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3.1 Global Ecology and Oceanography of Harmful Algal Blooms (GEOHAB)

(joint with IOC)

Kudela, Taguchi

Terms of Reference:

The Scientific Steering Committee of the GEOHAB Programme will

1. Coordinate and manage GEOHAB Core Research Projects (CRPs) in accordance with the GEOHAB Science and Implementation Plans.
2. Identify gaps in knowledge required to execute CRPs, and encourage targeted research activities to fill those gaps.
3. Review progress on CRPs over time and initiate new CRPs in priority research areas.
4. Foster framework activities to facilitate implementation of GEOHAB, including dissemination and information tools.
5. Establish appropriate data management activities to ensure access to, sharing of, and preservation of GEOHAB data, taking into account the data policies of the sponsors.
6. Promote comparative and interdisciplinary research on harmful algal blooms by providing coordination and communication services to national and regional research groups, encouraging explicit affiliation with GEOHAB via the endorsement process.
7. Collaborate, as appropriate, with intergovernmental organizations and their subgroups (e.g., ICES, PICES, FANSA, ANCA, WESTPAC/HAB, HANA, NOWPAP), as well as related research projects (e.g., GLOBEC, LOICZ, IMBER) and observational systems such as the Global Ocean Observing System and its regional alliances.
8. Report regularly to SCOR, the IOC Intergovernmental Panel on Harmful Algal Blooms (IPHAB), and the global HAB research community on the state of planning and accomplishments of GEOHAB, through annual reports and, as appropriate, the GEOHAB Web site, a GEOHAB Newsletter, *Harmful Algal News*, special sessions at scientific meetings, and other venues.
9. Interact with agency sponsors to stimulate the support of GEOHAB implementation through various mechanisms (e.g., direct support of GEOHAB initiatives and integration of the GEOHAB approach in national programs).

Acronyms

ANCA = IOC HAB working group for Central America and Caribbean Sea

FANSA = IOC HAB working group for South America

HANA = IOC HAB working group for North Africa

GLOBEC = Global Ocean Ecosystem Dynamics project

ICES = International Council for the Exploration of the Seas

IMBER = Integrated Marine Biogeochemistry and Ecosystem Research project

IOC = Intergovernmental Oceanographic Commission

LOICZ = Land-Ocean Interactions in the Coastal Zone project

NOWPAP = UNEP Northwest Pacific Action Plan

PICES = North Pacific Marine Sciences Organization

SCOR = Scientific Committee on Oceanic Research

WESTPAC/HAB = IOC SubCommission for the Western Pacific HAB working group

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SCOR-IOC Global Ecology and Oceanography of Harmful Algal Blooms (GEOHAB) Program Activities, 2012-2013

The GEOHAB project is preparing synthesis for completion of its first phase, at the end of 2013. GEOHAB-related activities will be continued after the end of 2013, under a different format, as described at the end of this report.

1. IPHAB-XI Meeting: Paris, France, April 2013

GEOHAB was represented by the SSC Chair (Raphé Kudela) at the Tenth Intergovernmental Panel on Harmful Algal Blooms (IPHAB-XI) meeting. An update on GEOHAB activities during the past two years was presented, and a resolution was passed (see attached) recommending support from IOC for a new international research project called GlobalHAB, with an invitation to SCOR to co-sponsor the project.

2. Implementation of Core Research Projects

The GEOHAB *Implementation Plan*¹, published in November 2003, specified the formation of Core Research Projects (CRPs) related to four ecosystem types—upwelling systems, fjords and coastal embayments, eutrophic systems, and stratified systems. Since then, initiation and implementation of these CRPs has been the primary GEOHAB objective through OSMs and other activities. All four of the CRP research plans have now been published and some implementation has been accomplished. A fifth CRP plan was published in late 2012 (see below).

A. Core Research Project: HABs in Upwelling Systems

This sub-group is chaired by Grant Pitcher (South Africa). The group is developing plans with other organizations for a meeting on climate change effects on HABs, in upwelling systems and beyond. This activity has been endorsed by the Intergovernmental Panel on Harmful Algal Blooms (IPHAB), ICES, and PICES. A preliminary workshop was held in 2013 at Friday Harbor, Washington (USA). Reports from the workshop were submitted to the sponsoring agencies, and an overview article was submitted to *Harmful Algae News*, attached to this report as an Appendix.

B. Core Research Project: HABs in Fjords and Coastal Embayments

This sub-group is chaired by Suzanne Roy (Canada). It held a workshop in May 2012 in Victoria, Canada, on Life Cycles of HABs, focusing particularly on benthic resting stages of harmful algal species (see http://www.geohab.info/index.php?option=com_content&view=article&id=113:geohab-special-issue-of-harmful-algae&catid=40). The outcomes of this OSM include the following: (1) a GEOHAB Meeting Report with synthesis, conclusions, and future research perspectives (see http://hab.ioc-unesco.org/index.php?option=com_oe&task=viewDocumentRecord&docID=10400); (2) the production of several mini-reviews to be incorporated in a special issue of an international journal, along with papers from the CRP on Stratified Systems.

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C. Core Research Project: HABs and Eutrophication

The sub-group on HABs and Eutrophication is chaired by Patricia Glibert (USA). The work of the group is complementary and somewhat combined with the SCOR/LOICZ Working Group 132 on Land-based Nutrient Pollution and the Relationship to Harmful Algal Blooms in Coastal Marine Systems, which has been disbanded after completing several publications, but continues to complete additional papers (see Tab 2).

D. Core Research Project: HABs and Stratification

The sub-group on HABs and Stratification is chaired by Robin Raine (Ireland). The group conducted a workshop on “Advances and challenges for understanding physical-biological interactions in HABs in Stratified Environments” at the Monterey Bay Aquarium Research Institution, Moss Landing, California, USA on 21-23 August 2012. The workshop reviewed the major discoveries relating to the physics, biology, ecology, and/or chemistry of HABs in stratified systems. Through presentations and group discussion, the participants identified critical remaining questions, and new technologies that may be needed to fulfill sampling protocols necessary to answer them. A goal of the meeting was to produce a conceptual model or ‘roadmap’ of the direction in which biological, physical, and chemical measurements of harmful algal blooms in stratified systems should be headed during the next 10 years, as well as a manuscript synthesizing the findings of this meeting. Another goal was to produce collaborative proposals to conduct a multidisciplinary field experiment addressing this subject. The outcomes of the meeting will be published in a GEOHAB Report. The report is drafted, and has been circulated to the OSM participants for final comments, and is currently being prepared for printing.

This CRP is also producing a special issue in *Deep-Sea Research II*. Guest editors include R. Raine, E. Berdalet, M. McManus, and H. Yamazaki. The special issue has recently (September 2013) been finalized and will be published imminently. It includes 21 peer-reviewed manuscripts and a preface.

E. Core Research Project: HABs in Benthic Systems (BHABs)

GEOHAB sponsored an OSM on HABs in Benthic Systems in Honolulu, Hawaii in June 2010, with Paul Bienfang as the convener. The OSM organizing committee has completed the science plan from the meeting, a report edited by E. Berdalet, P. Tester and A. Zingone, and printed in late 2012 (see http://hab.ioc-unesco.org/index.php?option=com_oe&task=viewDocumentRecord&docID=9693). The report contains the state of the art regarding research on benthic HABs and the main open questions for the coming years, in order to initiate and implement the CRP. Three follow-on activities have been proposed and are being actively pursued:

- Sampling/ID workshop focusing on BHAB organisms, proposed by Wayne Litaker and Patricia Tester (USA). Gires Usup (Malaysia) secured local funding for this activity, and the BHAB working group organized a workshop.
- YEOSU International Organization Collaboration Project (GEOHAB Asia & BHAB) proposal was submitted and successfully funded in 2011.

- The BHAB program was presented at the “International Conference on *Ostreopsis* Development (ICOD)” and was recently published (Zingone et al. 2012, *Cryptogamie Algologie* 33(2): 225-230).

3. 2013 GEOHAB Open Science Meeting

The SSC convened the final GEOHAB Open Science Meeting at IOC Headquarters in Paris, France in April 2012. The purpose of the meeting was to review the scientific advances accomplished under GEOHAB since its inception and to identify a near-future roadmap of GEOHAB-like activities to be pursued beyond 2013. To achieve these objectives, the meeting was structured with the following components:

- Invited presentations that reviewed GEOHAB’s past and present through its 5 Core Research Projects, Regional Programs and Targeted Activities, and topics that provided a general framework for future research on HABs.
- Concept papers (i.e., proposals for specific activities, such as research projects, training sessions, or comparisons among ecosystems) that could be implemented between 2014 and 2018. It was requested that the papers be based on GEOHAB planning documents, such as the GEOHAB Science and Implementation Plans, and the Core Research Project reports (www.geohab.info). The concept papers contributed to development of the GlobalHAB project concept and some may be implemented as activities beyond 2013.
- Poster sessions that broadened the number of topics that could be considered during the meeting and encouraged the widest possible scientific participation.
- Breakout discussion sessions among the participants based on both the invited presentations and the concept papers. Three breakout sessions were held:
 - What has GEOHAB accomplished and how was it done? What did and didn't work and why?
 - Which scientific objectives can effectively be implemented in the coming years and what are the best mechanisms to accomplish them, based on the Concept Papers that were submitted?
 - Based on the previous session’s outcomes, how should GEOHAB be structured to most effectively move forward in the future?

4. IOCCG/GEOHAB Working Group

The International Ocean Colour Coordination Group and GEOHAB are co-funding a working group on HABs and Ocean Colour. The group will

- Summarize the relevance of ocean colour-based harmful algal bloom observation systems.
- Summarize the wide variety of harmful algal bloom types with regard to ecosystem function, consistent with GEOHAB Core Research structures.
- Summarize the principal methodological difficulties for ocean colour in coastal and inland waters, with reference to previous IOCCG Working Groups and other ongoing initiatives, e.g. GEO Tasks, CoastColour, etc.
- Summarize our current understanding of the physics of phytoplankton community composition from a bio-optical and ocean colour perspective.

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- Review the relevance of Phytoplankton Functional Type (PFT) approaches (with reference to the IOCCG PFT Working Group) for harmful algal bloom observations across a variety of coastal and inland ecosystems.
- Review and summarize current and emerging harmful algal bloom-related ocean colour techniques, from reflectance-based community composition algorithms to ecosystem-specific change-detection algorithms, that is, research and operational applications.
- Compare the results of a variety of algorithms on selected bloom case studies, representative of the GEOHAB core research ecosystems with the specific addition of inland waters, and use these studies to provide a clear guide to ocean colour algorithm performance diagnostics, and optimal ocean colour-based approaches for various bloom and ecosystem types.
- Examine the utility of ocean colour observations beyond the event scale: multisensory and temporal analyses of ecological drivers and response for example systems, analysing and demonstrating the value of routine synoptic data and integration with other observations and models.
- Recommend future studies, measurements, protocols, etc. to develop, improve and better understand application limitations for harmful algal bloom-focused ocean colour algorithms
- Summarize, recommend, and present a future outlook for the development of new ocean colour observation systems, incorporating future sensors/systems.
- Prepare a monograph to be published within the IOCCG or GEOHAB series.
- Prepare a special issue in a peer-reviewed journal incorporating suitable review and case study chapters as papers.

The group has met twice and is working on a monograph for the *IOCCG Report* series and potentially a special issue of a peer-reviewed journal. This group anticipates finalizing the report before the end of 2013.

5. GEOHAB Modelling

Based in part on the successful collaboration between GEOHAB and IOCCG, GEOHAB participated in the GEO Blue Planet Symposium in Brazil 19-21 November 2012 (http://www.faro-project.org/blue_planet/announcement.html). Stewart Bernard (SSC member; South Africa) and Lourdes Velo-Suarez (Spain) represented GEOHAB, addressing the HAB observations and modelling needs within the GEO framework. Travel support was provided by IOCCG through the Fisheries Applications from Remotely-Sensed Ocean Colour (FARO) effort. A contributed chapter was written to be included in the “Oceans & Society: Blue Planet” book, anticipated to be published in 2014.

6. Publications and Endorsed Projects

A full list of GEOHAB reports, publications, and endorsed activities are available on the GEOHAB Web site. GEOHAB generated considerable interest from the community during this interval, and GEOHAB-endorsed work has been conducted in Australia, Canada, Chile, France, Philippines, Spain, South Africa, United Kingdom, and the United States. We continue to receive requests annually for project endorsements and are reaching out to the prior endorsed projects for inclusion in the GEOHAB synthesis activities.

7. GEOHAB Synthesis

At the end of 2013, the GEOHAB program will complete 10 years from the publication of its Implementation Plan. The SCOR Executive Committee has requested that GEOHAB conduct synthesis activities and complete its current phase of activity. Information from the Open Science Meeting will contribute to the synthesis documents, which will be a major focus of the final GEOHAB meeting in December 2013.

A. GEOHAB Summary Outcomes

Tentatively planned synthesis documents include the following:

1. Special issue from the meeting, with guest editors and the journal to be determined. The SSC is in favor of selecting an open-access journal, if possible. The SSC is currently also looking into possible publication of a monograph, rather than a special issue.
2. GEOHAB Science Summary—As part of our synthesis report to both IOC and SCOR, GEOHAB will revisit the Science Plan and CRP plans to review what has been accomplished and what remains to be achieved.
3. A summary/overview article was originally envisioned to be submitted to *Oceanography* in late 2013. All SSC members would be authors. This builds on the past *Oceanography* publications highlighting the mid-stream goals and accomplishments of the GEOHAB effort, and would be suitable for the scientifically literate public, policy makers, and program managers. Depending on task 1, this may be revised to represent an overview paper for the special issue.
4. Summary for Policy Makers. The SSC is strongly in favor of developing a *Summary* similar to previous efforts such as the *Ocean Fertilization* summary document (<http://unesdoc.unesco.org/images/0019/001906/190674e.pdf>). GEOHAB is working with IOC, SCOR, and NOAA to implement this effort.

8. Final GEOHAB SSC Meeting

The final GEOHAB SSC Meeting will be held in Barcelona, Spain on 3-5 December 2013, with many of the SSC members agreeing to an informal extension (December 6-8) to implement the GEOHAB Summary Outcomes. The meeting will discuss several topics: completion of GEOHAB synthesis products, implementation of concept papers from the Open Science Meeting, and plans for GlobalHAB.

Appendixes

- 1) HABs in a Changing World summary document from the Workshop on Harmful Algal Blooms in a Changing World (WKHABCW), to be submitted to *Harmful Algae News*
- 2) Draft report of the WKHABCW effort
- 3) IPHAB-XI.1 Recommendation

Harmful Algal Blooms in a Changing World

There are projections that the process of climate change will lead to increased frequency and severity of Harmful Algal Blooms (HABs). Indeed there is evidence that climate change already may be causing shifts in phytoplankton community composition, but the projections on climate-increasing the HAB impact remain, at this point, largely speculative. Although there are many intuitive linkages, these scenarios are founded on limited and often conflicting experimental data, so that scientific debate at this time cannot establish a link between HABs and climate change, let alone how dramatic any change in HABs might be in the future. Moreover, the field of HAB research lacks the rigorous organization structure of the Intergovernmental Panel of Climate Change, where scientists worldwide work in collaboration to quantify and evaluate trends in HAB impacts. HAB scientists need to proactively identify the fundamental parameters and research infrastructure needed to effectively address this important question if we are to have those data we need when called upon to forecast or explain changing HAB patterns.

It is important to recognize that the issue here is not simply whether a pattern might develop where fluctuations in HAB frequencies at times become more prevalent in the future. Instead, based on limited ecophysiological insights it is reasonable to postulate there will be fundamental changes in the distributions of HABs, bringing ecosystem and human health threats to extensive new regions, perhaps compounding current problems. There also likely will be increased “windows of opportunity” for existing regional HABs, intensifying existing threats at a time when humans will be relying more on coastal resources for food security. As it stands, the HAB research community is woefully unprepared to provide solid insights to the changes that will define the next generation’s access to many marine resources.

A workshop of international experts convened in March, 2013 at the Whiteley Center, Friday Harbor Laboratories, University of Washington (funded by PICES, GEOHAB and NOAA) to develop a preliminary assessment of where the field of HAB research stands in terms of addressing the HAB-climate change connection, and the directions it needs to move over the next decade. Three broad classes of HABs were considered: (1) toxic HABs that impact human health, (2) fish-killing HABs where the causative organisms affect both wild and aquaculture fish populations, and (3) high-biomass HABs, whether derived by natural or anthropogenic processes leading to hypoxia, foam, and other negative impacts. The key underlying consideration surrounding climate-related distributional changes in HABs is three-pronged: HAB species “getting there”, being adapted well enough to “remain there” over the course of the season, and ultimately “staying there” for multiple seasons. There is much in the invasive species research field that could be applied to investigate the HAB-climate change linkage.

The workshop deliberations used as a foundation the observed and predicted climate changes in the physical and chemical conditions in aquatic systems identified in the AR4 IPCC Synthesis Report on climate change, combining what is known about these effects on the physiology of both general phytoplankton as well as HAB species. The central questions asked were: what do we know about how the given parameter affects HAB species, what do we not know of importance in terms of this parameter's impacts, and which of these unknowns are the most pressing questions and how should we go about addressing them?

The topics considered included temperature (with its effects on cellular growth rates, nutrient uptake rates, toxin production and cellular lipid compositions) and stratification (with its impact on vertical nutrient flux, physical and chemical stability of the system and the prolonging of HAB windows of opportunity). Similarly, the effect of ocean acidification was examined in terms of success of HAB species and cellular toxin synthesis and accumulation, along with the effects from altered nutrient inputs associated with changing precipitation characteristics (e.g., pulsed terrestrial riverine flows) and facilitated transport of culturally derived nutrients. While each of these four broad parameters have known impacts on HAB species, the synergistic interactions among these drivers will determine the overall impact on HAB species success in phytoplankton communities; an interaction that, realistically, there is no evidence on which to inform.

The workshop participants felt that current insight on how climate change may influence grazing and light effects on HAB species is entirely insufficient. Many HABs species are both grazers and prey, but there is very limited information on how the balance of these processes might deviate as the ocean environment changes. There are model projections that climate change will alter patterns of cloud cover, and thus change light fields spatially in surface waters. While light is a key parameter affecting phytoplankton communities, and different species are known to be better light- or shade-adapted candidates, there is no indication so far that HAB species will be affected differently than non-HAB species.

An overriding theme during the workshop discussions was consideration of how environmental changes will impact HAB species relative to non-HAB species. Participants recognized that much of the HAB research to date has focused on the specifics of HAB organisms, which though essential for understanding the ecophysiology of the organisms provides limited insight to how HAB organisms interact within the broader phytoplankton communities. One of the key workshop findings was the need for a shift in the strategy of HAB research towards more comparative investigations that inform on the thresholds for shifting balance among HAB and non-HAB species in the context of climatically driven changes in coastal and oceanic environments.

The workshop participants also considered what new research tools would help move the science forward most quickly. The primary need at this time is organizing long-term sampling programs to collect HAB-centric datasets of relevant parameters across diverse geographical and oceanographic regimes. While regional and national monitoring programs already exist, none are sufficient to provide the data streams to assess changes in HABs in new, currently unaffected regimes. The vast majority of these HAB data also lack the essential calibrated oceanographic data to link HAB changes to climate-dependent parameters.

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Participants agreed that the most productive means to initiate these data collection streams is to collaborate with these existing coastal and offshore oceanographic monitoring sites to add a limited list of parameters (e.g., phytoplankton speciation, toxins etc.) to establish HAB “observer sites”. Recognizing that there are very limited laboratory facilities and expertise in many areas of interest, a shorter list of key parameters that are easily obtained with simple sampling approaches was developed to facilitate new outpost-type monitoring sites.

A second class of sentinel site was envisioned by participants, termed “super sites”, which while limited in number would be equipped with sophisticated monitoring equipment that enable high-frequency sampling of phytoplankton species composition along with a wide range of environmental parameters. Their purpose would be to enable in-situ investigations of the ecology of HABs in relation to non-HAB species. The goal of both “observer” and “super” sites is to ensure adequate datasets for statistical assessment of long-term change across multiple coastal and oceanic regimes.

New investigative approaches also will be needed to address the HAB-climate change relationship. It is recognized that isolates of given phytoplankton species differ in their growth responses to different stimuli, so there is a strong need to understand these localized differences in projecting climate change effects. One novel approach is conducting “common garden” style culture experiments, where many laboratories situated around the globe conduct identical experiments using precise established procedures to test the effects of one or more parameters on a single species isolated from their local waters. This approach provides the ideal mechanism for evaluating species response as well as characterizing their inter-strain variability. Other methods included cross-sectional research programs such as mesocosms and other enclosures using standardized methods, design, analysis, and assessment. Enclosed basin study sites, where HABs are a repetitive feature, were also cited as promising instruments for gauging the HAB competitive interactions in unrestricted coastal waters.

Participants also identified a strong need to develop measures for dealing with HAB outbreaks, including proactive (avoidance), abatement (halting) and mitigation (reduced impact) strategies. In addition, virtual assessment approaches to understand past outbreaks and forecast future outbreaks built upon detailed conceptual or heuristic models were felt to be underutilized. Participants felt that next logical step in focusing HAB/climate change research was to convene an Open Science Meeting on global change impacts on marine and freshwater HABs. The goals of this symposium would be to promote research in the topics along the lines identified by the workshop participants to be of high priority over the next decade, to bring new people and expertise into the field (i.e., to make climate change researchers aware of the HAB issue and how their expertise and methods may find rich ground for research), and to focus community efforts towards identifying the data needed to unequivocally demonstrate a linkage between HABs and climate change.

The workshop findings are now being integrated into a manuscript intended for publication in the international journal *Harmful Algae*. The findings will help provide a broader view to the HAB research community on some of the key gaps in our understanding to help focus global research efforts on addressing HABs and climate change.

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**ICES/PICES/IOC-GEOHAB WKHABCW REPORT
2013**

ICES SGHIE

**REPORT OF THE ICES/PICES/IOC-GEOHAB
WORKSHOP ON HARMFUL ALGAE BLOOMS IN A
CHANGING WORLD
WKHABCW**

18-22 March 2013

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Recommended format for purposes of citation:

REPORT OF THE ICES/PICES/IOC-GEOHAB WORKSHOP ON HARMFUL ALGAE BLOOMS IN A
CHANGING WORLD WKHABCW, 18-22 March 2013, Friday Harbor Laboratories,
United States of America.

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*Executive Summary***Highlights**

The workshop convened at the Whiteley Center, Friday Harbor Laboratories, University of Washington for a week of discussions and presentations. The 11 participants began the workshop by presenting their perspectives on the most pressing concerns about climate change effects on HABs. The following three topics then were considered through a combination of breakout and collective group discussions:

- 1) Assessment of the state of understanding of HAB's and climate change, focusing on the research topics of greatest need and likelihood of achieving over the next decade,
- 2) Description of two types of sentinel sites for observing change based on existing long-term monitoring stations.
 - a) The first would be "observer" or "sentinel" sites, where a minimal set of parameters are added to those measured at most long-term oceanographic monitoring sites. A second, shortened list of most key parameters were identified that could be measured in places where monitoring is not now done, or where instrumentation or expertise is limited. The goal at these sites is to detect change in HABs, by either capturing shifts in existing HAB frequency and intensities or the expansion of HABs into new areas.
 - b) The second set of sites, referred to as "super" sites, would be fewer in number and include a list of more sophisticated sampling goals. Beyond simply detecting change in HABs, these "super" sites would enable study of the ecological and oceanographic processes contributing to this change.
- 3) Detailed discussion on preliminary plans for an Open Science Symposium that focuses the HAB research community on: a) the bar needed to establish with high confidence that observed changes are due to climate change, b) to highlight the priority directions for HAB research on climate change related issues, and c) to attract new, non-traditional HAB researchers with new tools and expertise. The latter goal deals with the realistic outlook that funding for HAB research is not going to increase, but that there are fields of climate change research where the addition of HAB topics would both strengthen their goals while advancing HAB research in general.

Participants decided upon three approaches for communicating the workshop findings to the broader community. The first is as a journal publication (probably to *Harmful Algae*) that presents the detailed considerations covered during the workshop. The manuscript outline was prepared during the latter stages of the workshop and preliminary writing of this joint manuscript is underway. A second more condensed summary of the workshop findings will be prepared as a "commentary" type manuscript for *Nature* or *Science* that will help direct potentially interested non-HAB researchers to the main paper. Third, the background and central findings will be written for the broader public in an "opposite the editorial" (Op/Ed) format for newspaper and magazine distribution.

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1 *Welcome and opening of the Workshop*

The WKHABCW met March 18-22, 2013 at the Whiteley Center, Friday Harbor Laboratories, University of Washington. There were 11 invited participants from 5 countries, listed in Annex I.

The meeting goal was to assess what is known with certainty about existing climate change effects on the distribution, character and intensity of Harmful Algal Bloom (HAB) events, assess what the most pressing research issues are that likely can be addressed over the next decade, and identify the infrastructure needs for making significant advances in our understanding of HABs.

This workshop was organized as a “grass roots” effort by the organizers with funding provided through PICES, NOAA and SCOR-GEOHAB. The participants prepared a written statement before the workshop on their perspectives on the most pressing and achievable research goals and needs.

2 *Adoption of the agenda*

The participants reviewed the agenda (Annex 2) and this was adopted without any change.

3 *Terms of References*

SSGHIE EG resolutions approved in 2011

ICES/IOC/PICES Workshop on “HABs in a Changing World” (WKHABCW)

2011/2/SSGHIE08 The ICES/IOC/PICES Workshop on “HABs in a Changing World” (WKHABCW), chaired by Bengt Karlson*, Sweden, Mark Wells*, USA, and Raphael M. Kudela*, USA will be held at Friday Harbor Laboratories, Washington, USA on 18–22 March to:

- a) Review and consider recent research of climate effects on the ecology of HAB species and trophic interactions;
- b) Review and consider recent research on climate effects on the physiology/toxicity of HAB organisms;
- c) Review and consider recent research the impacts of projected changes in macro- and micro-nutrient distributions on HAB organisms.

Workshop participants will decide on the final topic areas after the initial discussions. The specific outcome of the workshop would be a participant-authored journal article communicating the synthesis of primary research directions to the broader HAB research community.

WKHABCW will report by 30 April 2013 (via SSGHIE) for the attention SCICOM.

4 Term of References A-C

4.1 Introduction

4.1.1 It was decided by the workshop participants to consider the three terms of references together.

- a) Review and consider recent research of climate effects on the ecology of HAB species and trophic interactions;
- b) Review and consider recent research on climate effects on the physiology/toxicity of HAB organisms;
- c) Review and consider recent research the impacts of projected changes in macro- and micro-nutrient distributions on HAB organisms.

The central links between climate change and HABs were considered first in terms of the known changes in physical parameters what is known about how these parameters affect the broad range of HAB organisms and their competitive success. The key underlying foundation of HAB occurrences pens upon the HAB species “getting there”, is being adapted well enough to “remain there” over the course of the season, and ultimately to “stay there” for multiple seasons. Three broad classes of HABs were discussed;

1. Toxic-HABs that impact human health (marine and freshwater cyanohabs) or have demonstrable ecosystem effects (e.g., domoic acid effects on marine mammals and birds, cyanohab effects on livestock).
2. Fish-Killing-HABs, whereby the causative organisms may be dinoflagellates (e.g., brevetoxins), raphidophytes (e.g., *Heterosigma*) and other genera that affect both wild fish and aquaculture operations.
3. High Biomass-HABs, whether derived from natural or anthropogenic processes, that can cause hypoxia, produce large quantities of foam leading to bird deaths and potential human impacts, generate anti-tourism effects (noxious), stimulate pathogenic bacteria activity, or negatively affect aquaculture operations.

Participants identified a fourth type of potentially emerging HAB-type concern as nutritionally inadequate blooms (NIPs). In this case, anthropogenically- or naturally-generated largely mono-specific blooms for prolonged periods may lead to depletion of one or more essential fatty acids in lower trophic levels with possible cascading effects on fecundity and survival throughout the food web. However, given the absence of key data on these potential effects, participants did not specifically address this issue in the climate change discussions.

The deliberations focused on the observed and predicted climate changes in the physical and chemical conditions in aquatic systems identified in the AR4 IPCC Synthesis Report on climate change, and what is known about these effects on the physiology of both general phytoplankton as well as HAB species. The central questions asked were: what do we know about how the given parameter affects HAB species, what do we not know of importance in terms of this parameters impacts, and which of these unknowns are the most pressing questions and how should we go about addressing them? Participants recognized that much of the past HAB

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research has focused on the specifics of HAB organisms rather than addressing how HAB organisms interact with non-HAB species. Given that any changes in HAB occurrences associated with climate change will represent a shifting balance between HAB species within the broader phytoplankton community, there needs to be a fundamental shift in HAB research to take into account these interactions.

The key factors considered included direct temperature effects on HAB and non-species, including cellular growth rates, nutrient uptake rates, toxin production, and cellular lipid compositions among other factors. Interlinked with temperature was increased degrees and duration of stratification of the water column, with its effects on not only nutrient inputs but also stability of the system against change. Changes in nutrient availability were considered, due to linked-changes in stratification but also as a result of changing precipitation characteristics with its effects on nutrient transport from terrestrial environments to coastal waters. Changes in precipitation were particularly important in terms of altering anthropogenic inputs associated with the increasing population of the coastal zones over the next few decades. The effects of ocean acidification on HAB species success and cellular toxin production and accumulation were discussed. A limited degree of evidence so far indicates that this may be a significant driving factor for altering the impacts of HABs with climate change. Discussion over the impacts of climate change on grazing pressure and mortality was less certain, given the considerably lower degree of our understanding of how mortality impacts bloom signatures. A shift towards “jellyfish” dominated predation has been predicted but very little is known about how this may disproportionately affect HAB species. Changing light regimes associated with increasing or decreasing cloud cover and increasing stratification was the only factor participants found unlikely to have a specific HAB associated impact. Although there will be clear impacts on the plankton community composition and production overall, based on available data it appears that HAB species would not be selected for or against by these changes. A complete discussion of these findings will be presented in a manuscript for submittal for publication in *Harmful Algae*.

New approaches to HABs and climate change research were considered by the participants. In addition to establishing “super” sites for studying the in situ dynamics among HAB and non-HAB species, several other approaches were identified. These included the “common garden” style culture experiments, where many laboratories situated around the globe conduct identical experiments using precise established procedures to test the effects of one or more parameters on a single species isolated from local waters. This approach provides the ideal mechanism for evaluating species response as well as characterizing the inter-strain variability. Other methods included cross-sectional research programs such as mesocosms and other enclosures using standardized methods, design, analysis, and assessment. Participants also identified a strong need to develop measures for dealing with HAB outbreaks, including proactive (avoidance), abatement (halting) and mitigation (reduced impact) strategies. In addition, there is a need for virtual assessment approaches to understand past outbreaks and forecasting future outbreaks built upon detailed conceptual or heuristic models.

Measuring the change in HAB frequency, intensity, and spatial distributions associated with climate change necessitates a network of monitoring stations. Recognizing limitations forced by funding and expertise, participants segment these monitoring sites into “Observer” sites and “Super” sites; the former being designed to simply detect the presence of HABs and the basic

environmental parameters associated with their outbreaks while the latter would help inform on the ecology and oceanography of the system that led to the HAB formation. A list of key parameters was identified by participants for each type of monitoring site along with appropriate sampling strategies and frequencies. There was particular concern given to selecting easily measured parameters for sites where instrumentation or expertise is lacking so that the network of Observer sites could be broadened greatly. In addition a list of existing known long-term data sets was developed that would be appropriate for identifying the past distribution and frequency of HAB events that could serve as ideal reference points moving forward into the future.

One of the main outcomes of the workshop discussions was identifying the need for a Open Science Meeting on global change impacts on rain and freshwater HABs, to be held in 2014-2015. The goals of this workshop would be to promote research in the topics identified by this group to be of high priority over the next decade, to bring new people and expertise into the field (i.e., to make other climate change researchers aware of the HAB-related questions where there expertise and new methods may find a rich ground for research), and to help the have community identify the types of information needed to unequivocally demonstrate a linkage between HABs and climate change. Several meeting designs were discussed and a steering committee to organize the meeting was established.

5 Recommendations

5.1 Proposed ICES/IOC/PICES SCIENTIFIC SYMPOSIUM ON HARMFUL ALGAE AND GLOBAL CLIMATE CHANGE

WKHABCW recommends the following steps be taken:

- 1) In cooperation with ICES, PICES, IOC, SCOR, GOOS and GEOHAB/GobalHAB to convene an open *Scientific Symposium on Harmful Algal Blooms and Climate Change* in 2014 or 2015 to:
 - a. provide examples of locations and events where climate change may be affecting HABs and their impacts;
 - b. identify and promote research on critical topics/aspects of the broader field of HAB research to advance our knowledge of the impacts of climate change on the global scale;
 - c. attract and retain new expertise from other scientific disciplines;
 - d. evaluate the use of new technologies for the collection and analysis of long term data on appropriate parameters;
 - e. develop the HAB component of global climate observing systems;
 - f. foster framework activities to facilitate identifying and responding to climate change-driven effects on HABs, including risk assessment with associated probabilities and uncertainties;

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- g. develop best practice recommendations for research and monitoring to fill critical knowledge gaps;
- 2) The steering committee for an open scientific symposium on harmful algal blooms and climate change should be co-chaired by a representative of the PICES HAB Section, the Chair of the IOC-ICES WGHABD, and the Chair of the GEOHAB SSC and other members to be identified in consultation with the ICES, the IOC-IPHAB Chair and the Secretariats of the sponsoring organizations.
- 3) To instruct the IPHAB Task Team on HAB Observation and Forecasting Systems to review the current technologies for HAB sensors and observing systems and recommend a globally distributed network HAB observing assets in coordination with 1) e. and working within the existing plans for global observing systems.
- 4) IPHAB Nations are requested to establish long-term sampling sites capable of detecting the emerging presence of new HABs or changing characteristics in existing HABs. These sites could include a recommended minimum set of parameters or a more comprehensive set that allows investigation of the selective processes leading to HAB development.
- 5) To request the ICES/IOC WGHABD to review and advise on the progress of the preparations for the open science meeting on Harmful Algal Blooms and Climate Change.
- 6) To invite the SCOR Working group 137 and PICES Working Group 27 on North Pacific Climate Variability and Change, the ICES/PICES Strategic Initiation on Climate Change Impacts on Marine Ecosystem, and representation from the GEO Blue Planet and GOOS to contribute advice and resources to help implement the objectives above.

6 *Closing of the workshop*

The Chairs thanked the participants for their input and closed the workshop on Friday 22 March.

Annex 1: List of participants

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*Co-chairs

Annex 2: Agenda

1. Produce an expert assessment of what is known and uncertain about the linkages between climate change and purported changes in the character, distribution, and intensity of HABs,
2. Produce a review/opinion paper or a high profile journal that will:
 - a. help to guide planning for HAB research holding the greatest promise for advancing our understanding of any climate linkages,
 - b. to provide funding agencies, managers, and interested stakeholders a cutting edge assessment of current knowledge and key gaps in our understanding,
 - c. to identify a limited number of candidate sentinel sampling/monitoring sites for detecting change, if we don't have adequate coverage already, with a prioritized list of variables as part of the assessment, and
 - d. to attract interest in non-HAB researchers who are developing new tools or approaches (molecular, cellular, sensor) that would help HAB researchers capture and incorporate current advances in other fields.
3. Plan an open science meeting for 2015 on HABs and climate change that focuses primarily on the key areas participants feel are likely to provide the most insight.

Recommendation IPHAB-XI.1

**HABS IN A CHANGING WORLD: A NEW GLOBAL APPROACH TO HAB
RESEARCH TO MEET SOCIETAL NEEDS**

The IOC Intergovernmental Panel on Harmful Algal Blooms,

Referring to the joint SCOR-IOC international science programme on the Global Ecology and Oceanography of Harmful Algal Blooms (GEOHAB) as established through IOC Resolution EC-XXXI.1, and the associated GEOHAB Science Plan and associated Implementation Plans,

Referring to IPHAB Resolution IPHAB-X.3 which anticipated that IPHAB would recommend that GEOHAB continue beyond 2013 pending discussions and decisions at its XI Session and that SCOR should be invited to continue as co-sponsor,

Referring to Resolution XXVI-11 of the Twenty-seventh Session of the IOC Assembly recognizing that the need for continued global coordination and regional cooperation on HAB research can be expected to remain at the same level or increase, and the invitation to the Scientific Committee on Oceanic Research (SCOR) to take active part in the process to systematically assess the need for, and potential focus of, a continued global harmful algal bloom research programme,

Noting the conclusions and recommendations of the GEOHAB Synthesis Open Science Meeting, 24–26 April, 2013,

Noting that GEOHAB provided a unique ability to address underlying scientific questions and concerns related to harmful algae and their science-based management,

Noting the achievements and ongoing activities of GEOHAB detailed in the GEOHAB report series and the contributions made to the scientific literature,

Noting that GEOHAB provided an interface between IOC and other international coordinating organizations for science such as SCOR, IOCCG, ICES, PICES, and GEO,

Noting that the GEOHAB Science Plan has been assessed by the GEOHAB Synthesis Open Science Meeting and found to continue to provide a basis for international coordinated research on HABs,

Noting that within the joint framework of IOC and SCOR, GEOHAB is expected to synthesize and conclude its activities by the end of 2013,

Recognizing that to fully realise the benefits of the accumulated investments in GEOHAB and to address new priorities identified by the IOC in collaboration with SCOR, it is necessary to extend a limited number of targeted research and framework activities within the GEOHAB Terms of Reference beyond the end 2013,

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Recognizing also that the Draft IOC Medium Term Strategy for 2014–2021 is moving from global environmental change research to global sustainability research, and that this change will require significant transformations in research processes, including adaptation of institutional arrangements to promote a new era of inter- and trans-disciplinary research aimed at understanding social-environmental process dynamics,

Noting that this research should provide relevant knowledge outputs and innovation that will meet societal needs,

Recommends that a new international research programme be formed on the foundations of the GEOHAB Science Plan, focusing on understanding HABs in the context of global sustainability, with a working name of GlobalHAB;

Further recommends the establishment of a GlobalHAB Scientific Steering Committee in consultation with partner organizations and in accordance with the draft Terms of Reference attached to this Recommendation as Annex I, including;

(i) To draft an Addendum to the GEOHAB Science Plan, extending the scope to include human and ecosystem health, and socio-economic impacts of HABs to enhance sustainable management of the oceans and coastal zone;

(ii) To identify specific targeted research and framework activities within GEOHAB for continuation beyond 2013 as part of GlobalHAB;

(iii) To develop an Implementation Plan that describes a decadal research programme focused on HABs in a Changing World;

Reiterates the invitation to SCOR to cosponsor the Scientific Steering Committee and invites other international scientific coordinating bodies to support GlobalHAB activities;

Urges Member States and their institutions to provide advice and resources to help implement GlobalHAB objectives.

Annex 1

The Scientific Steering Committee of the GlobalHAB Programme will:

1. Develop the Addendum to the GEOHAB Science Plan and a GlobalHAB Implementation Plan based on the recommendations of the GEOHAB Synthesis Open Science Meeting April 2013 and present the draft plan to IPHAB-XII.
2. Coordinate and manage GlobalHAB Research Projects (RPs) in accordance with the amended GEOHAB Science Plan and the GlobalHAB Implementation Plan.
3. Review progress of RPs, identify gaps in knowledge, and initiate new RPs in priority research areas.
4. Foster framework activities to facilitate implementation of GlobalHAB, including dissemination and information tools.

5. Establish appropriate data management activities, such as the SCOR-MBLWHOI- IOC/IODE DOI repository, to ensure access to, sharing of, and preservation of GlobalHAB data, taking into account the data policies of the sponsors, and taking into account ongoing data management activities of other IPHAB Task Teams.
6. Promote comparative and interdisciplinary research on harmful algal blooms by providing coordination and communication services to national and regional research groups, encouraging explicit affiliation with GlobalHAB via an endorsement process.
7. Coordinate, as appropriate, with IOC regional activities ANCA, FANSA, WESTPAC/HAB, and HANA.
8. Collaborate, as appropriate, with other intergovernmental organizations and their subgroups (e.g., IAEA, ICES, PICES, NOWPAP), as well as related research projects (e.g., LOICZ, IMBER), observational systems such as the Global Ocean Observing System and its regional alliances, and initiatives on risks and opportunities of global environmental change and for supporting transformation towards global sustainability.
9. Report regularly to SCOR (if SCOR accepts co-sponsorship) and the IOC Intergovernmental Panel on Harmful Algal Blooms (IPHAB), and the international HAB research community on the state of planning and accomplishments of GlobalHAB, through annual reports and, as appropriate, the GlobalHAB Web site, *Harmful Algae News*, special sessions at scientific meetings, and other venues.
10. Interact with agency sponsors to stimulate the support of GlobalHAB implementation through various mechanisms (e.g., direct support of GlobalHAB initiatives and integration of the GlobalHAB approach in national programs).

Acronyms

ANCA = IOC HAB working group for Central America and Caribbean Sea
 FANSA = IOC HAB working group for South America
 HANA = IOC HAB working group for North Africa
 GLOBEC = Global Ocean Ecosystem Dynamics project
 IAEA= International Atomic Energy Agency
 ICES = International Council for the Exploration of the Seas
 IMBER = Integrated Marine Biogeochemistry and Ecosystem Research project
 IOC = Intergovernmental Oceanographic Commission
 IODE: International Oceanographic Data and Information Exchange (IODE) of the Intergovernmental Oceanographic Commission
 LOICZ = Land-Ocean Interactions in the Coastal Zone project
 MBLWHOI: Marine Biological Laboratory/Woods Hole Oceanographic Institution
 NOWPAP = UNEP Northwest Pacific Action Plan PICES = North Pacific Marine Sciences Organization SCOR = Scientific Committee on Oceanic Research
 WESTPAC/HAB = HAB Project of the IOC Sub-Commission for the Western Pacific

Restricted distribution



IOC-XXVII/3 prov. Pt.3
Paris, 8 October 2013
Original: English

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION
(of UNESCO)

Twenty-seventh Session of the Assembly
Paris, 26 June - 5 July 2013

DRAFT SUMMARY REPORT

Extract Part 3

(Agenda item 5.4.2)

5. STRATEGIC DEVELOPMENTS

5.2 OCEAN-RELATED HAZARDS

5.4.2 Intergovernmental panel on Harmful Algal Blooms (IPHAB)

1. The Chair of the IOC Intergovernmental Panel on Harmful Algal Blooms (IPHAB), Dr Robert E. Magnien (USA), introduced this item and presented the report, work plan, decisions and recommendations of the Eleventh Session of the IOC Intergovernmental Panel on Harmful Algal Blooms Paris, 28–30 April 2013.
2. The IPHAB Chair emphasized the decisions and recommendations made regarding an international strategy for international cooperative research on HABs in a changing world: A New Global Approach to HAB Research to Meet Societal Needs; the development of a Global HAB Status Report; capacity building; a focussed effort to address Ciguatera, and the regional development of the Programme.
3. The IPHAB Chair requested the assistance of the Assembly in ensuring participation in IPHAB of the Member States not already members and recognition in the appropriate national agencies and institutions of IPHAB.
4. The IPHAB Chair urged the IOC Member States to carefully match the HAB Programme Work Plan with national priorities and potential funding in order to actively interact with and support its implementation.
5. The Assembly reiterated the widespread and permanent impacts of HAB events on fisheries, aquaculture, human health, and tourism. The Assembly confirmed the importance of shared efforts and cooperation in both HAB research and management practises. The Assembly underlined the importance of coordination between global and regional IOC HAB Programme activities to avoid duplication, enhance synergies and economise resources. The Assembly welcomed the development of a regular Global HAB Status Report and saw it as complimentary to the World Ocean Assessment. Furthermore, the development of GEOHAB into a research agenda for the coming decade entitled GlobalHAB was welcomed including a strong focus on Ciguatera jointly with WHO and FAO. The Assembly noted the long-term capacity building efforts of the IOC HAB Programme, particularly those for African Member States. The initiative on HABs and desalination was commended.
6. The Assembly expressed its appreciation to Denmark for its longstanding commitment to hosting the IOC Science and Communication Centre on Harmful Algae and to Japan for its longstanding support to WESTPAC-HAB. Denmark confirmed its commitment to do all it can to continue to host the Centre.
7. The representatives of 15 Member States and PICES took the floor. The following Member States and Organization chose to provide records of their plenary intervention on this agenda item for the informational annex to the meeting report: Republic of Korea, Thailand, USA and PICES.
8. The Assembly adopted Decision IOC-XXVII/Dec.5.4.2.

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The Assembly,

Recalling IOC Resolution XVI-4, which established the Intergovernmental Panel on Harmful Algal Blooms,

Having considered the Executive Summary Report of the 11th Session of the IOC Intergovernmental Panel on Harmful Algal Blooms (IPHAB), its seven Decisions and four Recommendations and the Work Plan for 2014–2015 adopted at the Session (IOC/IPHAB-XI/3s),

Taking into consideration the preoccupying impact of HAB on public health, food security, the development of tourism and a substantial proportion of economic activities in the world,

Recognizing that regional, national, and institutional requirements for management of HAB impacts, along with the IOC High Level Objectives, that drive IOC HAB Programme research and capacity development activities, have proven highly valuable to Member States over almost two decades; that the IOC fulfils a unique role in coordinating and implementing international and regional cooperation on HAB research, management and capacity development; and that the need for this continued coordination and regional cooperation can be expected to remain at the same level or increase,

Noting with satisfaction that IPHAB has continued to provide a strong and efficient mechanism to respond to new HAB-related problems experienced by Member States and to leverage resources from diverse sources to focus on priority needs,

Takes note of the Executive Summary Report of IPHAB-XI and the recommendations contained therein (IOC/IPHAB-XI/3s);

Notes that the IOC will help protect human health, economic interests and natural resources through its expanded focus on Ciguatera in cooperation with the WHO and FAO and by coordinating research needed by Member States through the Global HAB Programme;

Notes further that the development of a Global HAB Status Report is complementary to the World Ocean Assessment to provide for the first time a picture of the global distribution of HABs, their threats and relationships to nutrient enrichment and other causes;

Requests the IOC Executive Secretary to convene the 12th Session of the Panel prior to the 28th Session of the Assembly;

Invites SCOR to co-sponsor the Scientific Steering Committee for Global HAB and encourages active joint participation in the development and implementation of the science agenda;

Agrees that the regular budget for these activities will be considered as part of the overall IOC Programme and Budget resolution XXVII/DR.(6.1, 6.2);

Expresses its appreciation to the Government of Denmark for hosting and supporting the IOC Science and Communication Centre on Harmful Algae, as well as to other donors and Member States who are providing financial and in-kind support for the HAB Programme;

Urges funding agencies and institutions in IOC Member States to assist in the mobilization of funding that will ensure the implementation of the IPHAB Work Plan.

3.2 Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) (joint with IGBP)

Hall, Burkill

Terms of Reference

Agreed by IGBP and SCOR, April 2004

- To develop the IMBER Science Plan and Implementation Strategy, in accordance with guidance from the sponsoring organisations.
- To oversee the development of IMBER in accordance with its Science Plan and Implementation Strategy.
- To collaborate, as appropriate, with related projects of the sponsors IGBP and SCOR, and other related programmes and organisations (e.g., IHDP, DIVERSITAS, IOC and the Global Ocean Observing System (GOOS), etc.)
- To establish appropriate data management policies to ensure access to, sharing of, and preservation of IMBER data, taking into account the policies of the sponsors.
- To report regularly to SCOR and IGBP on the state of planning and the accomplishments of IMBER.

The IMBER SSC, its subsidiary groups and International Project Office shall operate in accordance with the operating procedures for IGBP Projects and the requirements of the other co-sponsors.

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**Integrated Marine Biogeochemistry and
Ecosystem Research (IMBER)**

Annual Report to SCOR, September 2013

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Annex 1 – New endorsed projects

Annex 2 – National IMBER Contributions

A. Introduction

IMBER (www.imber.info) is an international global environmental change research project with the goal to develop a comprehensive understanding of, and accurate predictive capacity for, ocean responses to accelerating global change and the consequent effects on the Earth System and human society. The challenge of the scientific community is to understand inter-relationships between biogeochemical cycles and ecosystems, and to quantify and predict responses of the marine system to natural and anthropogenic perturbations, on time scales ranging from years to decade, with local, regional and global focus.

IMBER research activities are organised around four themes that focus on interactions between biogeochemical cycles and marine food webs, the sensitivity to global change, feedbacks to the Earth System, and responses of society. IMBER research is supported by a network of 35+ national contributions, and by four regional research programmes, seven topical working groups, more than 35 endorsed projects, and a range of approaches to facilitate synthesis and integration, and strategic collaboration with other international research projects, programmes and initiatives.

Since its initiation in 2005, IMBER has placed a priority on coordination and networking activities that bring together diverse research communities to address IMBER research goals. IMBER has accomplished much during its first eight years, as evidenced by the many special issues of peer-reviewed journals and books that have been produced by the working groups and regional programmes (www.imber.info/index.php/Products/Publications).

IMBER is now entering the last two years of its initial 10-year science plan. At the same time, the global environmental change (GEC) research landscape is evolving. The Future Earth initiative, which is focused around three themes (*Dynamic Planet*; *Global Development*; and *Transformations toward Sustainability*), is developing, and the International Geosphere-Biosphere Programme (IGBP), IMBER's other sponsor, will end in December 2015. The transition towards Future Earth is potentially important for all GEC projects such as IMBER. IMBER has a history of undertaking activities that interconnect natural and social marine sciences and promoting integration across disciplines. As a result, the IMBER community is well placed to take the lead on developing the marine-focused efforts under Future Earth and proposing new research directions.

The IMBER Open Science Conference, which will take place in June 2014 in Bergen, Norway (www.imber.info/index.php/Meetings/IMBER-OSC-2014), will be important in developing directions for marine research at the international level for the next 5-10 years. The outputs from the Open Science Conference will provide a basis for a request to SCOR for a five-year project extension in the fall of next year.

B. Selection of IMBER Science Highlights, 2012-2013

Salihoğlu, B., S. Neuer, S. Painting, R. Murtugudde, E.E. Hofmann, J.H. Steele, R.R. Hood, L. Legendre, M.W. Lomas, J.D. Wiggert, S. Ito, Z. Lachkar, G.L. Hunt Jr., K.F. Drinkwater, and C.L. Sabine. 2013. Bridging marine ecosystem and biogeochemistry research: Lessons and recommendations from comparative studies. *Journal of Marine Systems*, 109-110 161-175.

Linked to IMBER IMBIZO II Workshop on regional comparative studies

Oceanic and coastal systems are integrated across space and time scales that span several orders of magnitude and include complex interactions among and within diverse and interlinked communities with implications for biogeochemical cycling. To understand and predict the effects of anthropogenic global change (e.g., warming temperatures, increasing acidification, harvesting resources) on the marine ecosystem, and its responses, there is growing interest in combining information on oceanographic and biogeochemical processes and on organisms and communities, ranging from microbes to higher trophic levels. Comparative studies of similar marine and coastal biomes offer a means to improve our understanding of the sensitivity of the key features of an ecosystem (e.g., habitat quality, food web components, and biogeochemical cycles) to planned and unplanned perturbations at different time and space scales, by bringing attention to the critical processes that differentiate one system from another and result in differences in ecosystem response to a changing ocean system.

Comparative studies based on long-term observations at fixed time-series stations make it also possible to evaluate long-term changes in the physical and biological environment, such as those driven by climate patterns. Moreover, based on a minimalistic observational framework grounded within a conceptual model, comparative studies could sometimes be a suitable alternative to costly and complex research endeavours designed to provide detailed end-to-end

assessment of marine ecosystem status. The understanding gained from these comparative studies allows development of models for investigating of potential future states and predicting responses of present-day marine and coastal ecosystems (Fig. 1).

Recently, for improved ecosystem-based management, end-to-end models that combine bottom-up and top-down components have been developed (Table 1). These large, complex models are intended for “strategic management evaluations” of particular ecosystems, rather than comparisons across several systems. An alternative is to combine aggregated versions of existing food-web models of the upper trophic levels, with NPZD formulations of the microbial web, and with simplified representations of the main physical forcing. Cross-ecosystem, multi-model comparisons are difficult to conduct, but essential to evaluate the robustness of the ecosystem responses to climate change and/or anthropogenic forcing. To conduct

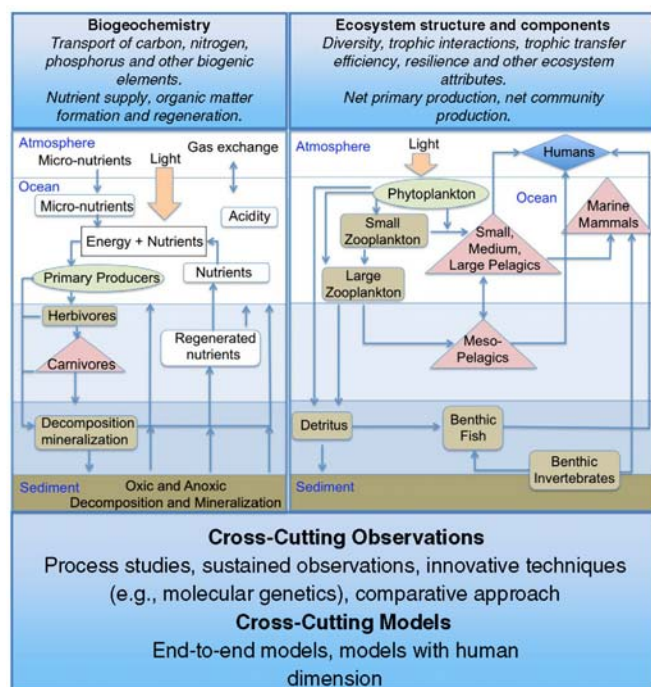


Figure 1. Biogeochemistry and ecosystem processes to be integrated in comparative studies, their interactions, and cross-cutting tools for comparison.

these kinds of studies, support by international activities such as IMBER is needed. The focus of

the IMBER project on interactions and feedbacks between food webs and biogeochemical cycling brings together two areas of marine science that have typically proceeded in parallel, with little cross integration.

The observational and modelling activities now underway through IMBER have a focus on end-to-end ecosystem studies, which is already influencing the structure of models and the types of observations. Within the IMBER regional programmes, comparative studies are underway which are providing synthesis and integration of historical and diverse data sets, the results of which provide a basis for across-region comparative studies. The IMBER focus on comparative studies from the outset will help ensure that the datasets and models are appropriate to undertake these studies. One challenge to the science community is to extend the comparative studies of the natural system to include human, social, economic and cultural effects. The global vision for clean, safe, biologically diverse and productive oceans and seas is the basis for managing sustainable human utilization of the goods and services provided by the seas.

This challenge requires the development of methods/metrics to describe the state of an ecosystem and mechanisms to minimize the impacts of human activities to avoid undesirable disturbances and tipping points. Ecosystem studies typically focus on key linkages between hydrography, pelagic food webs, benthic food webs and higher trophic levels such as fish.

Model	Description
NPZD (Nutrients, Phytoplankton, Zooplankton and Detritus)-type models	Represent lower trophic levels and biogeochemical cycles in marine ecosystems as Eulerian state variables with mathematically specified flows between each compartment.
Ecosim with Ecopath (EwE)	Defines the food web in the form of functional groups representing species and/or groups of species linked by trophic interactions.
ERSEM and ERSEM II	Among the first examples of end-to-end models, fish and seabirds were inclusions in the original models.
NEMURO.FISH	Formed by addition of a fish model to the detailed NPZD (nutrient, phytoplankton, zooplankton, detritus) model NEMURO.
SEAPODYM	A complex example of the coupled approach, which includes a biogeochemical model, vertically structured mesopelagic fish and an age-structured fish population model that can also include fishing pressure.
APECOSM	Uses size spectra to represent forage layers in models focusing on top predators.
ATLANTIS	Involves the explicit inclusion of physical and biogeochemical system components to higher trophic levels and incorporates the potential to consider human dynamics in some detail.
OSMOSE	A multispecies and Individual-based model (IBM) which focuses on fish species.
Multispecies Virtual Population Analysis (MSVPA) model	A trophic dynamics model focusing on interactions between fish species within exploited communities

Integrated studies of biogeochemistry and food webs need to be underpinned by one or more conceptual models of key ecosystem processes relevant to the study, and identification of the key high level (e.g., policy or societal) and scientific questions to be addressed. Together these can be used to inform field measurements required and the appropriate selection of models and other investigative tools.

New research endeavours should ensure that the results obtained are relevant for regional comparative works, especially as responses of marine ecosystems to global change are expected to differ among biogeographical or biogeochemical provinces. Understanding and defining what these responses might be is critical to the development of mitigation strategies and management policies. Well-designed comparative analyses, based on observations, models or both should be applied within and across ecosystems. As such, they provide an approach for identifying key processes and constraining the range of potential ecosystem responses.

Table 1. Examples of models combining (green-shaded) lower (light blue, top) and higher (light blue, bottom) trophic levels suitable for comparative studies.

Bakker, D.C.E., B. Pfeil, K. Smith et al. 2013. An update to the Surface Ocean CO₂ Atlas (SOCAT version 2). *Earth System Science Data Discussion*, 6, 465-512. [DOI:10.5194/essdd-6-465-2013](https://doi.org/10.5194/essdd-6-465-2013)

Linked to the SOLAS-IMBER Carbon – ‘Surface Ocean System’ and ‘Interior Ocean Carbon’ Groups

As a result of a large, international, collaborative effort of the marine carbon research community, the Surface Ocean CO₂ Atlas (SOCAT, www.socat.info) project was initiated in 2007 with the aim of providing a comprehensive, publicly available, regularly updated, quality-controlled, global data set of marine surface carbon dioxide measurements for the global oceans and coastal seas, following internationally agreed procedures and regional review. In addition, SOCAT gives open access to a 1° latitude by 1° longitude gridded product of mean monthly surface water *f*CO₂ (fugacity of carbon dioxide) data with minimal temporal or spatial interpolation and with a higher 0.25° latitude by 0.25° longitude resolution for the coastal seas.

The culmination of much hard work in data collection, data assembly and quality control by many seagoing marine carbon scientists around the world, SOCAT version 2, with 10.1 million surface water *f*CO₂ values from 2,660 cruises spanning more than four decades (Nov. 1968 – Dec. 2011), was presented publicly in June 2013 at the 9th International Carbon Dioxide Conference (ICDC-9) in Beijing, China (Figs. 2, 3).

The SOCAT products highlight the response of surface water *f*CO₂ and the oceanic CO₂ sink to increasing levels of atmospheric CO₂ in a changing climate, and are used in process studies of spatial and temporal (seasonal, inter-annual and decadal) variability and trends in surface water *f*CO₂, for example, in the North Atlantic, in the Pacific Ocean, in coastal seas, in the Arctic Ocean, in seasonally ice-covered Southern Ocean regions, near remote islands and oceanographic fronts.

The international importance of SOCAT is evident from the many recent scientific articles using SOCAT data products for quantification of the ocean carbon sink, process studies and ocean carbon modelling. Applications of SOCAT include process studies, quantification of the ocean carbon sink and its spatial, seasonal, year-to-year and longer-term variation, as well as initialisation or validation of ocean carbon models and coupled-climate carbon models.

Regular updates to SOCAT will extend its data record, improve its quality control, and will become a crucial tool in quantification and modelling of changes in oceanic CO₂ uptake and in global climate change research and assessments. Regular future SOCAT releases will require sustained funding for key players.

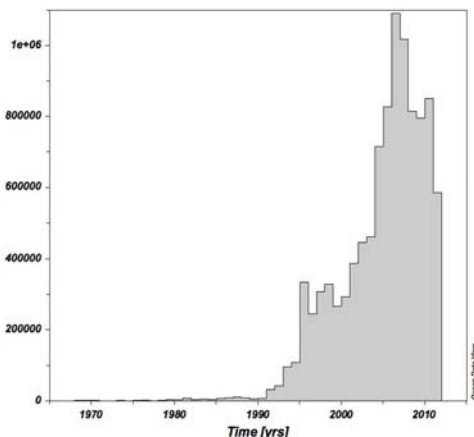


Figure 2. Number of annual data points for the 1968-2011 period included in SOCAT v.2

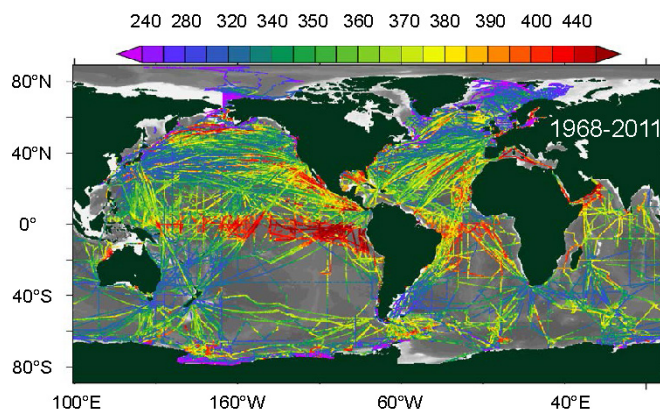


Figure 3. The global distribution of surface water fCO_2 values in SOCAT v.2 for 1968 to 2011 (from Bakker et al. (2013), *ESSDD*, 6, 465–512)

Gaichas, D., R. Gamble, M. Fogarty, H. Benoît, T. Essington, C. Fu, M. Koen-Alonso, and J. Link. 2012. Assembly rules for aggregate-species production models: simulations in support of management strategy evaluation. *Marine Ecology Progress Series*, 459, 275-292. Linked to the IMBER ESSAS regional programme

The concept of biological production has long served as a cornerstone in the development of the theory of resource management. An early focus on this issue in fisheries management research distinguished it from other approaches in population biology in the emerging field of ecosystem-based fisheries management (EBFM) that emphasizes sustainability at multiple levels of organization beyond single target species. Biological reference points (BRPs) for aggregated specific groups are then required, that help optimize yields while preventing overexploitation of individual species. The tradeoffs between yield and biodiversity objectives must be evaluated for a wide range of aggregation strategies using multi-species surplus production models and comparing several simulated fish communities.

Fish production parameters and BRPs (e.g., maximum sustainable yield, MSY) were estimated using a simple assessment model applied to each aggregated time series. Multi-species precautionary reference points could be defined that meet both yield and biodiversity objectives across full system, taxonomic, habitat, feeding, and size-based aggregations. Aggregation strategies were best able to meet both objectives when species with broadly similar productivity, life history, environmental sensitivity, and species interactions were aggregated. Implementation of EBFM requires a better understanding of the consequences of stock-aggregate management in achieving the maximization of sustainable fishery yields and biodiversity, that is, the prevention of collapse or extinction. The simulation modelling of hypothetical fish communities make it possible to explore how the estimation of BRPs at different levels of species aggregation affects the simultaneous achievement of the objectives of yield and of biodiversity, that is, maintaining ecosystem structure (Figs. 4, 5).

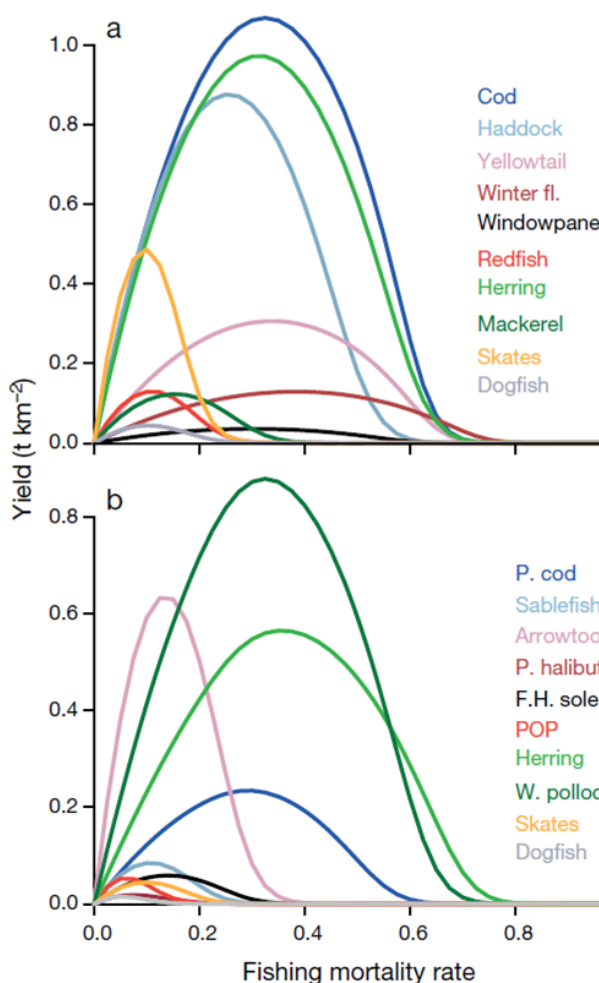


Figure 4. Yield curves for simulated 10-species interacting fish communities: (a) Georges Bank; (b) Gulf of Alaska; comparable species have similar colours. fl.: flounder; P.: Pacific; F.H.: flathead; W.: Walleye

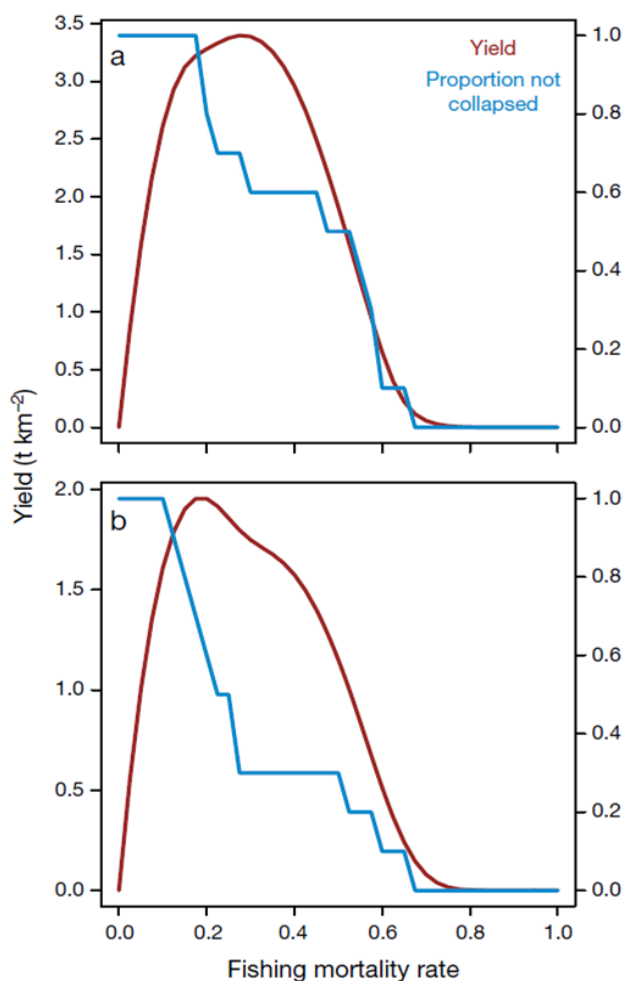


Figure 5. Full 10-species system aggregate yield and collapse curves (where collapse is defined as biomass <10% of unfished biomass) for (a) Georges Bank; (b) Gulf of Alaska

Management considerations based on simple extensions of traditional single-species production models provide one avenue for recasting the harvesting problem in a context that is familiar to fishery managers while accommodating a broader multi-species perspective, particularly for those stocks that are caught together in multi-species fisheries, interact highly, or have similar production characteristics. It is possible to achieve multiple EBFM objectives by managing aggregate species groups. And our simple assessment method estimated BRPs reasonably well for many species and aggregates without explicitly including species interactions, but showed some bias even with the high-quality simulated ‘data’ we used. However, poor aggregations sacrifice biodiversity for yield, leading to severely depleted (or extinct) stocks within the aggregate, as well as more subtle effects such as loss of genetic diversity. In managing species complexes, it appears that modest reductions from aggregate fishing mortality rate at MSY have the dual benefits of maintaining biodiversity and buffering against environmental uncertainty (Figs. 6, 7).

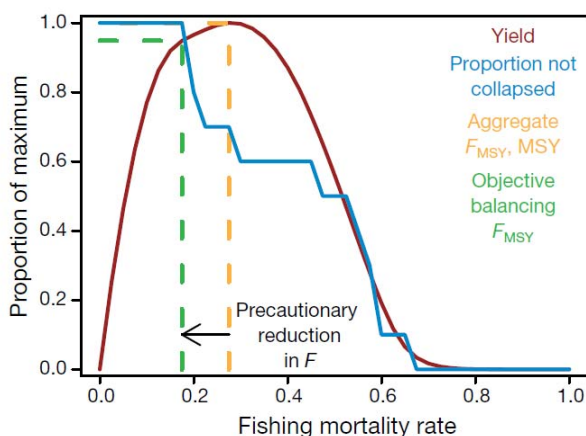


Figure 6. In multispecies complexes, fishing mortality rate F can be reduced from aggregate F_{MSY} (MSY , maximum sustainable yield) to prevent collapses. For the full 10-species Georges Bank model, nearly 95% of MSY can be achieved with no species dropping below 10% of unfished biomass

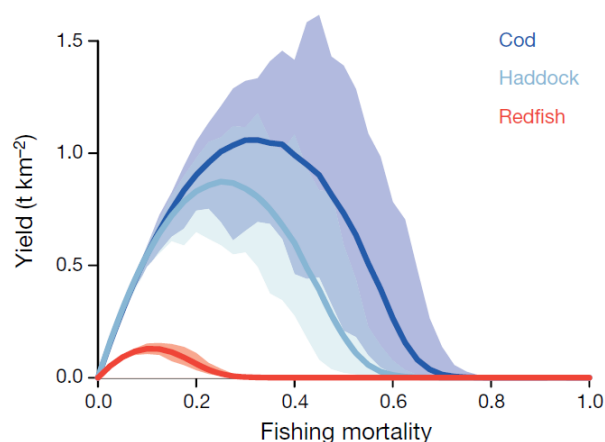


Figure 7. Average yield curves (lines) with ranges (shading) from 1000 stochastic runs for the Georges Bank groundfish complex

Glaser, M., P. Christie, K. Diele, L. Dsikowitzky, S. Ferse, I. Nordhaus, A. Schlüter, K. Schwerdtner Mañez, and C. Wild. 2012. Measuring and understanding sustainability-enhancing processes in tropical coastal and marine social-ecological systems. *Current Opinion in Environmental Sustainability*, 4, 300-308.

Linked to IMBER HDWG and CMWG activities

Tropical coastal and marine social-ecological systems (CM-SES) are diverse, complex and dynamic, facing special challenges as hotspots of biodiversity and centres of population growth, with high rates of direct human dependence on natural resources and a great diversity of stakeholders, institutions and scales of processes. CM-SES are also frequently beset by poverty, conflict, human security and well-being problems, weak social policy regimes and globalization-related economic and cultural pressures. Bio-geophysical and social vulnerabilities reinforce each other. In a collaborative effort between natural and social scientists, a number of processes have been identified that drive desirable social-ecological dynamics, link the debates on ecosystem services and social-ecological systems analysis and offer a framework for identifying key social-ecological processes. The social-ecological systems (SES) framework highlights the complex feedbacks between humanity and nature which can create unsustainable dynamics such as over- and destructive fishing, coastal erosion and pollution and undesirable outcomes such as degraded ecosystems and impoverished ecosystem users (Fig. 8).

Indicators are required to help identify the processes in a system, its state evolution and its management needs. Single measurements of state indicators show a system's position along multiple axes, while process indicators assess and explain its trajectory and speed of change. Sustainability science focuses on the state of such systems and mostly analyses undesirable social-ecological outcomes. Sustainability objectives need to be negotiated between disciplines

and stakeholders and effective monitoring needs to create transparency on processes and outcomes. Social-ecological sustainability in CM-SES is closely linked to system resilience and capacity to transform, but identification of the conditions under which sustainable human-nature feedbacks occur requires greater attention. Undesirable processes such as ocean acidification, over-fishing, biodiversity loss, and nutrient and chemical pollution drive oceanic and coastal systems to and beyond sustainability thresholds and must therefore also be a focus of scientific attention. Indicators on key, and often context-specific, ecological, socio-economic, and social-ecological processes are needed to provide meaning to regular measurements of system state by allowing for an understanding of the underlying causes of identified system changes.

More comparative research on sustainability policy is required, including the linkages between research, policy making, and stakeholder decision-making. As social-ecological analyses become more complex and increasingly global, stakeholder engagement in analysis and decision-making needs to expand, and research and policy-making need to diversify ways of actively engaging stakeholders at multiple levels.

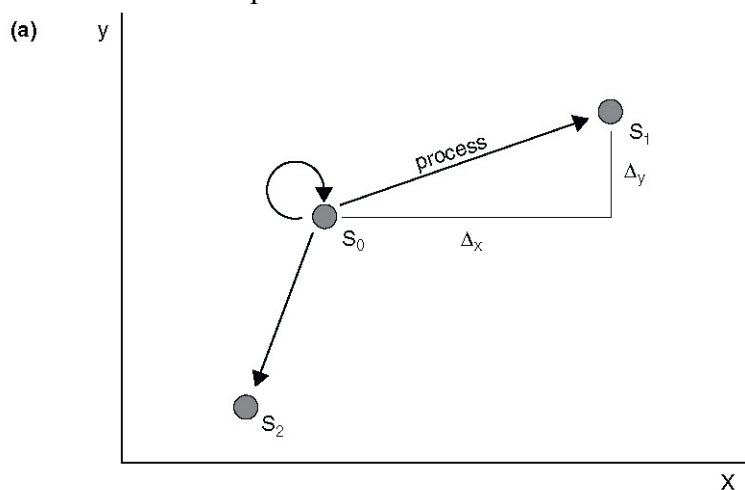
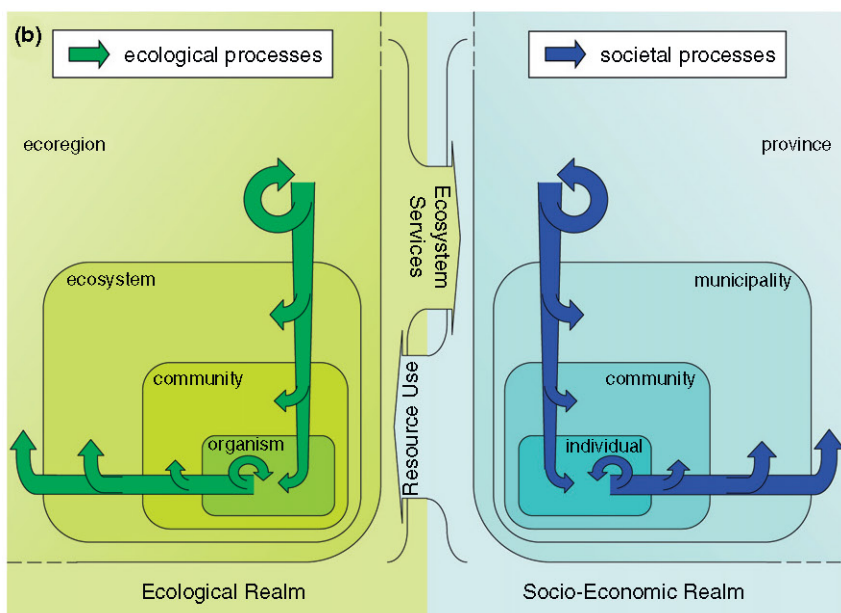


Figure 8

(a) System status (S_0 , S_1 , S_2) and processes of change. Only two axes are presented but n dimensions are theoretically possible in the coordinate system. Processes (defined as change over time) are indicated by deltas / arrows. A process can maintain or alter the system state.



(b) Realms of a social-ecological system contain multiple levels, and the processes connecting them. Shown system levels are exemplary and extendable to include further lower or higher levels. Social-ecological systems analysis needs to identify the important components and processes of the system under study by applying indicators.

IMBER Regional Programmes

Ecosystem Studies of Sub-Arctic Seas (ESSAS) Regional Programme

The ESSAS programme (www.imr.no/essas) focuses on the impacts of climate change on sub-Arctic marine ecosystems and their sustainability. The ESSAS Annual Science Meeting (January 2013, Hakodate, Japan) entitled, ‘*Spatial Dynamics of Subarctic Marine Ecosystems*’ focused on bioenergetics of sub-polar fish species; Arctic-Subarctic interactions; human dimensions of Subarctic seas exploring fisheries and fishing communities; and future directions and activities of ESSAS.

At the annual ESSAS SSC meeting, also held in January 2013, Dr. Sei-Ichi Saitoh (Hokkaido University, Japan) was appointed as the third SSC co-chair, the ‘*Working Group on Bioenergetics of sub-Arctic fishes*’ was launched, and three new Working Groups (*Human Dimension, Comparative Paleo-Ecology in Sub-Arctic Seas* and *Arctic-Subarctic Interactions*) were accepted for further development.

ESSAS held a joint workshop with the IMBER ICED programme in May 2012, in Yeosu, Korea during the 2nd ICES/PICES/IOC International Symposium on, *Effects of Climate Change on the World’s Oceans*. This workshop, ‘*Effects of climate change on advective fluxes in high latitude regions*’, reviewed the role of advection on the ecology of these high-latitude regions, including heat and nutrient fluxes as well as the advection of flora and fauna, and developed likely scenarios of these advective fluxes under climate change, and comparative studies of the responses in the Arctic and Antarctic regions.

ESSAS also organised sessions on, ‘*Subarctic-Arctic Interactions: Ecological Consequences*’, at the ICES Annual Science Conference (September 2012, Bergen, Norway) and the PICES Annual Meeting (October 2012, Hiroshima, Japan). These examined the influence of water exchange between the Arctic basin and surrounding shelves, and the warmer sub-Arctic basin on the physical and biological/ecological conditions in the two regions.

www.ices.dk/iceswork/asc/2012/themesessions/Abstracts%20Session%20M_ED.pdf and www.pices.int/meetings/annual/PICES-2012/2012-background.aspx

The 28th Lowell Wakefield Fisheries Symposium, *Responses of Arctic Marine Ecosystems to Climate Change* (March 2013, Anchorage, Alaska), organized by Franz Mueter (ESSAS co-chair) focused on present and future responses of Arctic marine ecosystems to climate change at all trophic levels, from plankton to marine mammals to humans.

ESSAS-related publications include several papers, special issues, and special sections in the *ICES Journal of Marine Science*, *Marine Ecology Progress Series*, *Deep Sea Research Part II: Topical Studies in Oceanography* and *Progress in Oceanography*; derived from the ESSAS-related projects (ISE, BEST/BESIRP, TROPHARCT, NORCAN, MENUUI, CAMEO and CANUSE) and from the May 2011 ESSAS OSM; and focusing on topics such as subarctic fish and crustacean populations - climate effects and trophic dynamics; comparative analysis of marine fisheries production; understanding ecosystem processes in the eastern Bering Sea; and harvested fish stocks in a changing environment. A special volume of *Progress in Oceanography*

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dedicated to former ESSAS SSC member, Bernard Megrey, is in preparation on the theme “Modeling and observational approaches to understanding marine ecosystem dynamics”.

Future ESSAS activities:

- The ESSAS ASM and SSC meeting will be held in April 2014 in Copenhagen, Denmark.
- ESSAS will convene a session on “*Changing ecosystems in sub-Arctic and Arctic regions*” at the IMBER OSC in June 2014, Bergen, Norway.

Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED) Regional Programme

The ICED programme aims at a better understanding of the climate interactions in the Southern Ocean, the implications for ecosystem dynamics, the impacts on biogeochemical cycles, and the development of sustainable management procedures. See www.iced.ac.uk/index.htm

During the IPY 2012 Conference (April 2012, Montreal, Canada), ICED scientists co-convened a session on '*Polar marine ecosystems: status and change*', that focused on advances in research in polar marine ecosystems, particularly those relating to IPY. ICED scientists were also prominent at the Polar Educators workshop, APECS workshop and at discussion panels.

As mentioned above, an ESSAS-ICED workshop at the 2nd ICES/PICES/IOC International Symposium (May 2012, Yeosu, Korea) compared the Arctic and sub-Arctic sectors for the Atlantic and Pacific and the Antarctic regions, with particular emphasis on the role of advection.

ICED sponsored the '*Southern Ocean Sentinel*' Workshop (May 2012, Hobart, Australia), to help develop the 'Southern Ocean Sentinel Monitoring' programme entitled '*Southern Ocean Ecosystem Change and Future Projections*'. It focused on the state of Southern Ocean food webs, how these might change in the future, and how to measure the specific impacts of climate change and ocean acidification.

During the XXXII SCAR Open Science Conference, July 2012, Portland, USA, a multidisciplinary ICED session was organised on '*Understanding the response of Southern Ocean ecosystems to climate change and exploitation*'.

In the framework of the EUR-OCEANS flagship programme on '*Polar Ecosystem Change and Synthesis*' (PECS), the European branch of ICED held two workshops on “*Identifying key links between biogeochemical processes and food web structure*”, in November 2012, Bremerhaven, Germany and in May 2013, Brussels, Belgium, to further discuss the coordination, integration and leadership of polar marine ecosystem science within Europe, and to develop a strategic briefing entitled “Polar Marine Ecosystems Research: Strategic directions for the EU Research Area”. This document highlights why research on polar marine ecosystems should be an essential component of the EU Research Area through the Horizon 2020 Work Programmes, and promotes collaborative research within Europe and internationally. www.eur-oceans.eu/sites/default/files/activities/2011/25935/Strategy%20EU%20Polar%20MER.pdf

ICED-related Publications include several papers, special issues, and special sections in *Nature Geoscience*; *Global Change Biology*; *Annual Review of Ecology, Evolution, and Systematics*; *Deep Sea Research Part II: Topical Studies in Oceanography*; *Marine Ecology Progress Series*; *Journal of Marine Systems*; *Progress in Oceanography*; *Current Opinion in Environmental Sustainability* and *Deep Sea Research Part I: Oceanographic Research Papers*; along with

several contributions to the 2012 book entitled “*Antarctic Ecosystems: An Extreme Environment in a Changing World*” ([DOI:10.1002/9781444347241](https://doi.org/10.1002/9781444347241)).

Future ICED activities:

- An ICED workshop on “*Circumpolar food webs and scenarios of change*” will be held in Cambridge, UK, November 2013.
- ICED will convene a session on “*Detecting, projecting and managing the impacts of change in Southern Ocean ecosystems*” at the IMBER OSC in June 2014, Bergen, Norway.
- The re-development of the online fieldwork map tool is underway, and a Southern Ocean wiki is under development, led by the ‘Sentinel’ programme.

CLimate Impacts on Oceanic TOP Predators (CLIOTOP) Regional Programme

The CLIOTOP programme aims to use a worldwide comparative approach to identify the impact of both climate variability and fishing on the structure and function of open ocean pelagic ecosystems and their top-predator species. See www.imber.info/CLIOTOP.html

The 2012 CLIOTOP SSC meeting held in September 2012 in Hobart, Australia, reviewed the progress of the CLIOTOP working groups, including synthesis publications, database development, analytical tools, dedicated workshops, and conference sessions and presentations. Olivier Maury stepped down as CLIOTOP SSC co-chair but remains as an SSC member, and has been replaced as CLIOTOP co-chair by Kevin Weng, University of Hawaii, USA, from January 2013.

The 2013 CLIOTOP SSC meeting and the 2nd CLIOTOP Symposium focusing on ‘*Certainty of change in pelagic systems – detection, attribution, and prediction*’ were held in February 2013, Nouméa, New Caledonia. The symposium brought together experts with different physical, biological, social perspectives to discuss cross-cutting themes such as ‘*Blue economy – what role for pelagic species and ecosystems?*’; ‘*Pelagic conservation-fisheries management conflicts – maximising dual objectives*’; ‘*Pelagic-coastal linkages – food and conservation*’ (www.imber.info/index.php/News/Newsletters/Issue-n-23-April-2013).

In an attempt to align CLIOTOP’s overall plan and working group objectives with the goals of IMBER as earlier requested by the IMBER SSC, the CLIOTOP SSC is taking a more applied outcome-oriented approach that should also be more compatible with national funding initiatives. Indeed, national programmes remain the dominant source of funding, which have limited several of the global comparative approaches proposed by CLIOTOP. In some countries, the focus of global change research is shifting from understanding the impacts of climate change to developing adaptation options. Consequently, developing adaptation options for open ocean and fisheries management bodies are likely to become a major focus beyond the current phase of CLIOTOP research. The CLIOTOP SSC also recognized that the connections with the activities of the other IMBER regional programmes relevant to research on top predators should be improved.

A CLIOTOP-associated session on ‘*Interdisciplinary Approaches to Cephalopod Biology*’ was organised at the ‘Cephalopod International Advisory Council’ Symposium, in October 2012, Florianópolis, Brazil.

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CLIOTOP-related publications include several papers, special issues, and special sections in *Climatic Change*; *Deep Sea Research Part II: Topical Studies in Oceanography*; *Journal of Marine Systems*; *Reviews in Fish Biology and Fisheries*; *Aquaculture Environment Interactions*; and *Fish and Fisheries*, and focusing on topics such as: Climate and oceanic fisheries; Squids and top predators.

Future CLIOTOP activities:

- A special issue of *Deep Sea Research Part II: Topical Studies in Oceanography* is in preparation following the 2nd CLIOTOP Symposium.
- CLIOTOP will convene a workshop entitled “*Beyond ‘Z’: what modelers need and empiricists have to offer to better incorporate higher trophic levels and humans in end-to-end models*” and a session on “*The pivotal role of the mesopelagic functional groups in biogeochemical cycles*” at the IMBER OSC in June 2014, Bergen, Norway.
- The 3rd CLIOTOP Symposium is scheduled for June 2015.

Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER) Regional Programme

SIBER (co-sponsored by the Indian Ocean Global Ocean Observing System, IOGOOS), is the newest IMBER regional programme, and focuses on understanding climate change and anthropogenic forcing on biogeochemical cycles and ecosystems in the Indian Ocean (www.imber.info/index.php/Science/Regional-Programmes/SIBER and www.incois.gov.in/Incois/siber).

The 3rd SIBER SSC meeting took place in October 2012 in Cape Town, South Africa, in conjunction with the Chapman Conference on the Agulhas Current System, in close liaison with CLIVAR Indian Ocean Panel (IOP), IOGOOS and the IndOOS Resource Forum (IRF), and to help reaching out to the relevant South African research community. The 4th SIBER SSC meeting took place in July 2013, Lijiang, China, again in close liaison with the CLIVAR IOP.

SIBER organised a session on ‘*Physical and biogeochemical processes in the Indian Ocean: Recent progress and toward future collaborations*’ during the Asia Oceania Geosciences Society (AOGS) – AGU Western Pacific Geophysics Meeting (WPGM) Joint Assembly meeting in August 2012, Singapore.

The SIBER mid-term symposium will be held in 2015, in conjunction with the 50th anniversary celebration of the International Indian Ocean Expedition (IIOE-2) (www.incois.gov.in/Incois/iioe/index.jsp and http://hab.ioc-unesco.org/index.php?option=com_oe&task=viewDocumentRecord&docID=11117).

SIBER researchers are making substantial contributions to the design and deployment of the Indian Ocean Observing System (IndOOS) / Research moored Array for African-Asian-Australian Monsoon Analysis and prediction (RAMA) for physical and biogeochemical observatories. Biogeochemical sensors deployed at a few sites have already provided data that was presented at the AOGS 2012 meeting, and in late 2013, additional biogeochemical sensors will be deployed at two other reference sites, provided by the Bay of Bengal Large Marine Ecosystem (BOBLME) project and by NOAA/RAMA. Under the IOGOOS framework, relevant activities also focus on issues of local or global importance, such as monsoons and ENSO, and also include capacity building, modelling and forecasting.

Efforts are proceeding to establish and support a SIBER Regional Office in Australia, sponsored by the Australia's Integrated Marine Observing System (IMOS) and the IOC Perth Office.

Overall, SIBER has strong collaboration with various regional actors (e.g., Indian Ocean Panel of the Variability and predictability of the ocean-atmosphere system project CLIVAR, and IOGOOS) and in this respect has developed a useful model for CLIVAR-IMBER collaboration.

Future SIBER activities:

- A SIBER special issue of *Biogeosciences* is in preparation on *Current biogeochemical and ecosystem research in the Northern Indian Ocean*. This will highlight results of benthic and pelagic process studies in the Arabian Sea, and more recently the Bay of Bengal and Andaman Sea, coastal studies in the Northern Indian Ocean, and numerous physical and biogeochemical modelling studies relevant to the wider Indian Ocean.
- SIBER will convene a workshop entitled, '*Eastern Indian Ocean upwelling research initiative planning Workshop Phase 3: physical dynamics and ecosystem responses*, and a session on '*Biogeochemical and ecological impacts of boundary currents in the Indian Ocean*' at the IMBER OSC in **June 2014**, Bergen, Norway.

C. IMBER Working Groups and Task Teams

SOLAS-IMBER Carbon (SIC!) Working Group

To oversee the marine carbon process studies, there are currently three joint SOLAS-IMBER carbon (SIC!) groups dealing with carbon in the surface ocean systems (SOS), carbon in the interior ocean (IOC) and ocean acidification (SIOA). A proposal submitted by the SCOR Working Group 134 on 'The Microbial Carbon Pump in the Ocean', to develop a new SIC! activity focusing on dissolved organic carbon production, transformation and storage was not accepted by the IMBER SSC. However, it was suggested that the remits of the existing SIC! Working Groups could be revisited to incorporate this topic, its possible interactions with the existing SIC! WGs, and potentially improve the studies of the various forms, sources, sinks and interactions of all pools of organic matter. It was also agreed that this should be done in collaboration with SOLAS and GEOTRACES.

Surface Ocean Systems (SIC!-SOS)

This working group focuses on data synthesis for the carbon in the surface ocean systems (SOS), and on instrumentation and technology development, Voluntary Observing Ships (VOS) and mixed layer sampling strategy.

The Surface Ocean CO₂ Atlas (SOCAT, www.socat.info) was first presented at the '*Ocean Carbon Cycle at a Time of Change: Synthesis and Vulnerabilities*' meeting, convened by SIC!-SOS, SIC!-IOC and IOCCP in 2011. The updated SOCAT v.2 was released at the 9th International CO₂ Conference (ICDC-9) in June 2013, Beijing, China. (see also the science highlight above). This atlas is a publicly available, high-quality dataset that can be used for: (i) process studies, (ii) quantifying ocean carbon sinks and its seasonal, year-to-year, decadal variation; and (iii) initialization and validation of ocean carbon cycle models. Regular updates

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are planned, and work has already commenced on SOCAT v.3. This will become a keystone dataset for carbon cycle science and is worthy of support.

A new activity supported by the SIC!-SOS is now underway which focuses on the comparison of different techniques for mapping pCO₂ in the global ocean. This effort also builds on the Regional Carbon Cycle and Process (RECCAP, www.globalcarbonproject.org/reccap) project which is now finalising a special issue of *Biogeosciences* (www.biogeosciences-discuss.net/special_issue83.html).

Future SIC!-SOS activities:

- A meeting with members of the Southern Ocean Observing System (SOOS, www.soos.aq) on the science of detecting change in the high-latitude ocean is being considered.
- SIC!-SOS members will co-convene, with SIC!-IOC and IOCCP, a session on ‘*The ocean carbon cycle at a time of change: Data syntheses, analyses and modelling*’ at the IMBER OSC in June 2014, Bergen, Norway. It aims to focus on surface-to-interior connections.

Interior Ocean Carbon (SIC!-IOC)

This working group co-ordinates international research on interior ocean changes in carbon and biogeochemistry, undertakes synthesis activities, and aims to develop sustainable observing systems, including the addition of oxygen sensors to the international ARGO float programme (ARGO-O₂).

A new SCOR Working Group ‘*Quality Control Procedures for Oxygen and Other Biogeochemical Sensors On Floats and Gliders*’ (http://scor-int.org/Working_Groups/wg142.htm), proposed by members of SIC!-IOC, was launched this year. Measuring dissolved oxygen from profiling floats adds greatly to our understanding of both physical and biogeochemical process. To date, almost 300 floats carrying dissolved oxygen sensors have been deployed, in the Pacific, the Southern Ocean and the tropical and subpolar Atlantic. The development and deployment of other biological sensors are also on-going for a “full Bio-Argo” network.

Several SIC!-IOC-related sessions were organised at the 9th International CO₂ Conference (ICDC-9) in June 2013, Beijing, China.

Currently, the focus of SIC!-IOC is to move forward with the inter-comparison study of the different methods to determine the changes in carbon in the ocean's interior (Fig. 9), and especially the global-scale oceanic accumulation of anthropogenic CO₂ since the 1990s. In this respect, the global synthesis of repeat hydrography, mainly based on work from the CARINA and PACIFICA projects, is on-going. Progress has been slower than anticipated, due to data quality control issues, but the aim is to complete it in 2014.

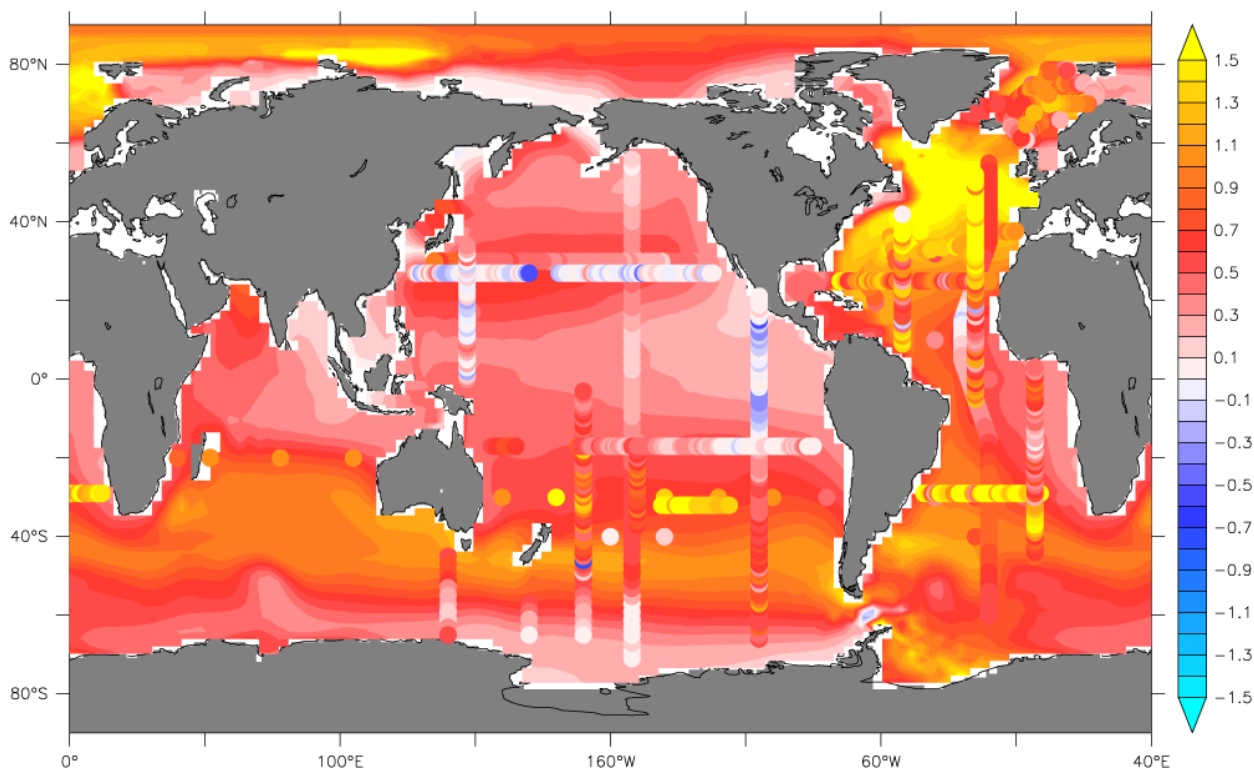


Figure 9 Interior trends of anthropogenic CO₂: It appears that an Atlantic-versus-Pacific pattern emerges clearly, but substantial differences exist between different methods. after Gruber et al. (unpublished, 2012), in mol m⁻² yr⁻¹

Future SIC!-IOC activities:

- The 3rd SIC!-IOC WG meeting will be held in conjunction with the ASLO/TOS/AGU 2014 Ocean Sciences Meeting in February 2014, Honolulu, Hawaii, USA.
- SIC!-IOC will convene, in partnership with SIC!-SOS and IOCCP, a session on “*The ocean carbon cycle at a time of change: Data syntheses, analyses and modelling*” at the IMBER OSC in June 2014, Bergen, Norway.

Ocean Acidification (SIOA)

This working group co-ordinates international research efforts and synthesis activities in ocean acidification. Within a single decade, ocean acidification has grown from involving only a few scientists to a research topic that has recently been considered the #1 research front in ecology and environmental sciences. While exciting, this rapid expansion has not been without its problems. For example, it has not been easy for experts to share information and train newcomers from different countries, which is essential to avoiding unnecessary duplication.

The SIOA was instrumental in the establishment of the *Ocean Acidification - International Coordination Centre (OA-ICC)* in summer 2012, IAEA's Environment Labs, Monaco, in coordination with the Ocean Acidification Reference Users Group (OA-RUG). Its goals are to foster international scientific collaboration, promote best practices, improve observational capacities and databases, and facilitate communication, outreach and synthesis (see www.iaea.org/nael/OA-ICC and <http://news-oceanacidification-icc.org>).

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The first OA-ICC Advisory Board meeting, chaired by SIOA member Carol Turley, included all SIOA members and other representatives (including the IMBER Chair, Eileen Hofmann), and was held in May 2013 in Monaco, following the SIOA meeting. The focus of the meeting was to discuss and organise future activities. The scientific credibility of the OA-ICC relies almost entirely on the SIOA. Through the recent interactions between OA-ICC staff and the SIOA Chair, Jim Orr, also OA-ICC Scientific Coordinator, the SIOA set the priorities and what should be done, also taking into account the context of the IAEA, host institution of the OA-ICC. To be cost effective, the current SIOA membership will most likely be maintained without changes until December 2015.

Future SIOA and OA-ICC activities:

- SIOA members will convene a session on “*Regional responses to climatic and non-climatic drivers in a high-CO₂ ocean*” at the IMBER OSC in June 2014, Bergen, Norway.
- OA-ICC has already begun to promote a series overarching international activities to serve not only the scientific community but also science users, including policy makers, media, and the general public. Recent and ongoing OA-ICC activities include: (1) helping to run an international exhibition stand that highlighted ocean acidification at the UNFCCC COP18 Climate Change Conference, in November 2012, Doha, Qatar; (2) running a comparison exercise for 7 publicly available packages that compute marine carbonate chemistry, in collaboration with IOCCP, and (3) supporting the 2nd International Workshop of the Global Ocean Acidification Observing Network (GOA-ON) held in July 2013, St. Andrews, UK, www.pmel.noaa.gov/co2/GOA_ON/2013; and the 6th SOLAS summer school to be held in Aug.-Sept. 2013, Xiamen, China, <http://mel.xmu.edu.cn/solassummerschool/>.
- During the next year, OA-ICC will also organize or help organize several workshops, including a GOA-ON observational workshop, a natural-social science connection workshop, an OA data curators' workshop, a OA-related capacity building workshop in South America), and further promote international collaboration and sharing of international ocean acidification research platforms and facilitating exchanges of early-career researchers.

Continental Margins Working Group (CMWG)

The joint IMBER-LOICZ CMWG held its first meeting in June 2012, Halifax, Canada. It was decided to rename the group the Continental Margins Working Group because, unlike its predecessor, the Continental Margins Task Team (CMTT), which was tasked only with drafting the Continental Margins Implementation Plan, the group has multiple responsibilities. These include convening the ‘*Biogeochemistry-ecosystem interactions on changing continental margins*’ workshop at IMBIZO III and revising the Science Plan and Implementation Plan (SPIS) drafted by the CMTT in order to develop a new strategy for continental margins research in light of the Grand Challenges in earth system science research for global sustainability.

The 2nd CMWG meeting was held in January 2013 in Goa, India. A strategic paper “*Living on the Margin in the Anthropocene: from Frontier to Engagement Arenas for Global Sustainability*” is in preparation for submission to a peer-review journal (see Fig. 10).

The SPIS for CM research will be structured according to this paper, to fit the requirements of the Future Earth Initiative and to facilitate the transition of on-going CM projects into this

transdisciplinary research phase. Material from the original draft may be repackaged into the new structure, but new material is also needed, especially, on the human dimensions.

During the IMBIZO III continental margins workshop it was recognized that specifically developed models would provide guidance to effective governance of social-ecological systems on CMs, which in turn would rely on communication and mutual understanding of the issues and capabilities of social and natural scientists.

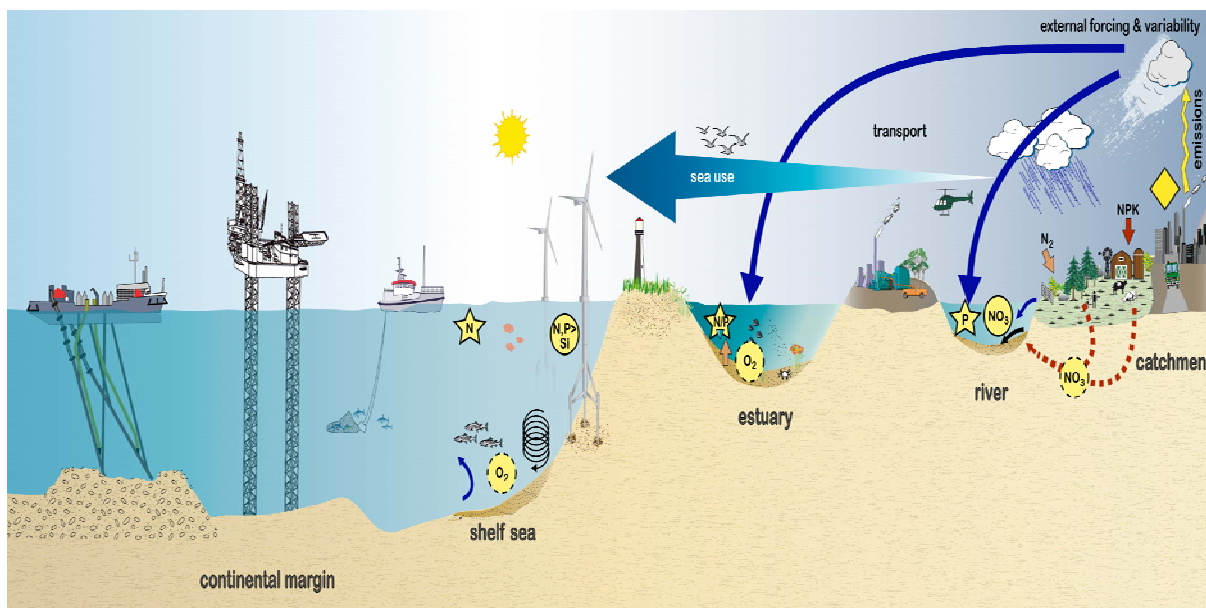


Figure 10: The Margin, comprising the coastal zone, continental slope and shelf (after K. Emeis, pers. comm.)

Future CMWG activities:

- CMWG members and colleagues will convene two sessions on “*Impacts of anthropogenic stressors and climate change on biogeochemistry-ecosystem in continental margins and feedbacks to earth system and society: Challenges and solutions*” and “*Environmental changes in Eastern Boundary Upwelling Systems: drivers, mechanisms and implications for the ecosystems*” at the IMBER OSC in June 2014, Bergen, Norway.
- A special issue derived from the IMBIZO III continental margins workshop and entitled “*Biogeochemistry-ecosystems interaction in changing continental margins in the Anthropocene*” has been accepted for the *Journal of Marine Systems*.

Data Management Committee (DMC)

The DMC promotes a cooperative data management approach - involving experienced data management specialists, from the start of a project, and training young scientists in good data management procedures.

As with previous IMBIZOs, the DMC organised an IMBER *Data management training course and workshop* the day before the start of IMBIZO III in Goa, India. About fifty IMBIZO III participants and local NIO researchers and students attended. Overall, the presentations and discussions provided useful information on how their science will benefit from improved data

management practices and this will facilitate data sharing. The presentations are available at www.imber.info/index.php/Meetings/IMBIZO/IMBIZO-III/Data-Management-Workshop.

In addition to its usual capacity building goal, this event made it possible for IMBER researchers to further identify data management needs of IMBER research projects, to start addressing the emerging challenges of the social and natural marine science integration and especially the marine social science data management, and start elaborating new recommendations specific to the management of new types of marine data. A revision/addendum is now under consideration for the IMBER Data Management Cookbook (2011), to consider such new marine data, related to –omics research (e.g., genomics, proteomics) that delivers huge amount of new data, and social science research where data and information are often not geo-referenced and have confidentiality-related access restrictions.

The IMBER metadata portal (<http://gcmd.nasa.gov/portals/imber>) within the NASA's Global Change Master Directory (GCMD) is actively populated and currently contains description of 32 endorsed projects and related activities.

The IMBER poster entitled, ‘*Contributions from the IMBER Data Management Committee to the scientific challenges of the changing marine ecosystems*’, was presented at several events, including the 3rd International Symposium on the Ocean in a High CO₂ World, September 2012, Monterey, CA, USA; the 2012 ICES Annual Science Conference, September 2012, Bergen, Norway; the CLIVAR international workshop on interdecadal variability of the global monsoons, September 2012, Nanjing, China; and the PICES 2012 Annual Meeting, October 2012, Hiroshima, Japan.

Future DMC activities:

- DMC will convene a workshop entitled “*Data Management for IMBER*” at the IMBER OSC in June 2014, Bergen, Norway.

Capacity Building Task Team (CBTT)

The CBTT objectives are to enhance marine research capabilities in less developed countries, enhance research capabilities globally in relevant IMBER activities, and strengthen graduate education in ocean sciences.

The CBTT organised a workshop on the “*Needs assessment for capacity development for integrated marine biogeochemistry and ecosystem research in the Asia-Pacific*” in July-August 2012, Shanghai, China. There were about twenty participants from 14 countries, including scientists, capacity building (CB) experts and representatives from IMBER, SCOR, the Asia-Pacific Network for Global Change Research (APN), the IOC Sub-commission for the Western Pacific (IOC-WESTPAC), and the Partnership for Observation of the Global Oceans (POGO). Included were presentations about CB experiences and case studies, and assessment of CB needs. Consideration was also given to potential collaborative activities for capacity development regionally and globally to help IMBER deliver its objectives. The capacity development needs for IMBER-related research in the Asia-Pacific region were identified using an information matrix developed from the capacity building efforts and challenges reported by the workshop participants.

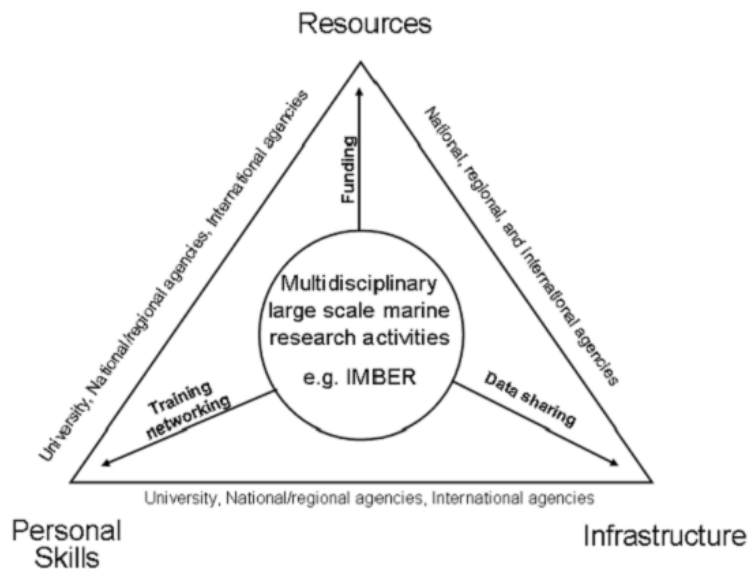


Figure 11. Three key components involved in capacity building, while national/regional agencies focus more on resources and infrastructure building, and universities provide more opportunity on personal skills development. Multidisciplinary large-scale marine research activities, such as IMBER, contribute to the three components through training, networking, financial support, data sharing, etc. (from “Developing Human Capital for Successful Implementation of International Marine Scientific Research Projects”. R.J. Morrison et al., *subm.*)

A meeting report titled, ‘*Capacity Building for Sustainable Marine Research in the Asia-Pacific Region*’, was also published in *EOS*, January 2013, and the main workshop report is available at www.apn-gcr.org/resources/items/show/1766. A small writing meeting held in March 2013, in Shanghai, China made it possible to further develop a strategic paper, ‘*Developing Human Capital for Successful Implementation of International Marine Scientific Research Projects*’, which was recently published on-line in *Marine Pollution Bulletin* (see <http://www.sciencedirect.com/science/article/pii/S0025326X13005377>).

Future CBTT activities:

- CBTT will convene a workshop entitled “*Capacity Development for IMBER*” at the IMBER OSC in June 2014, Bergen, Norway.
- CBTT is also encouraging the development of the next IMBER summer school, ClimEco4 in August 2014, Shanghai, China (see below).

Human Dimensions Working Group (HDWG)

The HDWG focuses on the interactions between human and ocean systems, and aims to create an integrated and interactive natural-social science marine research community within IMBER. Marie-Caroline Badjeck stepped down as HDWG Co-Chair at the end of 2012, but remains as an associate member.

HDWG members and colleagues convened the IMBIZO III workshop on ‘*Understanding and forecasting human-ocean-human interactions, drivers and pressures, with respect to global change*’ in January 2013 in Goa, India. Presentations analyzed the vulnerability and adaptation of marine-dependent communities to global change and governance response and

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methodological approaches to assess and mitigate the impacts of global change. A range of locations, issues and scales were covered, but several common themes and issues emerged: informal social networks are important for adaptation; responses can and should occur at several levels; lessons can be learned from comparative analyses; local issues are affected by local, regional and global drivers; greater interdisciplinarity is required to address these issues; there are several major disconnects between natural and social sciences; between science and policy; and between the public perception and the “reality” of global change.

The HDWG held its third meeting in conjunction with IMBIZO III, to further develop the HDWG work plan for the next five years and also the ‘*Assessment from Description, Appraisal and Typology*’ (ADApT) conceptual framework and template for case studies. IMBER-ADApT is an integrated decision support tool to enable decision makers and resource managers to identify options to improve their response to global change for the coastal and marine environment and related, vulnerable communities. IMBER-ADApT is based on a broad suite of case studies, focusing on fisheries and aquaculture, from a diversity of social, natural and governance systems, of activity sectors, including those related to fisheries and aquaculture, and of factors that can affect these, such as poverty and social justice.

Future HDWG activities:

- The IMBER-ADApT template will be soon widely distributed to solicit about 100 case studies
- A “Ghoti” paper on IMBER-ADApT will to be soon submitted to *Fish and Fisheries*
- A special issue of *Regional Environmental Change* on the contributions from the IMBIZO III HDWG-related workshop is in preparation.
- HDWG Meeting in March 2014, Halifax, Canada
- Analysis of case studies and development of the ADApT typology
- HDWG members and colleagues will convene three sessions entitled “*Not so simple: developing robust approaches to the use of indicators for ecosystem based fisheries management*”, “*Responses of society to marine and global changes as a core mandate for IMBER: ways forward*” and “*Future Oceans’ stewardship: roles, responsibilities and opportunities in small-scale fisheries*” at the IMBER OSC in June 2014, Bergen, Norway.

D. IMBER Project-wide Activities

IMBIZO III

IMBIZO is a Zulu word for a ‘gathering’. IMBER organised IMBIZO III in January 2013 in Goa, India, focusing on ‘*The future of marine biogeochemistry, ecosystems and societies - Multi-dimensional approaches to the challenges of global change in continental margins and open ocean systems*’. The aim was to explore the linkages and interactions between humans and marine systems and deepen our understanding of future ecological and biogeochemical systems in the continental margins and open ocean and their societal implications. IMBIZO III was co-sponsored by EUR-OCEANS Consortium (EU), IMR (NO), RCN (NO), NASA (US), OCB (US), PICES (INT), SCOR (INT), ECNU (CN) and SKLEC (CN). IMBIZO III brought together about 120 researchers, from the natural and social research fields, who represented 29 countries.

Following the proven IMBIZO format, three concurrent, but interacting, workshops dealt with (1) *Biogeochemistry-ecosystem interactions on changing continental margins*, (2) *Impacts of anthropogenic perturbations on the biological and microbial carbon pumps in the ocean*, and (3) *Understanding and forecasting human-ocean-human interactions, drivers and pressures, with respect to global change*. Joint daily plenary and poster sessions provided the opportunity for interdisciplinary discussion among participants from the three workshops. The meeting presentations are available online at www.imber.info/index.php/Meetings/IMBIZO/IMBIZO-III.

A mentoring programme was activated prior to IMBIZO III and matched about fifteen students and early-career researchers with experienced scientists. Advice and assistance was given on poster or presentation preparation, and on career development. A “lunch with scientists” was also held. At the end of IMBIZO III, a 3-hour tutorial session on ‘*Scientific Writing and Publishing*’ was attended by about 35 participants.

As mentioned above, a “*Data management training course and workshop*” was organised by the DMC the day before the start of IMBIZO III.

A meeting report, ‘*The Future of Marine Biogeochemistry, Ecosystems, and Societies*’, was published in *EOS*, May 2013, and the IMBER Update Newsletter issue n°24 focused on science highlights from IMBIZO III (see below).

Future IMBIZO III-related activities:

- A synthesis of the outcomes of IMBIZO III ‘*The Future of Marine Biogeochemistry, Ecosystems, and Societies*’ is in preparation as an article in the “*Breaking Waves*” section of *Oceanography*.
- Syntheses of the ideas and concepts presented and new scientific discoveries reported at IMBIZO III will be published in special issues of *Journal of Marine Systems* (Continental Margins Workshop), *Biogeosciences* (Open Ocean Workshop) and *Regional Environmental Change* (Human-Ocean Interactions Workshop).

ClimEco Summer Schools

IMBER ClimEco Summer Schools are held every two years and have proved to be a successful capacity building mechanism for students and early-career scientists. The first edition (2008) was co-organised by IMBER, GLOBEC and CLIVAR.

IMBER organised ClimEco3, in July 2012, Ankara, Turkey, focusing on ‘*A view towards integrated Earth System models. Human-nature interactions in the marine world*’. There were 10 lecturers and about 60 students from 26 countries with an array of social and natural science backgrounds. The participants were selected from the 168 applicants to facilitate hands-on training. The summer school was designed to provide participants with an overview of methods, models and approaches for analyzing the impact of climate change on marine ecosystems and the consequences for society. All the lectures were webcast live and were followed by several people from around the world. Recordings of the broadcasts are available at www.imber.info/index.php/Science/Working-Groups/Capacity-Building/Summer-Schools/ClimECO3-July-2012-Ankara-Turkey. Sponsors included IMBER, METU (TR), PICES (INT), CLIVAR (INT), SCOR (INT), EUR-BASIN (EU), OCB (US), KORDI (KR, now: KIOST).

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Future ClimEco activities:

- ClimEco4 entitled, '*Delineating the issues of climate change and impacts to marine ecosystems: Bridging the gap between research, assessment, policy and management*', will be held in early August 2014, Shanghai, China. It should focus on indices for evaluating marine ecosystems - what they are, how to construct them (for process/observation scientists), how to use them (for modellers from natural to social sciences), and how to combine them so that they can be used to inform policy and decision-making.

Funding from SCOR has been kindly requested to support participants from developing and emerging economies to attend the ClimEco4 summer school.

Open Science Conference (OSC) 2014

IMBER has been underway for eight years and it is now appropriate to begin elaborating a broad synthesis of its achievements and developing a strategic plan for the next phase of marine biogeochemical and ecosystem research.

The IMBER Open Science Conference, '*Future Oceans – Research for marine sustainability: multiple stressors, drivers, challenges and solutions*', to be held from 23 to 27 June 2014 in Bergen, Norway, is a key step in this process and is intended to provide a venue to the larger marine science community for presenting key findings of IMBER-relevant research, for promoting integrated syntheses of IMBER research, and for developing a new research agenda to guide future marine biogeochemistry and ecosystem research. We expect about 300 to 400 participants to attend.

Innovative discussion formats will be promoted, such as world cafés, panel discussions, breakout groups, poster sessions and exhibition booths. Facilitated scenario-testing/strategic sessions are also being considered for discussing future research needs, particularly those relevant to societal issues, such as marine food security, or vulnerability assessments of marine systems under global change.

The OSC will feature:

- keynote plenary presentations;
- multiple contributed parallel sessions focusing on IMBER achievements, ambitions and strategy development;
- several one-day topical workshops focusing on integration across the IMBER research themes, results from IMBER regional programmes and working groups, and IMBER-relevant research at the interface of natural and human sciences;
- targeted breakout groups focused on defining a new research agenda and implementation strategy for the next phase of marine research;
- a mentoring programme for students and early-career researchers; and
- poster sessions.

The list of accepted sessions and workshops is available at www.imber.info/index.php/Meetings/IMBER-OSC-2014/Sessions-Workshops.

Several scientific side-events and additional IMBER-related activities will be held in conjunction with the IMBER OSC 2014, including pre-conference events such as workshops for early-career

researchers on new research challenges, capacity building, and data management, and the IMBER SSC meeting to be held on 27-28 June 2014 in Bergen, Norway. Several social events, such as an ice-breaker, conference reception and conference dinner, will also be organized. These are funded by sponsorship raised locally or provided by local organizations. This is especially important for the OSC because it is an attempt to bring together and facilitate interactions and collaborations between the natural and social science marine research communities, both globally and locally. Current environmental issues facing society are at the interface between natural and social science, and it is imperative to support the development of an interdisciplinary community of researchers who understand and have the skills to address complex issues at this interface.

The OSC will help disseminate IMBER science results to a broader community, with both natural and social science representation. The keynote presentations will be broadcast live and subsequently posted on the IMBER website. Social media outlets will facilitate the involvement of a wider audience of marine researchers and research end-users, allowing a broader engagement in the strategic discussions. Results from the OSC will be published as peer-reviewed synthesis publications and special issues with contributed and solicited papers.

To facilitate future planning, the IMBER Scientific Steering Committee (SSC) is developing a strategic document to stimulate discussions that help define and implement the next phase of research in biogeochemical cycling-ecosystem interactions and human-ocean-human interactions. The general outline of this strategic document should include the following: a self-evaluation report; some highlights of success; new questions and new challenges; an overview of the new research landscape; some proposed new themes, issues, priority questions; some proposal for a new research agenda; a draft science plan and implementation strategy; and timeline. This document will be made available to participants in advance of the OSC. It will also be posted on the IMBER website for comment from individual researchers, research partners and marine organisations. Following this open consultation period, the document will be revised and updated by the IMBER SSC to reflect the inputs and suggestions of the community and to take into account the status of the IMBER dialogue with its current sponsors (SCOR and IGBP) and the 'Future Earth' initiative. It will then be sent to SCOR during late summer 2014, along with a request for a potential five-year project extension.

SCOR has agreed to support the participation of several researchers from developing and emerging economies in the OSC. Other confirmed sponsors are the North Pacific Marine Sciences Organization (PICES); Research Council of Norway (RCN); Institute of Marine Research (IMR), Bergen, Norway; University of Bergen, Norway; Norwegian Research School in Climate Dynamics (ResClim); and City of Bergen, Norway. Additional financial support has been requested from the International Council for the Exploration of the Sea (ICES), U.S. National Aeronautics and Space Administration (NASA), U.S. Ocean Carbon and Biogeochemistry (OCB) Program, Korea Institute of Ocean Science and Technology (KIOST). Additional funding proposals are being prepared for the Inter-American Institute for Global Change Research (IAI), Partnership for Observation of the Global Oceans (POGO), Japan Society for the Promotion of Science (JSPS), and several national research funding agencies and private philanthropic foundations.

The funding provided by external sponsors will especially facilitate participation of early-career researchers at an international science conference, thereby providing these individuals the

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opportunity to experience international science and to learn about advances in marine science that are being made as part of IMBER activities. They are potentially the next generation of leaders in marine science and entraining them in international science at an early stage will benefit them and the larger marine research community, and ensure that all regional communities are an integral part of planning the future directions of a marine global environmental change research agenda.

China-Japan-Korea (CJK) IMBER Symposia

The 6th China-Japan-Korea (CJK) IMBER Symposium focusing on “*Ocean Ecosystem Dynamics and Integrated Marine Biogeochemistry and Ecosystem Research*” will be held in October 2013 in Tokyo, Japan.

Continuation of the IMBER Regional Project Office

The IMBER Regional Project Office (RPO), established under a MoU with the East China Normal University in 2010 for an initial three-year period, has been renewed for another three years (2013-2016). The RPO is an essential facilitator in the IMBER efforts to reach out to the related research community in the Asia-Pacific region, and a very active partner of the International Project Office in many of its activities.

E. IMBER SSC membership

There are currently 15 IMBER SSC members. At the end of 2012, Dr. Mike Roman (Vice Chair) completed his second term of office on the SSC. The IMBER SSC nominated Dr. Tatiana Rynearson to fill this vacancy, and her nomination (2013-2015) was endorsed by IMBER’s sponsors (SCOR and IGBP). Dr. Alida Bundy replaced Dr. Roman as Vice Chair of the IMBER SSC.

At the end of 2013, Prof. Javier Arístegui (Vice Chair), Dr. Carol Robinson (Vice Chair), Dr. Jean-Pierre Gattuso and Prof. Nicolas Gruber will complete their second terms of office on the SSC. In February 2013, IMBER solicited the research community for nominations for their replacements with the following expertise, identified by the IMBER Executive Committee: human-ocean-human interactions, marine anthropology; marine/environmental economics; microbial ecology and biogeochemistry, meso-pelagic processes; carbon fluxes and budgets; biogeochemical modelling, carbon-climate interactions and ocean acidification. Fifty-seven submissions were reviewed extensively and a short list of nominees is now presented to SCOR and IGBP for their approval.

F. IMBER Cooperation

Cooperation with the ‘Variability and predictability of the ocean-atmosphere system’ project (CLIVAR)

CLIVAR (www.clivar.org), a core project of the World Climate Research Programme (WCRP), focuses on the role of the oceans in climate variability and change. Following several earlier, informal interactions, and thanks to the help of Ken Drinkwater, member of both IMBER and CLIVAR SSCs, the collaboration between the two projects have been increased: A joint meeting

of the Scientific Steering Committees of IMBER and CLIVAR was held in June 2012 in La Paz, Mexico, to explore possible topics and ways for active CLIVAR-IMBER collaboration. The presentations from this meeting are available at www.clivar.org/node/2509. There is already interaction between the CLIVAR ‘Pacific Implementation Panel’, ‘Asian-Australian Monsoon Panel’ and ‘Indian Ocean Panel’ and the IMBER regional programmes. CLIVAR is also a co-sponsor of the IMBER ClimEco summer schools.

There has been discussion on the possibility of establishing a joint IMBER-CLIVAR working group to establish stronger links with the climate research community, on specific topics, such as upwelling regions; natural decadal/multi-decadal variability; bio-physical feedbacks; oxygen minimum zones; impact of ocean acidification on marine ecosystems; and ocean carbon uptake. Consideration is also being given to how both projects could evolve partly together also in the context of the ‘Future Earth’ initiative (with which WCRP will partner). Joint studies on marine biophysical interactions and the dynamics of upwelling systems, which are productive fisheries areas, were suggested as starting points. Eastern boundary upwelling systems, upwelling systems associated to western boundary currents and equatorial upwelling systems should be considered, in their geophysical and ecological variability and the anthropogenic changes (e.g., global warming, extreme events, ocean acidification) affecting them, that could be observed or forecasted therein. There is already a research effort underway by the IMBER regional programme, SIBER, and the CLIVAR Indian Ocean Panel on upwelling in the Eastern Indian Ocean. An informal IMBER-CLIVAR working team was assembled in early 2013 to consider possible research questions that an upwelling research initiative should address. Representatives from the IOC and the former GLOBEC regional programme on small pelagics (SPACC) were also included.

Future IMBER-CLIVAR-related activities:

- A workshop entitled “*Eastern Indian Ocean Upwelling Research Initiative Planning Workshop Phase 3 – Physical Dynamics and Ecosystem Responses*”, and two sessions on “*Environmental changes in Eastern Boundary Upwelling Systems: drivers, mechanisms and implications for the ecosystems*” and “*Climate-biogeochemistry interactions associated with open-ocean oxygen minimum zones*” will be co-convened by IMBER and CLIVAR researchers at the IMBER OSC in June 2014, Bergen, Norway.

Partnership with Too Big To Ignore (TBTI)

IMBER has partnered with the *Too Big To Ignore* initiative (<http://toobigtoignore.net>), a research network that aims to promote and revitalize small-scale fisheries around the world. Its main goal is to improve understanding of the real contribution of small-scale fisheries to food security, nutrition, sustaining livelihoods, poverty alleviation, wealth generation and trade, as well as the impacts and implications of global change processes such as urbanization, globalization, migration, climate change, aquaculture, and communication technology on small-scale fisheries. Many of the objectives of the IMBER HDWG coincide with those of the initiative, which is led by IMBER SSC member Ratana Chuenpagdee. The TBTI inaugural meeting was held in September 2012 in St. Johns, Canada and focused on working principles guiding the partnership, on workgroups and regional activities, and on partners’ and individual members’ contributions to TBTI network. Among other activities, TBTI is currently running two surveys on *who’s who in small-scale fisheries research* and on the *research priorities for small-scale fisheries*. Key

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publication of TBTI interest: Bavinck, M., Chuenpagdee, R., Jentoft, S. and Kooiman, J. (Eds.) (2013). *Governability of Fisheries and Aquaculture: Theory and Applications*. Springer. [ISBN 978-94-007-6107-0](https://doi.org/10.1007/978-94-007-6107-0).

Contributions to international assessments

- Many SIC!-related research projects have contributed to a series of synthesis chapters for the Regional Carbon Cycle Assessment and Processes (RECCAP) effort (www.globalcarbonproject.org/reccap/). Several ocean-related papers are being published in *Biogeosciences* (see www.biogeosciences-discuss.net/special_issue83.html).
- Many of these syntheses and other contributions from the IMBER-related research projects and IMBER regional programmes are included in the *fifth Intergovernmental Panel on Climate Change Assessment Report (AR5)* of the Intergovernmental Panel on Climate Change' (IPCC, www.ipcc.ch). Richard Feely; Eileen Hofmann; Yukihiko Nojiri and James Overland are involved in Working Group I (*The Physical Science Basis*), and Kenneth Drinkwater; Jean-Pierre Gattuso; Yukihiko Nojiri and Carol Turley in Working Group II (*Impacts, Adaptation and Vulnerability*).
- IMBER researchers are involved in the United Nations 'Regular process for global reporting and assessment of the state of the marine environment, including socio-economic aspects', aka, UN World Ocean Assessment (UN-WOA; www.worldoceanassessment.org).
- IMBER has provided comments on the European Space Agency (ESA) science strategy (2006), as inputs to the *ESA Living Planet Symposium* (www.livingplanet2013.org), taking place in September 2013, Edinburgh, UK.
- IMBER is now considering how best to contribute to the activities of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES, www.ipbes.net).

G. Communication, Publications

Communication and Outreach

The IMBER Website, www.imber.info, remains our main communication tool, with about 250 unique visitors/days and about 14 clicks per visit.

The *IMBER Update Newsletter*, www.imber.info/index.php/News/Newsletters, is emailed to ~1,600 scientists three times a year, and re-directed through multiple channels to about 10,000 researchers:

- **Issue n°24** - August 2013, included articles about Science highlights from IMBIZO III, new endorsed project and the endorsed project POMAL
- **Issue n°23** - April 2013, included articles about Science Highlights from CLIOTOP, new National Contacts and the endorsed projects GENUS and AMT, and IMBER-related future events
- **Issue n°22** – Dec. 2012, included articles about research in the China Seas and Southern Ocean, the MEcoPAM endorsed project and the ICED regional programme.
- **Issue n°21** – Sept. 2012, included articles about the IMBER ClimECO3 summer school, the workshop organised by the IMBER Capacity Building Task Team, and Norwegian IMBER-related research.

The IMBER eNews Bulletin is published electronically every month, providing information about IMBER and IMBER-relevant activities and events. Calls for funding proposals, job opportunities, workshop and conference announcements are also included.

The IMBER contact database is continuously improved with about 3,600 contacts and detailed information for about 1,600 marine researchers.

The IMBER IPO YouTube channel was opened in October 2012 to disseminate the ClimEco3 e-lectures, www.youtube.com/channel/UCinzjRz7_TKHESn6uggCKlw and has gathered more than 400 views. Recently, an IMBER Twitter channel, https://twitter.com/imber_ipo has been developed.

The IMBER GCMD metadata portal has already been mentioned earlier (see, DMC).

Finally, the IPO and RPO staff and several IMBER researchers have presented more than a dozen IMBER poster and oral presentations at many national and international meetings.

Selection of IMBER Publications, 2012-2013

- Ashjian C.J., H.R. Harvey, M.W. Lomas, J.M. Napp, M.I.F. Sigler, P.J. Stabeno and T.I. Van Pelt (2012). Understanding Ecosystem Processes in the Eastern Bering Sea. *Deep Sea Research Part II: Topical Studies in Oceanography*, 65-70, 1-316 – 23 papers
- Dawe E.G., F.J. Mueter, Ó.K. Pálsson (2012). Theme Section on “Effects of climate and predation on subarctic crustacean populations”. In: *Marine Ecology Progress Series*, 469, 191-306 – 9 papers
- Drinkwater K. and P. Pepin (2013). Norway-Canada Comparison of Marine Ecosystems (NORCAN). *Progress in Oceanography*, 114, 1-126. – 8 papers
- Drinkwater K.F., R.R. Hood and N. Mihalopoulos (Eds.) (2013). Large-scale regional comparisons of marine biogeochemistry and ecosystem processes - research approaches and results. *Journal of Marine Systems*, 109-110, p.1-176. – 13 papers
- Drinkwater K.F., G.L. Hunt Jr, O.S. Astthorsson and E.J.H. Head (Eds.). (2012). Comparative Studies of Climate Effects on Polar and Subpolar Ocean Ecosystems: Progress in Observation and Prediction. *ICES Journal of Marine Science*, 69(7), p.1119-1327 – 22 papers
- Friedland K.D., Stock C., Drinkwater K.F., Link J., Leaf R., Shank B., Rose J., Pilskaln C.H. and Fogarty M. (2012). Pathways between primary production and fisheries yields of Large Marine Ecosystems. *PlosOne*, 7: e28945. doi:1371/journal.pone.0028945.
- Friedrich T., Timmermann A. et al. (2012). Detecting regional anthropogenic trends in ocean acidification against natural variability. *Nature Climate Change*, 2, 167-171; doi:10.1038/nclimate1372
- Gaichas S., Gamble R., Fogarty M., Benoît H. et al. (2012). Assembly rules for aggregate-species production models: simulations in support of management strategy evaluation. *Marine Ecology Progress Series*, 459, 275-292.
- Gruber N., Hauri C., Lachkar Z., Loher D., Frölicher T. and Plattner G.K. (2012). Rapid progression of ocean acidification in the California Current System. *Science*, 337(6091), 220-223. doi: 10.1126/science.1216773.
- Hauri C., Gruber N., Vogt M., Doney S.C., Feely R. A., Lachkar Z., Leinweber A., McDonnell A. M. P., Munnich M., and Plattner G.K. (2012). Spatiotemporal variability and long-term trends of ocean acidification in the California Current System. *Biogeosciences Discuss.*, 9, 10371-10428, doi:10.5194/bgd-9-10371-2012.

- Hunsicker M.E., Olson R.J., Essington T.E., Maunder M.N., Duffy L.M., Kitchell J.F. (2012). Potential for top-down control on tropical tunas based on size structure of predator-prey interactions. *Marine Ecology Progress Series*, 445, 263-277
- Krause E., Wichels A., Giménez L., Lunau M., Schilhabel M. B. & Gerds G. (2012). Small changes in pH have direct effects on marine bacterial community composition: a microcosm approach. *PlosOne*, 7: e47035. doi:10.1371/journal.pone.0047035.
- Nisumaa A.M., Schlitzer R., Hansson L. & Gattuso J.P. (2012). EPOCA data management activities: a summary. See www.imber.info/index.php/Science/Working-Groups/SOLAS-IMBER-Carbon/Subgroup-3/Publications-and-reports/EPOCA-data-management
- Pedrotti M.L., Fiorini S., Kerros M.E., Middelburg J.J., & Gattuso J.P., (2012). Variable production of transparent exopolymeric particles by haploid and diploid life stages of coccolithophores grown under different CO₂ concentrations. *Journal of Plankton Research*, 34(5), 388-398. doi: 10.1093/plankt/fbs012.
- Perry I., A. Bundy and E. Hofmann (Eds.) (2012). Aquatic and marine systems. *Current Opinion in Environment Sustainability*, 3(3), p.253-374. – 17 papers
- Renner A.H.H., S. E. Thorpe, et al. (2012). Advective pathways near the tip of the Antarctic Peninsula: Trends, variability and ecosystem implications. *Deep Sea Research Part I: Oceanographic Research Papers*, 63, 91-101.
- Roy A.S., Gibbons S. M., Schunck H., Owens S., Caporaso J. G., Sperling M., Nissimov J. I., Romac S., Bittner L., Mühling M., Riebesell U., LaRoche J. & Gilbert J. A. (2013). Ocean acidification shows negligible impacts on high-latitude bacterial community structure in coastal pelagic mesocosms. *Biogeosciences*, 10: 555-566.
- Salinger J. (Ed.) (2013). Climate and Oceanic Fisheries. *Climatic Change*, 119(1) - 16 papers
- Steele J.H., E.E. Hofmann, D.J. Gifford and K. Aydin (Eds.) (2012). End-to-End Modeling: Toward Comparative Analysis of Marine Ecosystem Organization. *Progress in Oceanography*, 102, p.1-114. – 8 papers
- Wang Z.A., Wanninkhof R., Cai W.J., Byrne R. H., Hu X., Peng T.H. & Huang W.J., 2013. The marine inorganic carbon system along the Gulf of Mexico and Atlantic coasts of the United States: insights from a transregional coastal carbon study. *Limnology & Oceanography*, 58(1): 325-342.
- Williamson P., Wallace D.W.R., Law C.S., Boyd P.W., Collos Y., Croot P., Denman K., Riebesell U., Takedai S., Vivian C. (2012). Ocean fertilization for geoengineering: a review of effectiveness, environmental impacts and emerging governance. *Process Safety and Environmental Protection*, 90(6), 475-488. doi: 10.1016/j.psep.2012.10.007.

Overall, IMBER has produced about 900 refereed research papers since its implementation, including about 150 papers and 8 special issues published in 2012-2013.

H. Support from SCOR

IMBER greatly appreciates the ongoing, key support received from SCOR, and the additional support to specific IMBER activities (especially, IMBIZO III and OSC 2014) provided by or channelled through SCOR, from other funding sources. In addition, IMBER welcomes the advice, assistance and information received from the SCOR President and secretariat, especially its Executive Director, Ed Urban, and Financial Officer, Liz Gross.

IMBER is requesting sponsorship to assist students and early career researchers from developing countries to attend the IMBER ClimEco4 summer school (August 2014, Shanghai, China).

I. Strategic development

IMBER is concerned about the potential impact of the emergence of the Future Earth initiative (FE) and the discontinuation of IGBP in late 2015 on the future of the project. Overall, IMBER welcomes the development of FE as a global platform that will further research on global environmental change, with a focus on challenges and solutions that have been recognised as critical for global sustainability. In this respect, SCOR's views and guidance would be greatly appreciated by the IMBER research community.

IMBER is already engaged in research topics that address several of the FE objectives, and many of its coordination and networking activities match the integrated approaches desired by FE. IMBER researchers undertake mainly basic (i.e., fundamental, disciplinary, curiosity-driven) natural science research; however, IMBER is also engaged in interdisciplinary and integrated activities focused on research at the interface between human and natural sciences. Expanding the IMBER research community and its impacts through cooperation with other research initiatives (e.g., SOLAS, LOICZ, CLIVAR, GEOTRACES) and partner organizations (e.g., PICES, ICES, EUROMARINE, US-OCB) will facilitate furthering IMBER goals within the context of FE. Several telecons between the core projects of the GEC programmes and FE and its sponsors, including ICSU have taken place in the past 1.5 years. A dedicated IMBER-FE teleconference is scheduled in late October 2013, and the SCOR Executive Director will participate in this meeting.

IMBER would like to develop an open dialogue with FE in cooperation with its current sponsors, IGBP and SCOR. In this respect, IMBER has already received input from SCOR Executive Director regarding the FE initiative and possible co-sponsoring of IMBER in the future. This information has been transmitted to FE.

Along with these new developments, a request for a five-year IMBER project extension will be presented to SCOR by late summer/fall 2014, in order to help deliver further the IMBER mission and deepen and widen its overall impact.

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ANNEX 1 – New Endorsed Projects (as of August 2013)

IMBER has endorsed 35 research projects to date that contribute to the delivery of its objectives. During the last year, 5 new projects were endorsed:

Variability of Ocean Ecosystems around South America (VOCES) (July 2013)

The overall goal of this project (January 2013 - December 2017) is to assess the impact of climate variability - both natural and anthropogenic - on the Humboldt, Patagonia and South Brazil Large Marine Ecosystems (LMEs). These ecosystems are amongst the most productive of the Southern Hemisphere, sustaining more than 20% of the global fish catch, hosting unique biodiversity and with CO₂ absorption rates comparable with the most significant uptake regions of the world's oceans. To achieve the project's goal we propose a two-pronged activity plan that, on the one hand, will synergize extant research programs through coordination efforts and, on the other hand, will fill research gaps left by those programs by encouraging collaborative research. We will link the efforts of scientists, educators and program managers from Argentina, Brazil, Chile, Peru, Uruguay and the USA. (<http://sacc.coas.oregonstate.edu/~sacc>)

BioGeochemical cycles in the SOUTHERN Ocean: Role within the Earth System (BIGSOUTH) (July 2013)

The BIGSOUTH project (January 2010 - November 2014) aims at achieving a detailed understanding of the processes controlling functioning and strength of the oceanic biological pump for representative key areas of the Southern Ocean (Atlantic sector (Weddell Gyre); Indian sector (30°E to Kerguelen Plateau); Australian sector (115° - 147°E); Ross Sea), including open ocean and sea-ice covered areas, in order to upgrade present-day assessments of the carbon sequestration capacity and nutrient cycling in the Southern Ocean and possible impacts on the global ocean. Therefore, we apply a unique combination of stable isotope (natural and spiked isotopic abundances), geochemical tracers, trace element and modelling tools to study the relevant biogeochemical processes and control factors (including Fe) acting on the fluxes of carbon and the two major macronutrients N and Si in the open and seasonally sea-ice covered water column. (www.co2.ulg.ac.be/bigssouth)

Sustainability of Marine Ecosystem Production under Multi-stressors and Adaptive Management (MEcoPAM) (June 2013)

The objectives of the MEcoPAM project (January 2011 - December 2015) are to identify and characterize the interactions of marine biogeochemical cycles and marine ecosystems, and to understand the response of typical marine ecosystem production to multi-stressors (such as physical processes, eutrophication, over-fishing and aquaculture), thereby improving our knowledge of the impact of multi-stressors on the sustainability of marine ecosystem production. The research areas include several unique sub-ecosystems in the Bohai Sea, Yellow Sea, and

East China Sea (e.g., the hypoxia zone off the Changjiang Estuary, and aquaculture sites in the Shandong Peninsula). The program is structured around five sub-projects: (1) Biogeochemical Dynamics of Marine Ecosystems; (2) Nutrient Cycles and Response to Multi-stressors; (3) Hydrodynamic Response to Multi-stressors and its Impact on the Supply of Nutrients; (4) Microbial Loop and Coupling with Biogeochemical Cycles; (5) Feedback Mechanisms of Ecosystem Structure and Function to Climate Change and Human Activities. In addition to field observations of the physical, chemical and biological properties of ecosystems in East China Sea, Changjiang Estuary and the coastal area of the Shandong Peninsula, historical data analysis, numerical modelling and microcosm experiments will be undertaken.

(www.imber.info/index.php/Science/National-Network/CHINA/MEcoPAM-project-website)

Atlantic Meridional Transect (AMT) (November 2012)

The Atlantic Meridional Transect (AMT) is a multidisciplinary programme (1995-present) that undertakes biological, chemical and physical oceanographic research during an annual voyage between the UK and destinations in the South Atlantic - previously the Falkland Islands, South Africa and Chile. These ~50°N to ~50°S Atlantic transects cross a range of ecosystems from sub-polar to tropical and from euphotic shelf seas and upwelling systems to oligotrophic mid-ocean gyres. AMT informs on trends and variability in biodiversity and function of the Atlantic ecosystem during this period of rapid change to our climate and biosphere. AMT is unique in its ability to repeat measurements of core parameters on basin scales on long NS transects of the Atlantic and to provides a platform for excellent multi-disciplinary oceanographic research. This unique spatially extensive decadal dataset continues to be deposited and made available to the wider community through the British Oceanographic Data Centre. An integral part of the AMT, which has resulted in more than 60 completed PhD theses, is to provide a training arena for the next generation of oceanographers. This aim has been enhanced recently through the development of the POGO-AMT fellowship programme (<http://ocean-partners.org>) which supports the participation of students or early career professionals from developing nations. Participants in this fellowship programme benefit from working alongside experienced researchers in the development of research skills, the formation of collaborative links and capacity building for their home institutes and countries. (www.amt-uk.org)

Marine Ecosystems Response in the Mediterranean Experiment (MERMEX) (November 2012)

MerMex (2011-2016) focuses on the understanding of the effects of key natural and anthropogenic forcings on ecosystems (from coastal zones to open-ocean, from pelagos to benthos) and organisms (from viruses to fishes) in Mediterranean Sea including western and eastern basins. Most of the Research objectives studied in MerMex were deduced from the Mermex article (*Progress in Oceanography*, 2011) in which ~100 co-authors so-called 'the MerMex group' presented current knowledge on biogeochemistry in the Mediterranean Sea and highlighted the uncertainty on the responses to global change in the 21st Century.

(<http://mermex.com.univ-mrs.fr>)

Terms of Reference:

- Organize national and international planning workshops as well as special sessions at international conferences to obtain community input on the design and implementation of GEOTRACES.
- Establish priorities for research on the sources, sinks, internal cycling, transport, speciation and fate of TEIs, and develop this information into an International Science Plan.
- Promote intercalibration of analytical methods, and the development of standard reference materials.
- Identify new instrumentation and related infrastructure that will help achieve GEOTRACES objectives.
- Define a policy for data management and sample archival.
- Forge scientific linkages with other research programs holding overlapping interests to create synergies where possible and avoid duplication of efforts. To the extent practical, this will involve cross-membership between the GEOTRACES Planning Group and the Planning Groups and Science Steering Committees of other programs.
- Interact with SCOR Working Groups that share common interests including, but not limited to, SCOR/IMAGES WG 123 on Reconstruction of Past Ocean Circulation (PACE) and SCOR/IMAGES WG 124 on Analyzing the Links Between Present Oceanic Processes and Paleo-Records (LINKS).

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		Angela Wagner	BRAZIL

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GEOTRACES SCIENTIFIC STEERING COMMITTEE
ANNUAL REPORT TO SCOR 2012/2013
July 2013

SCOR Scientific Steering Committee (SSC) for GEOTRACES

The SSC membership (listed above) includes members from 14 different countries, with diverse expertise, including marine biogeochemistry of carbon and nutrients; trace elements and isotopes as proxies for past climate conditions; land-sea fluxes of trace elements/sediment-water interactions; trace element effects on organisms; hydrothermal fluxes of trace elements; tracers of ocean circulation; tracers of contaminant transport; controls on distribution and speciation of trace elements; and ocean modelling.

1. SSC meeting

The seventh meeting of the GEOTRACES SSC was held on 29-31 October 2013 in Goa, India. The meeting was hosted by Sunil Kumar Singh from the Physical Research Laboratory (a Unit of Department of Space Government of India, Ahmedabad, India).

The meeting was attended by 16 members of the 2011/2012 SSC. Other attendees included Bob Anderson (Past SSC co-chair); Chris Measures (Co-chair of the Data Management Committee); Reiner Schlitzer (Co-chair of the Data Management Committee); Greg Cutter (Chair of the Standards and Intercalibration Committee); Ed Urban (SCOR); Ed Mawji (GEOTRACES Data Assembly Centre); and Catherine Jeandel (GEOTRACES International Project Office).

The morning of the first day was spent in presentations of national reports detailing GEOTRACES activities of the last year in 16 countries and also of the COST Action ES0801 (EU cross-national activities). The afternoon started with presentation of activities of the International Project Office. Subsequent discussion addressed GEOTRACES publications and outreach. The day concluded with a review of the international partnerships.

The morning of the second day of the SSC meeting focused on data management and intercalibration. An important discussion item was the Intermediate Data Product to be released in Spring 2014. During the afternoon, the GEOTRACES section cruises were reviewed. This included a presentation of the GEOTRACES International Arctic Programme, the GEOTRACES Mediterranean Cruise plans, and the BioGEOTRACES initiative. The day ended with discussion about GEOTRACES funding and rotations of SSC and Data Management Committee (DMC) members.

The third and final day of the SSC meeting started with a review of the applications from ten studies to become GEOTRACES Process Studies. Subsequent discussion addressed past and future GEOTRACES workshops and special sessions at scientific meetings. The meeting concluded with a discussion of GEOTRACES capacity building activities.

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The next SSC meeting is scheduled for 2-4 October 2013 in Bremerhaven (Germany) and will be hosted by Reiner Schlitzer at the Alfred Wegener Institute for Polar and Marine Research.

2. GEOTRACES Intercalibration

The GEOTRACES Standards and Intercalibration (S&I) Committee (G. Cutter, Chair; P. Andersson, L. Codispoti, P. Croot, R. Francois, M. Lohan, H. Obata, and M. van der Loeff) met on 1-3 May 2013 at the Swedish Museum of Natural History in Stockholm, Sweden to review Atlantic Ocean crossover station results and discuss several issues of relevance to the committee; the meeting was hosted by Per Andersson. The S&I Committee's charge is to ensure that accurate and precise data are generated in the GEOTRACES Program through the use of appropriate sampling protocols, analytical standards, and certified reference materials, and to ensure the active sharing of methods and results. There are few reference materials that actually represent real ocean waters, so as much as possible GEOTRACES cruises occupy stations along their transects that have been occupied by another GEOTRACES cruise, thus creating the "crossover" stations. Data from these crossover stations, particularly those in deeper waters, can be directly compared and if statistically significant differences are found, the investigators who generated the data can work together to resolve any underlying issues, for example, differences in calibration or blanks. To date, the S&I Committee has now examined more than 8,000 data points for trace elements and isotopes, mainly in the Atlantic Ocean, and water column hydrography (temperature, salinity, nutrients, and oxygen concentrations as a function of depth). Much of the data reviewed will be incorporated into the 2014 GEOTRACES Intermediate Data Product. Notices related to the S&I Committee evaluations have been sent to all the data suppliers, and the Committee will meet again in late September 2013 for a re-evaluation of results that have been resubmitted after a thorough intercalibration by the cruises' participants.

Another significant activity in 2012-2013 was the publication of further results from the GEOTRACES Intercalibration Programme in a special issue of *Limnology and Oceanography: Methods* entitled, "Intercalibration in Chemical Oceanography: <http://www.aslo.org/lomethods/si/intercal2012.html>. The editors of this special volume are Greg Cutter (USA), Peter Croot (UK), and Per Andersson (Sweden).

3. Data Management for GEOTRACES

The GEOTRACES Data Assembly Centre (GDAC) is hosted by the British Oceanography Data Centre (BODC), Liverpool, UK. GDAC is responsible for all GEOTRACES data activities from start to finish, including interacting with the Principal Investigators (PI) and national data centres, and will eventually become the central point for all GEOTRACES data.

The office is staffed by a single person: Edward Mawji. Under the present data model, GDAC will not contact a project scientist directly (unless the PI has granted prior permission) and all requests for data are channelled through the local/national data centres. This requires GDAC to have a good working relationship with each national data office. Considerable effort is spent each year trying to establish and maintain good working relationships with national data centres.

Working with the IPO

A good working mechanism has been established between GDAC and Elena Masferrer Dodas at the IPO. Information is freely exchanged between the two sites. The IPO has helped GDAC keep up to date with new developments and upcoming cruises; this has been especially important in 2012/2013 with so many GEOTRACES process studies approved at the 2012 SSC meeting.

Website progress

In 2011/2012, there was a desire from the GEOTRACES SSC and DMC to have a map interface as the front page of the GEOTRACES data management site hosted by BODC. In response to this request an interactive world map has been developed to aid in cruise and data discovery in a visual manner. With the list of GEOTRACES section cruises and process studies growing, such a capability greatly facilitates navigation.

The following functionalities were developed:

- An interactive map with the ability to load different layers. The layers available are past, future and process studies cruise lines.
- Cruise lines that are mouse-sensitive. When users rest the mouse over such elements they (1) obtain cruise names and (2) obtain a dropdown menu with links to cruise meta-information (dates, chief scientists, parameters/responsible PIs and data holdings).

A working version of this tool is available on the GDAC Web site; however, additional development is required to fix some obvious bugs. After the final version is released, a major Web site overhaul is planned by GDAC to make the maps and delivery mechanism more prominent on the Web site.

GEOTRACES Intermediate Data Project

In 2014, GEOTRACES plans to release an Intermediate Data Product. In preparation for this product, GDAC has been working closely with the GEOTRACES S&I Committee. Over the past 12 months, GDAC has spent considerable effort collecting and preparing files for the S&I meeting in May 2013. This involved compiling data from crossover stations and producing XML method documentation.

In preparation for the final intermediate data product, GDAC has started to load intercalibrated data from the IPY and GEOTRACES cruises into BODC's database (only data approved by the S&I Committee will be loaded into the database). Detailed data and metadata checks are required and final XML method and quality control documents need to be created.

Data overview

The data management of the project is now a huge undertaking, with 46 cruises associated with GEOTRACES and 815 data sets identified in BODC's database (expected to rise once missing metadata forms are submitted). More than 200 scientists have taken part in GEOTRACES cruises, with 14 different nations having run a major GEOTRACES/IPY section cruise or process study.

2012/2013 has been a relatively successful year; considerable progress has been made collecting data. With the Intermediate Data Product to be released in 2014, the GEOTRACES research

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community has made a massive effort to submit data to national data centres and GDAC. U.S. scientists have led the way, with the U.S. Biological and Chemical Oceanography Data Management Office (BCO-DMO) deserving a special mention for working with GDAC.

However, GDAC has noticed a problem with the quality of metadata being submitted. In 2012/2013, a significant amount of time and effort was wasted investigating missing metadata. Unfortunately, data are being submitted with no event information (e.g. CTD cast number), no reference to the bottle the sample was collected from and no methodology. All this information is required to meet the data management principles of BODC and GEOTRACES. This problem has arisen for several reasons. Some data centres do not require the same level of metadata as BODC and hence scientists were never asked by their national data centres to submit these metadata. This problem is mainly an issue for older IPY/GEOTRACES cruises that make up a large proportion of the IDP. The creation of metadata after the cruise is possible, but time-consuming. The problem has been reduced somewhat by designing metadata forms for GEOTRACES cruises and encouraging use of these forms.

Summary of GEOTRACES cruises

- 14 IPY cruises
- 2 compliant cruise
- 11 process studies
- 19 GEOTRACES cruises -13 sections

GEOTRACES section cruises:

GEOTRACES sections- 19 cruises

Pacific Ocean	GP13	2 cruises Australia and New Zealand
Pacific Ocean	GP03	1 cruise Japanese
Pacific Ocean	GP12	1 cruise France
Pacific Ocean	GP18	1 cruise Japanese
Pacific Ocean	GP02	1 cruise Japanese
Indian Ocean	GI04	1 cruise Japanese
Indian Ocean	GI03	1 cruise India
Atlantic Ocean	GA02	3 cruises Netherlands
Atlantic Ocean	GA10	2 cruises UK
Atlantic Ocean	GA06	1 cruise UK
Atlantic Ocean	GA11	1 cruise Germany
Atlantic Ocean	GA03	2 cruises USA
Mediterranean Sea	GA04N	1 cruise Netherlands
Mediterranean Sea	GA04S	1 cruise Spain

With the vast quantity of data from these cruises expected in 2013/2014, it becomes apparent that data need to be submitted by the time line specified. As ever, it is vitally important that scientists submit data following the GEOTRACES/BODC submission guidelines to ensure smooth processing and archiving.

In summary, GDAC policies are proving effective with clear results; PIs are following guidelines and metadata are being submitted.

4. Status of GEOTRACES Section Cruises

The anticipated decade-long field program is now well underway and is enjoying a successful implementation (Figure 1).

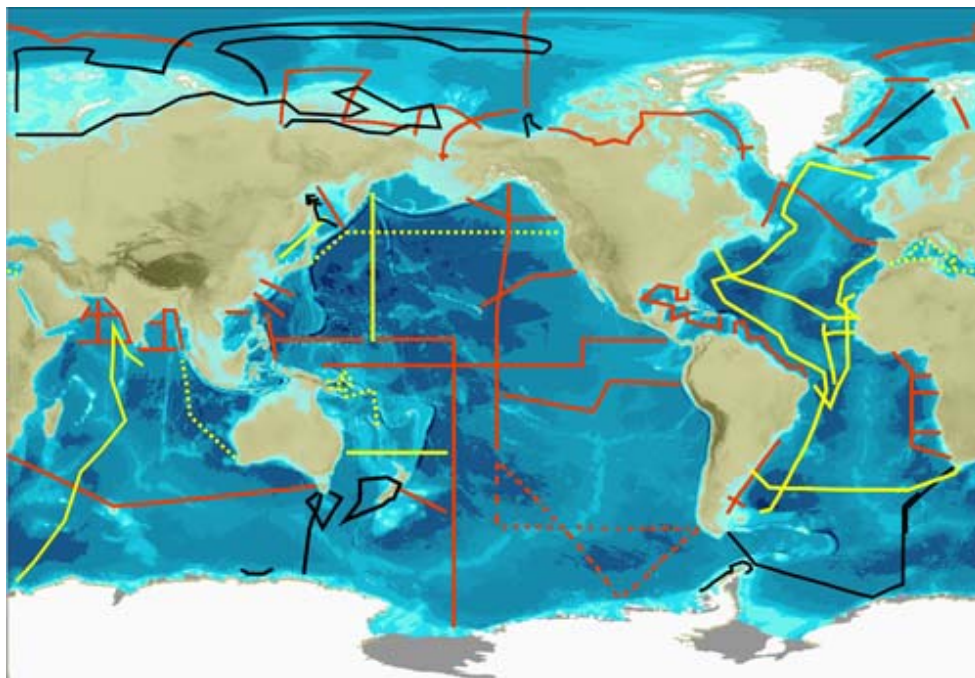


Figure 1. Status of GEOTRACES global survey of trace elements and their isotopes. In black: Sections completed as GEOTRACES contribution to the International Polar Year. In yellow: Sections completed as part of the primary GEOTRACES global survey (dotted yellow, completed during the past year). In red: Planned Sections. An updated version of this map can be found on the GEOTRACES home page <<http://www.geotraces.org>>.

5. GEOTRACES International Project Office

The GEOTRACES International Project Office (IPO) is based at the Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS) in Toulouse, France. The IPO is staffed by a single person, the IPO Executive Officer, Elena Masferrer Dodas. She works under the scientific supervision of Catherine Jeandel (CNRS, LEGOS, France). Ms. Masferrer Dodas was on maternity leave from 19 October 2012 to 25 March 2013. During this period, the GEOTRACES IPO was staffed by Ms. Paule Dossi.

The IPO is responsible for assisting the GEOTRACES SSC in implementing the GEOTRACES Science Plan and implementation plans of the programme; organising and staffing meetings of the

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SSC, working groups and task teams; liaising with the sponsors and other relevant organisations; seeking and managing programme finances; representing the project at international meetings; maintaining the project Web site and mailing lists; assisting the GDAC in securing information about upcoming cruises; and interacting with GEOTRACES national committees and groups, as well as with other international projects.

The IPO spent additional time on the following tasks in the past year:

Outreach: Two new items deserve description:

GEOTRACES eNewsletter: The e-Newsletter has been set up in order to disseminate the main scientific results of the GEOTRACES Programme and inform about all GEOTRACES activities. It is a bimonthly on-line publication available on the Web site and distributed through the GEOTRACES International mailing list. It includes highlights of main scientific results of GEOTRACES, summaries of GEOTRACES activities, GEOTRACES news, information about upcoming events (cruises, workshops, etc.) and the latest GEOTRACES-related papers published. The first issue was published in February 2013, with a total of 3 issues published so far. This publication replaces the previous *Science Highlights Newsletter*.

Outreach Library: To complement the educational material compilation, the IPO is assembling materials (images, figures, videos, etc.) to create a collection of compelling slides that show GEOTRACES results and work. These materials will be available on the GEOTRACES Web site for anyone to include in their presentations and help advertise the success of the programme.

GEOTRACES Facebook page: The IPO has set up and maintains a GEOTRACES Facebook page as requested by the SSC during last meeting. So far, 72 persons follow this page regularly. The GEOTRACES Facebook page is available on the following link:

<http://www.facebook.com/pages/GEOTRACES/255668524559825?ref=stream>

Communication tools: The GEOTRACES IPO has continued to improve and maintain the following communication tools:

GEOTRACES Web site <<http://www.geotraces.org>>: The project Web site, which provides up-to-date information about the GEOTRACES cruise programme and all GEOTRACES activities, has been overhauled this year. It has a new layout while maintaining the same structure. It also has new functionalities, such as the possibility to link the articles directly to Facebook, a GEOTRACES eNewsletter archive Web page, the possibility to create groups of users and make some pages (for instance, forum streams) only accessible to certain of these groups, etc. Maintaining and upgrading the programme Web site has consumed a considerable part of GEOTRACES IPO time this year.

The following addition to the Web site is worth describing:

*National and Regional Activities map: An interactive map has been set up on the GEOTRACES site. The map provides information about national representatives contact details and activities: <http://www.geotraces.org/science/national-activities>.

GEOTRACES Poster: A poster to be presented at international meetings and conferences has been designed and presented to several international conferences. A customizable template is available on the private GEOTRACES site.

Brochure: A brochure is available on the GEOTRACES Web site and printed copies can be requested from the GEOTRACES IPO.

Databases: The IPO is responsible to maintain the following databases:

GEOTRACES Peer-reviewed Papers and PhD Dissertations & Masters thesis Databases: Both databases have been set up by the IPO using the Mendeley free academic reference manager and they are available on the GEOTRACES Web site. The IPO updates them. This year, as requested by the SSC, the PhD dissertation database has been extended to include Master's theses. So far, 171 GEOTRACES peer-reviewed papers and 14 GEOTRACES-related PhD Dissertations and Master Thesis have been included.

GEOTRACES Researchers Database: The IPO worked with the GEOTRACES S&I Committee and the GEOTRACES Intercalibration Coordinators to set up a database of GEOTRACES Researchers' Analytical Expertise. 111 researchers have registered their expertise in the database so far. The S&I Committee has now validated the information for each researcher.

Other main tasks for the GEOTRACES IPO this year have included:

Funding: The GEOTRACES IPO has concluded one new funding agreement with the Alfred Wegener Institute (AWI) for Polar and Marine Research (Germany). The contribution initially envisaged for one year (2012) has been extended for another year (2013). French funding has been assured for one year more. Several meetings were held with sponsors.

Assisting GDAC: The GEOTRACES IPO is working closely with the GDAC and helps it to secure up-to-date information about new developments and upcoming cruises. This year, it was particularly important to compile information about the 8 new Process Studies approved during 2012 GEOTRACES SSC meeting.

Meeting organisation: The GEOTRACES IPO helped to organize the GEOTRACES Latin American Workshop (12-15 November 2012, Rio de Janeiro, Brazil), the Russian GEOTRACES Workshop (27-29 November, Moscow, Russia) and the upcoming 2013 SSC and join Data Management and S&I Committee meetings (29 September – 4 October 2013, Bremerhaven, Germany).

6. GEOTRACES Science Highlights

GEOTRACES scientists discover new variability in iron supply to the oceans with climate implications

Researchers based at the National Oceanography Centre Southampton (UK) and at the University of South Carolina (USA) have found that the amount of dissolved iron released into the ocean from continental margins displays variability not currently captured by ocean-climate prediction models. This could alter predictions of future climate change because iron, a key micronutrient, plays an important role in the global carbon cycle. The amount of iron leaking from continental margin sediments was previously assumed to reflect rates of microbial activity within the sediments. Dr. William Homoky and co-authors found that the rate of iron release from seafloor sediments close to continents is actually far more varied between regions because of local differences in weathering and erosion on land. The results of this study are published in *Nature Communications*:

http://www.geotraces.org/images/stories/documents/Publications/13_Homoky/ncomms3143.pdf



Figure 2. The image shows a satellite-captured view of a productive ocean margin in the western South Atlantic Ocean. Visible milky-blue swirls of ocean colour are blooms of tiny phytoplankton taking up carbon dioxide in the surface ocean. These blooms are caused by ocean currents, which stir nutrient-laden waters from the continental margins into the sunlit surface ocean. Rivers, like the South American Río de la Plata or River Plate shown here, are an important source of nutrient-rich material to shelf systems. Credit: NASA <http://visibleearth.nasa.gov/view.php?id=75351>

Latest Recommendations for Successful Analysis of Dissolved Osmium in Seawater

Analysis of osmium in seawater presents complex challenges, linked to its very low (femtomolar) concentrations and multiplicity of possible oxidation states. Early insights were provided by Karl Turekian's group at Yale where it was realized that osmium tends to concentrate both in oxidizing Fe-Mn nodules and in reducing organic-rich marine sediments. Efforts to directly measure the seawater osmium isotope composition and concentration began in earnest following the developments in early 1990s of highly sensitive N-TIMS and ICP-MS. Initial techniques that attempted to pre-concentrate osmium using column chromatography (Minoru Koide and collaborators at Scripps Institution of Oceanography) and co-precipitation (Mukul Sharma and collaborators at Caltech) were only partially successful, due to a lack of equilibrium between seawater and tracer osmium. A breakthrough came in 1998, when Sylvain Lévassour in Claude Allegre's group in Paris simultaneously oxidized and pre-concentrated osmium in liquid bromine at 90°C. Oliver Woodhouse and coworkers at the Woods Hole Oceanographic Institution

developed another procedure of directly distilling osmium from seawater and sparging it into an ICP-MS. These procedures appeared robust but yielded conflicting results. Subsequent work at Dartmouth (Sharma and collaborators) and Nancy (Maxence Paul and collaborators) has demonstrated that much higher temperatures and longer durations are required to fully equilibrate sample and tracer osmium. The complexities involved in storage of seawater osmium have also become apparent (see link to *Eos* report below). These findings resulted from U.S. National Science Foundation-funded GEOTRACES intercalibration efforts in the Pacific and Atlantic oceans. The new insights call into question much of the earlier data on the marine distribution of this important biogeochemical tracer and raise new issues: How actively is osmium cycled in the water column? What is the relative importance of the various sources? How important are anthropogenic inputs? The workshop on "Dissolved Osmium Isotope Analysis" held at the Palais de Congrès de Montreal on 24 June 2012 before the annual Goldschmidt Conference summarized the latest recommendations for successful seawater osmium analyses.

Reference:

Peucker-Ehrenbrink, B., M. Sharma, and L. Reisberg (2013), Recommendations for Analysis of Dissolved Osmium in Seawater, *Eos Trans. AGU*, 94(7), 73.

For further information: <http://onlinelibrary.wiley.com/doi/10.1002/2013EO070006/abstract>

A global compilation of dissolved iron measurements: focus on distributions and processes in the Southern Ocean

A data synthesis effort recently compiled more than 13,000 observations of dissolved iron concentrations that more than doubled the previous data compilation. A systematic analysis of the distribution of data in the Southern Ocean was performed using four regions, six basins and five depth intervals as a framework. Substantial variability in the depth-dependent trends were found between different basins and regions, which were indicative of the possible underlying influence of ocean physics, chemistry and biology. Alessandro Tagliabue's and co-authors (Tagliabue et al. 2012) analysis was able to highlight where observations are lacking in particular regions and times of year, which they hope will assist future sampling efforts. *Overall, more observations have been collected in the past 5 years under the auspices of the International Polar Year and GEOTRACES efforts than were collected in the prior ~15 years.* Nevertheless, despite this progress the seasonal cycle of iron that can be extracted from the well-sampled region south of Tasmania remains enigmatic. From more than 160 observations, the authors found little evidence of 'winter recharge' in iron concentrations and instead find the highest iron concentrations to be coincident with the highest phytoplankton biomass levels. This might reflect gaps in seasonal sampling between July and November or the influence of the so-called 'ferrous wheel' in driving the recycling of iron. This clearly highlights the need for more measurements of iron at 'seasonal transitions', even in well-sampled areas.

This dataset will prove useful for other regional synthesis studies or the evaluation of ocean biogeochemical models. It continues to be maintained by A. Tagliabue and is available from [GEOTRACES Data Assembly Centre web site \(http://www.bodc.ac.uk/geotraces/\)](http://www.bodc.ac.uk/geotraces/) and http://pcwww.liv.ac.uk/~atagliab/LIV_WEB/Home.html.

Reference:

Tagliabue, A., et al. (2012) A global compilation of dissolved iron measurements: focus on distributions and processes in the Southern Ocean, *Biogeosciences*, 9, 2333-2349, doi:10.5194/bg-9-2333-2012.

Substantial intra-basin variation of the dissolved metal/phosphorus ratio in the different water masses of the Indian Ocean

The first simultaneous, full-depth, and basin-scale section distribution of dissolved (D) aluminum (Al), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), cadmium (Cd), and lead (Pb) is reported in the Indian Ocean. In addition to widespread co-limitation for phytoplankton production by dissolved iron (DFe) and occurrence of redox-related processes, the authors observe an important variability of the dissolved metal/phosphorus ratio among the water masses within the Indian Ocean (up to a factor of 300 between Arabian Surface waters and Lower Circumpolar Deep Water). The Cu/P, Zn/P, and Cd/P ratios are within the same order of magnitude for both phytoplankton and deep water, whereas the Mn/P, Fe/P, and Co/P ratios of phytoplankton can increase 100-fold or more compared to those in deep water. Such results are questioning the validity of using an "extended Redfield ratio" to trace metals. The consistent mechanism yielding these variations remains to be understood.

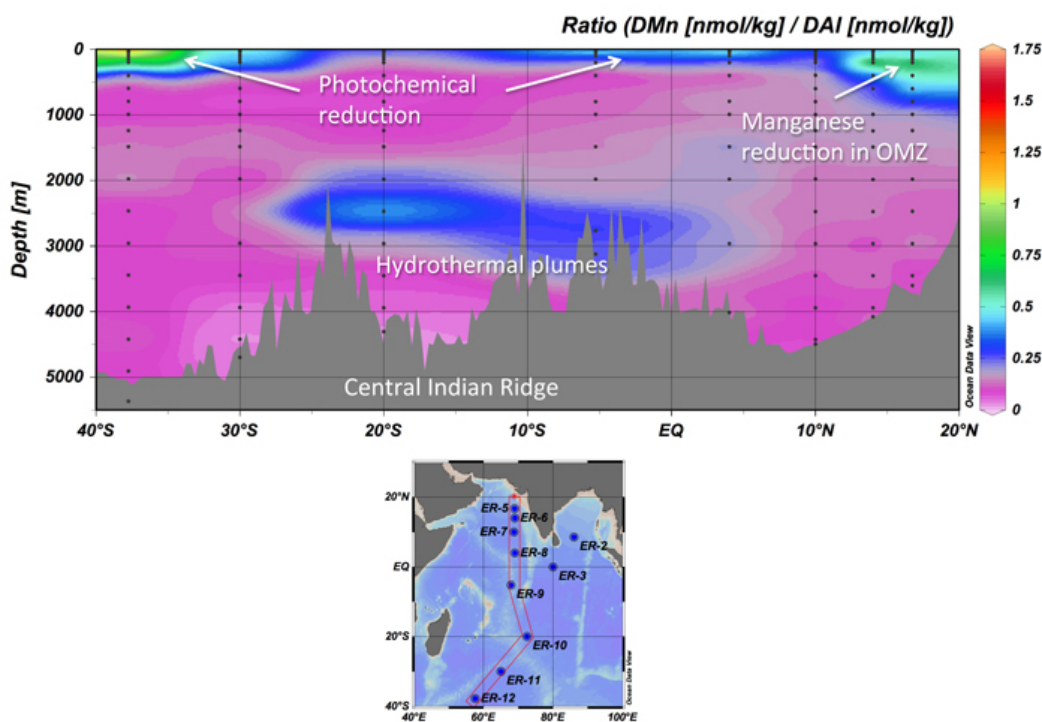


Figure 3. Meridional section distribution ($\sim 70^\circ\text{E}$) of the DMn/DAI ratio

Reference:

Thi Dieu Vu, H., Sohrin, Y. (2013) Diverse stoichiometry of dissolved trace metals in the Indian Ocean, *Scientific Reports* 3, DOI: 10.1038/srep01745

Available at : <http://www.nature.com/srep/2013/130429/srep01745/full/srep01745.html>

Arsenic detoxification by phytoplankton reveals that As species could be good proxies of P limitation

Some phytoplankton species have the capacity to modify surface water arsenic speciation, inhibiting its toxicity. Such detoxification is operative in oligotrophic waters when phosphate concentrations are below those for As. During the U.S. GEOTRACES North Atlantic transect, fine determination of As speciation allowed establishing the potential use of these detoxification products as indicators of P limitation. The new As indicator has been used to assess P-limitation in the North Atlantic Ocean, improving on the contradictory assessments using conventional proxies. The coupled relationship between As and P is a classic example of a biogeochemical cycle, and how such relationship can be used as a tool in oceanography.

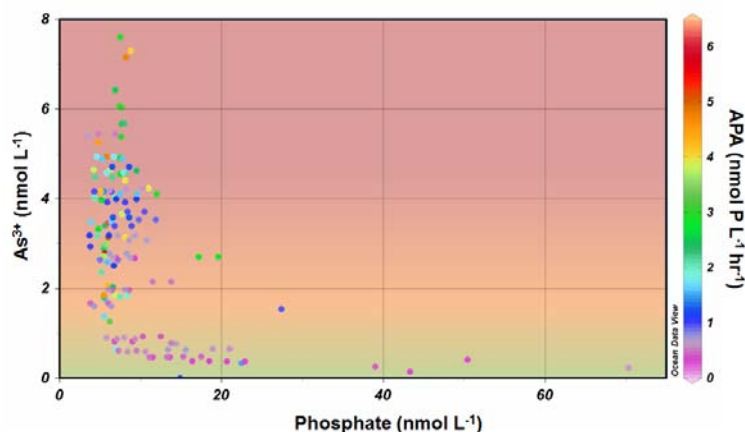


Figure 4. Relationship between inorganic phosphate, arsenite (As^{3+}) and alkaline phosphate activity (APA), the latter being an enzyme to cleave organic-bound phosphate and typically increasing with decreasing inorganic phosphate. Arsenate (As^{5+}) uptake by phytoplankton increases under low phosphate availability due to the chemical similarities between them. Detoxification includes reduction and excretion of As^{3+} , consequently indicating moderate (orange background) and extreme (red background) limitation of phosphate. No phosphate limitation occurs if As^{3+} levels are below 1 nmol L^{-1} (green background).

Reference:

Wurl, O., L. Zimmer, and G.A. Cutter. 2013. Arsenic and phosphorus biogeochemistry in the ocean: Arsenic species as proxies for P-limitation. *Limnol. Oceanogr.* 58: 729-740.

Significant role of dissolved/particulate Nd from the Ganga–Brahmaputra river system and Bay of Bengal margin in contributing to the dissolved Nd budget of the global oceans

Data on dissolved Nd concentrations and isotopic compositions measured along a 87°E transect (GI01 section, "Indian GEOTRACES") have been used in an inverse model in order to identify the respective effects of water mass mixing and Nd release from particulate matter in balancing this tracer budget in the Bay of Bengal. Results clearly underline that release from particulate phases supplied by the Ganga–Brahmaputra river system is required to explain both the distribution and budget of the Nd parameters. Calculations also suggest that supply of Nd from continental margin sediments is occurring at places identified as "hotspots of Nd release".

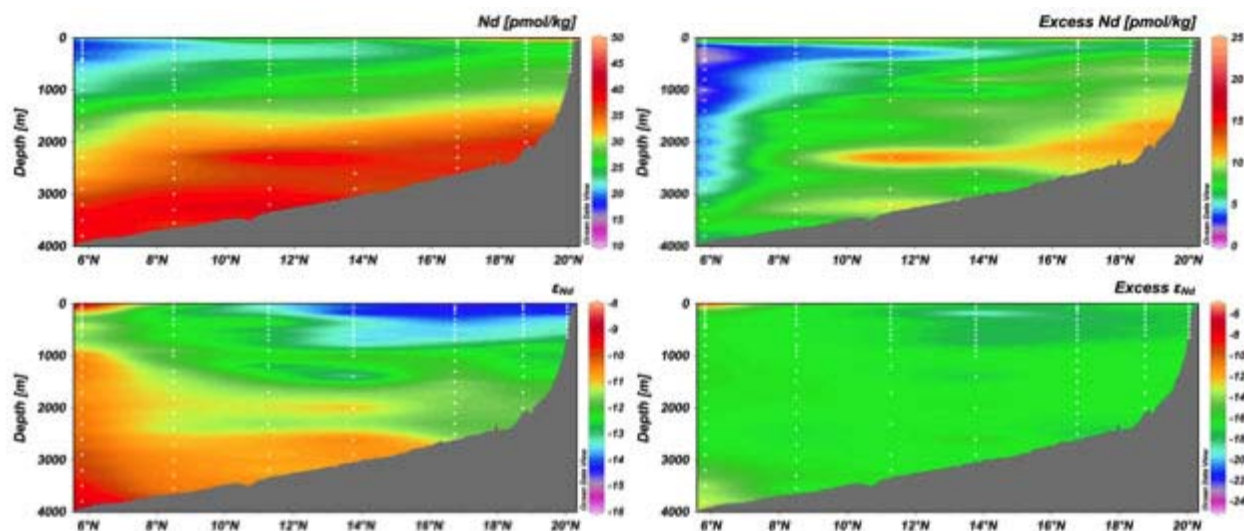


Figure 5. The distribution of concentration and isotope composition of dissolved Nd along the 87°E transect in the Bay of Bengal.

Reference:

Satinder Pal Singh, Sunil Kumar Singh, Vineet Goswami, Ravi Bhushan, Vinai Kumar Rai (2012), Spatial distribution of dissolved neodymium and ϵ_{Nd} in the Bay of Bengal: Role of particulate matter and mixing of water masses: *Geochimica et Cosmochimica Acta* 94:38-56, DOI: 10.1016/j.gca.2012.07.017.

Hydrothermalism: A Significant Dissolved Iron Source For The Deep Waters?

A north-south basin-scale full-depth section profile of dissolved Fe was realized in the Indian Ocean as part of the first GEOTRACES Japanese cruise (Nov. 2009-Jan. 2010). The data clearly show that hydrothermal Fe is distributed over 3000 km distance around a depth of ~ 3000 m, and that a large fraction of this Fe is truly dissolved. Several other sources supplying dissolved Fe to deep waters (e.g., terrestrial Fe input) with a persistent condition in the oxygen minimum zone (OMZ), were also evident.

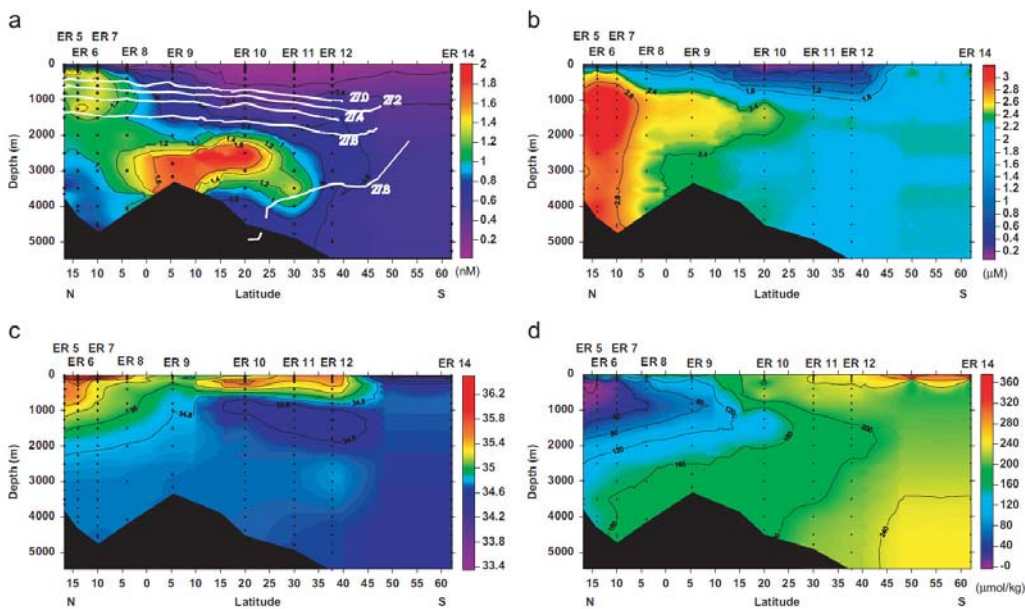


Figure 6. Vertical section profiles of (a) dissolved Fe concentration, (b) phosphate, (c) salinity, (d) dissolved oxygen. White number and line (a) indicate isopycnal surface.

Reference:

Jun Nishioka, Hajime Obata, Daisuke Tsumune (2013), Evidence of an extensive spread of hydrothermal dissolved iron in the Indian Ocean: *Earth and Planetary Science Letters* 361:26-33, DOI: /10.1016/j.epsl.2012.11.040

Basin-scale inputs of cobalt, iron, and manganese from the Benguela-Angola front to the South Atlantic Ocean

The African coast appeared to be a major source of dissolved total dissolved cobalt, iron, manganese, and labile cobalt to the South Atlantic basin, with high cobalt concentrations in the oxygen minimum zone of the Angola Dome and extending 2500 km into the subtropical gyre. Linear relationships between cobalt, N_2O , and O_2 , as well as low surface aluminum supported a coastal rather than atmospheric cobalt source. Point sources of the scale observed in this study likely serve as vital drivers of these tracer oceanic cycles.

Reference:

A.E. Noble, C.H. Lamborg, D.C. Ohnemus, P.J. Lam, T.J. Goepfert, C.I. Measures, C.H. Frame, K.L. Casciotti, G.R. DiTullio, J. Jennings, M.A. Saito (2012), Basin-scale inputs of cobalt, iron, and manganese from the Benguela-Angola front to the South Atlantic Ocean : *Limnology and Oceanography* 57 (4) p. 989-1010, DOI: 10.4319/lo.2012.57.4.0989

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New beautiful results on marine particle speciation, a challenge for the GEOTRACES community. Advanced Light Source x-ray spectromicroscopy (XANES) allows a fine description of the marine Fe pool chemical speciation and mineralogy. This work describes diverse arrays of iron particles (20- 700 nm), showing impressive variations in the oxidation state and composition of these iron particles between the coasts of South Africa and Antarctica. Moreover, different iron pools are occurring in different frontal zones. Because particle speciation is directly linked to the element solubilities, these differences may affect the production of bioavailable dissolved iron.

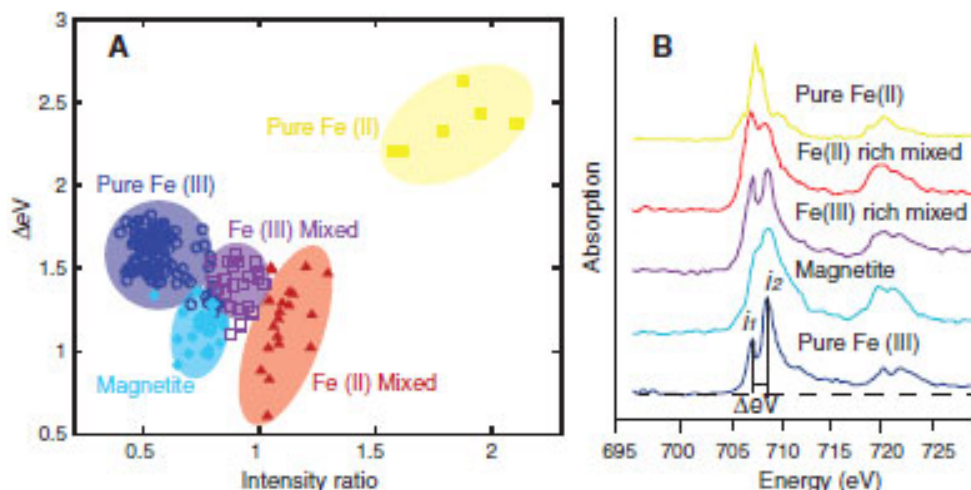


Figure 7. (A) Iron particle speciation plotted and defined accordingly to the particles' spectral features. Pure Fe(III), pure Fe(II), and magnetite phases occupy discrete fields, the mixed-valence species are distinguished by their variations in the spectral intensity ratios. (B) Generalized Fe L-edge XANES spectra of the five species identifies in the South Atlantic and Southern oceans; colors correspond to the fields in (A). The ΔeV value is calculated as the energy difference between peaks i_1 and i_2 ; the intensity ratio value is given as absorption intensity i_1/i_2 .

Reference:

B.P. von der Heyden, A.N. Roychoudhury, T.N. Mtshali, T. Tyliszczak, S.C.B. Myneni. (2012). Chemically and Geographically Distinct Solid-Phase Iron Pools in the Southern Ocean: *Science* 338 (6111):1199-1201, DOI: [10.1126/science.1227504](https://doi.org/10.1126/science.1227504)

Results from the GEOTRACES cruise section GIPY11

An interesting comparison of data of dissolved barium (Ba) and data of dissolved aluminium (Al) and silicate (Si) collected onboard the GEOTRACES cruise GIPY11 (ARK-XXII/2 *Polarstern* expedition) is presented in the article of Roeske and colleagues (Roeske et al., 2012). This comparison is used to distinguish between signals produced by the regeneration of sinking particles and signals derived from entrainment of shelf waters, adding to the analysis of Al and Si data of the same cruise by Middag et al. (2009). The two papers investigate whether the relationships between Ba, Si and Al differ between water masses and between the various deep Arctic Basins, and whether these differences can help us to infer deep water circulation and shelf water inputs.

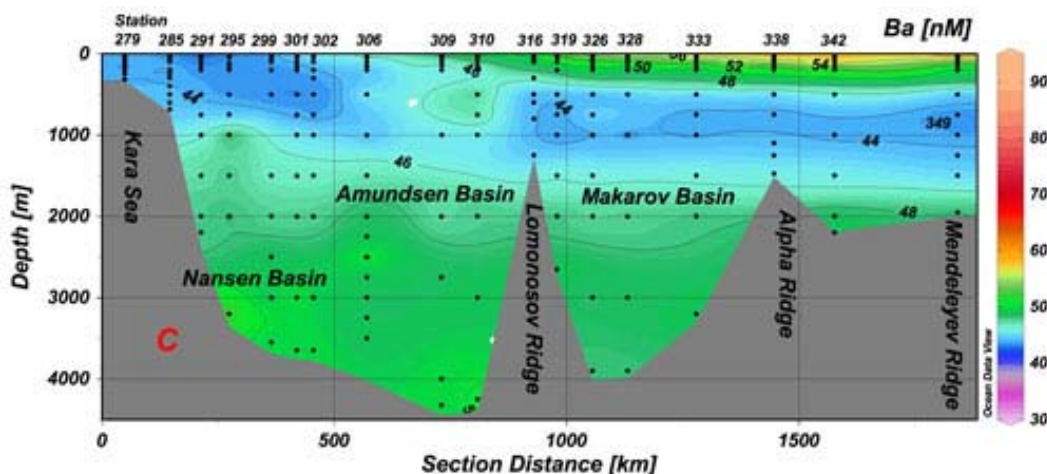


Figure 8. Distribution of Ba on section C, which reaches from the Kara Sea at 81.25°N to the Alpha Ridge at 84.5°N. Isolines are at 2 nM intervals. □ Source: *Marine Chemistry*.

References:

- Middag, R., de Baar, H.J.W., Laan, P., Bakker, K., (2009). Dissolved aluminium and the silicon cycle in the Arctic Ocean. *Marine Chemistry* 115, 176-195 □ □
- Roeske T., Rutgers vd Loeff M., Middag R., Bakker K. (2012), Deep water circulation and composition in the Arctic Ocean by dissolved barium, aluminium and silicate, *Marine Chemistry* 132-133, (56-67).

7. Workshops and events

Russian GEOTRACES Workshop

The first Russian GEOTRACES Workshop was held on 27-29 November 2012 in Moscow at the Shirshov Institute of Oceanology, Russian Academy of Sciences. About 90 persons participated, including Russian scientists from seven institutes, together with scientists leading the GEOTRACES program in Europe and the United States. During the workshop about 30 oral presentations were made (including 8 talks by young Russian scientists), along with 15 poster presentations. The workshop showed that research themes of Russian scientists in many respects correspond to the main GEOTRACES scientific goals. Particular Russian interests include estuarine chemistry (trace metals, radionuclides, and organic carbon compounds) of major rivers, biogeochemical processes (including trace metals and gases such as methane) on the Russian shelf, sedimentary and chemical fluxes between the shelf and open Arctic Ocean as well as the fluxes from atmosphere to the Arctic Seas.

The Russian workshop established international contacts and identified priorities for research into the marine chemistry of the Arctic Ocean. Research cruises that would address the main GEOTRACES scientific goals have been identified during discussion at the workshop. Issues linked with correct clean sampling and analysis of trace metals were discussed, since one of the main Russian problems is lack of special equipment to collect uncontaminated seawater samples for analysis of heavy metals. An obvious necessity is participation of Russian scientists in

intercalibration of the sampling procedures followed by the trace metal analysis, as well as training of young Russian scientists in the leading GEOTRACES' laboratories. All the participants supported a joint declaration (http://www.geotraces.org/images/stories/documents/workshops/Russian/Russian_GEOTRACES_Statement.pdf). Workshop participants suggested the rapid formation of a Russian GEOTRACES Committee to develop GEOTRACES activities and guide the scientific goals and implementation of the program in Russia.

GEOTRACES Latin American Workshop

To foster the involvement of Latin American (LA) scientists in the GEOTRACES program, the GEOTRACES SSC held a workshop in Rio de Janeiro (12-15 November 2012, Rio de Janeiro). About 40 scientists participated in the workshop, including representatives from 7 Latin American countries, scientists leading the GEOTRACES program in Europe and the United States, and 11 students. About 33 presentations were made during the workshop. The abstract collection is available on the following GEOTRACES web site:

http://www.geotraces.org/images/stories/documents/workshops/LA/2012_LA_Workshop_Abstacts_edited081112.pdf.

The Workshop had the following objectives: (1) Define scientific questions of global interest that are geographically proximal to LA nations; (2) Define scientific questions of national or regional interest that are too large, or too complex, to be addressed by a single nation or by small projects, and which therefore would benefit from international collaboration; (3) Identify opportunities and strategies for collaboration within the scope of the GEOTRACES Program; (4) Identify opportunities for technology transfer and training that would increase the capacity of scientists in LA nations to undertake GEOTRACES-related research. Participants at the meeting agreed on a final statement outlining important GEOTRACES science in the LA region, and synergies between GEOTRACES Activities and other science in LA:

http://www.geotraces.org/images/stories/documents/workshops/LA/GEOTRACES_LA_Statement.pdf.

GEOTRACES-COST Workshop –Stable isotopes of biologically important trace metals

A successful workshop was held at the Department of Earth Science and Engineering of Imperial College London (13-14 September 2012) to bring together, for the first time, the community of people working on stable isotopes of biologically important trace metals. The focus of the workshop was on the stable isotopes of Zn, Cd, and Fe, but isotope systems of other micronutrient and contamination-prone elements (particularly Pb) were also considered. Almost 50 people from 12 countries attended the workshop to share novel data and discuss analytical issues related to sampling and the isotopic measurements in the context of the GEOTRACES program. The Report of the Workshop is available on the GEOTRACES Web site at http://www.geotraces.org/images/stories/documents/workshops/Stable_Isotopes/workshop_Stable_isotopes_report_final.pdf.

The workshop was supported by COST Action ES0801 and SCOR. □ For further information: <http://www.geotraces.org/meetings/meetings-by-year/eventdetail/121/-/geotraces-cost-workshop-stable-isotopes-of-biologically-important-trace-metals>.

GEOTRACES-COST Voltammetric Workshop

This workshop was held in the frame of research activities at marine station Martinska, Rudjer Bošković Institute, Šibenik, Croatia on October 7-9. The meeting, which was very successful, gathering 40 participants from 14 countries, among them 14 PhD students and post-doctoral fellows. The event was co-organized by GEOTRACES, COST action ES801 and the Ruder Bošković Institute. All the participants expressed their interest and will to organize a follow-on meeting in two years as a necessity to discuss the role and use of electrochemistry in analysis and study of biogeochemical processes in aquatic systems. The Report of the Workshop is available on the GEOTRACES Web site at

http://www.geotraces.org/images/stories/documents/workshops/Voltammetry/VoltammetryWorkshopReport_COSTActionES0801.pdf. For further information about this workshop, see <http://www.geotraces.org/meetings/meetings-by-year/eventdetail/119/-/cost-geotraces-voltammetry-workshop>.

8. Special sessions at international conferences featuring GEOTRACES findings

Several special sessions with relevance to GEOTRACES were held at major international meetings including the following:

American Geophysical Union Fall 2012, 3-7 December 2012, San Francisco, USA

For further information: <http://fallmeeting.agu.org/2012/>

□

**OS013: Isotope Tracers in the 21st Century Ocean: New Results, Interesting Challenges, and Unique Opportunities* □

Conveners: Steven L Goldstein (Columbia University), Alison E Hartman (Lamont-Doherty Earth Observatory), Howie D Scher (University of South Carolina) and Torben Stichel (University of Hawaii at Manoa)

**OS036: Sources, Sinks, and Speciation of Marine Micronutrient Trace Elements* □

Conveners: Jessica N Fitzsimmons (MIT) and Christopher T Hayes (Columbia University)

ASLO 2013, Aquatic Sciences Meeting, 17-22 February 2013, New Orleans, Louisiana, USA

For further information: <http://www.aslo.org/meetings/neworleans2013/>

**SS57: Trace Elements and Isotopes in the Ocean and Atmosphere: the International GEOTRACES Program* □

Conveners: Peter Morton, Florida State University; Carl Lamborg, Woods Hole Oceanographic Institution

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**SS08: Biogeochemistry of Metal-binding Organic Ligands in the Ocean: Sources, Composition and Impacts on Trace Metal Cycling*

Conveners: Maeve C. Lohan (University of Plymouth); Sylvia G. Sander (University of Otago); Kristen N. Buck (Bermuda Institute of Ocean Sciences)

2013 Asia Oceania Geosciences Society Annual Meeting, 24-28 June 2013, Brisbane, Australia
For further information: <http://asiaoceania.org/aogs2013/public.asp?page=home.htm>

**Controls on the Biogeochemistry of the Northwestern Pacific Ocean and its Adjacent Marginal Seas* □

Main Convener: Dr. Tung-Yuan Ho (Academia Sinica, China-Taipei)

Co-conveners: Dr. Sohrin Yoshiki (Kyoto University, Japan), Prof. I-I Lin (National Taiwan University, China-Taipei) and Dr. George T F Wong (Academia Sinica, China-Taipei)

Forthcoming:

The 2013 Gordon Research Conference on Chemical Oceanography, 4-9 August 2013, Biddeford, Maine, USA

For further information: <http://www.grc.org/programs.aspx?year=2013&program=chemocean>

Goldschmidt 2013, 25-30 August 2013, Florence, Italy

For further information: <http://goldschmidt.info/2013/index>

**16h. Chemical Weathering in Marginal Environments* □

Conveners: Bernhard Peucker-Ehrenbrink and Morgan Jones □

Keynote: Catherine Jeandel (LEGOS, Toulouse)

**17a. The ins and outs of mud: chemical fluxes between sediments and seawater* □

Conveners: Silke Severmann and Rachel Mills □

Keynote: Ronnie N. Glud (University of Southern Denmark)

**17b. Constraining rates of ocean processes* □

Conveners: Laura Robinson and Matt Charette □

Keynote: Bill Jenkins (WHOI)

**17d Isotope geochemistry of the modern oceans* □

Conveners: Seth John, Julie Granger, Katharine Pahnke and Gregory F. de Souza □

Keynote: Curtis Deutsch (University of Washington)

**17g Metal-biota interactions in seawater* □

Conveners: Jay Cullen, Maeve Lohan and Martha Gledhill □

Keynote: Mak Saito (Woods Hole)

9. Capacity building

At-Sea Training GEOTRACES gratefully acknowledges support from SCOR to enable one scientist per year from a developing nation to participate in a GEOTRACES cruise. These opportunities are vital to the development of technical expertise in sampling and sample handling for contamination-prone elements aboard “dirty” ships.

Sampling Systems It is a goal of GEOTRACES that every nation carrying out oceanographic research should have access to a trace metal-clean sampling system. GEOTRACES offers guidance based on past experience in the design and construction of sampling systems as well as advice in operating these systems as shared facilities. A complementary goal is to establish a program whereby scientists who have accrued experience in operating these systems can share that knowledge with scientists from nations that are in the process of acquiring clean sampling systems.

An updated status of trace metal-clean sampling systems to support GEOTRACES research is provided in the table below. Scientists interested in developing one of these systems for their own use are encouraged to contact the GEOTRACES IPO or any member of the SSC, who will arrange for contact with an appropriate person to provide technical information about the design, construction and cost of a system.

Nation	Status	System/ Carousel	Bottles	Depth
Australia	Complete (2nd system planned)	Powder coated aluminum, autonomous 1018 intelligent rosette system	12 x 10-L Teflon-lined Niskin-1010X	6000 m; 6 mm Dynex rope
Canada	Complete	Powder coated aluminum with titanium CTD housing, Seabird Rosette	24 X 12-L GO-Flo	2300 m; conducting Vectran soon to be upgraded with 5000 m conducting Vectran 06/2013
China - Beijing	Complete	Towed fish	NA	Surface
China - Taipei	Complete	Teflon coated rosette	Multi- size GO-Flo	3000 m; Kevlar line
France	Complete	Powder coated aluminum with titanium pressure housing for CTD	12 X 12-L GO-Flo	8000 m; conducting Kevlar
Germany	CTD and bottles purchased, winch planned	Powder coated aluminum with titanium pressure housings and fittings	27 x 12-L OTE GO-Flo	8000 m; conducting Kevlar
India	Complete	Powder coated aluminum with titanium pressure housings and fittings	24 X 12-L Niskin-X	8000 m; conducting Kevlar
Italy	Complete	Go-Flo bottles on Kevlar line	5 x 20-L Go-Flos	Kevlar
Japan	Complete	Powder coated aluminum	12-L Niskin-X	10000 m; titanium armored cable
Netherlands	Complete	Titanium frame	24 X 12-liter	10000 m; conducting

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			GO-Flo	Kevlar
Netherlands	Complete	Titanium frame	24 X 27-liter ultraclean PVDF	10000 m; conducting Kevlar
New Zealand	Complete	Powder coated aluminum	5-L Teflon-lined Niskin-X	2000 m; 8 mm Kevlar line
South Africa	Complete	Powder coated aluminum, titanium housing/fittings	24 X 12-liter GO-Flo	6500 m; Kevlar cable
UK	In testing phase	Titanium frame, Ti pressure housings	24 10-L OTE	8000m conducting Kevlar
USA - CLIVAR	Complete	Powder coated aluminum	12 X 12-L GO-Flo	1500 m; conducting Kevlar
USA - GEOTRACES	Complete	Powder coated aluminum with titanium pressure housings and fittings	24 X 12-L GO-Flo	8000 m; conducting Kevlar
USA- University of Alaska Fairbanks	Complete	Seabird Rosette. Powder coated aluminum with Ti parts and pressure housing. Fires at pre-programmable depths	12 X 5-L Teflon-lined Niskin-X	No Kevlar line available yet.
USA- Old Dominion University	Complete	Seabird Rosette. SBE-19plusV2 CTD unit. Powder coated aluminum with Ti parts and pressure housing. Fires at pre-programmable depths	12 X 5-L Teflon-lined Niskin-X	2000 m 0.5-inch Kevlar wire
USA – Polar Programs	Complete	Powder coated aluminum with titanium pressure housings and fittings	12 X12-L Niskin-X	3000 m; conducting Kevlar

Acknowledgements

We offer our special thanks to Ed Urban, who continues to provide tremendous support and valuable advice to the planning of the GEOTRACES programme.

Written and compiled by:

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July 2013

3.4 Surface Ocean–Lower Atmosphere Study (SOLAS) (joint with IGBP, WCRP, and CACGP)

Coustenis, Law

Terms of Reference:

- To develop the Surface Ocean - Lower Atmosphere Study (SOLAS) Science Plan and an Implementation Strategy, in accordance with guidance of the sponsoring organisations.
- To oversee the development of SOLAS in accordance with its Science Plan/Implementation Strategy.
- To collaborate, as appropriate, with other related projects of IGBP, WCRP, SCOR and CACGP and related projects and programmes (e.g., IHDP, DIVERSITAS, IOC and the Global Ocean Observing System (GOOS), etc.)
- To establish appropriate data management policies to ensure access to, sharing of, and preservation of SOLAS data, taking into account policies of the sponsors.
- To report regularly to SCOR, IGBP, WCRP and CACGP on the state of planning and accomplishments of SOLAS.
- The SOLAS SSC, its subsidiary groups and International Project Office shall operate in accordance with the operating procedures for IGBP Projects and as required by other co-sponsors.

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Anja Engel	GERMANY	Lisa Miller	CANADA
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Hui-wang Gao	CHINA-Beijing	Patricia Quinn	USA
Christophe Garbe	GERMANY	Rafel Simo	SPAIN
Michele Graco	PERU	Jacqueline Stefels	NETHERLANDS
Christophe Heinze	NORWAY	Roland Von Glasow	UK
		Brian Ward	IRELAND

Executive Committee Reporter: Athena Coustenis

IGBP Liaison: Wendy Broadgate

Executive Officer: Emily Breviere

Annual Report from SOLAS to SCOR

Reporting period: June 2012- July 2013
Version of 12 July 2013 by Dr Emilie Brévière

SOLAS International Project Office, Kiel and Node Office, Norwich

The SOLAS Node Office (NO) was located at the University of East Anglia (UEA), UK, the former location of the IPO. The office was staffed by the project officer Kath Mortimer, funded by the UK NERC until the end of Sept. 2012, and benefited from the assistance of a student, Georgia Bayliss-Brown (former project officer) from June 2011 to August 2012 (10 hours per week), funded by IGBP block grant 2010-11. UEA provided office space and the Natural Environment Research Council (UK NERC) supported office activities until March 2012. The node shut down in Sept. 2012.

The SOLAS IPO is currently hosted at the GEOMAR Helmholtz-Centre for Ocean Research Kiel in Kiel, Germany. The office is staffed by the executive officer, Dr. Emilie Brévière, and the project officer, Stefan Konradowitz. GEOMAR provided office space and funds for both staff salaries until January 2013. The IPO activities were supported until January 2013 by the German Ministry of Education and Research (BMBF). The IPO in Kiel has benefited since August 2011 from the assistance of a student, Roberto Benavides (75 hours per month) funded by BMBF and from July 2012 to March 2013 from the assistance of another student, Jasmin Mögeltönder (75 hours per month), also funded by BMBF.

Since February 2013 and until January 2016, GEOMAR is providing office space and the salary of the executive officer, Dr. Emilie Brévière. The salary of the project officer, Stefan Konradowitz is covered by BMBF, via the SOPRAN Phase 3 funding. The IPO benefited until July 2013 from the assistance of Roberto Benavides (75 hours per month) funded by BMBF.

SOLAS Scientific Steering Committee

Since July 2011, Eric Saltzman (USA) has served as Scientific Steering Committee (SSC) Chair. Veronique Garcon (France) served as the SOLAS SSC Vice-Chair from July 2011 to Dec. 2012, and Cecile Guieu (France) has filled this role since May 2013. Ilan Koren from Israel joined the SSC in Jan. 2013. Since May 2013, SOLAS has had an Executive Committee composed of the Chair, Vice Chair, and SSC members Lisa Miller and Roland von Glasow. The 13th SOLAS SSC meeting was held in Tsukuba, Japan, on 27-30 May 2013. The current membership of the SSC is listed below:

Last name	First name	Country of employment	Gender	Scientific expertise	SOLAS expertise	Term end in 31 Dec
Dai	Min-Han	China-Beijing	M	Coastal carbon/acidification	Focus 3 - SIOA	2014
Engel	Anja	Germany	F	Microbial biogeochemistry, sea surface microlayer	MTS Marine Aerosols	2014
Gao	Huiwang	China-Beijing	M	Atmospheric deposition and ecological effect	MTS Nut Deposition - Task Team ADOES	2014
Gaiero	Diego	Argentina	M	Aerosol chemical composition/deposition	MTS Nut Deposition	2013
Garbe	Christoph	Germany	M	Air-sea physical interaction	Focus 2 - MTS EBUS - Liaison ESA	2013
von Glasow	Roland	UK	M	Atmospheric halogens/modelling	Task Team HitT- MTS Ship Plumes	2013
Graco	Michelle	Peru	F	Biogeochemical cycles in upwelling systems, OMZ	MTS EBUS	2014
Guieu	Cecile	France	F	Marine ecosystems/nutrients	MTS Nut Deposition	2014
Heinze	Christoph	Norway	M	Carbon cycle modeling/paleocean	Focus 3 - Paleo	2015
Koren	Ilan	Israel	M	cloud physics	Focus 1 - Cloud	2015
Miller	Lisa	Canada	F	Sea-ice/CO ₂ exchanges	Focus 3 - MTS Sea Ice	2013
Nojiri	Yukihiro	Japan	M	Ocean carbon	Focus 3 - SIOA	2015
Quinn	Patricia	USA	F	Aerosols/atmos chemistry	MTS Marine Aerosols	2014
Saltzman	Eric S.	USA	M	Atmospheric chemistry	Focus 1&2	2014
Simo	Rafel	Spain	M	Ocean biogeochemistry /trace gases	MTS Marine Aerosols	2014
Stefels	Jaqueline	Netherlands	F	Sulfur cycle/sea ice	MTS Sea Ice	2013
Ward	Brian	Ireland	M	Air-sea physical interaction	Focus 2- Liaison WCRP	2013

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In December 2013:

- Roland von Glasow and Jacqueline Stefels will rotate off the SOLAS SSC after two terms.
- Brian Ward, Christoph Garbe, Lisa Miller and Diego Gaiero will end their first terms on the SOLAS SSC.

SOLAS National Networks

Twenty-eight nations are part of the SOLAS network. Each has at least one representative:

Australia: Sarah Lawson and Andrew Bowie	Japan: Mitsuo Uematsu
Belgium: Christiane Lancelot	Korea: Kitack Lee
Brazil: Amauri Pereira de Oliveira	Mexico: Jose Martin Hernandez Ayon
Canada: Maurice Levasseur	Netherlands: Jacqueline Stefels
Chile: Laura Farias	New Zealand: Cliff Law
China (Beijing): Minhan Dai	Norway: Abdirahman Omar
China (Taipei): Gwo-Ching Gong	Peru: Michelle Graco
Denmark: Lise Lotte Soerensen and Mikael Sejr	Russia: Sergey Gulev
France: Remi Losno	Spain: Rafel Simo
Germany: Hermann Bange and Ulrich Platt	Southern Africa: Carl Palmer
India: Dileep Kumar	Sweden: Katarina Abrahamsson
Ireland: Brian Ward	Turkey: Baris Saglihoglu and Mustafa Koçak
Italy: Chiara Santinelli	UK: Phil Williamson
Finland: Gerrit de Leeuw	USA: Bill Miller

Starting in Jan. 2009, the national representatives of the SOLAS nations have been asked to report annually about the SOLAS activities in their countries. To facilitate the reporting effort, a template form is provided. In January 2013, 19 reports were received and posted on the SOLAS website. Information contained in the reports is a great source of information for the IPO to report to sponsors, but also to facilitate coordination of research and to distribute the results and progress from some nations to the rest of the SOLAS community via the Newsletters and the website. All the reports received during the reporting period are available in an Addendum to this report (see http://www.scor-int.org/2013EC/SOLAS_National_Reports.pdf).

Development of the SOLAS Mid-term Strategy (MTS)

Since 2008, SOLAS has supported the development of the Mid-term strategy (MTS) themes, identified as areas where progress can be accelerated significantly with the support of an international programme such as SOLAS. An overview article at the MTS themes was published in the journal *Environmental Chemistry* in early 2013.

Law C. *et al.* (2013) Evolving Research Directions in Surface Ocean - Lower Atmosphere (SOLAS) Science. *Environmental Chemistry*. Available on our SOLAS website and at http://www.publish.csiro.au/view/journals/dsp_journals_pip_abstract_Scholar1.cfm?nid=188&pip=EN12159

The SOLAS News Issue 15 (Summer 2013) contains scientific articles relating to many of the MTS themes. Each theme is at a different stage in its implementation, but there is a major amount of scientific activity ongoing and planned:

• **Sea-ice biogeochemistry and interactions with the atmosphere**

Recent activities of the MTS on sea-ice are intrinsically linked to SCOR WG 140, co-chaired by Jacqueline and Nadja Steiner. Their first unofficial meeting took place during the SOLAS OSC 2012 in the United States. The Full Members met officially for the first time virtually via Skype in Dec. 2012 and they had their first in-person meeting in March 2013 at the Gordon Research Conference on Polar Marine Science in Ventura, California, USA. They met in plenary and in task groups, TG1 on Methodologies and intercomparisons, led by Lisa Miller and Lynn Russell; TG2 on Data collection, led by Klaus Meiners and Martin Vancoppenolle; and TG3 on Modelling, led by Nadja Steiner and Clara Deal.

TG1 has 3 primary goals: 1) The methodological survey is well underway, over 100 pages to be submitted to the e-journal *Elementa: Science of the Anthropocene-Oceans* by the end of summer; 2) for the intercomparison of methods, the idea is to bring ice cores back from the field, to set up the scene to have lab/ice-tank studies and ice camp; 3) either a biogeochemistry section of a guide of best practices is planned to be added to the next edition of Hajo Eicken's sea-ice methods book or a type of 'living' on-line document will be produced.

TG2 has 2 primary goals. For the first, the group started to produce data inventories. The first dataset on Chl-a from Antarctica has been published Meiners et al. GRL 39, 2012, doi:10.1029/2012GL053478; from the Arctic, Michel and Gosselin are collating the data. Other parameters such as POC/N, DOC/N, nutrients, temperature and bulk salinity will be added to the dataset at some point after a person is hired to do the task. For the second goal, the standardized data-collection protocol will be written into the review of the TG1 and/or the manual of best practices.

TG3 has four primary goals. 1) A short paper/report will be written by modelers to help observationalists to better understand what kind of data and variables modelers need. 2) An overall review paper on the 'Role of sea ice in global biogeochemical cycles: emerging views and challenges' has been published in *Quaternary Science* by Vancoppenolle et al. (2013). Some more review papers on major biogeochemical processes are being discussed (DIC-system, Fe and nutrient distribution, light penetration, algal release from ice, ice-atmosphere coupling). 3) Four different 1D-intercomparison exercises were identified (L. Tedesco): general phytoplankton, DMS, physical ice-ocean, ice-atmosphere: long time-series data sets are being identified for this exercise. 4) Link to regional modeling and global Earth system models: there is a strong link with activities within the AOMIP/FAMOS program.

WG 140 will meet two or three additional times; the next meeting is likely to take place in March 2014 in Hobart, Tasmania, in conjunction with the IGC sea-ice symposium. It was identified that small workshops would facilitate the progress of the MTS and in preparing for fieldwork.

Linkages are in place with BEPSII and OASIS (<http://oasishome.net/>). OASIS will be endorsed by SOLAS in the coming months.

In a near future the leader of the MTS will approach the WCRP core project CliC (<http://www.climate-cryosphere.org/>) and look into the MOSAiC initiative (Multidisciplinary Drifting Observatory for the Study of the Arctic Climate-<http://www.mosaicobservatory.org/index.html>).

• **Atmospheric control of nutrient cycling and production in the surface ocean**

In Dec. 2010, an EU COST Action 735-funded workshop took place in Istanbul, Turkey on “Atmospheric versus land based controls of nutrient cycling and production in the surface ocean: from fieldwork to modelling” (coord. C. Guieu and B. Salihoglu). After a set of rejections by *Science*, *Nature Geosciences* and *PNAS*, the authors of what is now more a research paper and includes new model runs envision to submit it to *Global Biogeochemical Cycles* (Guieu C., O. Aumont, A. Paytan, L. Bopp, C.S. Law, N. Mahowald, E. P. Achterberg, E. Marañón, 2013, Complex biological responses to atmospheric deposition in Low Nitrate Low Chlorophyll regions of the ocean). Another clear outcome of this long publishing process is the birth of a new community composed of modellers and observers. Another product related to this theme and supported by SOLAS was a review paper was published in *Nature Geosciences*, as an outcome of the IGBP/SCOR Fast Track Initiative ‘Upper Ocean Nutrient limitation: processes, patterns and potential for change’. Moore et al., 2013, Processes and patterns of oceanic nutrient limitation, *Nature Geoscience*, doi:10.1038/ngeo1765. Finally, this MTS theme was largely covered in chapter 4 ‘Ocean-Atmosphere interactions of particles’ of ‘Ocean-Atmosphere Interactions of Gases and Particles’, which marked the end of COST Action-735. Lead Authors: G. de Leeuw and C. Guieu. Contributing authors (alphabetical): A. Arneth, N. Bellouin, L. Bopp, P. Boyd, H. Denier van der Gon, K. Desboeufs, F. Dulac, C. Facchini, B. Langmann, N. Mahowald, E. Maranon, C. O’Dowd, N. Olgun, E. Pulido-Villena, M. Rinaldi, E. Stephanou, T. Wagener.

With regard to conferences, two session topics under the theme ‘ocean and Atmosphere’ of the Goldschmidt 2014, CA, USA, June 9-13 are relevant to the MTS: ‘Atmospheric nutrient supply to the surface ocean’ and ‘Ocean acidification, nutrient availability and impact on ecosystems’.

Six national projects have been endorsed by SOLAS are related to this MTS. To achieve further progress, small thematic workshops on some hot topics, such as dust/ashes impacts, could be envisioned. The MTS leaders will get in contact with the bioGEOTRACES (<http://www.geotraces.org/science/biogeotraces>,) leaders (Phil Boyd, Carol Robinson and Maite Maldonado), especially on the dust/ash topic.

• **Air-sea gas fluxes at Eastern Boundary upwelling systems**

In the context of the EUR-OCEANS Flagship, Ivonne Montes started a post-doctoral fellowship in Sept. 2011 between Toulouse, Lima, and Kiel on this theme and will continue for an additional year at GEOMAR Kiel until September 2014. The ESA OceanFlux ‘upwelling’ project is progressing well (see later section). A series of field studies have been carried out: 1) the East South Pacific Cruises *Meteor*, German SFB754, Oct. 2012-March 2013. All cruises have been completed with great success; 2) a very successful SOPRAN *Meteor* cruise off Peru in Dec. 2012; 3) mesocosm experiments off Peru, between Feb. and Apr. 2015; 4) AMOP Mooring deployment carried out on Jan. 5, 2013. The mooring will be in place for 3 years; 5) Mooring site

visit by R/V *Olaya* or R/V *Humboldt* in summer 2013; 6) AMOP Cruise hopefully early 2014, R/V *L'Atalante* and *Olaya* together; 7) Training of Peruvian students: On the road course, ONTROC, IMARPE(?) - IGP-GEOMAR-LEGOS, 6 days between Feb. and Apr. 2014 in Lima, Peru.

Activities are underway to set up a meteorology and oceanographic station at Hormigas Islands (OceanSITES). The station is located close to the AMOP mooring. There is already a lighthouse at the site. A successful workshop sponsored by SOLAS, IRD/LEGOS, SOPRAN and IGP took place at IGP in Nov. 2012 entitled “Towards an integrative regional coupling in the EBUS”. It was co-organised by Ken Takahashi, Veronique Garçon and Boris Dewitte. A wide range of physical and biogeochemical topics were covered and a one-day series of talks for Peruvian students took place on the 28th. A SCOR Working Group proposal has been submitted on microbial biogeochemistry of low oxygen waters (OMZ mainly EBUS and coastal hypoxia) led by Sean Crowe from the University of British Columbia. The proposal is highly interdisciplinary, gathering biogeochemists, microbial oceanographers, modellers and physical oceanographers. Regarding the future plans, there will be 1) a plenary lecture on deoxygenation at the EUR-OCEANS Hot topics Conference in Las Palmas, Spain, 6-8 Nov. 2013; 2) session during the IMBER Open Science Conference in Bergen, Norway, 23-27 June 2014; and 3) a theme on Ocean Deoxygenation “Losing breath in the Ocean: what is next?” at the 46th Liege colloquium, 5-9 May 2014, Liege, Belgium. With regard to interaction between SOLAS, CLIVAR and IMBER, some discussions took place between Véronique Garçon and Ken Drinkwater from Bergen (CLIVAR SSG member and IMBER SSC member) to join forces on this MTS. Indeed, CLIVAR and IMBER have formed a group around a research opportunity on upwelling about a year ago and a report was written and presented by Drinkwater at the CLIVAR SSG meeting, early May 2013, Kiel, Germany. CLIVAR interest lies in the lack of resolution in the GCMs in upwelling areas that leads to biases in those GCMS and the role of large-scale circulation and its effects on upwelling variability. IMBER’s interest lies into the influence of upwelling on biogeochemistry and ecology in these regions. The leader was recently encouraged to contact GEOTRACES members and leaders of the PICES Working Group on North Pacific Climate Variability and Change (No. 27) chaired by Mike Foreman, Shoshiro Minobe and Emanuele Di Lorenzo.

• **Ship plumes: impacts on atmospheric chemistry, climate, and nutrient supply to the oceans**

A paper from Hasseløev et al. 2013 accepted in GRL informed that shipping contributes to ocean acidification, according to the global model study. Pre-2012 attempts to engage the ocean science community to focus on this topic were not so successful, although atmospheric scientists are interested. Recently, some projects on ship emissions, pollution and climate started, such as Clean North Sea Shipping and MeSMarT. A postdoc just started to work on impacts of ship emissions on the ocean at the Ocean University of China (Gao, Yao).

• **Ocean-derived aerosols: production, evolution and impacts**

A workshop took place in Raleigh, North Carolina on 4–6 June 2012 on “Status and prospects of sea spray aerosol research”. A summary paper from the workshop was accepted in *Atmospheric Science Letters*. Some recommendations were to ensure that the terminology is consistent among oceanographers, atmospheric scientists, etc., to create a size-resolved sea salt aerosols (SSA)

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observational database that includes composition, number concentration, etc. and to improve communication between interdisciplinary fields. A SOLAS workshop took place in Kiel, Germany, on 11–13 Dec. 2012 on ‘Marine polymer’, during which many questions were asked related to the “gel theory of marine aerosols”. The products of the meeting are not yet available. A SCOR WG 141 on Sea-Surface Microlayers, started in 2013, will contribute to the SOLAS MTS on ocean-derived aerosols. The group met at EGU in April 2013 but there is not yet a summary report from the meeting. Several field experiments have been planned and/or discussed: 1) WACS II, Western Atlantic Climate Study II, 17 days of ship time on RV *Atlantis* between Miami and Barbados with 30 scientists onboard in April-June 2014 with the goals to generate and characterize nascent SSA, simultaneously characterize the surface seawater properties and assess the relationships between SSA OC and ocean DOC and POC. 2) The PEGASO project (Plankton-derived Emission of Gases and Aerosols in the Southern Ocean) led by Rafel Simo has been funded. Its core activity is an oceanographic expedition to the Southern Ocean aimed at studying plankton production of aerosols and seeking evidence for biological influence in cloud waters. The cruise will be in Nov.-Dec. 2014 for 42 days. 3) The CORMORANT project (Cumulus Ocean Radiation Measurement Over a Natural Tropical Site), proposal was submitted to US DoE. The study area would be the Galapagos Islands, with field campaigns in Aug.-Sept. 2016 and March-Apr. 2017. The project scientific questions of relevance to SOLAS are the following: What is the relationship between boundary layer clouds, aerosols, air-sea fluxes and upper ocean properties around the relatively pristine region of the Galapagos? What are the effects of biological and organic sources of aerosols associated with ocean upwelling near the Galapagos on CCN and the evolution of clouds? How does the vertical structure of the boundary layer change with strong variations in the SST and air-sea fluxes about the Galapagos and what is the impact on cloud properties. 4) the SOCRATES project (Southern Ocean Cloud, Rain/Radiation, Aerosol Transport Experimental Study) between New Zealand and Antarctica is likely in Jan.-Feb. 2018. The scientific questions related to SOLAS are the following: Why do models systematically under-predict cloud cover over the Southern Ocean, particularly on the pole-ward side of the storm tracks? What processes determine the concentrations of cloud-forming aerosols, cloud droplets and ice crystals over the Southern Ocean? The project is seeking endorsement from SOLAS.

SOLAS Open Science Conference 2015

Plans for the OSC15 are well underway. The OSC15 will take place in Kiel, Germany at the Christian-Albrechts-Universitaet zu Kiel during the week of 14-18 September 2015. Advantages are that Kiel is easy to access internationally through Hamburg airport and a good shuttle services to Kiel in 1h-1.5h, hotels can be found in different price categories (from 50 to 120 euro per night), and it is a maritime environment where GEOMAR is located. The conference venue would be the University of Kiel. The capacity of the rooms available ranges from 20 to 800 seats. The meeting rooms are fully equipped, with space for poster boards, registration, and catering in the same building. The venue is not far from the centre of Kiel and good bus connections are available.

The local organising committee (LOC) has been formed and is composed of Hermann Bange (GEOMAR), Gernot Friedrich (Univ. Kiel), Christa Marandino (GEOMAR), Birgit Schneider (Univ. Kiel) and Emanuel Soeding (Future Ocean Cluster of Excellence Kiel).

The SOLAS OSC15 will be taking place in conjunction with two major events 1) the SOPRAN final meeting, to take place on the Monday, Sept. 14 (a day before the start of the OSC15) and 2) the OSC15 will be part of the Future Ocean Cluster of Excellence semester theme on “Processes at Ocean Interfaces: from science to society”. The OSC15 is one of the events of this summer theme; significant funding will then be dedicated to the OSC15. The Scientific Organising Committee will be composed of the SOLAS SSC and one member of the LOC. The first announcement was released in the SOLASnews Issue 15 in June 2013.

International SOLAS Summer School 2013 (<http://mel.xmu.edu.cn/solassummerschool/>)

The 6th SOLAS Summer School will take place for the first time in Xiamen, China, from 23 Aug. to 2 Sept. 2013, after five editions of the school being held in Cargese, Corsica, France. The 6th SOLAS Summer School (SSS) is continuing the format and styles of previous SSSs, with adaptation in terms of special sessions and practicals made to better suit the local facilities and settings. Things are on track for holding another successful SSS. This time again the Summer School benefits from the generous support from numerous Chinese and international sponsors, including SCOR.

COST Action 735

In late 2006, SOLAS was awarded networking funds from the European Coordination in the field of Scientific and Technical Research office (COST) for a dedicated ‘Action’ 735 which seeks to develop global air-sea flux data sets of gases and aerosols. The SOLAS IPO administered the networking funds.

The Action ended in October 2011 and to pull together its achievements, a final action event took place in November 2011 and a high-level textbook for publication in 2013 is currently underway. The book is entitled “Ocean-Atmosphere Interactions of Gases and Particles” and will be published by Springer. Information written on the Springer page:

<http://www.springer.com/earth+sciences+and+geography/earth+system+sciences/book/978-3-642-25642-4>

- Arguably the only book dealing with exchange of energy including heat, chemicals and biological organisms across the interface between ocean and atmosphere
- First synthesis of a set of disparate topics into a coherent treatment of the exchange of matter across the sea surface
- Deals with a very important topic required for an understanding of how the earth system operates

The oceans and atmosphere interact in a myriad of ways, including the exchange of energy including heat, chemicals and biological organisms across the interface between the two media. In this book the leading experts in this field internationally provide a state of the art account of these exchanges, particularly concentrating on the exchange of chemicals. They examine how gases and particles formed in the oceans affect the chemistry and physics of the atmosphere when they move from ocean to atmosphere. They also demonstrate how material deposited into

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the oceans from the atmosphere affects the biogeochemistry of the oceans. The mechanisms by which these exchanges occur is critically presented.

One chapter is devoted to the role of oceans in the uptake of natural and manmade CO₂ examining the ocean as a source of greenhouse gases CH₄ and N₂O to the atmosphere. The final chapter shows the role that atmosphere-ocean interactions play in earth systems science.

Keywords → Atmosphere ocean interaction - Biogeochemistry - COST 735 - Chemical Exchanges - SOLAS - Trace gases - air-sea interface

Chapter 1: Short-lived trace gases in the surface ocean and the atmosphere

Chapter 2: Transfer across the air-sea interface

Chapter 3: Air-sea interactions of natural long-lived greenhouse gases (CO₂, N₂O, CH₄) in a changing climate

Chapter 4: Ocean-Atmosphere interactions of particles

Chapter 5: Perspectives and Integration in SOLAS science.

Cost of the book: 53.45 euro

Fast-Track Initiatives

In May 2009, IGBP launched two fast-track initiatives (FTIs) proposed by SOLAS and other IGBP core projects. Both FTIs were co-endorsed by SCOR and both came to an end in 2011. The FTI publications appeared in 2012/2013.

→ **Megacities and the Coastal Zone: air-sea interactions** (2009-2011). Scientific coordinators: Roland von Glasow (UEA, UK) and Tim Jickells (UEA, UK).

As the world's population and urbanisation increase simultaneously, so does the number of cities with over 10 million inhabitants – megacities.

Many megacities, such as Mumbai and Los Angeles, are located in coastal regions. This juxtaposition leads to particular environmental consequences that have a direct impact on the health and prosperity of people living in and around such cities. The environmental and ecological effects of the alteration of coastlines and input of sewage from cities have received much attention over the years. But the effect of urban atmospheric emissions on the adjacent coastal waters and that of emissions from coastal waters on urban air quality have received lesser attention.

The results of the workshop held in Norwich, UK in April 2010 were presented via a poster at the IGBP Planet Under Pressure conference, in March 2012, London, UK; at the SOLAS OSC2012, in May 2012, Washington State, USA and via an oral presentation at the EGU, April 2012, Vienna, Austria. A paper from the workshop was recently published in *AMBIO*:

von Glasow R et al. (2012) Megacities and Large Urban Agglomerations in the Coastal Zone: Interactions Between Atmosphere, Land, and Marine Ecosystems. *AMBIO*, doi: 10.1007/s13280-012-0343-9 <<http://link.springer.com/article/10.1007/s13280-012-0343-9/fulltext.html>>

→ **Upper Ocean Nutrient Limitation: processes, patterns and potential for change** (2009-2011). The scientific coordinators are Mark Moore (NOCS, UK) and Matt Mills (Stanford Univ., USA). A workshop took place in Southampton, UK on 3-5 Nov 2010 to address the FTI-specific goals. An outcome of this workshop is a review paper published in *Nature Geoscience*:

Moore et al. (2013) Processes and patterns of oceanic nutrient limitation, *Nature Geoscience*. doi:10.1038/NGE01765

Task teams

SOLAS/IGAC Task Team: Halogens in the Troposphere (HitT)

The primary objective of the SOLAS/IGAC Halogens in the Troposphere task team (HitT) is to determine and quantify the importance of reactive halogen compounds in tropospheric chemistry and climate forcing. The goal of HitT is to facilitate international collaboration between laboratory, field, and model activities regarding tropospheric halogen chemistry especially in the following domains: polar regions, salt lakes, marine boundary layer (both remote and coastal), volcanoes, free troposphere, and urban areas.

The co-chairs are Roland von Glasow <mailto:R.von-Glasow@uea.ac.uk> (University of East Anglia, UK) and Ulrich Platt <mailto:ulrich.platt@iup.uni-heidelberg.de> (University of Heidelberg, Germany). Everyone interested by the activities of this task team can subscribe to the HitT mailing list at <http://www.hitt-task.net/>

Activities of the past year:

- During the SOLAS OSC12 conference in Washington State, a discussion session took place on the "Climate impact of seasalt-derived Cl atoms" that explicitly focused on the importance of the reaction of the Cl atom with the greenhouse gas methane. A brief report was published in the SOLAS newsletter issue 14 (<http://www.solas-int.org/publications/latest-newsletter.html>).
- A session contributing to the HitT Task team took place at the AGU Fall meeting, 3-7 Dec 2012, San Francisco, CA, USA. Session: A075: Tropospheric Chemistry and Tropical Oceans, Conveners: Rainer Volkamer, Alfonso Saiz-Lopez, Mitsuo Uematsu, Roland von Glasow.
- A workshop on Climate impact of seasalt-derived Cl atoms took place on 17-19 December 2012 at GEOMAR in Kiel, Germany, led by Roland von Glasow and Eric Saltzman. The workshop was co-sponsored by IGAC. The report and meeting minutes are available on the SOLAS website at <http://www.solas-int.org/activities/task-teams.html>.
- A session AS3.2 'Halogens in the Troposphere' was organised at EGU General Assembly, 7-12 April 2013, Vienna, Austria. Conveners: R. von Glasow, R. Sander, R. Volkamer, J. Plane and A. Saiz-Lopez. <http://meetingorganizer.copernicus.org/EGU2013/session/11585>.
- Polar session at DACA 2013, 8-12 July 2013, Davos, Switzerland http://www.daca-13.org/program/index_EN.

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Endorsed projects

Over the reporting period, SOLAS endorsed one project:

- DONUT-Dependence of Dissolved Organic matter cycling on atmospheric NUTrient inputs in the surface oligotrophic ocean. French project.

Information about obtaining support letters and endorsement are accessible on the new website. The endorsement submission forms and update reports will be shortly available on the SOLAS website. The submission form of the newly endorsed project and update reports received during the reporting period are available in an Addendum to this report.

SOLAS- IMBER Carbon Group

Much of the science of SOLAS Focus 3 overlaps with IMBER and thus a joint SOLAS/IMBER Carbon Group (SIC) was formed during a meeting held in Colorado in Oct. 2005. This group is working in close collaboration with International Oceanic Carbon Coordination Project (IOCCP). The SIC group is currently subdivided into three working groups:

- **WG1-Surface Ocean Systems.** Chair: Andrew Lenton (Australia)
- **WG2-Interior Ocean.** Chair: Nicolas Gruber (Switzerland)
- **WG3-Ocean Acidification.** Chair: Jim Orr (France) since Nov 2012

WG1-Surface Ocean Systems

To document SOCAT, two papers in *Earth Syst. Sci. Data* were published in 2013, ‘A uniform, quality controlled Surface Ocean CO₂ Atlas (SOCAT)’ by Pfeil et al. and ‘Surface Ocean CO₂ Atlas (SOCAT) gridded data products’ by Sabine et al.. The SOCAT version 2 (1968-2011) was released on 4 June 2013 at the ICDC9. It includes 10.1 million fCO₂ data points from 2,660 cruises. A paper is in preparation by Bakker et al. in ESSD. SOCAT has been a huge community effort since 2007; there are more than 100 contributors and data providers with multiple sources of funding, but unfortunately no long-term funding. Scientific results using the SOCAT database have begun to be published, for example, Rödenbeck et al. 2013, *Ocean Science* and Schuster et al. 2013, *Biogeosciences*. The activity of the Global Carbon Project RECCAP 1990-2009, Regional Carbon Cycle Assessment and Processes also contribute to this WG1. RECCAP aims to establish the mean carbon balance of large regions of the globe at the scale of continents and large ocean basins, including their component fluxes by comparing and reconciling multiple bottom-up estimates with the results of regional top-down atmospheric inversions, with attribution to main flux components. As part of this project the ocean community, with input from more than 20 countries from different modelling and observational communities, has produced 5 papers, of which SOLAS/IMBER WG1 members have authored or co-authored 4 of the 5 papers. Results such as in Lenton et al. (2013), showing a revised estimate of global ocean uptake based on new wind products and a convergence between approaches at the annual mean and basin scales, were presented at the ICDC9. However, at seasonal and interannual timescales there is little agreement between models and approaches, particularly at high latitudes; there is still work to do in this area. It is therefore difficult to say much about robust trends and longer-term changes in key areas such as the Southern Ocean. There is a critical need for ongoing observations. Plans for RECCAP2 were discussed at ICDC9. There will be a joint session between the WG1 and WG2 of SIC and IOCCP on ‘the ocean carbon cycle at a time of change:

Data syntheses, analyses and modelling' at the IMBER Open Science Conference Future Oceans, 23-27 June 2014, Bergen, Norway. A small initial meeting sponsored by SOLAS took place as a side event at the ICDC9 in Beijing to start planning on the comparison of pCO₂-based ocean CO₂ flux estimates. The event was organized by C. Rödenbeck. Discussions are underway about a potential meeting or side-meeting (e.g., IMBER 2014) to discuss the Southern Ocean and the detection of change in the marine biogeochemistry and the carbon cycle to contribute to the Southern Ocean Observing System (SOOS). Regarding future plans, it was mentioned that the WG1 would like to meet in person in the next year, maybe at the 2014 Ocean Sciences meeting in Hawaii.

Geoengineering is also increasingly discussed, with significant implications, analogous to volcanic eruptions, for which surface ocean feedbacks can be large. SIC WG1 may be able to contribute in a positive way to understanding this issue. WG1 plans on having a closer integration with WG3 given that many of expected changes with ocean acidification such as ecosystem structure, nutrient cycling and carbon uptake will be seen in the surface ocean.

WG2-Interior Ocean

The members of WG2 met in Salt Lake City in Feb. 2012 and their next meeting is scheduled to take place at Ocean Sciences 2014. The global synthesis of the repeat hydrography initiative is progressing since 2009, but slower than originally planned; participants have encountered some data quality control issues. The next steps of the group with regard to reaching the objective of the synthesis (to determine the global-scale oceanic accumulation of anthropogenic CO₂ since the 1990s) are to create an ad-hoc steering committee to oversee and coordinate the synthesis (Tanhua, Ishii, Mathis and Gruber), to have a small workshop at the ICDC9 in Beijing in June, to propose sessions at Ocean Sciences 2014 and at IMBER OSC 2014, to organize a large workshop for Ocean Science 2014 and have the synthesis completed by mid-2014. Other activities of the group lie in Oxygen+ on Argo, which had a special session at Ocean Sciences meeting in Feb 2012. A SCOR working group on sensor calibration was accepted, led by Arne Körtzinger (Germany) and Ken Johnson (USA).

WG3-Ocean Acidification

The most recent annual meeting from the group was on 13 May 2013 in Villefranche sur mer and 14 May 2013 in Monaco, supported financially by SOLAS. The SIOA proposed a central office as key to communicate, promote, and facilitate international OA research. The International Coordination Centre for Ocean Acidification Research (OA-ICC) is funded via IAEA and has been running since Jan. 2013. The Scientific Coordinator is Jim Orr, the Project Officer is Lina Hansson, and the programme manager is Michel Warnau. The office has an initial duration of three years. Its tasks are to implement overarching activities to accelerate advances internationally and avoid unnecessary duplication. A communication assistant is to be hired and a data curator to be hired and located in China. www.oceanunderstress.com, www.iaea.org/nael/OA-ICC, oceanacidification.wordpress.com

The activities of the center are to

- 1) Develop global observation network, leader Dick Feely;
- 2) Promote joint platforms and facilities, leader Ulf Riebesell;

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- 3) Develop collaboration between natural and social sciences, leader Jelle Bijma;
- 4) Promote exchange of students and postdocs, leader Jelle Bijma;
- 5) Intercomparison exercises, leader Minhan Dai;
- 6) Joint ocean acidification experiments, leader Jim Barry;
- 7) Promote best practices in OA research, leader Jean-Pierre Gattuso;
- 8) Online bibliographic database, leader Jean-Pierre Gattuso;
- 9) Data management, leader Jean-Pierre Gattuso;
- 10) Capacity building, leaders Lisa Robbins and Nelson Lagos
- 11) Information sharing and communication, leaders Dan Laffoley and Carol Turley.

A side event at 9th International Carbon Dioxide Conference, in Beijing, China on 3-7 June 2013 took place on 'shaping tomorrow's carbon cycle research: knowledge gaps, international collaboration, and funding priorities'. The side event was organized by the SOLAS-endorsed EU project CARBOCHANGE and the European Commission. The summary of the discussion and a brochure on EU carbon cycle projects produced by the European Commission are available at <http://carbochange.b.uib.no/media-centre/public-outreach/>

SOLAS Project Integration

In mid-Feb. 2013, the SOLAS project Integration office in Norwich shut down. For the past 2 years the project integrator, Shital Rohekar, has worked with the aerosol community to assemble the available aerosol/rain data, which has been submitted to the British Oceanographic Data Centre (BODC). The database contains more than 1,200 data points and is available at http://www.bodc.ac.uk/solas_integration/implementation_products/group1/aerosol_rain/

OceanFlux three projects update: collaboration between ESA and SOLAS

The European Space Agency (ESA) used funding from the project 'support to science element (STSE) OceanFlux' (STSE) to organise a topical conference entitled Earth Observation for Ocean-Atmosphere Interactions Science. ESA also led a special issue in *Ocean Science/Biogeosciences* Inter-Journal, closed in Jan 2013.

ESA has 3 OceanFlux projects established in collaboration with SOLAS:

- 1) 'Ocean-derived aerosols: production, evolution and impacts (OSSA)' main leader Gerrit De Leeuw, ending 31 Oct 2013, <http://oceanflux.fmi.fi>;
- 2) 'Air-sea flux of CO₂ and other long-lived radiatively active gases', main leader David Woolf ending 30 Nov 2013, <http://www.oceanflux-ghg.org>. The data processing system is online and will allow users to generate their own climatology using a huge selection of different model and EO datasets
- 3) 'Air-sea gas fluxes at Eastern boundary upwelling and Oxygen Minimum Zone', main leader Christoph Garbe, ending 31 Oct 2013, <http://upwelling.eu/>.

The end of the OceanFlux projects coincides with topical workshops: Sea Spray aerosol workshop for the OSSA theme, 30 Sept. and 1 Oct. 2013 in Galway, Ireland and 'air-sea Gas Flux Climatology, progress and future prospects' for the themes on GHGs and upwelling, 24-27 Sept. 2013, in Brest, France. ESA is very interested in continuing the collaboration with SOLAS

though additional funding, depending on its budget. Possible future themes should be communicated to ESA in a near future.

Long time series of multi-sensor, gridded, global satellite data sets are being put together, designed for climate scientists by an ESA activity named Climate Change Initiative. Early data sets are now available. An overview of the relevant data set is included in the SOLAS Newsletter issue 15 released in June 2013. Also, ESA is updating its science strategy document from 2006. Key science challenges in 5 Earth systems domains (one being ocean) that satellite data can contribute to solving have been identified. A writing team is currently updating the challenges; SOLAS feedback has been invited. The SOLAS MTS paper will be passed to the writing team for information. Input will be invited online (details to come in Sept.) and there will be a feedback session at the Living Planet Symposium (9-13 Sept. 2013 in Edinburgh). Christoph Garbe will represent SOLAS at the Symposium, supported by ESA/IGBP funds. Another new project (GlobCurrent) will start in the autumn on developing high-resolution ocean surface current information services for a wide variety of applications.

Other SOLAS activities

Additional activities involving an active IPO staff participation and/or use of SOLAS funding include the following:

→IGAC 2012 ‘Atmospheric Chemistry in the Anthropocene Conference’, Beijing, China on 17-21 Sept. 2012. SOLAS partially sponsored two speakers.

→PICES 2012 Annual Meeting “Effects of natural and anthropogenic stressors in the North Pacific ecosystems: Scientific challenges and possible solutions”, Oct. 12-21, 2012, Hiroshima, Japan. SOLAS sponsored Lisa Miller and two invited speakers to the sessions 10 and 14.

→Workshop on ‘Towards an integrative regional coupling in the Eastern Boundary Upwelling Systems (EBUS)’ 26-28 Nov. 2012, Instituto Geofísico del Perú (IGP), Lima, Peru
Contribution to the SOLAS Mid-Term Strategy initiative on “Air-sea gas fluxes at Eastern boundary upwelling and Oxygen Minimum Zone (OMZ) systems”

→Workshop on ‘Marine gels and their impact on atmospheric aerosol and cloud’, 11-13 Dec. 2012, GEOMAR, Kiel, Germany. Co-sponsored by IGAC. Contribution to the SOLAS Mid-Term Strategy initiative on “Ocean-derived aerosols: production, evolution and impacts”

→Workshop on HitT- Climate impact of seasalt-derived Cl atoms, 17-19 Dec 2012, GEOMAR, Kiel, Germany. Co-sponsored by IGAC. Contribution to the SOLAS/IGAC Task Team HitT

SOLAS communication

SOLAS website: <http://www.solas-int.org/>

The new SOLAS website was launched in early November 2012. It is hosted in Germany and has a clearer navigation system. This website is mobile device-friendly and can host password-protected pages. All comments about it are welcomed by the IPO.

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As a consequence of the staff shortage that occurred in 2012, it was decided at the SOLAS Executive Committee meeting in September 2012 that the project would issue only one newsletter per year from 2012 on instead of two. The issue 14 was published in September 2012 and focused on the SOLAS Summer School (SSS) 2011 and the Open Science Conference 2012; the scientific contributions were from former SSS students. Issue 15 was distributed in June 2013. It proposes a general update on various topics of SOLAS science and is organised by sections.

The SOLASNews newsletter emailed to ~2000 scientists and airmailed to ~150 scientists mainly, from developing countries. Copies are held by the SOLAS IPO for distribution at SOLAS-relevant conferences and meetings. The Newsletter is also available from the website. The SOLAS News is printed and airmailed from China courtesy of State Key Laboratory of Marine Environment Science, Xiamen University. Since issue 11, SOLAS also implemented an on-screen reader pdf version.

Regarding publications, the COST 735 synthesis book is currently with the publisher Springer to formatted and released in 2013, and an article in *Environmental Chemistry* entitled 'Evolving research directions in Surface Ocean – Lower Atmosphere Study (SOLAS) science' by Law et al. was published early in 2013 and describes the five SOLAS Mid-term Strategy themes.

E-bulletins are sent to over 2000 SOLAS scientists roughly every 6 weeks and previous issues are archived on the website at <http://www.solas-int.org/archive.html>. The bulletins contain news from SOLAS, opportunities for meetings, abstract submission deadlines, recent publications, vacancies and news from relevant partner project and collaborators.