allowing solar radiation to have a realistic daily cycle (McCreary *et al.*, 2001).

OMZs in layers 4 and 5. The large detritus efficiently exports nitrogen into the deep ocean, contributes mainly to the OMZ in layer 5, and lowers oxygen in layer 6. The relative amount of the two detrital classes is determined by P_1, with the amount of larger detritus increasing with P_1 (Eppley and Peterson, 1979); specifically, the percentage of large detritus is 10% when $P_1 < 0.31 \mu M/l$, 50% when $P_1 > 0.94 \mu M/l$, and varies linearly in between.

$$O_{4t} + \boldsymbol{v}_4 \cdot \nabla O_4 = \frac{\kappa}{h_4}\left(\frac{O_3 - O_4}{h_{34}} - \frac{O_4 - O_5}{h_{45}}\right) + \kappa_2 \nabla^2 O_4 - \kappa_4 \nabla^4 O_4 - \varphi\left(eD_4 + e' D_4'\right),$$

Equation (1)

Results

Our main run is able to simulate the major features of the observed oxygen field in the Indian Ocean. For example, the O_4 distribution from our main run (Figure 3, bottom panel) compares well with WOA05 observations in the same depth range (top panel), in terms of the spreading of higher oxygen concentrations from the southern hemisphere and the eastward shift of the upper ASOMZ (Figures 1 and 2. Due to data scarcity, the eastward shift is not well represented in the WOA05 data). The modelled oxygen field for layer 5 (not shown) also compares well with the observation, having no eastward shift.

We also obtained a suite of solutions to test the hypotheses presented at the end of section 1. Figure 4 shows two of these tests as well as the main run (top). The two tests illustrate the impacts of two physical processes in (1), namely, solutions without O_4 advection (middle) or without horizontal eddy mixing (a=0; bottom).

Clearly, the eastward shift is no longer present in the two tests. In addition, we explored the sensitivity of O_4 to other physical (Red Sea and Persian Gulf waters, and ITF) and biological (horizontal changes in detrital remineralization and sinking rates, etc.) processes, finding that their impact on O_4 is weak.

We conclude that the eastward shift of the upper ASOMZ results from the combined effect of *i)* remineralization rates being sufficiently low, *ii)* the advection of waters with higher oxygen concentrations from the south along the western boundary and *iii)* additional mixing induced by mesoscale eddies.

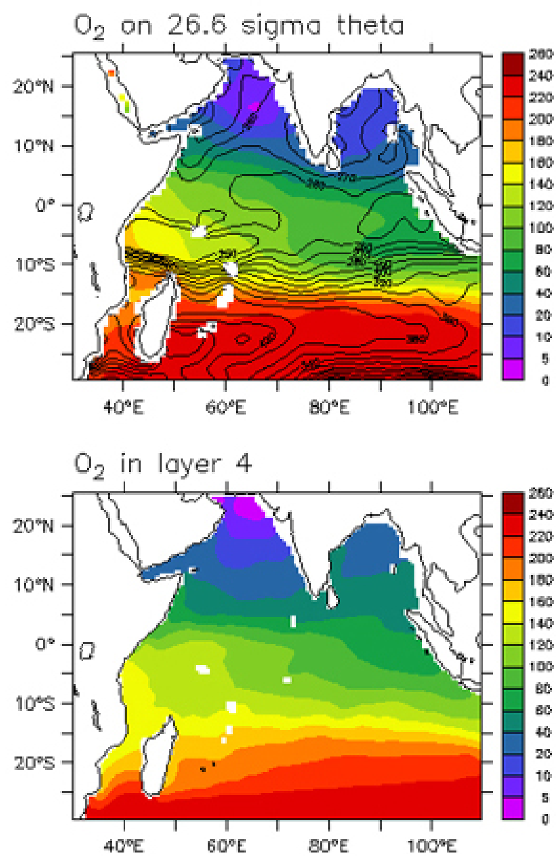

Figure 3: Maps of annual-mean oxygen concentrations from WOA05 on the 26.6-σ_θ density surface (top) and from layer 4 of our main run (bottom).

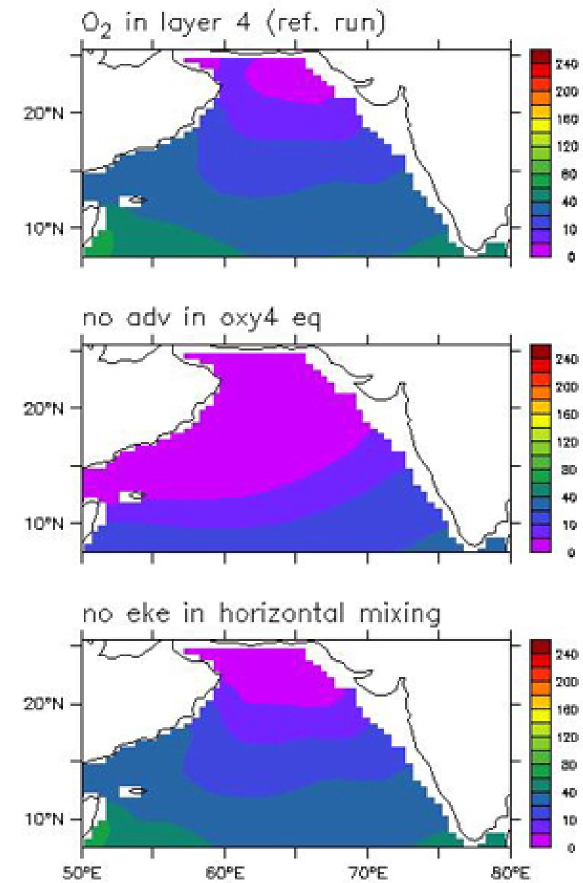

Figure 4: Maps of layer 4 oxygen concentrations for three different solutions: the main run (top left), no advection in layer 4 oxygen equation (middle), and spatially-uniform horizontal mixing (bottom).

Discussion

In this note, we have shown that our simple biophysical model is able to simulate basic properties of the ASOMZ, in particular the eastward shift of its upper part. There are a number of issues that we have not been able to cover here due to space limitations. For example, it is difficult to adjust model parameters to obtain realistic O_4 (and O_5), P_1, and N_4 fields in the same solution. One reason for this difficulty is uncertainty in the strength of vertical diffusion, which is an important pathway for bringing nutrients into the euphotic

In addition, mesoscale eddies are known to enhance the upward advection of nutrients (e.g., McGillicuddy, 1997; Resplandy *et al.*, 2011), and to represent this process we are investigating the impact of enhancements of κ due to E. Finally, another important issue is the choice of detrital sinking rates, as the ratios of e/w_s and e'/w'_s strongly impact the OMZ depth.

zone; in fact, it is not possible to obtain realistic fields when $\kappa_b \leq 0.1 cm^2/s$, values that are commonly used for diffusion in ocean models below the mixed layer.

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7.2 - Biogeochemical process studies across the western Indian continental shelf, Arabian Sea

Return to TOC

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The northern Indian Ocean hosts one of the planet's largest expanses of oxygen-depleted waters (Paulmier and Ruiz-Pino, 2008). In both the Arabian Sea and the Bay of Bengal there are mid-depth (~150-1000m) Oxygen Minimum Zones that span the entirety of the basins, and, particularly in the case of the Arabian Sea, have been the subject of extensive studies in recent decades (Cowie 2005). The processes occurring in these waters and in the underlying reducing sediments are of exceptional biogeochemical importance, through phenomena such as sedimentary C burial, nutrient cycling and production of N_2O (a potent greenhouse gas), to global C and N cycles, ocean productivity and global climate (Naqvi et al., 2009).

However, on the western Indian continental shelf, during the summer (SW) monsoon season, a further shallow zone of intensely O_2-depleted waters develops. Though upwelling is much stronger in the western Arabian Sea (e.g. off Oman), currents and hydrography along the narrow shelf zone are such that ventilation is sufficient, and residence times are short enough, that severe O_2 depletion does not occur in the water column over the shelf. By contrast, in the eastern Arabian Sea, equatorward flow (the West India Coastal Current) beginning in April and persisting through the summer leads to relatively weak upwelling and moderately high productivity. Due to strong stratification, arising from land runoff and local precipitation, weak ventilation and consequently longer residence times across a wider shelf, the upwelled water, originally containing little dissolved O_2, becomes completely anoxic along the entire west coast of India, and probably also off Pakistan, by September (Naqvi *et al.*, 2000).

This immense swath of hypoxic shelf waters represents the largest coastal hypoxic zone on earth (180,000km^2 or more), dwarfing the "dead zone" in the Gulf of Mexico by at least an order of magnitude. The phenomenon has now been studied based on observations at the Candolim Time Series (CaTS) location off Goa and along a series of cross-shelf transects since 1997 (Naqvi et

A key facet of the phenomenon, which may contribute to differences observed across the shelf (Figure 2), are the processes occurring within the sediments. Relevant benthic processes include community O_2 consumption and efflux of reduced chemical species, which may exert important controls on O_2 dynamics in overlying waters. Fluxes of O_2 as well as other dissolved gases, organic material, nutrients and metals between the sediments and overlying waters are modulated by sediment redox conditions and the activities of benthic microbes and fauna, which undergo wholesale seasonal changes. In shallow coastal waters, these fluxes may make important contributions to productivity and O_2 depletion in the water column, and to greenhouse gas emissions, and thus may be an integral part of overall biogeochemical system function. However, to date there have been few experimental studies of benthic processes on the western Indian shelf.

We have recently received funding, through an International Joint Project grant from the Royal Society of London and the Council of Scientific and Industrial Research (CSIR), New Delhi, to conduct preliminary benthic biogeochemical process studies at sites spanning an existing cross-shelf transect off Goa, where long-term water column studies are ongoing. In addition to exchange of personnel for cross-training in techniques, the project has involved two suites of benthic studies conducted at five sites. The sites range from a nearshore site (28m depth) close to the mouth of the Mandovi Estuary to a site at the shelf break, 85km off shore (164m depth). The studies were carried out at the same sites in October 2010 and April-May 2011, respectively representing hypoxic monsoon conditions and relatively oxygenated intermonsoon conditions. Whole sediment cores collected from each site were incubated at ambient bottom-water temperature. Benthic community O_2 consumption was measured by initially monitoring O_2 levels in stirred overlying waters in sealed chambers, while benthic fluxes of nutrients and dissolved organic C and total dissolved N were subsequently determined through time-series sampling over 3-day periods in incubations maintained at ambient bottom-water O_2 levels. Sediments and/or al., 2009). The results highlight that O_2 concentrations undergo wholesale fluctuation between monsoon and intermonsoon seasons (as illustrated by the CaTS data, Figure 1). The O_2 depletion results in intense denitrification and even sulphate reduction. One distinguishing feature of the coastal O_2 deficient zone is the extreme concentrations of N_2O (the highest ever recorded in seawater). The significance is major, both for the global N cycle and greenhouse gas emissions, and socio-economically, through severe impacts on both benthic and pelagic fisheries (Naqvi *et al.*, 2009).

Another important finding is that the extent of hypoxia has shown distinct interannual variability over the last 14 years, with the most intense conditions having occurred in 2001. However, comparison with the earlier data sets (e.g. collected during the 1970s), which showed no sign of sulfidic waters, suggests a recent intensification of hypoxia (Naqvi *et al.*, 2006). If so, whether it is driven by warming or increasing nutrient runoff from land, the phenomenon of increasing coastal hypoxia may be an indicator of what is to come, as may be predicted from the general decrease in ocean oxygenation projected by climate and circulation models (Keeling *et al.*, 2010) as well as due to increased eutrophication (Diaz and Rosenberg, 2008).Finally, cross-shelf analysis (Figure 2) reveals further key features. Firstly, in this case from a transect off Mangalore, comparison of intermonsoon and monsoon cross sections shows strong seasonal contrasts in all parameters, including the appearance of sulphide, N_2O and ammonia maxima during the monsoon hypoxic period. Notably, however, O_2 depletion and associated processes are spatially variable; at its peak near-bottom anoxia and the appearance of sulphide and ammonia are most pronounced in near-shore bottom waters whereas denitrification, and associated changes in nitrate, nitrite and N_2O, occur further offshore, within the water column. Together, such features demonstrate the complexity of the system and the importance of the western Indian shelf as a study area for understanding coastal hypoxia.

porewater profiles for each site are also being determined for elemental, stable isotope ($\delta^{13}C$ and $\delta^{15}N$), nutrient and biochemical composition, as well as grain-size distributions.

Finally, we have collected suspended particulate materials from the Mandovi and Zuari Rivers, in both monsoon and intermonsoon seasons, in order to characterise terrigenous organic matter inputs to the shelf. The results will provide the first linked assessments of sediment properties and key biogeochemical fluxes with parallel pelagic studies across the Indian continental shelf, and how these vary between monsoon and intermonsoon seasons.

A primary objective of the project is to provide pilot data that will guide a future UK-India collaboration. A meeting in Edinburgh, Scotland is scheduled for spring 2012 where plans will be put in place for a broader study of the Indian coastal hypoxic zone. The project will be cross-disciplinary, to involve a number of UK institutions as well as the National Institute of Oceanography of India, a wide range of *in situ* and *in vitro* experimental methods, and a team of microbiologists, geochemists and benthic ecologists. The project will focus on linked pelagic and benthic process studies across contrasting seasons, but also will include full characterisation of benthic microbial and faunal communities and sediment geochemistry. It would represent the first UK research funded under the SIBER banner, to compliment a range of recently funded Indian SIBER projects that include continuation and expansion of the ongoing observations at the CaTS site and in the adjoining Mandovi-Zuari Estuaries.

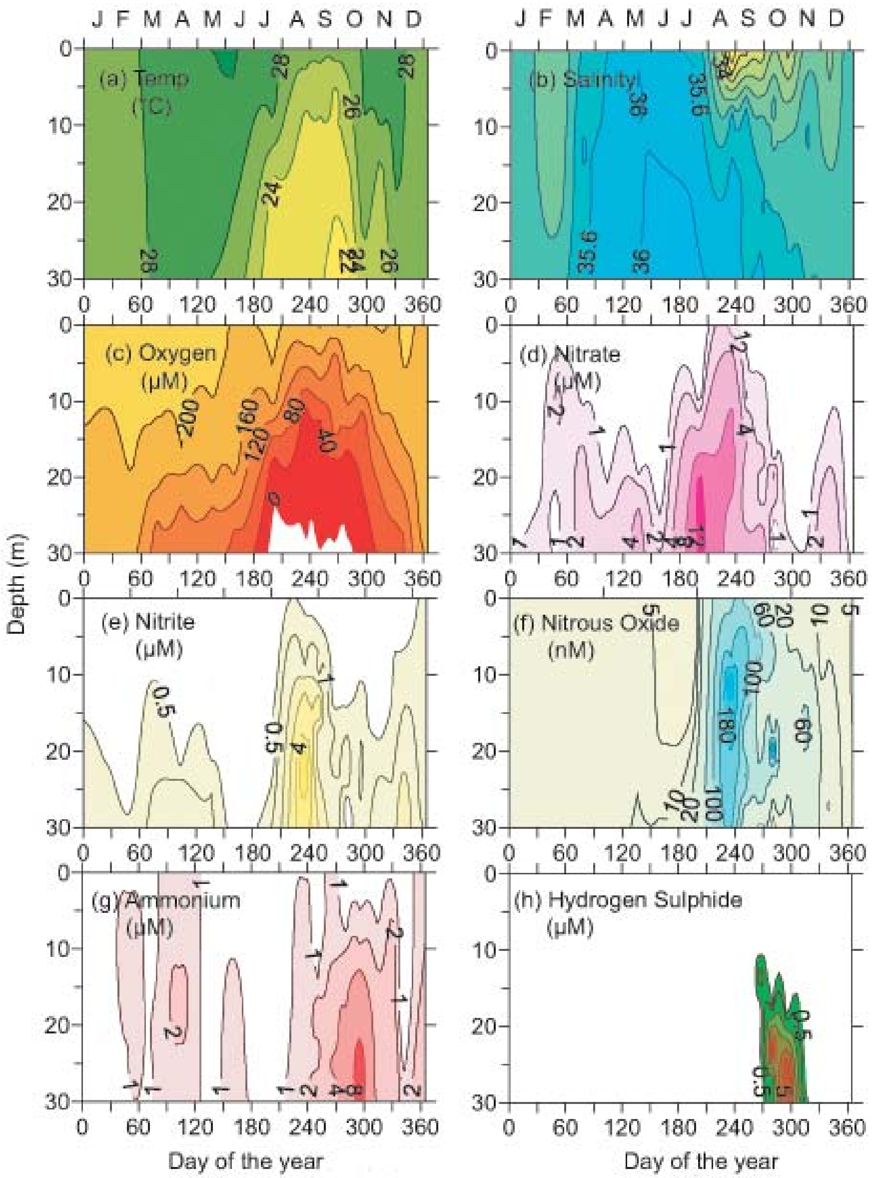

Figure 1: Monthly-/fortnightly-averaged records showing annual cycle of (a) temperature, (b) salinity, (c) oxygen, (d-g) inorganic nitrogen species and (h) hydrogen sulphide at the Candolim Time Series (CaTS) site (15°31′N, 73°39′E) based on observations from 1997 to 2006 (modified from Naqvi *et al.*, 2009).

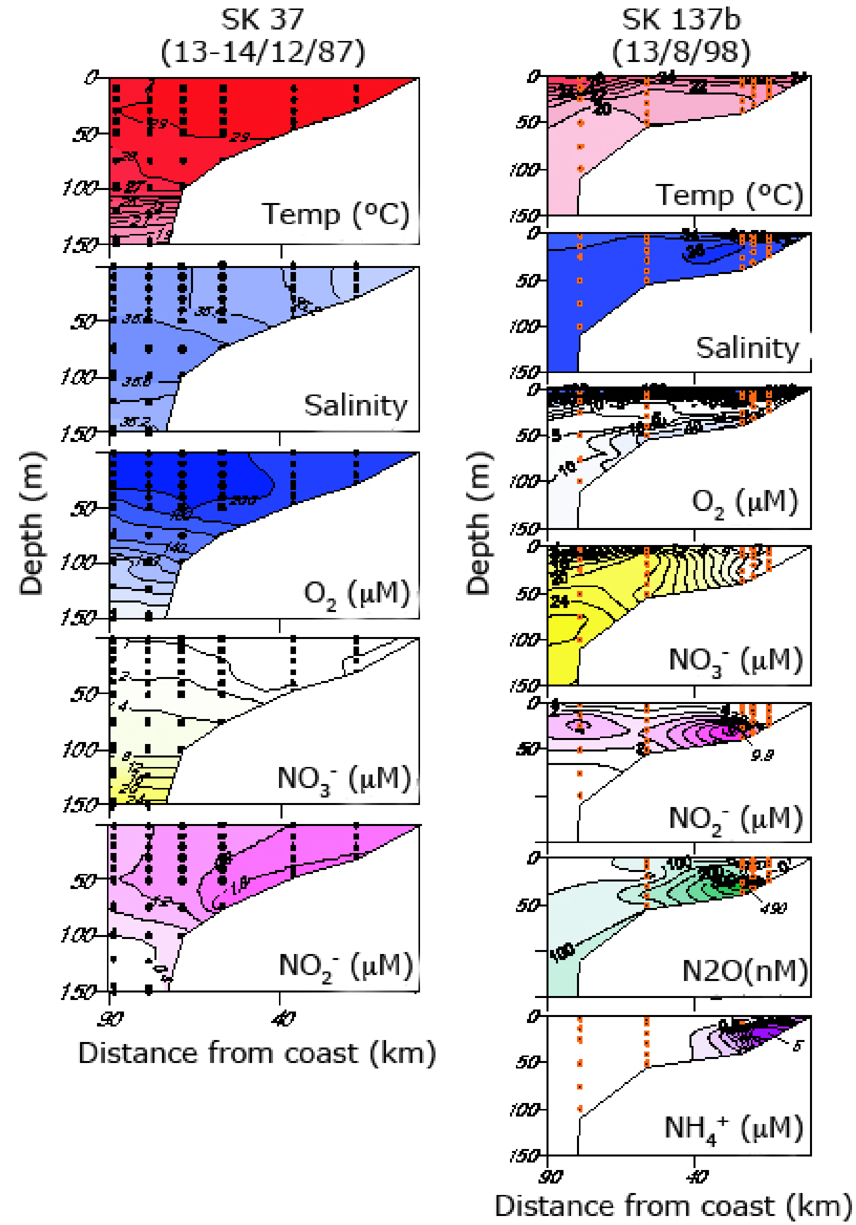

Figure 2: Cross-shelf sections of physico-chemical properties off Mangalore during the Northeast Monsoon (left set of panels) and the Southwest Monsoon (right set of panels). Nitrous oxide was not measured on Cruise SK37, and H_2S was not measured on Cruise SK137, but it was present at the shoreward end of the transect (modified from Naqvi *et al.*, 2009).

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7.3 - SIBER Theme 1: Boundary current dynamics, interactions and impacts

Return to TOC

Lynnath Beckley, Murdoch University, Perth, Western Australia

How are marine biogeochemical cycles and ecosystem processes in the Indian Ocean influenced by boundary current dynamics?

Boundary currents mediate transfer of global and regional forcing to local coastal scales and thus fundamentally alter biogeochemical fluxes and ecosystem processes. In the Indian Ocean, several boundary current systems are seasonally reversing in response to the monsoons (e.g., Somali and Java Currents). The southern hemisphere currents (Agulhas and Leeuwin) both flow south throughout the year. The Leeuwin Current, which is driven by the Indonesian Through Flow, is particularly anomalous in that it is the world's only major eastern boundary current that flows poleward. In general, the biogeochemistry and ecology of southern hemisphere currents have been less comprehensively studied than northern counterparts, and significant uncertainties still exist regarding their dynamics and interactions.

The primary mechanisms whereby boundary currents impact ecosystems include control of water temperature, nutrient supply and mixed-layer depth. Boundary

In the eastern Indian Ocean, much research relating to the boundary currents theme of SIBER is ongoing off the west and northwest coast of Australia, largely as a result of a series of research voyages with the RV *Southern Surveyor* and the RV *Solander*. Most of this research is multi-disciplinary and researchers are primarily from institutions such as CSIRO, AIMS, University of Western Australia and Murdoch University. In addition, considerable investment in the Integrated Marine Observing System (IMOS) has seen installation of oceanographic moorings, reference stations, coastal radar, acoustic monitoring and deployment of gliders and Argo floats in the region.

The results of an extensive cruise to investigate the biological oceanography of the Leeuwin Current from 22°-34°S during the austral autumn are currently being published. Weller *et al.* (2011) have examined the physical oceanography of the Leeuwin Current along the entire west coast and the empirical data showed good correlation with the Bluelink re-analysis product (BRAN). Thompson *et al.* (2011) have revealed narrow interleaving layers of low dissolved oxygen and higher nitrate at the northern stations which may fuel the phytoplankton bloom further south in the Leeuwin Current. The origin of these currents also mediate alongshore and cross-shelf transport of whole planktonic ecosystems, including early life history stages of species important in fisheries. Instabilities are commonly observed in boundary currents and they can be initiated through interaction with shelf topography. These instabilities give rise to meso-scale eddies and localized fronts and filaments, which allow cross-shelf transport of nutrients and plankton communities, both towards the coast and into the open ocean. These features can also form important aggregation points for fish and mega-fauna drawn to regions of enhanced nutrients, plankton and food supply.

Considerable work is taking place with respect to the southern hemisphere boundary currents in the western Indian Ocean and many of these projects fit into SIBER Theme 1. The Agulhas and Somali Current Large Marine Ecosystem (ASCLME) project involves 10 countries of the south west Indian Ocean and about 20 research cruises have taken place of which four were dedicated RAMA (Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction) and LOCO (Long-term Ocean Climate Observations) mooring cruises. ASCLME, in collaboration with NOAA, is responsible for the maintenance of three ATLAS (Autonomous Temperature Line Acquisition System) moorings along the 55°E line (8°, 12° and 16°S). The South African Environmental Observation Network (SAEON) delivers long-term reliable data for scientific research and informs decision-making; one long-term monitoring site has been established and a further two are planned. The African Coelacanth Ecosystem Programme (ACEP) is a large research programme involving 17 research institutions and many researchers and post-graduate students are engaged in projects relevant to SIBER.

At the South African marine science symposium in Grahamstown in April 2011, many presentations were well linked to the SIBER theme of boundary current processes. For example, there were talks on transport by the east Madagascar Current, shelf-edge upwelling in northern Mozambique as well as zooplankton and seabirds associated with Mozambique Channel eddies. Much attention was focussed on the KwaZulu-Natal Bight, north of Durban, South Africa and in particular the influence of the Agulhas Current on circulation and retention in this area. Other related studies in the Bight included nutrient fluxes, picoplankton, phytoplankton and primary production. The abstract book from this symposium can be found here.

layers requires examination but may be associated with N_2 fixation. Larval fish distributions have also been examined and some particle back-tracking using BRAN has helped confirm the origin of larvae of coastal fishes found out in oceanic waters (Holliday *et al.*, 2011a, Holliday *et al.*, submitted). BRAN has also been used to examine retention and dispersal of shelf waters influenced by interactions of the Leeuwin Current and coastal geography and this has implications for pelagic larvae of shelf biota (Feng *et al*. 2010). There has also been detailed biological oceanographic work in the northern Ningaloo Reef area and particulate nutrient fluxes over this fringing reef have been enumerated (Wyatt *et al*. 2010).

A study of the biological oceanography of the western rock lobster (*Panulirus cygnus*) commenced in 2010 in response to the remarkable decline in recruitment experienced in this major fishery during the past five years. The focus was on evaluating the pelagic environment of the planktonic phyllosoma stage of the rock lobster and an extensive area from 28-32°S and from the coast out to 111°E was surveyed. Attention is being given to ascertaining the trophic relationships of the phyllosoma larvae using isotope, genetic and fatty acid analyses. Experiments were conducted in aquaria aboard ship to examine feeding preferences and these were repeated in September 2011 using later stage phyllosoma larvae and similar results were achieved (Figure 1).

In 2010, the first extensive biological oceanography cruise to the remote Kimberley region of northern Australia was conducted. This ria coast experiences very large tides and considerable fluvial discharge during the summer and is under considerable pressure for development of oil and gas resources. Sampling for physics, chemistry, phytoplankton and zooplankton took place along five cross-shelf lines and the first preliminary publications have appeared (Thompson and Bonham, 2011 and Holliday *et al.*, 2011b). In addition, using the RV *Solander*, work on phytoplankton, zooplankton and fish larvae has been conducted in collaboration with a physical oceanography team investigating island wakes off the Kimberley coast.

Figure 1: Scientific team from University of Western Australia, Murdoch University, University of Auckland, University of Cape Town, CSIRO and the Western Australian Department of Fisheries aboard the *RV Southern Surveyor* during the 2011 rock lobster phyllosoma cruise off Western Australia.

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7.4 - Time Series Observations in the northern Indian Ocean

Return to TOC

D.M. Shenoy, H. Naik, S. Kurian and S.W.A. Naqvi, *National Institute of Oceanography, Goa, India*

N. Khare*, Ministry of Earth Sciences, New Delhi, India*

Being surrounded by land masses on three sides, the oceanography of the North Indian Ocean exhibits several features not observed in other oceans. Peninsular India divides the region into two major basins - the Arabian Sea and the Bay of Bengal. Although these basins lie within the same latitudinal belt, they experience contrasting hydrographical and biogeochemical conditions. The dominance of the monsoons that are known to respond to climate changes in controlling oceanographic processes make the region vulnerable to global warming. There are additional reasons to believe that the region will be among the first to respond to human-induced changes. These include fragility of ecosystems, a very delicate biogeochemical balance and a very high population density in the littoral countries, many of which are experiencing rapid economic/industrial growth. For instance, the North Indian Ocean houses one of the ocean's most severe oxygen minimum zones (OMZs). The continental margin area that comes in contact with water containing dissolved oxygen less than 0.2 mL L^{-1} is about 2/3 of such area globally. Moreover, a large volume of water within the region, especially in the Bay of Bengal, is just above the threshold of becoming suboxic (i.e. where dissolved oxygen becomes so limiting that respiration largely occurs through anaerobic pathways, greatly impacting cycling of redox-sensitive elements, especially nitrogen). With stronger stratification due to a warmer climate, altered subsurface circulation, lower seawater pH, and elevated anthropogenic nutrient loading, which is expected to be particularly high in this region, large changes in biogeochemical cycling and ecosystem functioning are expected.

The highly interesting oceanography of the North Indian Ocean has led to

The main thrust of the recently launched SIBER programme, as apparent from its title, is on sustained observations (see Hood et al., this issue). India has already launched a multi-institutional SIBER programme, supported by its Ministry of Earth Sciences (MoES). The programme consists of two project clusters, one focusing on the open ocean and the other on selected coastal areas. Under the open ocean cluster, repeat observations are being carried out at two fixed sites, one each in the Arabian Sea (Lat. 17°N, Long. 68°E) and the Bay of Bengal (Lat. 18°N, Long. 89°26′E). Whenever possible, sampling is also carried out at several other stations forming transects extending to these sites from the coast. In the other cluster, which deals with estuaries and coastal areas, sustained observations are being conducted in four areas - off Goa and Kochi along the west coast and in the Vellar-Coleroon estuaries and Hooghly-Matla estuaries and adjoining coastal waters along the east coast of India. The programme has now adopted CaTS observations; in addition, a new coastal time series is being initiated off Kochi by the Centre for Marine Living Resources and Ecology (CMLRE), Kochi.

The two open ocean sites will gradually be developed into full-fledged time series that will be accessible to the international community. Deep moorings with sediment traps and current meters have already been deployed at both sites (since 2007 in the Arabian Sea and 2010 in the Bay of Bengal). The Arabian Sea Time Series (ASTS) has been visited twice whereas Bay of Bengal Time Series (BBTS) has been visited three times since the programme was launched in 2010. The core measurements currently being made include temperature, salinity, dissolved oxygen, nutrients, nitrous oxide, methane, dimethyl sulphide, dissolved inorganic carbon (DIC), alkalinity, DOC, particulate organic carbon (POC), chlorophyll *a*, phytoplankton composition including picoplankton, zooplankton biomass and composition, total bacterial counts (TBC) and primary production. In addition, several specialised measurements to several international projects focusing on this region, particularly the Arabian Sea. The Joint Global Ocean Flux Study (JGOFS) has been the most notable of such efforts after the International Indian Ocean Expedition (IIOE). However, almost all of these programmes were implemented in the expedition mode with much lesser emphasis, relative to other oceanic areas, on sustained observations that are essential to differentiate natural variability from long-term human-induced changes. Thus, there is no equivalent in the Indian Ocean of HOT (Hawaii Ocean Time-Series) in the Pacific Ocean and BATS (Bermuda Atlantic Time-Series) in the Atlantic Ocean. In the open ocean the only long-term time series observations that have been carried out in the past were under an Indo-German collaborative project. This study, initiated in 1986, involved monitoring of particle flux to the deep sea through deployment of sediment traps at several sites in the North Indian Ocean. Limited ancillary measurements in the water column were also made as a part of this programme. The results of this project, published in scores of peer reviewed journals, showed, amongst other things, that particle fluxes to the deep sea are forced mainly by monsoon-related processes, with prominent seasonal as well as inter-annual changes.

Unfortunately, this programme had to be discontinued in 2001 due to limited ship time, and even though it was resumed in 2007, albeit on a smaller scale, by redeploying the western Arabian Sea trap (WAST), it continues to be plagued by problems arising mostly from piracy. There has been greater success in establishment of time series sites in coastal areas. The National Institute of Oceanography (NIO) initiated time series observations in 1997 at a coastal site off Goa (called the Candolim Time Series (CaTS)). Sampled at least once a month, except during rough weather, this observational programme has provided valuable insights into carbon, nitrogen and sulphur cycles, especially the processes related to seasonal occurrence of anoxia over the shelf (see Cowie and Naqvi, this issue). A similar observational programme is being run off Visakhapatnam along the east coast of India by the Regional Centre of NIO. This in-house project involves monthly observations at a station located 30km off the coast since 2007. A sediment trap mooring has also been deployed at Lat. 16.41°N, Long. 82.52°E. In addition to scientists from India, researchers from Sultan Qaboos University, Oman have also been collecting data since 2004 at four monitoring sites, two of which are located in the Gulf of Oman and two in the Arabian Sea near Masirah Island. Samples are collected twice a month in the Gulf of Oman and once monthly in the Arabian Sea. The data being collected include plankton diversity and hydrographic parameters such as temperature, salinity, oxygen, nutrients and dissolved organic carbon (DOC). These data will serve as baseline to assess human impacts on coastal ecosystems and improve understanding of seasonal and inter-annual changes associated with the monsoonal forcing.

investigate the biogeochemical and ecological processes under other funded projects are planned to be added in 2012. There are also plans to deploy moorings with several oceanographic and biogeochemical sensors at the two locations in collaboration with the Indian National Centre for Ocean Information Services (INCOIS), Hyderabad.

So far the sampling frequency has been lower than originally planned (six times every year). The availability of ship time is a major constraint as most of the time of the MoES research fleet is already committed to other funded projects. Efforts are underway to get additional ship time by chartering research vessel(s). The situation is also expected to improve after the new vessel being constructed by NIO is commissioned in 2012. In the case of the Arabian Sea, however, there is an additional, more serious, impediment – the threat by Somali pirates that has brought oceanographic observations in the region almost to a standstill (see the article by Maddison *et al* in this issue). In the recent past, several planned cruises had to be either cancelled or their tracks altered as a result of this threat. This included a visit to the ASTS by us in 2011. Like all oceanographers keen to pursue their research in the Arabian Sea, we hope that this issue will be addressed through concerted international efforts in the near future.

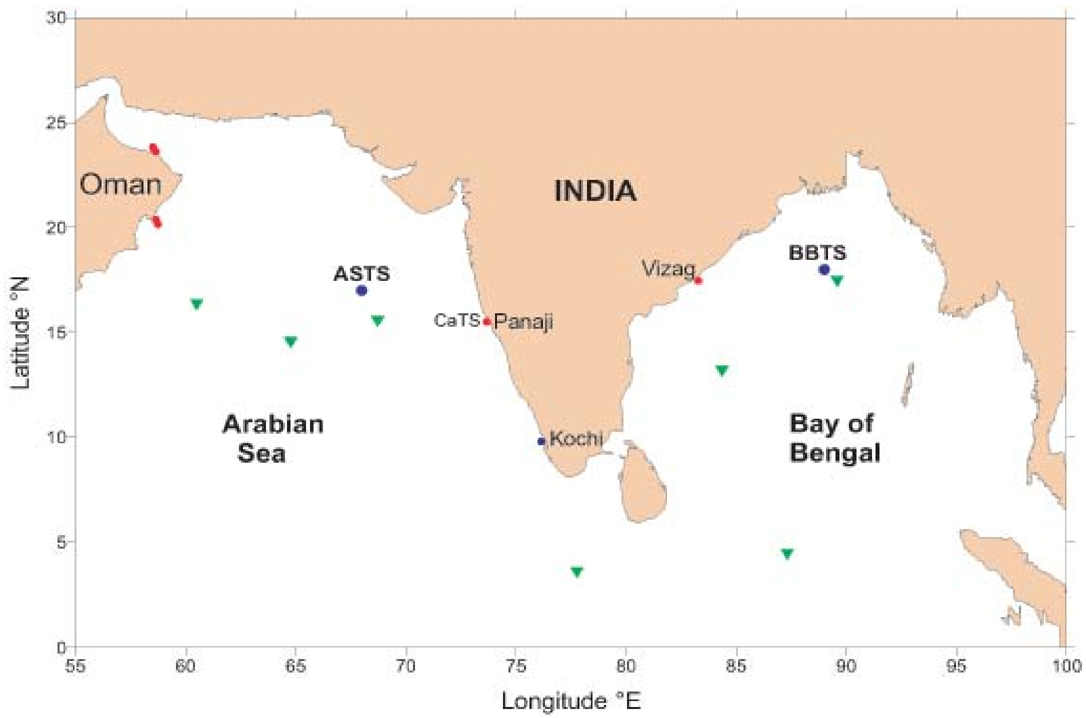

Figure 1: Time Series locations in the North Indian Ocean. Green triangles show positions of the Indo-German sediment traps (1986-2001). Red dots indicate presently operational coastal time series stations, and blue dots denote times series in the central Arabian Sea (ASTS), central Bay of Bengal (BBTS) and off Kochi initiated under the SIBER-India programme.

8 - Getting Underway - A Synopsis of Discussions and Accomplishments from SIBER-1 and SIBER-2

Return to TOC

Jerry Wiggert, University of Southern Mississippi, MS, USA

The inaugural meeting of the SIBER Scientific Steering Committee (SIBER-1) was held on 12-15 July 2010 at the Citigate Perth Hotel in Perth, Western Australia. In attendance for the opening proceedings was the combined membership of the IOGOOS, CLIVAR-IOP and the IndOOS Resources Forum (IRF) panels, along with the SIBER SSC. N. D'Adamo (Officer in Charge, UNESCO IOC Perth Office) _provided the introduction to the proceedings and acted as Master of Ceremonies.

N. Nannup gave the traditional 'Welcome to Country', with an accompanying didgeridoo performance by D. Nannup. This was an exceptional opening to the weeklong series of discussions, and all delegates were energized by N. Nannup's

As its first order of business following S. Nayak's keynote, the SIBER SSC formalized its leadership, with R. Hood installed as the SIBER Chair, W. Naqvi installed as SIBER co-Chair and J. Wiggert installed as SIBER Secretary. The SSC was also expanded to include four new members, S. Adam (MRC, Maldives), M. Bhikajee (MOI, Mauritius), S. Khokiattiwong (PMBC, Thailand) and M. Ravichandran (INCOIS, India) recommended by the IMBER and IOGOOS steering committees.

Coming into the SIBER-1 meeting, there were already some notable achievements stemming from the efforts of the then interim SIBER SSC that were outcomes of three workshops that occurred prior to SIBER-1. Based on the welcome. The joint meeting was then officially opened by the Governor of Western Australia, His Excellency K. Michael AC. Welcomes and keynote addresses were then given by J. de Jong (State of Western Australia), S. Nayak (Secretary, Ministry of Earth Sciences (MoES), India), W. Watson-Wright (Executive Secretary IOC, Asst. Director General UNESCO), and N. Smith (Deputy Director, Australian Bureau of Meteorology). These were followed by plenary presentations given by T. Moltmann (Australia's IMOS_), Y. Masumoto and W. Yu (CLIVAR-IOP), R. Hood (SIBER) and G. Meyers (IRF) that informed all delegates of progress and synergies being developed within and between their programmes. Following these opening morning activities, the four attending scientific panels, namely SIBER, CLIVAR-IOP, IOGOOS and IRF, deployed to carryout their individual agendas in afternoon sessions.Following up on his remarks from the morning's joint session, S. Nayak provided a keynote address to initiate the SIBER-1 discussions. The presence and participation of S. Nayak, both as Secretary-MoES and as a member of IRF, was of great significance for SIBER as it becomes established as an international advisory body for promoting biogeochemical and ecological research in the Indian Ocean. One research synergy that S. Nayak recommended pursuing was for SIBER to develop ties to the Indian Ocean component of the GEOTRACES programme that India is supporting. Enacting on his request, Sunil Singh (PRL, India) was invited to the SIBER-2 meeting to present an overview of the Indian GEOTRACES programme, which has stimulated tangible actions. These include informing the SIBER community of ship time possibilities on GEOTRACES cruises as well as a request for SIBER representation at GEOTRACES meetings.

S. Nayak also suggested that SIBER look to include spectral radiometers as part of the suite of instrumentation that leverages the moored platforms being installed in the Indian Ocean as part of the RAMA array. The optical data obtained could support efforts to calibrate and validate satellite-observed ocean colour data. As SIBER's drive to instrument the RAMA array with biogeochemical sensors gains traction (see below), and the fleet of bio-optical remote sensing platforms is refreshed (e.g., NASA's Visible Infrared Imager Radiometer Suite (VIIRS)), this request will remain topical and a high priority. It is also relevant to the remote sensing component of SIBER that is articulated in the Science Plan and Implementation Strategy (SPIS)_ that was recently published through financial and significant editorial support of the IMBER IPO.

Perhaps the most important outcome from S. Nayak's keynote and subsequent discussions with the SIBER SSC was the clear support he articulated regarding the SSC's request for resources that would enable the establishment of an International Programme Office (IPO). Following SIBER-1, S. Nayak's support was enacted and the SIBER-IPO was established at INCOIS in Hyderabad where it can share and leverage resources already in place to support the IOGOOS IPO (see article by Prakash). One outcome of this strategy has been the creation of the SIBER website_that is envisioned to be a dynamic resource that facilitates international collaborations, promotes interconnectivity between researchers keynote talks given at the first SIBER event held in Goa in October 2006, an AGU Geophysical Monograph was published in late 2009. The development of the SIBER-SPIS (noted above) was initiated at the SIBER workshop in November 2007. Finally, in April 2009 a third workshop was held in Goa that led to the establishment of the first national programme, SIBER-India. The research goals of SIBER-India were articulated within a 5-year proposal to MoES that consisted of coordinated open ocean and estuarine/coastal project clusters, with significant resource allocation toward the establishment of multi-disciplinary time series stations and process studies. At SIBER-1, W. Naqvi reported that funding for the 5-year SIBER-India programme had been approved.

Several other identified action items coming out of the SIBER-1 discussions were:

1. prioritization of RAMA sites to be instrumented with biogeochemical sensors;
2. establishment of effective linkages between SIBER and organizations focused on ocean carbon studies;
3. promotion of capacity building in the Indian Ocean rim nations.

These are ongoing efforts that are core components of SIBER's foundational strategy.The second annual meeting of the SIBER Scientific Steering Committee (SIBER-2) was held on 26-28 July 2011.

SIBER-2 was held in conjunction with the 8^{th} Indian Ocean Panel (IOP-8) meeting on 25-26 July and the 2nd IndOOS Resource Forum (IRF-2) on 29 July (Figure 1). A joint SIBER-IOP session was held in the afternoon on 27 July. The SIBER SSC members met from the afternoon of 26 - 28 July. Guest experts participating at the invitation of the SIBER SSC consisted of Z. Arifin (Research Centre for Oceanography, Indonesian Institute of Sciences), R. Hermes (BOBLME), R. Ramesh and S. Singh (Physical Research Laboratory) and P.N. Vinayachandran (Indian Institute of Science – CAOS).

pursuing SIBER-related marine studies and provides both a forum and a portal for data and resource sharing.

Figure 1: Group photograph of delegates participating in the joint SIBER, CLIVAR-IOP and IRF meetings held at the MGM Beach Resort in Chennai, Tamil Nadu, India in July 2011.

The first portion of the SIBER-2 meeting consisted of assessing progress to date, reviewing and refining the six research themes articulated in the SIBER SPIS, and considering how the newly established SIBER web portal could be put to most effective use. This latter discussion was wide-ranging, and resulted in numerous suggestions of functionalities that would be useful to incorporate. The underlying motivation consists of establishing the website as a well-recognized dissemination portal that can be accessed for information on research programs and job opportunities for both established researchers and students, and which can demonstrate to the various national programme agencies that an established framework for collaborative international research is in place.

A couple key aspects that were identified as necessary for promoting SIBER's prominence are for the web portal to be actively maintained with current topical items and that an inclusive contact list be compiled that would be used for notifying the broader SIBER community of breaking developments and for delivery of a SIBER newsletter.

For the rest of the meeting, the discussion revisited issues that were focal points of SIBER-1 and ventured into new areas of interest. For the former, the need to establish links and dialogue with international ocean carbon working groups and organizations remains of the highest priority. Means of accomplishing this were considered, and a working group was established that has been tasked to leverage pathways to organizations sponsored by IMBER and the IOC-Perth Office (SOLAS-IMBER Carbon Working Group and IOCCP, respectively). The working group will also be reaching out to form a subcommittee with external membership that includes leading ocean carbon experts. Related to this task, and another ongoing priority from SIBER-1, is the planned installation of pCO_2 sensors as part of the joint SIBER-IOP effort to exploit the RAMA array as a platform for obtaining co-located biogeochemical time series measurements. There were extensive discussions on RAMA site prioritization, since the nominal plan scoped out in the SIBER SPIS requires revising due to the piracy influence on research vessel availability (see article by Maddison *et al*). A significant outcome reported during these deliberations was that BOBLME would be supporting the cost for outfitting the Bay of Bengal flux mooring with biogeochemical instrumentation. A related discussion topic that arose during SIBER-2 was a call for the SIBER community's assistance in promoting the utility of Argo floats instrumented with biogeochemical sensors (in particular dissolved oxygen) so that efforts to obtain funds to similarly outfit additional floats would gain traction.

With the 50th anniversary of the International Indian Ocean Expedition (IIOE) on the near horizon, there was great interest in motivating efforts to mark this event. One concept was to coordinate research cruises that replicate the IIOE ship tracks, with one cruise in the eastern Indian Ocean on the new Australian ship RV *Investigator* and a second cruise in the western Indian Ocean organized by ASCLME. The preliminary step of submitting a ship time request for the *Investigator* has already been accomplished. Another possibility that is being pursued is to combine SIBER's mid-term open science meeting with a SCOR IIOE 50th anniversary symposium that is being planned and which could potentially be held in Goa at India's National Institute of Oceanography (NIO). This would be a particularly relevant connection to make since NIO was established in 1965 to provide regional support for the IIOE.

Capacity building and outreach were also discussed at length. Through steering committee members from ASCLME and BOBLME, and connectivity to NOAA and the IOC through members of the IOP and IRF, SIBER has the opportunity to leverage the in-place connections and networks of these partner organizations towards establishing training venues and promoting infrastructure expansion in Indian Ocean rim nations. One idea that resonated with the SSC was to establish one or more summer school(s) in location(s) around the Indian Ocean, with the goal of simplifying travel logistics, which would provide a means of exposing regional students and early career scientists to the broad expertise and international scope of the SIBER community.

In summary, SIBER has just embarked on its mission to promote and facilitate the establishment of sustained Indian Ocean research activities. Nevertheless it has already produced notable achievements and products of benefit to the region's oceanographic community. This bodes well for SIBER's future success, which may only be realized through continued concerted efforts by its members to motivate coordinated activities that leverage and exploit the infrastructure, networking opportunities and organizational entities that are already established in the region.

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9 - SIBER Ecosystem Modelling Workshop at NIOT-Chennai

Return to TOC

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U.S. Panda, ICNAM Project Directorate, National Institute of Ocean Technology, Chennai, India

S. Patra, ICNAM Project Directorate, National Institute of Ocean Technology, Chennai, India

Raleigh R. Hood, University of Maryland, Cambridge MD, USA

Following SIBER-2, Drs. Hood and Wiggert stayed on to lead a two-day workshop on ecosystem modeling at the National Institute of Ocean Technology (NIOT) campus in Chennai, India. A group of 12 scientists in the Integrated Coastal and Marine Area Management Project Directorate (ICMAM-PD), led by Dr. B.R. Subramaniam, were interested in discussing their efforts to develop ecosystem models for three sites along the Indian coast:

1. Chilika Lagoon (Asia's largest brackish water lagoon);
2. Kochi backwater;
3. Indian parts of Sundarban (the world's largest mangrove forest).

The Chilika lagoonal system was the center point of the discussions, since that is the focus for the researchers stationed at NIOT – Chennai. The lagoon is 65km long and ranges from 3 to 32km wide. The area exhibits seasonal variation that is at its minimum (906km^2) during the dry season (December-June) and which peaks (1165km^2) during the summer monsoon (July-October). A 60km long sand bar separates the lagoon from the western

With its demonstrated history of ecological sensitivity, and the interest in maintaining its economic, recreational and ecological aspects, a concerted monitoring effort has been initiated (noted above). Along with these surveys, a team of modelers has been assembled at the ICMAM-PD to leverage model-data synergies to gain further insight into how the Chilika Lagoon system functions, and to gain an ability to project how to maintain its environmental health. This is being addressed through application of the coupled physical-biogeochemical modeling initiated at ICMAM PD – Chennai.

The implementation of biogeochemical modules within physical models was the centerpiece topic of the workshop led by Drs. Hood and Wiggert in August 2010 (Figure 1) . Examples from past efforts in the Arabian Sea and Chesapeake Bay were used to illustrate the process of how best to strategically explore ecosystem model parameter space in the process of tuning the ecosystem components of such coupled models. The Chesapeake Bay model development was found to have particularly strong relevancies to the Chilika Lagoon system since both are shallow water systems with strong lateral salinity gradients governed by riverine input and linkage to coastal oceans. These gradients promote concomitant speciation shifts.

The experience of simulating the Chesapeake Bay system proved to be a useful source of guidance for the ICMAM modeling group, particularly in the realm of how such environmental gradients act to modulate zooplankton grazing pressure. Benthic exchange of remineralized nutrients, with several contributing sources of organic matter, was also explored *vis-à-vis* modeling techniques. Here, submerged vegetation (i.e., seagrass) was considered a notable contributor to benthic remineralization of organic matter in Chilika Lagoon; further, there was considerable discussion that centered on the degree to which the prevalent seagrass beds may influence the dynamics of the bottom

Bay of Bengal. A considerable body of fieldwork, from 36 stations of a prescribed sampling grid, has been collected, with concentrated efforts occurring over May 2004 – September 2006 and December 2008 – January 2011. The measured properties include currents, salinity, temperature, euphotic zone depth, turbidity, SPM, pH, dissolved oxygen, chlorophyll and inorganic nutrients. Stocks and species composition of phyto- and zooplankton, and standing stocks of microphytobenthos, seaweeds and seagrass, and meiobenthos were also determined.

There are a number of motivations behind the efforts of the ICMAM-PD to understand, monitor and preserve the Chilika Lagoon. For one, the site represents an important cultural heritage as well as significant socio-economic component of the state of Orissa. Chilika Lagoon, a semi-enclosed body of water connected with the Bay of Bengal by an inlet mouth, acts as a spawning and nursery ground for migratory species and local fisheries. The lagoon is also a valuable resource for tourism and recreation, and supports a considerable regional population that includes 60,000 fishers in 172 surrounding villages. Due to its vast potential wealth of living and nonliving resources, and its rich biodiversity, Chilika Lagoon was listed as a Ramsar Wetlands Site in January 1981. Due to severe ecological degradation and biodiversity reduction associated with siltation and sedimentation that was choking the mouth of the lake, the site was added to the Montreux Record in June 1993. To address this environmental degradation, the Government of Orissa established the Chilika Development Authority (CDA) in 1992. A major accomplishment of the CDA was the artificial opening of a new inlet mouth that connected Chilika Lagoon to the Bay of Bengal in September 2000, which led to a significant improvement in ecological conditions. The prestigious Ramsar Wetland Conservation Award 2002 was conferred on CDA for its impressive restoration measures and in November 2002 Chilika Lagoon became the 1st Asian site to be removed from the Montreaux Record.

boundary layer. This is certainly a question that can be pursued using the coupled physical-biogeochemical model being developed. These issues of seagrass influence on chemical budgets and physical processes are also currently not handled in the Chesapeake Bay configuration of Drs. Hood and Wiggert. Thus the exchange of ideas was truly of mutual benefit, making the modelling workshop stimulating and productive for all parties.

Figure 1: Group photograph of ecosystem modeling workshop participants gathered at the National Institute of Ocean Technology (NIOT) campus in Chennai. The 2-day workshop (1-2 August) was hosted by the Integrated Coastal and Marine Area Management Project Directorate (ICMAM – PD) and took place in the week following the SIBER-2 meeting.

10 - New to IMBER!

Return to TOC

10.1 - Four new endorsed projects

Return to TOC

- "Barite bio-organi-mineralization processes at mesopelagic depths" (**BIOBAM**). Leader: Stéphanie Jacquet, LOBP, Marseille, France. More info...
- "Processes Regulating Iron Supply at the Mesoscale - Ross Sea" (**PRISM-RS**). Leader: Dennis McGillicuddy, WHOI, Woods Hole, MA, USA. More info...
- "Changes in Carbon Uptake and Emissions by Oceans in a Changing Climate" (**CARBOCHANGE**). Leader: Christoph Heinze, University of Bergen, Norway. More info...
- "Coastal Ocean MIcrobial Plankton and Temperature" (**COMITE**). Leader: Xosé Anxelu G. Moran, Centro Oceanografico de Gijon/Xixon, IEO, Spain. More info...

More info about IMBER endorsed projects...

10.2 - Focus on CARBOCHANGE

Return to TOC

CARBOCHANGE - Changes in Carbon Uptake and Emissions by Oceans in a Changing Climate

Christoph Heinze (Project Director) and Friederike Hoffmann (Scientific Project Manager, CARBOCHANGE International Project Office, University of Bergen, Geophysical Institute & Bjerknes Centre for Climate Research, Norway.

A European Union's 7th Framework Programme, Large-scale integrating collaborative research project. March 2011 – February 2015; Budget: 7 million Euros.

CARBOCHANGE gathers a consortium of 28 research institutions from Europe, North America (USA and Canada) and Africa (Morocco and South Africa) with outstanding scientific expertise in the field of carbon cycle research.

The goal of CARBOCHANGE is to quantify the oceanic uptake of human-produced carbon dioxide from the atmosphere. Carbon dioxide (CO_2) from fossil fuel burning and land use changes is the main contributor to human-induced climate change. Currently, the ocean takes up about 25% of the CO_2 produced annually worldwide but this rate is subject to continuous change. **CARBOCHANGE investigates how large this uptake rate has been in the past, how it is changing at present and how it will evolve in the future under the influence of climate change.**

Understanding key processes and feedbacks

It is the interplay between physical, chemical and biological processes that determine whether a particular ocean region behaves as a net source or sink with respect to atmospheric CO_2. We address the identification and quantification of key biological and physical processes, as well as their contribution to the feedback between the climate system and the carbon cycle. Our aim is to deliver an understanding of the observed and model-derived variability in the ocean carbon sink, attribute this variability to physical/chemical /biological processes and thus strengthen the forecasting skills of numerical models by the development of new process parameterizations. Coupled Earth system models are employed to upscale key feedback processes to the global scale, to determine specific vulnerabilities of the carbon sink, and to predict its influence on the future climate evolution. The coupled model runs are of high importance to the 5th assessment report of the Intergovernmental Panel on Climate Change (IPCC). The spectrum of runs also includes stabilisation scenarios on feasible pathways for CO_2 emission reductions.

Process understanding

We aim at a quantification of the *key physical, chemical and biogeochemical processes* controlling net air-sea exchange of CO_2 in key regions of European interest. We will further identify, quantify, and explain the *feedback mechanisms associated with atmospheric CO_2 and resulting climate change* related to these processes.

We will provide a process identification of biological carbon cycling, improved process parameterizations for interactive carbon cycle climate models, upscaling of observational evidence to the large scale using models in order to quantify the impact on the atmospheric CO_2 concentration.We will provide new quantifications on the impact of climate induced changes in ice cover and ocean overturning from model sensitivity studies as well as from field data. The critical question of relevant model resolution will be answered through systematic experiments with ocean general circulation models.

Understanding future scenarios and vulnerability analysis

Here we will carry out an assessment of *the vulnerability of marine carbon sources and sinks* with respect to *future emission scenarios* and *associated climate change scenarios* using coupled Earth system models. We will perform coordinated runs with several Earth system models (ESMs and EMICs) and analyse the results for a spectrum of possible IPCC emission pathways as established for the 5thIPCC assessment report including mitigation/stabilisation scenarios. We will address the short term (100 years) and long term (500 years) impact of CO_2 emissions on the ocean carbon sink evolution.

Observing systems of the changing ocean carbon sink for integration with models

It is planned to combine and critically assess observational approaches and their data in order to address key scientific questions, identify synergies between different observing platforms and strategies, and to establish an efficient and coordinated design for the ocean component of the Integrated Carbon Observing System (ICOS). The proposed observing network is global in orientation, being linked to the international community outside Europe. The European contribution will focus primarily on the Atlantic Ocean, including the Arctic Ocean as well as key sectors of the Southern Ocean. Cooperation with related programmes (e.g. projects focussed on European marginal seas) will be established wherever possible to extend the network.

We will set up a network of observations which constrains the magnitude and

The field data will provide the information on progressing ocean acidification both at the surface and in the ocean interior which is essential for - and cannot be provided by - scientists investigating the impact of ocean acidification on marine ecosystems. We will provide highest quality field data on pCO_2, DIC, pH, temperature, salinity and oxygen which allow Atlantic Ocean and Southern Ocean carbon trends to be followed. These data are the prerequisite for a successful calibration of ocean carbon models.

We will collect and publish highest quality carbon system data on the interior ocean. We will produce and analyse trends in anthropogenic carbon storage and its vulnerability to climate change. Time series data for calibration of ocean carbon cycle models concerning the seasonal cycle and interannual variability distribution of carbon sources and sinks under present and past climate change conditions linking surface observations with time-series of subsurface ocean properties as well as interior ocean transports in key locations. We will use the combined network to detect and explain changes in the natural carbon cycle and the inventory of anthropogenic carbon in the ocean for integration of these observations and state-of-the art models. The goal is further, to perform a critical evaluation of the measurement network design in order to develop a long-term, sustained and efficient carbon observing system under climate change that can be carried forward and sustained in synergy with international research projects and specifically the evolving European Integrated Carbon Observing System ICOS (a European Research Infrastructure).

will be provided.

Integration of observations with models including systematic model calibration

We will integrate observational data and models by developing and applying frameworks for systematic data assimilation and model-data fusion, by using the most comprehensive data sets, including those compiled in the project, and by applying the most up-to-date hierarchy of models as well as the most important processes, including those used by and identified in this project. The time and space encompass seasonal to centennial and regional to global scales. Regional emphasis will be placed on the Arctic, the North Atlantic, and the Southern Ocean, regions of key importance for the global carbon cycle and where experience of the project team is extensive. Data-model integration will build on data assimilation methods, on model-data intercomparison relying on regional and global skill score metrics, on statistical detection-attribution methods, and on the effective use of the innovative Transport Matrix Method for model evaluation.We will establish model systems for projections towards climate stabilization and global synthesis by calibrating ocean carbon models and Earth System Models of intermediate complexity with respect to observations. We will quantify the magnitude and distribution of carbon sources and sinks in the ocean in the past (over the industrial period and the recent past) and present by data-model integration. We will further determine specific governing carbon system parameters, inventories, and fluxes relevant for improved quantification of the ocean carbon cycle under ongoing and future climate change and as input for studies on the impact of large scale ocean acidification.

A series of ocean carbon cycle model systems which will have been systematically calibrated through parameter adjustment with respect to observations on the changing ocean carbon sink will be provided to the community for exploitation in future scenarios, vulnerability analyses and ocean carbon budget compilations.We will achieve a systematic performance assessment of the carbon cycle models with respect to observations using novel skill score metrics. The models’ feedback behaviour will be analysed with respect to the models’ ability to reproduce the observations.

Data management, data synthesis and project outreach

New data sets and model results will be assimilated, quality-controlled and harmonized, and metadata will be fed into international data bases and programs. This will ensure long-term archiving, dissemination, and exploitation

A continuous technical and organizational data management infrastructure for observational data sets, and software for efficient use with large datasets will be provided. Annual estimates of the global and regional oceanic CO_2 sink including of results in the scientific community. Results from the project will be synthesized so that easily usable numbers and summaries are provided for concrete years. These reports will merge directly into political decisions on sustainable management as well as into international scientific assessments. CARBOCHANGE will thus provide science-based guardrails for political decisions on mitigation actions in order to control and alleviate the impact of carbon dioxide emissions and climate change.

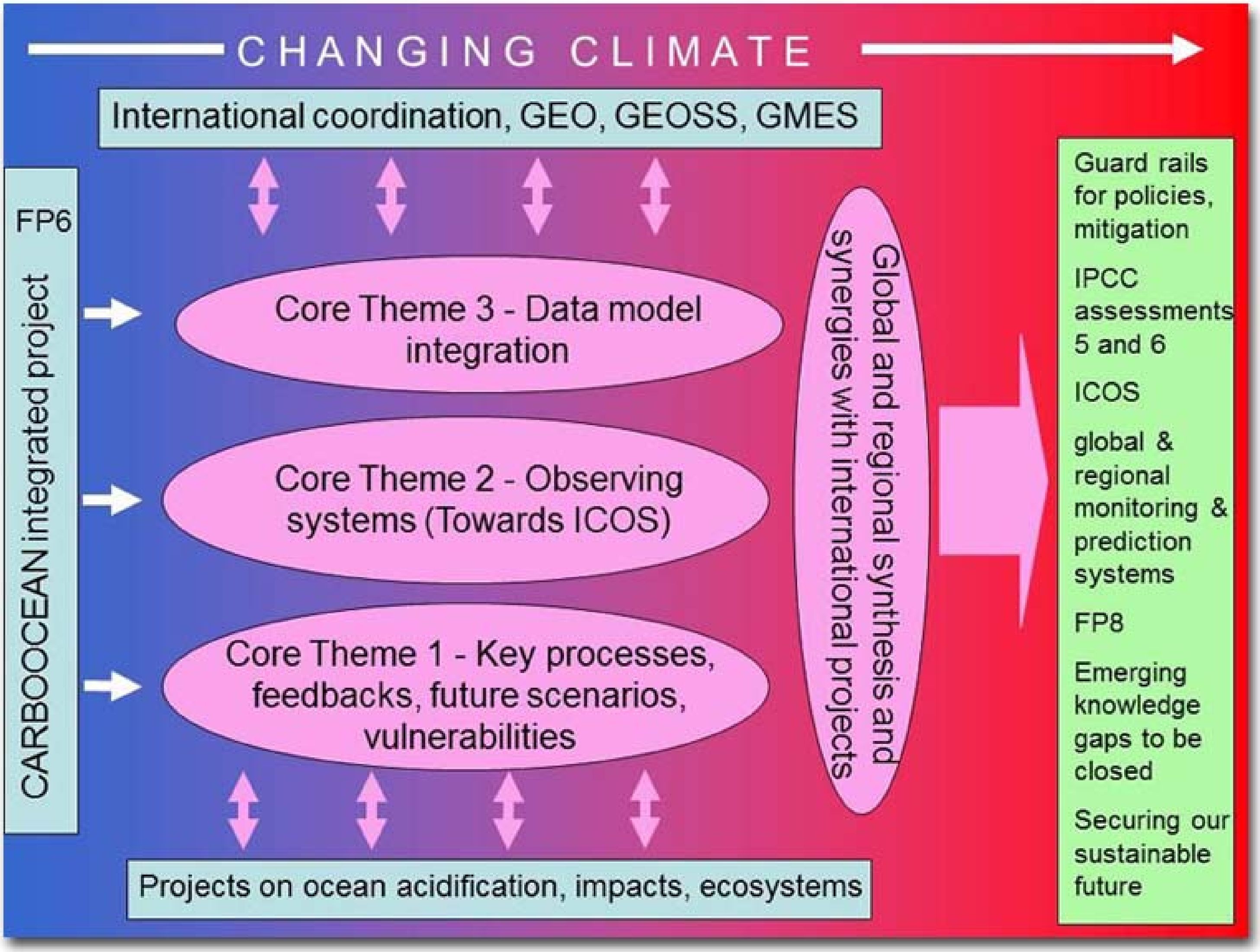
We will synthesise the results from observing systems and modelling achieved in the project as input to relevant policies and for enhancing synergies with international projects on carbon budgets. This work will directly feed into international assessments on the progressing climate change and related climate change mitigation.

the uncertainty, driving processes, merged and quality checked data sets of highest quality ocean carbon data for the global ocean will be produced. These data and information will be disseminated to the world wide community and specifically to policy makers.

Expected project delivery

CARBOCHANGE results will be optimal process descriptions and most realistic error margins for future ocean carbon uptake quantifications with models under the presently available observational evidence. The project will deliver calibrated future evolutions of ocean pH and carbonate saturation as required by the research community on ocean acidification in the EU project EPOCA and further projects in this field. The time history of atmosphere-ocean carbon fluxes past, present, and future will be synthesised globally as well as regionally for the transcontinental Regional Carbon Cycle Assessment and Processes (RECCAP) project.

Observations and model results will merge into Global Earth Observation System of Systems/Group on Earth Observation (GEOSS/GEO) through links with the European Coordination Action Carbon Observation System (COCOS) and FP7 project GEOCARBON, and will prepare the marine branch of the European Research Infrastructure ICOS. Results of the project will be summarized and forwarded to policy makers working on climate change mitigation through specifically targeted outreach papers.



Structure and framework of CARBOCHANGE

10.3 - Farewell to Juliette

Return to TOC

Juliette Rimetz-Planchon, who has been acting as Deputy Executive Officer since April, will be leaving the IMBER IPO at the end of 2011.

We would like to thank her very much for the amazing contribution that she has made during her short time with IMBER – amongst other things, the new website is mostly thanks to her hard work!

We are very sorry to see her go, but wish her great success in her new job.

Go well, Juliette!

From all at IMBER

11 - IMBER meeting report: 5th CJK IMBER Symposium and Training (November 2011, Shanghai, China)

Return to TOC

Jing Zhang, SKLEC, ECNU, Shanghai, ChinaHiroaki Saito, Fisheries Research Agency, Shiogama, Japan

Se-Jong Ju, KORDI, Gyeonggi-do, Korea

Sumei Liu, Ocean University of China, Qingdao, China

Sinjae Yoo, KORDI, Sa-Dong, South Korea

Liuming Hu, IMBER RPO, SKLEC, ECNU, Shanghai, China

The 5th China-Japan-Korea (CJK) IMBER Symposium and Training was held from 22-25 November, 2011 at East China Normal University (ECNU) in Shanghai, China. The purpose of this symposium was to provide a platform for marine scientists from the three countries to share and discuss the latest scientific achievements in the IMBER and Global Ocean Ecosystem Dynamics (GLOBEC) area. Over 80 IMBER scientists from the three countries participated in the symposium (Figures 1 and 2). A one-day training course for early career scientists and students followed on 25 November.

Marine scientists from China, Japan, and Korea (CJK) have been working actively in the areas of GLOBEC and IMBER science since the early 1990s. Various scientific workshops and training activities have been held periodically by these three countries. Since 2002, the China-Japan-Korea GLOBEC/IMBER symposia have provided GLOBEC, and more recently IMBER, scientists from these

- "The study on the physical dynamics of the Yellow Sea bottom cold water and its impact on the ecosystem";
- "Long-term change of structure and function in marine ecosystems of Korea";
- "Northwestern Pacific Ocean Study on Environment & Interactions between Deep Ocean & marginal seas (POSEIDON)".

Hiroaki Saito mentioned that IMBER-Japan mainly targets the North Pacific Ocean and its marginal seas. The major research projects include: Amur-Okhotsk, Population Outbreak of Marine Life (POMAL), Studies on Prediction and Application of Fish Species Alternation (SUPRFISH), and Studies on Prediction and Control of Jellyfish Outbreaks (STOPJELLY). IMBER-Japan, in collaboration with SOLAS-Japan planned nine cruises from 2004-2012. More IMBER cruises have been proposed from 2013-2015.

Chinese IMBER-related research was reviewed by Jing Zhang. The new national IMBER-related project "Sustainability of marine ecosystem production under multi-stressors and adaptive management (2011-2015)" is being undertaken by five Chinese organizations including the East China Normal University, Institute of Oceanology, Ocean University of China, Second Institute of Oceanography and Yellow Sea Fishery Research Institute. The aim is to investigate the countries, with the opportunity to collaborate, exchange, and compare the results of their research.

When GLOBEC ended in 2010, IMBER decided to continue with the symposium series. The 5th CJK IMBER Symposium focused on the impact of climate change and anthropogenic forcing on physical processes and biogeochemical cycles, ecosystem structure and functions, and fisheries in the northern Pacific region, and how these complex interactions, in turn, influence marine ecosystems and human society.Xiuzhen Li, the vice-chair of the State Key Laboratory of Estuarine and Coastal Research (SKLEC), ECNU, gave the welcome address. This was followed by an introduction to IMBER by Sumei Liu, a member of the IMBER Scientific Steering Committee. She also mentioned some of the upcoming IMBER events, such as the : $ClimECO_3$ summer school (July 2012, Turkey) and IMBIZO III (January 2013, India).

IMBER-related research and activities in the three countries were reviewed by representatives from each country (Figure 3). Se-Jong Ju reported the ongoing IMBER-related research projects in Korea, including:

- "KOREA EAST-1 (East Asian Seas Time-series)";
- "Understanding the mechanism of the East Sea ecosystem changes";
- "Assessment of the climate impact on the South Sea ecosystem";

sustainability of ecosystems and adaptive management. The project mainly focuses on four aspects:

- biogeochemical dynamics;
- nutrient cycles;
- physical processes and their effect on nutrient supplies;
- coupling of the microbial loop and biogeochemistry.

Jing also reviewed the aspects of the project that were implemented during 2011.

The oral presentations were grouped into four session themes:

- Impact of climate change on physico-chemical and biological properties of marginal seas (Chaired by Se-Jong Ju);
- The impact of anthropogenic activities on marine biogeochemistry and ecosystem dynamics (Chaired by Hiroaki Saito);
- Development of the biological indicators to detect and evaluate changes in marine ecosystem structure and function (Chaired by Sumei Liu);
- The application of end-to-end food web models: predicting the impact of environmental change on marine ecosystems (Chaired by Jing Zhang).

Figure 1: Participants of the 5th China-Japan-Korea (CJK) IMBER Symposium and Training.

Session themes

Impact of climate change on physicochemical and biological properties of marginal seas:

Presentations focused mainly on studies of elemental cycles (nutrients, sulfur, iron, etc.) and biological properties (algae and zooplankton) of the Northwest Pacific ranging from the open ocean to coastal regions (i.e. South and East China Seas, Yellow Sea).S

everal presentations considered the role of the Kuroshio Current in fish (sardine recruitment in the Kuroshio Extension Regions) production and marine ecosystems. The spatial and temporal heterogeneity of local planktonic communities and biomass were shown to be strongly coupled with the physico-chemical properties and local circulation pattern changes (i.e. episodic river plume and upwelling events) due to natural and anthropogenic forcings.

Development of the biological indicators to detect and evaluate changes in marine ecosystem structure and function:

These presentations focused on the interactions between the biological processes and ecological environments, including the Yellow Sea, East China Sea, South China Sea and north Pacific Ocean. Biological indicators include bacteria, archaeae, viruses, phytoplankton and zooplankton. Environmental changes include hypoxia, radioactive materials released after the Fukushima nuclear accident in Japan, upwelling, eddies, freshwater discharge and cold water masses.

The marine end-to-end food web: the impact of environmental change on marine ecosystems:

Presentations in this session covered a range of topics including new

The impact of anthropogenic activity on marine biogeochemistry and ecosystem dynamics:

Anthropogenic impacts on marine ecosystems are very apparent in eastern Asian coastal regions.

Major science achievements presented included:

1. Understanding the temporal change in the ecosystem and biogeochemical cycles of Chinese coastal waters responding to the recent increase in anthropogenic forcings;
2. Valuation of ecosystem services in coastal Chinese waters;
3. Understanding the impact of aquaculture on coastal water carbonate system;
4. Use of four Ra radioisotopes to investigate biogeochemical cycles.

applications for satellite data extraction that have been successfully applied in extracting sea ice cover from Bohai in North China, dispersal of Changjiang effluent plumes in the East China Sea, as well as the Chl-a distribution and eddies in the East Sea or Sea of Japan. There were also reports about the culture of kelp to reduce eutrophication in the coastal environment and uptake CO_2 from the atmosphere through the accumulation of organic matter biomass. Several presentations discussed progress in numerical techniques in simulating ecosystem parameters (e.g. nutrients, TSM and Chl-a).

Figure 2: Symposium venue (left) and poster presentations (right).

Discussion session

The open discussion focused on the outreach of this 5^{th} CJK Symposium and regional IMBER-related activities.Regionally coordinated joint research activities using a data-sharing mechanism of the sediment cores from the marginal seas

It was proposed that the CJK Symposium seek collaboration with PICES and form joint activities in the near future (e.g. topic session in PICES Annual Meetings).

(e.g. Yellow Sea and East China Sea) were proposed. This would provide the opportunity to understand climate change through history. As sample analysis can differ from one laboratory to another, the standardization and/or inter-comparison of methods may present a challenge.

The variability of the Kuroshio Current and its influence on the marginal seas is an important issue in IMBER research activities in the region, and studies need the collaboration of research in China, Japan and Korea.

It was proposed that a special issue of papers presented at this CJK Symposium be published in an international peer-reviewed journal..

Figure 3: Jing Zhang (China), Hiroaki Saito (Japan), Se-Jong Ju (Korea) reported on the IMBER-related research and activities in their respective countries.

China-Japan-Korea IMBER training course

Combined with the symposium, the China-Japan-Korea IMBER training course for early career scientists and students was held at the East China Normal University on 25 November 2011 (Figure 4). Sinjae Yoo, Hiroaki Saito, Xinyu Guo and Jing Zhang presented information about IMBER, the North Pacific Marine Sciences Organization (PICES) and Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems (FUTURE) programmes, as well as systemic knowledge about physical, chemical, and multi-disciplinary ocean science approaches.

Figure 4: Participants of the China-Japan-Korea IMBER training course.

CJK-2011-Report.doc 5.44 MB

12 - Announcements

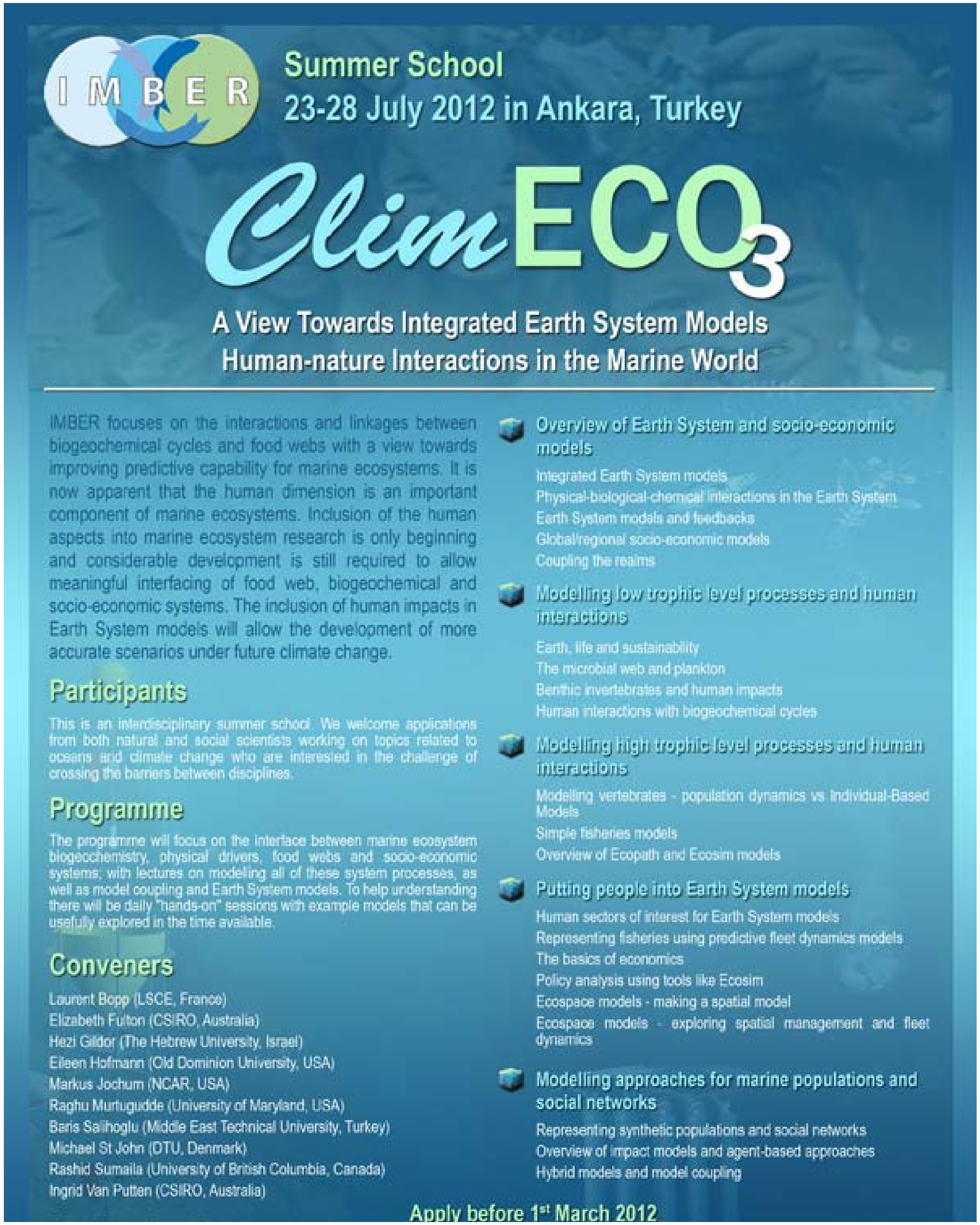
Return to TOC

12.1 - IMBER future events

Return to TOC

ClimECO$_3$: IMBER Summer School (23-28 July 2012, Ankara, Turkey)

More info and registration...


IMBER
Summer School
23-28 July 2012 in Ankara, Turkey
ClimECO3
A View Towards Integrated Earth System Models
Human-nature Interactions in the Marine World
IMBER focuses on the interactions and linkages between biogeochemical cycles and food webs with a view towards improving predictive capability for marine ecosystems. It is now apparent that the human dimension is an important component of marine ecosystems. Inclusion of the human aspects into marine ecosystem research is only beginning and considerable development is still required to allow meaningful interfacing of food web, biogeochemical and socio-economic systems. The inclusion of human impacts in Earth System models will allow the development of more accurate scenarios under future climate change.
Participants
This is an interdisciplinary summer school. We welcome applications from both natural and social scientists working on topics related to oceans and climate change who are interested in the challenge of crossing the barriers between disciplines.
Programme
The programme will focus on the interface between marine ecosystem biogeochemistry, physical drivers, food webs and socio-economic systems; with lectures on modelling all of these system processes, as well as model coupling and Earth System models. To help understanding there will be daily "hands-on" sessions with example models that can be usefully explored in the time available.
Conveners
Laurent Bopp (LSCE, France)
Elizabeth Fulton (CSIRO, Australia)
Hezi Gildor (The Hebrew University, Israel)
Eileen Hofmann (Old Dominion University, USA)
Markus Jochum (NCAR, USA)
Raghu Murtugudde (University of Maryland, USA)
Baris Salihoglu (Middle East Technical University, Turkey)
Michael St John (DTU, Denmark)
Rashid Sumaila (University of British Columbia, Canada)
Ingrid Van Putten (CSIRO, Australia)
Overview of Earth System and socio-economic models
Integrated Earth System models
Physical-biological-chemical interactions in the Earth System
Earth System models and feedbacks
Global/regional socio-economic models
Coupling the realms
Modelling low trophic level processes and human interactions
Earth, life and sustainability
The microbial web and plankton
Benthic invertebrates and human impacts
Human interactions with biogeochemical cycles
Modelling high trophic level processes and human interactions
Modelling vertebrates - population dynamics vs Individual-Based Models
Simple fisheries models
Overview of Ecopath and Ecosim models
Putting people into Earth System models
Human sectors of interest for Earth System models
Representing fisheries using predictive fleet dynamics models
The basics of economics
Policy analysis using tools like Ecosim
Ecospace models - making a spatial model
Ecospace models - exploring spatial management and fleet dynamics
Modelling approaches for marine populations and social networks
Representing synthetic populations and social networks
Overview of impact models and agent-based approaches
Hybrid models and model coupling
Apply before 1st March 2012

IMBIZO III (28-31 January 2013, Goa, India)

The future of marine biogeochemistry, ecosystems and societies.

Multi-dimensional approaches to the challenges of global change in continental margins and open ocean systems.

Summary

Marine ecosystems are essential to life as we know it on this planet, yet the oceans are undergoing fundamental change. More than 20% of the global population resides within 100km of the coast, leading to increasing pressure on the ecosystems in continental margins; more than 90% of natural and farmed fish production is supported by the continental margin ecosystems, thus serving as an important food source. Meanwhile, global change has added a new set of threats, such as increased acidification and warming of the oceans. Humans are both a driver and a recipient of this change and it has become increasingly critical to understand, at multiple scales from the local to the global, how biogeochemical cycles, ecosystems, societies, governments and people, might respond to these changes and threats. The objective of IMBIZO III is to explore the linkages and interactions between humans and marine systems to create understanding of the possible futures of the interrelated ecological and biogeochemical systems in the continental margins and in the open ocean and their societal implications.

Meeting format

We will follow the proven IMBIZO format of three concurrent but interacting workshops, and joint plenary and poster sessions. This has been found to provide a forum for stimulating discussion between interdisciplinary experts and also linkages between biogeochemistry, ecosystem and social science research. To facilitate effective discussion, each workshop will be limited to 40 participants, so participation will be selective. The participants, coming from communities with active interests in the topics, will be chosen to provide balance in scientific disciplines as well as geographic distribution

Workshops

Each of the three workshops will include oral and poster presentations to showcase the current state of knowledge in each area and discussion sessions to identify key questions to be addressed by IMBER.

More info...

12.2 - IMBER endorsed events

Return to TOC

TOS/ASLO/AGU 2012 Ocean Sciences Meeting (20-24 February 2012, Salt Lake City, Utah, USA)

IMBER is involved in eight special sessions:

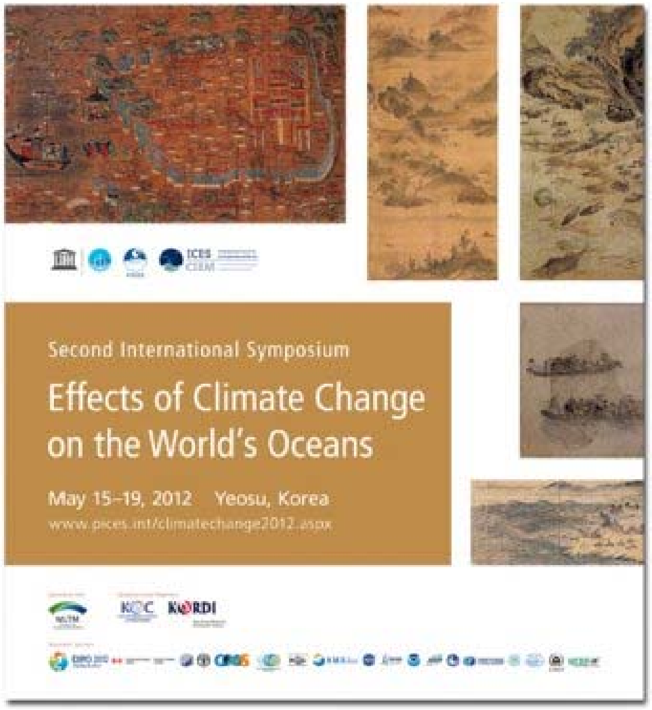
- 'Early life history: new insights into the early life stages and reproductive dynamics of large marine vertebrates', Session 124 (IMBER/CLIOTOP Working Group 1);
- 'Influences of environmental variability on top predator distribution, abundance and behavior', Session 136 (IMBER/CLIOTOP Working Group 2);
- 'The changing ocean carbon cycle: data syntheses, analyses and modeling', Session 074 (SOLAS-IMBER Carbon Working Group);
- 'Shedding light on the dark ocean: advances in linking physical and microbial oceanography to biogeochemistry', Session 158;
- 'Biogeochemical cycles of continental margins: drivers and impacts', Session 031 (Continental Margins Working Group);
- 'Changing Biogeochemistry and Ecosystems in the Western North Pacific Continental Margins Under Climate Change and Anthropogenic Forcing', Session 038 (Continental Margins Working Group);
- 'Arctic-subarctic interactions', Session 180 (ESSAS);
- 'Oceanographic Processes at the Antarctic Continental Margins', Session 033 (ICED).

More info...

2nd ICES/PICES/IOC International Symposium (15-19 May 2012, Yeosu, Korea)

Second international symposium on "Effects of Climate Change on the World's Oceans"IMBER workshop sponsored by ESSAS and ICED on "Effects of climate change on advective fluxes in high latitude regions" (14 May 2012)

More info...



Planet Under Pressure (26-29 March 2012, London, UK)

IMBER is involved in three sessions:

- "Ocean Acidification: ecological impacts and societal implications" (SOLAS-IMBER Ocean Acidification (SIOA) working group). More info...
- "Global science for governance of oceanic ecosystems and fisheries" (IMBER-CLIOTOP). More info...
- "Toward a sustainability-science knowledge-network on marine-ecosystems: achieving innovative, transdisciplinary stewardship across multiple scales" (IMBER Human Dimensions Working Group). More info...

Early registration deadline: 20 January 2012

More info...

EGU General Assembly (22-27 April 2012, Vienna, Austria)

OS3.1 IMBER/SOLAS special session on "Sensitivity of marine ecosystems and biogeochemical cycles to global change".

Deadline for abstract submission: 17 January 2012

More info...

Capacity development for IMBER in the Asian Pacific Region (July 2012, ECNU, Shanghai, China)

Members of the Capacity Building Task Team (CBTT) will conduct research using a case study approach to assess capacity building efforts undertaken in the Asia-Pacific region. This workshop will facilitate analysis and evaluation of these efforts and identify capacity development needs that still need to be addressed.

The results of this workshop will provide IMBER, relevant international agencies and decision makers with a scientific basis for developing a capacity building strategy to enhance integrated marine biogeochemistry and ecosystem research in the Asia-Pacific region.

More info...

The list of IMBER relevant meetings in 2012 are available here

13 - Publications

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- Anthony, K.R.N., J. Kleypas and J.-P. Gattuso (2011) Coral reefs modify their seawater carbon chemistry - implications for impacts of ocean acidification. Global Change Biology 17 3655-3666. More info...
- Bach, L.T., U. Riebesell K.G. Schulz (2011) Distinguishing between the effects of ocean acidification and ocean carbonation in the coccolithophore *Emiliania huxleyi.* Limnology and Oceanography 56(6) 2040-2050. More info...
- EPOCA: The guide for policymakers "Ocean acidification – Questions Answered", produced by the International Ocean Acidification Reference User group (RUG). Now available in German. More info...
- Fiorini, S., J.J. Middelburg and J.-P. Gattuso (2011) Testing the effects of elevated pCO_2 on coccolithophores (*Prymnesiophyceae*): comparison between haploid and diploid life stages. Journal of Phycology 47(6) 1281-1291. More info....
- Frommel, A.Y., R. Maneja, D. Lowe, A.M. Malzahn, A.J. Geffen, A. Folkvord, U. Piatkowski, T.B.H. Reusch and C. Clemmesen (2011) Severe tissue damage in Atlantic cod larvae under increasing ocean acidification. Nature Climate Change. doi:10.1038/nclimate1324. More info...
- Form, A.U. and U. Riebesell (*in press)* Acclimation to ocean acidification during long-term CO_2 exposure in the cold-water coral *Lophelia pertusa*. Global Change Biology. More info...
- Gruber, N., Z. Lachkar, H. Frenzel, P. Marchesiello, M. Münnich, J.C. McWilliams, T. Nagai and G.-K. Plattner (2011) Eddy-induced reduction of biological production in eastern boundary upwelling systems. Nature Geoscience 4 787-792. More info...
- Joubert, W.R., S.J. Thomalla, H.N. Waldron, M.I. Lucas, M. Boye, F.A.C. Le Moigne, F. Planchon and S. Speich (2011) Nitrogen uptake by phytoplankton in the Atlantic sector of the Southern Ocean during late austral summer. Biogeosciences 8 2947-2959. More info...
- Kleypas, J.A., K.R.N. Anthony and J.-P. Gattuso (2011) Coral reefs modify their seawater carbon chemistry – case study from a barrier reef (Moorea, French Polynesia). Global Change Biology 17 3667–3678. More info...
- Mackey, A.P., A. Atkinson, S.L. Hill, P. Ward, N.J. Cunningham, N.M. Johnston and E.J. Murphy (in press) Antarctic macrozooplankton of the southwest Atlantic sector and Bellingshausen Sea: Baseline historical distributions (Discovery Investigations, 1928–1935) related to temperature and food, with projections for subsequent ocean warming. Deep-Sea Research II. More info...
- Saba, V.S., M.A.M. Friedrichs and the PPARR team (2011) An evaluation of ocean color model estimates of marine primary productivity in coastal and pelagic

- regions across the globe. Biogeosciences 8 489-503. More info...
- Secretariat of the Pacific Community (SPC) (2011) Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change. Johann Bell, Johanna Johnson and Alistair Hobday (Eds.). More info...
- Thomalla, S.J., H.N. Waldron, M.I. Lucas, J.F. Read, I.J. Ansorge and E. Pakhomov (2011) Phytoplankton distribution and nitrogen dynamics in the Southwest Indian subtropical gyre and Southern Ocean Waters. Ocean Science 7 113-127. More info...
- Thomalla, S.J., N. Fauchereau, S. Swart and P.M.S. Monteiro (2011) Regional scale characteristics of the seasonal cycle of chlorophyll in the Southern Ocean. Biogeosciences 8 2849-2866. More info...

Notify us of your publications!For IMBER linked publications, please include the statement 'This study is a contribution to the international IMBER project' in the acknowledgments section.

More info about IMBER publications...

14 - List of acronyms

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- ACEP: African Coelacanth Ecosystem Programme
- ACT: Agulhas Current Time-Series
- ARC: Agulhas Return Current
- ASCLME: Agulhas and Somali Current Large Marine Ecosystems
- ATLAS: Autonomous Temperature Line Acquisition System
- BOBLME: Bay Of Bengal Large Marine Ecosystems
- *CLIVAR:* Climate Variability and Predictability Programme
- DBCP: Data Buoy Cooperation Panel
- EEZ: Exclusive Economic Zone
- FAO: Food and Agriculture Organization of the United Nations
- GEF: The GEF unites 182 member governments – in partnership with international institutions, civil society, and the private sector providing grants to developing countries and countries with economies in transition, linking local, national, and global environmental challenges in order to promote sustainable futures for all. Established in 1991, the GEF is today the largest public funder of projects to improve the global environment investing in over 2,700 projects
- GEOSS: Global Earth Observing System of Systems

- IGBP: International Geosphere-Biosphere Programme
- IOC: UNESCO Intergovernmental Oceanographic Commision
- IOGOOS: Global Ocean Observing System in the Indian Ocean
- *IOP: Indian Ocean Panel*
- *INCOIS: Indian National Centre for Ocean Information Services*
- *IndOOS: Indian Ocean Observing System*
- IRF: *IndOOS Resource Forum*
- IPO: International Project Office
- LME: Large Marine Ecosystem
- LOCO: Long-Term Ocean Climate Observations
- NIOZ: Royal Netherlands Institute for Sea Reasearch
- NOAA: National Oceanic and Atmospheric Administration
- RAMA: Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction
- SAIAB: South African Institute for Aquatic Biodiversity
- SAP: Strategic Action Programme
- SCOR: Scientific Committee on Oceanic Research
- SIBER: Sustained Indian Ocean Biogeochemical and Ecological Research
- SPIS: Science Plan and Implementation Strategy
- TDA: Transboundary Diagnostic Analysis
- UNDP: United Nations Development Programme. UNDP partners with people at all levels of society to help build nations that can withstand crisis, and drive and sustain the kind of growth that improves the quality of life for everyone. On the ground in 177 countries and territories, we offer global perspective and local insight to help empower lives and build resilient nations
- WIOSEA: Western Indian Ocean Sustainable Ecosystem Alliance

Should you wish to contribute an article for the IMBER Update, please contact Lisa Maddison

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