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

(joint with IOC)

Enevoldsen, 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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Global Ecology and Oceanography of Harmful Algal Blooms (GEOHAB) Program Activities, 2013-2014

The GEOHAB project is continuing to prepare a synthesis for completion of its first phase, at the end of 2014. GEOHAB-related activities will be continued after the end of 2014, under a different format, as part of a new initiative called GlobalHAB (see Tab 4).

1. IPHAB and SCOR Meetings

GEOHAB was represented by the SSC Chair (Raphe Kudela) at the Tenth IOC Intergovernmental Panel on Harmful Algal Blooms (IPHAB) meeting. An update on GEOHAB activities during the past two years was presented, and a resolution was passed recommending support from IOC for a new international initiative called GlobalHAB, with an invitation to SCOR to co-sponsor. Kudela presented the GEOHAB annual report at the SCOR meeting in Wellington, New Zealand. SCOR thanked GEOHAB, but declined to continue support for GlobalHAB as a research project.

2. Synthesis of Core Research Projects (Science Highlights)

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 open science meetings (OSMs) and other activities. A fifth CRP plan was published on Benthic HABs. All of the CRPs are continuing in some capacity, but the primary focus for this reporting interval is on synthesis activities.

A Science Highlights

Based in part on the successful collaboration between GEOHAB and the International Ocean Color Coordination Group (IOCCG), GEOHAB participated in the “Oceans and Society: Blue Planet Initiative” sponsored by the Group on Earth Observatories (GEO). Stewart Bernard (SSC member; South Africa) and Lourdes Velo-Suarez (Spain) represented GEOHAB, addressing the HAB observations and modelling needs within the GEO framework. While GEOHAB often focuses on science objectives, a significant contribution from this effort was the publication of recommendations for development of global HAB observation and prediction systems (Bernard et al. 2014). A significant highlight from that synthesis is the following:

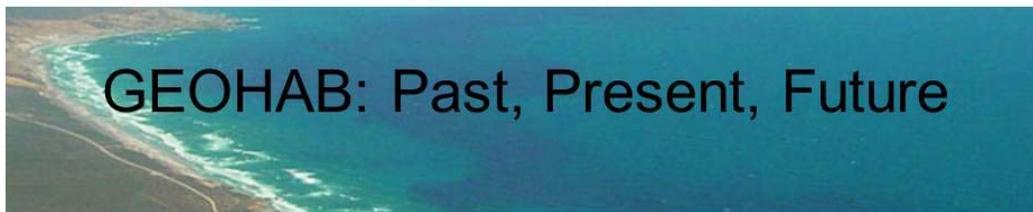
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“Global HAB-related economic losses across marine and freshwater systems can be estimated at +/-US\$10 billion annually. Using a typical Value Of Information (VOI) estimate of 1% of the “resource” (in this case HAB-related losses), a comprehensive HAB observing and forecasting system would represent a value of +/- US\$100 million annually.”

IOCCG and GEOHAB are also co-funding a working group on HABs and Ocean Colour. The full group has met twice and is working on a monograph for the *IOCCG Report* series. A subset of the group met in Barcelona, Spain in December 2013, to finalize the monograph contents.

B. GEOHAB Open Science Meeting Report

The SSC convened a synthesis GEOHAB Open Science Meeting at IOC Headquarters in Paris, France in April 2012. Fifty-one scientists from the 5 continents attended the meeting. Participants actively evaluated the progress achieved by GEOHAB and its main limitations. Participants identified the main challenges for future research on HABs worldwide. The SSC is currently finalizing this report, and we expect to publish this in time for the International Conference on Harmful Algae, to be held in October 2014 in New Zealand.



“We all came to Paris because we recognize a fundamental problem (HABs), and cannot solve this problem in our individual laboratories. This requires an international approach.”



3. Publications and Endorsed Projects

A full list of GEOHAB reports, publications, and endorsed activities is available on the GEOHAB Web site (www.geohab.info/publications-66). Overall, GEOHAB generated considerable interest from the community during this interval, and GEOHAB-endorsed work has been conducted in Australia, Canada, Chile, China, France, Germany, Ireland, 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 previously endorsed projects for inclusion in the GEOHAB synthesis activities.

Specifically, the newest publications during the 2013-2014 period include two new GEOHAB Reports, from the "HABs in Fjords and Coastal Embayments" and "HABs in Stratified Systems" CRPs:

GEOHAB 2013. *"Global Ecology and Oceanography of Harmful Algal Blooms, GEOHAB Core Research Project: HABs in Fjords and Coastal Embayments. Second Open Science Meeting. Progress in Interpreting Life History and Growth Dynamics of Harmful Algal Blooms in Fjords and Coastal Environments"*. S. Roy, V. Pospelova, M. Montresor, and A. Cembella (Eds.), IOC and SCOR, Paris, France and Newark, Delaware USA, 52 pp.

GEOHAB 2013. *Global Ecology and Oceanography of Harmful Algal Blooms, GEOHAB Core Research Project: HABs in Stratified Systems. Workshop on "Advances and Challenges for Understanding Physical-Biological Interactions in HABs in Stratified Environments."* M.A. McManus, E. Berdalet, J. Ryan, H. Yamazaki, J.S. Jaffe, O.N. Ross, H. Burchard and F.P. Chavez (Eds.). IOC and SCOR, Paris and Newark, Delaware, USA, 88 pp.

and a special issue with 21 papers in *Deep Sea Research, Part II*:

- R. Raine, E. Berdalet, M.A. McManus, H. Yamazaki (Guest Eds.). 2014. "Harmful Algal Blooms in Stratified Systems", special issue in *Deep-Sea Research, Part II: Topical Studies in Oceanography*, 101:1-254.
- R. Raine, E. Berdalet, M. McManus, H. Yamazaki. Harmful algal blooms in stratified systems, Pages 1-3.
- E. Berdalet, M.A. McManus, O.N. Ross, H. Burchard, F.P. Chavez, J.S. Jaffe, I.R. Jenkinson, R. Kudela, I. Lips, U. Lips, A. Lucas, D. Rivas, M.C. Ruiz-de la Torre, J. Ryan, J.M. Sullivan, H. Yamazaki. Understanding harmful algae in stratified systems: Review of progress and future directions. Pages 4-20.
- R. Raine. A review of the biophysical interactions relevant to the promotion of HABs in stratified systems: The case study of Ireland. Pages 21-31.
- T. Wyatt. Margalef's mandala and phytoplankton bloom strategies. Pages 32-49.
- Andrew J. Lucas, Grant C. Pitcher, Trevor A. Probyn, Raphael M. Kudela. The influence of diurnal winds on phytoplankton dynamics in a coastal upwelling system off southwestern Africa. Pages 50-62.

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- J.P. Ryan, M.A. McManus, R.M. Kudela, M. Lara Artigas, J.G. Bellingham, F.P. Chavez, G. Doucette, D. Foley, M. Godin, J.B.J. Harvey, R. Marin III, M. Messié, C. Mikulski, T. Pennington, F. Py, K. Rajan, I. Shulman, Z. Wang, Y. Zhang. Boundary influences on HAB phytoplankton ecology in a stratification-enhanced upwelling shadow. Pages 63-79.
- H. Farrell, P. Gentien, L. Fernand, P. Lazure, M. Lunven, A. Youenou, B. Reguera, R. Raine. Vertical and horizontal controls of a haptophyte thin layer in the Bay of Biscay, France. Pages 80-94.
- W.O. Smith Jr., X. Liu, K.W. Tang, L.M. DeLizo, N. Hai Doan, N. Lam Nguyen, X. Wang. Giantism and its role in the harmful algal bloom species *Phaeocystis globosa*. Pages 95-106.
- U. Lips, I. Lips. Bimodal distribution patterns of motile phytoplankton in relation to physical processes and stratification (Gulf of Finland, Baltic Sea). Pages 107-119.
- J.-J. Wang, D. Ling Tang. Phytoplankton patchiness during spring intermonsoon in western coast of South China Sea. Pages 120-128.
- A. H.V. Timmerman, M. A. McManus, O.M. Cheriton, R. K. Cowen, A. T. Greer, R. M. Kudela, K. Ruttenberg, J. Sevadjian. Hidden thin layers of toxic diatoms in a coastal bay. Pages 129-140.
- L. Velo-Suárez, S. González-Gil, Y. Pazos, B. Reguera. The growth season of *Dinophysis acuminata* in an upwelling system embayment: A conceptual model based on in situ measurements. Pages 141-151.
- C. Alves-de-Souza, D. Varela, C. Contreras, P. de La Iglesia, P. Fernández, B. Hipp, C. Hernández, P. Riobó, B. Reguera, J. M. Franco, J. Diogène, C. García, N. Lagos. Seasonal variability of *Dinophysis* spp. and *Protoceratium reticulatum* associated to lipophilic shellfish toxins in a strongly stratified Chilean fjord. Pages 152-162.
- P. A. Díaz, M. Ruiz-Villarreal, L. Velo-Suárez, I. Ramilo, P. Gentien, M. Lunven, L. Fernand, R. Raine, B. Reguera. Tidal and wind-event variability and the distribution of two groups of *Pseudo-nitzschia* species in an upwelling-influenced Ría. Pages 163-179.
- M.L. Artigas, C. Llebot, O.N. Ross, N.Z. Neszi, V. Rodellas, J. Garcia-Orellana, P. Masqué, J. Piera, M. Estrada, E. Berdalet. Understanding the spatio-temporal variability of phytoplankton biomass distribution in a microtidal Mediterranean estuary. Pages 180-192.
- H. Yamazaki, C. Locke, L. Umlauf, H. Burchard, T. Ishimaru, D. Kamykowski. A Lagrangian model for phototaxis-induced thin layer formation. Pages 193-206.
- M. J. Doubell, J. C. Prairie, H. Yamazaki. Millimeter scale profiles of chlorophyll fluorescence: Deciphering the microscale spatial structure of phytoplankton. Pages 207-215.
- I.R. Jenkinson, J. Sun. Drag increase and drag reduction found in phytoplankton and bacterial cultures in laminar flow: Are cell surfaces and EPS producing rheological thickening and a Lotus-leaf Effect? Pages 216-230.
- T. Wyatt, A. Zingone. Population dynamics of red tide dinoflagellates. Pages 231-236.
- X. Dai, D. Lu, W. Guan, H. Wang, P. He, P. Xia, H. Yang. Newly recorded *Karlodinium veneficum* dinoflagellate blooms in stratified water of the East China Sea. Pages 237-243.
- S. O'Boyle, G. McDermott. Observations of a thin near surface layer in an estuarine environment: An exceptional bloom of the dinoflagellate *Akashiwo sanguinea* in the Lee estuary (Lough Mahon), Co. Cork, in September 2010. Pages 244-248.
- H. Farrell, L. Velo-Suarez, B. Reguera, R. Raine. Phased cell division, specific division rates and other biological observations of *Dinophysis* populations in sub-surface layers off the south coast of Ireland. Pages 249-254.

1. Implementation Activities and Plans for the Coming Year

A. CRP Activities

The final GEOHAB SSC Meeting was 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. While GEOHAB is sunsetting, several potential implementation activities were discussed and prioritized if additional funds become available. This includes two projects that were highly ranked at the Paris OSM:

- 1) Linkages between HABs and Hypoxia (proposed by Grant Pitcher, South Africa)
- 2) Quantifying HAB resting stage emergence and deposition fluxes: A comparative workshop and training program (proposed by Don Anderson, USA)

A third proposed effort, addressing the linkage between HABs and caged fish activity, was recommended as a submission to SCOR as a Working Group.



The GEOHAB SSC recommended providing partial funding to the first two activities as part of the transition from GEOHAB to GlobalHAB. This recommendation is pending budget decisions about the synthesis publications. The full concept papers are provided in the Appendix.

As part of the synthesis, the GEOHAB SSC, in coordination with the CRPs, identified a series of publications (targeting the journal *Oceanography*) that are currently in preparation, pending identification of funds for publication:

1. Kudela, Berdalet, Urban, Enevoldsen. The Global Ecology of Oceanography and Harmful

- Algal Blooms Programme: History and Impacts.
2. Pitcher, Figueras, Kudela, Moita, Reguera, Ruiz-Villareal. The ecology and oceanography of HABs in eastern boundary upwelling systems: A GEOHAB Core Research Project
 3. Glibert, Burford. Harmful Algal Blooms, nutrients, and eutrophication.
 4. Reguera, Raine, Berdalet. Understanding harmful algae in stratified systems.
 5. Roy, Cembella. HABs in fjords and coastal embayments.
 6. Tester, Berdalet, Lemée, Litaker, Penna, Vila, Zingone. Harmful Algal Blooms in benthic systems.
 7. McGillicuddy, Allen, Fernand. Advances in modeling harmful algal blooms.
 8. Bernard, Velo-Suarez, Kudela. Developing Global Capabilities for the Observation and Prediction of Harmful Algal Blooms.
 9. Bernard, Kudela, Roy, Glibert, Simis, Hu, Matthews, Moore, Werdell, Pitcher, Dowell. Assessing the utility of global ocean color for harmful algal bloom research and monitoring.
 10. Usup, Liu, Furuya. GEOHAB Asia: Development, successes, and future steps.
 11. Wells, Karlson, Kudela. Harmful Algal Blooms and Climate Change.
 12. Berdalet, Magnien, Enevoldsen, Kudela. Establishment of the GlobalHAB International Coordination Effort: From Research to Mitigation.

B. Synthesis Activities

As discussed above, GEOHAB is in its final synthesis phase. The SSC agreed to utilize the 2014 ICHA meeting (16th International Conference on Harmful Algae, to be held in Wellington from the 27 to 31 October 2014) as a venue for dissemination of the Paris OSM Report, and for disseminating information about the transition from GEOHAB to GlobalHAB. GEOHAB will have a booth at the meeting where we can highlight accomplishments and activities. This will likely represent the final public outreach/meeting efforts for GEOHAB.

Furthermore, this information will be presented at the International Conference "One Ocean, One Planet", to be held in Barcelona on 17-21 November 2014 (<http://www.fnob.org/en/international-ocean-research-conference>). The poster (Berdalet et al.) is coauthored by the present GEOHAB SSC members.

C. GlobalHAB (see Tab 4)

2. Plans for the Coming Year

GEOHAB reaches the end of its current Terms of Reference and funding in 2014. We propose to carry forward our existing balance of NSF funds to complete synthesis activities during the transition to GlobalHAB. If SCOR chooses to endorse GlobalHAB as an infrastructural activity, GEOHAB will make recommendations to IOC and SCOR for implementation of that programme, but GEOHAB will wrap up its formal activities.

Appendix: Concept Papers Endorsed by GEOHAB SSC for Potential Funding**QUANTIFYING HAB RESTING STAGE EMERGENCE AND DEPOSITION FLUXES: A COMPARATIVE WORKSHOP AND TRAINING PROGRAM**

Donald M. Anderson¹, Esther Garces², Suzanne Roy³, Marina Montresor⁴, Allan Cembella⁵, Akira Ishikawa⁶, Silvia Angles⁷, Anke Kremp⁸, Chris Gobler⁹, Cheryl Greengrove¹⁰, Stephanie Moore¹¹

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Many harmful algal bloom (HAB) species produce dormant cysts or resting spores during their life histories. Some also produce temporary or “pellicle” cysts that are less resistant, but which still provide a refuge during difficult conditions. Hereafter, for convenience, these will all be included under the umbrella term “resting stage.” The resulting alternation between a dormant, resting stage and a vegetative existence in the plankton is critically important in many aspects of bloom dynamics. Resting stage germination provides the inoculum for blooms, and the transformation back to the resting state can remove substantial numbers of vegetative cells from the population and act as a major factor in bloom decline, while also providing the inoculum for future blooms.

As critical as these life history transformations are for many HAB species, quantitative data on many aspects of resting stage formation, deposition, and germination are lacking. Direct measurements of resting stage emergence and deposition fluxes are limited, as measurement methods are difficult, prone to artifacts, and for emergence fluxes, limited to shallow waters, leaving major deposition or accumulation zones in deeper waters unstudied in this regard. Several emergence trap designs have been proposed and used in field studies of some HAB species, but no concurrent measurements have been made to ascertain the similarity and differences between approaches. The measurements are indeed challenging, as it is necessary to isolate a portion of bottom sediments without altering the chemistry or physical environment, capture small numbers of newly germinated cells before they divide, all while avoiding contamination from potentially abundant vegetative cells of the same species in the surrounding water. Likewise, sediment traps with designs ranging from simple to sophisticated have been used but never evaluated or compared in terms of efficiency and accuracy in the context of HAB resting cell dynamics. Again, these devices are susceptible to artifacts depending on current speed, resuspension events and the swimming behavior of the cells of interest. As a result of these limitations in methodologies, progress towards one of GEOHAB’s major goals has been limited – namely the development of comprehensive models of the dynamics of cyst- or spore-forming HAB species.

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Here we propose a series of community workshops that will compare and evaluate methods for direct measurements of the rates of major life history transitions in HAB resting stages. These include in situ measurements of germination rates and emergence fluxes, as well as encystment rates and resting stage depositional fluxes to bottom sediments. A related workshop activity would involve examination of the manner in which these rate measurements can be incorporated into HAB numerical models.

Two and perhaps three separate workshops are envisioned for this program. The first would convene interested workers at a site and a time where HAB resting cysts and spores are present in bottom sediments and are germinating, with relatively easy access in terms of water depth and research vessel availability, and with appropriate laboratory and field facilities for instrument preparation and deployment, and for analysis of samples. With concurrent deployment of devices of different designs and careful experimental planning with appropriate controls, comparative studies can be conducted and each of multiple approaches evaluated for a range of HAB species. Presentations and discussions will also be held on "best practices" for laboratory experiments that quantify germination using cultures and sediment samples. Some characteristics of resting stage formation and germination will only be possible to resolve in the laboratory.

The second workshop would focus on quantifying the formation and deposition of resting stages in field populations. The site for the workshop would again be a location where blooms of the target species are recurrent, predictable, and accessible. Multiple designs of sediment traps and collection methods can be evaluated, concurrent with methods for assessing levels of sexual induction and resting stage formation in the plankton. The latter would include traditional cytological methods, as well as novel optical and molecular approaches.

The third workshop in this series would involve modelers as well as biologists in an effort to refine methods to incorporate resting stage dynamics into HAB population dynamics models. In addition to defining the critical processes that need to be parameterized, the meeting would help to identify common approaches and computer code that can be shared among species and applications.

Potential funding sources for this project could include international agencies such as IOC-UNESCO, SCOR and national funding agencies such as the U.S. National Science Foundation (NSF) and the U.S. National Oceanic and Atmospheric Administration (NOAA).

Note also that this proposed workshop series covers an important but relatively narrow area of HAB population dynamics, and thus could be combined with other GEOHAB concept proposals related to life history transformations.

LINKAGES BETWEEN HARMFUL ALGAL BLOOMS AND ANOXIA

Pitcher, Grant C.

Fisheries Research and Development, Private Bag X2, Rogge Bay 8012, Cape Town, South Africa
(GrantP@daff.gov.za)

Participants

The following participants are committed and funded to undertake this project within the southern Benguela upwelling system:

Durand, Pierre M., Department of Molecular Medicine, University of Witwatersrand and National Health Laboratory Service, Johannesburg, SA

Pitcher, Grant C., Fisheries Research and Development, Cape Town, SA
Probyn, Trevor A., Fisheries Research and Development, Cape Town, SA
Schroeder, Declan C., Marine Biological Association, Citadel Hill, Plymouth, UK
Sym, Stuart, School of Animal, Plant and Environmental Sciences, University of the Witwatersrand, Johannesburg, SA
Other participants will be identified following establishment of other systems to be included in the project for the purposes of comparison.

Summary

Oxygen deficiencies in coastal environments have increased during recent decades and eutrophication is considered a causal factor. Here high biomass dinoflagellate blooms (red tides) are often deemed the cause of anoxia. However the transient character of these events has contributed to a poor understanding of the causes and timing of bloom mortality leading to anoxia. This study will seek to establish the nature of phytoplankton mortality within blooms and the role of microbial activity in carbon transformation and oxygen consumption. Quantitative estimates of these processes will contribute to the prediction of anoxia linked to HABs. St Helena Bay in the southern Benguela upwelling system offers a unique environment to further study and quantify these links and for the purpose of comparison it is intended that parallel studies are undertaken in other systems.

Project outline

Oxygen deficit in the oceans is a critical determinant of biological and ecological processes and the expansion of hypoxia and anoxia represent major perturbations to the diversity, structure and functioning of coastal marine ecosystems. Dissolved oxygen is now recognized as a property of the ocean that has changed dramatically, with oxygen deficiencies having increased in frequency, duration, and severity during recent decades. Rates of oxygen decline are considered to be greatest in coastal regions and evidence for eutrophication as an important causal factor is increasing. Temperature also interacts through a multitude of processes to control the extent of oxygen depletion, and projected warming associated with climate change shows an increase in susceptibility of coastal marine ecosystems to hypoxia and/or anoxia.

Anoxia is regularly listed as a major consequence of harmful algal blooms (HABs), but the linkage of blooms to anoxia and consequent mortalities within ecosystems is poorly established. Four categories of anoxia have been defined: permanent, seasonal, episodic and diel. Events of anoxia linked to HABs are typically confined to the episodic and diel categories and their local and transient character has contributed to our poor understanding of these events. Specifically the causes and timing of bloom mortality leading to anoxia are unknown. In contrast to the efforts to establish the conditions, mechanisms and strategies that control phytoplankton cell growth and bloom development, considerably less effort has focused explicitly on phytoplankton mortality and as a consequence the mechanisms that control abrupt bloom termination in natural systems are not well understood. Until recently phytoplankton were considered somewhat immortal unless eaten by predators, but it is now known that spontaneous death may result, particularly under adverse environmental conditions, as a consequence of infection by viruses or as a result of programmed cell death, with significant ecological impact. To date our studies have focused on the role of nutrient input and limitation in bloom development and demise rather than the role of microbial activity in carbon transformation and oxygen consumption.

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This study will seek to establish the nature of mass, episodic phytoplankton mortality within HABs leading to the transfer of organic matter to the heterotrophic microbial community. Quantitative estimates of these processes will contribute to the prediction of anoxia linked to HABs. Our approach will be to track bloom development and demise through moored instrumentation at sites known to be susceptible to anoxia. In addition to monitoring dissolved oxygen concentration, measurements will also be made to quantify micro-zooplankton grazing, virus-mediated cell lysis and programmed cell death, as plankton mortality processes. These measurements will be made before, during and after the onset of anoxia.

Upwelling systems are subject to the risk of hypoxia and anoxia, and of the world's four major eastern boundary current systems, water column shelf anoxia is best known in the Humboldt and Benguela Currents. Here episodic events of anoxia have been linked to red tides in areas such as Paracas Bay and St Helena Bay, respectively. In St Helena Bay recent observations have shown that these events are confined to relatively shallow waters during periods of downwelling, when subthermocline nutrients are inaccessible leading to bloom stress. St Helena Bay therefore offers a unique environment to further study and quantify the links between HABs and anoxia. For the purpose of comparison it is intended that parallel studies are undertaken in other systems, including other upwelling systems (e.g., Paracas Bay) and other systems subject to regular anoxia linked to HABs.

Timeline and deliverables

- 2013: Initiate project in the southern Benguela upwelling system.
Identify collaborators in other systems prone to anoxia associated with HABs.
Secure additional funding.
- 2014-15: Undertake field and experimental work.
- 2016: Conclude project through comparative assessment of findings and publication of results.

Relevance to GEOHAB

The project seeks to further our knowledge of the ecology and oceanography of HABs leading to events of anoxia in upwelling and other systems. Although bloom development will be tracked, the project will focus on the processes associated with bloom mortality and associated anoxia. Quantitative estimates of these processes will contribute to prediction of anoxia triggered by HAB events.

Funding sources

Funding to initiate the project in the southern Benguela upwelling system is secured. Funding to extend the project to additional systems will be accessed following identification of these systems. Extension of the project may be achieved by funding of co-supervised post-doctoral students through bi-national or bi-lateral agreements.

SEA-CAGE FISH FARMING AND HABS: EVIDENCE FOR CAUSALITY IN TEMPERATE COASTAL ECOSYSTEMS?

Lincoln MacKenzie, Cawthron Institute, Nelson, New Zealand

Presented by Dr Raphael Kudela, Ocean Sciences Dept., University Of Southern California, USA

Introduction

The rearing of finfish in sea-cages has many benefits including the creation of valuable high-protein food, reducing the pressure on wild fisheries and supporting economic development and employment. In some countries it is a significant contributor to the national economy. Nevertheless for a variety of reasons (environmental sustainability, disease and parasites, food and water quality, use of therapeutics, effects on the benthos, effect on wild fisheries, occupation of public space, landscape values etc.) the operation of sea-cages in temperate coastal waters is controversial. The effect of sea-cages on the benthic environment is well studied but the effect on the water column is less well understood. A frequently cited concern is the potential to cause eutrophication leading to the generation of HABS, as a result of the large quantities of combined nitrogen that are introduced into the water column in the fish feed. On the face of it this concern is justified, but when existing published evidence is examined, it is not at all clear that there really is a close association. Because of the rapid assimilation, dilution and dispersion of dissolved and particulate nutrients, in many situations it appears to be difficult to directly attribute a response by the phytoplankton to sea-cage effluents. Justified or not, the perception that sea-cage fish farming leads to increased problems with HABS invariably becomes an important environmental planning question on which it is difficult to confidently provide an expert opinion.

A brief review of the literature

Several studies have demonstrated that coastal eutrophication is associated with the increased incidence of HABS (Anderson et al. 2002, 2008; Heisler et al. 2008), but in none of these studies were sea-cages identified as a significant cause. Searching the international literature does not reveal a strong relationship between HABS and sea-cage fish farming, except in the most confined, poorly flushed and grossly polluted situations where the nutrient loads from the farms clearly far exceed the assimilative capacity of the water body (e.g. Romdhane et al., 1998). There is little published evidence that phytoplankton biomass is enhanced by nutrient inputs from fish farm cages (Beveridge et al., 1994; Pitta et al., 1999; Wu et al., 1994), even when these farms are in enclosed inland locations with restricted water exchange (e.g. Navarro et al., 2008). In the few countries (e.g. Scotland) where systematic evaluations have been made (e.g. Rydberg et al., 2002; Scottish Executive Central Research Unit, 2002; Gubbins et al. 2005; Smayda 2006,) no connection between the occurrence of HABS and fish farm wastes has been identified. In a large study of the nutrient impacts of farmed Atlantic Salmon on the pelagic ecosystem in Chile, Buschmann et al. (2006, 2007) stated that ““there is little scientific evidence that nutrient loading from salmon farms is sufficient to initiate and sustain harmful algal blooms...””, though they acknowledged that “... nearly all the rigorous pelagic ecosystem science related to HABS has occurred outside the areas directly influenced by salmon farms” In Korea and other regions where *Cochlodinium polykrikoides* blooms have caused serious problems, blooms originate offshore as the result of large scale oceanographic processes and there is no strong evidence that implicates coastal eutrophication in their origin and development (Kudela et al., 2008, Kim et al. 2010). *Heterosigma akashiwo* is notorious for its effect on salmon farms in the USA and Canadian Pacific

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North-West regions though Rensel (2007) stated that “It is evident that fish farms do not cause *H. akashiwo* blooms in marine waters of Western Washington and the data suggest that it is unlikely they exacerbate blooms.” Nutrient inputs from fish farms may have contributed to the well-known case of the eutrophication of the Seto Inland Sea, Japan in the mid-20th century (Okaichi, 1997; Imai et al. 2006) but the more influential factors were massive effluent inputs from urban and industrial sources.

Norway is the largest producer of farmed salmon in the world and although toxic and noxious algal blooms are a common problem in the coastal waters of Scandinavia there is no suggestion in the literature that sea cages cause or exacerbate this. The extensive problems with *Pseudochattonella* and *Chrysochromulina* in the 1990s has been attributed to oceanographic processes (Graneli et al., 1993). A recent risk assessment of the environmental impacts of Norwegian aquaculture (Taranger et al., 2011) reached the conclusion that the risk of regional eutrophication in all areas associated with sea-cage salmon farming was low. New Zealand and Australia both have rather small sea-cage salmon farming industries in sheltered fjord-like locations though in both countries these are about to undergo significant expansion. Toxic and noxious HABs are relatively common (e.g. MacKenzie et al. 2011) in salmon farming regions in New Zealand but there has been little if any convincing evidence of causality over the 30 year history of the industry.

The proposal

As the brief discussion above shows there is little convincing proof of a cause and effect relationship between sea-cage fish farming and HABs. This is contrary to the views of some in the HAB science community (e.g. Fukuyo 2012: “Development of fish aquaculture almost always accelerates eutrophication of culture area and consequent occurrence of HABs.”). In fact given that these sea-cages can be responsible for high rates of nutrient loading to enclosed waters, it is puzzling that their effects are not more obvious and well documented. There may be a considerable amount of information on this topic in the ‘grey literature’ such as locally commissioned environmental assessment reports that would shed more light on it. The proposal is to develop a project under the GEOHAB umbrella that would be aimed at drawing out this information so that a consensus can be reached on where HAB related problems associated with sea-cages occur and what can be done to mitigate them. The proposal does not aim to address issues surrounding intensive pond culture nor sea-cages in tropical systems where data would not be directly comparable with temperate coastal ecosystems.

This proposal encompasses aspects of at least three of the programme elements from the GEOHAB Science Plan, including: Nutrients and Eutrophication, Comparative Ecosystems and Observation Modelling and Prediction

The specific objectives may include:

- A comprehensive review of published and unpublished data and the knowledge and opinion of local experts in all countries (e.g. Norway, Scotland, Ireland, USA/Canada, Japan, Korea, China, Australia, New Zealand etc.) with significant temperate sea-cage fish farming industries. This review may ultimately comprise series of papers focussed on specific regions published as a special journal issue or stand-alone volume.

- Foster the development of novel technologies to track effluent plumes from sea-cages to enable direct observations of their effects on the water column (e.g. drone-mounted remote sensing).
- Provide guidelines for effective monitoring of water quality and HABs associated with sea-cages, encourage research on in situ autonomous instrumentation to achieve this.
- Development of biophysical simulation models to more accurately predict the impact of fish farm effluents on the phytoplankton in general and HABs in particular.
- Identify means by which the environmental effects of fish farms effluents and their potential for stimulation of HABs might be minimised.
- Provide guidelines for the attributes necessary for the optimum location and nutrient loading rates of sea-cages to minimise the risk of HABs. Generic guidelines could be published under the GEOHAB banner.
- Encourage multidisciplinary research to accurately quantify nutrient assimilation, remineralisation and loss rates in waters and sediments of fish farming regions to parameterize biophysical models.

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

Burkill

Terms of Reference

- 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, July 2014**

A. Introduction

The Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) project (www.imber.info) is an international global environmental change research project, co-sponsored by the International Geosphere-Biosphere Programme (IGBP) and the Scientific Committee on Oceanic Research (SCOR). IMBER science is directed at addressing the goal of developing 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 IMBER Science Plan and Implementation Strategy (SPIS) published in 2005 outlined science questions and approaches for addressing this goal. The SPIS was updated in 2010 when the Global Ocean Ecosystems Dynamics (GLOBEC) project ended and some of its activities were incorporated into IMBER. Thus, IMBER is now approaching its ten-year mark, and it is appropriate to assess project accomplishments, reconsider the project goal and science questions, and to develop an agenda that will form the basis for the next 10 years of IMBER research.

To assist in the process of project evaluation and future planning, IMBER convened an Open Science Conference (OSC) titled, '*Future Oceans – Research for marine sustainability: multiple stressors, drivers, challenges and solutions*', in June 2014 in Bergen, Norway. The goals of the OSC were to provide the opportunity for the larger marine science community to present key findings from IMBER-relevant research, to promote integrated syntheses of IMBER research, and to develop a science plan for future IMBER research. Prior to the OSC during spring 2014, a draft position paper was prepared using inputs gathered from IMBER regional programmes, working groups, and partner organizations. From these inputs, five research themes emerged:

- Continued integration of marine biogeochemistry and ecosystem research
- Impacts of global change and climate variability on marine systems
- Role of multiple drivers and stressors, and responses of society
- Integration of marine biodiversity and conservation
- Integration of ocean-human systems

Also data management and capacity building were highlighted as important mechanisms for facilitating and implementing the research challenges and questions included in the five themes.

The draft position paper was provided to participants prior to the OSC and presented in a plenary presentation. Each of the themes, data management, and capacity building were discussed in breakout groups during the OSC and the inputs from each were reported in a plenary session. In parallel, an online survey was implemented to allow for additional inputs from OSC participants and the community. The position paper is now being revised based on these inputs and subsequent discussions with the IMBER Scientific Steering Committee. The primary change is that the five themes will be incorporated into a small number of overarching grand challenges

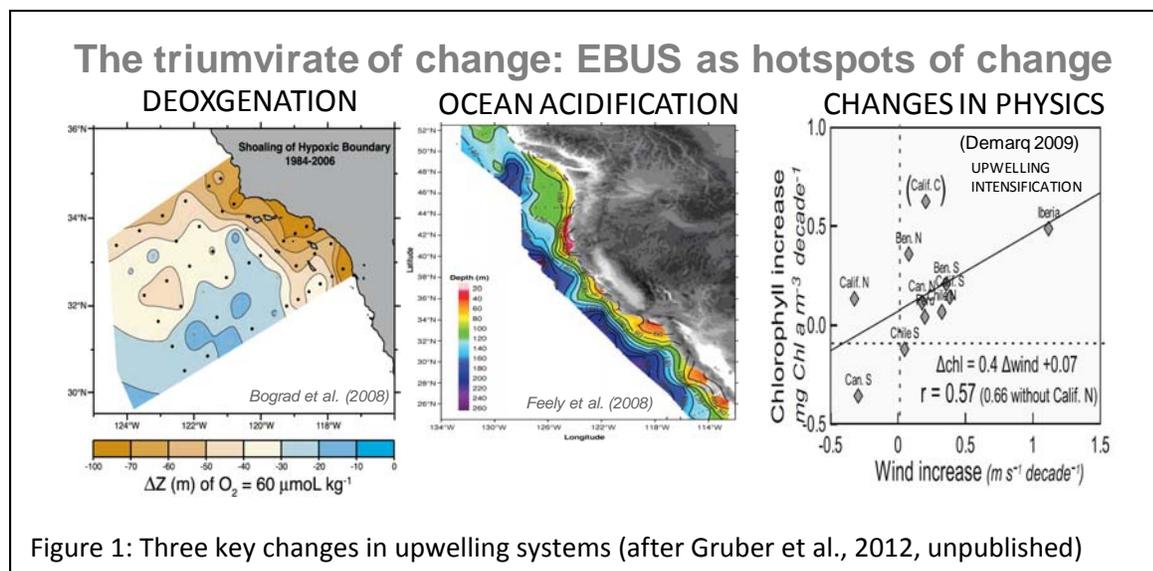
that provide direction for IMBER research beyond 2015. The intent is to have a draft of the revised paper available for community comments by mid- to late August 2014. A summary of the position paper will be provided to SCOR for discussion at the annual meeting in September 2014 with follow-on interactions with IMBER. The final version of the paper should be available by the end of 2014 and this will provide the basis a 10-year extension request to SCOR.

IMBER has a strong commitment to basic curiosity-driven science and this is the foundation on which an agenda for the next 10 years of research will be based. However, the environmental issues facing society, particularly those relating to global environmental change, are at the interface between natural and social sciences and humanities, where the understanding provided by curiosity-driven, natural science merges with problem-driven, societally relevant and mostly integrated research. This is underscored by the science highlights presented in the next section, which are drawn from the plenary presentations given at the IMBER OSC. Each of these presentations focused on scientific achievements, but also provided a view to the future. For all, the research challenges that were highlighted involved some degree of coupling between natural, human, policy and governance systems related to the marine realm.

A clear message to IMBER from OSC plenary and contributed presentations, the inputs to the position paper, and feedbacks received from the OSC participants is that research that includes these interfaces must be part of any future science agenda. While the research landscape and its organisation are evolving at the global level, the IMBER community is well poised to take the lead in developing this area of marine research. Exciting changes and challenges are facing our community and dealing with these in a proactive, forward-thinking manner is key, both for now and the future.

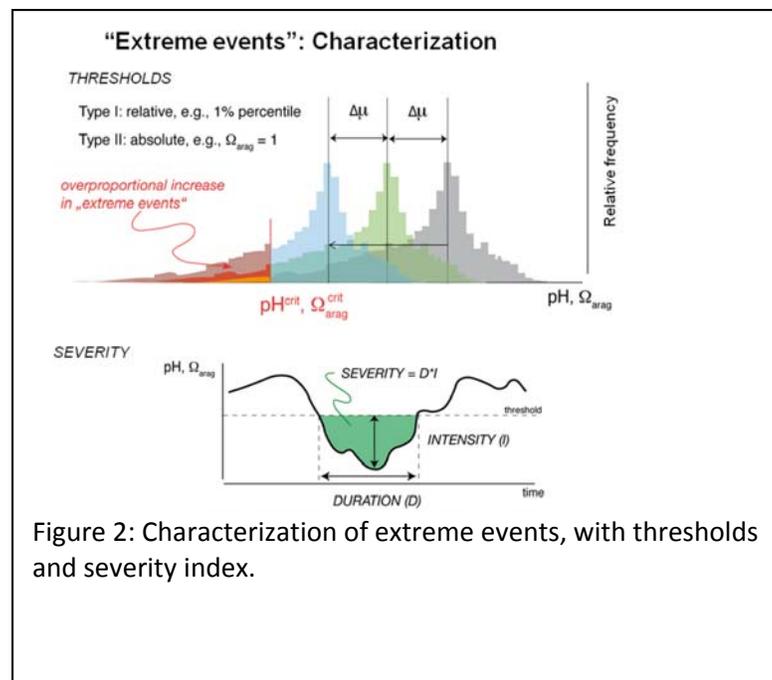
B. IMBER science highlights from the Open Science Conference, 2014

The IMBER OSC was attended by about 485 participants, who represented 48 countries, including 16 developing countries. The final programme included 5 plenary sessions, 11 workshops and 21 contributed sessions, representing all IMBER science themes, regional programmes, working groups, and related communities. The science highlights presented in this section, which are drawn from the OSC plenary presentations, provide an overview of IMBER science achievements, highlight the rationale for the five themes in the draft position paper, and introduce new ideas for future IMBER research.

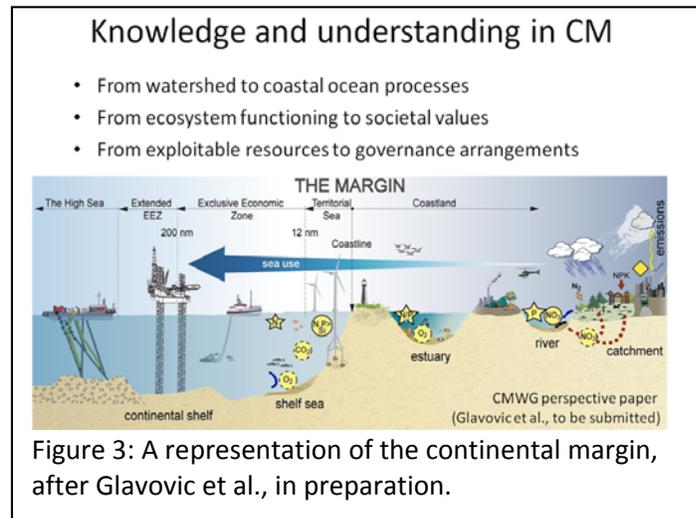


Plenary Talk, Nicolas Gruber: This presentation, “*Warming up, turning sour, losing breath – the regional perspective*”, focused on the consequences of pH changes, ocean acidification, and de-oxygenation using specific examples from the California Current, an eastern boundary current upwelling system (Fig. 1). Recent advances in observational capability have captured changes in the physical, biological and chemical characteristics of the California Current resulting from ocean acidification and low oxygen.

Advances in modelling capability and incorporation of new observations into models have allowed projections of these trends into the future, identification of important controlling processes, and attribution of uncertainty to the future projections. The latter effort has highlighted the importance of extreme and rare events in driving change in marine systems (Fig. 2). The combined modelling and observational efforts allow identification of marine ecosystems that are most vulnerable to the effects of changing pH and reduced oxygen and provide guidance about controlling processes.



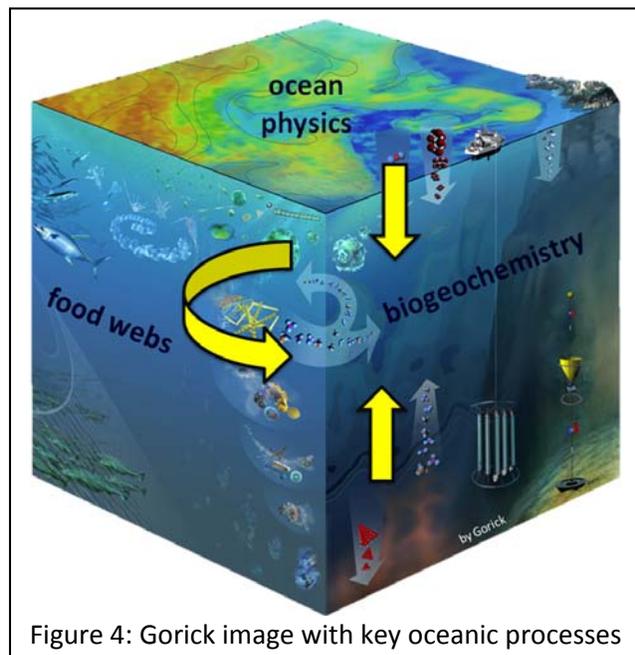
Plenary Talk, Kon-Kee Liu: Research accomplishments and future research needs for continental margins were presented in,



“*Anthropogenic impacts on biogeochemical processes and ecosystems in continental margins – lessons learned from cases around the globe and future perspectives*”. This presentation focused on the growing importance of continental margins for providing resources and services for human, marine and maritime activities. At the same time these systems are vulnerable, and climate-related changes are moving continental margins towards possible tipping points. New research strategies that foster sustainable use of continental margins are being developed

that include from the outset consideration of innovation, risk and governance (Fig. 3).

Plenary Talk, Coleen Moloney: From its beginning, IMBER has had a focus on integrating marine biogeochemical cycling and food web dynamics. The presentation, “*Food webs and biogeochemistry in a changing marine environment*”, provided a synthesis of IMBER accomplishments in developing end-to-end views of marine ecosystems (Fig. 4). This approach is key to developing and exploring (e.g., climate and fishing) scenarios of future changes in the marine environment, understanding its resource and service provision, and to furthering predicting capacity at local and intermediate complexity/integration levels (Fig. 5).



New process understanding, such as mixotrophy and parasitism, remain to be incorporated into trophic process models. However, the progress that has been made is substantial and for some marine ecosystems, scenario testing and projections are a reality.

Models of intermediate complexity for ecosystem assessments (Fig. 5), which extract information from a suite of models developed for different aspects of an ecosystem, were highlighted as the approach for scenario testing and projecting future states of marine ecosystems.

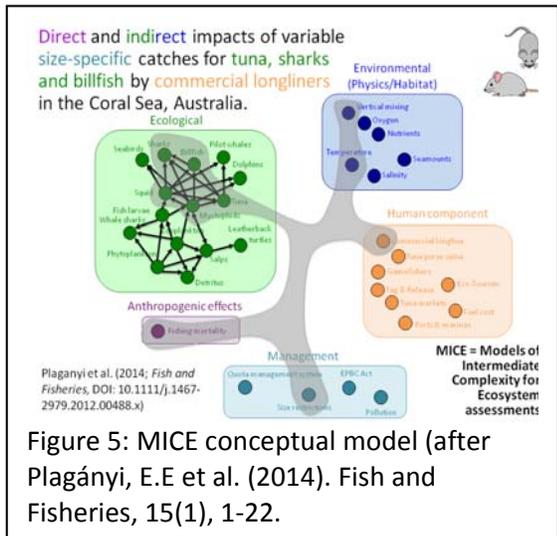


Figure 5: MICE conceptual model (after Plagányi, E.E et al. (2014). *Fish and Fisheries*, 15(1), 1-22.

Plenary Talk, Jean-Pierre Gattuso: Advances in an area of marine research that has been a priority focus for IMBER (and SOLAS) were summarized in, “*Drivers of and responses to ocean acidification*”. This presentation highlighted potential impacts of ocean acidification, but took the longer view that these impacts are acting in combination with other drivers and stressors (Fig. 6). The potential role of ocean acidification at local, regional and global levels is significant, but understanding of related physical-chemical,

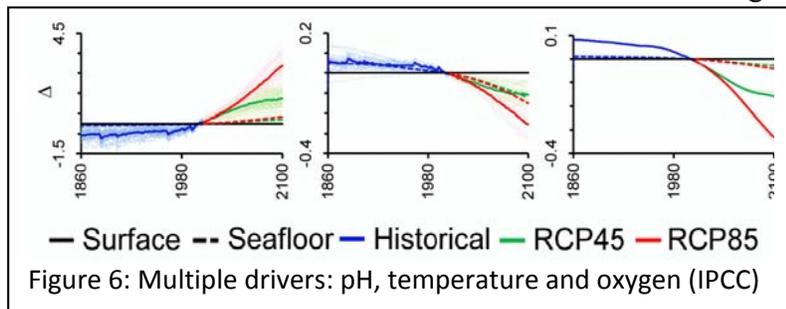


Figure 6: Multiple drivers: pH, temperature and oxygen (IPCC)

physiological, ecological, societal processes associated or depending on ocean acidification is still limited, especially when multiple drivers and stressors are considered (Fig. 7). This is an area for future research and the IMBER community is well positioned to take the lead.

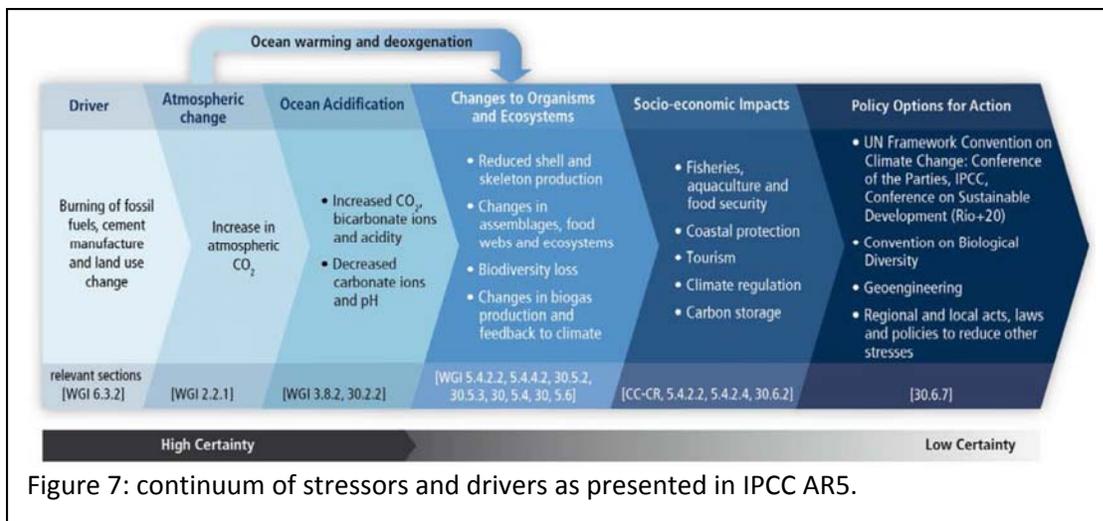
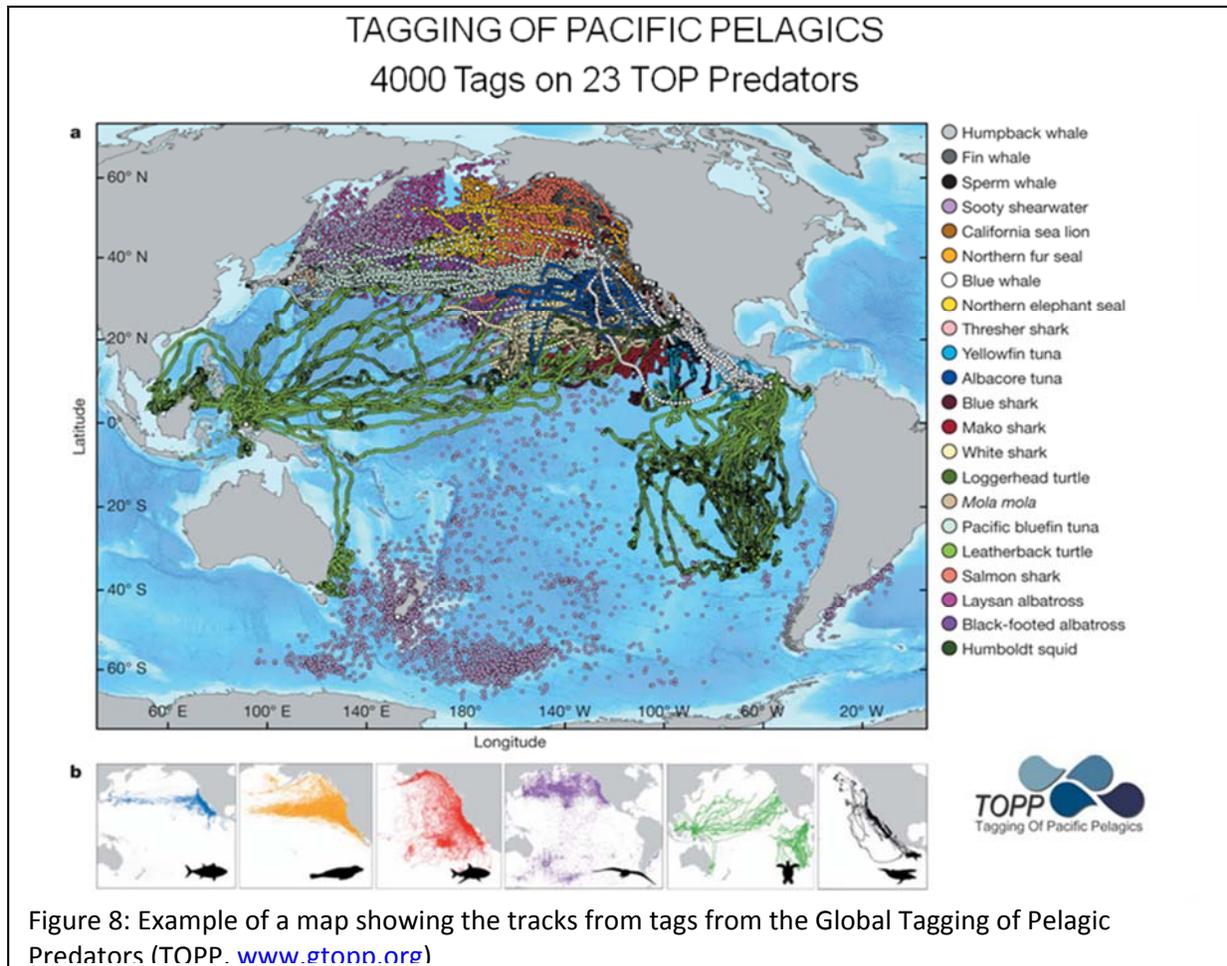


Figure 7: continuum of stressors and drivers as presented in IPCC AR5.

Plenary Talk, Claudio Campagna: The potential biodiversity crisis that the marine environment is facing in the coming decades was presented in, “*Marine Conservation in the time of Global Change*”. This potential crisis is associated with the values issues of human society in terms of how marine resources are viewed. Efforts are underway to explore the threats and trends for iconic species’ biodiversity.



Among useful new methods and approaches are tagging and remotely sensed monitoring of individuals, which provides information on behaviours, habitat use, and species range (Fig. 8). The establishment of Marine Protected Areas provides one possible approach for conservation for marine biodiversity, but more evaluation and research are needed to determine the effectiveness of these regions. Limited progress has been made in terms of conserving biodiversity in the marine environment, and much remains to be done. Marine biodiversity and conservation is an important area for future IMBER research and it is a natural extension of the research that is ongoing in the regional programmes.

Plenary Talk, Alistair Hobday: The contributions that IMBER research has made to the

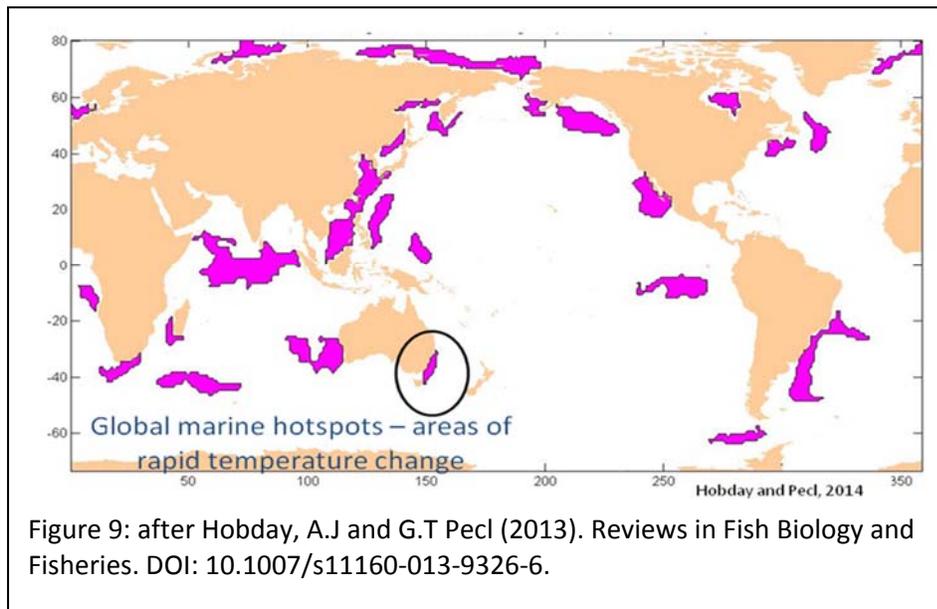


Figure 9: after Hobday, A.J and G.T Pecl (2013). Reviews in Fish Biology and Fisheries. DOI: 10.1007/s11160-013-9326-6.

understanding of responses of top predators to global change were summarized in the presentation, “*Climate change impacts and adaptation options for high trophic level marine species*”. New integrated approaches, methodologies used at the individual or species’ levels, and new data (e.g., inter-

oceanic comparison of top predator diets and ecosystem trophic structure) have improved prediction capability for various scenarios of climate change, such as changes in habitat suitability for commercial species (Fig. 9) and allowed linkages to be made between areas of rapid temperature change to threats to key marine species and fisheries (Fig. 10).

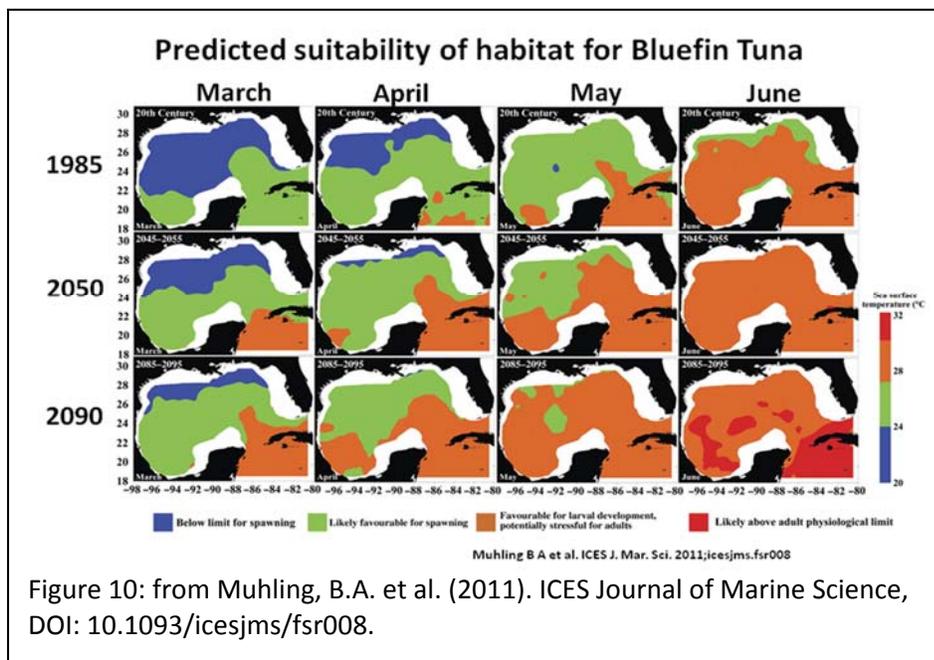


Figure 10: from Muhling, B.A. et al. (2011). ICES Journal of Marine Science, DOI: 10.1093/icesjms/fsr008.

A new conceptual vulnerability research framework was proposed that explores adaptation options, applicable either locally or at the species level. The adaptation process is iterative, and closely links ecological and societal systems and their respective vulnerability. Changes are underway in many marine systems and change is predicted to continue. Continued

documentation of these changes (e.g., fisheries decline) is important to developing the understanding and strategies needed to change the trajectory of the change and to help species, people, and institutional systems to adapt to the change. Options exist to respond to climate

change effects on pelagic top predators, but adaptation will be difficult for open ocean species, and will require the involvement of managers, policy makers, and institutions from the outset.

Plenary Talk, Alida Bundy: “*Dead ends and grasping hands: failed governance and the need to integrate human-ocean interactions into global change science*” focused on research needs

for improving understanding of human-ocean interactions, with specific examples drawn from marine fisheries. A social-ecological systems approach and a truly integrated dialogue across the natural and social science disciplines and among multiple stakeholders are needed,

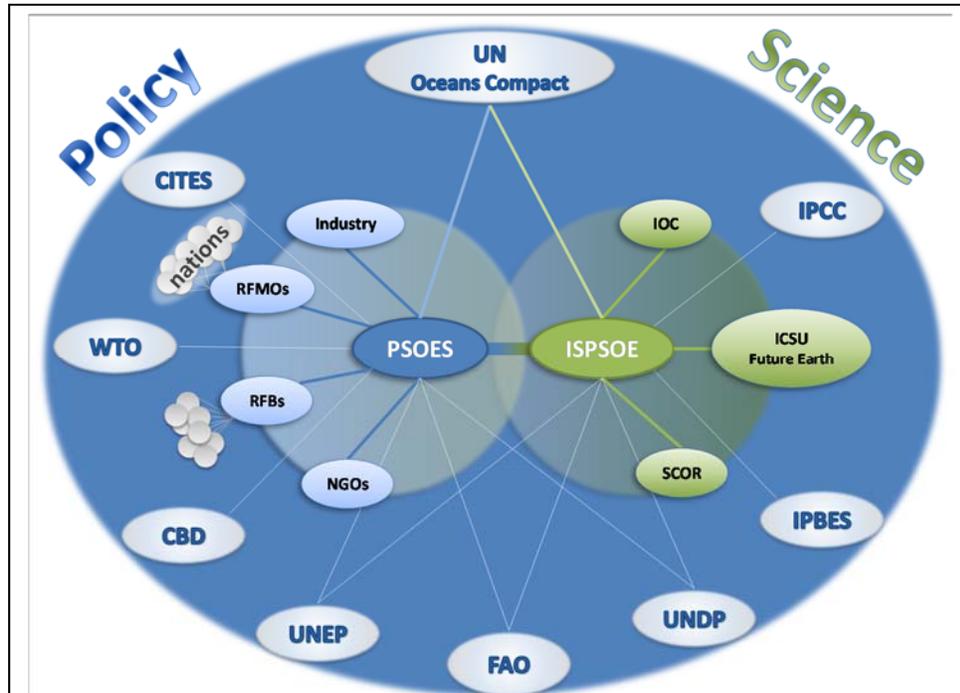


Figure 11: Schematic organization of the proposed science-policy partnership including a Partnership for the Sustainability of Ocean Ecosystem Services (PSOES) and a International Scientific Program for the Sustainability of Oceanic Ecosystems (ISPSOE), in: Maury O. et al. (2013). *Current Opinion in Environmental Sustainability*, 5, 314-319.

which requires a new integrated, co-designed research agenda (Fig. 11). Development of science-policy partnerships, through the institutions involved in the assessment and management of marine resources and services, *and* also at the level of the individual research, is a start to this process. The IMBER-ADApT decision support tool was developed by the IMBER Human Dimensions Working Group. This tool will enable decision makers, researchers, managers and local stakeholders to improve responses, make decisions efficiently to transition towards marine sustainability, and evaluate where to most effectively allocate resources to reduce vulnerability and enhance resilience of communities to marine global change. This approach will advance and improve the impact of current research endeavours underway in the IMBER regional programs.

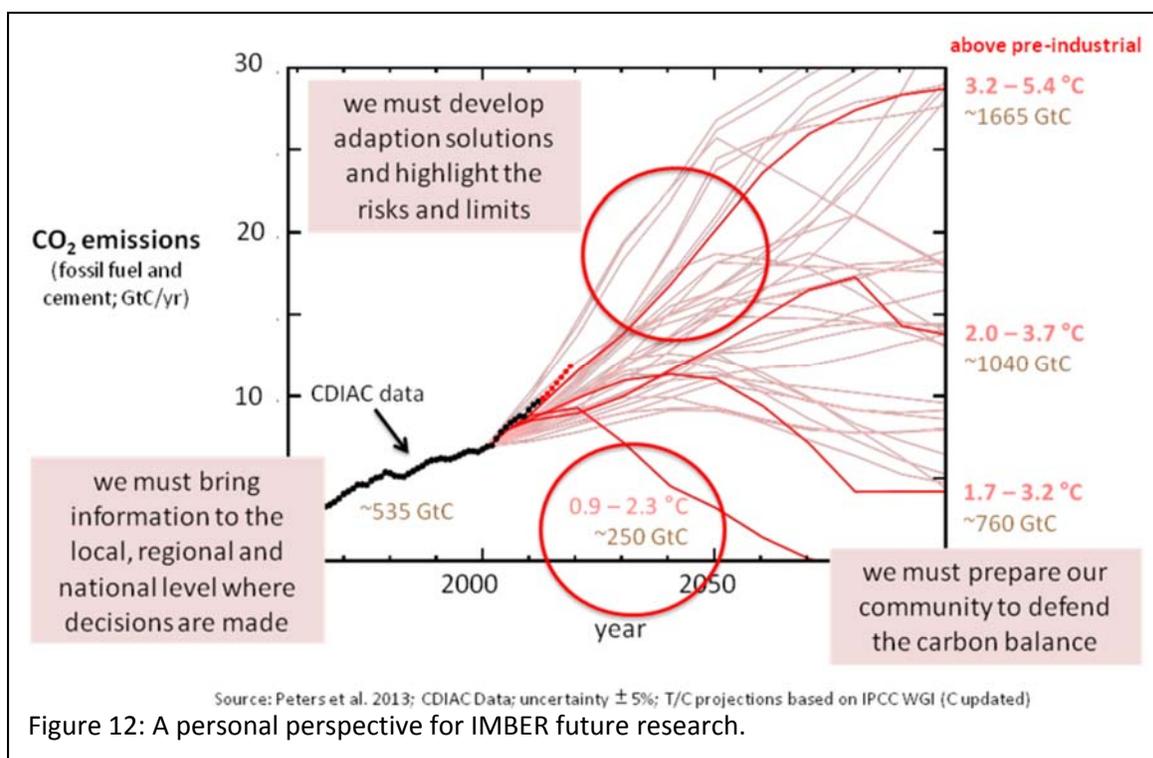


Figure 12: A personal perspective for IMBER future research.

Plenary Talk, Corinne Le Quéré: Inputs from the Future Earth Scientific Committee, that also built upon recent progress by the IPCC from inputs by the marine research community, were provided in, “*From CO₂ surveys, nutrient budgets, ecosystem process studies and modelling, to the Future Earth era: preserving our strengths and shaping new opportunities for the IMBER community*”. The approaches used by IMBER and the IPCC are complementary to developing scenarios, projections and predictions, that help decision-making processes (as based on scientific evidence for environmental policy) and help promote sustainable societal transitions. The strengths of the IMBER community and the possible pathways for a strong IMBER-related contribution in Future Earth (Fig. 12) were highlighted.

C. 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. In April 2014, ESSAS held its Annual Science Meeting (ASM) in Copenhagen, Denmark. The focus for this meeting was the paleo-ecology of the Subarctic Seas, biology and ecology of Arctic cod species, human responses to major shifts in fisheries, comparative and modelling studies, and the biological impacts of the Atlantic Multidecadal Oscillation. The ESSAS SSC met following the ASM to review recent ESSAS activities and to develop a future research plan. Following a request from ESSAS, Greenland appointed a new member, AnneDorte Burmeister, a crab biologist, as a replacement on the ESSAS SSC for Kai Weiland, who no longer is working in Greenland waters. The ESSAS co-

chairs convened a session on, “*Changing ecosystems in sub-Arctic and Arctic regions*”, at the **IMBER OSC** in June 2014, Bergen, Norway.

ESSAS Working Groups

The *WG on Modelling Ecosystem Response* is involved in a special volume on *Modeling and observational approaches to understanding marine ecosystem dynamics* in *Progress in Oceanography* that is to be dedicated in memory of Bern Megrey, former chair of this ESSAS WG.

The *WG on Climate Effects at Upper Trophic Levels* completed its terms of reference with the publication of a special topic session in *Marine Ecology Progress Series* in 2013 and the WG was terminated.

The *WG on Arctic-Subarctic Interactions* has organized a theme session at the ICES ASC in Spain in September 2014 and a workshop at the PICES annual meeting in Korea in October 2014, both on advection and exchanges between the Arctic and Subarctic.

The *WG on Bioenergetics of Subarctic Fishes* aims to develop deeper understanding of climate’s impact on the match between juvenile fish and their prey and the implications of that relationship for future production.

The *WG on Human Dimensions* formed last year under the leadership of Keith Criddle, who gave a presentation at the ESSAS ASM.

The *WG on Comparative Paleo-Ecology in Sub-Arctic Seas* sponsored a special session during the ASM. The WG will explore potential mechanisms linking climate, oceanographic, ecological and human system relationships from the Holocene to the Anthropocene.

Multinational Activities (endorsed by ESSAS)

A Norwegian and U.S. Climate Change and Marine Ecosystems (*NUCCME*) Workshop was held in May 2013 focused on the marine environment, fisheries management and human dimensions, jointly with CLIFFIMA, a Nordic Council Network that investigates climate change issues, including human dimension aspects. A related special issue in *Climatic Change* is in preparation.

The 2011 international Atlantic Multidecadal Oscillation (AMO) workshop published its special issue in the *Journal of Marine Systems* in 2014, describing the temporal variability of the AMO, the spatial structure of the SSTs within the North Atlantic, the possible mechanisms governing the AMO dynamics, the impacts on other physical characteristics such as currents and sea ice, past variability in temperature from paleo-records, the biological impacts of the AMO including effects on phytoplankton, zooplankton and fish stocks, and the links to temperature changes in the Antarctic and the Pacific.

The ESSAS-endorsed project *TROPHARCT* assembled a series of 5 joint papers from Canadian, U.S., Russian and Norwegian scientists plus an introductory paper, published during 2013 in a special section of *Marine Ecology Progress Series* under the title “*Harvested fish stocks in a changing environment*”.

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Future ESSAS activities

The next ASM and SSC meetings will be held in June 2015 at the University of Washington in Seattle. In response to a new project initiated at the University of Washington, 'Future in Ice', a day to 1.5-day meeting on ice and its effects on biology will be held at the ASM. Additional potential session topics include paleo-ecology, human dimensions, and bioenergetics.

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. www.iced.ac.uk/index.htm.

As part of a thematic workshop, "*Polar Marine Ecosystems Research: Strategic directions for the EU Research Area*" (Brussels, Belgium, May 2013), a joint ICED/EUR-OCEANS Consortium Flagship Project (Polar Ecosystem Change and Synthesis, PECS) strategy document for Polar Marine ecosystem research was presented to senior European Commission members. Such research should form an essential component of the EU Research Area funded by the EC Horizon 2020 funding programme. This is already promoting European and international collaborative research and some of the aims of the strategy have appeared in recent calls of Horizon 2020, thereby fulfilling the workshop's objective.

During the ICED Scientific Steering Committee Meeting (SSC), held in Cambridge, Maryland, USA in November 2013, progress over the last 5 years was reviewed and the key directions and priorities were agreed upon for the next 5 years. The ICED Workshop on 'Southern Ocean Food webs and Scenarios of Change' in Nov. 2013, focused on exploring quantitative, future scenarios based on the latest available climate models, ecological data and models, and information on fisheries and the associated critical challenges

The *Workshop on Ecosystem Essential Ocean Variables (eEOVs) for the Southern Ocean*, March 2014, focused on biodiversity indicators and indicators of marine ecosystem structure, function, and dynamics; composite indices; and expert advice to policymaker. A proposal for a related Working Group has been submitted to SCOR.

ICED scientists have participated in the SCAR Horizon Scan Retreat, April 2014, with 80 participants, for identifying the most important scientific questions in and from the southern polar regions over the next two decades. A series of documents have been submitted to the Commission for the Conservation of Marine Living (CCAMLR) Working Group on Ecological Monitoring and Management highlighting relevant ICED science and ways of interfacing with policy.

Several scientific papers were published that consider Southern Ocean change, ecosystem structure and function, links between ecology and biogeochemistry, and management of the Southern Ocean.

One ICED-related session was organised at the IMBER OSC (Bergen, Jun 2014), with a panel discussion on ‘*Challenges for evidence-based management of Southern Ocean ecosystems*’. The ICED community contributed to the forthcoming IPCC AR5 Report (Climate Change 2014: Impacts, Adaptation, and Vulnerability Working Group II), led by A. Constable.

An ICED stakeholder event (joint with WWF) was held in June 2014, which brought together key sectors with an interest in Antarctic krill: the fishing industry, scientists, and conservation organisations.

Future ICED activities

- A joint AnT-ERA/AntClim21/ICED session on ‘Impact of climate change on Antarctic biota’ will be convened at the SCAR Open Science Conference, Aug. 2014, New Zealand.
- An ICED community paper on scenarios is being developed. ICED will strengthen our science areas as outlined in the IMBER Position Paper and we will work to establish a clear and strong role for ICED within CCAMLR, SCAR and Future Earth.
- The re-development of the online fieldwork map tool is still underway, and a Southern Ocean wiki is developing, 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.

A *Deep-Sea Research II* special issue developed from the 2nd CLIOTOP symposium is now being edited by CLIOTOP SSC members. CLIOTOP Working Groups have held a range of meetings and have generated a large number of publications. The website hosted by IMBER IPO is allowing us to showcase CLIOTOP scientific outputs (www.imber.info/CLIOTOP.html).

The CLIOTOP SSC held its 9th Meeting in June 2014, in Bergen, just prior to the IMBER OSC. Osamu Abe (Japan) replaced Hideki Nagano (Japan) as an SSC member. Several of the working groups will soon be concluded, and the SSC is now discussing a new structure for a proposed CLIOTOP phase III, for the next five years.

CLIOTOP SSC members convened 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.

Selected Working Group Activities

- Co-sponsored session with Marine Bird Mammal – Advisory Panel at PICES FUTURE Open Science Meeting workshop in April 2014 entitled “*Top predators as indicators of climate change: statistical techniques, challenges and opportunities*”.
- “Diet Workshop: analysis of a full stomach contents dataset using classification tree methodology modified for complex diet data”, October 2013, Australia

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- “Stable Isotope Workshop: Pelagic Top Predators and N Isotopic Baselines” February 2014, Hawaii, USA
- Website developed for ISOZOO programme investigating the role of lower trophic level dynamics in structure of pelagic food webs: <http://www.isofoo.org>.
- The CLIOTOP Scenario Group (involving also representatives from industry and RFMOs) first met in November 2013 and started to establish Oceanic System Pathways (OSPs). The objective is to develop model-based scenarios jointly with stakeholders.
- Participation in the IUCN workshop “*Multidisciplinary Workshop to Address Ecosystem-Level Impacts of Fisheries Bycatch on Marine Megafauna: Biodiversity Conservation through Mitigation, Policy, Economic Instruments, and Technical Change*” in October 2013; in the ‘*Building 21st century scenarios for global oceanic ecosystem and fisheries*’ meeting, in November 2013.
- Participation in several meetings about fishing capacity in various regions, with the International Seafood Sustainability Foundation, the European Commission, or the Inter-American Tropical Tuna Commission.

Science Highlights

CLIOTOP is now becoming better recognized within the open ocean research community, with increasing balance in research between tuna and fisheries, and non-exploitation issues with other top predators (seabirds, marine mammals and turtles).

Results from CLIOTOP activities were published in a special issue of *Deep-Sea Research II*, on the “Role of squids in pelagic ecosystems” (2013).

Future CLIOTOP activities

- Workshop on “Variability in the movement patterns of marine predator populations: physiological, behavioural and environmental drivers in the Bio-logging 5 Symposium, September 2014.
- Several sessions proposed for the ICES/PICES 3rd International Symposium on Climate Change Effects on Marine Ecosystems, March 2015.
- Participation in the Euro BASIN workshop ‘Futures of the North East Atlantic Ocean by 2040- a Stakeholder Consultative Workshop’, November 2014.
- Planned participation in several meetings related to seafood sustainability, fisheries economics and fishery management.
- The 3rd CLIOTOP Symposium is scheduled for September 2015.

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

SIBER is a basin-wide research initiative sponsored by IMBER and the Indian Ocean GOOS (IOGOOS) Programme, with close ties to CLIVAR’s Indian Ocean Panel (IOP), and focuses on understanding climate change and anthropogenic forcing on biogeochemical cycles and ecosystems in the Indian Ocean, in order to predict the impacts of climate change, eutrophication and harvesting (www.imber.info/index.php/Science/Regional-Programmes/SIBER and www.incois.gov.in/Incois/siber).

The SIBER SSC met in China, July 2013 following the Second International Symposium on Boundary Currents convened with CLIVAR's Pacific Panel and Indian Ocean Panel (IOP) and the IndoOS Resources Forum (IRF). A joint session was also convened with CLIVAR/IOP. The International Indian Ocean Expedition 50th Anniversary (IIOE-2) planning efforts have emerged as a major SIBER activity. The second IIOE-2 Reference Group meeting was convened in China, Nov. 2013 to help define the overarching science and societal drivers for IIOE-2, and assess planned and ongoing national activities in the IIOE-2 timeframe (2015-2020). In addition, a strategy was developed for promoting national IIOE-2 planning efforts and an IIOE-2 organizational framework/governance structure was adopted. Another Reference Group meeting needed for the East Africa/SW IO constituency for a more general IIOE-2 engagement was convened in March 2014 in Mauritius. The chair of SIBER, Prof. Raleigh Hood, is chairing a SCOR committee to draft a IIOE-2 Science Plan. This plan will be reviewed at a workshop in Bremen, Germany on 12-13 September 2014.

The Eastern Indian Ocean Upwelling Research Initiative (EIOURI) has also emerged as a major SIBER activity. This initiative, which is envisioned as a 5-year process study and program under the emerging IIOE-2 in the Eastern Indian Ocean, embraces upwelling as a unifying IIOE-2 theme, with basin-wide relevancy. Three workshops have been convened so far (two in 2013 and one in 2014) with a final workshop was held at the IMBER Open Science Conference, June 2014.

SIBER-motivated biogeochemical sensor deployments are continuing in the Indian Ocean. A biogeochemical sensor package deployed on a RAMA mooring at the equator and 80°E on 22 May 2010 was recovered and the data have been analyzed. In addition, a CO₂ sensor package has been deployed in the Bay of Bengal with support from BOBLME, and a RAMA mooring has been deployed at the flux reference site at 26°S, 97°E equipped with a BGC sensor. Finally, a new SIBER/CSIRO Australian research initiative in the Eastern Indian Ocean is aimed at quantifying nutrient fluxes through the Indonesian Throughflow.

In addition to the SIBER International Project Office, located at INCOIS in Hyderabad, India, efforts are continuing to establish a Regional Program Office in Western Australia supported jointly by Australia's Integrated Marine Observing System (IMOS) and the IOC Office in Perth. The SIBER SSC has provided guidance documents on how to define responsibilities and tasks of this RPO and partition these between IMOS and the IOC Perth office.

A SIBER-related session on 'Biogeochemical and Ecological Impacts of Boundary Currents in the Indian Ocean' was held at the IMBER OSC in Bergen, Norway, June 2014.

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:

- The next SIBER SSC meeting will be convened in Phuket, Thailand, in October 2014, jointly with the IOGOOS Program and the IndoOS Resources Forum (IRF).

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- The SIBER special issue in *Biogeosciences* on Current biogeochemical and ecosystem research in the Northern Indian Ocean is still in preparation.

D. *IMBER Working Groups and Task Teams*

SOLAS-IMBER Carbon (SIC!) Working Group

To oversee 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). It has earlier been suggested that the remit of the existing SIC! Working Groups could be revisited to incorporate the topic of the Microbial Carbon Pump in the Ocean, 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 surface ocean systems (SOS), and on instrumentation and technology development, Voluntary Observing Ships (VOS) and mixed layer sampling strategy.

SIC!-SOS members co-convened 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, 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).

The global synthesis of repeat hydrography initiative is progressing well since 2009 and has made major advances in the last year. The secondary data quality control effort of the GLODAP2 group is nearly completed and the data are planned to be released in June 2014. An ad-hoc steering committee with Masao Ishii (Japan), Jeremy Mathis (USA), Toste Tanhua (Germany), and Nicolas Gruber (Switzerland) was formed at a synthesis workshop in Beijing, held in conjunction with the 9th International CO₂ conference, to oversee the work to determine the global-scale oceanic accumulation of anthropogenic CO₂ since the 1990s. The synthesis group held a workshop at the 2014 Ocean Sciences meeting in order to discuss the first results and agree on a draft outline of a high-profile paper. The final results will be presented at the IMBER OSC where this synthesis group is organizing a dedicated session on “*The ocean carbon cycle at a time of change: Data syntheses, analyses and modelling*” in partnership with SIC!-SOS and IOCCP. WG2 is also continuing to support the growing Bio-Argo programme, with A. Körtzinger and K. Johnson being in charge of SCOR WG 142 on sensor calibration. This group also held its first workshop at the 2014 Ocean Sciences Meeting.

Ocean Acidification (SIOA)

SIOA co-ordinates international research efforts and synthesis activities in ocean acidification. Within a single decade, ocean acidification research 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 met in May 2014, in Villefranche-sur-mer and Monaco and SIOA members convened 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.

The Ocean Acidification International Coordination Centre (OA-ICC), initiated and mainly driven by the SIOA, is now half-way through its first three years of funding (2013-2015). It aims to foster scientific collaboration at the international level, promote best practices, improve observational capacities and databases, and facilitate communication and outreach. The OA-ICC is supervised by a Science coordinator (SIOA's current chair). The OA-ICC advisory board includes all SIOA members. The chair of the advisory board is Carol Turley, another SIOA member. The OA-ICC produced several key products that already have become fundamental building blocks for the ocean acidification research community and to ocean acidification science users, including the OA-ICC web site, www.iaea.org/ocean-acidification; OA-ICC news stream at news-oceanacidification-icc.org; OA-ICC bibliographic database, <http://tinyurl.com/oaicc-biblio>; OA-ICC data compilation at <http://tinyurl.com/oaicc-data> (now containing 409 datasets); an SIOA/IOCCP/CARBOCHANGE comparison study of the seven publicly available software packages that compute marine carbonate chemistry was published in *Biogeosciences Discussions*; and the OA-ICC slide set *Things you should know about ocean acidification*, produced for scientists to facilitate making presentations on ocean acidification to non-scientists <http://www.iaea.org/ocean-acidification/page.php?page=2189>.

Additionally, the OA-ICC helped support international scientific meetings where ocean acidification figures prominently, while also promoting understanding of ocean acidification at non-scientific meetings for international negotiations and discussions. The science meetings included the 2nd Global Ocean Acidification Observation Network (GOA-ON) workshop (July 2013) and the 6th SOLAS summer school (Xiamen, China, summer 2013). Additionally, the OA-ICC organized and funded a data curators' workshop (Monaco, April 2014) to move towards the goal of a “one-stop shop” for ocean acidification data. The OA-ICC brought ocean acidification understanding to policy-makers and negotiators by supporting and helping to run an international exhibition stand that highlighted ocean acidification at the UNFCCC COP19 in Warsaw. The OA-ICC also participated in and provided expertise at a UN Law of the Sea (UNICPOLOS) 3-day meeting on ocean acidification (New York, June 2013) and provided information to delegates through the GOA-ON side event at the GEO Summit (Geneva, Jan 2014).

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Future SIOA and OA-ICC activities

The OA-ICC will continue to perform routine operations of data management and bibliographic organization, maintain its web site, and post articles to the new stream. Moreover, there are also plans in 2014 and 2015 to launch intercomparison of calcification and boron-isotope measurements, and discussions are underway to determine if the OA-ICC can provide new and consistent routines to propagate errors and compute buffer factors in the publicly available packages that compute carbonate chemistry. The OA-ICC is now in the advanced stages of planning of two training workshops on ocean acidification in late 2014 in Chile and Italy; in 2015, three others are planned to be held in Southeast Asia, Africa, and the Pacific Islands. Additionally, OA-ICC is helping to organize and fund a natural-social science connection workshop on the socioeconomics of ocean acidification (early 2015) as well as the 3rd international GOA-ON observational workshop (2015). Outreach will continue to grow, especially with regard to policymakers at the next COP meetings in Lima and Paris.

Continental Margins Working Group (CMWG)

The current Continental Margins Working Group (CMWG), co-sponsored by IMBER and LOICZ, held its third meeting before the IMBER Open Science Conference: Future Oceans in Bergen, Norway, June 2014.

As human activities dominate key global processes in the Anthropocene era, there is an urgent need to secure sustainability by implementing transformative governance strategies to safeguard Earth's life-support systems for long-term human wellbeing. Nowhere is this endeavour in greater demand than at the ocean-land interface – the continental margins, which are experiencing a quadruple squeeze:

- Population growth, development intensification and rising demands for energy-intensive resources.
- Ecosystem degradation and loss.
- Rising CO₂, climate change and alteration of marine biogeochemistry and ecosystems.
- Ecosystem tipping points and rapid and irreversible changes in social-ecological systems and societal responses.

In this respect, the CMWG is drafting a perspective paper, currently under review, intended as the manifesto for the great needs in future continental margins research. It stresses continental margins are an engagement arena for global sustainability research and action, because more than one-third of the world population resides within the coastal belts that have a direct dependence on marine ecosystem services in continental margins, which are threatened by multiple stressors, both natural and man-made. With the hope to implement the strategies laid out in the perspective paper in future research activities, a longer paper is also in preparation to expand on the five strategic points, illustrated with examples of real cases:

1. To build knowledge and understanding of social-ecological systems on continental margins that cover the spectrum from ecosystem functioning to exploitable resources, societal values, institutional frameworks and governance regimes;

2. To develop innovative methodologies, strategies, guidance and good practices that identify opportunities to unlock the potential of the resources of continental margins, on a sustainable basis, and promote risk reduction;
3. To design governance regimes that are inclusive, reflexive, adaptive and enforceable;
4. To test alternative place-based institutionalized structures and processes for securing equitable distribution of costs and benefits to users of continental margins while sustaining ecosystems; and
5. To experiment with and establish new research epistemologies, partnerships and practices on continental margins – the frontline of the sustainability crisis in the Anthropocene.

Besides the longer paper, an on-line version of a science plan and implementation strategy (SPIS) for future continental margins research is under development.

Following the IMBIZO III (Jan. 2013) Workshop 1 on “*Biogeochemistry – ecosystem interactions on changing continental margins*”, a special issue entitled “*Biogeochemistry-ecosystems interaction in changing continental margins in the Anthropocene*” is being published in the *Journal of Marine Systems*. The main conclusion is that ecosystem responses to biogeochemical change are complex and impact major margin services, including primary production, fisheries production, nutrient cycling, shoreline protection, chemical buffering, and biodiversity. Despite regional differences, complexities, and uncertain feedbacks, the societal consequences of these changes are unarguably large and mandate coherent actions to reduce, mitigate and adapt to multiple stressors on continental margins.

The CMWG members and colleagues convened 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.

Future CMWG activities:

- After three years of operation, the CMWG will undergo re-organization. Since IGBP, the common parent organization of IMBER and LOICZ, will stop operation at the end of 2015, CMWG will have to undergo a transformation following the two sponsoring projects. Future continental margins research will make significant contributions to the grand collective effort of transformation toward sustainability in the future.

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. The IMBER Data Management Committee (DMC) is composed by a mix of natural science scientists, sea-going scientists, and data experts.

A Data Management Workshop, co-chaired by C. Chandler, T. O’Brien and A. Piola, DMC members, was held as part of the IMBER Open Science Conference, <http://www.imber.info/index.php/Meetings/IMBER-OSC-2014/Sessions-Workshops/Data->

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[Management-for-IMBER](#). In order to facilitate the discussions during the workshop, an online survey was distributed before the IMBER OSC.

The IMBER DMC has recommended that IMBER adopt the Directory Interchange Format (DIF) as a discovery metadata standard. The advantage in using DIF is that records can be easily created and managed through NASA's Global Change Master Directory (GCMD). A customized metadata portal within GCMD has been set up for IMBER, which can be accessed at <http://gcmd.nasa.gov/portals/imber/>, with entries for 32 endorsed projects and related activities.

A survey of the GCMD holdings associated with IMBER is currently on-going to determine which Regional Programmes, Endorsed Projects and Contributing Projects have a suitable metadata record.

The DMC recommends:

- To fully integrate data management activities in all IMBER project-wide events;
- To assure that endorsed projects are prepared to comply with IMBER DM policies; and
- To organize a meeting of data scientists of IMBER-endorsed projects and regional programmes.

Capacity Building Task Team (CBTT)

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

A Workshop held in Shanghai in March 2013 aimed at synthesizing the outputs of an international CB workshop (31 July 31–4 August 2012 in Shanghai, China), to finalize a strategic paper to be submitted to a peer-reviewed journal. This meeting was also dedicated to explore future actions of capacity building for marine research in the Asia-Pacific region.

The main outputs of these CBTT efforts included an *EOS* article (2013) and a synthesis paper on “Developing human capital for successful implementation of international marine scientific research projects” in *Marine Pollution Bulletin* (2013). Capacity building in marine sciences faces several challenges, such as the training in multidisciplinary research, increasing capacity for overall synthesis of scientific data, building the capacity of technical staff, keeping highly qualified personnel in marine scientific research roles, as well as the cross-cultural issues in training and minimizing duplication in training activities. Potential solutions to these challenges are provided, along with some priorities for action aimed at improving the overall research effort.

An IMBER Capacity Building workshop was held as part of the IMBER Open Science Conference (OSC) in Bergen, Norway in June 2014, to gain information, knowledge and experience from participants about how capacity building can be developed to support IMBER science for next 5-10 years. In order to facilitate the discussions during the workshop, an online survey was prepared before the Bergen meeting in June.

CBTT worked together with the IMBER IPO and RPO to secure external funding resources to support the IMBER ClimEco4 Summer School, which will be held at East China Normal University, Shanghai, in August 2014.

Future CBTT activities:

In 2014-2015, CBTT plans to organize a small workshop with 5-6 participants to work on the CB requirements for the future, sustainable IMBER studies. The expected output of this workshop will be a “White Paper”-type report for the new IMBER research agenda for the next 5-10 years.

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.

The first IMBER-ADApT paper was completed and submitted to the *Ghoti* section of *Fish and Fisheries* in November 2013. The special volume of *Regional Environmental Change*, resulting from the HDWG-led IMBIZO III Workshop “*Understanding And Forecasting Human-Ocean-Human Interactions, Drivers And Pressures, With Respect To Global Change*” is in preparation.

IMBER-ADApT templates were revised and starting in September 2013, invitations were sent out to collect more case studies for the development of IMBER-ADApT.

The 4th IMBER HDWG meeting was held in March 2014 in Canada. It was decided to further reduce number of questions in the IMBER-ADApT template, to revise and re-submit the *Ghoti* paper, to prepare several papers on shellfish mortality and on the conceptual approach to typology, and to develop a book on IMBER-ADApT case studies. Some changes in the HDWG leadership are anticipated in the future. One HDWG member, Sarah Cooley, stepped down in April 2014, due to a new job situation. One of the new IMBER SSC members, Eddie Allison, became a HDWG member in June 2014.

HDWG members and colleagues convened two sessions entitled “*Responses of society to marine and global changes as a core mandate for IMBER: ways forward*”, with co-sponsorship of PICES, and “*Future Oceans’ stewardship: roles, responsibilities and opportunities in small-scale fisheries*” at the IMBER OSC in June 2014, Bergen, Norway, and one of the HDWG co-chairs (Alida Bundy) gave a plenary presentation during the OSC.

Future HDWG activities:

- Next HDWG meeting planned to coincide with the PICES meeting in Santos City, Brazil.
- Hold workshop prior to the Too Big to Ignore (TBTI) meeting in Merida (Sept. 2014).

E. IMBER project-wide activities

Open Science Conference (OSC) 2014

The IMBER Open Science Conference, ‘*Future Oceans – Research for marine sustainability: multiple stressors, drivers, challenges and solutions*’, held from 22-27 June 2014 in Bergen, Norway (www.imber.info/index.php/Meetings/IMBER-OSC-2014), provided a venue to the

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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.

The OSC helped disseminate IMBER science results to a broader community, with both natural and social science representation. The plenary presentations were broadcast live and subsequently posted on the IMBER website. Social media outlets (mainly Twitter) facilitated the involvement of a wider audience of marine researchers and research end-users, allowing a broader engagement in the strategic discussions.

Overall, the IMBER Open Science Conference attracted more than 720 contributions and gathered about 485 participants representing 46 countries, including 16 developing countries. The final programme included 5 plenary sessions, 11 workshops and 21 contributed sessions, representing all IMBER science themes, regional programmes, working groups, and related communities, with a total of 140 poster and 325 oral presentations. Results from the OSC will be published as peer-reviewed synthesis publications and special issues with contributed and solicited papers.

SCOR agreed to support the participation of several researchers from developing and emerging economies. Other sponsors included the following:

- Research Council of Norway (RCN);
- Institute of Marine Research (IMR), Bergen, Norway;
- University of Bergen (UiB), Norway, Norwegian Research School in Climate Dynamics (ResClim), and the City of Bergen, Norway;
- the State Key Laboratory of Estuarine and Coastal Research (SKLEC), East China Normal University (ECNU), Shanghai, China;
- the U.S. National Aeronautics and Space Administration (NASA);
- U.S. Ocean Carbon and Biogeochemistry (OCB) Program;
- Korea Institute of Ocean Science and Technology (KIOST);
- Academia Europaea (AE);
- European Geosciences Union (EGU);
- European Space Agency (ESA);
- International Council for Science (ICSU), Future Earth (FE) programme;
- Gordon and Betty Moore Foundation (GBMF).

Several sessions and workshops are co-sponsored by the following organisations and initiatives, including the Earth System Governance (ESG) project, Future Ocean Alliance (FOA), International Council for the Exploration of the Sea (ICES), North Pacific Marine Science Organization (PICES) and Variability and predictability of the ocean-atmosphere system (CLIVAR) project. Finally, several exhibitors contributed to the success of this event, including Aquatic Biosystems, Marine Harvest, National Geographic and Sea-Bird Electronics.

The funding provided by external sponsors aimed especially at facilitating participation of early-career researchers (32 were supported), thereby providing these individuals the 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 benefit them and the larger marine research community, and helps ensure that all regional communities are an integral part of planning the future directions of a marine global environmental change research agenda.

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 ClimEco4 Summer School titled, ‘*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, in Shanghai, China (www.imber.info/index.php/Early-Career/IMBER-Summer-Schools/ClimEco4-August-2014-Shanghai-China). It will focus on indicators that inform us about the impact of global change on marine ecosystems and the human populations that depend on them, and on how to combine them so that they can be used to inform policy and decision-making.

Topics covered in lectures include an overview of climate change impacts on marine ecosystems from a biophysical and human perspective, information about indicators, models, analysis, linking indicators to a regulatory or management perspective, and bridging the gap between research and information that is practically useful for management. Practical sessions each afternoon will enable participants to try out the methods and techniques covered in lectures. Several participants are providing datasets, which will be augmented with additional data if necessary, so groups can select indicators and use them to evaluate the state of a system or species. Students will present their results at the end of the course.

Sixty-four participants from 30 countries were selected from the almost 170 applications received. The Scientific Committee on Oceanic Research (SCOR) agreed to support the participation of several researchers from developing and emerging economies.

The multidisciplinary lecturers are natural and social scientists: Alida Bundy (DFO, Canada), Laura David (University of the Philippines, Philippines), Beth Fulton (CSIRO, Australia), Eric Galbraith (McGill University, Canada), Xianshi Jin (Yellow Seas Fisheries Research Institute, China), Scott Large (NOAA, USA), Stéphane Pesant (University of Bremen, Germany), Keith Sainsbury (CSIRO & University of Tasmania, Australia), Rashid Sumaila (UBC, Canada) and Ingrid van Putten (CSIRO, Australia).

China-Japan-Korea (CJK) IMBER Symposia

The 6th China-Japan-Korea (CJK-6) IMBER Symposium focusing on “*Ocean Ecosystem Dynamics and Integrated Marine Biogeochemistry and Ecosystem Research*” was held in October 2013, Tokyo, Japan (www.imber.info/index.php/Meetings/IMBER-Sponsored-and-Endorsed-Meetings/2013/6th-China-Japan-Korea-IMBER-Symposium-3-4-October-2013-Tokyo-Japan), with the following goals:

- To advance our understanding of marine biogeochemistry and ecosystem dynamics for the sustainable use of ecosystem services;

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- To understand the response of various marine ecosystems to multi-stressors and drivers, from climate change to anthropogenic forcing.

More than 50 IMBER scientists from the three countries participated in the Symposium, with 30 oral presentations and 16 posters showing IMBER-related research achievements.

A meeting report, ‘*Changes in Marine Environments and Responses of Ecosystem Dynamics in the East Asian Pacific*’, was published in *Eos* in February 2014 (DOI: 10.1002/2014EO070007), and the IMBER Update Newsletter issue n°25 included several science highlights from CJK-6.

Austral Summer Institute XIV

IMBER co-sponsored the Austral Summer Institute XIV (ASI XIV, www2.udec.cl/oceanoudec/asi-14/eng), held in January 2014 in Concepcion, Chile, which focused on *Coastal and Open Ocean Studies through Multiple Approaches*. One of the courses was taught by Kay-Christian Emeis (CMWG member), dealing with “Changing biogeochemical cycles in the coastal ocean”. Nineteen students, from Argentina, Chile, Brazil, Belgium, Colombia, Cuba, Germany, Uruguay and USA, attended.

Status of the International Project Office (IPO, Norway)

The IPO is hosted until April 2017 by the Institute of Marine Research (IMR) in Bergen, Norway. The IMR has recently indicated that the IPO should be soon relocated, more closely to the management team of the new formed *Johan Hjort Centre for Marine Ecosystem Dynamics*, sponsored by four Bergen institutions: the Institute of Marine Research, the Nansen Environmental and Remote Sensing Centre, the University of Bergen and its spin-off, Uni Research Ltd. This pro-active, positive aspiration is a positive sign and will be carefully considered and valued.

Continuation of the IMBER Regional Project Office (RPO, China)

The IMBER Regional Project Office (RPO), established under a Memorandum of Understanding between IMBER and its host institution, 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 IMBER-related research community in the Asia-Pacific region, and a very active partner with the International Project Office in many of its activities.

F. IMBER SSC membership

There are currently 15 IMBER SSC members. At the end of 2013, Javier Arístegui (Vice Chair), Carol Robinson (Vice Chair), Jean-Pierre Gattuso and Nicolas Gruber completed their second term 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 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 presented to and later approved by SCOR and IGBP in late 2013: Edward H. Allison (M, US), expertise: human-ocean interactions, marine anthropology; Katrin Rehdanz (F, DE), expertise: marine/environmental

economics; Gerhard J. Herndl (M, AT), expertise: microbial ecology and biogeochemistry, meso-pelagic processes; Laurent Bopp (M, FR), expertise: carbon fluxes and budgets: biogeochemical modelling, carbon-climate interactions and ocean acidification.

N.B.: the country codes mentioned after the names refer to the current country of affiliation of the nominees, not necessarily their nationality.

At the end of 2014, Ken Drinkwater, Eugene Murphy, Hiroshi Ogawa, Alberto Piola and Sinjae Yoo will complete their second term of office on the SSC. Nominations for replacements were solicited from the research community through a call for nominations disseminated in March 2014. The required fields of expertise identified by the IMBER Executive Committee are:

- physical oceanography, satellite oceanography and climate interactions in changing marine environments
- marine biogeochemical cycles, and dynamics of organic matter and nutrients in changing marine environments,
- biological and ecological oceanography, and ecosystem dynamics in changing marine environments, and
- integrated studies of social, ecological and biogeochemical marine systems.

Fifty-one nominations were received and reviewed by the IMBER Executive Committee. A short list of 6 possible SSC candidates with the expertise that will be required by IMBER in the future was discussed during the SSC meeting in June 2014.

To more evenly distribute changes to the IMBER SSC, it was agreed to extend Eugene Murphy and Alberto Piola for one more year and continue Ken Drinkwater as an ex-officio member. This decision was made in consultation with the IMBER co-sponsors. This arrangement will avoid large changes in the SSC membership, especially now that IMBER is undergoing a transition and organization of the GEC projects is changing. The SSC discussed potential nominees for the three open positions. Discussions are ongoing and once the nominees have confirmed their interest in participating in the IMBER SSC, their nominations will be provided to SCOR and IGBP. It is anticipated that the nomination process will be completed in August.

G. IMBER cooperation

IMBER has been closely collaborating for many years with SOLAS (see SIC!) and LOICZ (see CMWG) and have ongoing joint activities. The IMBER-CLIVAR joint activity is relatively new and is now beginning to develop its own identity as described below.

Cooperation with the ‘Variability and predictability of the ocean-atmosphere system’ project (CLIVAR) on the IMBER/CLIVAR Joint Research Initiative on Upwelling

In 2013, a WG was assembled under the leadership of Ken Drinkwater to undertake joint research by CLIVAR and IMBER on upwelling ecosystems. One member from SOLAS was also included. This team was asked to develop an implementation plan to tackle 2-3 issues of joint interest through workshops and/or working groups. A research effort directed at upwelling in the Eastern Indian Ocean has been initiated through the joint efforts of IMBER’s SIBER programme and CLIVAR’s Indian Ocean Panel. Two workshops were held in 2013 to develop a Science Plan and Implementation Strategy and a third workshop entitled “*Eastern Indian Ocean*

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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*” were co-convened by IMBER and CLIVAR researchers during the IMBER Open Science Conference in Bergen, June 2014.

Future IMBER-CLIVAR-related activities:

A workshop aiming at investigating the potential effects of climate change on upwelling systems will be held in conjunction with the PICES/ICES/IOC 3rd Symposium on Climate Change in the World’s Oceans in Brazil in March 2015. The most recent global and regional models will be used to determine future scenarios in the upwelling regions of the world’s oceans. These, together with information on the present trends in upwelling, will be used to determine the likely impacts on the primary and secondary production and further on fish and fisheries. Output from the workshop will be a report to IMBER, CLIVAR and SOLAS, as well as a primary publication comparing and contrasting the physical and biogeochemical (e.g., oxygen) scenarios in the major upwelling regions of the world under future climate change.

There is also a plan for further joint collaboration. Comparative studies will be conducted on major upwelling areas around the globe, for example, within eastern (EBCs) and western boundary currents (WBCs), along the equator, in the Indian Ocean, in polar regions, etc. and will cover physical, biogeochemical, biological, fish and fisheries processes and trends. Projection scenarios will be developed based on global and higher resolution regional models. Of major importance will be potential effects on fisheries resources that, in turn, will be used to explore the effects of different management strategies under climate change in order to maximize societal benefits. The results will be published in primary scientific and socio-economic journals together with research recommendations to improve estimation of ecosystem changes in upwelling regions under climate change and the potential effects on their dependent societies.

It should also be noted that IMBER has strong links with the observations community:

Indian Ocean Global Ocean Observing System (IOGOOS)

SIBER (under the sponsorship of IMBER and IOGOOS), the kindred physical oceanography alliance known as the Indian Ocean Panel of GOOS/CLIVAR (IOP), the IndOOS Resources Forum (IRF) (supporting SIBER and IOP in strategic and operational terms), are stimulating progress in specific components of GOOS contributing to building IndOOS, such as the Argo programme, XBT, SOOP, satellites, buoys etc. SIBER is especially involved in the on-going deployment of biogeochemical sensors on Indian Ocean Observing System (IndOOS) / Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA). Under the IOGOOS framework, relevant activities focus on issues of local or global importance, such as monsoons and ENSO, and also include capacity building, modelling and forecasting.

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/).

- 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). IMBER-related researchers markedly who are significantly involved in the IPCC AR5 Work include Nicolas Bates, Laurent Bopp, Andrew Constable, Sarah Cooley, Scott Doney, Kenneth Drinkwater, Richard Feely, Jean-Pierre Gattuso, Nicolas Gruber, Christoph Heinze, David Karl, Corinne Le Quere, Salvador Lluch-Cota, Yukihiko Nojiri, James Orr, Svein Sundby, Toste Tanhua, Carol Turley, and Rik Wanninkhof.
- 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) that took place in September 2013, Edinburgh, UK.
- IMBER has also contributed to the activities of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES, www.ipbes.net), especially through nominations of IMBER-related researchers for relevant IPBES activities and committees.

H. Selection of IMBER Publications

Overall, IMBER has produced about 1000 refereed research papers since its implementation, including about 150 papers and 12 special issues published in 2013-2014.

Special Issues

- Canadell, J., P. Ciais, C. Sabine, and F. Joos (2013). REgional Carbon Cycle Assessment and Processes (RECCAP). *Biogeosciences*, 9-11 (special issue 107) - www.biogeosciences.net/special_issue107.html
- Cowie, G., H. Kitazato, R.H. Hood, S.W.A. Naqvi, and A. Gooday (2013). Current biogeochemical and ecosystem research in the Northern Indian Ocean. *Biogeosciences*, 10-11 (special issue 138) - 6 papers. www.biogeosciences.net/special_issue138.html
- Denman, K., R. Feely, J.-P. Gattuso, H.-O. Pörtner, U. Riebesell, D. Schmidt, and A. Waite (2013). The ocean in a high-CO₂ world III. *Biogeosciences*, 10 (special issue 129) - 19 papers. www.biogeosciences.net/special_issue129.html
- Drinkwater, Ken and Pierre Pepin (2013). Norway-Canada Comparison of Marine Ecosystems (NORCAN). *Progress in Oceanography*, 114, 1-126. www.sciencedirect.com/science/journal/00796611/114
- Landry, Michael R. and Michio J. Kishi (2013). Sensitivity of marine food webs and biogeochemical cycles to enhanced stratification. *Progress in Oceanography*, 119, 1-108 - 10 papers. www.sciencedirect.com/science/journal/00796611/119
- Liu, K.-K., C.-K. Kang, T. Kobari, H. Liu, C. Rabouille, and K. Fennel (2013). Biogeochemistry and ecosystems in the western north Pacific continental margins under climate change and anthropogenic forcing. *Biogeosciences*, 10-11 (special issue 125) - 23 papers. www.biogeosciences-discuss.net/special_issue105.html
- Riebesell, U., J.-P. Gattuso, T. F. Thingstad, and J. Middelburg (2013). Arctic ocean acidification: pelagic ecosystem and biogeochemical responses during a mesocosm study.

- Biogeosciences, 10 (special issue 120) - 21 papers.
www.biogeosciences.net/special_issue120.html
- Robinson, C., F. Azam, N. Jiao, H. Thomas, and G. Herndl. (2103). The impact of anthropogenic perturbations on open ocean carbon transformation, export and sequestration. Biogeosciences, 11 (special issue 148) - 6 papers.
www.biogeosciences.net/special_issue148.html
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- Zhang, Jing, Jilan Su, Ling Tong and Qisheng Tang (2013). Spring Bloom Processes and the Ecosystem: The Case Study of the Yellow Sea. Deep Sea Research Part II: Topical Studies in Oceanography, 97, 1-116 - 12 papers.
www.sciencedirect.com/science/journal/09670645/97
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Individual Publications

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- Bell J. D., Reid C., Batty M. J., Lehodey P., Rodwell L., Hobday A. J., Johnson J. E. and Demmke A. 2013. Effects of climate change on oceanic fisheries in the tropical Pacific: Implications for economic development and food security. Climatic Change, DOI: 10.1007/s10584-012-0606-2.
- Bignami S., Sponaugle S. and Cowen R. K. (2013). Response to ocean acidification in larvae of a large tropical marine fish, *Rachycentron canadum*. Global Change Biology, 19(4), 996-1006. DOI: 10.1111/gcb.12133
- Bijma J., Pörtner H.-O., Yesson C. & Rogers A. D., 2013. Climate change and the oceans - what does the future hold? Marine Pollution Bulletin, 74(2), 495-505
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- Gazeau F., van Rijswijk P., Pozzato L. & Middelburg J. J., 2014. Impacts of ocean acidification on sediment processes in shallow waters of the Arctic Ocean. PLoS ONE 9(4): e94068. DOI: 10.1371/journal.pone.0094068

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Communication and Outreach

The IMBER Website, www.imber.info, remains our main communication tool, with an average of about 250 unique visitors per day. It has received a lot of attention during the last reporting period because of the Open Science Conference.

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°26** – May 2014, included articles about ESSAS and Arctic and Sub-Arctic research, Anoxia in the Far Eastern Marine Biosphere Reserve (Peter the Great Bay), Ocean Colour for Climate, the Austral Summer Institute XIV (ASI XIV) at University of Concepción, Chile, the comings and goings of IMBER members, and recent IMBER publications and events
- **Issue n°25** - December 2013, included articles about Science highlights from the 6th China-Japan-Korea IMBER Symposium (3-4 October 2013, Tokyo, Japan), the CLIOTOP *Deep Sea Research II* volume on the role of squids in pelagic ecosystems; the IMBER endorsed project INCT-TMCOcean and some announcements about the IMBER Open Science Conference and the IMBER ClimEco4 Summer School
- **Issue n°24** - August 2013, included articles about Science highlights from IMBIZO III, new endorsed project and the endorsed project POMAL

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, and workshop and conference announcements are also included.

The IMBER contact database is continuously improved, with about 10,000 email contacts, and detailed information for about 1,800 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 so far more than 2,500 views. Recently, an IMBER *twitter* channel, https://twitter.com/imer_ipo has been developed. The IMBER OSC plenary presentations have also been recently uploaded for further dissemination.

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

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.

I. Support from SCOR

IMBER greatly appreciates the ongoing, key support received from SCOR, and the additional support to specific IMBER activities (especially OSC 2014 and ClimEco 4) provided by or managed 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.

J. Strategic development

IMBER is now entering the last year of its initial 10-year science plan. The IMBER science community has clearly indicated a desire for the project to continue. The enthusiasm and support shown at the recent OSC indicated that there is a strong community of researchers engaged in IMBER science. The position paper now being finalized is intended to provide guidance for the development of a new research agenda for the next phase of IMBER research.

The position paper will provide the basis for a request to SCOR for a second 10-year period of IMBER research. The grand challenges and science themes in the position paper are being derived from community inputs and strategic discussions. Thus, this is a reflection of what the IMBER community perceives to be the important research areas.

At the same time, the organizational structure for international global environmental change (GEC) research is changing. The IGBP, which co-sponsors IMBER with SCOR, will end in December 2015 and Future Earth will be operational at this time. Future Earth is intended as a 10-year initiative that is being developed around three themes, Dynamic Planet, Global Development and Transformations toward Sustainability, with a goal of addressing challenges and solutions for global sustainability. The core projects currently sponsored by the IGBP were invited in early 2013 to become core projects under Future Earth.

IMBER has a history of connecting natural and social sciences and promoting integration across disciplines and communities. IMBER is already engaged in research topics that address several of the Future Earth objectives, and many of its coordination and networking activities match the integrated approaches desired by Future Earth. As a result, IMBER is well placed to take the lead in developing marine-focused efforts under Future Earth. The transition to a Future Earth core project should not require additional modifications to IMBER science goals or implementation plan.

As with SCOR, the position paper will form the basis for a request to Future Earth to incorporate IMBER as core project. The request will include a description of what IMBER can bring to Future Earth in terms of science and as an international network of researchers. The request will also include what IMBER expects from Future Earth, such as support for SSC meetings and integrated activities, funding at the same level as provided by SCOR, and some specific assistance provided for fund raising, outreach, communication and engagement of stakeholders. It is anticipated that the formal IMBER request to Future Earth will be made in late Fall 2014.

3.3 GEOTRACES*Volkman***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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Pinghe Cai	CHINA-Beijing	Katherina Pahnke	GERMANY
Luidmila Demina	RUSSIA	Micha Rijkenberg	NETHERLANDS
Jordi Garcia-Orellana	SPAIN	Alakendra Roychoudhury	S. AFRICA
Vanessa Hatje	BRAZIL	Géraldine Sarthou	FRANCE
Tung-Yuan Ho	CHINA-Taipei	Yoshiki Sohrin	JAPAN
Phoebe Lam	USA	David Turner	SWEDEN
Maeve Lohan	UK	Angela Wagner	BRAZIL
Maria Maldonado	CANADA		

Executive Committee Reporter: John Volkman

**GEOTRACES SCIENTIFIC STEERING COMMITTEE
ANNUAL REPORT TO SCOR 2013/2014
June 2014**

1. SCOR Scientific Steering Committee (SSC) for GEOTRACES

Co-Chairs

Ed Boyle, USA
Reiner Schlitzer, Germany

Maeve Lohan, UK
Maria T (Maite) Maldonado, Canada
Olivier Marchal, USA
Katharina Pahnke, Germany
Micha Rijkenberg, Netherlands
Alakendra Roychoudhury, South Africa
Géraldine Sarthou, France
Yoshiki Sohrin, Japan
David Turner, Sweden
Angela Wagener, Brazil

Other Members

Andrew Bowie, Australia
Pinghe Cai, China-Beijing
Ludmila L. Demina, Russia
Jordi Garcia-Orellana, Spain
Vanessa Hatje, Brazil
Tung-Yuan Ho, China-Taipei
Phoebe Lam, USA

The SSC membership (listed above) contains representatives of 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.

2. Progress on implementation of the project

Four years after the launch of GEOTRACES, the programme is enjoying a successful implementation. This is true in terms of implementation of the cruise field programme (with more than 50 cruises, 654 stations completed and about 1,014 data sets identified), data management and intercalibration (with the first Intermediate Data Product released in February 2014) and scientific results published (about 450 papers published).

2.1 Status of GEOTRACES field programme

The field programme is progressing very successfully, with 50 cruises already completed (654 stations sampled). At the time this report is written, two more cruises, one French and one Indian, are at sea completing sections in the Atlantic and Indian oceans, respectively.

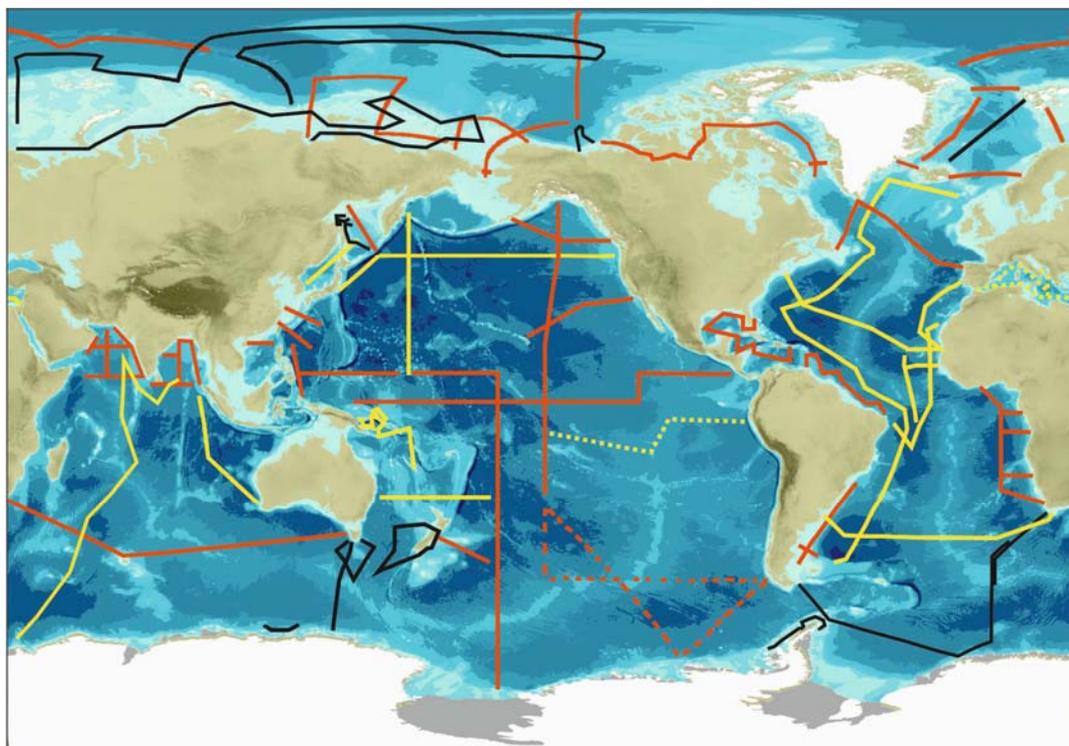


Figure 1. Status of GEOTRACES global survey of trace elements and their isotopes. In black: Sections completed as the GEOTRACES contribution to the International Polar Year. In yellow: Sections completed as part of the primary GEOTRACES global survey (dotted yellow, completed during the past year). In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

2.2 GEOTRACES Intermediate Data Product 2014

The GEOTRACES Intermediate Data Product (IDP2014) was released on February 25 at Ocean Sciences Meeting 2014 (Honolulu, Hawaii) during a “town hall” session attended by more than 350 individuals. Journals such as *Science* and *Nature* have featured reports describing the release of the product (see later in report).

The IDP2014, containing hydrographical and marine geochemical data acquired during the first three years of the programme, consists of two parts: the **digital data package** and the **eGEOTRACES Electronic Atlas**.

The **digital data package** (available at <http://www.bodc.ac.uk/geotraces/data/idp2014/>) contains data from 15 cruises and more than 70 hydrographic and geochemical parameters. The data product covers the Arctic, Atlantic and Indian oceans, with data density being the highest in the Atlantic Ocean. The growing body of data from the Pacific Ocean will be included in the next data product.

The **eGEOTRACES Electronic Atlas** (available at <http://www.egeotraces.org>) is based on the digital data package and provides 2-D and 3-D images of the ocean distribution of many of the

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parameters, as shown in the Figures 2 and 3 below. The 3-D images provide geographical context crucial for correctly assessing extent and origin of tracer plumes as well as for inferring processes acting on the tracers and shaping their distribution. The numerous links to other tracers, sections and basins found on section plots and 3-D images allow quick switching between parameters and domains to facilitate comparative studies. In addition, eGEOTRACES can help in teaching and outreach activities and can also help convey societally relevant scientific results to interested non-scientists and decision makers.

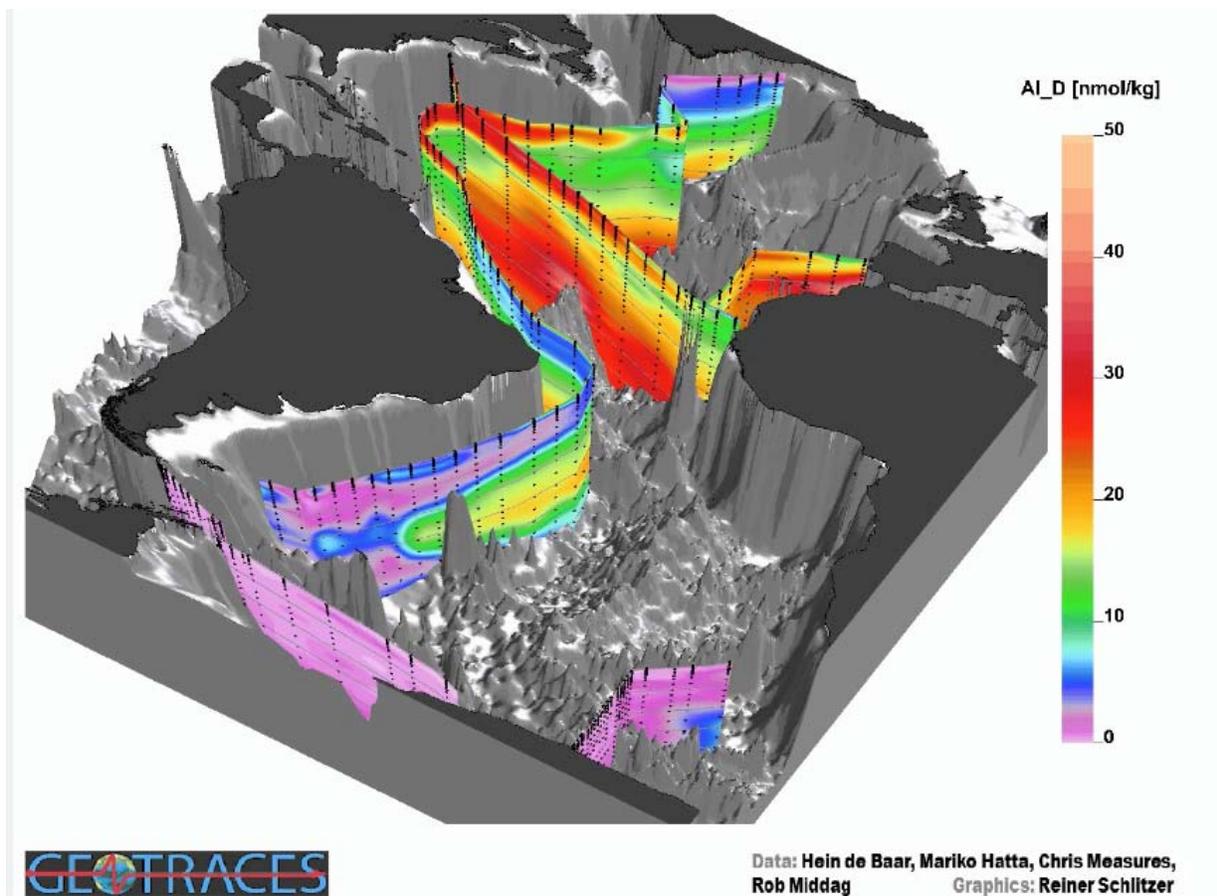
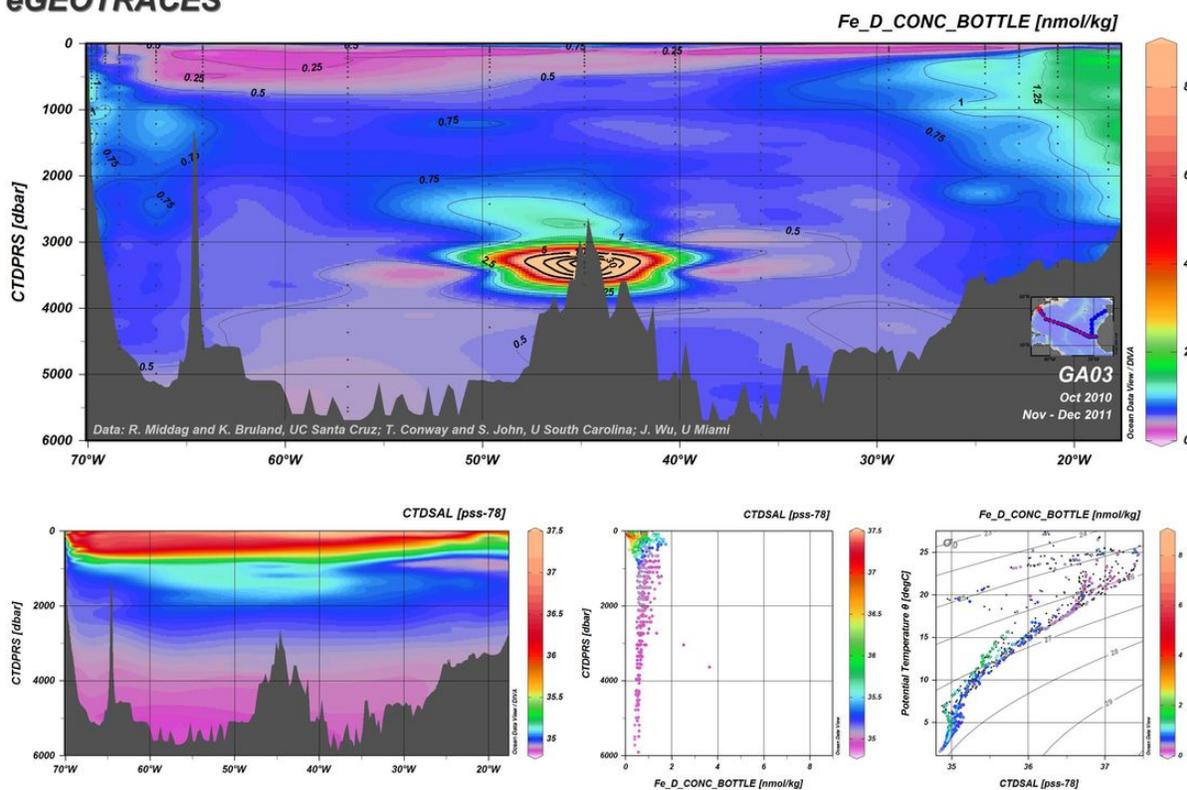


Figure 2. 3-D scene showing the distribution of dissolved aluminium (Al) in the Atlantic Ocean. Aluminium is a tracer of terrigenous inputs: in this image, high surface values are reflecting the dust inputs of Saharan origin between African and U.S. coasts, but there are also high concentrations at depth along the margins, also observed for other tracers, that might reflect Al release from the deposited sediments.

eGEOTRACES



(c) 2014 Reiner Schlitzer, Alfred Wegener Institute, Bremerhaven, Germany

Figure 3. Full-depth distribution of dissolved iron (Fe) along [GEOTRACES GA03](#) section in the Atlantic Ocean. Prominent features include the plume of hydrothermal Fe emanating from the Mid-Atlantic Ridge, and high Fe concentrations near the continental margin, especially off NW Africa, where margin sediments and Saharan dust both serve as significant sources.

The IDP2014, as well as other future GEOTRACES data products, will have a digital object identifier (DOI) assigned. Users of the data are requested to cite the data using the package DOI. Users are also asked to cite all relevant original publications from researchers that made the measurements. Details of publications that should be cited are provided point-by-point in the IDP dataset and are updated on the online database as new papers are published.

Rather than wait until the end of the programme, GEOTRACES sought instead to create and release a data product at a time when the programme is very active and actually still expanding, both in terms of the observations as well as scientific analysis of the data produced so far. By releasing and sharing the data now, GEOTRACES intends to strengthen and intensify collaboration within the oceanographic community; specifically, to attract and invite colleagues from other disciplines to join and devote their unique knowledge and skills to marine geochemical problems. At the same time, GEOTRACES is seeking feedback from the ocean research community to improve future data products.

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SCOR Booth at Ocean Sciences 2014

In addition of the Town Hall session, the IDP2014 was also presented in the SCOR Booth at Ocean Sciences Meeting. The booth was equipped with a screen where images from the eGEOTRACES continually displayed, making it possible to make live demonstrations of the product. Interested people were also invited to navigate through eGEOTRACES. In addition, relevant scientific discoveries made in the first three years of the programme were shown in a banner.



Figure 4. Bob Anderson and Reiner Schlitzer staffing the SCOR Booth at Ocean Science 2014.

GEOTRACES also handed out USB memory sticks containing the complete *eGEOTRACES* set of images at the Town Hall event and at the booth. The advantage of the thumb-drive version is that it does not require an Internet connection, so that users can browse the atlas with no download delays.

GEOTRACES is very grateful to SCOR for the opportunity to participate in the SCOR Booth.

2.3 GEOTRACES publications and science highlights

GEOTRACES publications

Since last report, 240 peer-reviewed papers including GEOTRACES scientific results have been added to the GEOTRACES publications database; overall, about 450 GEOTRACES publications have been produced from the beginning of the project. The release of the IDP2014 has been object of broad media coverage, with reports published in printed or on-line versions of newspapers or journals (in Germany alone, reports have been published more than 111 times). Two publications about the IDP2014, one in *Science* and other in *Nature*, merit special mention:

Malakoff, D. (2014). Oceanography. Chemical atlas shows where seas are tainted--and where they can bloom. *Science* (New York, N.Y.), 343(6175), 1070. doi: [10.1126/science.343.6175.1070](https://doi.org/10.1126/science.343.6175.1070)

Morrison, J. (2014). Digital atlas shows oceans' iron levels. *Nature*, News. doi: [10.1038/nature.2014.14774](https://doi.org/10.1038/nature.2014.14774)

The official magazine of The Oceanography Society, *Oceanography*, has devoted a special issue to the topic of changing ocean chemistry. One paper of this issue is dedicated to the GEOTRACES Programme:

Anderson, R.F., Mawji, E., Cutter, G.A., Measures, C.I., & Jeandel, C. (2014). GEOTRACES: Changing the way we explore ocean chemistry. *Oceanography*, 27(1), 50–61. doi:[10.5670/oceanog.2014.07](https://doi.org/10.5670/oceanog.2014.07)

In addition, the *Limnology and Oceanography: Methods* special issue devoted to the topic of GEOTRACES intercalibration is now completed. This open access issue containing 24 papers is available on the following web site: <http://www.aslo.org/lomethods/si/intercal2012.html>.

Finally, a special issue dedicated to the results of the GEOTRACES Data-Model Synergy Workshop (14-17 November 2011, Barcelona) has been submitted to the journal *Progress in Oceanography*.

GEOTRACES science highlights

Below is a selection of recent GEOTRACES science discoveries:

Slow-spreading ridges could be major oceanic iron contributor

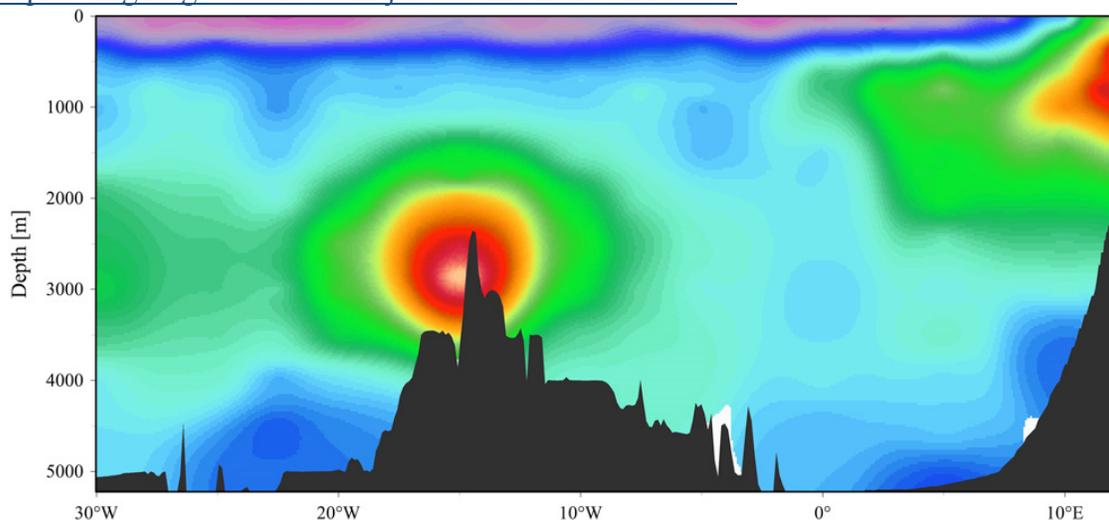


Figure 5. A zonal section of dissolved iron in the South Atlantic. The higher iron concentrations (in warm colours red, orange) reveal a large plume at $\approx 2,900$ m depth and 2 km in height. □

Reference:

Saito, Mak A., Abigail E. Noble, Alessandro Tagliabue, Tyler J. Goepfert, Carl H. Lamborg, William J. Jenkins (2013) Slow-spreading submarine ridges in the South Atlantic as a significant oceanic iron source *Nature Geoscience* 6 (9), 775-770 DOI: 10.1038/ngeo1893

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A large dissolved iron- and manganese-rich plume has been detected by Saito and co-authors over the slow-spreading southern Mid-Atlantic Ridge. This discovery calls into question the assumption that deep-sea hydrothermal vents along slow-spreading ridges were negligible contributors to the oceanic iron inventory. This result urges reassessment and a likely increase in estimates of the contribution of hydrothermal vents to the ocean supply of iron.

Latest discoveries in zinc concentrations and isotopes in the ocean (4 papers)

Zinc (Zn) is an essential micronutrient for phytoplankton and plays a key role in productivity of the ocean. Despite the importance of this element, the processes which govern its cycling in the ocean are poorly understood. Thanks to GEOTRACES, an unprecedentedly large volume of data has been reported, revealing fascinating results (4 papers):

Copper and zinc oceanic mass balance revisited

Little and co-workers (2014; see reference below) propose an update of the oceanic copper (Cu) and zinc (Zn) mass balance, with an original approach that takes into account the hitherto ignored constraint of their isotopes. They establish an up-to-date inventory of the input fluxes of these tracers with their isotopic signatures, discuss the internal processes that might fractionate both tracers, and evaluate one major sedimentary sink: sediments deposited beneath oxic water columns. Although the Cu oceanic mass balance appears to be roughly in balance, the Zn one is far from being constrained. Isotopes reveal that either an "isotopically light sink" or "isotopically heavy source" is missing.

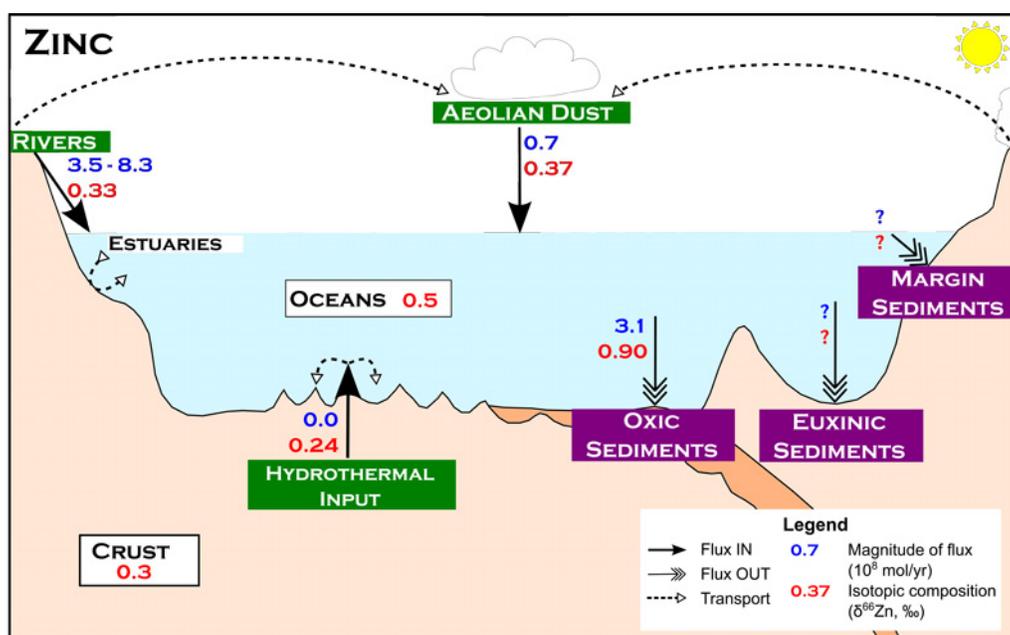
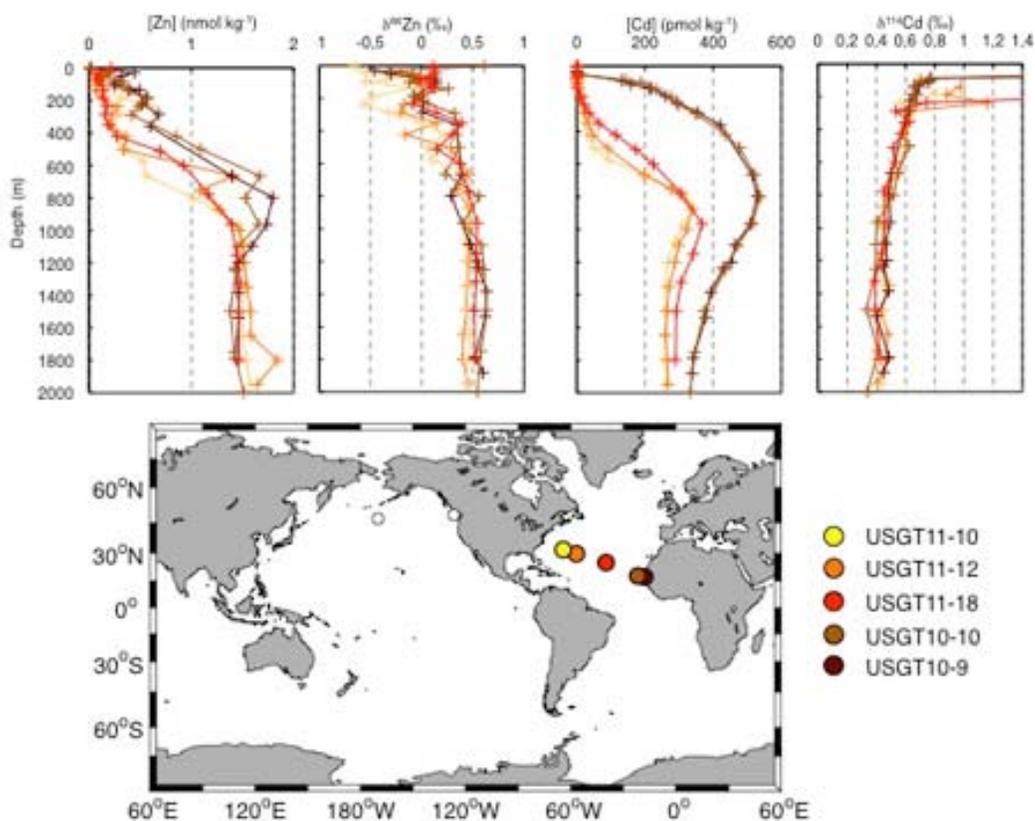


Figure 6. This figure illustrates the global ocean isotopic mass balance of Zn.

Sinking organic matter: a major driver of the oceanic zinc cycle?

A new study by John and Conway (2014), presenting the first high-resolution coupled profiles of both dissolved Zn and cadmium (Cd) concentration and isotope ratios from the GEOTRACES North Atlantic (GA03) section, suggests that scavenging of isotopically heavy Zn onto organic matter plays an important role in the surface marine cycling of Zn, and may be important for understanding why Zn, like silicon (Si), has a deeper regeneration in the ocean than nitrogen (N), phosphorus (P), and Cd. The new GEOTRACES data is supported by modelling and culture experiments, which show that while Cd and major nutrients are quickly released as phytoplankton degrade, a significant portion of the Zn is instead scavenged back onto organic matter.



□ **Figure 7.** Zn and Cd concentration and stable isotope profiles along the North Atlantic GA03 section.

First full-depth profiles of zinc isotopes in the ocean, thanks to IPY/GEOTRACES cruise (GIPY5)

Three major and original features are deduced from the first three full-depth profiles of zinc measured by Zhao and co-workers (2014) in the Southern Ocean:

- below 1000 m, the comparison of the results with North Atlantic and Pacific ocean data reveals that the oceanic zinc (Zn) isotopic composition appears to be homogeneous ($\delta^{66}\text{Zn} = +0.53 \pm 0.14$ per mil (2SE = 0.03, n = 21)).

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- oceanic Zn isotopic composition is more variable in the upper 1000 m ($\delta^{66}\text{Zn}$ values are more variable); these new Zn isotope data are consistent with a scenario whereby Zn removal from the surface ocean occurs via two processes: a dominant one that does not involve an isotopic fractionation (incorporation of Zn into organic matter associated with only diatom frustules) and a lesser one that preferentially removes the light isotope (metabolic uptake into the cells of all phytoplankton).
- a mass balance calculation is proposed to explain the homogeneous Zn isotopic composition of the deep ocean. The $\delta^{66}\text{Zn}$ value is slightly heavier than all the possible external sources ($\sim +0.35$ per mil). Thus, an isotopically light sink is required but not identified yet. The author's working hypothesis is that the burial of isotopically light Zn in cellular organic matter could represent the light sink from the oceanic dissolved pool.

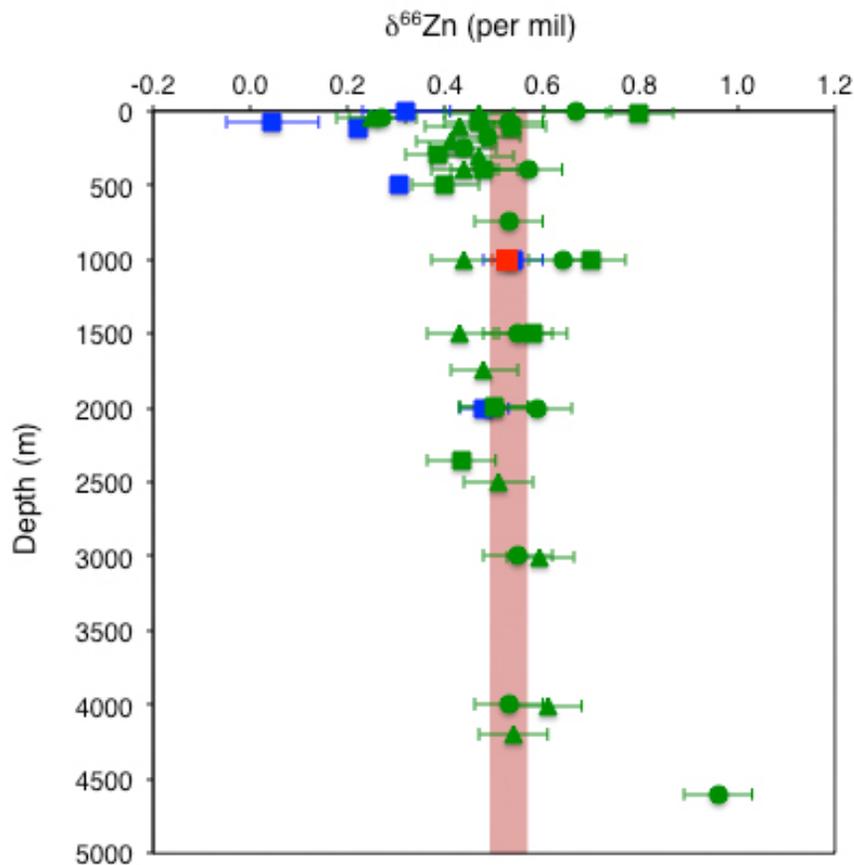


Figure 8. Zinc (Zn) isotopic data for IPY GEOTRACES samples from the Southern Ocean (green), plotted with data from the same laboratory for the GEOTRACES BATS intercalibration site in the Atlantic (blue, Boyle et al., 2012) and for the SAFe sample at 1000m in the Pacific (red). There is variability in Zn isotopes at depths shallower than about 500m, and a sample from the sediment-water interface in one depth profile at 67°S is anomalous, but in between all seawater samples yet published have a mean $\delta^{66}\text{Zn}$ of 0.53 per mil, with a spread of only 0.06 per mil (± 2 standard errors of the mean). What does the largest data set of zinc concentration ever reported tell us?

Wyatt and colleagues (2014) measured Zn distribution at high resolution (556 discrete samples) between Cape Town and Montevideo in the South Atlantic Ocean (40°S) on board the UK GEOTRACES GA10 cruise. The surface Zn concentrations measured are among the lowest reported for the global ocean (0.015–0.39 nM). An intriguing result was the fact that Zn concentrations were very low down to depths of 500 m, which was similar to that of silicate (Si) concentrations. Using the strong relationship between Zn and Si, the authors present a new tracer Zn* ($Zn^* = Zn - 0.065 \times Si + 0.209$), which illustrates that Zn is removed from surface waters in the Southern Ocean and remineralised deeper in the water column. This results in very low Zn concentrations in Sub-Antarctic-Mode Water (SAMW), which is the main pathway for supplying nitrate and phosphate to the thermocline waters of the South and North Atlantic oceans. These low Zn concentrations in SAMW may result in growth-limiting Zn concentrations in the surface waters of both the South and North Atlantic sub-tropical gyres.

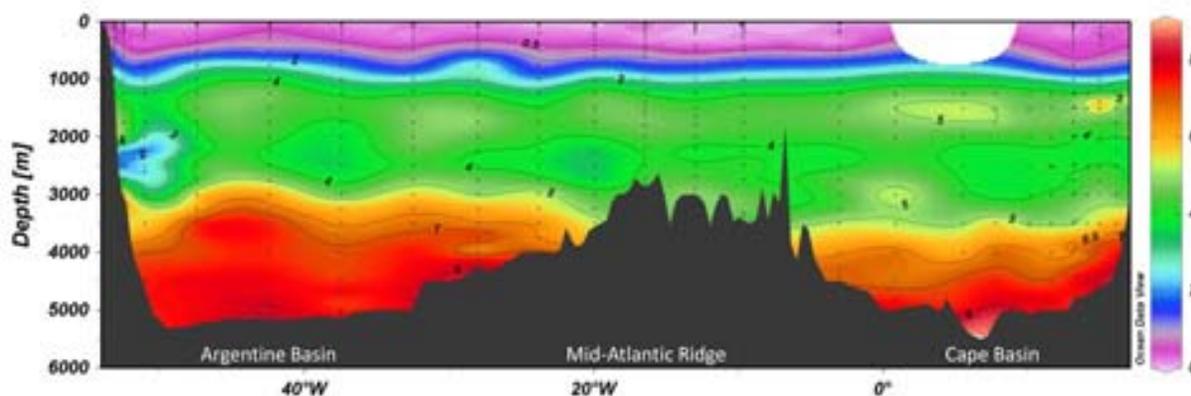


Figure 9. Concentrations of Zn along GA10 section (~40°S). Warm colours indicate high concentrations. □

References:

- Boyle, E. A., John, S., Abouchami, W., Adkins, J. F., Echegoyen-Sanz, Y., Ellwood, M., Flegal, A. R., Fornace, K., Gallon, C., Galer, S. (2012). GEOTRACES IC1 (BATS) contamination-prone trace element isotopes Cd, Fe, Pb, Zn, Cu, and Mo intercalibration. *Limnology and Oceanography: Methods*, 10, 653–665. doi: 10.4319/lom.2012.10.653
- John, S. G., & Conway, T. M. (2014). A role for scavenging in the marine biogeochemical cycling of zinc and zinc isotopes. *Earth and Planetary Science Letters*, 394, 159–167. doi:10.1016/j.epsl.2014.02.053.
- Little, S. H., Vance, D., Walker-Brown, C., & Landing, W. M. (2014). The oceanic mass balance of copper and zinc isotopes, investigated by analysis of their inputs, and outputs to ferromanganese oxide sediments. *Geochimica et Cosmochimica Acta*, 125, 673–693. doi:10.1016/j.gca.2013.07.046
- Wyatt, N. J., Milne, A., Woodward, E. M. S., Rees, A. P., Browning, T. J., Bouman, H. A., Worsfold, P. J., Lohan, M. C. (2014). Biogeochemical cycling of dissolved zinc along the GEOTRACES South Atlantic transect GA10 at 40°S. *Global Biogeochemical Cycles*, 28(1), 44–56. doi:10.1002/2013GB004637.
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Determining simultaneously iron, zinc and cadmium isotopes in small volumes of seawater is possible now.

The first simultaneous method for the determination of these three isotope systems in seawater has been published. This method is designed for use on only a single litre of seawater, representing a 1–20 fold reduction in sample size and a 4–130 decrease in blank compared to previously reported methods. The procedure yields data with high precision for all three elements, allowing estimation of natural variability in the ocean, which spans 1–3‰ for all three isotope systems. Simultaneous extraction and purification of three metals makes this method ideal for high-resolution, large-scale endeavours such as the GEOTRACES program.

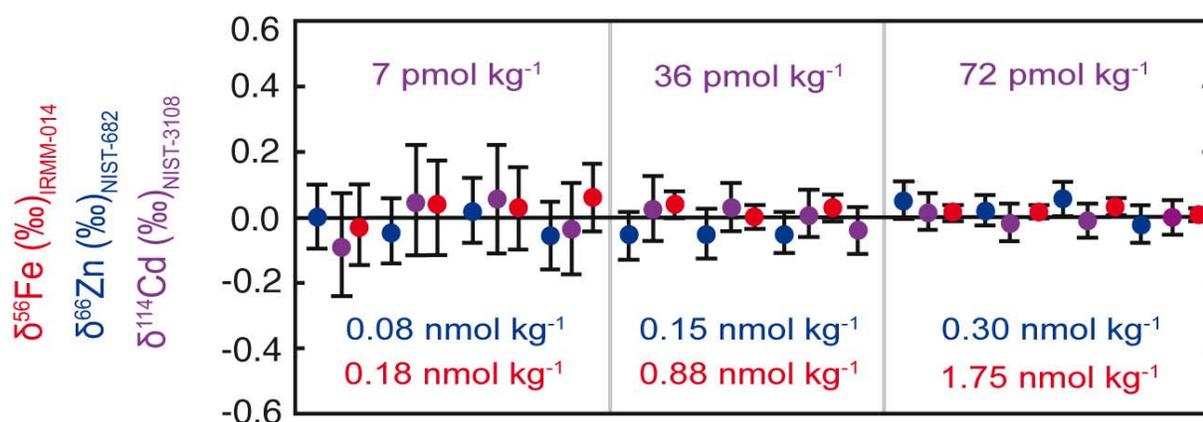


Figure 10. 'Metal-free' seawater doped with varying concentrations of 'zero' isotope standards, processed through the simultaneous method, and then analysed by double spike MC-ICPMS for Fe, Zn and Cd isotope ratios. All values were determined within 2 sigma error (error bars shown) of zero.

Reference: Tim M. Conway, Angela D. Rosenberg, Jess F. Adkins, Seth G. John (2013), A new method for precise determination of iron, zinc and cadmium stable isotope ratios in seawater by double-spike mass spectrometry, *Analytica Chimica Acta*, Volume 793, Pages 44-52, DOI: [10.1016/j.aca.2013.07.025](https://doi.org/10.1016/j.aca.2013.07.025).

New data on oceanic rare earth elements concentrations and neodymium isotopic compositions (3 papers)

Early 2014 was favourable to the publication of new data of rare earth element (REE) concentrations and neodymium (Nd) isotopic compositions in extreme areas of the ocean: the southern Atlantic Ocean, the northeast corner of the Pacific Ocean, and the remote South Pacific Ocean. Three different groups (Garcia-Solsona et al.; Haley et al.; Molina-Kescher et al.; see references below) published in *Geochimica Cosmochimica Acta* on REE distributions.

These three works confirm the conservative behaviour of Nd isotopic composition far from main biogeochemical disturbances, such as lithogenic inputs or significant biological activity. But more importantly, they reveal features in the behaviours of the REE that might need to be considered more closely. These features rely on particle/dissolved exchanges that are not understood yet, but they also yield unexpected decoupling along the REE array.

In January 2014 (Vol. 125), Garcia-Solsona and co-workers (Toulouse, France) described the distribution of dissolved and particulate REE and seawater Nd isotopic composition in samples from the IPY/GEOTRACES Bonus Good Hope (BGH) cruise between South Africa and the Southern Ocean (57°S). This work

- demonstrates the role of the South African submarine margins as sources of neodymium; shows that at open-ocean stations, dissolved and particulate REEs have acquired a marine signature (particles present negative cerium anomalies) as a result of dissolved/particulate exchange likely driven by the biological activity;
- reports positive Lanthanum (La) anomalies, observed in both particulate and dissolved phases, that could be linked to the oceanic barium cycle and the partial dissolution of barite crystals; and
- finds that Nd isotopic composition behaves conservatively in the Antarctic Circumpolar Current (ACC), supporting the use of ϵNd as a water mass mixing tracer in BGH deep waters.

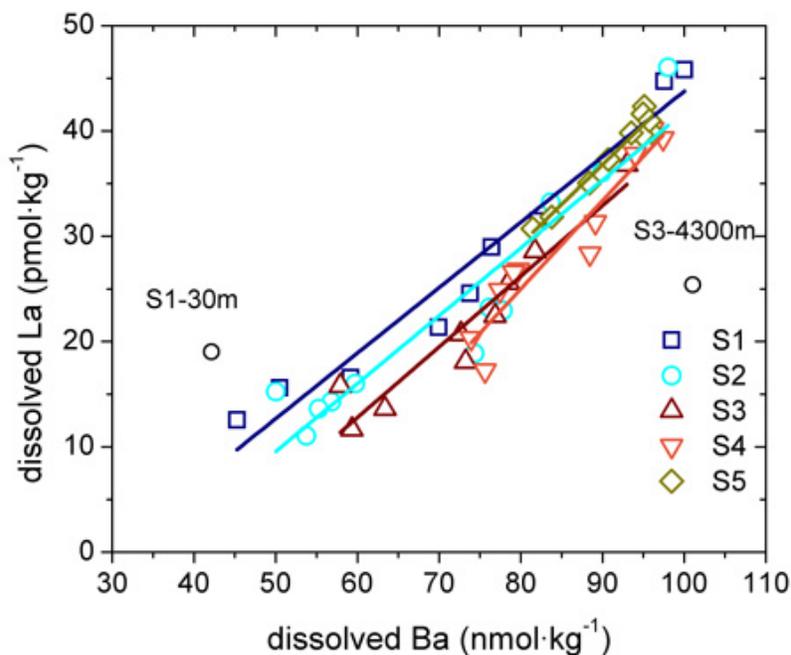


Figure 12. This figure shows linear correlations between dissolved La and Ba concentrations.

Two weeks later (Vol 126) Haley and co-workers (Corvallis, USA) presented the first combined distributions of dissolved REEs and Nd isotopes in the Gulf of Alaska. They reveal for the first time that

- ϵNd signatures allow tracing eddies that carry shelf waters to open gyre regions;
- two pools of REEs could be distinguished in this productive area using a statistical approach: one pool complexed to carbonate ion and largely behaving "quasi-

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conservatively", the second pool "bioreactive" and complexed by organic molecules as siderophores and only significant in the near-surface ocean; and

- the conservative fraction of the REE and its Nd isotopic composition is consistent with the hypothesis that a pool of seawater older than 1000 years is maintained in this far northeast Pacific Ocean, as already indicated by ^{14}C ages.

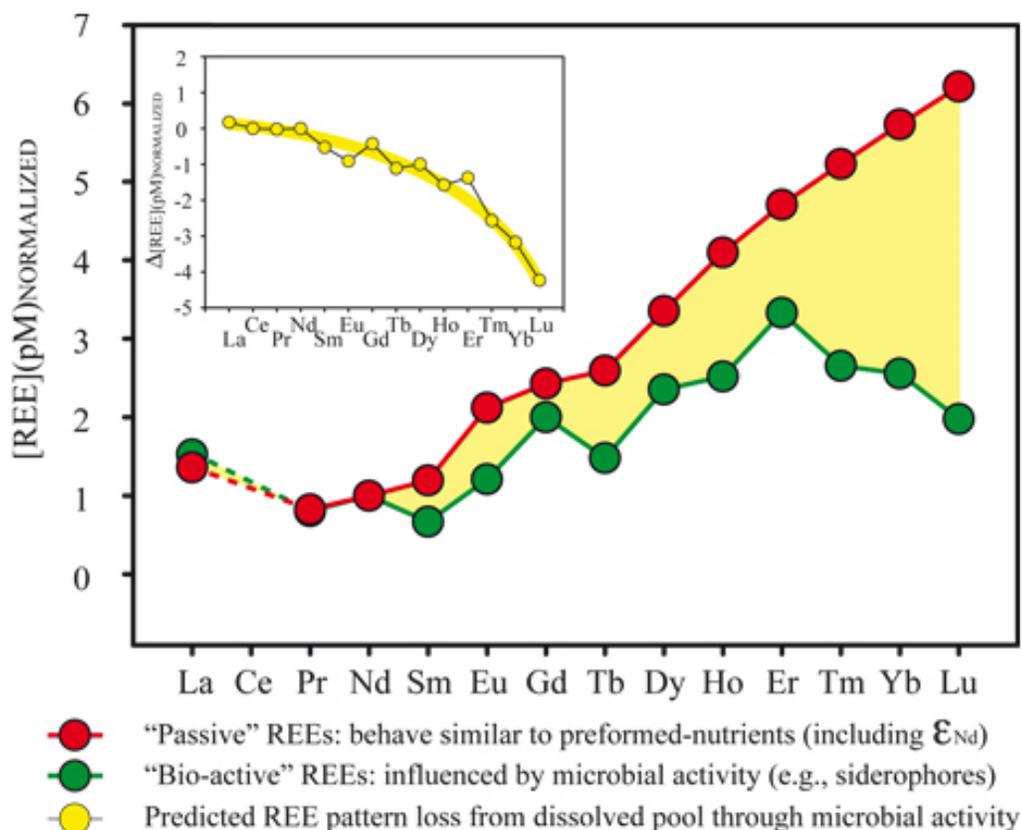


Figure 13. REE patterns.

In early February 2014 (vol 127), Molina-Kescher and co-workers (Kiel, Germany) proposed the first detailed analysis of dissolved Nd isotopes and REEs in intermediate and deep waters along a zonal transect between South America and New Zealand (~40°S). These authors

- confirm the reliability of ϵNd as water mass tracer in this area;
- propose the tagging of South Pacific water masses never done before. Among others, they identify the influence of residual North Atlantic Deep Water (NADW) in the westernmost South Pacific, characterised by the most negative ϵNd ; and
- demonstrate that biogeochemical cycling and scavenging processes in the Eastern Equatorial Pacific and release of LREEs from the sediment in the southeast Pacific Ocean influence the distribution of the dissolved REE concentrations.

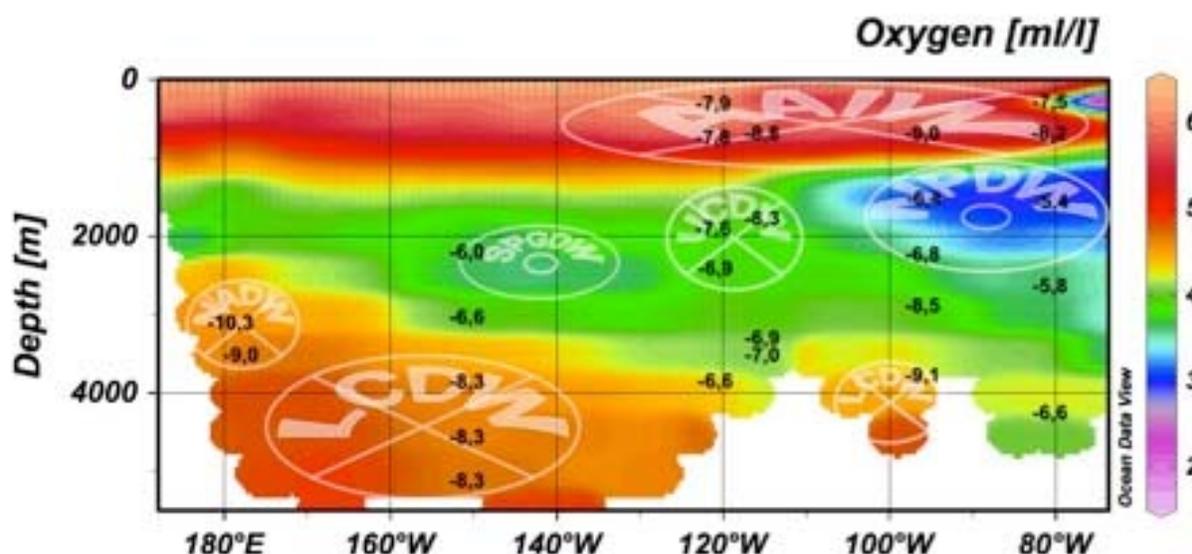


Figure 14. Zonal cross section along the South Pacific at $\sim 40^{\circ}\text{S}$ showing oxygen concentrations (ml/l), represented by the colour gradient, and measured ϵNd signatures (black values) at their corresponding depths. The flow direction of the water masses are also shown by transparent circles, where crosses represent the sense of movement into the picture and centred dots represent movement out of the picture. Water mass abbreviations: LCDW (Lower Circumpolar Deep Water), NADW (North Atlantic Deep Water), AAIW (Antarctic Intermediate Water), SPGDW (South Pacific Gyre derived Deep Water) and NPDW (North Pacific Deep Water). Oxygen concentrations are from the database of the World Ocean Atlas 09.

References:

- Garcia-Solsona, E., Jeandel, C., Labatut, M., Lacan, F., Vance, D., Chavagnac, V., & Pradoux, C. (2014). Rare earth elements and Nd isotopes tracing water mass mixing and particle-seawater interactions in the SE Atlantic. *Geochimica et Cosmochimica Acta*, 125, 351–372. doi:[10.1016/j.gca.2013.10.009](https://doi.org/10.1016/j.gca.2013.10.009).
- Haley, B. A., Frank, M., Hathorne, E., & Pias, N. (2014). Biogeochemical implications from dissolved rare earth element and Nd isotope distributions in the Gulf of Alaska. *Geochimica et Cosmochimica Acta*, 126, 455–474. doi:[10.1016/j.gca.2013.11.012](https://doi.org/10.1016/j.gca.2013.11.012).
- Molina-Kescher, M., Frank, M., & Hathorne, E. (2014). South Pacific dissolved Nd isotope compositions and rare earth element distributions: Water mass mixing versus biogeochemical cycling. *Geochimica et Cosmochimica Acta*, 127, 171–189. doi:[10.1016/j.gca.2013.11.038](https://doi.org/10.1016/j.gca.2013.11.038).

New revelations on boundary scavenging in the North Pacific

Thorium (Th) and protactinium (Pa) are very efficient tracers of particle dynamics in the ocean. More particularly, their relative distributions inform on the intensity of "scavenging", in other words, the processes that remove dissolved elements from seawater by their precipitation or adsorption on particles. Thanks to 12 new profiles in the North Pacific, Hayes and co-authors observe a much larger relative difference in scavenging intensity between the Subtropical gyre and Subarctic Pacific gyre than within each of these regions. This effect is greater for Pa than for Th, likely reflecting the fact that biogenic silica, a phase produced by diatoms which has a strong affinity for Pa, is much more prevalent in the north. While highlighting the role of biogeography,

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the study also finds that in the deep ocean, manganese oxides, an inorganic phase, may play an additional role in Pa scavenging.

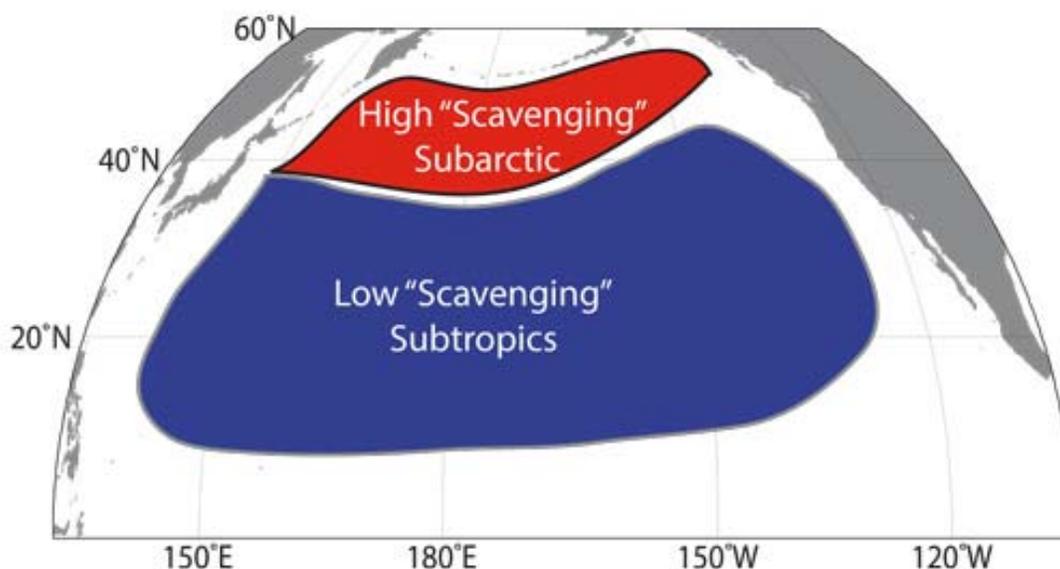


Figure 11. Simplified figure showing scavenging intensity in the Pacific Ocean.

Reference:

Hayes, C. T., Anderson, R. F., Jaccard, S. L., François, R., Fleisher, M. Q., Soon, M., & Gersonde, R. (2013). A new perspective on boundary scavenging in the North Pacific Ocean. *Earth and Planetary Science Letters*, 369-370, 86–97. doi: 10.1016/j.epsl.2013.03.008.

3. Activities

3.1 GEOTRACES Intercalibration Activities

During the 2012-2013 period, three major Standards and Intercalibration (S&I) Committee meetings were held, in order to review data that would eventually be incorporated into the 2014 Intermediate Data Product. Almost all of the data reviewed were from the GEOTRACES Crossover Stations where two section cruises occupied the same station during their transects. The S&I Committee members who reviewed these data were Gregory Cutter (Chair; Old Dominion University, USA), Per Andersson (Swedish Natural History Museum), Louis Codispoti (University of Maryland, USA), Peter Croot (National University of Ireland, Galway), Roger Francois (University of British Columbia, Canada), Maeve Lohan (University of Plymouth, UK), Hajime Obata (University of Tokyo, Japan), and Michiel van der Loeff (Alfred Wegner Institute, Germany).

The first meeting to review TEI data was hosted by Maeve Lohan at the University of Plymouth in March 2012. Data and metadata from 6 Crossover Stations in the Atlantic Ocean were examined, totalling approximately 3,600 data points reviewed and discussed during the 3-day meeting.

Although little radionuclide or particulate results were available for this review, much was learned about how to conduct the reviews for the 2013 meetings when more data would be available. One of the major problems encountered was that most of these data had not been submitted to the GEOTRACES International Data Assembly Centre, so the committee had to contact investigators to obtain the data. Moreover, metadata were either missing or poorly presented, making the Committee's tasks much more difficult. These and other lessons learned were then applied to the 2013 meetings and in particular, there was a December 2012 deadline to submit data to GDAC for review by the S&I Committee and eventual incorporation into the 2014 IDP.

The second data review meeting occurred in May 2013 at the Swedish Museum of Natural History in Stockholm and was hosted by Per Andersson. All the data and metadata were compiled at GDAC, making the process of evaluations much easier. The major focus was examining the Atlantic Crossover Stations and all of these comparisons were completed where sufficient TEI results were available. All data originators were sent the committee evaluations (meets individual TEI criteria; doesn't meet criteria, but with more information may be acceptable; doesn't meet criteria for multiple reasons and likely cannot be accepted), and they were asked to submit their revised data and metadata, and explanations for any discrepancies, by the end of August 2013 for the committee's meeting in September 2013. The reviewed data represented the bulk of hydrographic and TEI results that would be placed in the 2014 IDP, so this meeting was a major step towards compiling the first four years of GEOTRACES field data.

The third S&I Committee meeting during the 2012-2013 period was held in conjunction with the Data Management Committee just prior to the International SSC Meeting in Bremerhaven, Germany at the Alfred Wegner Institute in September 2013. The S&I Committee reviewed revised data that were based on recommendations from the May meeting, and additionally examined data from the Japanese Indian Ocean cruise (GI04), for which there was no crossover station. In the case of GI04, the cruise followed intercalibration protocols by taking replicates samples and distributing them to various labs for TEI determinations. This was the first time the Committee had examined such data. Results indicated that the procedure worked very well. The Committee also reviewed some of the Crossover Station data from 2009 IPY cruises that had not been previously examined. The Committee then met jointly with the DMC to recommend which data sets should be placed in the 2014 IDP.

After the last 2013 meeting, two members of the S&I Committee, Lou Codispoti and Roger Francois, completed their terms on the Committee and stepped down. The SSC Chairs sent them thank you letters for their years of service to GEOTRACES. Two new members were appointed: Karen Casciotti from Stanford University, USA, and Tina van der Flierdt, UK. Both of these scientists had served as Elemental Coordinators during the first intercalibration phase of GEOTRACES and are therefore ideal as the newest members of the Committee. Another intercalibration milestone during 2012 was the completion of the special volume of *Limnology and Oceanography: Methods* on Intercalibration in Chemical Oceanography, in which much of the GEOTRACES intercalibration results from the 2008 and 2009 cruises are presented: <http://www.aslo.org/lomethods/si/intercal2012.html>. Finally, the Committee completed revisions of individual sections of the GEOTRACES Sampling Protocols by the end of 2013 for general editing, collating, and placement on the web site in 2014.

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3.2 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, maintaining the data website, updating GEOTRACES maps and BODC's address book, and liaising with the GEOTRACES Data Management and Standards and Intercalibration committees. GDAC will eventually become the central access point for all GEOTRACES data. The office is staffed by a single data specialist: Dr. Edward Mawji.

This year, GDAC would like to highlight the following tasks:

GEOTRACES Intermediate Data Project

In 2014, GEOTRACES released an intermediate data product (IDP) at the Ocean Sciences Meeting in Honolulu, Hawaii, USA. All of GDAC's efforts in 2013 and 2014 focused on preparing the IDP2014. The IDP was divided into two parts: tier 1 data and tier 2 data. Tier one data were assessed by the S&I Committee and were deemed to meet the high data quality of GEOTRACES. Tier two data had not been intercalibrated/quality controlled by the S&I Committee. To help the S&I Committee carry out its review role, GDAC spent considerable effort compiling data from Crossover Stations and supplying the supporting metadata. This process was very successful, although valuable lessons were learned that will be used when preparing the next IDP. In the future, improved communication between GDAC and the S&I Committee will be sought. The time frame allowed for the S&I Committee to quality control (QC) data was unrealistic; this unfortunately altered all other deadlines. For example, the final submission of QC data to GDAC was changed to 17 December 2013, leaving GDAC with a nearly impossible task of preparing data for the IDP2014 release in February.

GDAC's main role in preparing for the IDP2014 was to quality control metadata and load intercalibrated data from the IPY and GEOTRACES section cruises into BODC's database. Detailed data and metadata checks were carried out and XML method and quality control documents were created.

Working with the GEOTRACES International Project Office

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 year, the IPO has been hugely important in helping GDAC prepare the GEOTRACES IDP2014 and was fundamental in distributing tier 1 and tier 2 documents and keeping track of scientists' replies in regards to having their data included in the IDP2014.

Data overview

The data management of the project is now a huge undertaking, with 50 cruises associated with GEOTRACES and 1,014 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.

2013/2014 has been a successful period; considerable progress has been made collecting data, especially from the IPY cruises and section cruises included in the IDP2014. A massive effort was made over the last 12 months by the GEOTRACES research community to submit data to national data centres and GDAC. U.S. (through the Biological and Chemical Oceanography Data Management Office) and Dutch scientists have really led the way and deserve a special mention.

Summary of GEOTRACES cruises

- 12 IPY cruises
- 5 compliant cruise
- 13 process studies
- 20 GEOTRACES cruises -14 sections

Six section cruises have taken place in the last 20 months; collecting data from these cruises and older section cruises will be the GDAC priority over the coming year.

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

3.3 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 one person, the IPO Executive Officer, Elena Masferrer Dodas. She works under the scientific supervision of Catherine Jeandel (CNRS, LEGOS, France).

The IPO is responsible for assisting the Scientific Steering Committee (SSC) in implementing the GEOTRACES Science Plan and implementation plans of the programme; organising and staffing meetings of the 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 Facebook page; maintaining the project mailing lists; preparing GEOTRACES science highlights and the bimonthly GEOTRACES eNewsletter; maintaining the GEOTRACES publications database and the GEOTRACES Scientists Analytical Expertise Database; assisting the GDAC in securing information about upcoming cruises; and interacting with GEOTRACES national committees and groups, as well as other international projects.

This has been a special year for the GEOTRACES programme and thus, the IPO, due to the release of the IDP2014. The IPO has been highly involved in the preparation of the IDP2014 and therefore, we would like to highlight the main tasks of the IPO in relation to the IDP:

- Assisted GDAC in keeping track of scientists' replies in regards to having their data included in the IDP2014. (The right of scientists to not include their data in the IDP was respected.)
- Built the IDP2014 publications on-line database and maintaining it up-to-date.

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- Organised the GEOTRACES Intermediate Data Product Town Hall at Ocean Science Meeting 2014 (24 February 2014, Hawaii, USA).
- Coordinated the preparation of the eGEOTRACES thumb drives.
- Prepared materials for the release of the IDP2014 including:
 - 2 special issues of the GEOTRACES eNewsletter
 - 1 banner showing main relevant findings of the programme
 - 1 new brochure describing the IDP2014
 - Press releases about the IDP2014
- Communicated the release of the IDP2014 broadly. Special attention was given to identify and communicate it to main stakeholders in each country, as well as other scientific communities that could be interested in the product.
- Coordinated the SCOR Booth at Ocean Science and staffed it.
- Assisted in the organisation of the GEOTRACES Intermediate Data Product Town Hall that will be held at Goldschmidt 2014 (June 10, 2014, Sacramento, USA).

The number of GEOTRACES publications including scientific results is increasing progressively. The IPO is doing an important job of tracking GEOTRACES publication and preparing science highlights of main relevant findings. Since June 2013, 240 new peer-reviewed papers have been added in the database, which represents more than a doubling of the total number of publications included (currently it contains 450 publications in total) since the previous annual report to SCOR.

With 7 issues published, the bimonthly eGEOTRACES eNewsletter it is now well established. The eNewsletter is very well received by the GEOTRACES community and the IPO is receiving very positive feedback about it.

3.4 Special sessions at international conferences featuring GEOTRACES findings

The major event this year has been the release of the GEOTRACES Intermediate Data Product at the Ocean Science Meeting 2014 (February 25, Honolulu, Hawaii, USA). The Town Hall session was very successful, with more than 350 participants and a special ovation from the public when the first eGEOTRACES 3D scene was displayed.

A second town hall session to introduce the Intermediate Data Product 2014 was held at Goldschmidt 2014 (June 10, Sacramento, California, USA).

In addition, several special sessions with relevance to GEOTRACES were featured or planned at major international conferences, including the following:

2013 Gordon Research Conference on Chemical Oceanography: Theme - Chemical Geography of the Sea, 4-9 August 2013, University of New England Biddeford, ME, United States.

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

*Overview of the U.S. GEOTRACES North Atlantic Section
Discussion Leader: Robert Anderson (Columbia University)

*Results from U.S. GEOTRACES North Atlantic Section
Discussion Leader: Laurie Juranek (Oregon State University)

*Benthic and nearshore processes
Discussion Leader: Lelia Hawkins (Harvey Mudd College)

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

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

*17d Isotopic and elemental tracers of marine biogeochemistry and circulation
Convenors: Seth John, Julie Granger, Katharine Pahnke and Gregory F. de Souza

*17g Metal-biota interactions in seawater
Convenors: Jay Cullen, Maeve Lohan and Martha Gledhill

*17b. Constraining rates of ocean processes
Convenors: Laura Robinson and Matt Charette

11th International Conference on Paleoceanography, 1-6 September 2013, Sitges, Spain.

For more information: <http://www.icp2013.cat>

*Invited plenary "Perspectives Lecture" publicising the forthcoming Intermediate Data Product: "New insights into geochemical proxies from GEOTRACES" by Bob Anderson.

Ocean Science Meeting 2014, 23-28 February 2014, Honolulu, HI, United States.

For more information: <http://www.sgmeet.com/osm2014/default.asp>

*018 - Advancing the frontiers of the Si cycle in terrestrial, coastal, and open ocean ecosystems

Organisers: Paul Treguer, European Institute for Marine Studies; Joanna Carey, U.S. Environmental Protection Agency; Mark Brzezinski, Marine Science Institute, University of California; Christina De La Rocha, European Institute for Marine Studies; Robinson Fulweiler, Boston University; Manuel Maldonado, Centro de Estudios Avanzados de Blanes.

*037 - Dynamics of Coupled Processes in the Ocean: A tribute to the career of Dr. James Murray

Organisers: Laurie Balistrieri, USGS/UW Oceanography; Kathryn Kuivila, USGS; Hans Jannasch, MBARI

*080 - Biogeochemistry of Trace Elements and their Isotopes

Organisers: Rob Middag, University of Otago; Alessandro Tagliabue, University of Liverpool; Peter Sedwick, Old Dominion University; Claudine Stirling, University of Otago; Andrew Bowie, University of Tasmania; Jingfeng Wu, University of Miami.

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*092 - From VERTEX to GEOTRACES: honoring Ken Bruland's contributions to marine biogeochemical cycles

Organisers: Gregory Cutter, Old Dominion University; Ana Aguilar-Islas, University of Alaska; Kristen Buck, Bermuda Institute of Ocean Sciences; William Landing, Florida State University; Maeve Lohan, Plymouth University.

*114 - Application of natural and anthropogenic radionuclides to the study of ocean processes

Organisers: Matt Charette, WHOI; Marcus Christl, ETH Zurich; Nuria Casacuberta, ETH Zurich; Ken Buesseler, WHOI.

*116 - Advances in approaches to assess metal-binding organic ligands and perspectives on the impacts of ligands on metal-biota interactions in the oceans

Organisers: Maeve Lohan, University of Plymouth; Kristen Buck, Bermuda Institute of Ocean Sciences; Sylvia Sander, University of Otago.

*146 - Marine micronutrient trace element cycling in oxygen minimum zones

Organisers: David Janssen, University of Victoria; Maija Heller, University of Southern California; Christina Schallenberg, University of Victoria.

*060 - Submarine Groundwater Discharge - from Ridge to Reef: Groundwater Evolution, Climate, Land-Use, Coastal Hydrology and Marine Biogeochemical Impacts

Organisers: Steven Colbert, University of Hawaii Hilo; Henrieta Dulaiova, University of Hawaii; Craig R. Glenn, University of Hawaii; Jason Adolf, University of Hawaii

Forthcoming:

International Conference on Atmospheric Dust, 1-6 June 2014, Castellaneta Marina, Italy.

For further information: <http://www.dust2014.org>

*Dust in the Sea -- Impact on Biogeochemistry and Climate □

Organisers: Christel S. Hassler, Université de Genève and Véronique Schoemann, Université Libre de Bruxelles.

Goldschmidt 2014, 8-13 June 2014, Sacramento, California, United States.

For further information: <http://goldschmidt.info/2014/index>

*17e: Trace Elements, Microbes, and Biogeochemical Cycles in the Ocean Environment □

Co-convenors: Kathy Barbeau, Maite Maldonado, Benjamin Twining

*16g: Sources, sinks and stores: integrating isotope and geochemical proxies for past and present surface processes, from elementary reactions to global change □

Co-convenors: Tim Conway, Penelope Lancaster, Damien Lemarchand

3.5 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	Powder coated aluminium, autonomous General Oceanics 1018 intelligent rosette system	12 x 10-L Teflon-lined Niskin-1010X	6000 m; 6 mm Dynex rope
Australia	2nd system (in progress)	Polyurethane powder-coated aluminium Seabird rosette with CTD and other sensors, auto-fire module, and all titanium housings and fittings	12 x 10-L Teflon-lined OTE external-spring Niskin-style bottles	6000 m 24mm Dyneema rope
Brazil	Complete	GEOTRACES WATER SAMPLER - 24-bottle sampler for use with modern equipped 911plus CTD	24 X 12-L GO-Flo	3000 m; Kevlar cable
Canada	Complete	Powder coated aluminium 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 aluminium with titanium pressure housing for CTD	24 X 12-L GO-Flo	8000 m; conducting Kevlar
Germany	CTD and bottles	Powder coated aluminium with titanium pressure	27 x 12-L OTE GO-Flo	8000 m; conducting Kevlar

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	purchased, winch planned	housings and fittings		
India	Complete	Powder coated aluminium 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 aluminium	12-L Niskin-X	10000 m; titanium armored cable
Netherlands	Complete	Titanium frame	24 X 12-liter GO-Flo	10000 m; conducting Kevlar
Netherlands	Complete	Titanium frame	24 X 27-liter ultraclean PVDF	10000 m; conducting Kevlar
New Zealand	Complete	Powder coated aluminium	5-L Teflon-lined Niskin-X	4000 m; 8 mm Kevlar line
South Africa	Complete	Powder coated aluminium, 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 aluminium	12 X 12-L GO-Flo	1500 m; conducting Kevlar
USA - GEOTRACES	Complete	Powder coated aluminium 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 aluminium 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 aluminium 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 aluminium with titanium pressure housings and fittings	12 X12-L Niskin-X	3000 m; conducting Kevlar

4. GEOTRACES Funding

GEOTRACES receives income from several nations. In the 2013-2014 period, income has been received from Dutch, French, German, Japanese, U.K., and U.S. sources. This multinational funding has been important for GEOTRACES. From the United States, the National Science Foundation is the major contributor to the work of GEOTRACES and in the reporting period, one grant ended and another one started.

5. Plans for coming year

Field programme

The main cruises in the forthcoming year will happen in the Pacific Ocean and especially in the Arctic Ocean, to implement the international GEOTRACES research Arctic programme defined during the GEOTRACES Arctic Workshop held in Vancouver, Canada, on 2-4 May 2012 (http://www.geotraces.org/images/stories/documents/workshops/Arctic/2012_Arctic_Workshop_Canada/Arctic_report_June12.pdf).

Intermediate Data Product

While working to further develop the GEOTRACES Intermediate Data Product for the next release in 2016, a review of the process of building the IDP2014 will be done in the coming months. The main objective of this review is to prepare a document about the *lessons learned* in the process of producing the IDP2014 so that the next intermediate data product can benefit from this experience. The principal persons involved in the creation of the product include the S&I Committee, Ed Mawji (GEOTRACES Data Manager), and Reiner Schlitzer (GEOTRACES SSC co-chair). In addition, feedback received by IDP2014 users, through the form available on the site when downloading the product, will also be examined and included in the report.

Workshops

Atlantic Synthesis Workshop

GEOTRACES plans to organise an Atlantic Synthesis Workshop in order to synthesise Atlantic Ocean sections across the range of trace elements and isotopes. The aim of this workshop will be to make a comprehensive examination of Atlantic data (being the core data included in the IDP2014, but other data might be also included) and interpret results from the entire basin perspective. The workshop will include, as well, some thematic focused sessions (e.g., processes such as hydrothermal plumes, boundary exchange, etc.).

Indian Ocean Planning Workshop

At the same time, GEOTRACES is planning to hold an Indian Ocean planning workshop to review the GEOTRACES action plan for this ocean basin, considering other international initiatives in this area such as the International Indian Ocean Expedition-2 (IIOE-2).

Acknowledgements

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

Written and compiled by:

Ed Boyle (Co-Chair GEOTRACES SSC)

Reiner Schlitzer (Co-Chair GEOTRACES SSC)

Elena Masferrer Dodas (GEOTRACES IPO Executive Officer)

June 2014

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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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Minhan Dai	CHINA-Beijing	Ilan Koren	ISRAEL
Anja Engel	GERMANY	Lisa Miller	CANADA
Hui-wang Gao	CHINA-Beijing	Yukihiro Nojiri	JAPAN
Christophe Garbe	GERMANY	Patricia Quinn	USA
Michele Graco	PERU	Alfonso Saiz-Lopez	SPAIN
Christophe Heinze	NORWAY	Rafel Simo	SPAIN
		Brian Ward	IRELAND

Executive Committee Reporter: Athena Coustenis

IGBP Liaison: Wendy Broadgate

Executive Officer: Emily Breviere

SOLAS Annual Report to SCOR**Reporting period: July 2013- May 2014****Version of 2 June 2014 by Dr Emilie Brévière****I. Progress on implementation of project science and implementation plans, and schedule for major project activities, including open science meetings, major data releases, synthesis activities, and project completion*****I.a. SOLAS Scientific Steering Committee***

Since July 2011, Eric Saltzman from the United States has served as Scientific Steering Committee (SSC) Chair; his term will end in Dec. 2016. Since May 2013, Cecile Guieu from France has been Vice-Chair. Alfonso Saiz-Lopez from Spain joined the SSC in Jan. 2014. SOLAS has an Executive Committee composed of the Chair, Vice Chair, Lisa Miller and Roland von Glasow (from May to Dec 2013) and Christoph Heinze (since Jan. 2014).

The SOLAS SSC met in Tsukuba, Japan, 27-30 May 2013 for its 13th SSC meeting and will meet on 16-18 June in Tel Aviv, Israel for its 14th SSC meeting. The current membership of the SSC is listed below (15 members including Chair):

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
Garbe	Christoph	Germany	M	Air-sea physical interaction	Focus 2 - MTS EBUS - Liaison ESA	2016
Graco	Michelle	Peru	F	Biogeochemical cycles in upwelling systems, OMZ	MTS EBUS	2014
Guieu	Cecile	France	F	Marine ecosystems/nutrient	MTS Nut Deposition	2014

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Heinze	Christoph	Norway	M	Carbon cycle modeling/paleooceno	Focus 3 - Paleo	2015
Koren	Ilan	Israel	M	cloud physics	Focus 1 - Cloud	2015
Miller	Lisa	Canada	F	Sea-ice/CO ₂	Focus 3 - MTS Sea Ice	2016
Nojiri	Yukihiro	Japan	M	Ocean carbon	Focus 3 - SIOA	2015
Quinn	Patricia	USA	F	Aerosols/atmos	MTS Marine Aerosols	2014
Saiz- Lopez	Alfonso	Spain	M	Atmospheric halogens/modelling	Th 5- Atmospheric Chemistry	2016
Saltzman	Eric S.	USA	M	Atmospheric chemistry	Focus 1&2	2016
Simo	Rafel	Spain	M	Ocean biogeochemistry	MTS Marine Aerosols	2014
Ward	Brian	Ireland	M	Air-sea physical interaction	Focus 2- Liaison WCRP	2016

In December 2014:

- Minhan Dai, Cecile Guieu, Trish Quinn and Rafel Simo will rotate off the SOLAS SSC after two 3-year terms.
- Anja Engel, Huiwang Gao and Michelle Graco will end their first 3-year terms on the SOLAS SSC.

1.b. Development of the SOLAS Mid-term strategy

Since 2008, SOLAS has supported the development of its Mid-term Strategy (MTS) themes, identified as areas where progress can be accelerated significantly with the support of an international programme such as SOLAS. The themes are described in the following paper:

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

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 the BEPSII SCOR WG 140, chaired by Jacqueline Stefels and Nadja Steiner. BEPSII had its second meeting in March 2014 after the IGS International Symposium on Sea Ice in a Changing Environment in Hobart, Australia. Goals of the meeting were to evaluate the progress of the three Task Groups (TGs), to establish what is still missing and to set a timeline for the coming period.

TG1 (led by Lisa Miller and Lynn Russell) has 3 primary goals:

- 1) The methodological survey has been submitted to the e-journal *Elementa: Science of the Anthropocene-Oceans*.
- 2) For the intercomparison of methods, several potential field stations were identified and an overview of parameters that need to be intercompared, including a first approach for such a campaign, has been drafted. Not all parameters can and need to be intercompared simultaneously. Hence, it was concluded that splitting-up into different campaigns is the best way forward. Possibilities for campaigns in Japan (Saroma-ko Bay) and Finland (Tvarminne) will be further investigated and stimulated. The actual realization is beyond the scope of BEPSII.
- 3) Recommendations for best practices on biogeochemical methods will be explored in the coming period. New and existing papers will be placed on the new BEPSII website.

TG2 (led by Klaus Meiners and Martin Vancoppenolle) has 2 primary goals:

- 1) The production of new data inventories and datasets by collation of existing data has resulted in the first dataset on chlorophyll-a from Antarctica pack ice (published by Meiners et al. GRL 39, 2012, doi:10.1029/2012GL053478). In addition, five other projects are ongoing or were initiated: 1. Arctic chlorophyll-a; 2. chlorophyll-a from Antarctica fast ice; 3. Inorganic carbon parameters; 4. macro-nutrients; and 5. Iron.
- 2) A standardized protocol for meta-data collection will be derived from the ASPeCt log sheet and made available on the BEPSII website.

TG3 (led by Nadja Steiner and Clara Deal) has four primary goals:

- 1) A short paper on “recommendations from modelers to observationalists” is underway.
- 2) Within the task to produce review papers on the major biogeochemical processes, several topics were identified: 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). A special issue in an on-line journal that allows continuous publication will be explored. Planned reviews are on the following topics: the DIC system, Fe distribution and controls, nutrient distribution, light transfer in ice, algal release from ice, DMS(P) in ice, and ice-atmosphere exchange of halogens. A few more topics were identified for which lead authors will be sought.
- 3) The 1D-model intercomparison exercises are taking shape. Eight modeling groups will contribute. The target is to use two sites for model evaluation, one in the Arctic, and one in the Antarctic. A series of four simulations for each site has been developed, with the aim to understand the coupling between ice physics and ocean biology.

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- 4) The link to regional modeling and global earth system models will be explored through activities within the AOMIP/FAMOS program.

To facilitate collaboration and scientific outreach of developments and results from the BEPSII community, a website will be built and options for future financial support will be explored.

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

In Dec. 2010, a 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*, what is now a more research-oriented paper and includes new model runs, was submitted to *Global Biogeochemical Cycles* in August 2013

Guieu C., O. Aumont, A. Paytan, L. Bopp, C.S. Law, N. Mahowald, E. P. Achterberg, E. Marañón, B. Salihoglu, A. Crise, T. Wagener, B. Herut, K. Desboeufs, M. Kanakidou, N. Olgun, F. Peters, E. Pulido-Villena, A. Tovar-Sanchez, C. Völker, 2013, The significance of episodicity in atmospheric deposition to Low Nutrient Low Chlorophyll regions

Following the reviewers’ suggestions, the modelling aspect has been developed and the paper now provides a representation of the spatial and temporal impacts of dust pulses in the oligotrophic ocean. The paper has been under review since March 2014. Another clear outcome of this long publishing process is the birth of a new community composed of modellers and observers.

A review paper was published in *Nature Geosciences*, the 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. This paper is also part of “*Nature Geoscience Insight*, September 2013 Volume 6, No. 9: “Marine cycles in flux” that highlights ‘some of the most intriguing advances in the microbial biogeochemistry of the oceans, a field that is very much in flux’.

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, one hot session topic under the theme “Oceans and Atmosphere” (Fluids, solids and gases interfaces in the ocean and atmosphere) of the Goldschmidt 2014, California, USA, June 9-13 is relevant to the MTS: ‘Natural and Anthropogenic Impacts on Ocean Chemistry (Nutrients, Oxygen and the Biological Pump)’; Chairs: Cecile Guieu, Linn Hoffman, Martha Gledhill, Jay Cullen. N. Olgun, as a Keynote speaker will give a presentation: “Volcanic Nutrients and their Impacts on the Surface Ocean Biogeochemistry: A New SOLAS Perspective”. Six projects endorsed by SOLAS are related to the MTS.

To achieve further progress, small workshops on some hot topics, such as dust/ashes impacts, are envisioned. The MTS leaders will get in contact and keep the communication flow with the bioGEOTRACES activity (<http://www.geotraces.org/science/biogeotraces>, leaders Philip Boyd, Carol Robinson and Maite Maldonado), especially on the dust/ash hot topic.

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

In the context of the EUR-OCEANS Flagship, Ivonne Montes started a postdoctoral fellowship in Sept. 2011 between Toulouse, Lima and Kiel on the theme. Her fellowship ended in Feb. 2014 at GEOMAR, Kiel, as Montes was recruited as a scientist at IGP, Peru. The ESA OceanFlux ‘upwelling’ project is ending 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) German mesocosms experiments off Peru, between Feb. and Apr. 2016;
- 3) AMOP Mooring deployment carried out on Jan. 5, 2013 from R/V *Meteor* and recovered 21 Feb. 2014;
- 4) One visit to the mooring site by R/V *Olaya* in June 2013;
- 5) French AMOP Cruise is taking place (25 January-23 February 2014) with R/V *L’Atalante*.

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 there.

A plenary lecture by Andreas Oschlies (GEOMAR, Kiel, Germany) on deoxygenation took place at the EUR-OCEANS Hot topics Conference in Las Palmas, Spain, 6-8 Nov. 2013. The 46th Liège colloquium took place on 5-9 May 2014 in Liège, Belgium on "Low oxygen environments in marine, estuarine and fresh waters", Véronique Garçon was co-organizer and member of the Scientific Committee, The colloquium received support from SCOR through SOLAS.

With regard to interaction between SOLAS, CLIVAR and IMBER, some discussions happened 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 formed a group around a research opportunity on upwelling in 2012. A proposal was submitted in April 2014 by CLIVAR/IMBER/SOLAS to Future Earth for a Fast-Track Initiative or cluster activity on ‘Upwelling Systems in a Changing Climate: from Biophysics and Ecosystems to Marine Resource Management’. The applicants are Kenneth Drinkwater, Lead Scientist, Peter Brandt, Manuel Barange, Enrique Curchister, Véronique Garçon, Raleigh Hood, Shoshiro Minobe, Salvador Lluch Cota, Ryan Rykaczewski, and Lynne Shannon.

A SCOR working group on Microbial Community Responses to Ocean Deoxygenation was approved in November 2013 for 4 years, with Bess Ward is the Chair and V. Garçon is a Full Member. The WG is highly interdisciplinary, gathering biogeochemists, microbial oceanographers, modelers and physical oceanographers.

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Regarding future plans, there will be 1) a session during the IMBER Open Science Conference in Bergen, Norway, 23-27 June 2014 chaired by A. Oschlies, L. Stramma and V. Garçon, 2) an EU ESF COST Action: GOOD (Global Ocean Oxygenation/Deoxygenation) proposal is to be submitted in early 2015 and 3) IOC will launch a coordinated action around the topic of Oceanic Oxygen and Climate.

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

The earlier SOLAS White Paper on Ship Plumes explored the consequences for atmospheric chemistry, which has important consequences for respiratory health impacts on humans (Corbett et al., 2007; Winebrake et al., 2009) and may affect radiative budgets important for climate change (Lauer et al., 2009). Recent publications have broadened the scope of this subject area by highlighting the potential effects of ship-based emissions on ocean chemistry (Hassellöv et al., 2013; Hunter et al., 2011; Ito, 2013), and on Arctic sea ice (Browse et al., 2013). Since international shipping is a growing transport activity with weak environmental regulation, the time is ripe for an integrated assessment of the environmental consequences of ship plumes. Initiatives to regulate ship-based emissions are both slow and controversial, due to the multinational jurisdictional complexities of governance and industry concerns about potential increased costs. Tighter regulation of ship-based emissions, therefore, cannot be achieved without a sound scientific basis quantifying impacts and potential benefits to affected ecosystem services (air quality, ocean and coastal waters, and land terrestrial and freshwater aquatic environments). The SOLAS programme can provide an appropriate mechanism for coordinating this research effort. Existing ship plume research has been well summarised in the recent SOLAS review of evolving research directions (Law et al., 2013).

There is currently no established community working on this issue. The research capacity to address ship plumes in an integrated manner exists, but collaboration is at best extremely limited among researchers working on a) shipping and its emissions; b) atmospheric dispersion and chemistry; and c) ocean biogeochemistry. Here, SOLAS could contribute by convening a workshop to explore the potential for development of an integrated research programme.

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

A workshop took place in Rayleigh, North Carolina, on 4-6 June 2012 on “Status and prospects of sea spray aerosol research”. An outcome of this workshop is the following paper:

Meskhidze et al. 2013. Production mechanisms, number concentration, size distribution, chemical composition, and optical properties of sea spray aerosols. *Atmospheric Science Letters*, DOI: 10.1002/as12.441

The WACS 2012 cruise took place in August 2012 in the North Atlantic, focusing on the production and properties of nascent sea spray aerosol in different ocean biological regimes. Several papers have been published reporting results from the cruise and more are in preparation. Published papers include the following:

- 1) Frossard et al. 2014. Side-by-side comparison of four techniques explains the apparent differences in the organic composition of generated and ambient marine aerosol particles, *Aerosol Sci. Technol.*, 48, DOI:10.1080/02786826.2013.879979;

- 2) Long et al. 2014. Light-enhanced primary marine aerosol production from biologically productive seawater, *Geophys. Res. Lett.*, 41, 2661-2670, doi:10.1002/2014GL059436; and
- 3) Quinn et al. 2014. Contribution of sea surface carbon to organic matter enrichment in seaspray aerosol, *Nature Geoscience*, 7, 228-232, DOI:10.1038/NGEO2092

SCOR WG 141 on Sea-Surface Microlayers (SML), approved in 2012, will contribute to the SOLAS MTS on ocean-derived aerosols. Members of the group are currently working on a guide to best practices to study the ocean's surface. The guide is expected to be completed this summer, and will be showcased during a 4-day workshop at Ocean University of China in Qingdao. The workshop is being held in October and will include training students in SML sampling techniques and promoting SML research to the next generation of oceanographers. Members of the group will be attending the SOLAS Open Science Conference in Kiel, Germany in September 2015, and will organize a special session on the SML at a major international ocean science meeting in late 2015 or 2016.

A workshop was held at the University of Washington in March 2014 on “Clouds, Aerosols, Radiation, and the Air-Sea Interface of the Southern Ocean: Establishing Directions for Future Research”. The workshop was sponsored by DOE. The workshop initiated the planning of a proposed multi-national, multi-platform experiment SOCRATES to be conducted in 2018. A relevant oral and poster session took place at the 2013 AGU Fall meeting (9-13 December, in San Francisco, CA) led by Volkamer, R.M. and N. Meskhidze on Marine Trace Gases and Aerosols.

A relevant oral and poster session also took place at the 2014 Ocean Sciences meeting (23-28 February 2014 in Honolulu, HI) led by W.L. Miller and D.J. Kieber, on Surface Ocean – Lower Atmosphere Study (SOLAS): Advances and Impacts of Ocean Derived Aerosols and Atmospheric Nutrient Inputs.

A series of field experiments are planned:

- 1) WACS II, Western Atlantic Climate Study II, will take place in May and June 2014, targeting the same region of the North Atlantic and production and properties of nascent sea spray aerosol. The 2014 cruise will have a larger component of surface seawater measurements of organic matter composition and ocean biology;
- 2) The PEGASO project (Plankton-derived Emission of Gases and Aerosols in the Southern Ocean) led by Rafel Simo is 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 1 Jan.-6 Feb. 2015;
- 3) The CORMORANT project (Cumulus Ocean Radiation Measurement Over a Natural Tropical Site) proposal was submitted to US DoE. The study area is the Galapagos Islands, with field campaigns in Aug.-Sept. 2016 and March-Apr. 2017. The project scientific questions of relevance to SOLAS concern 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?

I.c. 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)

The Surface Ocean CO₂ Atlas (SOCAT) is a largely volunteer, international activity by the marine carbon community, with more than 100 contributors to assemble surface ocean carbon dioxide (CO₂) data in a uniform, quality-controlled format. Version 1 was made public in 2011, version 2 in 2013, and the release of version 3 is planned for 2015. SOCAT version 2 provides 44 years of surface water fCO₂ (fugacity of CO₂) values from 1968 to 2011 for the global ocean and coastal seas, with 10.1 million unique data points. The SOCAT synthesis and gridded data products can be interrogated via interactive online viewers or downloaded in a variety of formats via the SOCAT website (www.socat.info). Three publications document SOCAT versions 1 and 2 (Pfeil et al., 2013; Sabine et al., 2013; Bakker et al., 2014).

About 3 million new fCO₂ values from 1957 to 2013 have been submitted to SOCAT version 3. Quality control by regional groups is about to start. The quality-control criteria have been adapted for version 3 to accommodate calibrated CO₂ data from new sensors and alternative platforms. A major thrust is to streamline data submission and data entry procedures. Testing the automation system will commence soon.

Applications of SOCAT include process studies, quantification of the ocean carbon sink, its seasonal to year-to-year variation, and ocean carbon cycle modelling. The 2013 Global Carbon Budget (www.globalcarbonproject.org/carbonbudget/) has used SOCAT for quantification of the annual ocean carbon sink. A new initiative, the Surface Ocean pCO₂ Mapping intercomparison (SOCOM), will compare surface ocean CO₂ gridded products, derived by a variety of methods, many of them based on SOCAT. To date, 25 scientific articles and 3 book chapters cite SOCAT. A SOCAT Community Event will take place on 23 June 2014 (IMBER Open Science Conference, Bergen, Norway). Finally, Steve Hankin of NOAA/PMEL was replaced by Kevin O'Brien on the SOCAT global group. Hankin, with support from the NOAA Climate Program Office, has been instrumental in SOCAT since 2007, responsible for designing the SOCAT online quality control system, the interactive viewers and the automation system.

Further, in 2013 the Global Carbon Project continued its focus on The Regional Carbon Cycle Assessment and Processes (RECCAP). Several regional groups continued working on regional GHG budget products and major progress has been made on the Asia Chapter. Plans for RECCAP2 were discussed at ICDC9. There will be a joint session between the WG1 and 2 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 side event to discuss the Southern Ocean and the detection of change in the marine biogeochemistry and the carbon cycle-Southern Ocean Observing System (SOOS) might take place at the IMBER OSC 2014 (to be confirmed). Regarding future plans, the WG1 is planning on meeting in person at the next Ocean Sciences meeting (to be confirmed).

Geoengineering is increasingly discussed by policymakers, with significant implications, analogous to volcanic eruptions, for which surface ocean feedbacks can be large. SIC WG1 may contribute to such a topic.

The WG1 plans on having a closer integration with WG3, given that many of expected changes with ocean acidification (e.g., ecosystem structure, nutrient cycling and carbon uptake) will be seen in the surface ocean.

***WG2-Interior Ocean.** Chair: Nicolas Gruber (Switzerland)- update from Feb. 2014.

WG2 did not meet in 2013, but is planning to meet at the IMBER Open Science Conference in June in Bergen. The global synthesis of repeat hydrography initiative is progressing since 2009 and has made major advances in the last year. The secondary data quality control effort of the GLODAP2 group is nearly completed and the data are planned to be released also at the IMBER OSC in June. An ad hoc steering committee to oversee the work to determine the global-scale oceanic accumulation of anthropogenic CO₂ since the 1990s was formed at a synthesis workshop in Beijing (held in conjunction with the 9th International CO₂ conference). Its members are Masao Ishii (Japan), Jeremy Mathis (USA), Toste Tanhua (Germany), and Nicolas Gruber (Switzerland). At the Beijing workshop an action plan was agreed to, with the goal to finish a high-profile paper by summer 2014. The synthesis group held a workshop at the 2014 Ocean Sciences meeting in order to discuss the first results and agree on a draft outline of the paper. The final results will be presented at the IMBER OSC, where this synthesis group is organizing a dedicated session. WG2 is also continuing to support the growing Bio-Argo program, with WG2 SC members Arne Körtzinger and Ken Johnson co-chairing a SCOR working group on sensor calibration (SCOR WG 142). This group also held its first workshop at the 2014 Ocean Sciences Meeting.

***WG3-Ocean Acidification.** Chair: Jim Orr (France)

The most recent annual meeting of the SIOA working group was in May 2014, supported financially by SOLAS and IMBER. The Chair of the SIOA working group is Jim Orr. SIOA Members are all Members of the Advisory Board of the OA-ICC (Ocean Acidification International Coordination Centre), based at the IAEA Environment Laboratories in Monaco since 2012 for 3 years. Many SIOA Members are focal points for the OA-ICC activities, and Jim Orr is the Scientific Coordinator of the project. IAEA Project Officer is Lina Hansson and Programme Manager Michel Warnau. There is an OA-ICC web site (www.iaea.org/ocean-acidification) and a news stream (www.news-oceanacidification-icc.org). A data curator, based at Xiamen University in China, is working on the OA-ICC data compilation on the biological response to ocean acidification; updated published experimental data are easily available at <http://www.iaea.org/ocean-acidification/page.php?page=2195>. The OA-ICC bibliographic database currently holds more than 2,000 references and includes citations, abstracts and keywords (<http://tinyurl.com/oaicc-biblio>).

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The activities of the OA-ICC are to promote 1) the development of a global observation network; 2) use of joint platforms and facilities; 3) collaboration between natural and social sciences; 4) intercomparison exercises; 5) joint ocean acidification experiments; 6) best practices in OA research; 7) online bibliographic database; 8) data management; 9) capacity building; and 10) information sharing and communication.

The OA-ICC is also supporting intercomparisons, the first of which has resulted in a recent publication that compares publicly available software to compute carbonate chemistry, in collaboration with the International Ocean Carbon Coordination Project (IOCCP) and the EU CARBOCHANGE project.

I.d. SOLAS Metadata Portal

The SOLAS metadata portal was set up by the SOLAS project integration initiative (2007-2013) with the intention to help SOLAS scientists identify what SOLAS-related data exist, the data originators, and where the data are currently stored. The portal is hosted by NASA and the metadata files are stored on the international standard Global Change Master Directory (GCMD). The resource is freely available to the entire community.

The SOLAS metadata portal is an ongoing effort. Scientists can help support the SOLAS Metadata base by completing a simple template available at <http://tinyurl.com/328zjr5> and email it to solas@geomar.de.

I.e. 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 (University of East Anglia, UK) and Ulrich Platt (University of Heidelberg, Germany). Anyone 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:

- Polar session at DACA 2013, 8-12 July 2013, Davos, Switzerland http://www.daca-13.org/program/index_EN
- A poster and oral session on Halogens in the Troposphere took place at the 2014 EGU Vienna on 28 April 2014.

Task Team: Asian Dust and Ocean EcoSystems (ADOES)

The goal of ADOES is to quantitatively understand the deposition flux and bioavailability of Asian dust, and its impact on biogeochemical processes and ocean ecosystem in order to provide scientific bases for the mechanism of eolian dust-ocean ecosystem-radiative gases-climate change. The co-chairs of this task team are Huiwang Gao (Ocean University of China, China), Guangyu Shi (Chinese Academy of Sciences, China) and Mitsuo Uematsu (University of Tokyo,

Japan). A poster on ADOES activities was presented at 50th Anniversary of the IOC/WESTPAC celebration, 26 June-5 July 2013. A joint session on Status, trends and effects of climate, natural disturbances and anthropogenic stressors on ocean ecosystems (by Dr. Uematsu Mitsuo, Dr. Thamasak Yeemin, Prof. Dr. Huiwang Gao) was held at the IOC-WESTPAC 9th international Scientific Symposium, 2014, 22-25 April 2014, Vietnam.

A major joint research project with Canada on “Impacts of ocean acidification on estuary and nearshore marine ecosystems and biogeochemical processes of biogenic active gases” was funded (3.3 million RMB) by the Natural Science Foundation of China (2014-2018). PI is Gui-Peng Yang from Ocean University of China and Co-PI is Maurice Levasseur, from University of Laval, Canada

The project “Atmospheric deposition and its impact on marine primary production and nitrogen cycle (2014-2018)” was funded (15 million RMB) by MOST (Ministry of Science and Technology of the People’s Republic of China). PI is Huiwang Gao from Ocean University of China.

The publication in April 2014 of the e-Book “Western Pacific Air-Sea Interaction Study (W-PASS)” as an open-access book marked the end of the Western Pacific Air-Sea Interaction Study (W-PASS) project. The book is edited by M. Uematsu, Y. Yokouchi, Y. W. Watanabe, S. Takeda. The Joint 7th ADOES Workshop with Asian SOLAS will be hosted by Ocean University of China in 2014 to promote regional exchanges.

I.f. SOLAS Open Science Conference 2015

The OSC15 will take place in Kiel, Germany at the Christian-Albrechts-Universitaet zu Kiel during the week of 7-11 September 2015.

The local organising committee (LOC) is composed of Hermann Bange (GEOMAR), Gernot Friedrich (Univ. Kiel), Christa Marandino (GEOMAR), Birgit Schneider (Univ. Kiel), Emanuel Soeding (Future Ocean Cluster of Excellence Kiel) and a young scientist (finished his PhD 6 months ago) Jonathan Durgadoo (GEOMAR).

Structurally, the SOLAS OSC15 will be taking place in conjunction with two major events 1) the SOPRAN final meeting, to take place on the Monday, 7 Sept. (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 is composed of the SSC and one member of the LOC. The conference website is up and running using Conference Manager, a SCOR-provided tool (www.solas-int.org/osc2015.html). The registration will open on 1 Sept 2014. For this edition of the OSC, SOLAS is inviting 7 keynote speakers and will select about 20 other speakers from the poster abstracts pool, a significant new feature of this OSC. The conference scientific theme will be forward looking and the themes of the 8 plenary sessions will be those forming the Future SOLAS plan.

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I.g. SOLAS v2.0

In the first 10 years of the lifetime of SOLAS, the community has accomplished a great deal towards the goals of the original Science Plan & Implementation Strategy (IGBP report 50, 2004) and Mid-Term Strategy (launched in 2008 and described in Law *et al.*, 2013). But there are still major challenges ahead that require coordinated international research by ocean and atmospheric scientists, as this was identified by the community at the last SOLAS Open Science Conference in 2012. With this in mind, in Spring/Summer 2013, SOLAS has begun an effort to define research themes of importance for SOLAS research over the next decade. The SOLAS Scientific Steering Committee members drafted eight short White Papers. SOLAS being a bottom-up organisation, an online community consultation was carried out in Fall 2013 to give the community the possibility to provide feedback and input on the White Papers, and to inform SOLAS if their research field is represented in the White Papers. But, respondents also were asked more openly what they think SOLAS should be like within the next decade and what they think are the main SOLAS science questions to be addressed.

In addition, on 3-5 December 2013, Tom Bell from the Plymouth Marine Laboratory (PML), UK hosted a very successful workshop to brainstorm on the scientific scope of SOLAS v2.0. Thirteen bright and highly motivated SOLAS early-career scientists from around the world, many of them SOLAS Summer School alumni, met and constructively brainstormed about the next 10 years of SOLAS. To help place Future SOLAS in the context of the Future Earth initiative, two socio-economists from PML were invited to take part to the workshop. Together, the group defined what ecosystem services mean in terms of Future SOLAS science and identified where the natural and social sciences can work together. The recommendations and outcome of this workshop are feeding into a document describing the next phase of SOLAS. (A full report of the workshop is available on the SOLAS website.)

During the next phase, with regard to scientific sponsorship, SOLAS will seek to continue its relationship with current sponsors SCOR, WCRP and iCACGP, but not from IGBP as the programme is ending at the end of 2015. SOLAS will also seek endorsement of the new ICSU initiative Future Earth: Research for Global Sustainability. A proposal describing the next phase of SOLAS and formally asking for its extension is to be submitted to the above-mentioned programmes.

To draft such a proposal based on the White Papers, taking into account feedback from the online community consultation and young scientists' workshop, another workshop took place on 9-10 January 2014 in Galway, Ireland. Brian Ward from the National University of Ireland in Galway hosted this workshop. Some of the current and former SOLAS Scientific Committee members, one of the early-career scientists from the workshop hosted in PML, and the SOLAS Executive Officer met and set up the structure and content of the proposal. The meeting participants developed a table of contents for the extension proposal:

- I. Executive Summary
- II. Introduction
- III. a) Science themes – with proposed activities?
 - Theme 1: Greenhouse gases and the oceans
 - Theme 2: Air sea interface and fluxes of mass and energy

- Theme 3: Atmospheric deposition and ocean biogeochemistry
- Theme 4: Aerosols, clouds and ecosystems
- Theme 5: Atmospheric chemistry, ocean biogeochemistry b) Integrated studies
- IV. SOLAS science and society
- V. SOLAS management and organization a) IPO
 - Communication, Education and Capacity Building
 - Data management
- VI. Linkages to other programs
- Appendices
- References

The proposal is well underway and an advanced draft is expected to be ready in summer 2014 to be submitted to the expected endorsing bodies.

Engagement with Future Earth: Research for Global Sustainability

Since the Future Earth interim Secretariat was opened, SOLAS has had regular communication with Future Earth officers on various topics. SOLAS contributed to the formulating of the Memorandum of Understanding to be signed between projects and Future Earth, to search for Future Earth Scientific Committee members and Engagement Committee members, and to develop the Future Earth Strategic Research Agenda. Cecile Guieu, SOLAS Vice Chair, gave a short presentation in September 2013 at one of the monthly webinars organised by Future Earth to inform about SOLAS. Finally, the SOLAS Executive Officer and Chairman attended and contributed to the first Future Earth Global Environmental Change projects meeting in Washington, D.C., USA, in January 2014. SOLAS envisions transitioning into Future Earth before the end of 2014.

II. Activities (including capacity building) and publications that resulted from the project's work since the previous year's report

II.a. International SOLAS Summer School 2013

The SOLAS International Summer School is a biennial, two-week program designed to immerse early-career scientists in SOLAS sciences and provide them with the skills necessary for their future scientific careers. SOLAS believes that by providing excellent training, it adequately prepares these future scientists to contribute to the understanding of global change and its significant environmental and societal challenges.

Following the previous, highly successful summer schools held in France, in 2013 the program moved east, "Far East", and was held in Xiamen, Fujian Province, P.R. China from 23 August to 2 September 2013. It was co-chaired by Dr. Véronique Garçon of CNES/LEGOS and Dr. Minhan Dai of Xiamen University. Sixty-nine students from 24 different countries attended the summer school, along with 15 world-leading scientists.

As with previous schools, the 6th SOLAS Summer School was divided into three sections. The first week consisted primarily of plenary lectures covering a diverse range of topics. These included an introduction to SOLAS, carbon and iron cycles in the ocean, greenhouse/trace gases

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and their relationship to climate change, atmospheric chemistry and modeling, air-water gas exchange, ocean physics and coastal processes, remote sensing and time series observations, marine ecology, aerosols, marine genomics, macronutrients, solar radiation, and biogeochemical modeling over long time scales. In addition to these, special sessions were also arranged that covered ethics in science, scientists and the press, and the changing Earth.

Poster sessions were also held during the first 3 days of the program and 4 winners were selected by the faculty (Shlomit Sharoni, Israel; Hilary Palevsky, USA; Young-shin Kwon, South Korea; Meri Eichner, Germany). Having the poster sessions occur at the start of the school allowed the students to learn about each other's research and fostered networking during the remainder of the school.

The second section coincided with the start of the second week when the school became more interactive. Students were divided into small groups (averaging 8-10 per group) and took part in hands-on practicals that introduced them to techniques regularly employed in the field. Laboratory work focused on atmospheric and carbon cycle modeling, marine molecular ecology, and gas exchange. Students were also given the opportunity to collect, process, and analyze samples taken along the Jiulong River Estuary aboard Xiamen University's research vessel, *Ocean II*. These results were then presented before the faculty and peers, giving the students a chance to not only interpret their results, but to practice their communication skills.

Prior to their arrival in Xiamen, students were told to prepare a 5-minute oral presentation (along with a poster) on their research. After the poster sessions, each student attended a mandatory "Oral and Communications" workshop whereby faculty provided constructive criticisms and guidance on their posters and students were given the chance to practice and refine their 5-minute presentations.

In the final section of the summer school, in addition to lectures on more advanced SOLAS science topics, each student presented their oral presentations in plenaries, drawing on the skills and lessons they learnt just a few days earlier. Faculty and students each voted for their top three during these sessions and winners were announced at the closing ceremony (Faculty selections: Eva Mayol, Spain; Natalie Freeman, USA; Neil Clark, UK; Student selections: Jana Schneider, Germany; Raissa Philibert, South Africa; Shlomit Sharoni, Israel).

Another, equally important, though less discussed, aspect of the Summer School was the varied opportunities for networking it provided, even outside of the classroom. While exploring Xiamen, its surroundings, and culture during their free time, students and faculty alike were subconsciously creating those networks and linkages that are critical to the interdisciplinary and collaborative nature of science today.

Each iteration of the Summer School has been highly successful, as evidenced by the high number of applications received. The 6th School was no different, with well over 200 applications received for the limited spots. Furthermore, the feedback from the anonymous, post-program evaluations given to faculty and students was overwhelmingly positive. Without the support of groups such as the Asia-Pacific Network for Global Change, PICES, Scientific Committee on Oceanic Research, the State Key Laboratory of Marine Environmental Science (Xiamen

University), the National Natural Science Foundation of China, the Natural Environment Research Council, Xiamen University, the State Oceanic Administration of China, the Centre Nationale d'Etudes Spatiales, Ocean Carbon and Biogeochemistry and many more, this program would not have been possible.

No discussion has taken place yet with regard to the next SOLAS Summer School.

II.b. COST/SOLAS Synthesis book

The EU COST Action 735 was managed by the SOLAS IPO and its project integration sought to develop global air-sea flux datasets of gases and aerosols (2006-2011). The last and major outcome of the action is the publication in open access of a Springer textbook in 2014 entitled *Ocean-Atmosphere Interactions of Gases and Particles*. A considerable number of SOLAS scientists contributed to this major effort led by Peter Liss and Martin Johnson, the editors. The book is the first synthesis of a set of disparate topics into a coherent treatment of the exchange of matter across the sea surface. See <http://link.springer.com/book/10.1007/978-3-642-25643-1>

Book content description: The oceans and atmosphere interact through various processes, including the transfer of momentum, heat, gases and particles. In this book leading international experts come together to provide a state-of-the-art account of these exchanges and their role in the Earth-system, with particular focus on gases and particles. Chapters in the book cover: i) the ocean-atmosphere exchange of short-lived trace gases; ii) mechanisms and models of interfacial exchange (including transfer velocity parameterisations); iii) ocean-atmosphere exchange of the greenhouse gases carbon dioxide, methane and nitrous oxide; iv) ocean atmosphere exchange of particles and v) current and future data collection and synthesis efforts. The scope of the book extends to the biogeochemical responses to emitted/deposited material and interactions and feedbacks in the wider Earth-system context.

II.c. SOLAS synthesis paper in Earth's Future in prep.

SOLAS is preparing a paper to contribute to the IGBP synthesis effort, which likely will be published in the journal *Earth's Future*, Wiley in early 2015. Five major achievements have been selected to be reported in the paper. The main contributors are Bob Duce, Natalie Mahowald, Cliff Law, Philip Boyd, Hermann Bange, Eric Saltzman, Trish Quinn, and Emilie Breviere as of now. A draft is well underway.

II.d. IGBP 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. Both FTIs came to an end in 2011. The FTI on 'Upper Ocean Nutrient Limitation: processes, patterns and potential for change' coordinated by Mark Moore (NOCS, UK) and Matt Mills (Stanford Univ., USA) had a workshop in Southampton, UK on 3-5 Nov. 2010. 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

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II.e. Future Earth Fast Track Initiatives and/or Clusters Activities

In February 2014, Future Earth launched a call for FTI and clusters activities. SOLAS was involved in two proposals (100kUSD for 2 years). The outcome of the proposal review will be known by the end of June 2014.

- 1) “Upwelling Systems in a Changing Climate: From Biophysics and Ecosystems to Marine Resource Management”, proposal submitted in collaboration with CLIVAR and IMBER
- 2) “International, Interdisciplinary Polar Science Network“, proposal submitted in collaboration with IGAC, OASIS/AICI, HitT, BEPSII, ASP, ArcticNET, AINA, CRAICC, PEEEX, SVALI, DEFROST, NORDFROST, CliC, CLIVAR, ISAC, DBO, SEARCH

II.f. OceanFlux three projects update: collaboration between ESA and SOLAS

The OceanFlux project series aimed at reinforcing the scientific collaboration between ESA and SOLAS. The overall project objective was twofold: 1) Support the development of novel products and enhanced EO-based observations responding to the needs of the SOLAS community and 2) Advance in the integration of EO-based products, in-situ data and models in order to contribute to SOLAS major scientific gaps. Three projects have been identified and carried out (2011-2013), and the major features and accomplishments follow.

Ocean Flux GHG, <http://www.oceanflux-ghg.org>

The OceanFlux Greenhouse Gases project is now nearing completion. The project has published 4 journal papers on altimeter gas transfer velocity algorithms, Arctic air-sea CO₂ fluxes and wave breaking statistics and another 6 journal papers are in draft form.

All of this work has exploited satellite Earth observation, in situ data, and modelling approaches. The project has released a version of its global CO₂ flux climatology and the data processing system (called FluxEngine) that was used to create the climatology is available for the community to use and exploit. Further updates to the processing system and the climatology are expected over the next few months.

OceanFlux Upwelling, <http://upwelling.eu/>

OceanFlux Upwelling aimed at exploring the potential of EO technology to characterize the role of ocean upwelling processes as sinks and/or sources of greenhouse gases, with a distinctive focus on the Peru-Chile and Benguela Eastern Boundary Upwelling Systems (EBUS).

In this context, image-processing techniques have been used to extract fluxes of GHGs from EO data. Through concomitant information on gas solubility and gas transfer velocities, the partial pressure of GHG in the ocean has been extracted. A new non-linear and multi-scale processing method for complex signals has been applied to infer a higher spatial resolution and properly map the GHG fluxes. These analyses have been linked to a coupled physical bio-geochemical model (ROMS-BioBus). The project has been officially completed, but a further 6-month extension is foreseen, allowing a further refinement of the super-resolution CO₂ ocean fluxes algorithm (merging different data sources) and validating the methodology enlarging the two test areas beyond the initial upwelling zones.

OceanFlux SSA, <http://oceanflux.fmi.fi>

The Oceanflux Sea-Spray Aerosol (OSSA) project focused on the development of a new sea-spray aerosol (SSA) source function (SF) and effects of SSA on climate. Using two independent data sets, SSA fluxes and particle number concentrations, the OSSA SF has been parameterized in terms of five log-normal modes and the Reynolds number. It encapsulates effects of wave height, and accounts for the different flux relationships associated with rising and waning wind speeds and dependences on SST and salinity. The OSSA SF, together with a scheme for the organic fraction, was implemented in the aerosol-climate model ECHAM-HAMMOZ. Comparison of modeled concentrations of SSA and OM with in situ data and PARASOL-retrieved AOD suggest areas for further improvement. The simulated SSA contribution to the indirect radiative effect is positive, which is ascribed to the tendency of SSA to suppress both the in-cloud supersaturation and the formation of cloud condensation nuclei from sulphate.

The end of the OceanFlux projects coincided with topical workshops: Sea Spray aerosol workshop for the OSSA theme, 30 Sept.-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, Brest, France. ESA is very interested by continuing its collaboration with SOLAS, although additional funding will depend on its budget. In order to continue collaboration and identify areas of common interest, ESA, EGU and SOLAS are organizing a topical conference on "Earth Observation for Ocean-Atmosphere Interactions Science 2014 - Responding to the new scientific challenges of SOLAS". The conference will be held in Frascati (Rome), Italy on 28-31 October 2014. This joint ESA-EGU-SOLAS Conference aims at bringing together the Earth observation and SOLAS communities, as well as scientific institutions and space agencies involved in the observation, characterisation and forecasting of ocean-atmosphere interactions and their impacts.

II.g. Collaboration with PICES

- SOLAS co-sponsored the Topic Session on “The changing carbon cycle of North Pacific continental shelves and marginal seas” at the 2013 PICES Annual Meeting in Nanaimo, Canada, Oct. 2013 by supporting the attendance of the invited speaker KK Liu. Lisa Miller represented SOLAS at the Annual Meeting.
- A half-day workshop will take place in 17-26 Oct. 2014 in Korea on “SOLAS into the future: Designing the next phase of the Surface Ocean-Lower Atmosphere Study within the context of the Future Earth Program” at the PICES annual meeting 2014 “Toward a better understanding of the North Pacific: Reflecting on the past and steering for the future”. The workshop was proposed and will be run by Lisa Miller, Minhan Dai and Yukihiro Nojiri.
- Leticia Cotrim Da Cunha, SOLAS Brazil national representative and colleagues from Latin American countries submitted a proposal to run a one-day workshop on SOLAS matter at the Effects of Climate Change on the World’s Ocean Meeting in 2015 in Brazil.

II.h. Swedish SOLAS events in Sweden

On 1819 Nov. 2013, about 25 SOLAS scientists from Swedish Institutions met at the Royal Swedish Academy of Sciences in Stockholm. Three SOLAS Scientific Steering Committee Members and three representatives of Swedish funding agencies joined them to discuss how to enhance the engagement of Swedish researchers in SOLAS, in particular in the context of the Future Earth initiative. The participants successfully established a matrix mapping Swedish

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capacity in relation to the SOLAS scientific scope and a list of current members of the Swedish network. During this workshop, it was also identified that David Turner, an established scientist at Gothenburg University, is working with his group on ship plume emissions and their impacts on the surface ocean. David accepted to lead the 'Ship Plumes' SOLAS emerging issue, taking over from Roland von Glasow. This successful workshop was initiated, organised and supported by the Swedish Secretariat for Environmental Earth System Sciences (SSEESS). This workshop revived the SOLAS network in Sweden. A 2-day Swedish symposium is planned to take place in August 27-28, 2014 in Gothenburg.

II.i. SOLAS visited the EU, Brussels

A SOLAS delegation composed of Brian Ward, Cecile Guieu, and Christoph Heinze, accompanied by Wendy Broadgate from IGBP visited the European Commission in Brussels, Belgium on 25 Nov 2013, to improve the chances for an EU call related to SOLAS activities (also for prospective funding of the IPO) under Horizon 2020.

II.j. SOLAS Symposium day in Israel

SOLAS will have a special symposium day on 19 June 2014 in the Lopatie Conference Centre at the Weizmann Institute of Science campus in Rehovot, Israel. The symposium is aimed at interdisciplinary exchange of ideas, insights, and knowledge, between scientists whose work deals with SOLAS-related processes. The symposium day will take place back to back with the 14th SOLAS Scientific Steering Committee meeting.

II.k. SOLAS France days, July, Paris

SOLAS Scientists in France are organizing a 2-day workshop, 7-8 July in Paris, France. SOLAS scientists, established and younger, from French institutes will share results and knowledge, with the ultimate goal to determine how SOLAS France can contribute to Future SOLAS v2.0.

II.l. SOLAS communication

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

The **SOLASNews newsletter** (NL) is emailed to about 2,200 scientists and airmailed to about 100 scientists, mainly from developing countries. Copies are held by the SOLAS IPO for distribution at SOLAS-relevant conferences and meetings. The NL is also available from the SOLAS website. The SOLASNews is printed and airmailed from China courtesy of the State Key Laboratory of Marine Environment Science, Xiamen University. Since issue 11, SOLAS also implemented an on-screen reader pdf version. Issue 15 (summer 2013) proposed a general update of the large scope of SOLAS activities, from the SOLAS Mid-term Strategies to the SOLAS/IMBER Carbon Groups and the Focus 2. Issue 16 is well underway and expected to be published in early June 2014.

E-bulletins are sent to more than 2,200 SOLAS scientists, roughly 10 times per year 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.

Flyers. The IPO has created an A5 flyer, with the support of the IGBP designer Hilarie Cutler. The flyer informs on the current scientific structure of SOLAS and updates on its plans for the future.

The flyer was distributed at 2014 Ocean Sciences Meeting in Hawaii and other SOLAS-relevant events.

Booth at Ocean Sciences. SCOR had a booth (#10) at the 2014 Ocean Sciences Meeting in Hawaii on 23-28 February 2014. SOLAS was invited to display project research information. The SOLAS PO and some SSC members attending the meeting and staffed the booth. This was the first time SOLAS had been represented at a booth and it was a positive experience.

II.m. SOLAS National Networks

Scientists from 29 nations are represented in the SOLAS network. Each nation has one or two representatives:

Australia: Sarah Lawson and Andrew Bowie
Belgium: Christiane Lancelot
Brazil: Leticia Cotrim Da Cunha (NEW)
Canada: Maurice Levasseur
Chile: Laura Farias
China (Beijing): Minhan Dai
China (Taipei): Gwo-Ching Gong
Denmark: Lise Lotte Soerensen and Mikael Sejr
France: Remi Losno
Germany: Hermann Bange and Ulrich Platt
India: Dileep Kumar
Ireland: Brian Ward
Italy: Chiara Santinelli
Finland: Gerrit de Leeuw

Japan: Mitsuo Uematsu
Korea: Kitack Lee
Mexico: Jose Martin Hernandez Ayon
Netherlands: Jacqueline Stefels
New Zealand: Cliff Law
Norway: Siv Lauvset (NEW)
Peru: Michelle Graco
Poland: Timo Zielinski (NEW)
Russia: Sergey Gulev
Spain: Rafel Simo
South Africa: Carl Palmer
Sweden: Katarina Abrahamsson
Turkey: Baris Saglihoglu and Mustafa Koçak
UK: Tom Bell (NEW)
USA: Bill Miller

Implemented in Jan. 2009, the national representatives of the SOLAS nations are asked to report annually about the SOLAS activities in their countries. To facilitate the reporting effort, a template form is provided. In January 2014, 19 reports were received and posted on the SOLAS website. The information contained in the reports has been/are a great source of information for the IPO to report to sponsors, but also to facilitate the coordination job and to redistribute 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.

II.n. Endorsed projects

Over the reporting period, SOLAS endorsed three projects: OASIS, NETCARE, and WDAC II. Information about support letters and endorsements are more accessible on the new website. The endorsement submission forms and update reports will be shortly available on the SOLAS website.

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III. Income and expenses for the past year and budget for the coming year, including funding from all sources (not only SCOR funding)

III.a. SOLAS International Project Office, Kiel

The SOLAS IPO is hosted at the GEOMAR Helmholtz-Centre for Ocean Research Kiel in Kiel, Germany. The office is currently staffed with the Executive Officer, Dr. Emilie Brévière and the Project Officer, Stefan Konradowitz. GEOMAR provides office space and has funded the Executive Officer's salary since 1 February 2011. The Project Officer's salary has been supported since 1 February 2013 by the German Ministry of Education and Research (BMBF) via the German national SOLAS project 'SOPRAN' Phase 3. The IPO has benefited since mid-March 2014 from a master's student's help with the OSC2015 (38 hours per month), funded by BMBF until mid-Sept 2014.

GEOMAR will provide office space and the salary of the executive officer, Dr. Emilie Brévière until January 2016. The salary of the project officer, Stefan Konradowitz covered by BMBF, via the SOPRAN Phase 3 funding is secured until January 2016 too.

III.b. SOLAS Funding

The Executive Officer salary, office space and in kind provided by GEOMAR until January 2016. The Project Officer salary and some travel support are provided by BMBF via SOPRAN phase 3 until January 2016. The U.S. National Science Foundation (via SCOR) provides annual funding until 1 Sept. 2015, when the current grant to SCOR ends, but SOLAS funding will be requested in the grant renewal proposal. One-third of this amount is used for the annual meeting of the SOLAS/IMBER working group on Ocean Acidification and the other two-thirds of the SCOR contribution covers the cost of the SSC meeting. IGBP provides an annual block grant, contributing to the cost of the SSC meeting. French CNRS provided funding in 2013 and 2014 for the SOLAS Vice Chair for SOLAS-related travel. Xiamen University provided support for the printing and shipping of the annual SOLASNews newsletter.

The future of the SOLAS IPO is currently unknown beyond January 2016. Various paths are being investigated.

3.5 International Quiet Ocean Experiment

Urban, Feeley

The International Quiet Ocean Experiment is a project under development by SCOR and the Partnership for Observation of the Global Oceans (POGO). Funding was initially provided by the Alfred P. Sloan Foundation, but that funding is now completed. Since the 2013 SCOR meeting, activities of the IQOE co-chairs and SCOR and POGO staff has focused on review of the report and working on responses to the review. In addition, IQOE co-funded a workshop on Predicting Sound Fields—Global Soundscape Modelling to Inform Management of Cetaceans and Anthropogenic Noise” in April 2014 in The Netherlands. This workshop relates to one of the major IQOE themes.

The timeline for the International Quiet Ocean Experiment (IQOE) has been as follows:

- 27-29 October 2010—Exploratory workshop at the University of Rhode Island
- 10-11 February 2011—Meeting at Florida Atlantic University to complete report from Rhode Island meeting and article for *Oceanography* magazine, and plan open science meeting
- 30 August-2 September 2011—Open Science Meeting at UNESCO Headquarters, Paris
- 15 June 2013—Science Plan sent to Review
- 24 January 2014—Last review received
- 1 September 2014—Response to Review sent to SCOR and POGO report monitors

It is planned to for the IQOE co-chairs to submit the response to review to SCOR and POGO around 1 September 2014. The SCOR Executive Committee will discuss the IQOE response to review in closed session and will announce the outcome of its discussions during the meeting.

3.6 Second International Indian Ocean Expedition (IIOE-2) Hood, D’Adamo, Burkill

SCOR has convened a committee to develop a Research Plan for the Second International Indian Ocean Expedition (IIOE-2), chaired by Raleigh Hood. The full membership of the committee follows.

Name	Expertise	Institution	Country
Raleigh Hood, Chair	Biological oceanography	University of Maryland	USA
Hermann Bange	Chemical oceanography and air-sea interactions	Helmholtz Centre for Ocean Research	Germany
Lisa Beal	Physical oceanography	University of Miami	USA
Lynnath Beckley	Fisheries oceanography	Murdoch University	Australia
Greg Cowie	Organic Ocean chemistry	University of Edinburgh	UK
Harry Hendon	Tropical Climate and climate prediction	The Centre for Australian Weather and Climate Research	Australia
Juliet Hermes	Physical oceanography and climate, observations	South African Environmental Observation Network	South Africa
Makio Honda	Biogeochemistry	JAMSTEC	Japan
Frank Peeters	Paleoceanography	Vrije Universiteit	Netherlands

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Sunil Singh	Chemical oceanography	Physical Research Laboratory	India
Weidong Yu	Physical oceanography	First Institute of Oceanography	China-Beijing
Liaison to IOC			
Nick D'Adamo	Physical oceanography	Perth Office, Australia	IOC
SCOR Staff			
Ed Urban	Marine Biology	University of Delaware	SCOR

The committee has been working remotely and will meet for the first and only time on 12-13 September 2014 in Bremen, before the SCOR meeting. The committee's term is from 1 June 2014 to 31 December 2015. Its terms of reference are the following:

1. Gather input from the international community about research interests in the Indian Ocean for 2016-2020.
2. Condense and summarize this research into international research priorities.
3. Plan IIOE-2 Workshop for 12-13 September 2014 in Bremen, Germany
4. Promote the IIOE-2 concept in national and international fora.
5. Liaise with national planning committees on IIOE-2 development.
6. Help plan launch of IIOE-2 in Goa, India in December 2015.

The committee will hand off its Research Plan to the IIOE-2 Interim Planning Committee before the IOC General Assembly in June 2015.