# 2.0 WORKING GROUPS

## 2.1 Disbanded Working Groups, p. 2-1



**2.2 Current Working Groups—** The Executive Committee Reporter for each working group will present an update on working group activities and progress, and will make recommendations on actions to be taken. Working groups expire at each General Meeting, but can be renewed at the meeting and can be disbanded whenever appropriate.



## 2.3 Working Group Proposals

## 2.1 Disbanded Working Groups

### 2.1.1 WG 125: Global Comparisons of Zooplankton Time Series (2004) *Costello*

**Terms of Reference:**

- Identify and consolidate a globally representative set of "long zooplankton time series" (selected from the data sets listed in Table 1, plus perhaps from additional regions for which time series can be pieced together from a sequence of shorter programs).
- Facilitate migration of individual data sets to a permanent and secure electronic archive.
- Develop and share protocols for within-region and within-time period data summarization (e.g., spatial, seasonal and annual averaging, summation within taxonomic and age categories).
- Based on the above, develop priorities and recommendations for future monitoring efforts and for more detailed re-analysis of existing sample archives.
- Carry out a global comparison of zooplankton time series using (in parallel) a diverse suite of numerical methods, examining
    1. Synchronies in timing of major fluctuations, of whatever form.
    2. Correlation structure (scale and spatial pattern) for particular modes of zooplankton variability (e.g., changes in total biomass, replacement of crustacean by gelatinous taxa, alongshore or cross-shore displacements of zoogeographic distribution boundaries).
    3. Amplitude of variability, both for total biomass and for individual taxa, and comparison to the amplitude of population fluctuations of predator species (fishes, seabirds, marine mammals). Is there amplification at higher levels of the food web?
    4. Likely causal mechanisms and consequences for the zooplankton variability, based on spatial and temporal coherence with environmental and fishery time series.
    5. Sensitivity and specificity of data-analysis tools.

**Co-Chairs:**

**David Mackas**
Institute of Ocean Sciences, Fisheries and Oceans Canada
PO Box 6000
Sidney, BC,
CANADA V8L 4B2
Tel: +1-250-363-6442
Fax: +1-250-363-6690
E-mail: mackasd@pac.dfo-mpo.gc.ca

**Hans M. Verheye**
Marine & Coastal Management (Research & Development)
Private Bag X2, Rogge Bay 8012
Research Aquarium, Beach Road, Sea Point
Cape Town, SOUTH AFRICA
Tel.: +27(0)21 430 7015
Fax: +27(0)21 434 2144/2899
E-mail: hverheye@deat.gov.za

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| | | | |
|---|---|---|---|
| **Full Members** | | **Associate Members** | |
| Patricia Ayon | PERU | Alyona Arashkevich | RUSSIA |
| Sanae Chiba | JAPAN | David Checkley | USA – Sponsored by GLOBEC |
| Young-Shil Kang | KOREA | | |
| Todd O’Brien | USA | Harold Bachelder | USA – Sponsored by PICES |
| Mark Ohman | USA | Juha Flinkman | FINLAND |
| Chris Reason | SOUTH AFRICA | A. Lopez-Urrutia | SPAIN |
| Anthony Richardson | AUSTRALIA | Welbjørn Melle | NORWAY – Sponsored by ICES |
| Andy Solow | USA | Luis Valdes | SPAIN |

**Executive Committee Reporter:** Mark Costello

The group’s special issue of *Progress in Oceanography* has been published (Special Issue of *Progress in Oceanography*, Volumes 97–100, Pages 1-186 (May–July 2012) and the group has been disbanded.

### 2.1.2 SCOR/IAPSO WG 127: Thermodynamics and Equation of State of Seawater (2005) *Smythe-Wright*

**Terms of Reference:**

- To examine the results of recent research in ocean thermodynamics with a view to recommending a change to the internationally recommended algorithms for evaluating density and related quantities (including enthalpy, entropy and potential temperature). Such recommendations would take into account the reformulation of the International Temperature Scale (ITS-90).
- To examine the most accurate recent knowledge of the freezing temperature of seawater, the calculation of dissolved oxygen, and the behaviour of seawater at high salinity.
- To examine the feasibility of using simple functions of three-dimensional space to take account of the spatially varying concentrations of alkalinity, total carbon dioxide, calcium and silica place on the determination of density in the ocean.
- To extend these concepts to a wider range of physical/chemical issues of relevance to the internal working of the ocean and of its interaction with the atmosphere and to present and potential future observational techniques.
- To write a set of related recommendations on the above topics in the form of a report to SCOR/IAPSO and a review or series of reviews to be published in the scientific literature.

**Chair:**

**Trevor J. McDougall**
CSIRO Marine and Atmospheric Research
GPO Box 1538
TAS 7001, AUSTRALIA

Tel: +61-3-6232-5250
Fax: +61-3-6232-5000
E-mail: Trevor.McDougall@csiro.au

**Other Full Members:**

| | |
|---|---|
| Chen-Tung Arthur Chen | CHINA-Taipei |
| Rainer Feistel | GERMANY |
| David Jackett | AUSTRALIA |
| Brian King | UK |
| Giles Marion | USA |
| Frank Millero | USA |
| Petra Spitzer | GERMANY |
| Dan Wright | CANADA |

**Associate Member:**

| | |
|---|---|
| Rich Pawlowicz | CANADA |
| Steffen Seitz | GERMANY |
| Peter Tremaine | CANADA |

**Executive Committee Reporter:** Eugene Morozov

The group has been disbanded and follow-up work will be handed by the new joint group with the International Association for the Properties of Water and Steam (IAPWS) (see **section 4.4.3**).

### 2.1.3 WG 130: Automatic Visual Plankton Identification (2006) *Costello*

**Terms of Reference:**

- To encourage the international co-operation of software developers and marine scientists to use and enhance an appropriate open-source development platform, so that a common toolset can be built up over time that is of value to the community
- To evaluate the limits of taxonomic resolution possible from image-based classifiers and develop means of improving the taxonomic resolution that can be achieved from plankton images. The working group will establish a basis for standards in taxonomic reporting by automatic labelling instruments.
- To review existing practices and establish standards in the use of reference image data used for training automation machines and in training people.
- To establish a methodology for inter-comparison/calibration of different visual analysis systems.
- To develop open-source software for application by the marine ecology, taxonomy and systems developers. Publish the products of reviews by members of the Working Group, selected presented papers and workshop reports in an internationally recognised, peer-reviewed journal or a book by a major publisher

**Co-chairs:**

**Mark C. Benfield**
Louisiana State University
Dept. Of Oceanography and Coastal Sciences
Baton Rouge, LA 70803, USA
Tel: +1-225-578-6372
Fax: +1-225-578-6513
E-mail: mbenfie@lsu.edu

**Phil Culverhouse**
School of Computing, Communications & Electronics,
University of Plymouth,
Plymouth, PL4 8AA
UNITED KINGDOM
Tel: +44 (0) 1752 233517
Fax: +44 (0) 1752 232540
E-mail: pculverhouse@plymouth.ac.uk

**Full Members**

| | |
|---|---|
| Josué Alvarez-Borrego | MEXICO |
| Elena Arashkevich | RUSSIA |
| Philippe Grosjean | BELGIUM |
| Rubens M. Lopes | BRAZIL |
| Angel Lopez-Urrutia | SPAIN |
| Maria Grazia Mazzocchi | ITALY |
| Michael Edward Sieracki | USA |
| Hans M. Verheye | SOUTH AFRICA |

**Associate Members**

| | |
|---|---|
| Carin J. Ashjian | USA |
| J.M.H. du Buf | PORTUGAL |
| Gabriel Gorsky | FRANCE |
| Xabier Irigoien | SPAIN |
| Norm McLeod | UK |
| Song Sun | CHINA-Beijing |
| Bob Williams | UK |

**Executive Committee Reporter:** Mark Costello

Group members were thanked and the group disbanded.

**2.1.4 SCOR/IAPSO WG 133: OceanScope** ***Feeley***
**(2008)**

Terms of Reference

1. Identify ocean observations and scientific needs with respect to parameters and geographic location
2. Given these needs, identify and prioritize marine routes for sustained ocean observations
3. Classify and identify commercial vessel types suitable for sustained observations
4. Identify available technologies that can enhance vessel capability for ocean observations
5. Identify and prioritize instrument needs to meet future mission requirements
6. Identify and develop procedures (hardware and software) to meet communications needs
7. Develop procedures and algorithms for managing data flow, handling, and archival. Address related issues of data ownership (e.g., when routes occur within national Exclusive Economic Zones), data availability and data dissemination. In general, the expectation is that data would be made freely and widely available to all interested users.
8. Address what kind(s) of organizational structure(s) will best serve to initiate, implement, and sustain an integrated international merchant marine-based ocean observation program, linked closely to existing ocean observing systems and programs with access to appropriate and sufficient long-term funding sources (e.g., an "Ocean (or Interior) Space Center")

Co-chairs:

H. Thomas Rossby
Graduate School of Oceanography

University of Rhode Island
215 South Ferry Road
Narragansett, RI 02882 USA
trossby@gso.uri.edu

Kuh Kim
School of Earth and Environmental Sciences
Seoul National University
Seoul, Korea
Tel: +82-2-880-6749
Fax: +82-2-887-5613
kuhkim@snu.ac.kr or
kuhkim@gmail.com

<u>Other Full Members</u>

Peter Hinchliffe (UK)
David Hydes (UK)
Markku Kanerva (Finland)
Peter Ortner (USA)
P.C. Reid (UK)
Fred Soons (Netherlands)
Ute Schuster (UK)
Javier Valladares (Argentina)
Yasuo Yoshimura (Japan)

# 2-6

Associate Members

Bill Burnett (USA)
Richard Burt (UK)
Earl Childress (UK)
Jim Churnside (USA)
Joe Cox (USA)
Rich Findley (USA)
Charles Flagg (USA)
Arnold Furlong (Canada)
John Gould (UK)
Gwyn Griffiths (UK)
James Hannon (USA)
Van Holliday (USA)
Paul Holthus (USA)
Robert Luke (USA)
Jerry Mullison (USA)
Glenn Pezzoli (USA)
Steve Piotrowicz (USA)
Tom Sanford (USA)
Corinna Schrum (Norway)
Satheesh Shenoi (India)
Peter Sigray (Sweden)
Denise Smythe-Wright (UK)
Darryl Symonds (USA)
Michael Twardowski (USA)

**Executive Committee Reporter**: Missy Feeley

The group published its report on line (see http://www.scor-int.org/Publications/OceanScope_Final_report.pdf) and is working through various forums to implement their ideas. The group has been disbanded.

## 2.2 Current Working Groups

### 2.2.1 WG 131: The Legacy of in situ Iron Enrichment: Data Compilation and Modeling (2007) *Compton*

**Terms of Reference:**

- Compilation of a database for open access (via the Internet) of the following experiments:
    - the 1999-2001 era (IronEx-1, IronEx-2, SOIREE, EisenEx, SEEDS-1), plus 1992 S.O. JGOFS;
    - the 2002 experiments (SOFeX-North, SOFeX-South, SERIES); and
    - the 2004 experiments (Eifex, SEEDS-2, SAGE, FeeP), plus natural fertilizations CROZEX, KEOPS

This effort will include a commonly agreed data policy for users to best acknowledge the original data producers (e.g., by offering co-authorship and perhaps assignment of digital object identifiers for individual data sets). Obviously, a practical description of methods used, calibration etc. (so-called metadata) will also be included. In essence, the WG members are committed to send their data files to the common data centre, and encourage their colleagues in any given experiment to do the same. Finally, an official data publication or publication(s) will be placed in a suitable venue, for example, in the special issue on the SCOR WG (see item 4. below) and in *Eos* (Transactions Am. Geophys. Union). In 2006-2007 efforts are already underway for compilation and rescue of the EisenEx dataset, also there is very good progress for SEEDS-2, SERIES, CROZEX and KEOPS. However, the statement in the original proposal that no meeting would be necessary to achieve the first term of reference was overly optimistic. It appears that a face-to-face meeting sponsored by SCOR or some other internationally recognized organization is necessary to work out the details of bringing together the data sets in a way that will make it possible to achieve the other terms of reference.

**Co-chairs:**

Philip Boyd
Centre for Chemical and Physical Oceanography
Department of Chemistry
P.O. Box 56, Dunedin
NEW ZEALAND
Tel: +(64)(03) 479-5249
Fax: +(64)(03) 479-7906
Email: pboyd@alkali.otago.ac.nz

Dorothee Bakker
School of Environmental Sciences
University of East Anglia
Norwich NR4 7TJ
UNITED KINGDOM
Tel. +44 1603.592648
Fax. +44 1603.591327
Email: D.Bakker@uea.ac.uk

**Executive Committee Reporter:** John Compton

# 2-8

## Annual report on the activities of SCOR WG 131
## The legacy of in situ iron enrichment experiments 1993 to 2004

In 2011/2012, we have been working on two manuscripts to be submitted to popular journals with a view to publicising the relational database on BCO-DMO that was the main product from WG 131. Dorothee Bakker is leading the production of an article entitled "*The legacy of in situ iron enrichment experiments 1993 to 2004*" for the AGU journal *EOS*. Philip Boyd is writing a longer commentary piece for The Oceanography Society journal *Oceanography* entitled "*A new database to explore the findings from large scale ocean iron-enrichments*". The Boyd et al. article outlines and explores three potential uses for such datasets - insights into geoengineering; better understanding the effects of altered environmental drivers across foodwebs; and biogeochemical model validation. We hope that both articles will be submitted in late 2012.

Recently, the overview paper from the 2004 EIFEX experiment was finally published (Smetacek et al., 2012) and the embargo on public access to the datasets was lifted. We have been in contact with the voyage leaders, about these data and also those from the recent Indo-German experiment LOHAFEX. Here is a recent email response on September 3 from Dr. Christina Klaas:

> "Dear Phil, I plan to have all of the data available in PANGEA (at least what I have; one scientist, however, requested that his dataset be password protected, the rest will be open access). From there, everybody will be able to download it. I am still busy with other matters but will try to prepare the data tables for PANGEA ASAP. Cheers, Christine"

Cyndy Chandler at BCO_DMO has strong links with the data-managers at PANGEA, and so we should be able to readily make links between the WG 131 relational database and PANGEA such that our database will enable access to all of in situ enrichment experiments conducted since IronEX in the early 1990s, and hence our data rescue will be virtually complete.

Philip Boyd and Dorothee Bakker (co-chairs WG 131)

Smetacek, V. *et al*. Deep carbon export from a Southern Ocean iron-fertilized diatom bloom. *Nature* **487**, 313–319 (2012).

### 2.2.2 SCOR/LOICZ WG 132: Land-based Nutrient Pollution and the Relationship to Harmful Algal Blooms in Coastal Marine Systems *Taguchi*
(2007)

**Terms of Reference:**

1. Integrate the existing IOC-HAB database and nutrient loading databases into a compatible GIS format.
2. Advance the development of a GIS coastal typology database.
3. Interrogate the above databases for relationships between HAB species, nutrient loading/forms/ratios, and coastal typology and develop broad relationships between nutrient loading and distributions of specific HABs.
4. Explore possible changes in HAB occurrences in the future (year 2030), using the relationships developed above (3.) and global nutrient export patterns under the Millennium Assessment scenarios for 2030.
5. Publish the results of these analyses in peer-reviewed scientific journals. Papers will be developed on 1) the global perspective, including the next generation of global nutrient and HAB maps; 2) regional highlights; and 3) individual case studies. We will also develop articles for the GEOHAB newsletter and for the GEOHAB and Global News websites, and a graphic-rich report (under the GEOHAB umbrella) that will be targeted for management.

**Co-chairs:**

Patricia Glibert
Horn Point Laboratory
University of Maryland Center for Environmental Science
P.O. Box 775, Cambridge MD 21613
USA
Tel: +1-410-221-8422
Fax: +1-410-221-8490
E-mail: glibert@hpl.umces.edu

Lex Bouwman
RIVM/ LBG
P.O. Box 1
3720 BA Bilthoven
THE NETHERLANDS
Tel.: +31-30 2743635
Fax: +31-30 2744419
E-mail:
lex.bouwman@rivm.nl

| **Other Full Members** | **Associate Members** |
|---|---|
| Adnan Al-Azri (Oman) | Arthur Beusen (Netherlands) |
| J. Icarus Allen (UK) | Richard Gowen (UK) |
| Hans Dürr (The Netherlands) | Rencheng Yu (China-Beijing) |
| Paul Harrison (China-Beijing) | |
| Jorge A. Herrera-Silveira (Mexico) | |
| Sandor Mulsow (Chile) | |
| Sybil Seitzinger (USA) | |
| Mingjiang Zhou (China-Beijing) | |

**Executive Committee Reporter:** Satoru Taguchi

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SCOR/LOICZ Work Group 132

**Land-based Nutrient Pollution and the Relationship to Harmful Algal Blooms in Coastal Marine Systems**

*Patricia Glibert*, University of Maryland Center for Environmental Science
*Lex Bouwman*, Netherlands Environmental Assessment Agency
Working Group Co-Chairs

Harmful algal blooms (HABs) are a worldwide concern, as they cause fish and shellfish kills, intoxicate seafood with toxins, form unsightly scums, or detrimentally impact ecosystem function, often with economic and/or human health consequences. Of major interest is the extent to which land-based nutrient pollution contributes to these events and how the frequency or duration of such events may change in the future as nutrient loads and climate change. Nutrient pollution from land comes via rivers from the runoff and leaching of nitrogen and phosphorus from fertilizers and manure and from sewage effluent, as well as other emerging sources, such as aquaculture. Nutrient pollution also differs regionally and spatially in the amounts and forms of nutrients exported. Both loads and forms of nutrients can affect the environmental suitability for HAB proliferation and are expected to change in the future, with population growth on the one hand and nutrient management efforts on the other, as well as with synergistic effects of changes with climate. Addressing these questions quantitatively has been the objective of this Working Group, jointly funded by SCOR and LOICZ.

To address these questions, various databases and models were explored and advanced. The complexity of the relationship between nutrients and HABs requires a range of model approaches (Glibert et al., 2010). Estimating nutrient export to the coastal zone has been a challenge, but enormous advances have been made with respect to global models over the past several years. The Working Group has used the annual global river export data for sediments and different forms of carbon, nitrogen, phosphorus and silica from the IOC Global Nutrient Export from WaterSheds model (Global NEWS) (Seitzinger et al., 2010). However, these models have not taken into account the increasing nutrient loads from aquaculture. Both shellfish and finfish aquaculture are currently increasing rapidly in many parts of the world, particularly in Southern and Eastern Asia (Figure 1). To advance our understanding of these changing nutrient sources, the river nutrient export data of Global NEWS were complemented with worldwide estimates for nutrient release from shellfish and finfish aquaculture. A simple model was developed on the basis of available literature data on the various types of feed used in the different aquaculture systems, feed conversion ratios, and assimilation efficiencies. Results indicate that shellfish aquaculture may release about 2 million tonnes of nitrogen per year by transforming phytoplankton to dissolved and particulate forms. Finfish aquaculture may contribute a similar quantity. Although on the global scale this is a minor source to coastal marine ecosystems compared to river export, on regional and local scales it may be important. The spatial allocation of the aquaculture nutrient release was refined with maps published by FAO, and information from Chile and China. Future projections of aquaculture loads were made using the Millennium Ecosystem Assessment scenarios (Bouwman et al., 2011).

Nutrient export has different effects in the coastal zone depending on the degree of retention of the receiving water. To account for such differences on a global scale, differences in typology of the coastal environment have been applied. The coastal typology models of Laruelle et al., (2009) and Dürr et al. (2011) were used by the Working Group.

Nutrient loads alone, however, are not sufficient to create HABs. While more nutrients, in general, promote the growth of more phytoplankton, more nutrients do not always promote the preferential growth of HABs relative to other phytoplankton. It is well recognized in the physiological literature that many HABs preferentially thrive in reducing, rather than oxidizing, environments. Although there is a great range in physiological capability by species and their state of growth, in general, HABs generally use reduced forms of nitrogen such as ammonium and urea more than nitrate. Thus, to address this, the Global NEWS models were modified to differentiate the export of ammonium and nitrate (Fig. 2). Scenario prediction of future change in the ratio of ammonium/nitrate export were also developed based on the Millennium Ecosystem Assessment assumptions.

Global HAB distributions were also compiled for a number of different types of HABs and regional time series of HABs and nutrient loading have been summarized from different parts of the world, that is, South America, Gulf of Mexico, United States, Gulf of Oman, and Hong Kong. The first spatially referenced global maps of several HAB species were published.

Finally, to address the potential synergistic effects of climate change and nutrients, the POLCOM-ERSEM Global coastal ocean model, a coupled-forced-biogeochemical model (Allen et al., 2001), calibrated with Global NEWS nutrient data was applied. Simulations with the POLCOM-ERSEM Global coastal ocean model were made for the NW European shelf and Baltic Sea, Indonesia and Asia. Based on literature reviews, a suite of chemical (nutrients by form and proportion) and physical (temperature and salinity) parameters were defined that characterize the habitat of several HAB types. For this analysis, two generic HAB types were used, one a high-biomass bloom-former, analogous to *Prorocentrum* spp., and a toxin-former, analogous to *Karenia* spp. Both are species groups that have been documented to cause blooms worldwide. Current conditions and future (2100) projections were estimated. The future conditions were based on the "A1B" scenario of the Intergovernmental Panel on Climate Change (IPCC), a scenario that is considered to be among the mid-line estimates of the range of IPCC model ensembles. The model output defined the number of months during the year when the conditions of the individual criteria and when the summed conditions of the collective criteria were met. As an example, here we illustrate the projected change in the suitable habitat for species with "*Prorocentrum*" characteristics for one criterion only, temperature, for the NW European shelf (Fig. 3).

While the expansion in range due to temperature is illustrated here, the overall expansion in habitat when all criteria are used differs, but nevertheless illustrates expansion. The difference is because the suitability of all parameters for growth—not just temperature, but also nutrients and other conditions—must align in both space and time. In all, the current projections were remarkably robust with regard to fidelity with the geographic regions where such blooms have been previously documented. Furthermore, globally, these model projections illustrate large differences in the potential expansion, both regionally and with species type, when all modeled criteria were applied.

Of key concern is the projection of expansion in in regions where major aquaculture operations now exist, for example, along the NW European shelf. The overall approach of this model is currently based on a few relatively simple “rules” of physiology for the HABs. As more is known about their physiology, and as models continue to advance, this approach can be refined and more detailed scenarios can be developed. Such a tool may aid managers in developing nutrient reduction strategies and in protecting vulnerable aquaculture operations.

The working group is now completing its work, having met in Geesthacht, Germany in 2008; Beijing, China in 2009; Glyfada, Greece in 2010; and, as a subgroup, in Plymouth, England in 2012. It has published several of the individual component models described above and several synthesis papers are now in review or revision.

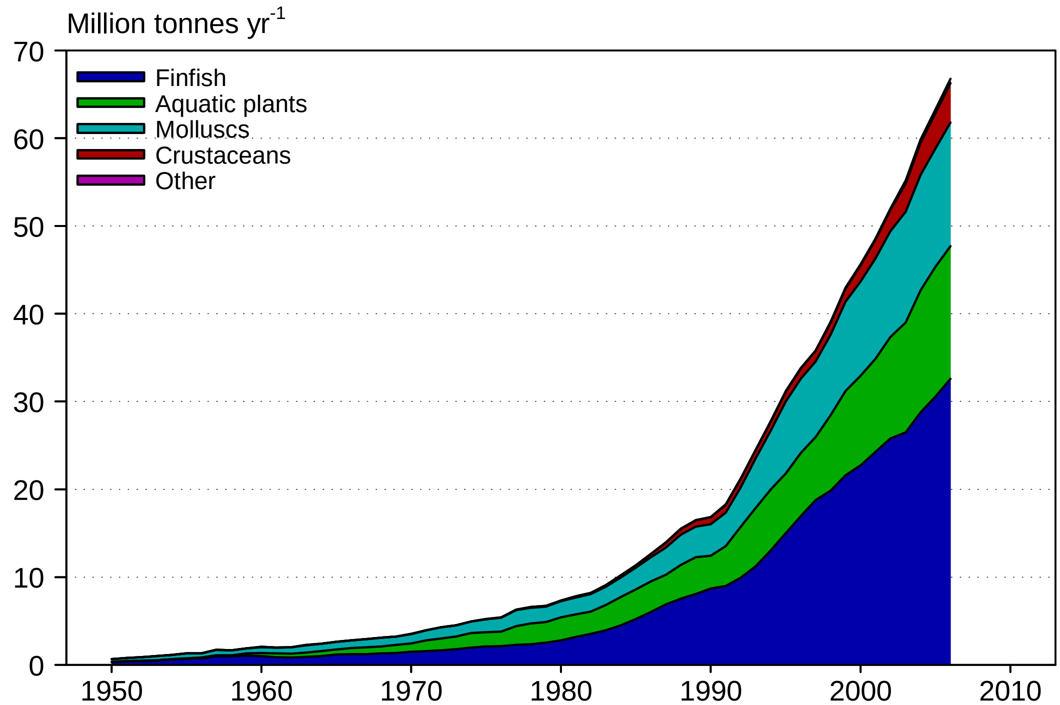



Figure 1. Global change in aquaculture production over time.

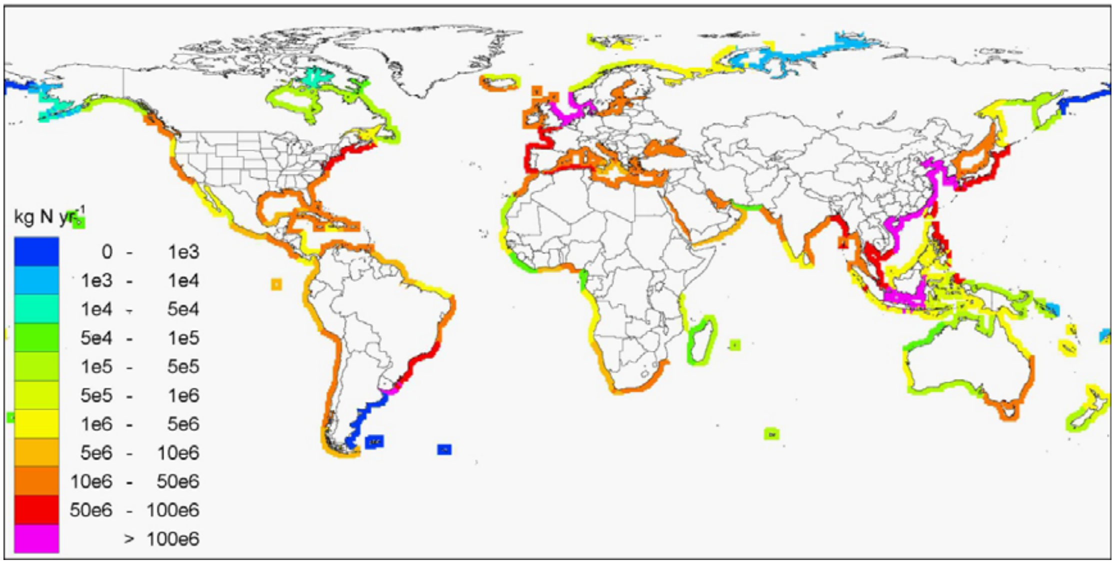
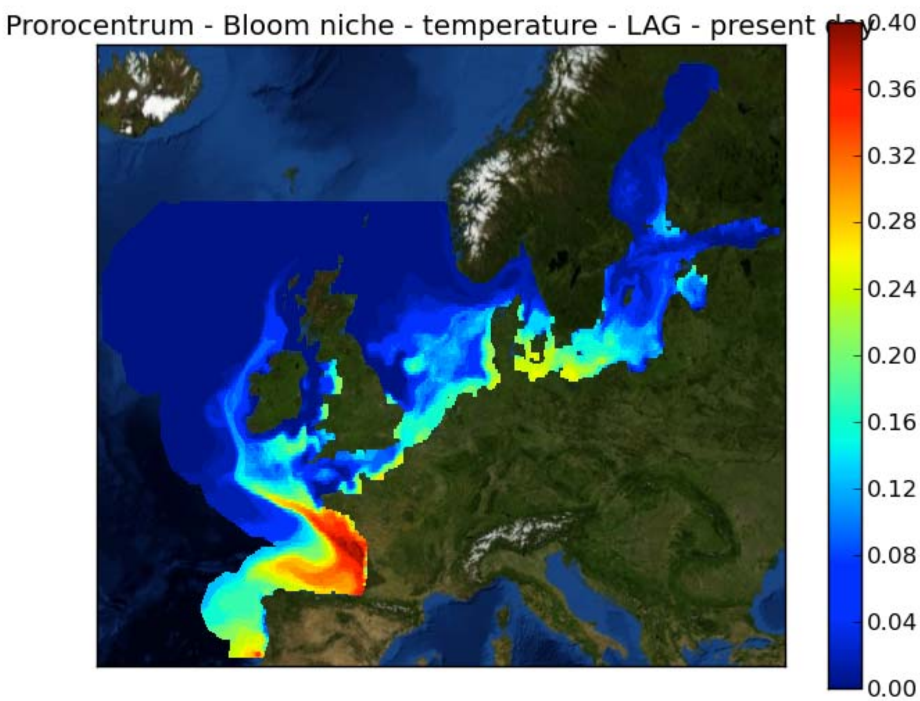



Figure 2. Ammonium export to the coastal zone based on modified Global NEWS models.



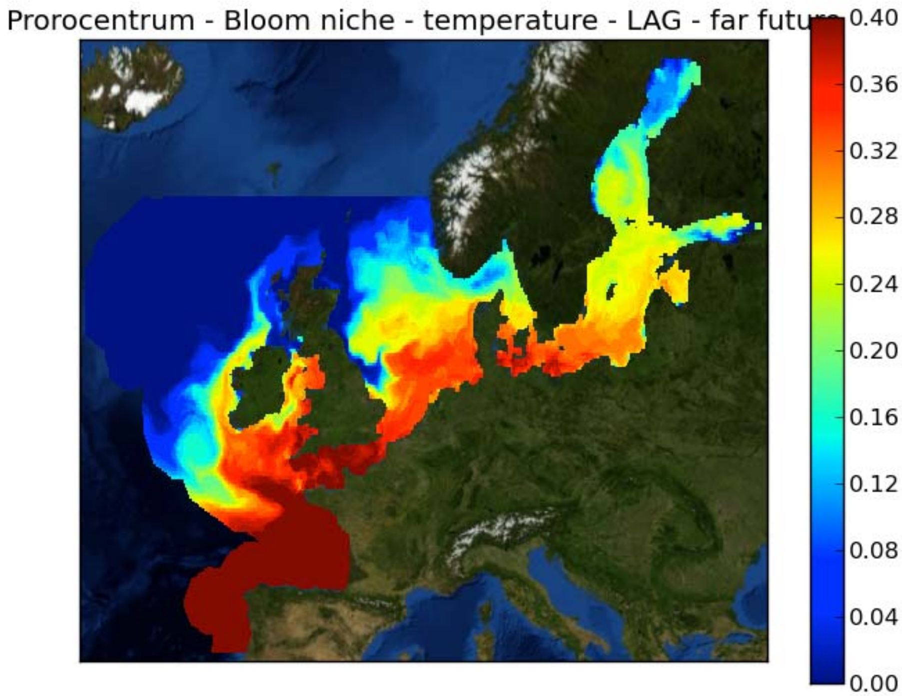



Figure 3. Change in suitability of temperature for growth of *Prorocentrum* –type HAB species from present to far future (2100) for the for NW European shelf. The projections illustrate the number of months in a year during which the conditions for this parameter would be suitable for growth. Note that when multiple chemical parameters are collectively considered (not shown), an expansion is still noted, but the temporal and spatial extent differs from that of this single parameter analysis.

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**SCOR/LOICZ Working Group 132**
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**Published**

Glibert, P.M., J. I. Allen, L. Bouwman, C. Brown, K.J. Flynn, A. Lewitus and C. Madden. 2010. Modeling of HABs and Eutrophication: Status, Advances, Challenges. *Journal of Marine Systems*, 83(3-4): 262-275.

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**In Final Revision or Review**

Glibert, P. Harmful Algal Blooms in Asia: an insidious and escalating water pollution phenomenon with effects on ecological and human health. *Asia Network Exchange*. In review.

Glibert, P., Y. Artioli, J.I. Allen, L. Bouwman, and A. Beusen. Climate change projected to expand harmful algal blooms differentially in temperate waters. *Nature Climate Change.*

Bouwman et al. Global hindcasts and future projections of inland and coastal nitrogen and phosphorus loads due to finfish aquaculture. *Reviews in Fisheries Science*

**In Preparation**

Glibert, P., Y. Artioli, J.I. Allen, L. Bouwman, and A. Beusen *et al.* Projections of synergistic climate change and eutrophication effects on harmful algal blooms using global modeling approaches. *Progress in Oceanography* In prep.

Van Apeldoorn, D., AHW Beusen, AF Bouwman, P. Glibert. Global model of ammonia river discharge. *Global Biogeochemical Cycles.*

Bouwman, L., A. Beusen, C. Overbeek, M. Pawlowski, P.M. Glibert, J. Herrera, S. Mulsow, R. Yu, M.J Zhou. Mariculture: A major cause of coastal eutrophication.

**Selected Invited Presentations recognizing the work of the Working Group**

Glibert, P.M. 2010. Eutrophication and Harmful Algal Blooms: From global patterns to physiology. EUTRO 2010 Conference, Denmark.

Glibert, P.M. 2011. Eutrophication, ecological stoichiometry and the lower food web of the Sacramento-San Joaquin Estuary, California. ASLO 2011 Aquatic Sciences Meeting, Puerto Rico.

Glibert, P.M. 2011. Eutrophication, ecological stoichiometry and aquatic food webs. Chinese Academy of Sciences. Qingdao, China.

Glibert, P.M. 2012. Nutrient pollution and harmful algal blooms: A global analysis. LOICZ Open Science Conference, Yantai, China.

Glibert, P.M. J.I. Allen,, Y. Artioli, L. Bouwman , A. Beusen. 2012. Temperate region expansion of harmful algal blooms projected with aquaculture expansion and climate change: Report of SCOR/LOICZ Working Group 132. 15th International Conference on Harmful Algal Blooms, Korea.

### 2.2.3 SCOR WG 134: The Microbial Carbon Pump in the Ocean (2008) *Sundby*

**Terms of Reference:**

- Summarize representative microbial data on biomass, production and diversity of functional groups (AAPB, CFB, Roseobacter, Archaea) and overall microbial communities, as well as DOC data focusing on the context of RDOC dynamics along environmental gradients (productivity/temperature/salinity gradient such as estuarine to oceanic waters); Establish the current state of knowledge about microbial processes that produce RDOC at the expense of DOC, and identify essential scientific questions regarding microbial carbon pump to be addressed in the future;
- Assess the available techniques for quantifying microbial functional groups and demonstrating the bioreactivity of marine DOC, document state-of-the-art techniques and parameters addressing microbial processing of organic carbon, and establish/standardize key protocols for the essential observation/measurements;
- Convene International Workshop(s) and publish a special volume in an internationally recognized peer-reviewed journal, or a protocol book (practical handbook) by a major publisher on measurements of the key parameters related to microbial processing of carbon in the ocean.
- Make recommendations for future research related to the microbial carbon pump in the ocean, toward development of a large-scale interdisciplinary research project.

**Co-chairs:**

Nianzhi Jiao
Cheung Kong Professor and Deputy Director
State Key Laboratory of Marine Environmental Sci.
Xiamen University
Xiamen 361005 P. R. China
Tel & Fax: +86-592-2187869
Email: jiao@xmu.edu.cn

Farooq Azam
Scripps Institution of Oceanography
University of California, San Diego
Tel: +1-858-534-6850
fazam@ucsd.edu

| **Other Full Members** | **Associate Members** |
|---|---|
| Xosé Antón Álvarez-Salgado (Spain) | Ronald Benner (USA) |
| Arthur Chen (China-Taipei) | Craig Carlson (USA) |
| Dennis Hansell (USA) | Feng Chen (USA) |
| Gerhard Herndl (Netherlands) | Sang-jin Kim (Korea) |
| Gerhard Kattner (Germany) | David Kirchman (USA) |
| Michal Koblížek (Czech Republic) | Ingrid Obernosterer (France) |
| Nagappa Ramaiah (India) | Carol Robinson (UK) |
| Colin Stedmon (Denmark) | Richard Sempere (France) |
| | Christian Tamburini (France) |
| | Steven Wilhem (USA) |
| | Susan Ziegler (Canada) |

**Executive Committee Reporter:** Bjørn Sundby

# 2-18

## SCOR WG134-The Microbial Carbon Pump in the Ocean
### Annual report of SCOR WG134 (August 2011 -- August 2012)

## I. Meetings and Academic activities

### (A) Meetings held

**1) A Forum on Marine Carbon Sink** supported by the Chinese Science & Technology Association was convened by WG134 member Nianzhi Jiao in Sanya, China, 15-16 December, 2011. Twenty experts from China and the United States, including 3 other WG134 members, attended the forum. The forum was focused on carbon sink formation processes and controlling mechanisms, observation approaches and carbon sink indices. Influences of land inputs on microbial/biological carbon sequestration in the coastal ocean was considered to be a handle for marine carbon sink management.

**2) Ocean Science meeting** at Salt Lake City, Utah, USA, 20-24 February, 2012.
A session titled "Shedding Light on the Dark Ocean: Advances in Linking Physical and Microbial Oceanography to Biogeochemistry" was convened by WG134 members Gerhard J. Herndl, Dennis Hansell, et al. Another session titled "Dissolved Organic Matter and the 'Hidden' Carbon Cycle" was convened by WG134 member Dennis Hansell and other colleagues.

**3) The Second International Conference on Marine Science and Earth System**
Shanghai, China, 2-4 July, 2012.
A special session titled "Microbes and Carbon Cycling in the Ocean" was convened by WG134 member Nianzhi Jiao and Chuanlun Zhang. A workshop on ocean carbon sink-related protocols was convened by Nianzhi Jiao, which attempted to call the attention of the audience and colleagues to the differences between carbon fixation and sequestration. and relevant comparable protocols, which are not yet established. As a follow up, a website of carbon sink in the ocean will be set up for long-term exchange and cooperation among colleagues.

**4) ASLO Aquatic Science Meeting**, Lake Biwa, Japan, 09-13 July, 2012.
A session titled "The Global Ocean Ecosystem: Patterns, Drivers and Change" was convened by WG134 member X. Antón Alvarez-Salgado and other colleagues.

(The WG members participated in many relevant meetings, such as: The **Joint meeting between International Society of Protistologists (ISOP) and International Society for Evolutionary Protistology (ISEP),** Oslo, Norway, July, 2012. Symposium speaker Protist: Virginia Edgcomb. Field Protistology: Cornerstone for understanding the diversity, ecology and evolution of microbial eukaryotes; the **Symposium on Aquatic Microbial Ecology SAME-12,** Rostock, Germany, 28 August - 2 September, 2011. WG134 member Michal Koblizek gave a lecture on photoheterotrophic metabolism and carbon utilization in Aerobic Anoxygenic Phototrophs).

### (B) Meetings to be held in the coming months

**5) 14th International Symposium on Microbial Ecology, Copenhagen, Denmark.**
The 14th International Society for Microbial Ecology Conference will be held at the Bella Center, Copenhagen, Denmark, from 19 to 24 August 2012. Nianzhi Jiao will give an invited talk at the session on "Microbes in a changing ocean" (Conveners: Stephen Giovannoni and

Osvaldo Ulloa) 20 August, 2012. WG member Virginia Edgcomb will give an oral presentation at the session on "Microbial Ecology in Extreme Environments".

**6) The 3rd Meeting of the SCOR WG134,** Hanse Institute for Advanced Study (HWK), Delmenhorst, Germany, 26-29 August, 2012. (local organizers: Meinhard Simon and Gerhard Kattner).

The workshop at HWK will be the last one of the SCOR WG 134 formal WG meetings, which aims at summarizing the progress of microbial and geochemical research in the context of the MCP in the recent past and the impact of the MCP concept on microbial oceanography research with respect to DOM cycling and diagenetic alterations. In addition, future research activities within the conceptual framework of the MCP will be discussed and put forward. Results of the workshop will be published in the final report of WG 134 to SCOR and made publicly available on the Web pages of the working group (http://www.scor-int.org/Working_Groups/wg134.htm) and http://mme.xmu.edu.cn/mcp/eindex.asp).

The workshop is planned for 60 participants, experts in the field of microbial oceanography and geochemistry, Full and Associate members of SCOR WG 134 and ~35 other scientists from Germany (<10 persons), other European countries, USA, Canada, China, Japan.

**SCOR WG134 3rd Meeting**

***Microbial Carbon Pump in the Ocean***

26-28 August 2012

Hanse-Wissenschaftskolleg (HWK), *Institute for Advanced Study*, Delmenhorst, Germany

Agenda

| **Date**: Sunday, Aug 26, **Time**: 17:00-19:00, | | | |
|---|---|---|---|
| **Time** | **Topic** | **Speaker (names are tentative)** | **Chair** |
| 17:00 | Welcome | Simon | Kattner |
| 17:15 | Marine Microbiology and DOM research facilities in northwest Germany | J. Rullkötter, ICBM<br>R. Amann, MPI Bremen<br>D. Wolf-Gladrow, AWI<br>M. Schulz, Univ. Bremen | |
| 18:15 | Summary of the SCOR WG134 first term | Nianzhi Jiao | Azam |
| 19:00 | **Dinner at HWK** | | |
| 20:30 | **Meeting of SCOR working group members** | | |

| Open science meeting<br>**Date**: Monday, Aug 27, **Time**: 8:30- 18:00 | | | |
|---|---|---|---|
| Time | Topic | Speaker | Chair |
| Session 1: DOM sources and budgets | | | Kattner |
| 08:30 | Ocean DOM budgets | Dennis Hansell | |
| 08:55 | The neutral reactivity theory: a mechanistic explanation for the stability of DOM in the deep ocean | Thorsten Dittmar | |
| 09:20 | Tracing Bacterial C and N in the Microbial Carbon Pump | Ronald Benner | |
| 09:45 | DOC export from tropical rivers in the world | Chen-Tung Arthur Chen | |
| 10:10 | Export of labile and refractory DOM from the coastal to the open ocean | Xosé Antón Álvarez-Salgado | |
| 10:35 | **Coffee break** | | |
| Session 2: Interactions of bacterioplankton lineages with DOM. | | | Herndl |
| 11:00 | Bacterioplankton community composition in the upper ocean | Rudi Amann | |
| 11:25 | Ecology of Flavobacteria and other high level bacterial taxa in the oceans | David Kirchman | |
| 11:50 | A molecular perspective on the ageing of marine dissolved organic matter | Boris Koch | |
| 12:15 | **Lunch at HWK** | | |
| 14:00 | The *Roseobacter* clade and its potential significance for the microbial carbon pump | Meinhard Simon | Kirchman |
| 14:25 | Gammaproteobacteria (tentative) | Bernhard Fuchs | |
| 14:50 | Carbon fixation in the dark ocean | Gerhard Herndl | |
| 15:15 | Seasonal variations in bacterial community and DOM concentrations in tropical coastal regions | Nagappa Ramaiah | |
| 15:40 | Title to be announced | Craig Carlson | |
| 16:05 | **Coffee break** | | |
| 16:30 | Marine photoheterotrophic bacteria | Michal Koblizek | Hansell |
| 16:55 | Viral infection and organic matter transformation | Markus Weinbauer | |
| 17:20 | Protists in marine oxyclines | Virginia Edgcomb | |

| | | | |
|---|---|---|---|
| 17:35 | Biomarker of the MCP and MCP activities in the earth's history | Chuanlun Zhang | |
| 18:00 | **Dinner at HWK** | | |
| 20:00 | **Poster session and discussions** | | |
| **Closed workshop (members of WG 134 and invited persons)**<br>**Date**: Tuesday, Aug 28 **Time** | | | |
| Session 3: Status report on the MCP concept | | | |
| 09:00 | A critical review of the MCP concept and its impact on research on DOM biogeochemistry | Farooq Azam | Jiao |
| 09:30 | Open Discussion | | |
| 10:30 | **Coffee break** | | |
| 11:00 | Short statements by WG members on the MCP and its impact and applicability | WG members | Azam |
| 11:30 | Open Discussion | | |
| 12:00 | **Lunch at HWK** | | |
| Session 4:<br>The future of the WG 134 - MCP mechanism based research and "Protocols/Standards for Microbial/ Biological Sequestration of Carbon in the Ocean" | | Members of WG 134 | Jiao / Azam |
| 14:00 | Proposal to become an IMBER working group | Carol Robinson | |
| 14:30 | Ocean carbon sink and protocols | Yao Zhang | |
| 14:50 | Permanent observatory & on board movable lab & mesocosm system | Rui Zhang | |
| 15:05 | Chinese open programs: 2011 program,<br>MOE international center,<br>Planed MCP studies funded by M. S&T of China | Nianzhi Jiao | |
| 15:30 | Other contributions and discussions;d<br>Discussions on wrapping up the work of WG 134 e.g. Review L&O, Summary | Farooq Azam and WG 134 members | |
| 15:40 | Open Discussion | | |
| 16:10 | **Coffee break** | | |
| Session 5: Scheduled / planed MCP academic events | | | |
| 16:40 | IMBIZO workshop (one of the three IMBER workshops) 2013 | Nianzhi Jiao<br>Farooq Azam<br>Carol Robinson<br>Helmuth Thomas | |

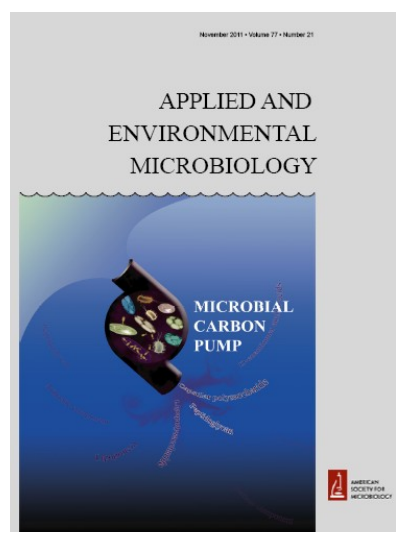
| | | | |
|---|---|---|---|
| 17:00 | ISME-15 in Korea 2014 | Sang-jin Kim | |
| 17:15 | Financial statements | Shuya Luo | |
| 17:25 | Closing remarks | Farooq Azam | |
| 18:00 | **Dinner in Bremen** | | |
| **Date**: Wednesday, Aug 29, Departure | | | |


**7) IMBER IMBIZO III**: The future of marine biogeochemistry, ecosystems and societies, Goa, India, 28-31 January, 2013.

IMBIZO III will comprise three interdisciplinary workshops, held in parallel. To ensure an environment conducive to interaction and discussion, each workshop will be limited to approximately 40 participants. WG 134 members (Nianzhi Jiao, Farooq Azam and Carol Robinson), together with Helmuth Thomas, will convene the workshop 2 of IMBIZO III on “The impact of anthropogenic perturbations on open ocean carbon sequestration via the dissolved and particulate phases of the biological carbon pump”.

8）The 15th International Symposium on Microbial Ecology (ISME-15) will be held in Korea, with WG134 members Kang-jin Kim, Nianzhi Jiao, Joe Zhou are involved as local organizers.  (ISME participants are about 2000).

## II. WG134 Publications




1) **AEM special section**
   A special section on MCP in *Applied and Environmental Microbiology* was published in 2011.(**Applied and Environmental Microbiology, Nov. 2011, Vol. 77, No. 21**) .
2) **Molecular biogeochemical provinces in the eastern Atlantic Ocean**
   Editors: Boris Koch, Gerhard Kattner, Gerhard Herndl. Special Issue in *Biogeosciences*, 2011. This issue includes a preface and 8 papers covering aspects of marine organic carbon fluxes and the molecular mechanisms which convert labile biomolecules into semi-labile and refractory organic compounds in the Atlantic surface ocean. Phytoplankton

characterization, bacterial abundance and production and radiocarbon dating provided the metabolic context for the DOM characterization.

**3)** Kawasaki N, R Sohrin, H Ogawa, T Nagata and R Benner. 2011. Bacterial carbon content and the living and detrital bacterial contributions to suspended particulate organic carbon in the North Pacific Ocean. Aquat. Microb. Ecol. 62: 165-176.

**4)** Kaiser K and R Benner. 2012. Organic matter transformations in the upper mesopelagic zone of the North Pacific: chemical composition and linkages to microbial community structure. J. Geophys. Res., 117, C01023,doi: 10.1029/2011JC007141.

**5)** Edgcomb V P, W Orsi, J Bunge, S-O Jeon, R Christen, C Leslin, M Holder, GT Taylor, P Suarez, R Varela and S Epstein. 2011. Protistan microbial observatory in the Cariaco Basin, Caribbean. I. Pyrosequencing vs. Sanger insights into species richness. ISME J. 5:1344-1356.

**6)** Orsi W, V P Edgcomb, S O Jeon, C Leslin, J Bunge, G T Taylor, R Varela and S Epstein. 2011. Protistan microbial observatory in the Cariaco Basin, Caribbean. II. Habitat specialization. ISME J. 5:1357-1373.

**7)** Orsi W, Y C Song, S Hallam and V P Edgcomb. 2012. Effect of oxygen minimum zone formation on communities of marine protists. ISME J. doi: 10.1038/ismej.2012.7

(B) Publication in planning

The Encyclopedia of Life Sciences Series (ELOSS), one of UNESCO's publication arms, has invited WG 134 member **Ramaiah Nagappa** to contribute a chapter on Microbial Carbon Pump in the Ocean. We will seek to publish the output of the IMBIZO III workshop 2 as a special issue of *Biogeosciences*. Additional research papers related to the MCP are expected to continue to be published in relevant journals.

## III. Research projects

1) An NSFC major research plan (RMB 4 million) on microbial ecology process and its role in carbon cycling in South China Sea was launched in 2011 (PI: **Nianzhi Jiao**).
2) Regressive evolution of photosynthesis in anoxygenic prokaryotes. Project GACR P501/10/0221. Principal Investigator: **Michal Koblizek**, 2010-2014.
3) The use of lipid biomarkers for analyses of composition and physiological status of aquatic microbial communities. Project AV CR M200200903. Principal Investigator: **Michal Koblizek**, 2009-2011.
4) R&D project Research Center Algatech (EC funded). Co-PI: **Michal Koblizek**, 2011-2014.
5) A cruise proposal to the Danish Center for Marine Research has been funded (Leader: **Colin A. Stedmon**), which will be a part of the project "North Atlantic-Arctic coupling in a changing climate: impacts on ocean circulation, carbon cycling and sea-ice." The primary research focus that is relevant to the WG will be to use RDOM signature of water masses to differentiate between and trace freshwater from the Arctic Ocean and Greenlandic glacial melt. The cruise will take place in September 2012.
6) A major project proposal (USD 5 million) on the MCP has been approved by the Ministry of S&T of China. It will last for 5 years starting from 2013. (PI: **Nianzhi Jiao**)
7) Two cruises designed to evaluate organic carbon dynamics of the meso- and bathypelagic ocean have been funded by the U.S. National Science Foundation. **Dennis Hansell** will serve a chief scientist on these cruises, one to the Ross Sea in January-March 2013 and the other in the Gulf of Alaska in June-July 2013.

8) A MINECO (Spanish Ministry of Economy and Competitiveness) project (Leaders: J. Arístegui & WG134 member **X.A. Álvarez-Salgado**; Participant: WG134 member **G.J. Herndl**) to study dark-ocean water mass boundaries and mixing zones as “hot-spots” of microbial biodiversity and biogeochemical fluxes across the Mediterranean Sea and the Eastern North Atlantic has been launched on January 2012. The project includes a trans-Mediterranean cruise from the Levantine basin to the Gulf of Cadiz in July 2013. The total budget is 1.37 M€ including a PhD fellowship and ship time of R/V *Sarmiento de Gamboa.*
9) Development of an Autonomous Instrument for Combined in situ Tracer Incubation Studies and Preservation of Microbial Samples for Genomic, Transcriptomic, and Proteomic Analysis (PI: **Virginia Edgcomb**) (C. Taylor, Co-PI) NSF Ocean Technology and Interdisciplinary Coordination (OCE-1061774).
10) WG 134 member **Virginia Edgcomb**'s investigation of protist communities in a coastal OMZ (Saanich Inlet, British Columbia, Canada) collaboration with S. Hallam, UBC.
11) The Ministry of Earth Sciences of Government of India has provided a 5-year grant to WG 134 member **Ramaiah Nagappa** to investigate on “Qualitative and Quantitative Evaluation of Processes Governing Microbial Carbon Pump in the Indian Ocean Regions”.

## IV. Academic Honors

1) WG134 member Prof. **Nianzhi Jiao** was elected a member of the Chinese Academy of Sciences (CAS) in 2011.
2) WG 134 member Prof. **Chen-Tung Arthur Chen** was reappointed a vice chair of the International Geosphere Biosphere Programme in 2011.
3) WG 134 member **Ronald Benner** was elected a Fellow of the American Geophysical Union (AGU) in 2011.
4) WG 134 member **Virginia Edgcomb** was awarded the 2012 Seymour H. Hutner Prize in Protistology by International Society for Protistologist.
5) WG 134 member **Michal Koblizek** has continued his service to the Czech National Committee of the Intergovernmental Oceanographic Commission, UNESCO.
6) WG 134 co-chair **Farooq Aazm** is selected by the ASM to receive the 2013 D. C. White Award for interdisciplinary research and mentoring.

### 2.2.4 SCOR/InterRidge WG 135: Hydrothermal Energy Transfer and its Impact on the Ocean Carbon Cycles (2008) *Coustenis*

**Terms of Reference:**

- **Synthesize** current knowledge of chemical substrates, mechanisms and rates of chemosynthetic carbon fixation at hydrothermal systems as well as the transfer of phytoplankton-limiting micronutrients from these systems to the open ocean.
- **Integrate** these findings into conceptual models of energy transfer and carbon cycling through hydrothermal systems which would lead to quantification of primary production in view of a future assessment of the contribution of these systems to the global-ocean carbon cycle.
- **Identify critical gaps** in current knowledge and proposing a strategy for future field, laboratory, experimental and/or theoretical studies to bridge these gaps and better constrain the impact of deep-sea hydrothermal systems on ocean carbon cycles.

**Co-chairs:**

Nadine Le Bris
Universite Pierre et Marie Curie
66650 Banyuls-sur-Mer
FRANCE
Email: Nadine.Le.Bris@ifremer.fr

Chris German
Geology & Geophysics
Woods Hole Oceanographic Institution
Woods Hole. MA 02543 USA
Phone: +1 508 289 2853
Email: cgerman@whoi.edu

| **Other Full Members** | **Associate Members** |
|---|---|
| Wolfgang Bach (Germany) | Philip Boyd (New Zealand) |
| Loka Bharathi (India) | Thorsten Dittmar (Germany) |
| Nicole Dubilier (Germany) | Julie Huber (USA) |
| Katrina Edwards (USA) | Bob Lowell (USA) |
| Peter R. Girguis (USA) | George W. Luther III (USA) |
| Xiqiu Han (China-Beijing) | Tom McCollom (USA) |
| Louis Legendre (France) | W.E. Seyfried, Jr. (USA) |
| Ken Takai (Japan) | Stefan Sievert (USA) |
| | Margaret K. Tivey (USA) |
| | Andreas Thurnherr (USA) |
| | Toshitaka Gamo (Japan) |
| | Françoise Gaill (France) |

**Executive Committee Reporter:** Missy Feeley

SCOR-WG 135 joint with InterRidge

**Hydrothermal Energy Transfer and its Impact on the Ocean Carbon Cycles**

Co-Chairs: Nadine Le Bris (France) and Chris German (USA)

Annual WG Report 9/08/2012

**Hangzhou meeting**. The second WG group Meeting was held in Hangzhou, China on 10-11 October 2011. It was hosted by the Second Institute of Oceanography, State Oceanic Administration of China. Dr Xiqiu Han, a member of the WG, was greatly appreciated as our host and organizing committee leader. The visit included additional exchanges with colleagues and seminars for students from several meeting attendees. The group of attendees involved Loka Bharathi (India), T. Gamo (Japan), Chris German (US), G.W. Luther (US), X. Han (China), N. Le Bris (France) and L. Legendre (France), Sylvia Sander (NZ), and Stefan Sievert (US).

The first objective of the meeting was to initiate the discussion on the two WG review papers that aim at synthesizing knowledge on (1) carbon fixation processes at the seafloor and shallow subseafloor and the contribution of the different biological pathways in ecosystem primary production, and (2) export of iron from the subseafloor to the upper ocean and the related impact of vent emissions on ocean carbon budgets. The second objective was to discuss the integration of this information into conceptual models aimed to address the role of ridge hydrothermal systems on ocean carbon biogeochemistry on a more quantitative basis. Discussions of two subgroups, lead by L. Legendre on the second day, set the basis for these approaches.

**Modelling.** The first subgroup addressed the productivity of vent ecosystems, from the perspective of estimating carbon that is fixed chemosynthetically and can be transferred to consumers or to the water column. The second subgroup considered the potential role that hydrothermal systems may play in regulating the global-scale biogeochemical cycle of the micro-nutrient Fe in the deep ocean, and thus the global ocean carbon budget. The building of the two conceptual models has already generated interesting discussions on research priorities and the degree of simplification that is necessary for the initial models.

Following the Hangzhou meeting, the two sub-groups have been focussing upon formalizing the model approach with the help of L. Legendre. A preliminary version of the water column Fe model was completed by early 2012, and a revised version of the model is now being developed. A similar approach has been initiated for the seafloor ecosystem model. As done for the water column model, the task requires simplifying the number of fluxes considered in the initial version of the model, and constraining the unknowns for such complex systems that involve a variety of chemoautotrophic pathways and related abiotic conditions/energy sources. Further plans are to circulate draft paper versions to the whole WG, to allow integration of contributions from other WG members.

**International workshop.** Multiple options to coordinate a workshop in late Summer 2012 have been explored, but proved impossible in terms of availability of suitable venues in Europe at dates that did not conflict with the organisers' own schedules and/or other InterRidge-related events. The early-2013 period is now being considered for the organization of this event.

### 2.2.5 WG 136: Climatic Importance of the Greater Agulhas System (with WCRP and IAPSO) *Compton*

(2009)

**Terms of Reference:**

- Facilitate collaboration between existing and planned (observational and modeling) studies in the greater Agulhas Current system, such that we minimize the gaps in the research, maximize the scientific outcome, and encourage estimates on the robustness of key findings (e.g. multiple model ensembles).
- Write a review paper (for publication in a peer-reviewed journal) that highlights the importance of the greater Agulhas system in terms of global climate, reviewing the current levels of both understanding and uncertainty as to how changes in the system come about, how they effect climate, and vice versa.
- Identify key components of the circulation which deserve further study through physical/palaeo observations and/or models, some of which may act as indices/proxies (through sustained observation) that can help describe the state of the Agulhas system on decadal to climate time scales. Communicate these findings to regional and international strategic planning committees, such as CLIVAR, GOOS, GEOSS, GO-SHIP etc.
- Write a proposal for, and organize, a Chapman Conference on the "Climatic Importance of the Greater Agulhas System", to be held in 2012.

**Co-chairs:**

| | |
|---|---|
| Lisa Beal (USA)<br>RSMAS/MPO<br>University of Miami<br>4600 Rickenbacker Causeway<br>Miami, FL 33149<br>Phone:+1- 305-421-4093<br>lbeal@rsmas.miami.edu | Arne Biastoch (Germany) Leibniz-Institut für Meereswissenschaften (IFM-GEOMAR)<br>FB1 Ozeanzirkulation und Klimadynamik<br>Düsternbrooker Weg 20<br>24105 Kiel<br>Germany<br>phone: ++49 (0)431 600-4013<br>fax : ++49 (0)431 600-4012<br>abiastoch@ifm-geomar.de |
| **Other Full Members**<br>Meghan Cronin (USA)<br>Will de Ruijter (Netherlands)<br>Juliet Hermes (South Africa)<br>Johann Lutjeharms (South Africa) - deceased<br>Graham Quartly (UK)<br>Tomoki Tozuka (Japan)<br>Rainer Zahn (Spain) | **Associate Members**<br>Shekeela Baker-Yeboah (USA)<br>Jeff Book (USA)<br>Tom Bornman (South Africa)<br>Paolo Cipollini (UK)<br>Ian Hall (UK)<br>Alan Meyer (South Africa)<br>Wonsun Park (Germany)<br>Frank Peeters (Netherlands)<br>Pierrick Penven (France)<br>Herman Ridderinkhof (Netherlands)<br>Jens Zinke (Netherlands) |

**Executive Committee Reporter:** John Compton

# WG 136 Annual Report 2011/2012

SCOR Working Group 136: On the Climatic Importance of the Greater Agulhas Current System.

Lisa Beal and Arne Biastoch, co-Chairs

We have not had a WG meeting since our last annual report. Our next and final meeting will be in October, during the Chapman Conference in South Africa. However, we have been continuing to work towards our third and fourth terms of reference by (1) Formulating and delivering a plan to CLIVAR/WCRP for sustained observations in the greater Agulhas region as part of GOOS/GCOS, and (2) Designing and organizing a Chapman Conference on the Agulhas system.

## 1. WG Membership and Terms of Reference

Our roster of full members has changed in the wake of the sad passing of Johann Lutjeharms last year, who was the most internationally recognized scientist and researcher of the Agulhas. We have arranged for a Memorial Lecture in Johann's honour, to be given by Arnold Gordon during the Chapman Conference in October. Our full members are now Lisa Beal, Arne Biastoch, Meghan Cronin, Will de Ruijter, Juliet Hermes, Francis Marsac, Graham Quartly, Mike Roberts, Tomoki Tozuka, and Rainer Zahn.

As a reminder, our terms of reference are the following:

1. To facilitate collaborations between existing and planned studies of the region (ongoing).
2. Write a review paper on the climatic importance of the greater Agulhas (complete).
3. Identify key components of the region that deserve further study and/or sustained observations (complete - reported in Section 2 below).
4. Organize a Chapman Conference with participation of the African science community (scheduled for October - see Section 3).

A further goal of the WG was to contribute to capacity building in East African countries that border the Great Agulhas System (ongoing).

## 2. Science Plan for Sustained Observations in the Greater Agulhas System

Following our meeting last year, held in combination with the "In-Region Capacity Building Workshop of the WMO/IOC Data Buoy Cooperation Panel (DBCP)" in Mauritius (May 2-6 2011), and the discussions there, we developed a Science Plan and submitted it to the International CLIVAR Indian Ocean Panel (IOP) for consideration as an official element of IndOOS and GOOS. IndOOS contained no plans for sustained observations anywhere along the western boundary.

**The WG136 Science Plan for the Agulhas region was adopted as part of IndOOS in March 2012**. The main elements of our observing system plan are:

1. **A surface flux reference station**. The Agulhas is a region of strong net heat loss from the ocean, which influences storm track development and rainfall over Africa. A

reference station will provide in situ, high-quality, high-resolution time series of episodic and long-term changes in the climate and ecosystems. Importantly, a reference mooring will provide the means for improving and assessing errors in synthesis surface flux products. This would be the first such mooring in the Southern Hemisphere.

2. **A reference mooring in the Mozambique Channel.** Flow through the Mozambique Channel is part of the global thermohaline circulation, linking inflow from the Pacific Ocean with the Agulhas Current. A decade of observations in the Channel (LOCO, INATEX) represent the only oceanic time series to exceed even one year in the region and have shown important changes linked to Indian Ocean Dipole events. A reference mooring (or two), in combination with satellite sea surface height data, can continue to provide information on decadal variability in the region.
3. **Monitoring array across the Agulhas Current**. The volume, heat, and freshwater transports of the Agulhas provide a measure of the Indian Ocean gyre and overturning strengths, and are related to leakage fluxes into the Atlantic Ocean. Changes in Agulhas leakage have been implicated in past climate transitions, through influence on the Atlantic meridional overturning circulation. Sustained observations of the most significant Western Boundary Current in the Indian Ocean are a priority.

The full Science Plan, together with our response to IOP member reviews, which includes more details of each of the three components above, are provided with this report. On behalf of IOP, Yukio Masumoto wrote,

> "IOP agrees with the view shown by SCOR WG 136 and fully supports the recommendation, and decided to include the three proposed observation components as a part of IndOOS."

Our next steps are to develop an Implementation Plan. The observing system will only be successfully implemented with international participation and cooperation. In particular, partnerships in South Africa are vital. Discussions towards this are scheduled as part of our Chapman Conference and final WG meeting in October later this year.

**3. Chapman Conference, October 8-12, 2012, Stellenbosch, South Africa**
Our Chapman Conference proposal was successful and over the last six months we have been working towards making the conference a success. Details of the conference program can be found at the AGU Web site: http://www.agu.org/meetings/chapman/2012/ecall/index.php. With our goals to facilitate collaborations, develop new programs, and build capacity in Africa (TOR 1), we chose to hold the conference in South Africa and to schedule ample group activities and discussions. WG members raised $95,000 towards conference costs and travel support, which is substantially greater than is typical, according to AGU staff. Support comes from a variety of sources, including Thermoscientific, *Nature*, Dutch institutes NIOZ and IMAU, ONR Global, IRD (Institut de Recherche pour le Développement), IOC Perth, as well as major contributions from NOAA, NSF, and IUGG.

We have 16 confirmed invited speakers, from Europe, the United States, Japan, and Africa, and a total of 103 abstracts. The South African Minister for Science and Technology, Mrs Naledi

Pandor, will open the conference, and the AGU President, Mike McPhaden will close. Immediate past president of IAPSO, Lawrence Mysak, will give a short welcome on behalf of IAPSO and IUGG. There will be a Johann Lutjeharms Memorial Lecture given by Arnold Gordon. We are currently finalizing the program with AGU staff. Acceptance letters and registration details will go out this week.

# **Science Plan for the Southwest Indian Ocean region and Greater Agulhas System**: Recommendations for sustained observations as a component of the Indian Ocean Observing System and GOOS/GCOS.

SCOR Working Group 136, June 2011

## The Significance of the Region

The Greater Agulhas System is a key component of the global ocean circulation and climate (Beal et al., Nature, 2011). Within the Indian Ocean it is an integrator of dynamical changes related to wind, density, and planetary wave signals, as well as an integrator of water mass (air-sea flux) changes throughout the basin and beyond. Changes in these signals can result from interannual, decadal, and long-term trends related to Asian Monsoon, Indian Ocean Dipole (IOD), El Nino-Southern Oscillation (ENSO), Southern Annular Mode, and anthropogenic climate change. The Agulhas draws waters from the Red Sea, Arabian Basin, tropical gyre, Indonesian Throughflow, subtropical gyre, Atlantic, and Southern Oceans. The Agulhas system both responds to these signals and feeds back on them, for instance through its heat transport which will change in relation to wind and air-sea flux forcings over the basin. Its strength is also fundamental to the strength of the Indian Ocean overturning circulation.

Globally, the Greater Agulhas System, through its Retroflection and Leakage of warm and salty waters into the Atlantic, forms a choke point of the thermohaline circulation, feeding waters into the upper arm of the Atlantic meridional overturning circulation. Paleoclimate reconstructions show that Leakage has peaked at the onset of glacial terminations throughout the last 500 Kyrs and ocean model experiments suggest that ongoing increases in Leakage under anthropogenic climate change could strengthen the Atlantic overturning, at a time when warming and meltwater input in the North Atlantic is predicted to weaken it.

More regionally, the Greater Agulhas system (including its sources) impacts rainfall and storm development over South Africa, and coral health, productivity, and distribution of fishes within the marine ecosystems and fisheries of developing East African nations, such as Kenya, Tanzania, Madagascar, and Mozambique. These nations and their marine resources are vulnerable to water mass changes imported from across the basin (e.g. increased heat content and pCO2), which are stirred and mixed with coastal waters. Mozambique eddies have also been shown to influence phytoplankton production and aggregation, and the foraging behaviour of top marine predators like swordfish and tuna, such that variability in the important pelagic fisheries of the Agulhas are likely associated with remotely forced changes to the eddy kinetic energy of the system.

**Targeted Observations in the Greater Agulhas System as an Integral Component of IndOOS and GOOS**

The importance of understanding climate variability on decadal timescales has come to the forefront over the last decade, with the need to distinguish natural modes of variability of the ocean-atmosphere system from anthropogenic changes. In response, the international community, particularly through international CLIVAR working panels (such as the Indian Ocean Panel) and OceanObs white papers, have developed a collaborative plan for a global ocean observing system (GOOS), consisting largely of tropical arrays, ARGO floats, surface drifters, repeat CTD and XBT sections, and satellite data. **Observations at the western boundary of the Indian Ocean - i.e. of the Greater Agulhas System - are a vitally important missing element to this observing system.** Here are several reasons why sustained observations in the Greater Agulhas System should be an explicit component of IndOOS and GOOS:

- The Agulhas system is linked upstream to tropical IOD events which are largely coupled with Pacific winds and ENSO, and downstream with the strength of the Atlantic overturning circulation, making it an effective link between the Pacific, Indian, and Atlantic tropical arrays.
- Monitoring of the Gulf Stream and Kuroshio is already underway. No such monitoring exists in the Southern Hemisphere, where the Agulhas is the strongest and most significant of the western boundary currents.
- Sustained observations of the Agulhas system can be likened to having a “finger on the pulse” of climate variability over the Indian basin, because the Agulhas is a natural integrator of water mass and dynamical signals throughout the basin.
- Climate change projections predict substantial changes in the Agulhas region, including warming and a poleward shift in the westerlies, resulting in increased interocean exchange and a spin up of the Southern Hemisphere "supergyre". Increased leakage into the Atlantic Ocean could have feedbacks onto the climate system through changes in the Atlantic Meridional Overturning Circulation (Beal et al., 2011).
- Ocean and climate models need *in situ* observations for verification. In a highly variable and eddying regime like the greater Agulhas system, robust, long-term data are crucial for verification of models and climate predictions. Continuous coverage in time is essential to constrain models to allow the evaluation of key quantities like Agulhas leakage, which are extremely difficult to observe.
- Unlike the Gulf Stream or Kuroshio, the large moisture source of the warm Agulhas Current region contributes significantly to continental precipitation, where it feeds societal water resources (Gimeno et al., 2010).
- Observations of the Agulhas system need to be targeted. As a dynamic and divergent system, observations at the western boundary are not achieved effectively with floats and drifters, because they have a short residence time. Sea surface height data is contaminated at the land-ocean boundary by small-scale tropospheric moisture changes and aliased tides. Sea surface temperature data are often obscured by clouds as a result of the

expansion of the marine boundary layer and enhanced convection over the warm waters of the Agulhas. High density XBT sections can provide upper ocean heat content in the Agulhas Current off Durban (IX21, ~quarterly) and in the Agulhas leakage off Cape Town (AX25, ~semi-annually), but lack the temporal resolution and density information to provide decadal variability of heat and mass transports.

- The developing East African countries which border the Greater Agulhas system are vulnerable to degradation of their marine resources and fisheries, and to severe weather systems. They would benefit from sustained observations of some of the key oceanic processes which ultimately impact their coastal zones. Such data will improve both regional ocean and weather forecasting and preparedness.

**A Science Plan for Sustained Observations in the Greater Agulhas System**

As stated in SCOR Working Group 136 (On the Climatic Importance of the Greater Agulhas System) Terms Of Reference (TORs), we are mandated to: "Identify key components of the circulation which deserve further study through physical/palaeo observations and/or models, some of which may act as indices/proxies (through sustained observation) that can help describe the state of the Agulhas system on decadal to climate time scales" (TOR 3). And to: "Communicate these findings to regional and international strategic planning committees, such as CLIVAR, GOOS, GEOSS, GO-SHIP etc".

At a recent meeting of SCOR WG 136, held jointly with the 2nd Data Buoy Cooperation Panel (DBCP) Africa/Western Indian Ocean Capacity Building Workshop (May 2-6, Balaclava, Mauritius), a Science Plan for the southwest Indian Ocean and Greater Agulhas System was discussed amongst a group of about 50 regional and international scientists. International groups/programs represented included Agulhas-Somali Current Large Marine Ecosystem (ASCLME) project of the United Nations Development Plan (UNDP), the World Meteorological Organisation (WMO), and UNESCO's Intergovernmental Oceanographic Commission (IOC). Guided by principles outlined in the OceanObs09 Framework for Sustained Ocean Observing, it was identified that sharing of data and resources (e.g. ship time) are essential to achieve our goals for the region, which are based on strong community and collaborations that facilitate data collection, knowledge transfer, new research, and sustained observations. Hence, community and collaboration building will be continued via a Chapman Conference proposed by WG 136 to be held in South Africa in 2012. During our Science Plan discussions, the resources and needs of regional scientists, including those from Kenya, Tanzania, Mozambique, Madagascar, Mauritius, and South Africa, were shared and acknowledged. **The following three key components for a sustained observing system are recommended:**

★ **An air-sea flux buoy in the Agulhas System**, positioned within the region of maximum negative surface fluxes. These represent some of the largest surface fluxes anywhere in the world.

★ **Long-term monitoring of the water masses and transports of the Agulhas Current**. A plan to monitor mass transports via a ground-truthed satellite proxy is underway (Beal, Agulhas Current Time-series), but important heat content and water mass changes remain unobserved. A strategic plan for a multi-country long-term array is vital.

★ **A reference mooring in the Mozambique Channel** to continue an existing 10-year time series (Ridderinkhof and de Ruijter, Long-term Ocean Climate Observations, INdian ATlantic EXchange in past and present climate). LOCO is the only time series in the region to exceed even one year, excepting sea level data. By maintaining a reference mooring or two and utilising sea surface height data, this time series can continue and provide rare *in situ* information of decadal variability in the region.

Following the process described by the OceanObs09 Task Team for Integrated Framework for Sustained Ocean Observing**, these three components should become part of the strategic plan of IndOOS and GOOS as soon as possible**. Developing sustained observations in the southwest Indian Ocean is seen as a priority, both by the international experts of SCOR WG 136 and by regional scientists. Once a part of GOOS, developing these components will become an official goal of the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM), who can help seek commitments from regional countries, and provide technical training. Moreover, regional scientists will gain leverage to lobby their managers and government representatives to support these observations, in particular through ship time, as part of an international endeavour of both regional (fisheries and forecasting) and far-reaching scientific significance (climate). Finally, international scientists can justify their goals in working with regional scientists to sustain these observations.

**Additional Scientific Priorities for the Region**

During discussions, several important observations/studies needed with some urgency in the region were noted, particularly by regional scientists. **These are not seen as key components of a global observing system, but are recognised as important near-term goals of scientific significance**. Scientists in Kenya face the extreme challenges of piracy, theft, and vandalism in the waters offshore Kenya and Somalia and are unable to collect measurements from ships or surface buoys as a result. They need ocean observations to study the **variability of the East Africa Coastal Current** (as far as we are aware, heat and mass transport variability is entirely unknown) and to assimilate for weather forecasting. It was suggested that unmanned vehicles - both ocean and wave gliders - could be the answer to making measurements in this region. Such vehicles could collect temperature, salinity, and velocity data across the East African Coastal Current, as well as meteorological measurements, leading to improved regional forecasting. In the case of an ocean glider program, DBCP and ASCLME are already committed to helping launch a training program and pilot mission for the Kenyans to get them started. However, a full-blown program will need international collaboration and funding.

Scientists from South Africa, Seychelles, and Mauritius expressed the importance of measuring the **variability of the South Equatorial Current**, which directly impinges on the fisheries and marine ecosystems of the latter two island nations. For example, these measurements could greatly improve forecasting of coral bleaching events. There is a good opportunity to measure variability in the South Equatorial Current by adding instrumentation underneath the existing ATLAS moorings at 8°S and 16°S. A 75 kHz ADCP would profile currents down to 800 m depth and could be combined with a thermistor chain. This would be of minimal cost, with no extraneous ship time involved, over and above that currently required for regular maintenance of the moorings. The Seychelles currently provide a coastguard escort to assist in the maintenance of the 8°S mooring, which is within the piracy zone.

Toxic algal blooms occurring to the south and east of Madagascar during austral summer have adversely affected the health of fish, turtle and shark populations and caused some human fatalities. Scientists from Madagascar have an **urgent need to gather measurements to assess the physical and biochemical factors causing the toxic bloom and its extent and longevity.** A near-coastal bloom occurs every year and for approximately one year out of two a related feature extends thousands of kilometres offshore, with chlorophyll concentrations far exceeding those of a typical spring bloom in the region. UK scientists have studied the bloom using satellite data, and have collected biological samples during one summer. It's development and offshore extent could be linked to the South Indian Counter Current (SICC), a broad eastward surface current with water mass properties which show it to be connected to a recirculation of the Agulhas system. The origins and connections of the SICC and its importance for heat transports, water mass transformation, blooms, and eddy formation are largely unknown. An international program to collaborate with Madagascan scientists and gather in situ physical and biological measurements is needed. Coordination with the Dutch and their new mooring program in the East Madagascar Current could lead to sharing of ship time and other resources.

**Science Plan for the Southwest Indian Ocean region and Greater Agulhas System**, SCOR WG 136: Response to IOP Reviewers

In response to formal reviews of the Science Plan by CLIVAR Indian Ocean Panel members we here provide clarifications and further justifications for the three main elements of a sustained observing system in the southwest Indian Ocean (Sections 1 - 3). In addition, we include some ideas and ongoing activities related to implementation of sustained observations in the southwest Indian Ocean (Section 4).

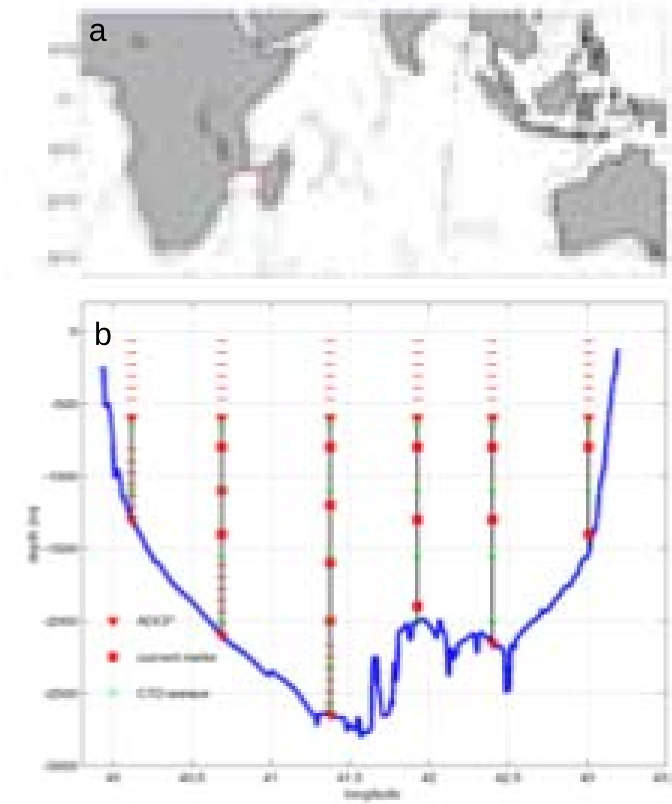



Figure 1: (a) Location of the Mozambique Channel mooring array, (b) Configuration of the array.

**1. Reference Mooring in the Mozambique Channel**

The Mozambique Channel moorings (Ridderinkhof & de Ruijter, Long-term Ocean Climate Observations (LOCO), INdian ATlantic Exchange in past and present climate (INATEX)) represent the only oceanic time series in the region to exceed even one year, excepting sea level data. By maintaining a reference mooring or two and utilising sea surface height data, this time series can continue to provide rare *in situ* information of decadal variability in the region.

The mooring array across the narrows of the Mozambique Channel has been maintained since 2001 (Ridderinkhof *et al*., 2010, figure 1). The array captures a western boundary flow which is part of the global thermohaline circulation, linked upstream to the Pacific via the South Equatorial Current and Indonesian Throughflow (Schott *et al*., 2010), and downstream to the Atlantic via the Agulhas Current. The array data has shown that southward flow through the Channel is manifested by a series of large, deep-reaching anticyclonic eddies carrying substantial amounts of heat and salt (Swart *et al*., 2010). Farther south these eddies can interact with and destabilise the Agulhas Current, causing large meanders which propagate downstream and affect the frequency and timing of Agulhas Ring shedding (Penven *et al*., 2006). Intermediate and deep Atlantic and Antarctic water masses flow in the

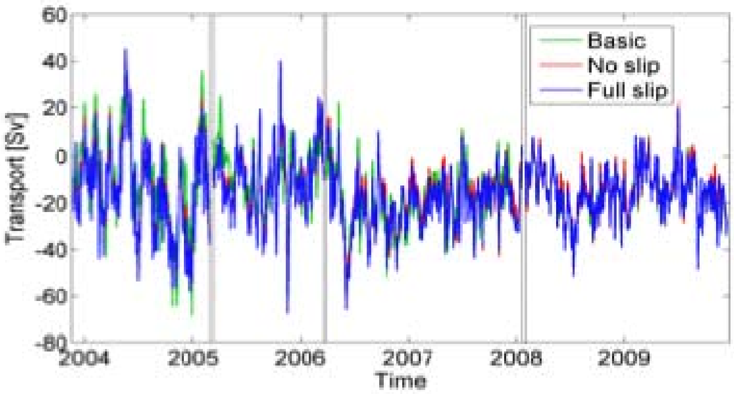



Figure 2: Time series of transport through the Mozambique Channel (three curves represent different lateral boundary conditions).

Tropical and subtropical modes of variability from the Pacific and Indian Oceans converge in the Channel and are measured at the array. For instance, the full 2006-2009 Indian Ocean Dipole cycle is captured by the array, revealing surprisingly large transport fluctuations within the Channel and an apparent regime shift in both the mean and variability of the transport since May 2006 (Ridderinkhof *et al*., 2010, figure 2). Further, there is evidence that this variability propagates southward and modulates the Agulhas Retroflection and leakage on interannual time scales (Schouten *et al.*, 2002), although simultaneous, long term measurements downstream would be necessary to confirm this hypothesis.

Comparing a number of models with observations from the array, Van der Werf *et al.* (2009) show that simulations have limited success capturing the characteristics of the Channel flow, largely because of its eddying nature. Furthermore, the Mozambique array data are the only measure of how climate modes, such as Indian Ocean Dipole and El Niño-Southern Oscillation, affect transports in the Indian Ocean. Therefore, continuation of these observations, in some capacity, is vital. In February 2012, the existing 7-mooring array will be replaced with 3 'representative' moorings , a step towards development of an implementation plan for a much reduced monitoring array (figure 6).

Penven, P., J. R. E. Lutjeharms & P. Florenchie (2006), Madagascar: A pacemaker for the Agulhas Current system; Geophys. Res. Letters, 33, doi:10.1029/2006GL026854, 2006.

Ridderinkhof, H., P. M. van der Werf, J. E. Ullgren, H. M. van Aken, P. J. van Leeuwen, and W. P. M. de Ruijter (2010), Seasonal and interannual variability in the Mozambique Channel from moored current observations, J. Geophys. Res., 115, C06010, doi:10.1029/2009JC005619.

Schott, F. A., S.-P. Xie, and J. P. McCreary Jr. (2009), Indian Ocean circulation and climate variability, Rev. Geophys., 47, RG1002, doi:10.1029/2007RG000245

Schouten, M. W., W. P. M. de Ruijter, & P. J. van Leeuwen (2002), Upstream control of Agulhas Ring shedding, J. Geophys. Res., 107, 3109.

Swart, N. C., J. R. E. Lutjeharms, H. Ridderinkhof, & W. P. M. de Ruijter (2010), Observed characteristics of Mozambique Channel eddies, J. Geophys. Res., 115, C09006, doi:10.1029/2009JC005875.

van der Werf, P. M., P. J. van Leeuwen, H. Ridderinkhof, & W. P. M. de Ruijter (2010), Comparison between observations and models of the Mozambique Channel transport: Seasonal cycle and eddy frequencies, J. Geophys. Res., 115, C02002, doi:10.1029/2009JC005633.

## 2. Surface flux reference station in the Greater Agulhas System

The Agulhas system is a region of intense air-sea interaction (figure 3), due to enhanced latent and sensible heat fluxes. These heat fluxes impact the atmosphere both locally and remotely. Locally, the surface heat fluxes tend to destabilize the atmospheric boundary layer, causing deep convection and clouds, and causing high winds from aloft to be mixed down to the surface (Rouault and Lutjeharms, 2000, Liu et al. 2007). Similarly, barometric pressure gradients on either side of the atmospheric warm anomaly can result in wind convergence and deep convection (Minobe et al. 2008). Remotely, as a result of enhanced atmospheric baroclinicity, the Agulhas influences storm development, storm tracks, and the regional atmospheric circulation (Reason 2001, Nakamura and Shimpo 2004). Moreover, moisture fluxes from the Agulhas provide the primary source for rainfall over southern Africa (Gimeno et al. 2010) and can also contribute to extreme rainfall events and tornadoes over the continent (Rouault et al. 2002).

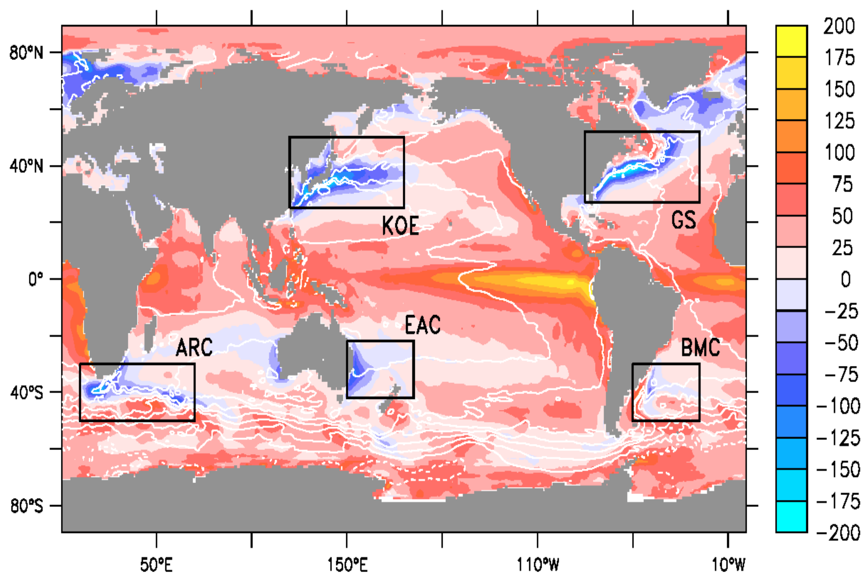



Figure 3. Climatological mean net surface heat flux into the ocean(Wm-2), with mean dynamic sea level contours shown in white. Boxes highlight the western boundary current extension regions in each basin. From Cronin et al. (2010).

The southern reaches of the Agulhas system are also characterized by large absorption of $CO_2$ (Takahashi et al. 2009), where both the biological and solubility pumps likely play a role. Model studies indicate that ocean acidification will lead to Southern Ocean surface waters becoming undersaturated with respect to calcium carbonate biominerals (e.g. aragonite, calcite) within a matter of decades (Orr et al. 2005).

Owing to the importance of the region scientific communities, in addition to ours, have recommended that a surface flux reference station be initiated in the Agulhas system: Cronin *et al.* (2010) in an OceanObs09 Community White Paper, and the CLIVAR high latitude flux working group. The need for a reference station mooring is to provide *in situ* high-quality, high-resolution time series of episodic and rapid changes in the climate and ecosystems, as well as long-term changes, and for investigating processes affecting variability. Importantly, a reference mooring provides the means for improving and assessing errors in synthesis products that can resolve the full horizontal, vertical and temporal structure of air-sea interaction by combining *in situ* and remotely-sensed data with numerical models.

The ideal location for the surface flux reference station is in a region of strong mean net surface heat loss from the ocean, and a region where the mooring can survive and be maintained (http://www.pmel.noaa.gov/people/cronin/ARC/ARC.html). While a surface mooring can be designed to survive relatively strong upper ocean currents, energetic deep eddies in combination with intense upper ocean currents can be very challenging and are believed to have caused the break to the Agulhas Return Current (ARC) surface mooring that was deployed at 30°E, 38.5°S (figure 4) in late 2010. This location was in the trough of a semi-permanent meander downstream of the Agulhas Plateau. However, in January 2011, an unusual early retroflection occurred, causing the jet to flow directly over the mooring site. Subsequent analyses of the German AG01 model output and the Japanese OFES output indicate that maximum deep currents at that location were greater than 35 $cms^{-1}$. These models, as well as other data sets, however, show that a location to the north and east (34°E, 36°S, figure 4) should be suitable for a surface mooring deployment.

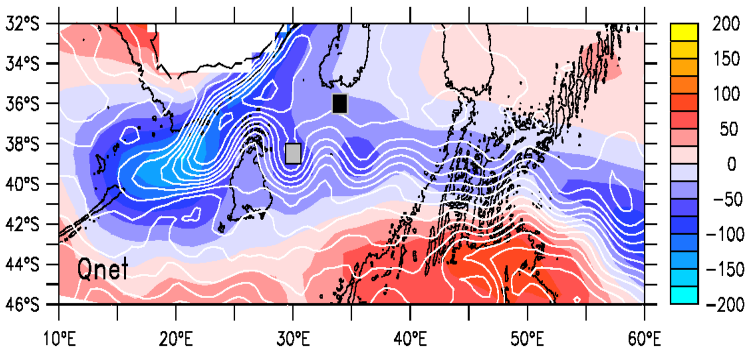


Figure 4. Same as Fig 1, but for Agulhas region. Grey square is original ARC site. Black square is proposed new site.

The ARC mooring deployment in 2010 demonstrated that there are strong partnerships that can be formed to support, maintain, and utilise the Agulhas system reference station data. Funding for the ARC mooring was provided by NSF and NOAA. Shiptime for the deployment cruise was provided by ASCLME and for the recovery cruise by TAAF. Educational outreach occurred through partnerships between the PMEL Ocean Climate Station group and NOAA Adopt-A-Drifter program, GLOBE-Africa, the South African Weather Service, SAEON and ASCLME. The data were also shown at the DBCP-2 capacity building workshop in Mauritius. While the deployment was short, the ARC mooring had 100% data return and are being used by a variety of groups, including a student at the University of Cape Town.

Cronin, M.F. & Co-Authors (2010), Monitoring ocean-atmosphere interactions in western boundary current extensions. Proceedings of the "OceanObs'09: Sustained Ocean Observations and Information for Society" Conference (Vol. 2), Venice, Italy, September 2009, Hall, J.; Harrison, D.E. & Stammer, D. (Eds.), ESA Publication WPP-306, doi:10.5270/OceanObs09.cwp.20

Gimeno, L., A. Drumond, R. Nieto, R. M. Trigo, and A. Stohl (2010), On the origin of continental precipitation. Geophys. Res., Lett., 37, 7 pp., L13804, doi:10.1029/2010GL043712.

Liu, W. T., X. Xie, and P. P. Niiler (2007), Ocean-atmosphere interaction over Agulhas Extension meanders, J. Climate, 20(23), 5784–5797.

Nakamura, H., and A. Shimpo (2004), Seasonal variations in the Southern Hemisphere storm tracks and jet streams as revealed in a reanalysis dataset. J. Climate 17(9), 1828-1844.

Orr, J.C. & Co-Authors (2005), Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. Nature, Vol. 437, No. 7059, pp. 681–686, doi:10.1038/nature04095.

Reason, C. J. C. (2001), Evidence for the influence of the Agulhas Current on regional atmospheric circulation patterns. Journal of Climate, 14(6): 2769-2778.

Rouault, M., and J. R. E. Lutjeharms, (2000), Air-sea exchange over an Agulhas eddy at the subtropical convergence, The Global Atmoshere and Ocean System, 7, 125–150.

Rouault, M., SA White, CJC Reason, JRE Lutjeharms, and I. Jobard (2002), Ocean–Atmosphere Interaction in the Agulhas Current Region and a South African Extreme Weather Event, Weather and Forecasting, 17(4), 655–669.

Takahashi, T. & Co-Authors. (2009), Climatological mean and decadal change in surface ocean pCO2 and net sea-air CO2 flux over the global oceans. Deep-Sea Research Part II: Topical Studies in Oceanography, Vol. 56, pp. 554-577, doi:10.1016/j.dsr2.2008.12.009

**Monitoring Array across the Agulhas Current**

Strong motivations for sustained observation of the Agulhas Current were given in the original Science Plan document, and are illustrated in detail in the Nature Review by Beal *et al.* (2011). In summary, the volume, heat, and freshwater transports of the Agulhas provide a measure of the Indian Ocean gyre and overturning, and are related to leakage fluxes into the Atlantic. Such observations must be targeted, because the western boundary is a dynamic and divergent system where transport measurements are not readily achieved with floats and drifters owing to their short residence time. In addition, the utility of “off the shelf” satellite data to monitor the system is seriously limited by the proximity of land, aliased tides, and cloudiness. A strategic plan for a multi-country, long-term array is needed.

Discussions have already begun among the Agulhas community, including regional and international oceanographers, on the design and logistics for an Agulhas monitoring system. Although it is too early to provide an implementation plan, an array of moored current meters, temperature sensors, and CTDs is currently perceived as the best design. South African scientists are willing and able to play a significant role in the implementation of such an array and some instrumentation would be available across Dutch, US, and South African groups.

A few of the design elements for an effective array are beginning to emerge: the top of the moorings should be greater than 600 m depth, to limit blow-down and wire damage, with the upper water column profiled by 75 Khz ADCPs (as for the Dutch Mozambique Channel moorings). Water mass data above this could be captured using small and cheap temperature sensors tethered above the large top ADCP float (as successfully implemented on the Australian Indonesian Throughflow array, Wijffels & Sloyan, pers. comm.). Below the ADCP float, single-point current meters at 500 m intervals or so would suffice to capture the current. CTDs and cheaper temperature sensors could be interspersed to limit the expense of capturing water mass variability. Implementation of CPIES (Inverted Echo Sounder with Current and Pressure sensors) to replace some (or all?) full-depth moorings needs to be investigated. These worked effectively to capture volume and temperature transport in the Kuroshio during ASUKA (Book *et al.*, 2002).

Use of gliders to capture transport variability of the Agulhas was considered. However, with order 0.25 $ms^{-1}$ speeds, gliders travel at a fraction of the speed of the current (figure 5), and hence would be deflected onto very oblique sections crossing the current. Furthermore, it would take 10-14 days to complete a 200-300 km-long section across the current with a glider, a period twice the advective time-scale of the dominant meander mode. As a result, transport estimates would be heavily aliased. Our experience from a ship survey is that such aliasing can result in a transport bias of 30 Sv and more. Finally, the Agulhas runs to 2000 m deep, twice the depth capability of gliders.

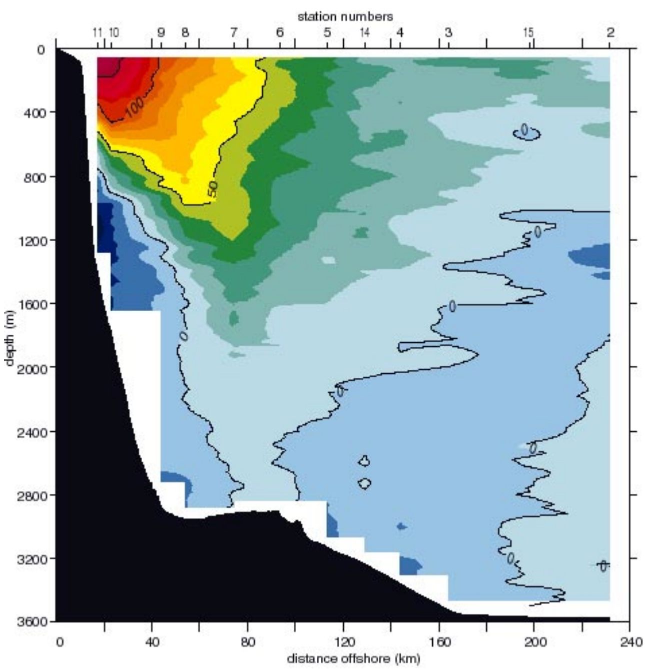



Figure 5. Velocity cross-section of the Agulhas Current at 32°S.

Aside from an initial purchase of instrumentation, which could be offset by some pooling among international groups, a mooring array would incur ongoing costs associated with ship time, technicians, and batteries for turn-arounds, say every 22- 26 months. Instrument maintenance and replacement will be necessary at times, but from experience with other arrays, failure rates are less than 10% and instruments typically last more than a decade. Ship time could be leveraged regionally through partnerships with South African programs e.g. DEA, ACEP and in particular through the Western Indian Ocean Sustainable Ecosystem Alliance.

The optimal latitude for an Agulhas monitoring array is unclear at present. The ACT line (figure 6), nominally at 34°S, was chosen to be situated along an altimeter (TOPEX/Jason) ground track where the inshore edge of the current is typically more than 40 km offshore and thus outside the coastal zone (Rouault & Penven, 2011). The idea is then to calibrate the along-track altimeter data with the *in situ* data from ACT and produce a multi-decadal time series of Agulhas Current transport via satellite proxy. There are some challenges in producing the proxy (e.g. accuracy of sea surface height data, tides, wet tropospheric correction at land/sea interface) and it won't be clear until the end of the ACT project how accurate the proxy time series turns out to be and what ground truth data are needed to sustain it. Moreover, the proxy relates only to volume transport, leaving heat and freshwater transports unmonitored. An alternative to the ACT line would be latitude 32°S, where the Current is narrower, weaker (important for minimizing blow-down of moorings), and its path is more stable (meander amplitude smaller). However, since the core of the Current is only 20 km offshore here, it is a poor site for combining with satellite data. Recently, a South African group (DEA) has deployed a line of current meter moorings here out to 2500 m, or about the average position of the core of the Agulhas, with the intention to maintain the line indefinitely. This program could be augmented, either at 32 or 34°S, with some additional instrumentation, technician, and ship time to create a full array capable of monitoring volume, heat, and salt transports in the long term.

Beal, L. M., W. P. M. de Ruijter, A. Biastoch, R. Zahn, and SCOR/IAPSO/WCRP Working Group 136 (2011), On the role of the Agulhas System in Ocean Circulation and Climate, Nature, 472, 429-436, doi:10.1038/nature09983.

Book, J. W., M. Wimbush, S. Imawaki, H. Ichikawa, H. Uchida, and H. Kinoshita (2002), Kuroshio temporal and spatial variations south of Japan determined from inverted echo sounder measurements, J. Geophys. Res., 107(C9), 3121, doi:10.1029/2001JC000795.

Rouault, M. J., and P. Penven (2011), New perspectives on Natal Pulses from satellite observations, J. Geophys. Res., 116, C07013, doi:10.1029/2010JC006866.

## ★Towards Implementation

The three elements of the Science Plan for the Southwest Indian Ocean (figure 6), justified and developed herein, would benefit greatly from full partnership with the Alliance. A Western Indian Ocean Sustainable Ecosystem Alliance is being developed through the two active Large Marine Ecosystem Projects in the region (the Agulhas and Somali Current Large Marine Ecosystems Project and the South West Indian Ocean Fisheries Project). This Alliance aims to bring together all of the countries, IGOs, NGOs, academic, scientific and commercial entities and ventures working within the region into one cooperative partnership for monitoring and management of the western Indian Ocean. Many scientific components of the Alliance have already evolved and fundamental ocean/atmosphere observations, such as RAMA buoys and the Dutch Mozambique array, are already a regular undertaking through a number of agreements, MoUs and Aides-Memoire. Data handling, quality control and processing of data through a 'Science-to-Governance' process is also evolving through a number of bilateral and multilateral agreements. Analysis of the products and their benefits to communities and to national GDPs has started and is being expanded, once again through partnerships and cooperative agreements.

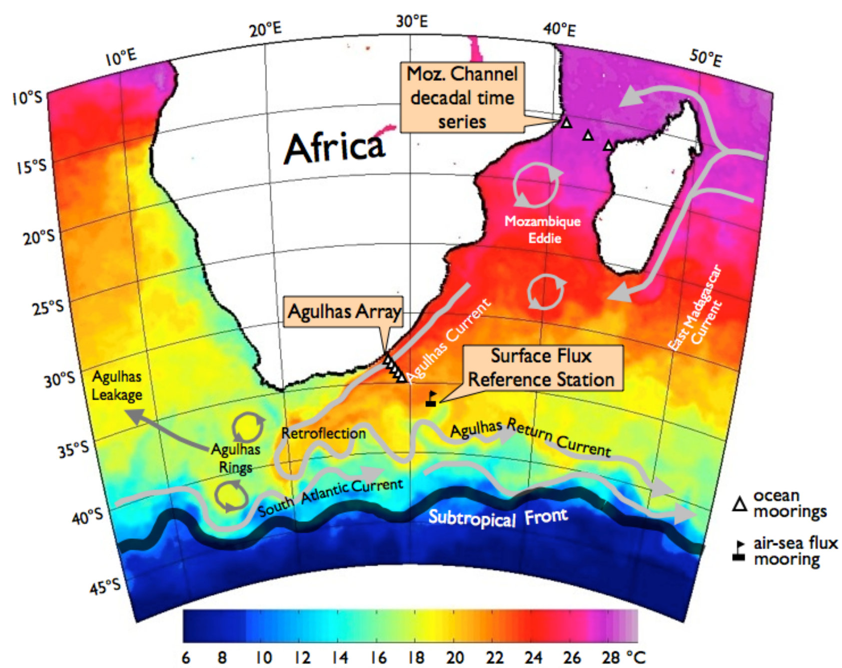



Figure 6. Approximate sites of the three proposed components for a sustained observing system in the southwest Indian Ocean as part of IndOOS and GOOS. Background image is SST. Adapted from Beal *et al*., 2011)

Implementation of the Science Plan would also benefit from development of an oversight committee, involving the major observational groups, South African, Dutch, US, and the Alliance (including East African scientists), plus other contributing parties, to manage the three elements. This committee would be tasked with gaining commitments for ship time, equipment and a maintenance budget, with assembling an international team of technicians, and to ensure scientific and operational outputs, including scientific papers, technical innovations (such as real-time data collection), and archiving and dissemination of data. A capacity building component, involving university students and young technicians from East African countries, such as Mozambique, Mauritius and Kenya, is vital to sustain western Indian Ocean observations over the long term.

Further community discussions and development of an Implementation Plan will take place during the next DBCP meeting in Kenya, April 2012, and during the Chapman Conference on the Agulhas System in South Africa, October 2012.

### 2.2.6 WG 137: Patterns of Phytoplankton Dynamics in Coastal Ecosystems: Comparative Analysis of Time Series Observation *Volkman*

(2009)

**Terms of Reference:**

- Identify existing long time series of phytoplankton data in coastal oceans around the world
- Facilitate migration of individual data sets to a permanent and secure electronic archive (Requirements for development of a fully-stocked phytoplankton data-base greatly exceed the resources of this WG. However, we expect to produce a small working proto-type, based on the existing archive (to be identified) to demonstrate the value of sharing data through an international database.)
- Develop the methodology for global comparisons for within-region and within-time period data summarization (e.g. spatial, seasonal and annual averaging, summation within taxonomic and functional group categories). The goal is to clarify what level of detail provides the optimal tradeoff (i.e. information gain vs. processing effort).
- Based on the above, develop priorities and recommendations for future monitoring efforts and for more detailed re-analysis of existing data sets.
- We will carry out a global comparison of phytoplankton time series using (in parallel) a diverse suite of numerical methods. We will examine:
    - Synchronies in timing of major fluctuations, of whatever form.
    - Correlation structure (scale and spatial pattern) for particular modes of phytoplankton variability (e.g. changes in total biomass, species composition shifts, among different geographic distribution).
    - Amplitude of variability, both for total biomass and for individual dominant species, and a comparison to the amplitude of population fluctuations.
    - Likely causal mechanisms and consequences for the phytoplankton variability, based on spatial and temporal coherence with water quality time series.
- Through comparative analysis, we will address the 3 guiding questions.

**Co-chairs:**

Kedong Yin
Australian Rivers Institute
Griffith University
Brisbane, Queensland
Australia
k.yin@griffith.edu.au

Hans W. Paerl
Institute of Marine Sciences
University of North Carolina at Chapel Hill
Morehead City, North Carolina, USA
hpaerl@email.unc.edu

| | |
|---|---|
| **Other Full Members** | **Associate Members** |
| Susan I. Blackburn (Australia) | Borgne, Robert Le (New Caledonia) |
| Jacob Carstensen (Denmark) | Elgin, Perry (USA) |
| James E. Cloern (USA) | Jassby, Alan (USA) |
| Paul J. Harrison (China-Beijing) | Kuparinen, Jorma (Finland) |
| Ruixiang Li (China-Beijing) | Leppänen, Juha-Markku (Finland) |
| McQuatters-Gollop, Abigail (UK) | Malone, Thomas (USA) |

| | |
|---|---|
| Todd O'Brien (USA)<br>Clarisse Odebrecht (Brazil)<br>N. Ramaiah (India)<br>Katja Philippart (The Netherlands)<br>Adriana Zingone (Italy) | Moncheva, Snejana P. (Bulgaria)<br>Morán, Xosé Anxelu G.(Spain)<br>Picher, Grant (South Africa)<br>Smayda, Theodore J. (USA)<br>Wiltshire, Karen (Germany)<br>Yoo, Sinjae (South Korea)<br>Zhu, Mingyuan (China-Beijing) |

**Executive Committee Reporter:** John Volkman

# SCOR WG 137:
# Global Patterns of Phytoplankton Dynamics in Coastal Ecosystems: Comparative Analysis of Time Series Observations

## Annual Report 2012

**Kedong Yin and Hans W. Paerl**

**August 12, 2012**

### 1. Activities since June 2011 (last annual report)

SCOR WG 137 had its 2nd meeting in Napoli, Italy, during 27-30 September 2011, hosted by Prof. Adriana Zingone, Stazione Zoologic Anton Dohrn, Naples, Italy. At this meeting, key WG objectives and activities made in the first meeting were discussed, specifically (1) members and other participants made presentations and had extensive discussions on their own estuarine/coastal case studies; (2) members were assigned to be responsible for working on terms of references; (3) members formulated 10 scientific questions for the WG to address, using individual data sets, case studies and published materials; (4) members agreed on the data policy and contributing data and (5) plan the 3rd meeting place in Japan, forming a joint SCOR/PICES workshop; and (6) Richard Gowen will have a post-doctor to work with the project.

The website for data sets has been set up and is available now, http://wg137.net.

### 2. 2nd Meeting Summary

During the first meeting in October 2010, participants presented their systems and proposed research questions and other relevant subjects. In the second meeting, the focus was on presenting new products: comparisons and synthesis of different data sets from different regions, and new approaches to examine multiple data sets. Also, new participants presented their case studies and joined the existing 'research questions' group or took a lead in revised agreed set of research questions. Current and future roles, contributions and collaborative efforts of participants were discussed. The 2nd meeting also discussed places for the 3rd meeting.

**3. Data policy document**

In the first meeting, participants discussed data policy including data contribution, authorships, acknowledgements, and data availability and have achieved an agreement on the policy. After the meeting, the data policy document was approved in the 2nd meeting. The document is in the website.

4. Membership

Richard J. Gowen was added as an associate member (his affiliation: Fisheries and Aquatic Ecosystems Branch, Agriculture Food and Environmental Science Division, Agri-Food and Biosciences Institute, Newforge Lane, Belfast, BT9 5PX, UK)

**Appendix 1. Summary for the second meeting, Naples, Italy 27-30 September, 2011.**

Co-Chairs: Kedong Yin and Hans Paerl
Second meeting, Italy
Date: September 27-30, 2011
Local host: Adriana Zingone
Stazione Zoologic Anton Dohrn, Naples
Meeting Venue: Villa Angelina in Massa Lubrense, Napoli, Italy

**Table of contents**



**1. Meeting Summary**

During the first meeting in October 2010 participants presented their systems and proposed research questions and other relevant subjects. In the second meeting, the focus was on presenting new products: comparisons and synthesis of different data sets from different regions, and new approaches to examine multiple data sets. Also, new participants presented their case studies and joined the existing 'research questions' group or took a lead in revised agreed set of research questions. Current and future roles, contributions and collaborative efforts of participants were discussed. The 2nd meeting also discussed places for the 3rd meeting.

**2. Meeting objectives:**

a. Progress made by participants
b. Reviewing and revising research questions
c. Discussion of the approaches (what data sets to use, what analysis to perform, and so on) to address questions and formulate the framework (outline) of papers related to the questions (this will take most of the time, if necessary, split into groups for each paper).
d. Determining take home assignments: participants will formulate tasks for writing papers and determining who contributes what section(s) of the paper.

**3. Meeting program and presentations**

| | | |
|---|---|---|
| **Sept 26** | **Arrival and registration** | |
| **Sept 27** | **Day 1 (15 to 20 min Presentations on progress on the 9 questions and 3 tasks)** | |
| | Welcome by local host | Adriana Zingone |
| | Objectives of the meeting | Hans Paerl & Kedong Yin |
| | Task 1 Use of phytoplankton as indicators of global change at the land-sea interface | Jim Cloern |
| | Phytoplankton in the Patos Lagoon estuary: a long short story | Clarisse Odebrecht . |
| | Cyanos like it hot: impacts of climate change | Hans Paerl |
| | Question 8: How much local-scale variation can be explained by progressively larger-scale variation? | Katja Philippart |
| | Emergence of picocyanobacteria and *Alexandrium catenella* in the context of a 38-year time series of biogeochemical variables in a temperate coastal lagoon | Yves Collos |
| | Changes in phytoplankton observed in Korean waters (Yellow Sea and East Sea) | Sinjae Yoo |
| | Detecting changes in phytoplankton community structure using lifeform and state-space theory 'Testing the Smayda Reynolds hypothesis'. | Richard Gowen |
| | The WG137 Data System: A summary of available data, visualization, and analysis tools | Todd O'Brien |
| | Question 4: What are the competitive advantages of motility and how do they relate to the vertical structure of the water column? | Peter Thompson et al |
| Sept 28 | Question 5: How does variability in hydrology/salinity, residence time influence phytoplankton? | Peter Thompson et al |
| | Task 2, Phytoplankton biovolume conversion, research connected to WG 137 | Paul Harrison |
| | Question 3: How is phytoplankton cell size a reflection of environmental conditions across systems? | Diana Sarno, Adriana Zingone et al. |
| | Question 6: What are the common seasonal patterns along single species & communities? | Adriana Zingone et al |
| | CoDAR observations from Villa Angelina in the Gulf of Naples | Enrico Zambianchi, University of Naples |
| | Question 7: What are the patterns that can be revealed by different time series analyses methods? (methods, tipping points/thresholds, early-warning signals) | Peter Thompson et al |
| | Question 9: What role do bottom-up vs. top-down processes play in regulating planktonic communities? To what extent does phytoplankton composition affect food quality? | Monika Winder et al |

| | | |
|---|---|---|
| Sept 29 | Continued discussions on questions | Open to WG 137 discussion |
| | Plans and task assignments | |
| | The 3rd meeting place and dates | |
| | Concluding remarks | Hans Paerl and Kedong Yin |
| Sept 30 | Tour to the Amalfi coast | |
| Oct 1 | Departure | |

**4. List of registered Participants for SCOR WG137 2nd meeting**

| | Name | Affiliation | email |
|---|---|---|---|
| 1 | Yin, Kedong (co-chair) | School of Marine Sciences<br>Sun Yat-Sen (Zhongshan) University<br>Guangzhou, China<br>Griffith Univeristy, QLD, Australia | yinkd@mail.sysu.edu.cn<br>k.yin@griffith.edu.au |
| 2 | Paerl, Hans W. (co-chair) | Institute of Marine Sciences, University of North Carolina at Chapel Hill, Morehead City, North Carolina, USA | hpaerl@email.unc.edu |
| 3 | Cloern, James E. | U.S. Geological Survey, Menlo Park, California, USA | jecloern@usgs.gov |
| 4 | Harrison, Paul J. | Division of Environment, Hong Kong University of Science and Technology, Hong Kong | Harrison@ust.hk |
| 5 | Lehtinen, Sirpa | Marine Research Centre<br>Finnish Environment Institute (SYKE)<br>Erik Palmenin aukio 1, 00251 Helsinki<br>Finland | sirpa.lehtinen@ymparisto.fi |
| 6 | McQuatters-Gollop, Abigail | Sir Alister Hardy Foundation for Ocean Science, Citadel Hill, Plymouth, PL1 2PB, United Kingdom, | abiqua@sahfos.ac.uk |
| 7 | O'Brien, Todd | National Marine Fisheries Service—NOAA, 1315 East-West Highway, Silver Spring, MD 20910, USA | Todd.OBrien@noaa.gov |
| 8 | Collos, Yves | Ecologie des Systèmes Marins Côtiers<br>Université Montpellier 2, CC093<br>34095 Montpellier Cedex 5, France | Yves.Collos@univ-montp2.fr |
| 9 | Ramaiah, N | National Institute of Oceanography, Dona Paula, Goa 403 004, India | ramaiah@nio.org |
| 10 | Winder, Monika | IFM-GEOMAR Kiel, Germany;<br>UC Davis, CA, USA | mwinder@ifm-geomar.de |
| 11 | Sinjae Yoo | Korea Ocean Res. & Dev. Inst.<br>Sa-Dong 1270, Ansan | sjyoo@kordi.re.kr,<br>sinjae.yoo@gmail.com |

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|---|---|---|---|
| | | South Korea 426-170 | |
| 12 | Odebrecht, Clarisse | Lab. Ecologia de Fitoplâncton e Microorganismos, Instituto de Oceanografia, Universidade Federal do Rio Grande-FURG, C.P. 474 96201-900 Rio Grande, RS, Brasil | doclar@furg.br |
| 13 | Zingone, Adriana | Stazione Zoologica A. Dohrn, Villa Comunale, Italy | zingone@szn.it |
| 14 | Sarno, Diana | Stazione Zoologica A. Dohrn, Villa Comunale, Italy | diana@szn.it |
| 15 | Wright, Heather Ann | Stazione Zoologica A. Dohrn, Villa Comunale, Italy | heather.wright@szn.it |
| 16 | Thompson, Peter | CSIRO Marine and Atmospheric Research, Hobart, 7001, Australia | Peter.A.Thompson@csiro.au |
| 17 | Katja Philippart | Royal Netherlands Institute for Sea Research | katja.philippart@nioz.nl |
| 18 | Richard Gowen | Fisheries and Aquatic Ecosystems Branch, Agriculture Food and Environmental Science Division, Agri-Food and Biosciences Institute, Newforge Lane, Belfast, BT9 5PX, UK | Richard.gowen@afbini.gov.uk |
| | Local participants | Stazione Zoologic Anton Dohrn, Naples, Italy | |

## 5. Data sets available for use by participants.

Todd O'Brien *et al.* (representing all WG137 data contributors)

At the time of the second WG137 meeting (September 2011), a total of 74 phytoplankton time-series sites have been processed. Adding to this total additional non-processed but "in hand" data, there will easily be more than 100 sites in the WG137 collection. This total will likely exceed 150 by the third WG137 meeting, as the ICES working group on phytoplankton and microbial ecology (WGPME) is building a collection of North Atlantic phytoplankton time series. As Todd O'Brien is the data coordinator for both groups, permission is automatically being requested to include these data in the WG137 study. The http://WG137.net web site contains links to an interactive map and data and site summary tables that list and link to standard summary pages for each of the existing time-series sites.

Two new online time-series tools are available to the WG137 community. The COPEPOD Interactive Time-series Explorer (COPEPODITE, http://www.st.nmfs.noaa.gov/copepodite/) is a publicly available, online toolkit that allows any user to upload their own time-series data and select from a variety of standard analysis and visualizations to be applied their data. The second tool is the Multi-Site Time-Series Explorer (MSTSE). This tool is not public, with access controlled by email-based login. The MSTSE allows WG137 members to select variables from and combine any of the 74+ time-series sites to look at cross-site correlations within similar variables or against climate indices and/or hydrographic variables (i.e., "how are cyanobacteria correlated with SST in the Pacific, Atlantic, Mediterranean, and Baltic?).

The COPEPOD time-series tools were originally developed to work with zooplankton data (and primarily zooplankton "total biomass" or "total copepods" data). As species data were rare within the zooplankton data groups, new methods and analysis for working with species and functional groups will be developed over the next year to better serve WG137's needs. Analysis at weekly (versus monthly) bins may also be useful for many of the WG137 sites.

**6. Agreed research questions: who does what?**
**(non-participants were encouraged to add their names or raised their own questions. Please also see notes )**

**Yin, Kedong,** Richard Gowen**,** Hans Paerl, Nathan Hall, Katja Phillipart, Peter Thompson, N Ramaiah, Adriana Zingone**,** Monika Winder, Alexandra Kraberg, Sirpa Lehtinen, Todd O'Brien, Yves, Collos, Abigail McQuatters-Gollop,

- **Q1:** Do changes in nutrient supplies, sources (new vs. regenerated), concentrations and ratios cause shifts in phytobiomass and community composition?
  - Q1-Subqustion 1: Yin et al., nutrients vs community structure indices
  - Q1-Subqustion 2: Gowen et al., nutrients vs community status
  - Q1-Subqustion 3: Collos et al. ammonium/nitrate, Si, vs community structure (diatoms/(diatoms+dinos)), hypothesis HN4, or DON favours dinoflagellates

**Alexandra Kraberg,** Nathan Hall, Abigail McQuatters-Gollop, Hans Paerl, Sirpa Lehtinen, Peter Thompson, Todd O'Brien

- **Q2:** Are there temperature thresholds that determine dominance of different phyto groups and do temp regimes and ranges govern interactions?

**Adriana Zingone**, Jim Cloern, Hans Paerl, Nathan Hall, Todd O'Brien, Sirpa Lehtinen

- **Q3:** How is phytoplankton cell size a reflection of environmental conditions across systems?

**Peter Thompson**, Nathan Hall, Adriana Zingone, Sirpa Lehtinen

- **Q4:** What are the competitive advantages of motility and how do they relate to the vertical structure of the water column? Advantages, light, nutrients,

**Peter Thompson**, Paul Harrison, Hans Paerl, Kedong Yin, Adriana Zingone, Todd O'Brien, Nathan Hall, Katja, (Kevin Sellner, Lu Douding).

**Q5:** How does variability of hydrology/salinity, residence time influence phytoplankton?

Methods of estimating residence times:

Characterizing residence times scales; day, week, fortnight, month, season, year, multiple years

Selecting representative ecosystems

What phytoplankton community structure indicators to be used?

How to establish the relationship between residence times and phytoplankton community structure?

**Adriana Zingone**, Alexandra Kraberg, Abigail McQuatters-Gollop, Katja Phillipart, N Ramaiah, Peter Thompson, Lu Douding, Monika Winder, Li Ruixiang , Nathan Hall, Peter Henriksen, Todd O'Brien, Kedong, Yves, Clarisse, Richard, Sirpa Lehtinen

- **Q6:** What are the common seasonal patterns along single species & communities?

**Peter Thompson**, Jacob Carstensen, Todd O'Brien, Abigail McQuatters-Gollop, Monika Winder, Katja Philippart, Todd O'Brien, Richard, Kedong

- **Q7:** What are the patterns that can be revealed by different time series analyses methods? (methods, tipping points/thresholds/breaks-phases/ early-warning signals)
  - What is suitable scale for sampling frequency
  - Level of taxonomy
  - Daily sampling (short period, Richard, Western Irish)
  - Spatial variability/resolution, HK data have 80 stations within 40 km x20 km
  - Linear slope differences in species, other various parameters among different regions or different types of environments

**Katja Philippart**, Monika Winder, Abigail McQuatters-Gollop, Jim Cloern, Sirpa Lehtinen, Todd O'Brien

- **Q8:** How much local-scale variation can be explained by progressively larger scale variation?

**Monika Winder**, Katja Philippart, Jim Cloern, Alexandra Kraberg, Sirpa Lehtinen, Hans Henrik Jakobsen, N Ramaiah. Todd O'Brien

- **Q9:** What role does bottom-up vs. top-down processes play in regulating planktonic communities? To what extent does phyto comp affect food quality?
  - Seasonality
  - Spatial pattern with zooplankton (using time series)
  - Relationship with zooplankton
  - Time series, develop species composition index for food quality
  - Fishery seafood production in regions to be examined as background
  - CPR data contribution

**Tasks (from the 1st meeting)**

**Jim Cloern**, Abigail McQuatters-Gollop, Katja Philippart, Kedong Yin ….

- **Task 1.** What are the global patterns in processes of phytoplankton variability?

**Paul Harrison**, Adriana Zingone, Hans Henrik Jakobsen, Xu Jie …

- **Task 2.** Common Conversion Tables (biovolume, C, C:Chl*a*)

**7. Notes on the 2nd meeting**
**(MANY THANKS to Abigail and Heather for taking excellent notes!!!)**

**by Abigail** McQuatters-Gollop,

**September 27, 2011**
**GENERAL MEETING OBJECTIVES**
1) Identify which systems are climatically and which are anthropogenically driven.
2) How will we develop the reference conditions to use to compare changes between systems?
3) Need to define anthropogenic and climatic trends in terms of drivers
4) Classify our systems as primarily anthropogenically driven or climatically driven along a gradient
5) List of papers for authorship by SCOR 137 with action point list by the end of the meeting

**Jim Cloern Task 1**
- We know that open-ocean phytoplankton dynamics is primarily driven by climate, but what are the drivers in marine systems which are connected to land?
- Key drivers: nutrients from land, river damming, hydrologic manipulations, fishing, introduced species, freshwater run off, tidal mixing, oceanic inputs, trophic cascade
- Combination of natural and anthropogenic drivers make coastal systems complex. Sometimes climate signals may at times overwhelm these drivers.
- Climate signals can manifest at multiple scales: events (such as hurricanes), seasonal variability, annual variability (e.g., freshwater inflow), decadal oscillations (ENSO, NAO), regime shifts

**Clarisse Odebrecht**
- Patos Lagoon, Brazil – short-term variation in phytoplankton is high, clear influence of wind direction, intensity. Residence time (< 1 day to one month) is a key factor in controlling phytoplankton variability.
- Signal from climate oscillations (El Niño, La Niña) is bigger than the seasonal signal in phytoplankton.

**Hans Paerl**
- Climate change affects cyanobacteria (cyanos) through: stratification, viscosity, temperature. Climate changes may be working with other pressers (such as nutrients) to exacerbate changes in cyanos.
- Picoplankton are key component of Pamlico Sound, and likely of other systems, but they are just not routinely examined.
- Diatoms like it cool (temp) and fast (flushing), cyanos like it hot and slow
- Salinity is not a barrier to cyano expansion

**Katja Philippart: Q8 – How much local-scale variation can be explained by large-scale variation?**
- Many local changes in the plankton are observable at the large-scale as well, indicating the importance of large-scale climate drivers

- Some regime shifts are synchronous between Atlantic and Pacific oceans
- So coastal systems are influenced by large-scale climate drivers as well as local conditions
- 4 nested hypotheses:
    - H0: no trend
    - H1: all time series (t-s) have underlying trends related to mesoscales (100km)
    - H2: all t-s have trends related to macroscale (1000km)
    - H3: only global trends
- Stepwise approach for analysis
- Start with broad phytoplankton indicators (such as phytoplankton biomass) and then use functional groups or even species information where possible to further explore changes in phytoplankton

**Q8 Approach**

- Need to rank drivers in importance
    - Key drivers: nutrients from land, river damming, hydrologic manipulations, fishing, introduced species, freshwater run off, tidal mixing, oceanic inputs, trophic cascade
    - Need indicators for priority drivers for each region:
        - Trophic cascade (Baltic): top predator abundance (e.g., cod, grazer biomass)
        - Nutrients (Tolo Harbour): changes in sewage inputs
    - Additional model parameters: residence time, turbidity, salinity, nutrient indicator (is phosphorus most appropriate?)
- Please send Katja:
    - Additional model terms you think of
    - Are these terms additive or multiplicative?
    - Are there other region types (besides LME, etc.)?
    - CPR – Katja will let Abigail MG know the spatial areas for CPR data extraction

**Yves Collos**

- Thau lagoon – France, heavy oyster aquaculture. In summer, oysters filter entire lagoon in a single day!
- Interannual variability in *Synechococcus* driven by temperature
- *Alexandrium* linked to picocyanobacteria

**Sinjae Yoo**

- Yellow Sea subjected to high degree of anthropogenic impacts but East Sea is mostly climate-driven
- SST-related increase in plankton biomass after late 1980s in Yellow Sea and East Sea
- Lack of good phytoplankton temporal-spatial relationship in Korean waters so relationship was created between Secchi depth and chl-a. An increase in chl-a was found during post 1990
- DIN and DIP have significantly increased in Korean waters since early 1980s

**Richard Gowen**

- Aim: to develop an index that can be used to detect change in plankton community.

    - Driven by policy needs!
- Plankton are variable in space and time and (in the UK at least); there are no definable unique indicator species
- Change in plankton community should not be quantified against an absolute notation!
- Life-forms allow us to retain information on species abundance and seasonal dynamics without being overwhelmed with spatio-temporally variable detail
- State space theory detail in Richard's ppt
- Plankton Index shows deviation from a reference regime (envelope) in state space
- Temporal change in Plankton Index shows trends in a phytoplankton dynamics in a region
- Trends in index can be linked to pressure (anthro- or climate-)

**Todd O'Brien**

- SCOR 137 website – data exploration tools
- Pre-made dataset summaries available online – includes anomaly plots
- Tool kit to explore your own data
    - Will show climate indicators too
- Copepod watermark to protect data rights
- Multi-site T-S Explorer (MSTSE)
    - Controlled access to database behind the scenes

**Peter Thompson: Q4 - What are the competitive advantages of motility and how do they relate to the vertical structure of the water column?**

- Huon estuary - *Gymnodinium* grazed by *Polykrikos schwarzi*
- One of the advantages of vertical migration is that the organisms group together in a thin layer while moving, while the predators are distributed in the water column so grazing is reduced
- Diatoms don't prefer particular form of N – any kind will do
- Is the time scale of stratification important?
- Which systems have shown a shift from non-motile to motile species?
    - Gulf of Finland (in Klais et al. 2011 *PLoSOne*)
- Possible advantages of motility:
    - Retention
    - Sex
    - Light access
    - Buoyancy – cyanos
        - $CO_2$
        - Nutrients
    - Sinking
    - Predation
    - Nutrients
    - Temperature
    - Escape benthic grazing (maybe)

**Q4 Approach**

- **TASK (all):** Which aspects of this question are you most interested in investigating? Let Peter know.

- We can look at motility in a thin layer over a deeper water column (get Nathan's help)
- **TASK (Richard)** – to ask Robin Rain about using his data

**Peter Thompson: Q5 - How does variability in hydrology/salinity, residence time influence phytoplankton?**

- We expect different impacts of residence times depending on length, and we need ecosystems with data for each of the following bins:
    - 1 day
    - 1-10 days
    - 10 – 100 days
    - 100-1000 days
    - >1000 days
- What is the relationship between taxa and residence time? Is there a biomass-free indicator of community? Maybe the Plankton Index, but monthly data is needed.
- Percentage diatoms (Diatoms/(Diatoms + Dinos)) provides more info than the Diatom:Dino ratio as from it you can tell which group is changing. The percentage can also be based on abundance or biovolume.
- Which changes are attributable to nutrients and which to residence times?
- Tasks:
    - Identify suitable datasets
    - Agree on biomass-free indicator of abundance
    - Progress check in 6 months
    - Draft paper in 12 months
- We must be careful: To make clear in our paper we do not assume that biomass inc?? with residency time; we need to define residence time and know how we calculate it; in relation to the particular region of the estuary we are talking about; make sure we consider inflow; consider relevant biological aspects (e.g., Thau Lagoon oysters)

**Q5 approach:**

- **TASK (Nathan)** to send literature list on residence times to Peter
- Characterize ecosystems by residence times in bins
- Look for patterns between residence time and phytoplankton across and between ecosystems
- Progress update reviews in 3 and 6 months
- Will look at both chlorophyll and phytoplankton index (see above) data

**Paul Harrison: Task 2 - Biovolume Conversion from Abundance**

- How much variability for biovolume of same species is there between datasets?
- What is variation in biovolume due to?
- Is the relationship in variation the same among datasets from the same/different latitudes, coastal areas?
- HELCOM has published a standard protocol for biovolume calculation
- We want species that are represented in >4 datasets
- Constructing biovolume table for SCOR 137 use

**Diana Sarno: Q3 – How is phytoplankton cell size a reflection of environmental conditions across systems?**

- Q3a: How to get the best representation of the size structure of samples? Based on sites, not taxonomy
- Q3b: What is the distribution of cell size over the years? Are there interannual/seasonal trends or patterns? Is there a spatial change in distribution?
- Q3c: Does the distribution of cell size vary in relation with environmental conditions?
- Q3d: How does size structure vary across geographical regions?

**Q3 Approach (Adriana)**

- For the moment Adriana will just explore her data but will ask for Sirpa's help soon

**Let's come to an agreement on size classes:**

- Picoplankton: < 3 u (most inclusive)
- Hans to contact Bill Li for input

**Adriana: Q6 - Common seasonal patterns for single species and communities**

- Plankton phenology driven by light, temp, nutrients, turbulence
- Species may occur whenever, or wherever, suitable conditions are present
- Functional group phenology more important than species phenology
- Contrasting view: species phenology IS important
- No clear relationships observed between physiology of a species and its occurrence in the ecosystem
- Q6a: What is the seasonality of individual species across time series(t-s)?
    - Which species to use?
    - Which species common across sites?
    - Do the same species have similar seasonal patterns across sites?
    - Are there changes in species abundance across sites?
- Q6b: What are the seasonal patterns for phytoplankton communities across sites?
    - Which species are at each site?
    - Do the same species belong to similar associations at each site?
    - Are there typical associations linked to seasons that are similar across sites?
- We need a specific methodology that we can all follow with our own datasets. We need this project to be manageable, both with number of sites and number of species. Peak and center of gravity are relatively independent of abundance, unlike bloom duration or maxima, so may be more appropriate here.

**Q6 approach:**

- What are the species that can be used for comparison across sites?
    - **TASK (all):** Send SPECIES-only list to Adriana – only include reliable species which are quantitatively recorded (not p/a), and remove cyanobacteria, benthic species and non-marine species
    - A short list will then be narrowed down
- Next step will be to make common-format graphs showing seasonal patterns for same species across sites
- Assessment of methods:
    - CPR center of gravity
    - Monika – method in R
    - Mackas method??

**Enrico Zambianchi: HF radar observations in the Gulf of Naples**

- Gulf of Naples is well-monitored for circulation
- This can be an early warning system for disasters
- Not all circulation is driven by wind in Gulf

**Richard Gowan**

- Margalef life-form approach
  - Species groups are dependent on suitable habitat (hydrological conditions + nutrients) (Smayda & Reynolds)
  - But these are unclear and spp are included in multiple groups
- We could test the probability of finding these life-forms in different regions with the SCOR 137 datasets
- Possibly too many categories for life-forms, we could narrow them down to a smaller group, and test this approach geographically

**Monica: Q9**

**To what extent does phytoplankton composition affect food quality?**

- What drivers affect phytoplankton quality?
  - Not Chl-a concentration, species composition, size, biogeochemistry
- Diatoms most nutritious phytoplankton group
- Approach:
  - Simple or advanced
  - Brett and Arhonditsis are developing a model to predict phytoplankton food quality based on:
    - Phytobiomass
    - Taxonomic composition
  - Starting with SF Bay and upscaling to other sites

**What roles do bottom-up and top-down play?**

- Need to look for a master relationship between phytobiomass and nutrients. Why don't datasets for systems follow just one model?
  - Richard Gowan to give data for some well-understood sites
- Light availability is better predictor of primary production than nutrients in shallow regions – but we just don't have the data to examine this thoroughly
- Need data from a system with long residence time and low production like open ocean (Sanjae)
- Why do lakes have a nicer relationship between N and phytobiomass?

**Q9: Research Approach**

- We want to create an index of food quality for upper trophic levels based on phytoplankton community composition.
- Test to what extent phytoplankton composition affects food quality using data from San Francisco Bay. For zooplankton will use a dominant copepod species. Once the model works, this approach can be tested on other datasets. The first step is a literature review and model development.
  - Suggestion from Peter: For sites that have both phyto and zooplankton, we could look at this relationship exploratory, without using a model, as an initial step. Looking at this spatially may provide different insights.

- Exploration of top-down and bottom-up process regulation on phyto community will come at a later stage

**Peter: Q7 – What are the patterns that can be revealed by different time series analyses methods?**

- Variation in phytoplankton community clear even at coarse scale (Australian example, pigment analysis)
- What is the minimum monitoring frequency needed to detect changes in phytos?
    - Which taxonomic resolution?
    - For rare or just common species?
    - Rate of changes?
    - Ecosystem seasonality?
- Most of our observations are not independent in time or space and independence is needed for statistical analysis
    - How far apart in space and time do they have to be to treat them as independent?
        - Are monthly means far enough apart to be independent?
            - It depends on – if you are looking at common species, rare species or functional groups
- Beware when using regression with time series (t-s): make clear we aren't using it for prediction, but just to get a trend
- Do we need to correct for concentration of sample (depth integration v surface sampling) in a system to make seasonalities comparable?
    - Conversion to per square meter – would this help? Maybe but not practical.
    - Not sue if a generic correction method exists, so best strategy may be to just go with what we've got
- If log transformed, we get too many 0s (absences) which throws the trend
    - We need to decide as a group how to deal with 0s
    - What about replacing 0s with half of the minimum? (Todd)
    - Would be best to get consensus with ICES WGPME and SCOR WGZE
- Annual means could solve some of these issues – as they remove seasonal variability and can deal with 0s
    - Annual means – we need to make sure that there is consistency in their calculation within datasets (i.e., first get monthly means, then annual; interpolate (or not) for missing months; etc.)
- Species name resolution – be careful to be consistent with species names. WoRMS is a great resource for resolving species names
- Divide alpha by n-1 to get an adjusted p value to use to determine significance as a certain number of correlations will be by chance if you repeatedly use a dataset
- Spectral analysis may provide technique to look at temporal variability
- Additional group members: Heather? Richard?

**Q7 Approach**

**Goal: To produce a manual on spatial and temporal sampling frequency and analysis methods**

- Q7a –What is the best sampling frequency? How does this change with taxonomic level?

  - SCOR 137 dataset sampling ranges from weekly to....
  - Richard has daily for W. Irish Sea for some period of time
  - Peter is developing this question with Naples dataset to apply to other datasets later
- Q7b - What spatial resolution is needed for spatial independence of samples?
  - Can experiment with CPR and Hong Kong dataset (76 stations, 25 years of data)
- Q7c – Can we detect step changes with our analysis methods?
  - Linear regression may allow comparison between sites (by comparing slopes)
  - Possible stepwise shift techniques to evaluate or test: Rodionov, Bayesian shift approach
- Output by end of next year in form of a ms and/or manual
- Let's define long-term as at least 10 years (for our purposes)
- Discussion topic: Use of HPLC for trend detection
- Discussion topic: What to do with 0s?
- **TASK (all):** Send Peter references where people have applied statistical methods to phytoplankton data
- Are there any statistical methods developed by WGZE that we can apply here?

**Jacob (given by Todd)**

- Need owners of each dataset to verify the numbers are correct
- Next step – species name reconciliation and functional grouping

**Discussion on the WG's future:**

- Possible funding source by PICES. They want an end-to-end ecosystem model and need phytoplankton input. We need to make 10-15 slides for Sanjae to present to PICES showing our usefulness in looking at:
  - Relationship between phyto and zooplankton and climate change and anthropogenic drivers.
  - San Francisco Bay could be a good case study **(TASK: Jim)**
  - Neuse is good example **(TASK: Hans)**
  - Slide with our datasets on it – global map **(TASK: Todd)**
  - CPR regime shift NA and map of global CPR samples **(TASK: Abigail)**
  - Response to anthro change in Thau **(TASK: Yves)**
  - Patos Lagoon cyanos **(TASK: Clarisse)**
  - SCOR Objectives **(TASK: Kedong)**
  - **TASK: Hans to coordinate slides – send to Hans by Oct 4 (This was completed by 9 Oct. Thanks everyone!!)**
  - Stress that our group is global, which could be attractive to PICES as it is seeking to broaden out from just the Pacific. However, our dataset is biased towards the North Atlantic and needs more focus on the North Pacific. (Our efforts were successful and we will meet with PICES/Hiroshima in fall, 2012…details coming soon)

**Q2 Approach**

- **TASK (Alexandra)** We need a brief email update from Alexandra if possible please!
- Maybe we can explore some individual species and their relationships with temperature, so which temperature ranges certain species are found in. Paul has done this with *Noctiluca*.

**Q1 Approach**

- Now led by Kedong and Richard
- Richard – will look at nutrients and community structure using life-form state-space approach
- Kedong – Will look at nutrients vs. community structure indices
- Yves – ammonium/nitrate, silicate, vs community structure (percent diatoms)

**NEXT STEPS**

**Proposal:** ***Use our time series data sets and propose collaboration with PICES***

- Contribute a slide show from this working group that can be used by Sinjae at an upcoming PICES meeting to support continued SCOR efforts.

**Deadline:** By end of 1st week in October. Sinjae will present this Oct.14th (The presentation was successful and we will meet with PICES, fall of 2012, Hiroshima, Japan. Details will be forthcoming. Thanks again Sinjae!).

**Tasks:**

- Each contributing member will send 2-3 slides of their proposed "drivers" of climate change or anthropogenic input to Hans.
- Hans will filter the contributions and then create a document or slide show that can be submitted to PICES for consideration.
- One slide that could show the overall goal of this working group.
- Send a slide that have small summary of the slide

**considerations whether** or not our data sets are representative because of our coverage. We are primarily in the North Atlantic and Europe with the exception of additional data sets such as the U.S. and then the South Atlantic.

### 8. Presentation abstracts

Cloern, James
Gowen, Richard
Harrison, Paul
Odebrecht, Clarisse
Paerl, Hans
Phillipart, Katja
Sarno, Diana, received
Thompson, Peter (3 abstracts)
Winder, Monica
Yoo, Sinjae
Yves, Collos
Zingone, Adriana

## Phytoplankton as Indicators of Ecosystem Response to Global Change at the Land-Sea Interface

**James Cloern**

The great challenge of environmental science is to learn how human activities interact with natural processes to cause change across Planet Earth's habitats. Nearshore coastal ecosystems, such as estuaries, bays and inland seas, are influenced by both large-scale climate forcing and local-scale disturbances from human actions such as nutrient enrichment, aquaculture, fishing, species introductions, habitat transformations, river damming and water diversions. Interactions between large- and local-scale processes elicit complex responses to global change at the land-sea interface. Despite a perceived acceleration of these changes in recent decades, our understanding of their regional and global impacts and ramifications is incomplete because we have not systematically analyzed all available observational data. However, focused programs of data synthesis are under way, some using phytoplankton and microbial communities as indicators of environmental change. For example, ICES sponsored a 2006 workshop on long-term phytoplankton series leading to a 2009 special issue of Journal of Sea Research; AGU sponsored a 2007 Chapman Conference leading to a 2010 special issue of Estuaries and Coasts; both ICES and SCOR support working groups to compile, compare, and synthesize time series of phytoplankton and microbial communities. Syntheses of globally distributed observational programs are now revealing patterns and processes of ecosystem change in the coastal zone. I will discuss examples and propose a conceptual model for understanding dynamics of estuarine-coastal ecosystems where perturbations from terrestrial, atmospheric, oceanic sources and human activities converge to cause changes that cascade across local to global scales.

## Detecting changes in phytoplankton community structure using lifeform and state space theory: Testing the Smayda-Reynolds hypothesis

**Richard Gowen**

The populations of species that make up the phytoplankton community in coastal waters are not constant in time or space and there is no fixed assemblage of species each with its own unique abundance that defines the phytoplankton of a particular coastal region. This inherent variability and the recurrent cycles of species succession and production need to be accounted for when quantifying change in phytoplankton community structure in response to human pressure. This presentation describes a method based on lifeform and state space theory.

Life forms, as groups of phytoplankters that carry out the same function in the marine ecosystem, derives from Margalef and provides a means of reducing the volume of data typically available from phytoplankton monitoring, while retaining important information on species succession. The system-state space approach derives from systems theory and thermodynamics and enables the instantaneous state of the phytoplankton component of pelagic ecosystems to be defined using lifeforms as state variables (illustrated graphically by a point plotted against orthogonal axes corresponding to each pair of lifeforms). Data from one location forms a cloud of points (regime) in state-space around which a seasonal and inter-annual envelope of variability can be plotted. An index (the phytoplankton community index: ranging from 1 = no change to 0 = complete change) can be calculated from the new points that plot into a reference envelope over the total number of new points allows a statistical analysis of spatial and temporal changes in phytoplankton community structure.

The potential for using trends in the index to relate shifts in phytoplankton community structure to human pressure and the use of different micro-plankton and plankton lifeform combinations to derive a holistic plankton indicator are briefly discussed.

### Task 2: Conversion of Phytoplankton Species Abundance to Biovolume and Carbon

**Harrison, P.J, A. Zingone, and H. Jacobsen**

There are several methods that have been used to determine the biovolume for a species. The most common way is to assume the cell approximates a certain geometric shape and use the mathematical volume formula for that species. Previous estimates of the biovolume of various phytoplankton species have been mainly from a few lab grown species, except for the HELCOM data set for the Baltic Sea. The biovolume estimates from field samples should have a larger coefficient of variation since there is more variation in environmental factors such as nutrients, light, temperature and salinity in the field.

We have obtained 10 data sets of estimates of biovolumes mostly from temperate regions (one tropical and one subantarctic data set). We have eliminated freshwater species, cyanobacteria and benthic pennate diatoms and will not use identifications that have been made only to the genus level. Most of the datasets have now been checked for taxonomic and nomenclatural synonymies, errors, etc. We will compare the biovolume for field grown species (the 100 most common species which are mainly diatoms and dinoflagellates since they are easier to identify to the species level) with the much smaller number of lab grown species and determine the coefficient of variation for each species.

Many of the other questions posed by WG 137 can use the biovolumes determined in Task 2 to convert the routine species abundance into biovolume to take into account the large difference in cell size of the various species. Tentatively, the biovolume conversion table will be finalized by the end of this year.

### Phytoplankton in the Patos Lagoon estuary: a short long (his)story

**Clarisse Odebrecht, Lumi Haraguchi, Paulo C. Abreu**

A long-term study is being conducted in the shallow microtidal Patos Lagoon estuary, Southern Brazil (32° 07′ S–52° 06′ W), in order to detect possible natural and/or anthropogenic impacts. The warm temperate Patos Lagoon Estuary receives waters from a 200,000 km$^2$ watershed shared by southeastern Brazil and northeastern Uruguay. The water outflow occurs through an 800 m wide inlet, flanked by two 4 km long jetties, at the southernmost part of the lagoon near Rio Grande city adjacent to the Atlantic Ocean. Surface water temperature, salinity, inorganic dissolved nutrients, chlorophyll and phytoplankton species composition and abundance are sampled at different time scales (hourly–daily: 1984/1985 and 2004/2005; weekly: 1986, 1988 to 1990; monthly: 1994 up to present). In the short term, phytoplankton abundance and species composition is mainly driven by hydrology, as a result of the wind action. Freshwater and marine species are observed according to the prevalence of northerly and southerly winds, which cause the lagoon outflow and marine input and outflow, respectively. Highest chlorophyll values are observed during periods of brackish water outflow, following the marine inflow. Throughout the year, diatoms and a taxonomically heterogeneous group of small flagellates dominate the phytoplankton. Cyanobacteria and dinoflagellates are more abundant in periods of lower and higher salinity, respectively, and follow distinct seasonal patterns as a result of meteorological conditions and light regime. In the long-term, a positive correlation between mean annual chlorophyll *a* and annual rainfall indicate that phytoplankton growth and biomass accumulation in the estuary are closely related to rainfall and freshwater discharge. Peaks of river discharge are associated with *El Niño* episodes (negative *El Niño* Southern Oscillation; ENSO Index), when rainfall significantly increases in the region. Low discharge periods occur during *La Niña* when drought conditions are observed. These phenomena have direct influence on salinity variations in the estuary, with low values recorded during *El Niño* years (1994–1995, 1997–1998, and 2002–2003) and high salt-water intrusion during *La Niña* years (1999–2000). Freshwater discharge to the Atlantic Ocean has an overriding influence on ecological processes in the adjacent coastal ocean region. It was observed that when rainfall exceeds 1500 mm year$^{-1}$, which is typical of *El Niño* years, phytoplankton biomass decreases, probably due to high freshwater runoff that flushes the phytoplankton biomass out the estuary. Changes in estuarine water and sediment dynamics as well as physicochemical water characteristics induce significant biological changes and ecological responses. It is clear that phytoplankton species composition, abundance, and biomass strongly respond to ENSO events.

## Cyanos like it *Hot*: Impacts of climate change

**Hans W. Paerl* and many other contributors**

Cyanobacteria are the Earth's oldest (~ 3.5 bya) oxygen evolving organisms, and they have had major impacts on shaping our modern-day biosphere. Conversely, biospheric environmental perturbations, including human nutrient enrichment, and climatic changes (global warming, hydrologic changes, increased frequencies and intensities of tropical cyclones, more intense and persistent droughts), strongly affect cyanobacterial growth and bloom potentials in estuarine and coastal marine ecosystems. These changes can act synergistically to promote cyanobacterial dominance and persistence. We examined synergistic human and climatic (warming, changes in rainfall amounts and patterns) controls on both non-harmful and harmful (toxic, hypoxia-generating, food web disrupting) bloom-forming cyanobacteria (CyanoHABs) along the freshwater to marine continuum. This synergy is a formidable challenge to water quality, water supply and fisheries managers, because nutrient thresholds for bloom formation and control may be altered in response to contemporaneous changes in thermal and hydrologic regimes. In particular, regional and global warming will tend to increase cyanobacterial dominance and persistence, because this phytoplankton group thrives under elevated temperatures. Rising temperatures cause shifts in critical nutrient thresholds at which cyanobacterial blooms can develop. In practical terms, this implies that nutrient input reductions aimed at controlling cyanobacterial blooms should be more aggressively pursued in a warming world.

Measures to reduce nutrient input may not always suffice, for instance, in densely populated urban areas, in watersheds with intense agriculture, or in systems that are highly eutrophic naturally. Here the increased risk of cyanobacterial blooms due to global warming will have to be addressed by additional measures such as artificial mixing and enhanced flushing. Synergistic effects of nutrients and climate will also necessitate more intense monitoring of waters susceptible to cyanobacterial blooms, because warming will allow blooms to start earlier in spring and last longer into fall. Moreover, monitoring programs should be attentive to newly invading cyanobacterial species expanding their biogeographical ranges. In oligohaline to euhaline estuarine ecosystems, hydrologic modifications, including changes in freshwater inflow due to increased storm activity and/or droughts will impact nutrient inputs, flushing rates (water residence time), vertical stratification, and overall salinity regimes, all of which affect cyanobacterial diversity and dominance. In upper estuarine regions enhanced vertical mixing and increased flushing (reducing residence time) will likely be needed in systems where nutrient input reductions are neither feasible nor possible. However, because freshwater supplies are finite and in many regions dwindling (due to increased demands and climatic changes), such physical manipulations will be limited. Overall, improved nutrient management, especially of non-point sources will be the most feasible and practical approach to long-term CyanoHAB control in a warmer, stormier and more extreme world.

Relevant publications:
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2. K.D. Jöhnk et al., *Global Change Biol.* **14**, 495 (2008).
3. C. Wagner, R. Adrian, *Limnol. Oceanogr.* **54**, 2460 (2009).
4. J.A. Elliott, *Global Change Biol.* **16**, 864 (2010).
5. S. Kosten et al., *Global Change Biol.*, in press; doi:10.1111/j.1365-2486.2011.02488.x (2011).
6. H.W. Paerl, N.S. Hall, E.S. Calandrino, *Science Total Environ.* **40**, 739 (2011).
7. A. Stüken et al., *Phycologia* **45**, 696 (2006).

## Q8 – How much local-scale variation can be explained by large-scale variation?

**Katja Philippart, Monika Winder, Abigail McQuatters-Gollop, Jim Cloern, Sirpa Lehtinen, Todd O'Brien**

Long-term observations in the Marsdiep, the westernmost tidal inlet of the Wadden Sea, revealed two regime shifts in species composition, i.e. between 1977-1978 and 1987-1988 (Philippart et al. 2000). These changes could at that time be satisfactorily explained as being the result of changes in riverine inputs, resulting in local shifts in nutrient concentrations and ratio's. The second shift between 1987 and 1998 occurred, however, simultaneously with a rather sudden increase in phytoplankton biomass in the adjacent Northwest European Shelf and the eastern central North Atlantic (McQuatters-Gollop et al. 2011). This shift was described before for the North Sea and related to a shift in hydrography (e.g., Beaugrand 2004). Remarkably, the shift in phytoplankton in NW European marine waters coincided with a shift in the western Atlantic and the Pacific (Saba et al. 2010). The regime shift in the Pacific was explained as being the result of a climate oscillation with alternating cold and warm phases with a period of approximately 50 years, with different effects at different spatial scales (Chavez et al. 2003). Such simultaneous shifts at large scales with different impacts on local scales suggest the strong influence of large climate impacts on developments in phytoplankton in coastal waters, by influencing local estuarine conditions and the inputs form land and open sea. Proposed is to examine the relationship between local and large-scale variation by setting up a series of hypotheses and subsequently test which hypothesis best explains the local dynamics in phytoplankton. To perform this analyses, we would require untransformed data sets on chlorophyll-a from as many coastal stations as possible, with a preference of a wide distribution of stations over the globe.

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2. Chavez et al. Science 299, 217 (2003) DOI: 10.1126/science.1075880
3. McQuatters-Gollop et al. Nature 472, E1 (2011) doi:10.1038/nature09950
4. Philippart et a. L&O 45 (2000) doi:10.4319/lo.2000.45.1.0131
5. Saba et al. GBC 24, GB3020 (2010) doi:10.1029/2009GB003655

## Question 3: How is phytoplankton cell size a reflection of environmental conditions across systems?

**Diana Sarno, Adriana Zingone et al**

Phytoplankton size structure is recognized as a fundamental property for the functioning of pelagic ecosystems both from an ecological and a biogeochemical point of view. Individual size affects most aspects of phytoplankton physiology, such as nutrient uptake, light affinity, photosynthesis and respiration, settling rates. Cell size also influences grazing relationships, directing energy flow through microbial or herbivore pathways, modulating the efficiency of the biological pump in transporting carbon towards deep layers.

In general, oligotrophic areas are dominated by small-sized cells which fuel a microscopic food web whereas eutrophic areas are characterized by large phytoplankton forming the basis of the traditional food web. Nevertheless, exceptions to this rule have been described.

The objective of Q3 is to explore to what extent cell size of phytoplankton communities can be considered a reflection of environmental conditions inside and across systems.

Initially, the topic will be approached testing different methods on the Gulf of Naples data series. As a first step, we are going to use several parameters, such as the Equivalent Spherical Diameter, the Biovolume and the Carbon Content, to get an ataxonomical representation of the size structure of individual samples. We also planned to build size spectra, or "individual size distributions" (White et al., 2007), which are frequency distributions in which the number of individuals in a size class is plotted against the average size of that size class. Size spectra have been used to analyze phytoplankton size structure in different conditions and environments (for ex. Cermeno & Figueiras 2008) and during time-series (Huete-Ortega et al. 2010).

Following steps will include 1) the description of the distribution of cell size over the year with the aim of understanding if there are trends and/or patterns characteristic for the different seasons and 2) the analysis of the distribution of cell size in relation with different environmental conditions (hydrographic conditions, nutrient availability, etc).

Finally, different data sets will be used to compare the size structure across geographical regions having diverse environmental conditions.

**References**

1. Cermeno, P. and Figueiras, F. G. (2008) Species richness and cell-size distribution: the size structure of phytoplankton communities. Mar. Ecol. Prog. Ser., 357:79-85.
2. Huete-Ortega M, Maranon E, Varela M, Bode A (2010) General patterns in the size scaling of phytoplankton abundance in coastal waters during a 10-year time series. J Plankton Res 32:1-14.
3. White, E. P., Ernest, S. K. M., Kerkhoff, A. J. et al. (2007) Relationships between body size and abundance in ecology. Trends Ecol. Evol., 22, 323–330.

## Plankton Motility

**Peter Thompson, Nathan Hall, Adriana Zingone, Sirpa Lehtinen and others**

More than 30 years of data from grazing-dilution experiments show that microzooplankton are an important determinant of net phytoplankton growth. The impact grazing has on the population dynamics of specific taxa is, however, very poorly understood. The importance of taxa-specific grazing in the development of a naturally occurring bloom of the vertically-migrating, toxic dinoflagellate, *Gymnodinium catenatum* was examined in the Huon Estuary (Tasmania – Australia). Results showed that grazing was highly selective with a strong preference for fucoxanthin (diatoms) over peridinin (dinoflagellates) during most of the year. During the dinoflagellate bloom in late summer, at all depths except 10 m, the peridinin-specific grazing rates became sufficient to control dinoflagellate growth. A 1D model using parameters from the field observation was used to test the hypothesis that the aggregation in a thin layer reduces predation and may be a key strategy in the development of these dinoflagellate blooms. The 1D model showed that when grazing saturated at observed dinoflagellate densities, the vertical migration of phytoplankton results in an decrease of ~40 % in total grazing. Both experimental and model results support this hypothesis; that phytoplankton concentrating into a thin layer that undergoes diel vertical migration may result in decreased losses to microzooplankton grazing.

## Residence time and hydrology

**Peter Thompson, Paul Harrison, Hans Paerl, Kedong Yin, Kevin Sellner, Adriana Zingone, Lu Douding. Todd O'Brien, Alexandra Kraberg, Abigail McQuatters-Gollop, Katja Phillipart, N Ramaiah, Monika Winder, Li Ruixiang , Nathan Hall, Peter Henriksen**.

> A case study from SW Australia: Long term trends in rainfall and their impacts on phytoplankton ecology in a southwest Australian estuary.

Most of Australia has low erratic rainfall combined with small coastal catchments and high evaporation resulting in annual discharge from rivers that are amongst the lowest and most variable in the world. The southwest of Australia has seen a pronounced decline in rainfall over the last 30 years at ~ 10 mm/y with 2010 dropping to 268 mm less than the 30 year average. This drying trend has resulted in lower river runoff and a range of impacts on southwest estuaries. Evidence from Wilson Inlet, a bar built estuary along the south coast of Australia suggests pronounced impacts on nutrient cycling and phytoplankton dynamics. The estuary is approximately 14 km in length and 4 km wide and has an area of 48 $km^2$. The estuary has an average depth of approximately 1.8 m and a volume of approximately 120 x $106m^3$. Typically, the entrance of the estuary is blocked by a sand bar for 7 to 9 months each year. Since the 1930s, Wilson Inlet has been artificially opened to control local flooding when it exceeds ~1m above mean sea level. In recent years, when the Inlet did not reach this height the bar was not artificially breached. As a consequence of not being opened to the sea, despite a reduction in rainfall and river flow, the average salinity of the Inlet has been reduced significantly. Since 1999, the salinity has fallen ~ 10 ppt. Associated physical and chemical impacts include reduced stratification, a lower frequency of bottom water hypoxia and a reduction in bottom water ammonium concentrations. Biological consequences include a reduction in chlorophyll a and a reduction in diatoms within the Inlet.

## Q7 Method development

**Peter Thompson, Jacob Carstensen, Todd O'Brien, Abigail McQuatters-Gollop, Monika Winder, Katja Philippart, Todd O'Brien**

An initial investigation of artificial data sets with quarterly sampling that spanned 25 years with different degrees of seasonal amplitude and different amount of a consistent long trend, were examined. Seasonal variation (intra-annual) typically varies with latitude so a range of seasonal amplitudes that varied by a factor of 10 were considered. In addition, longer term trends (inter-annual) were allowed to vary from 0.2 to 2% of the intra-annual amplitude. Long term trends were detectable in all tested scenarios using linear regression with raw data and seasonally de-trended data.

Using the Naples station time series data a similar analysis was undertaken on largely weekly data commencing in 1984. Conventional time series analysis was not possible due to missing data (most species do not appear regularly and the series has a gap between 1993 and 1996). Various levels of taxonomic resolution were tested. With species pooled to Class (i.e., all diatoms) a simple linear regression showed a significant long term trend although the data failed tests for normality and homoscedasticity. The seasonally amplitude was large. Across all data, the highest monthly mean (May) was 81 times the lowest monthly mean (December). Removing the monthly mean concentrations (de-trending) solved the problem of heteroscadiscity and improved the estimated precision of the long term trend by 20%. Randomly resampling at monthly intervals did not change the conclusions significantly. Randomly resampling at quarterly intervals did not result in a significant long term trend being detected. Repeating this analysis at lower taxonomic levels showed increasing problems with the distributions of data (normality and homoscasticity). Alternative methods of estimating long term change when the time series was broken were investigated. Significant differences were detected over time spans from 1 to 6 years for genera. The statistical analysis used weekly data pooled to seasonal means and compared across years in a 2 way ANOVA (year, season).

Recommendations

1. Where frequent observations exist there may be some advantage to aggregating the data into longer time steps. This improves normality (due to the central limit theorem) and may still allow trends to be detected.
2. More effort is needed to find a transformation that improves species abundance data.

## Question 9: What role does bottom-up vs. top-down processes play in regulating planktonic communities? To what extent does phytoplankton composition affect food quality?

**Monika Winder, Katja Philippart, Jim Cloern, Alexandra Kraberg, Sirpa Lehtinen, N Ramaiah**

Environmental perturbation and climate change are important drivers for phytoplankton dynamics and their taxonomic composition, which largely affect food availability for zooplankton and energy transfer to upper trophic level. Energy transfer from primary producers to consumers were seen to depend largely on the overall quantity of edible and digestible phytoplankton biomass, however novel insights have clearly shown that the transfer of phytoplankton to zooplankton biomass might equally depend on quality aspects of the phytoplankton (Brett and Mueller-Navarra 1997, Sterner and Elser 2009, Van Donk et al. 2011). Quality encompasses all features of the food that makes the item suitable for ingestion and for fulfilling the consumer's nutritional requirements and thus "quality" is an encompassing term that includes stoichiometric composition, biochemical make-up, and morphological characteristics. These traits affect zooplankton growth and reproduction directly, since zooplankton require an adequate intake of all necessary building blocks. It is expected that in concert with seasonally changing phytoplankton species composition the availability of essential macromolecules to zooplankton changes with critical consequences for zooplankton reproduction and recruitment (Arts et al. 2009).

The goal of this project is to investigate to what extent phytoplankton species composition affect food quality for zooplankton. We propose to apply a food quality index to long-term phytoplankton time series that are available from different estuarine and coastal sites by using compositional food quality ranking based on taxonomic phytoplankton composition. It has been shown that biochemical composition varies considerable among phytoplankton taxa (Brett and Mueller-Navarra 1997), such as diatoms and cryptophytes contain high food quality, whereas cyanobacteria fail to support higher trophic level production (Müller-Navarra et al. 2004). This approach is currently tested using the long-term phytoplankton dataset from the San Francisco Estuary. After it has been successfully tested at this site, it will be applied to other ecosystems.

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## Changes in phytoplankton observed in Korean waters (Yellow Sea & East Sea)

**Sinjae Yoo**

Although there is enough indirect evidence that indicates continuing eutrophication in the Yellow Sea since 1970s, no long term time-series of chlorophyll-a or phytoplankton density data exist that directly show an enhanced productivity for the past decades. In this study, four-decade time-series of Secchi depth data are converted to chlorophyll-a using a relationship derived from chlorophyll-a –Secchi depth data obtained over a 10-year period (n=97). The reconstructed chlorophyllSD data show a stationary period from late 1960s up to 1990 followed by a rapid linear increase, which continued as of 2010. The increase compared with the stationary period of 1960-1990 was about 70%. While this increase itself is consistent with known eutrophication trend in the Yellow Sea, the timing of increase is not clearly understood at this time: Other signs of eutrophication (e.g., algal blooms) appeared in the early 1980s. However, the trend coincides with the warming trend started in the late 1980s in the western North Pacific region. Unlike the Yellow Sea, the East Sea (Japan Sea) ecosystem has not been influenced much by human activities. The reconstructed chlorophyll-a time-series from the East Sea did not show a linear trend but there was a shift in early 1990s (with 10% increase after the shift) accompanied by the shifts in water temperature and salinity. It is interesting that the shifts in the chlorophyll-a occurred at a similar time in the two seas under different forcing. This implies that the eutrophication process in the Yellow Sea is confounded by climate change effects.

**Emergence of picocyanobacteria and *Alexandrium catenella* in the context of a 38 year time series of biogeochemical variables in a temperate coastal lagoon**

**Yves Collos et al**.

Emergence of both picocyanobacteria (*Synechococcus*) and *Alexandrium catenella* occurred in the mid-1990s in Thau lagoon following a 30 year oligotrophication period leading to undetectable soluble reactive phosphorus (SRP) levels in winter. Increasing water temperature and the high sensitivity of picocyanobacteria to this variable as well as their ability to take up low SRP levels provided an ecological niche for their development. Evidence from confocal microcopy indicates that phagotrophy of those small cells by *A. catenella* allows periodic dominance of this toxic dinoflagellate over strictly autotrophic members of the phytoplankton community.

**Question 6: Common seasonal patterns for single species and communities**

**Adriana Zingone & the Q6 group**

Recurrent seasonal variations in marine phytoplankton, i.e. phenological patterns, are of extreme importance as they can synchronise the trophic web and determine the ecological performance of a species, thereby affecting the outcome of environmental selection. While the role of endogenous control has been widely demonstrated for plants and animals, external factors such as physical and chemical characteristics of the environment, grazers and pathogens, are considered to be the only drivers of seasonality in phytoplankton. Time series provide a unique opportunity to study phenological patterns along with their causes and their variations over time. We propose to compare the seasonal patterns of individual species and species communities across time series available in WG 137. To this end, we plan to identify a common list of species that are both identifiable and widespread, and to select appropriate visualization procedures and statistical methods to illustrate and analyze their seasonal patterns across time series in relation with local environmental variability. The next step will be to assess whether these species belong to the same communities and play similar functional roles across sites.

## 9. Acknowledgement

We acknowledge Stazione Zoologic Anton Dohrn for hosting the SCOR WG137 2$^{nd}$ meeting in Massa Lubrense, Napoli, Italy. We thank the local organizer Prof. Adriana Zingone who has done a successful job for the meeting success and she has also done a wonderful job in servicing the meeting and participants!!!

### 2.2.7 SCOR/IGBP WG 138 on Modern Planktic Foraminifera and Ocean Changes (2010)

***Feeley***

**Terms of Reference:**

1. Synthesize the state of the science of modern planktic foraminifera, from pioneering to ongoing research including
    1. their spatial and temporal distribution in the world ocean
    2. their calcification mechanisms and shell chemistry
    3. and their eco-phenotypical and genotypical variability

   as a peer-reviewed publication in an open-access journal (**deliverable 1**).

2. Provide guidelines (cookbooks) in terms of species identification, experimental setup for culture studies, laboratory treatment prior to geochemical analysis (**deliverable 2**) by identifying existing gaps in the available knowledge in order to direct future research.

3. Establish an active Web-based network in cooperation with ongoing (inter)national research programmes and projects to guarantee an open-access world-wide dissemination of results, data and research plans (**deliverable 3**).

4. Document the work of the group in a special issue of an open-access journal (**deliverable 5**) in connection with a specialized symposium with special emphasis on modern ocean change i.e. thermohaline circulation and ocean acidification, during one of the AGU or EGU conferences, ideally held at the joint EGU/AGU meeting (envisaged for 2013 or 2014) and/or at the FORAMS 2014 meeting in Chile (**deliverable 4**).

**Co-chairs:**

Gerald Ganssen
Department of Earth Sciences
Faculty of Earth and Life Sciences
Vrije Universiteit
de Boelelaan 1085
1081HV Amsterdam
THE NETHERLANDS
Tel. +31205987369
E-mail: g.m.ganssen@vu.nl

Michal Kucera
Fachbereich Geowissenschaften
Eberhard Karls Universität Tübingen
Hölderlinstrasse 12, DE-72076 Tübingen
GERMANY
Tel. +49 7071 29 74 674
Fax +49 7071 29 57 27
e-mail: michal.kucera@uni-tuebingen.de

| | |
|---|---|
| **Other Full Members** | **Associate Members** |
| Jelle Bijma (Germany) | Caroline Cleroux (USA/France) |
| Jonathan Erez (Israel) | Kate Darling (UK) |
| Elena Ivanova (Russia) | Lennart de Nooijer (The Netherlands) |
| Margarita Marchant (Chile) | Steve Eggins (Australia) |
| Divakar Naidu (India) | Baerbel Hoenisch (USA) |
| Daniela Schmidt (UK) | Sangmin Hyun (Korea) |
| Howard Spero (USA) | Zhimin Jian (China) |

| | |
|---|---|
| Richard Zeebe (USA) | Thorsten Kiefer (Switzerland)<br>Dirk Kroon (UK)<br>Stefan Mulitza (Germany)<br>Frank Peeters (The Netherlands)<br>Ralf Schiebel (France)<br>Michael Schulz (Germany)<br>Kazuyo Tachikawa (France)<br>Rashieda Toefy (South Africa) |

**Executive Committee Reporter:** Wolfgang Fennel

SCOR/IGBP Working Group 138
**Modern Planktonic Foraminifera and Ocean Changes**

Co-chairs: Gerald Ganssen (Amsterdam) and Michal Kucera (Bremen)

Second annual report: 10.9.2012
Reporting period: September 2011 – August 2012

Following its final approval and membership consolidation in early 2011, the working group has started implementing its goals by organizing a kick-off meeting coupled with a mini-symposium for young researchers in September 2011. The kick-off meeting set the agenda for the upcoming years, identified priorities and served as a basis for outreach work in an innovative format of short video clips. The first half of 2012 has been used by WG members to work towards individual products. Specifically, the structure of a planned eBook/special issue in an open journal summarizing the state of the art of knowledge on modern planktonic foraminifera has been developed and a suitable publication outlet has been identified. A website on the eForams platform has been developed and is currently being filled with content, of which two projects are ongoing: a taxonomic database and an annotated list of references. The priority for the second year of the WG is to achieve progress in two key areas: standardization of taxonomy and standardization of methods. To this end, *topical workshops on these two topics are planned for early 2013*.

Specific achievements during the reporting period include

**Kick-off meeting 29.8.-2.9. 2011**

The kick-off meeting took place in the historical premises of Het Bethanienklooster in Amsterdam. Additional funding for the kick-off meeting was secured from the EuroProx project of the VU University of Amsterdam. The meeting was attended by 18 WG members and guests. Progress in synthesizing knowledge on all aspects of modern planktonic foraminifera was identified as the first priority and the guidelines of the conditions of the publication of such synthesis in an open-access outlet were agreed. It was decided to use the eForams platform to develop a WG website and to this end, Jaroslaw Tyska from the Polish Academy of Sciences, who is one of the founders of eForams, was invited to join the WG as associated member. Finally, the meeting was used to complete the concept of video clips documenting the work of the WG, to shoot a series of interviews with WG members and to document the meeting with young researchers.

*A more detailed report on this meeting has been published in PAGES newsletter (attached)*

**Engagement with the community & transfer of expertise**

An important aim of the WG is transfer of expertise. Therefore, one day of the kick-off meeting (1.9.2011) was assigned to a mini-symposium in which 19 young researchers (PhD students and junior postdocs) from six countries presented their results in poster presentations. Two keynote lectures by WG members (Kucera and Spero) followed and all participants got further engaged in discussions during a social event. An overarching aim was to establish a longer-term cooperation between the WG members and young researchers, who will thus be able to closely follow and contribute to the aims of the SCOR WG. The mini-symposium was widely advertised and booked out early.

*List of participants is attached. Further details can be found in the attached PAGES Newsletter report.*

In order to document the aims and work of the WG, we have chosen an innovative format of short video documentaries. These were produced professionally by ScienceMediaNL, with financial support from multiple third-party sources, including SCOR. One clip highlighted and explained the importance of studying modern planktonic foraminifera. This clip is entitled *A Foram's Tale – Documentary* and is intended for a broad informed public:

> http://www.youtube.com/watch?v=xfZ_9UWcAB8&feature=youtu.be

The second clip is entitled *A Foram's Tale – Culturing process* and it serves to document the process of cultivation of live foraminifera for a more specialist audience. The expertise in handling of live planktonic foraminifera in cultures is essential for development of geochemical proxies and a better understanding of the physiology of the organism. At present, there are a handful of senior experts with skills in this field that are not sufficiently documented. This clip is designed to help to close this gap and accompany the development of a guideline for culturing work on planktonic foraminifera:

> http://www.youtube.com/watch?v=6MakjP6MkdE&feature=relmfu

Both clips have been widely publicized, including in the *SCOR Newsletter* (nr 20, October 2011) and the IGBP website, and have been picked on numerous other platforms such as the Paleowave blog and the Aquatic Sciences Network. A shorter version of the documentary clip was produced and screened at multiple international meetings, such as the TOS/ASLO/AGU 2012 Ocean Sciences Meeting in Salt Lake City.

**Web platform**

Following the decision at the kick-off meeting, a web platform to support the work of the WG was established on eForams. The purpose is to generate a web-based resource for communication within the working group (foram-blog, discussions of chapter content and taxonomy) and for structured access to information, data and images (wiki). The preliminary version is operational, but not all areas are yet open to public. Currently being developed are a taxonomic database and a reference database.

> http://www.eforams.org/index.php/WG138_Startpage

**Outlook**

Considering that there are two related, but not overlapping, priorities for action (standardization of taxonomy and of methods), it was decided to organize two topical workshops in 2013, rather than a single second WG meeting. The purpose of the workshops is to review knowledge, produce recommendations, and generate text and data needed for the WG publication (deliverables 1, 2 and 5). The workshops will advertised broadly and made available for experts outside of SCOR, with dedicated spaces for young researchers, to further facilitate transfer of knowledge.

**Overview of progress on individual deliverables:**

1. Synthesize the state of the science of modern planktic foraminifera, from pioneering to ongoing research including as a peer-reviewed publication in an open-access journal (**deliverable 1**).

> A concept of chapters for a virtual book/special issue has been developed (thus effectively merging deliverables 1 and 5) and the journal *Biogeosciences* has been identified as an optimal outlet. Negotiation with the journal has been initiated. Work on individual chapters

is in progress.

2. Provide guidelines (cookbooks) in terms of species identification, experimental setup for culture studies, laboratory treatment prior to geochemical analysis (**deliverable 2**).

To this end, two workshops are planned for 2013, which will serve to produce the content for this deliverable. Publication will commence both through deliverable 1 and 3.

3. Establish an active Web-based network in cooperation with ongoing (inter)national research programs and projects to guarantee an open-access world-wide dissemination of results, data and research plans (**deliverable 3**).

The concept of such resource has been developed. The draft version is online.

4. Document the work of the group in a special issue of an open-access journal (**deliverable 5**) in connection with a specialized symposium with special emphasis on modern ocean change, i.e., thermohaline circulation and ocean acidification, during one of the AGU or EGU conferences, ideally held at the joint EGU/AGU meeting (envisaged for 2013 or 2014) and/or at the FORAMS 2014 meeting in Chile (**deliverable 4**).

Deliverable 5 – see deliverable 1. We are still planning to promote the science of the WG by organizing special sessions at FORAMS2012 and/or another related meeting.

Attachment 1: Membership of SCOR/IGBP WG 138

**Full Members:**
1. Co-chair: Gerald Ganssen (proxies), The Netherlands
2. Co-chair: Michal Kucera (ecology and diversity), Germany
3. Jelle Bijma (ecology), Germany
4. Jonathan Erez (calcification, symbiosis, proxies), Israel
5. Richard Zeebe (bio-physico-chemistry), USA
6. Howard Spero (calcification, symbiosis, proxies), USA
7. Margarita Marchant (ecology), Chile
8. Divakar Naidu (micropalaeontology), India
9. Daniela Schmidt (microstructure), UK
10. Elena Ivanova (paleo applications), Russia

**Associate Members:**
1. Frank Peeters (spatio-temporal distribution), The Netherlands
2. Stefan Mulitza (proxies), Germany
3. Michael Schulz (ecological modeling), Germany
4. Thorsten Kiefer (PAGES), Switzerland
5. Caroline Cleroux (deep dwelling species), USA/France
6. Jaroslaw Tyszka (eForams), Poland
7. Lennart de Nooijer (calcification), The Netherlands
8. Steve Eggins (microgeochemistry), Australia
9. Kate Darling (genotypes), UK
10. Baerbel Hoenisch (bio-chemico-physics), USA
11. Zhimin Jian (micropaleontology), China
12. Dirk Kroon (micropalaeontology and taxonomy), UK
13. Rashieda Toefy (ecology), South Africa (at SA SCOR expense)
14. Sangmin Hyun (paleoceanography, sedimentation), Korea (at Korea's SCOR expense)
15. Kazuyo Tachikawa (paleoceanography, proxies), France (at French SCOR expense)

Attachment 2: List of young researchers participating in the mini-symposium on 2.9.2011

Kristina Arthur, Free University Amsterdam, PhD student
Ralf Aurahs, University of Tübingen, Postdoc
Wouter Feldmeier, Free University Amsterdam, PhD student
Jeroen Groeneveld, AWI Bremerhaven, postdoc
Tim Haarmann , Bremen University, PhD student
Lukas Pieter Jonkers, University of Barcelona, Postdoc
Heather Johnstone, Bremen University, postdoc
Azumi Kuroyanagi, Tokio University, postdoc
Gianluca Marino, University of Barcelona, Postdoc
Raphael Morard, Roscoff, Postdoc
Aurore Movellan, Angers University, PhD student
Victoria Peck, British Antarctic Survey, PhD student
Gert-Jan Reichart, Utrecht University, Academic
James Rae, Bristol University, PhD student
Tilla Roy, Gif-sur-Yvette, Postdoc
Paolo Scussolini, Free University Amsterdam, PhD student
Sanne Vogels, Free University Amsterdam, PhD student
Agnes Weiner, University of Tübingen, PhD student
Jos Wit, Utrecht University, PhD student

# SCOR/IGBP working group on modern planktonic foraminifera kicked off

## Amsterdam, The Netherlands, 29 August - 2 September 2011

Gerald M. Ganssen[1] and Michal Kucera[2]

[1]Department of Earth Sciences, VU University, Amsterdam, The Netherlands; g.m.ganssen@vu.nl
[2]Department of Geosciences, University of Tübingen, Germany; michal.kucera@uni-tuebingen.de

Planktonic foraminifera have been the true heroes of paleoceanographic research since the birth of the discipline. The ornate shells of these microscopic amoebae are arguably the most important carriers of paleoclimate information available to scientists. Our ability to reconstruct past climate states and comprehend biotic responses to changing oceanic conditions depends on a complete understanding of their ecology, biology and physiology. The quantitative unravelling of the mechanisms by which they incorporate geochemical tracers into their shells is crucial for reconstructing oceanic temperature, pH and salinity.

*Figure 1: Light micrograph of a living* Orbulina universa *caught off Southern California. This specimen illustrates the complex ecology and physiology of modern planktonic foraminifera, which need to be fully understood to make the most of the geochemical proxy signals, locked in their calcite shells. A dense network of calcite spines and rhizopodia surround a new spherical shell, providing a daytime habitat for thousands of dinoflagellate symbionts (yellow spots) that are distributed along the spines. Symbiont-derived nutrition is supplemented by feeding on crustaceans and other planktonic organisms. Here,* O. universa *has been fed a laboratory-grown* Artemia *nauplius whose tissue is digested in vacuoles inside the shell. The shell is approximately 0.5 mm across. Photo: Howard J. Spero, University of Calfiornia Davis.*

In recent decades, research on these aspects of planktonic foraminifera has been lagging behind the rapid development of sophisticated geochemical tools and numerical ecological models and their application. To bridge this gap, the Scientific Committee on Oceanic Research (SCOR), together with the International Geosphere Biosphere Programme (IGBP), jointly established a new working group (WG) in 2011, with the aim to stimulate new research, benchmark the current knowledge and disseminate the results to a broad audience. For details of the proposed work of the group, please visit: www.scor-int.org/Working_Groups/SCOR_WG_Foraminifera_revised.pdf.

The first workshop of the SCOR/IGBP Working Group 138 on “Modern Planktonic Foraminifera and Ocean Changes" took place in a stimulating atmosphere of the medieval monastery environs of “Het Bethanienklooster” in Amsterdam. The participants (WG members and invited guests) of the kick-off workshop set the priorities for future work, specified the terms of reference and shaped and planned the deliverables. Specifically, the WG agreed to

a) set-up a Web-based network in cooperation with ongoing (inter)national research programmes and projects to guarantee an open-access, world-wide dissemination of results, data and research plans and

b) to synthesize the state of the science of modern planktonic foraminifera, from pioneering to ongoing research as an eBook or a special issue of an open-access journal. Contents for this foram compendium were drafted. The group decided that eForams (http://eforams.org) will be used as the Internet platform for the deliverables of the WG. The "WG138-eForams fusion" will thus represent an innovative experiment in developing new ways of science dissemination. In the same spirit of innovation in communication with its stakeholders, the WG has documented its aims in short video clips, which are freely available on the Internet (under: *A Foram's Tale* on YouTube).

In order to expose the aims of the WG to young researchers, the kick-off meeting was accompanied by a one-day focus symposium. It was attended by 18 early-career researchers from six countries and featured keynote presentations by Michal Kucera on genetic diversity and Howie Spero on calcification mechanisms and shell chemistry. The participants were briefed on the progress of the WG and engaged in discussions during the day, over posters and during the scenic canal boat trip in Amsterdam (*SCOR Amsterdam meeting* also on YouTube). On the morning of the following day, the participants including WG members, guests and young researchers reviewed the deliverables and considered the time plan and modalities to achieve the completion of the ambitious aims of the group.

This marked the closure of the workshop, where the pleasant and open atmosphere set the pace for the work of SCOR/IGBP WG 138. The workshop constituted an excellent opportunity for the group of experts, who met in this form and constellation for the first time, to review the current status and most recent developments in modern planktonic foraminiferal research and engage in exciting and stimulating discussions with the next generation of scientists.

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**2.2.8 SCOR WG 139 on Organic Ligands – A Key Control on Trace Metal Biogeochemistry in the Ocean (2011)** ***Compton***

**Terms of Reference:**

1. To inform the Ocean Sciences community of this WG and related objectives via a widely distributed publication in *EOS* or analogous journal.
2. To summarize published results on all aspects of metal-binding ligands in the oceans (e.g., distributions, chemical structure, sources, sinks, stability constants), and to contribute to the organic ligand database for use in biogeochemical models and for those working in the field (including results from ongoing GEOTRACES, SOLAS and CLIVAR efforts). The summary will be included in a review paper published after year 2, as well as in the database on the proposed website.
3. To expand upon the ligand intercalibration programme, initiated by GEOTRACES, to evaluate key analytical issues with currently employed methodologies and determine how to best link ongoing efforts in trace metal and organic geochemistry to assess natural metal-binding ligand.In a recent intercalibration the preservation of samples for Fe and Cu-organic speciation by freezing at -20°C as been found suitable and will enable to make samples taken during GEOTRACES cruises available to interested scientists. A large intercalibration will thus be possible in the future without additional joint cruises or sampling exercises, but could be performed with samples from several 'normal stations' of a GEOTRACES leg. Results from intercalibration efforts will be presented in a manual available via download from the proposed WG website.
4. To identify how best to incorporate published and future data into biogeochemical models.
5. To debate the nature of sampling strategies and experimental approaches employed in laboratory and field efforts in workshops and meeting discussions that are needed to enhance our understanding of the links between the provenance, fate, distribution, and chemistry and biological functions of these organic metal-binding ligands in the oceans.
6. To recommend future approaches to ligand biogeochemistry in a designated symposium, including ongoing GEOTRACES field efforts (i.e., regional surveys and process studies), integration of CLE-ACSV and organic geochemistry techniques, and the need for rapid incorporation of this research in biogeochemical models. Such future recommendations will also be included in the aforementioned downloadable manual on the WG website.
7. To establish a webpage for this SCOR working group, to promote a forum for discussion of ideas and results in form of a blog, soliciting input from the trace metal biogeochemistry, organic geochemistry and modeling communities and provide a platform to propose special sessions on trace metal-binding ligands at international meetings such as Ocean Sciences, AGU and/or EGU.
8. To produce conclusions resulting from the outcome of the above objectives in the form of a Website, a journal special issue or book, and a report to SCOR.

**Co-chairs:**

**Sylvia Sander**
(Chair 1st third of 4 year term, vice-chair remaining time)
Department of Chemistry
University of Otago
P.O.Box 56
Dunedin 9054
NEW ZEALAND
sylvia.sander@otago.ac.nz
Tel: + 64 3 479 7844
Fax: + 64 3 479 7906

**Kristen Buck**
(Chair 2nd third of 4 year term, vice-chair remaining time)
Bermuda Institute of Ocean Sciences
17 Biological Station
Ferry Reach
St. George's GE 01
BERMUDA
kristen.buck@bios.edu
Tel: +1-441-297-1880 x711
Fax: +1-441-297-8143

**Maeve Lohan**
(Chair 3rd third of 4 year term, vice-chair remaining time)
School of Geography, Earth and Environmental Sciences,
University of Plymouth,
Plymouth, PL4 8AA
UNITED KINGDOM
maeve.lohan@plymouth.ac.uk
Tel: +44-(0)1752-233011

| | |
|---|---|
| **Other Full Members** | **Associate Members** |
| Kathy Barbeau (USA) | Philip Boyd (New Zealand) |
| Ronald Benner (USA) | Ken Bruland (USA) |
| Martha Gledhill (UK) | Peter Croot (UK) |
| Katsumi Hirose (Japan) | Jay Cullen (Canada) |
| Ivanka Pizeta (Croatia) | Thorsten Dittmar (Germany) |
| Alessandro Tagliabue (France) | Christine Hassler (Australia) |
| Rujun Yang (China-Beijing) | Rick Keil (USA) |
| | James Moffett (USA) |
| | François Morel (USA) |
| | Micha Rijkenberg (Netherlands) |
| | Mak Saito (USA) |
| | Barbara Sulzenberger (Switzerland) |
| | Stan van den Berg (UK) |

**Executive Committee Reporter:** John Compton

## SCOR Working Group 139

Annual Report, July 2012

The first meeting of the new Scientific Committee on Oceanic Research (SCOR) Working Group (WG) 139: 'Organic Ligands- A Key Control on Trace Metal Biogeochemistry in the Ocean' was held on 25 February 2012, following the ASLO Ocean Sciences Meeting in Salt Lake City, Utah. This WG's aim is to improve our understanding of the role of organic metal-binding ligands in oceanic biogeochemistry through an international interdisciplinary collaboration of members comprising trace metal biogeochemists, organic geochemists, and biogeochemical modelers.

Organic metal-binding ligands control the bioavailability of trace metals and, thus, influence pivotal global elemental cycles, such as those of carbon and nitrogen. To date, the sources, chemical structures, and degradation mechanisms of organic metal-binding ligands remain poorly understood, making it difficult to model them with sufficient confidence to predict how they, and consequently trace metal cycles, will respond to projected global alteration of continental aridity (dust supply), ocean acidification, and oceanic oxygen minimum zones due to a changing climate. Consequently, the overarching goals of SCOR WG 139 are to (1) Promote improvements in quality, accessibility, and development of analytical methodologies for characterizing metal-binding ligands in seawater, (2) Characterize which components of the dissolved organic matter pool make a significant contribution to biogeochemistry of trace metals in the ocean, and (3) Identify the role of ligands in microbial ecology and marine biogeochemical cycles.

During the successful first meeting, members agreed upon the proposed terms of reference (TOR) to define the work statements for WG 139. The TOR identified included implementation of ways to improve methodology for determining organic ligands, expansion of ligand intercalibration exercises, launch of a new database for organic metal-binding ligand data, and publication of WG outcomes in peer-reviewed literature and in a best practice guide for the determination of organic metal-binding ligands. Over the next nine months our action plan includes facilitating a new intercalibration exercise, completing summaries of important building blocks (e.g., methods currently applied, time-series ligand data, biochemical pathways of trace metals) for the best practice guide, and identifying additional funding sources to drive this project forward.

Following the first meeting, the updated TOR and meeting notes, including upcoming action items, have been posted on the SCOR WG 139 webpage (http://www.scor-int.org/Working_Groups/wg139.htm). About 50% of the short review documents requested from the first meeting, which will be used toward the best practices manual, have been submitted to the WG chairs and will soon be posted on the SCOR WG 139 Web page. The remaining documents are in progress according to the assigned members. Two short notes on the scope of WG 139 have been written for publication in *EOS* and *Chemistry International* (the IUPAC magazines), respectively (See Publications, below). The intercalibration of numerical evaluation of simulated titration data involves 30 researchers, from both within and beyond this WG. Five sets of simulated titration data were constructed and distributed to the community by co-chair S.

Sander and member I. Pizeta. Results are due back from participants at the beginning of August. The outcome of this exercise will be published in *EOS* and/or a full peer-reviewed paper. It is envisioned that a specific Web page and the database for published trace metal binding ligand data will be hosted at the University of Otago, Department of Chemistry, by a local IT support person. Co-chair S. Sander has taken responsibility for both and has already applied for a University of Otago research grant to cover personnel costs for a research assistant to accomplish these tasks.

A second meeting of SCOR WG 139 is planned for Saturday, 16 February 2013, before the ASLO Aquatic Sciences Meeting to be held in New Orleans, Louisiana. While this meeting will again be for members only, we have additionally organized a special session on 'Biogeochemistry of metal-binding organic ligands in the ocean: Sources, composition and impacts on trace metal cycling,' which has been accepted. The co-chairs will begin soliciting abstract submissions for this session from the broader community in August. This session will function as a community-wide forum to highlight recent accomplishments in metal-binding ligand characterization and approaches for assessing ligand composition, sources, and impacts on trace metal cycling in the aquatic environment and to discuss future efforts in this field. We are inviting abstracts from throughout the multidisciplinary field of dissolved organic matter and interactions with trace metals in alignment with the goals and TORs of WG 139.

WG 139 is currently fully sponsored by SCOR, with additional funding being sought to cover future costs related with the TORs, specifically with regard to Web site and database development, capacity building in developing countries and intercalibration exercises. While an application for EU funding to sponsor a larger workshop in 2014 was unsuccessful, co-chair S. Sander has applied for funding from her institution (University of Otago) to finance a research assistant to populate the database, manage a dedicated SCOR WG 139 Web page, and to assist with the preparation of an intercalibration exercise and standard reference sample for trace metal-binding ligands. IUPAC funding will additionally be sought to finance the dissemination of the best practice guidelines for the analysis of complexation trace metals by organic ligands in seawater.

Holding the SCOR WG meeting in combination with larger ocean sciences conferences (such as the OSM in 2012) has proven to be an excellent choice, primarily because a large number of members are already planning to attend these conferences, which allows for greater participation in the WG meeting. Secondly, additional travel costs for members are minimal for these combined efforts, as many are able to use alternate funds for their travel. For the first WG 139 meeting, a total of US$3,634 was used, which is much less than the allotted $15,000 for these meetings. We expect a similar savings for the second WG meeting planned in conjunction with the ASLO Aquatic Sciences meeting in New Orleans in 2013. These savings are expected to allow for supplemental meetings to facilitate progress toward WG 139 TORs.

**Publications in 2012:**

Buck, K. N., M. C. Lohan, and S. G. Sander. 2012. Metal-binding organic ligands as the focus of a new SCOR Working Group. IUPAC *Chemistry International*. 34(4).

Sander, S., K. N. Buck, and M. Lohan. 2012. Improving understanding of organic metal-binding ligands in the ocean. EOS 93**:** 244.

CHEMISTRY International
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## Metal-Binding Organic Ligands

The trace metals iron (Fe), copper (Cu), nickel (Ni), cobalt (Co), cadmium (Cd), and zinc (Zn) are essential micronutrients to marine phytoplankton, controlling primary productivity in up to half of the open ocean, from tropical to polar regions. Consequently, these metals exert a major influence on the global carbon cycle and play a key role in regulating climate. However, the availability of these metals to the biota is governed by speciation, whereby trace metals are bound by organic ligands that may reduce or enhance metal bioavailability, depending on the metal and the resulting metal-ligand complex. Organic ligands are defined as molecules that can bind to, and form a stable complex with, trace metals in the aquatic dissolved (typically <0.2 µm) phase. Electrochemical techniques have shown that trace metals in seawater are overwhelming bound (up to 99.999%) by organic ligands, and that these ligands are ubiquitous in the ocean. More recently, organic geochemical techniques have shown that at least some Fe-binding ligands are produced by the biota. Over the past three decades, major advances in analytical techniques have led to a consensus on accuracy and precision for total dissolved trace metal analyses and dramatically improved our knowledge on the global and regional distributions of trace metals. In contrast, our understanding of trace metal-binding ligands and their pivotal biogeochemical functions remains at a comparatively early stage. To date, we know little about the composition, distributions, and provenance of metal-binding ligands, which is hindering further advances in the field of trace metal biogeochemistry.

By combining the expertise and analytical advances of trace metal biogeochemists, organic geochemists, and modelers, this community is poised to make a significant step towards assessing metal-binding ligands in the ocean and defining new research directions for metal speciation. This will enable trace metal speciation data to be better incorporated into global climate models to predict how organic complexation, and consequently trace metal cycles, will respond to projected changes in ocean acidification and oceanic oxygen minimum zones. To facilitate this effort, an ICSU Scientific Committee on Oceanic Research (SCOR) Working Group 139: Organic Ligands—A Key Control on Trace Metal Biogeochemistry was formed.

This SCOR Working Group met for the first time in February 2012 following the ASLO Ocean Sciences Meeting in Salt Lake City, Utah, to approve and commence on the Working Group's terms of reference. Members of Working Group 139, comprised of trace metal biogeochemists, organic geochemists, and biogeochemical modelers, have identified three overarching goals to be advanced over a four-year term:

1. promote improvements in quality, accessibility, and development of analytical methodologies for characterizing metal-binding ligands in seawater
2. characterize which components of the dissolved organic matter pool make a significant contribution to biogeochemistry of trace metals in the oceans
3. identify the role of ligands in microbial ecology and marine biogeochemical

cycles

Following the first meeting, the Working Group has begun working towards building a database to link trace metal biogeochemistry and organic geochemistry data at established time-series stations, advancing the ligand intercalibration program initiated by GEOTRACES, and summarizing methodological approaches to assess metal-binding ligands in seawater. The next SCOR Working Group 139 meeting will be on 16 February 2013 preceding the ASLO Aquatic Sciences Meeting in New Orleans, Louisiana. We have proposed a scientific session for the Aquatic Science meeting to complement the SCOR Working Group 139 goals.

Anyone interested is welcome to join our e-mail list by contacting the co-chairs and to participate in the proposed scientific session. Information, progress, and updates on future meetings, database development, and upcoming intercalibration exercises may be found via the SCOR website.

www.scor-int.org/Working_Groups/wg139.htm

For more information, contact Kristen N. Buck <kristen.buck@bios.edu>, Bermuda Institute of Ocean Sciences, Bermuda; Maeve C. Lohan <maeve.lohan@plymouth.ac.uk>, University of Plymouth, United Kingdom; or Sylvia G. Sander <sylvias@chemistry.otago.ac.nz>, University of Otago, New Zealand.

### 2.2.9 WG 140 on Biogeochemical Exchange Processes at the Sea-Ice Interfaces (BEPSII) (2011)

***Volkman***

**Terms of Reference:**

1. Standardisation of methods for data intercomparison.
2. Summarizing existing knowledge in order to prioritise processes and model parameterizations.
3. Upscaling of processes from 1D to earth system models.
4. Analysing the role of sea ice biogeochemistry in climate simulations.

**Co-chairs:**

**Jacqueline Stefels**
University of Groningen
Centre for Life Sciences
Ecophysiology of Plants
PO Box 11103
9700 CC Groningen
The Netherlands
Phone: 31 (0)50 3636137
E-mail: j.stefels@rug.nl

**Nadja Steiner**
Fisheries and Oceans Canada
CCCma
University of Victoria
P.O. Box 1700 STN CSC
Victoria, BC V8W 2Y2
CANADA
Fax: +1-250-363-8247
Phone: +1-250-363-1433 or +1-25-363-6402
E-mail: Nadja.Steiner@ec.gc.ca

| | |
|---|---|
| **Other Full Members**<br>Gerhard Dieckmann (GERMANY)<br>Elena Golubeva (RUSSIA)<br>Delphine Lannuzel (AUSTRALIA)<br>Sang Heon Lee (KOREA)<br>Lynn Russell (USA)<br>Paul Shepson (USA)<br>Jean-Louis Tison (BELGIUM)<br>Martin Vancoppenolle (BELGIUM) | **Associate Members**<br>TBD |

**Executive Committee Reporter:** John Volkman

# SCOR WG 140 on Biogeochemical Exchange Processes at the Sea-Ice Interfaces (BEPSII)

# Report 2012

## Kick-off meeting

An *unofficial* kick-off meeting was held as a side-meeting during the SOLAS Open Sciences Conference from 7-10 May 2012 in Cle Elum (USA).
Following a group discussion on SCOR's feedback to shorten and clarify the terms of reference, new TOR were formulated:
*The proposed working group will bring together experimentalists and modellers that each have their own and combined goals:*

1. Standardization of methods for data intercomparison.
2. Summarizing existing knowledge in order to prioritize processes and model parameterizations.
3. Upscaling of processes from 1D to earth system models.
4. Analyzing the role of sea ice biogeochemistry in climate simulations.

Specification (*to be confirmed during the Full Members meeting later in the year*):

- In order to evaluate currently available data of important parameters and to make recommendations for further data collection needed for the validation of models, a thorough evaluation of existing and new methods is required. As a first step a **review** will be published on existing methods including a discussion of strengths and weaknesses. This will lead to **recommendations** of preferred methods and recommendations for intercomparison exercises. Throughout the project period we will work on the step-wise building of a **guide of best practice**.
- In order to improve communication and exchange of information, modellers will provide a guide for experimentalists that detail the requirements of their models. This will guide the experimentalists to produce a **special issue** with reviews on the major biogeochemical processes on relevant time and space scales and to make recommendations for improved data collection and the creation of databases. The production of databases will be stimulated.
- Tools are needed to understand and quantify simulation-critical processes, to prioritise the processes to be implemented in the next scale of models and how to simplify models without losing important information. Prioritisation will result from the **intercomparison of 1D models** (see below) and the subsequent evaluation of the role of parameters, biogeochemical complexity and of bio-physical coupling in the model outcome. This will be published in a peer-reviewed paper.
- From this collaboration, model development that will quantify our knowledge on the impact of sea ice biogeochemistry on climate and how climate change feeds back onto sea ice biogeochemistry will be strengthened via
    - development of parameterisations accurately representing biogeochemical processes in 1-D models based on active model activities described in Vancoppenolle et al. (France)), Tedesco et al. (Finland), Steiner et al. Lavoie et al. (Canada) ), Jin et al (U.S), other emerging models will be welcomed to participate.
    - application of these and simplified parameterisations in regional models to study spatial impacts and significance on larger scales (examples are: NEMO-LIM-PISCES (France, Vancoppenolle), NEMO-CICE-CAEM (Canada, Steiner), xxx (USA, Deal, Elliott), xxx (Finland, Tedesco)).

- Sensitivity studies in/with earth system models (e.g. CanESM (Can), CESM (US), IPSL-CM4 (France)) can only be performed very limitedly due to the temporal restrictions in earth system model development. However regional climate model output from the international Coordinated Regional Downscaling experiment (CORDEX) will be used to force regional models and evaluate longterm impacts.

To achieve these goals, three **task groups (TG)** were formulated:
1. TG-Methods: this group is responsible for 3 products: Review on methodology, recommendations for intercomparisons, guide of best practice
2. TG-Data: responsible for 2 products: Inventory of available data, recommendations for a database
3. TG-Models: responsible for 4 products: Recommendations from modellers to observationalists, review paper on major biogeochemical processes, intercomparison of 1D models and publication of a review, application in regional models with climate scenario's.

Following recommendations by SCOR-international, the list of **full membership** was finalized:

| Full members | Institute | Country | Specialization |
|---|---|---|---|
| Jacqueline Stefels (co-chair) | Univ of Groningen | Netherlands | Ice-ocean S-cycle, microbial processes |
| Nadja Steiner (co-chair) | IOS (Fisheries and Oceans Canada) and CCCma | Canada | Sea-ice, biogeochemical and earth system modelling |
| Delphine Lannuzel | Antarctic Climate & Ecosystems CRC, University of Tasmania | Australia | Ice-ocean trace metal biogeochemistry |
| Jean-Louis Tison | Univ Libre Brussel | Belgium | Ice physics and gas composition |
| Martin Vancoppenolle | LOCEAN, Univ Pierre et Marie Curie | France | Sea-ice biophysico-chemical modeling |
| Gerhard Dieckmann | Alfred Wegener Institute for Polar Research | Germany | Sea-ice ecology, C-cycle |
| Sang Heon Lee | Pusan National University | Korea | Ice and ocean primary production |
| Paul Shepson | Purdue University | USA | Atmospheric chemistry, ozone, halogens |
| Lynn M. Russell | Scripps Inst. of Oceanography | USA | Organic aerosols |
| Elene Goloubeva | Russian Academy of Science (Novosibirsk) | Russia | Ice-ocean physical modelling |

## Meetings & Products

- In a collaborative effort between the communities associated with the IPY-project OASIS and the SOLAS sea-ice network, an article has been prepared for EOS (Shepson et al. 2012), which discusses emerging issues in this field and linkages between disciplines. The paper introduces BEPSII to which several of the authors are associated (Annex I).
- BEPSII has presented itself at the IPY2012 meeting in Montreal, March 2012 (poster presentation in Annex II) and the SOLAS Open Sciences Conference from 7-10 May 2012 in Cle Elum (USA).

- In Cle Elum, a discussion session was devoted to “Improving our understanding of and capacity for model projections of sea ice-ocean biogeochemistry” The goal of this session was to engage observationalists and modelers in a discussion of model-data scaling issues and approaches, and the hidden problems involved in transferring understanding from fine-scale observations and process measurements to coarse-scale models. One clear outcome was the necessity for networking and collaboration, a main task of this SCOR working group. A summary of the session outcomes is enclosed (Annex III) and a short version thereof will be published in the SOLAS newsletter of autumn 2012.
- The TG-methods has been working on the set-up of a review on current sea-ice methodology. The outlines have been formulated (Annex IV) and a scientific publication is now in preparation.

## Upcoming

In November 2012 a meeting with full members will be organized. The possibilities for video-conferencing are currently explored.
Agenda items are:

- Finalizing of membership of the TGs, including associate members.
- Specifying the products and timelines for each of the TGs
- Dates and places for TG meetings
- General WG meeting in 2013

# ANNEX I

Eos, Vol. 93, No. 11, 13 March 2012

By P. B. Shepson, P. A. Ariya, C. J. Deal, D. J. Donaldson, T. A. Douglas, B. Loose, T. Maksym, P. A. Matrai, L. M. Russell, B. Saenz, J. Stefels, And N. Steiner

*Eos*, Vol. 93, No. 11, 13 March 2012

EOS

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PAGES 117–124

# Changing Polar Environments: Interdisciplinary Challenges

PAGES 117–118

In the past few decades, there has been enormous growth in scientific studies of physical, chemical, and biological interactions among reservoirs in polar regions. This has come, in part, as a result of a few significant discoveries: There is dramatic halogen chemistry that occurs on and above the sea ice in the springtime that destroys lower tropospheric ozone and mercury [*Simpson et al.,* 2007; *Steffen et al.,* 2008], the sunlit snowpack is very photochemically active [*Grannas et al.,* 2007], biology as a source of organic compounds plays a pivotal role in these processes, and these processes are occurring in the context of rapidly changing polar regions under climate feedbacks that are as of yet not fully understood [*Serreze and Barry,* 2011].

Stimulated by the opportunities of the International Polar Year (IPY, 2007–2009), a number of large-scale field studies in both polar environments have been undertaken, aimed at the study of the complex biotic and abiotic processes occurring in all phases (see Figure 1). Sea ice plays a critical role in polar environments: It is a highly reflective surface that interacts with radiation; it provides a habitat for mammals and micro-organisms alike, thus playing a key role in polar trophic processes and elemental cycles; and it creates a saline environment for chemical processes that facilitate release of halogenated gases that contribute to the atmosphere's ability to photochemically cleanse itself in an otherwise low-radiation environment. Ocean-air and sea ice–air interfaces also produce aerosol particles that provide cloud condensation nuclei.

Sea ice is undergoing rapid change in the Arctic, transitioning from a perennial or multiyear ice pack to a thinner, seasonal first-year ice pack, thereby transforming the Artic into a more Antarctic-like system. Most climate models project an ice-free summer Arctic by the end of the century, with some projections indicating considerably sooner. Such changes in critical interfaces will likely have large effects across the system, from habitat loss to dramatic changes in heat and water vapor fluxes and changes in atmospheric chemistry. Arctic changes will teleconnect throughout the globe via induced changes in ocean circulation and concomitant modification of weather systems. The loss of sea ice is likely to alter human behavior on a large scale, including adaptive behavior of subsistence hunters across the Arctic and utilization of new trade routes opening across the Canadian archipelago.

To help humans adapt, improve Arctic climate and weather predictions, and better understand the impacts of a seasonally ice-free Arctic on ecosystems and humans, it is essential that scientists understand interactions among components of the entire ocean-climate-cryosphere-human system and potential feedbacks at their most fundamental levels. In particular, the complexities of polar systems must be properly captured in Earth system models. Although the Antarctic may serve as a model for some aspects of the future Arctic system, its contrasting response to climate change emphasizes that many key processes exhibit differing challenges at both poles. One approach to tackling research questions involving climate change in polar regions is to examine topics for focused study as a thematically organized set. This set, discussed below, parallels some of the major scientific and public interest advances of the IPY.

### *Sea Ice Processes*

Sea ice is both a reservoir and a substrate for biogeochemical compounds. Physical forces interact with chemical and biological processes within the ice in complex ways,

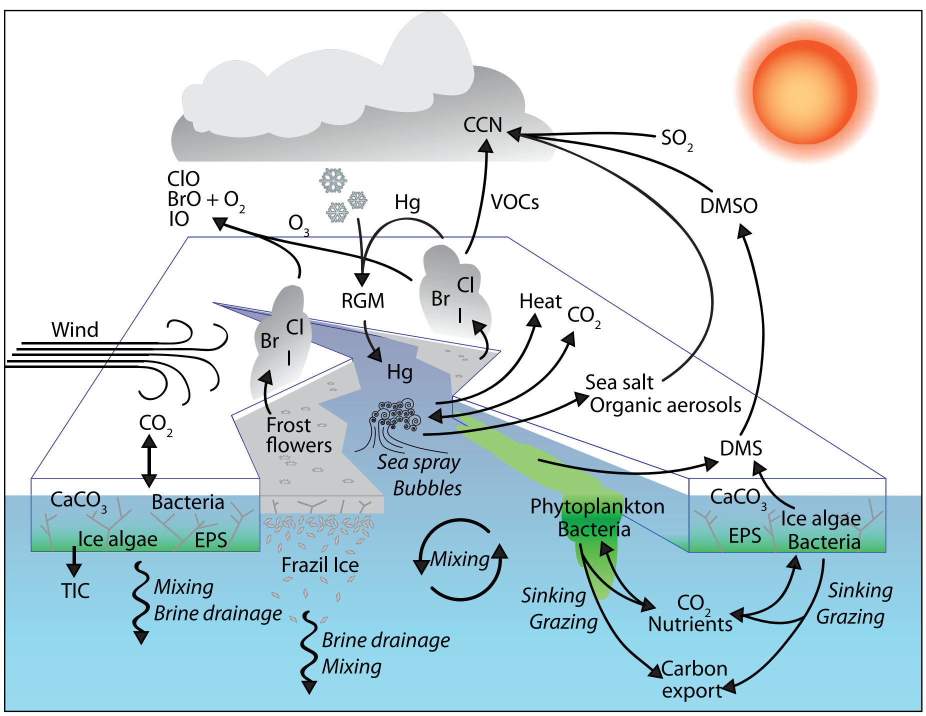


*Fig. 1. Schematic of some ocean-atmosphere-sea ice-snowpack interactions among the chemical, physical, and biological processes in polar regions. These include but are not limited to feedbacks involving such chemical species as volatile organic compounds (VOCs), cloud condensation nuclei (CCN), total inorganic carbon (TIC), dimethyl sulfoxide (DMSO), reactive gaseous mercury (RGM), dimethyl sulfide (DMS), exopolymeric substances (EPS), and other molecular exchanges, as shown.*

By P. B. Shepson, P. A. Ariya, C. J. Deal, D. J. Donaldson, T. A. Douglas, B. Loose, T. Maksym, P. A. Matrai, L. M. Russell, B. Saenz, J. Stefels, and N. Steiner

thereby enforcing limits to the production and consumption of biogenic gases (e.g., oxygen, carbon dioxide, and dimethyl sulfide) throughout the seasonal cycle [*Loose et al.,* 2011]. Gas transport through sea ice pore spaces is temperature dependent and typically minor when the ice is cold, but it increases in warm springtime ice. Subfreezing temperatures inside sea ice can promote calcium carbonate precipitation, driving the carbonate system away from seawater equilibrium, thereby altering the net transport of inorganic carbon between the atmosphere and the deep ocean. However, the magnitude depends on physical rates and pathways that are poorly constrained.

Direct exchange at the air-sea interface also occurs through cracks, leads (long, thin breaks in the ice caused by the combined action of wind and water currents), polynyas (areas of open water surrounded by sea ice), and open water. Sea ice reduces the surface area available for air-sea fluxes, but turbulent ice-ocean and ice-air interfacial stresses, buoyant convection, and wind waves potentially increase gas, aerosol, moisture, and heat transfer above what would be expected over a continuous, quiescent ice cover. Estimates of biogenic material exchanges in the polar ocean and their impact on larger scales will require a good knowledge of constraints on these processes.

### *The Polar Microbial Loop*

Scientific understanding of the flow of energy and material within marine ecosystems and the role of microbes in elemental cycles lags in polar regions. Despite its inherent environmental extremes, sea ice provides a habitat for cryoadapted algae and bacteria, which may catalyze physical changes in the surrounding cryosphere. Exopolymers, proteins, and polysaccharides, produced by microbes as a defense against freezing, alter the microstructure of sea ice and the production of organic aerosols that could act as cloud condensation nuclei. Dense pigment layers not only affect ice albedo but also influence ice structure and stability via solar energy absorption.

In concert with their direct impact on the polar carbon cycle, microbes produce other climatically active species, including dimethyl sulfide and halocarbons, which are precursors of aerosols and reactive oxidizing compounds (e.g., bromine and chlorine atoms). Currently, significant gaps remain in understanding these biologically mediated processes due to the limited number of polar studies fully integrating rate measurements of biological, chemical, and physical processes with good temporal and spatial coverage.

### *Primary Aerosols*

Sea salt aerosol, an important primary aerosol in polar regions, is generated from breaking waves or wind blowing over ice, snow, and frost flowers on the sea ice. Large changes in sea salt aerosol inputs, energy exchange above leads and polynyas, and fluxes of biological and biologically derived material become more likely as the timing and extent of open water are altered. Evidence is clear that organic components from biological activities contribute a substantial fraction of the atmospheric aerosol [e.g., *Orellana et al.,* 2011]. These bio-organic compounds can influence important chemical and physical properties of aerosols, such as their solubility, surface tension, morphology, growth, and oxidation. These physical properties control aerosols' climatic and health effects.

Consequently, understanding the significance of biological particles and associated biogenic volatile compounds (e.g., dimethyl sulfide) for atmospheric processes and air-ice-snow interfaces is of great importance. Key issues to address involve characterizing bio-organic matter and understanding its transformation processes, including its effects on cloud nucleation and climate.

### *Reactive Halogens in Polar Regions*

Many Arctic and Antarctic coastal stations record springtime events of depletion of ground-level ozone and mercury related to halogens released through a complex interplay between gas phase and condensed phase chemistry and meteorology in the lower troposphere. Global Ozone Monitoring Experiment satellite observations of atmospheric backscattered ultraviolet radiation have identified large clouds of bromine oxide (BrO) in springtime over sea ice in both hemispheres. BrO affects the tropospheric oxidizing capacity and is part of a natural biogeochemical cycle leading to the widespread and persistent removal of ground-level ozone and atmospheric mercury, converting the latter into nonvolatile products that reach the surface via either dry or wet deposition. However, exact halogen sources (open water, sea ice, snow, frost flowers, or aerosols) and the mechanisms for halogen release remain a source of controversy.

There is new evidence for extremely active iodine oxide and chlorine chemistry in polar regions, yet their distributions, sources, and magnitudes are also uncertain. Changing sea ice extent and character may significantly affect absolute and relative concentrations of all these reactive halogens; active research and observations via surface measurements from atmospheric platforms and satellites will help to resolve such uncertainties.

### *Anthropogenic Impacts*

As Arctic seasonal sea ice retreats, anthropogenic pressures from sources inside and outside the Arctic will increase. Expanded infrastructure, coupled with increased ship traffic and resource development, will change the chemical nature and concentration of trace gases and particulates in the Arctic boundary layer and will increase pollutant loading to ground and ocean waters. Local effects (e.g., from ship traffic) could include increased sulfur emissions, which will provide cloud-forming particles that alter albedo and precipitation, while increased black carbon emissions will decrease local albedo. Increases in other transportation-related pollutants and long-range transport of Eurasian emissions will alter oxidative chemistry (e.g., via increased inputs of nitrogen oxides).

Anthropogenic impacts on the Arctic will occur on a wide range of scales—from community to regional to pan-Arctic. Human and material infrastructure will be required to mitigate anthropogenic effects and feedbacks at all these levels. Thus, solid scientific understanding of the relationships between anthropogenic pollutants and the physical, chemical, and biological state of the polar environments is necessary to inform decision makers in the development of sound and effective public policy regarding management of polar environments.

### *Upscaling*

A major challenge in understanding and predicting physical, chemical, and biological exchanges among ocean, atmosphere, sea ice, and snow, within the context of a changing ice and climate regime in the polar regions, is in bridging gaps between scale size and scientific issues. Some measurements are done in laboratories at the microscale level, while others are made from satellites. While their key goals are to measure and model small-scale processes driven by or linked to interactions with sea ice, scientists also aim to understand the significance and applicability of these processes on the 1- to 100-kilometer (or larger) scales of satellite observations and Earth system models.

However, a single-model grid cell or satellite footprint often contains a wide range of ice types and states, and the scales of interest depend on the processes studied. Quantifying the system-wide effects of new ice formation or ice deformation requires considering different temporal or spatial scales for biology, chemistry, or physics. Hence, large-scale models currently designed to represent physical air-ice-ocean interactions will require creative approaches to adequately represent such small-scale processes. Tackling these challenges requires connecting effectively across disciplines, developing models in parallel on all scales, and considering scaling and heterogeneity issues when designing field process studies to interpret and evaluate satellite observations.

### *Effective Organization of Polar Interdisciplinary Research*

Perhaps the most important lesson from recent sea ice studies is that physical, chemical, and biological processes interact in distinctive and complex ways and should not be studied independently of one another. Rapidly changing polar environments challenge the scientific community to develop robust and reliable models applicable on both small and system-wide scales for the poles and the entire Earth. A better understanding of how chemical and biological species exchange among all ocean, air, snow, and ice reservoirs is needed to anticipate and understand the effects of sea ice loss in polar environments. With this information, researchers can better prepare community planners and public policy makers for what may lie ahead.

In addition, an effective organizational structure will help the scientific community articulate research priorities and identify optimized and cost-effective approaches during the current period of funding challenges. For example, because individual countries, including the United States, manage few icebreakers and other polar research platforms, an organized research community can play a role in brokering priorities and organizing coordinated field campaigns in both polar regions. Several initiatives have been undertaken to get organized. The International Geosphere-Biosphere Programme's Surface Ocean–Lower Atmosphere Study (SOLAS) has formulated sea ice biogeochemistry as one of its new foci, and the IPY's Ocean-Atmosphere-Sea Ice-Snowpack project (OASIS) [*Shepson et al.*, 2003] has recently decided to continue with a second phase aimed at more effective coordination and approaches that seek to interconnect the necessary disciplines, e.g., meteorology; climate science; atmospheric chemistry; polar ocean biology; and sea ice physics, chemistry, and biology. The SOLAS and OASIS communities will work together through the new Scientific Committee on Oceanic Research working group of the International Council for Science, known as the Biogeochemical Exchange Processes at the Sea-Ice Interfaces, which was formed in late 2011.


## Acknowledgments

This article was developed from discussions at a recent OASIS workshop held in Telluride, Colo. See the updated OASIS Web site (www.oasishome.net) for more information, workshop presentations, and reports on future activities as they are generated.


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## Author Information


Paul B. Shepson, Purdue University, West Lafayette, Indiana; E-mail: pshepson@purdue.edu; Parisa A. Ariya, McGill University, Montreal, Quebec, Canada; Clara J. Deal, University of Alaska Fairbanks; D. James Donaldson, University of Toronto, Toronto, Ontario, Canada; Thomas A. Douglas, U.S. Army Cold Regions Research and Engineering Laboratory, Fairbanks, Alaska; Brice Loose, University of Rhode Island, Narragansett; Ted Maksym, Woods Hole Oceanographic Institution, Woods Hole, Mass.; Patricia A. Matrai, Bigelow Laboratory for Ocean Sciences, West Boothbay Harbor, Maine; Lynn M. Russell, Scripps Institution of Oceanography, La Jolla, Calif.; Benjamin Saenz, University of California, Santa Cruz; Jacqueline Stefels, University of Groningen, Groningen, Netherlands; and Nadja Steiner, Fisheries and Oceans Canada, Victoria, British Columbia, Canada

# ANNEX II

Poster presentation at IPY-2012 in Montreal, March 2012

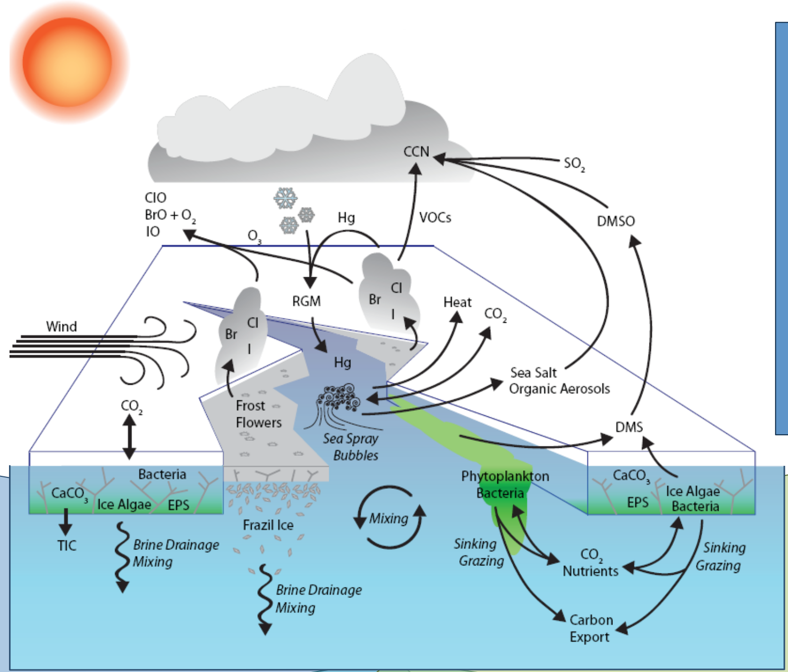
# Sea Ice Biogeochemistry: Building a Community to Take the Research Forward

## Anticipated products:

- Standardized methodologies (review, book of protocols)
- Numerical model parameterisations on local, regional, and global scales.
- Pooled efforts and resources for international field campaigns.

## Foci:

- Physical forcings of biochemical processes in sea ice and at sea-ice-snow-atmosphere interfaces
- Role of ice biota in structuring ice chemistry and ice physical properties
- Sea ice as a source of primary atmospheric aerosols and reactive halogens
- Sea-ice feedbacks to anthropogenic climate change
- The global relevance of small-scale processes




*...to achieve quantitative understanding of the key biogeochemical-physical interactions and feedbacks between the ocean and the atmosphere, and of how this coupled system affects and is affected by climate and environmental change.*

## BEPSII

### Biogeochemical Exchange Processes at the Sea-Ice Interfaces

*...to identify the feedbacks between biogeochemical and physical processes at the ocean–ice-snow-atmosphere interfaces and within the sea-ice matrix. By bringing together experimentalist and modellers, a major improvement of sea-ice biochemistry models from the micro to the global scale will be achieved.*

*...to determine the importance of OASIS chemical, physical and biological exchange processes on tropospheric chemistry, the cryosphere, and the marine environment, and their feedback mechanisms in the context of a changing climate.*

*...promoting international cooperation in planning and conducting oceanographic research, and solving methodological and conceptual problems that hinder research...*

## Contacts:


Patricia A. Matrai, Bigelow Laboratory for Ocean Sciences, E. Boothbay Harbor, ME, USA. PMatrai@bigelow.org

Lisa A. Miller, Institute of Ocean Sciences DFO, Sidney, B.C., Canada. Lisa.Miller@dfo-mpo.gc.ca

Jacqueline Stefels, University of Groningen, Groningen, The Netherlands. j.stefels@rug.nl

Nadja Steiner, Institute of Ocean Sciences DFO, Sidney, B.C., Canada. Nadja.Steiner@dfo-mpo.gc.ca


## Links:

*http://www.solas-int.org/* (Mid-Term Strategy)
*http://oasishome.net/*
*http://www.scor-int.org/wkgroups.htm* (WG 140)

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**ANNEX III – Discussion session at SOLAS OSC, Cle Elum, May 2012**

**Improving our understanding of and capacity for model projections of sea ice-ocean biogeochemistry**

**Nadja Steiner, Clara Deal, Kristina Brown**

The goal of this session was to engage observationalists and modelers in a discussion of model-data scaling issues and approaches, as well as the hidden problems involved in transferring understanding from fine-scale observations and process measurements to coarse-scale models. One clear outcome was the necessity for networking and collaboration which is one of the main tasks of the newly established SCOR working group BEPSII (Biogeochemical Exchange processes on Sea-Ice Interfaces). However, while modellers and observationalists work in the same field, their different approaches warrant transdisciplinary research principles for successful collaboration: Scientists of both sides need not only in-depth knowledge and know-how of the other discipline, but skills in mediation and communication, commitment, open mindedness, a readiness to question held beliefs, and respect for each others approaches.

For practical purposes small-scale sea ice processes such as microphysics, algal response to nutrients, and radiation transfer must be simplified and parameterized in large-scale biogeochemical models. This requires understanding and quantification of simulation-critical processes. The importance of identifying the relevant mechanisms has been pointed out in three short introductory talks on parameterizing gas exchange from an air-sea ice, ocean-sea ice and ice internal perspective. Key processes pointed out with respect to exchange at the interfaces were: windspeed, shear at the ice/ocean boundary, buoyant convection, surface roughness, carbon fluxes in brines and under-ice waters, energy budget and snow cover effects; and with respect to the control of gas concentrations in ice: initial entrapment, bubble nucleation, brine movement (convection), and sea ice permeability.

Significant challenges are involved in scaling knowledge from point and patch measurements up to regional and global scales. While we start to consider above mentioned processes in local scale models, we need to address the importance of observed small-scale processes on larger scales and eventually to the accuracy of climate change projections when going from 1D to 3D models. Generalizations across regions based on observations are useful and perhaps necessary within the spatially heterogeneous Arctic, however regions should also be characterized based on their physical and chemical properties and likely responses to climate forcing. Even if we don't know how representative the average is, mean values and standard deviations are helpful statistics for modellers. While a standard run is tuned to a mean value, sensitivity studies explore the influence of the observation-constrained parameter range on the outputs of the model. With more measurements over time, standard deviations can be reduced as models are developed in tandem with observations. Eventually, it is important to understand why there are similarities and variability. The goal is to simplify because we know what the important processes and variables are rather than because we have limited knowledge.

Observationalists traditionally sample and study processes at relatively fine scales, but these days, complex system questions are often driving the observations. To compare with model scales observationalists need to either collect enough data to determine representative averages (statically significant) or make observations on the same scale as the model, e.g. eddy covariance measurements with a 5km foot print. Sampling over a broad range of scales allows scientists to compare and contrast forcings over the entire domain. Building networks between sampling programs is one way to achieve

this goal. Coordinating multi-scale field measurements with complementary modeling is a good way to approach the model-data scaling and the best way to ensure continuous two-way communication amongst obervationalists and modelers. Communication will need to include information on the resolution or grid-size models are working on as well as the components, processes and parameters included in these models. That way observationalists can understand what scales are needed, and which observations can best feed into these models. In turn observationalists need to provide feed back on what variables are important for certain processes, so they can be considered in the model. Models are useful to help understand how observed data fit into the larger spatial and temporal scales and hence can recommend timing and location of future observations.
The potential development of simple, easy-to-use box models for observationalists to use with their own data has been suggested as a possibility for improved understanding and communication.

Part of the discussion was devoted to technical and logistical difficulties:Temporal and spatial heterogeneity has been identified as a serious barrier. Critical ice ocean exchange processes and algal influences are happening during spring and fall transition times, when the ice environment is unsafe and challenging to access. Hence, often only one season is known well, causing difficulties in scaling up to an annual cycle. Dire needed time series studies are rare and limited to organizations with continuous funding. Spatial variability is extensive and differences hard to pin down. Technological and methodological barriers exist in several respects: Collecting ice algae/plankton in a way that meaningful physiological measurements can be made is a challenge, rate information is more difficult to obtain than biomass. Most of the methods used severely perturb the system (e.g. melting), hence the development of in situ sensors is of major importance as well as facilities to test those (cold labs, ice tanks). Microenvironments are problematic (e.g. inside brine pocket), often automating an analysis leads to a loss of precision. Some organisms stick to the ice and cannot be extracted while the culturing of ice micro-organisms is still in a trial state. Optical measurements (e.g. sea gliders with fluorometers) could provide an opportunity for scalable measurements that can be worked into models. Measurement comparisons are complicated by methodological differences. Developing consistent methodologies (guide of best practices) is a task of major importance and will be addressed within the SCOR working group. Snow has been pointed out as a critical parameter strongly influencing radiative transfer and thus ice warming, brine processes, and ultimately ice biology (e.g., algal growth, attachment, and nutrient availability). Snow cover is not well constrained and/or parameterized in (global) models, although efforts are on the way to alleviate the shortcoming.

## ANNEX IV

## Methods for Biogeochemical Studies of Sea Ice: The State of the Art

(L. Miller, M. Gosselin, L. Sørensen, G. Dieckmann, S. Elliot, A. Fransson, F. Fripiat, C. Garbe, V. Schoemann, J.-L. Tison, M. van Leeuwe, E. Wolff, etc.)

**I. The rise of sea-ice biogeochemistry and new methodological needs**

- A. Biogoechemical studies of sea ice
- B. Previous reviews and we're not going to reiterate them

**II. The nature of sea ice and unique methodological challenges**

- 1.Cold
- 2. Heterogeneity
- 3. General problems with the brines
  - a. Origins of brines collected by sack-holes
  - b. Poor representation of the particulate fraction
- 4. Frost flowers (how do we sample these?), other thin brine layers

**II. Biological processes (most well developed)**

- A. Biomass/Biota:
- B. Net growth rate: oxygen dynamics, change in biomass: Chl a, POC, PON, bSi, POP, cell abundance, pigments
- C. Primary production: tracer incubation, fluorescence analysis, remote sensing
- D. Bacterial activity: change in biomass: cell abundance, tracer incubation
- E. Recommendations: under-ice optical methods, partly to tackle the heterogeneity problem

**III. Chemical concentrations**

- A. General requirements for reporting data
  - 1. *In situ* temperature, bulk salinity, and derived brine volume
  - 2. Recommendations for standard sample identification and labelling?
- B. Nutrients:
  - 1. JGOFs/Repeat Hydrography protocols for most analyses
  - 2. Brines: centrifuging
  - 3. Bulk:
- C. Gases (except $CO_2$): $O_2$, $N_2O$, $CH_4$ (and other hydrocarbons, VOCs), $N_2$, Halocarbons, Ar, Ne,
  - 1. Brines
  - 2. Bulk
  - 3. In situ probes
- D. Carbonate system: $pCO_2$, TIC (DIC), Alk., pH, PIC,
  - 1. Analyses genearlly according to Dickson manual
  - 2. Brines
  - 3. Bulk
  - 4. In situ probes
  - 5. Recommendations: Inter-calibrations, thermodynamic parameterizations
- E. Trace elements:

1. Follow GEOTRACES protocols for equipment prep and analyses.
2. Bulk
3. Brines

F. Organics:

1. EPS, POC, TOC, PON, TOM (not clear what is most useful)
2. Recommendations of which fractions/compounds are most useful to measure

G. Sulphur species (DMS, DMSP, DMSO, etc.)

1. Brine
2. Bulk

**III. Ice-Atmosphere fluxes**:

A. Micrometeorological methods (eddy covariance, gradient methods, eddy accumulation, dissipation)
B. Flux chambers
C. Aerosols
D. Parameterizations (including remote sensing)

**IV. Additional requirements/issues:**

A. Physical properties (permeability, brine volume, ice temp., liquid/air permeability, ice texture, salinity)
B. Radiation forcing (light, heat)
C. Snow cover/snow properties
D. Frost flowers (comparison/suggestions of different methods for collection)

**V. Suggestions for the future:**

A. Dedicated field and laboratory studies to test and compare methods:

1. $CO_2$ system and fluxes
2. Primary production
3. Others?

B. New technologies

1. In situ probes (C-system, other gases, etc?)
2. others?

## 2.3 Working Group Proposals

### 2.3.1 Proposal for a SCOR Working Group on Surface Waves in Ocean Circulation and Climate System *Coustenis*

Abstract

Surface waves, as the most energetic motion in the ocean, are traditionally left out of large- scale ocean general circulation and climate models. Recent studies have shown that ocean surface waves could have decisive influence on basin scale temperature structure and circulation pattern through the surface wave-induced vertical mixing. This working group will explore and identify the crucial importance of surface waves in the upper ocean and climate system through modulation of the ocean vertical mixing and air-sea interaction, and will assess new observational programs needed to better parameterize the wave-induced vertical mixing in the upper ocean and the air-sea interaction processes at sea surface. This will make it possible to improve ocean and climate models by including the mixing effects associated with the surface waves through the whole water column.

Rationale

Wind energy input to surface waves is estimated as 60~70 TW (Wang and Huang, 2004; Rascle et al., 2008), which is much greater than the mechanical energy from all other sources in the ocean. A review by Wunsch and Ferrari (2004) clearly states the critical role of surface waves in vertical mixing of momentum and energy in the global ocean. However, nearly all previous scientific studies of large-scale oceanic and climate phenomena treat waves as a superfluous nuisance. Part of the reason is that waves were thought to be of small scales and therefore irrelevant; the other factor is that wave studies have been confined to studying waves for the sake of understanding the dynamics of waves only (Yuan and Huang, 2012). In fact, vertical mixing in the upper ocean and air-sea fluxes at the sea surface are not only strongly modulated but also determined by the surface wave conditions.

Climate and weather are essentially ocean-atmospheric interaction phenomena. Their dynamic and thermal regimes imply physical coupling of atmosphere and ocean in such a complicate way that the physical details are still elusive. The past parameterization approach to study such coupled models appear to have reached a limit in their performance, and failed to reproduce aspects of important observed air-sea interaction phenomena such as the phase of the ENSO cycle and tropical-cyclone intensity, among others. There is an urgent need for better physics for related numerical models.

Air-sea interaction phenomena, including weather and climate, represent a complicated chain of inter-connected and coupled processes. If, for example, global warming is happening non-uniformly, it will lead to changes of the atmospheric pressure gradients and therefore of wind systems, which should bring about alterations to the wave fields. The latter will provide feedback on the winds and, most importantly, on the ocean mixing (Cavaleri et al., 2012). If the average prevalence or size of surface waves increases, which appears to be the case over the last 25 years (Young et al., 2011), they can mix the ocean deeper (Babanin, 2006). Since 2-3m of ocean water has the same heat capacity as the entire dry atmosphere (Soloviev and Lukas, 2003) and the deeper ocean is cold, such extra mixing should dampen the surface ocean warming. So, surface wave plays crucial role in the climate system.

Scientific Background

Simulations of the wave-mixing effects in climate models clearly demonstrate significant feedbacks from the ocean because of the additional mixing due to wave actions. This feedback impacts both the magnitudes and global distribution of primary atmospheric features such as temperature oscillations, pressure patterns and rainfall. When wave mixing is included, rainfall in summer months in Southeastern Asia, for example, is increased by 3mm per day. When full GCMs are explicitly coupled with the wave models (i.e., climate-model winds are used to generate and drive the waves, whose effects are then fed to the upper ocean), the correlation between simulated and observed sea temperatures increases by as much as 30% (Qiao et al., 2010). Note that the outcome is not entirely local, for the ocean circulation is affected, which makes the sea surface temperature is not necessarily decreased locally.

This working group will bring together the wave-coupled effects on the upper ocean, weather and climate. Weather and climate are phenomena of very different scales (days vs. years and decades, respectively). Both scales, however, are much larger with respect to the scale of ocean surface waves (seconds). Consequently, wave-related air-sea interactions in weather and in climate research have not been coupled due to the following two main reasons: In terms of geophysics, there is a traditional perception that processes of such distant scales can be studied and modeled separately, and exchange between the scales can be parameterized as some larger-scale average (mean fluxes of energy and momentum in this case). In terms of technicality, the computational costs of such coupling have been prohibitive until recently, and are still very expensive.

The fluxes, however, are not constant in the course of wave evolution, even if the wind is constant. These fluxes are determined by a great variety of wave-related properties which vary at time scale of hours, which is comparable with the lower time scale of evolution for weather patterns. Since the concurrent wave pattern is very complicated, it appears necessary to know the wave properties explicitly at each step of cyclone development.

On the atmospheric side of the ocean interface, waves determine the surface drag that is how much the surface winds are slowed down because of the wave presence. In very simple terms, the drag should increase as the winds grow, but there is experimental evidence that this growth slows down and even decreases at higher wind speeds (Powel et al., 2003), either due to aerodynamic effects imposed by waves (e.g., Donelan et al., 2006) or due to spray produced by the waves (e.g., Kudryavtsev and Makin, 2011), or due to a combination of these and other influences. Recent hurricane-wave coupling investigations have demonstrated the significance of such feedback processes (Moon et al., 2008).

Below the surface, the effects of turbulence induced by breaking waves have long been appreciated (Soloviev and Lukas, 2003). The mixing and the turbulence induced by non-breaking waves, however, are new concepts (Yuan et al, 1999; Qiao et al., 2004; Babanin, 2006). The non-breaking wave-induced mixing can affect the water column to a depth of the scale of the wavelength, which is of the order of 100m and is comparable with the mixed layer depth; while, the wave breaking-related mixing only affects the scale of wave height. Therefore, the non-breaking wave effects provide a ready explanation for turbulence diffusion or advection in order to mix the seasonal ocean layer through the thermocline below. Ever since the proposal of this concept, it has been confirmed through extensively tested in the laboratory (Babanin and Haus, 2009; Dai et al, 2010; Savelyev et al, 2012) and in the field (Pleskachevski et al., 2011).

Implementation of this wave-turbulence mixing in climate models leads to significant impacts, as mentioned above, both on the atmospheric side and in the ocean (Qiao et al., 2010). This implementation is particularly necessary since the wind/wave climate itself has been changing, both in the mean and in its extremes (Young et al., 2011). The wind/wave growth is most relevant for ocean mixing, air-sea interactions and extreme oceanic conditions. The sea drag coefficient, which is the main property to describe the air-sea interaction in GCMs, also explicitly depends on the waves as discussed above. Thus, it appears that neither climate trends nor wave trends can be adequately addressed unless GCMs are fully coupled with wave models.

*In short, without accounting for the wave effects directly, the physics of large-scale ocean circulation and air-sea interactions is inaccurate, inadequate and incomplete.* The proposed working group will bring together experts in ocean waves, ocean circulation and climate models. Two main reasons make coupling of waves with the dynamics of large-scale phenomena necessary and feasible now: First, since the waves evolve in response to air/sea forcing, by receiving energy and momentum from the winds and by passing it on to ocean turbulence and currents, their feedback cannot be efficiently averaged and parameterized, but has to be unambiguously evaluated and accounted for at every instant. Second, modern-day computer facilities have caught up with the needs of coupling small-scale and large-scale phenomena.

Terms of Reference

The proposed working group would

1. Summarize past results of surface wave effects on upper ocean and lower atmosphere through upper ocean vertical mixing and air-sea fluxes;
2. Identify new observational programs and improved observational techniques needed to fill gaps in understanding essential physics and dynamics of the wave-induced vertical mixing in upper ocean and air-sea fluxes to provide useful information for parameterization;

3. Explore new and effective ways to make the atmosphere, wave and general ocean circulation models to couple together seamlessly and efficiently. This would be the necessary steps to establish new generation coupled atmosphere-ocean general circulation models for research and operational forecast from ocean/atmosphere dynamical process, tropical cyclones to climate;
4. Convene both open and by invitation working group meetings and publish the progressive assessments in open literatures such as publishing a special issue of a major journal dedicated to this topic, or proceedings of the Air-Sea Symposium;
5. Finally, produce a comprehensive final report incorporating the study results and the state-of-the-arts summary of the above topics in a monogram to be published by a leading publishing house, such as the Cambridge University Press, as a milestone and land mark for the air-sea fully coupled climate modeling.

Working Group Membership, Group Activities and Capacity Building

(1) Membership

Ten full members are as follows (Profs. Fangli Qiao and Alexander V Babanin will co-chair WG)

**Full Members**

| | Name | Institute/University | Nation | Gender |
|---|---|---|---|---|
| 1 | Fangli Qiao | First Institute of Oceanography | China | M |
| 2 | Alexander V Babanin | Swinburne University of Technology | Australia | M |
| 3 | Mikhail Dobrynin | University of Hamburg | Germany | M |
| 4 | Yign Noh | Yonsei University | Korea | M |
| 5 | Erick Rogers | Naval Research Laboratory | USA | M |
| 6 | Anna O. Rutgersson | Uppsala University | Sweden | F |
| 7 | Fredolin T. Tangang | National University of Malaysia | Malaysia | M |
| 8 | Hendrik L. Tolman | NCEP | USA | M |
| 9 | Yuliya Troitskaya | Institute of Applied Physics | Russia | F |
| 10 | Judith Wolf | National Oceanography Centre | UK | F |
| | **Associate Members** | | | |
| 1 | Tal Ezer | Old Dominion University | USA | M |
| 2 | Safwan Hadi | Institute of Technology Bandong | Indonesia | M |
| 3 | Norden E Huang | National Central University | China | M |
| 4 | Somkiat Khokiattiwong | Phuket Marine Biological Center | Thailand | M |
| 5 | Nadia Pinardi | University of Bologna | Italy | F |
| 6 | Ian Young | Australian National University | Australia | M |
| 7 | Yeli Yuan | First Institute of Oceanography | China | M |

Note: All 10 members and 7 associated members are Professors.

(2) Working group activities
Annual meetings (by invitation only): The attendees would be limited to the members and invited experts in the proposed subject to summarize the progress and assess the future direction of action for the working group. It is proposed that three annual meeting will be organized during 2013- 2015. The first and second meetings will be in China and Australia in 2013 and 2014, an article to EOS (2013) and an article to BOMS (2014) are expected respectively. The venue of the third meeting in 2015 will be discussed among working group members and a proceedings or a special issue of a journal is expected in the third year.

Scientific sessions (Open to public): organize 2 scientific sessions at the General Assembly of the European Geosciences Union and in 2014 and 2016 to announce the progress and to solicit a wider view from the community on the proposed subject.
Symposium: In 2016 of the last year of this working group, a special Air-Sea Interaction Symposium will be organized in China, dedicated to the wave-coupled effects in ocean circulation, weather and climate.

Additional editorial meeting of selected members in the last year will be organized, if necessary, to work out the final report which will be published by a leading publishing house, such as the Cambridge University Press.

(3) Capacity building
Other than the open meetings, capacity building will be accomplished mainly through two additional kinds of activities:

Firstly, establish and maintain a Web site as a “virtual workshop” that can be used by the scientific community for exchange and discussion of ideas, results, and future planning on the surface wave effects in ocean and climate; and secondly, to host two training courses on wave effects on ocean and climate, and support at least 25 trainees from all different countries each time on the platform of the UNESCO/IOC Regional Training and Research Center on Ocean Dynamics and Climate (http://www.fio.org.cn/english/training_center/index.htm ). The chair of this working group will seek additional financial support for the related capacity building.

<u>The Relationship with Previous SCOR Working Groups and Other Organizations</u>
WG 28 air-sea interaction focused the traditional air-sea exchange processes, while the present WG will focus on the surface wave effects on air-sea interaction with a special emphasis on the effects in the water column through mixing. WG 69 studied small-scale turbulence and mixing in the ocean, while the present WG will focus on the surface wave-induced mixing; WG 103 focused on wave breaking on upper ocean dynamics, while the present WG will focus on the non-breaking surface wave-induced mixing; WG 121 focused on mixing in the deep ocean, whereas the present WG will focus on the ocean mixing in the upper ocean. The work of this group is closely relevant to the SCOR-IGBP-WCRP-CACGP Surface Ocean – Lower Atmosphere Study (SOLAS), Intergovernmental Oceanographic Commission (IOC), as well as

to the World Climate Research Programme (WCRP) and the International Association for the Physical Sciences of the Ocean (IAPSO)

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## 2.3.2 Proposal for a SCOR Working Group on an "International Nutrients Scale System" to improve the global comparability of nutrient data *Taguchi*

Introduction

Measurements of nitrogen (as NO3), phosphorus (as PO4), and silicon (as Si(OH)4) are fundamental for much oceanographic work in hydrography, biogeochemistry and biology. For example, accurate measurements of the nutrients are essential for tracing the uptake of anthropogenic carbon into the ocean. They can also be used for tracing changes in the deep ocean that are crucial to our understanding of global change. However, at the current time the reliabilities of such assessments are uncertain, due to the lack of widely useable reference materials that would allow complete confidence in comparing crucial data sets, from different laboratories worldwide. Large global observing programs (e.g., CLIVAR), and more local projects, require more-comparable information to support assessments of the health and productivity of coastal oceans, changes to the deep oceans, sustainability of marine ecosystems, and predictability of climate change, as well as other processes that affect the Earth's population on many levels. The accuracy of chemical oceanographic measurements depends on calibration against certified reference materials to ensure comparability over time and among laboratories world-wide. In 2002, a U.S. National Research Council (USNCR) report (Dickson et al., 2002) clearly stated that key parameters (including nutrients) lacked reliable and readily available reference materials. Comparability of nutrient and other data over time and among different research groups is urgently needed. The USNRC report identified the most urgently required chemical reference materials based on certain key themes for oceanographic research. At the top of the report's list of the new reference materials needed were standards for the measurement of nutrients. The report stated: "There is an urgent need for a certified reference material for nutrients. Completed global surveys already suffer from the lack of previously available standards, and the success of future surveys as well as the development of instruments capable of remote time-series measurements will rest on the availability and use of good nutrient reference materials." Similarly, the IPCC Report in 2007 highlighted the current problem inherent in comparing existing data sets: "Uncertainties in deep ocean nutrient observations may be Responsible for the lack of coherence in the nutrient changes. Sources of inaccuracy include the limited number of observations and the lack of compatibility between measurements from different laboratories at different times" (Bindoff et al., 2007).

Marine chemists have, however, been active in the pursuit of establishing reliable comparability of nutrient measurements. The history behind this is described in the section on "History of the development of the RMNS" below. A consensus has been achieved in realizing (i) the limits imposed on the work by the purity of "off-the-shelf" chemicals, (ii) the form that reference materials should take, (iii) the quantities that they would need to be produced in, and (iv) that use of the reference materials would also need to be accompanied by adherence to "best practice for their use". To guarantee comparability of data from different laboratories and from different research cruises, a single international "scale" for nutrients needs to be developed, and then recommended for use throughout the world-wide marine chemistry community. This has already been achieved by the use of Certified Reference Materials (CRMs) for measurements of the CO2 system (Dickson, 2003; 2010).

We are now in a position where the tools are available for this goal to be achieved. An equivalent to the carbonate systems CRM has now been developed for nutrients. These are the RMNS (Reference Materials for Nutrients in Seawater) produced by KANSO (General Environmental Technos Co., Ltd.) in Japan. They are being produced on a large enough scale to meet global demand, and are being independently certified by the Metrology Institute of Japan. But, as in the case of CRMs for CO2 measurements, the adaptation of RMNS will depend on trust being developed in these materials in laboratories around the world and their availability being matched to appropriate best practice in their use.

We see this being taken forward as an "International Nutrients Scale System (INSS)" for seawater analysis, to establish comparability and traceability of nutrient data in the ocean. A major challenge with this work and one which is particularly important for the study of changes in properties of deep water masses is to develop a system by which the data within laboratories and between laboratories is comparable at the 0.1 % level. This should be both within individual cruises and extend to allowing comparison between cruises separated by decades.

The WOCE guidelines published in 1991 (Joyce et al., 1991) suggested that this level of precision (0.1 %) was achievable by the better laboratories individually. However, this level of relative accuracy has not been achieved between laboratories. The aim for INSS is to put into place the tools needed for the improvement of inter-laboratory precision. Key to achieving the required accuracy is having reliable RMNS which enable the linkage of data between laboratories.

Getting and maintaining accuracy down to the 0.1 % level will be a two-stage process. Firstly the RMNS are being certified by the National Metrology Institute of Japan (NMIJ), but this certification stops at a level of uncertainty (expanded uncertainty of measurement stated as the standard uncertainty of measurement multiplied by the coverage factor k = 2, which for a normal distribution corresponds to a coverage probability of approximately 95%.) around 1.0 % for Nitrate and Silicate, but only around 5 % for Phosphate. At the moment the process of testing that the RMNS are stable at the 0.1 % level is underway. (A task of the SCOR working group would be to determine that the producer is achieving this level of stability.) The next stage is to agree a method for assigning values to the RMNS to an accuracy of 0.1 %. This task requires two things (1) consensus between laboratories (who can demonstrate they are producing data which is internally consistent at the 0.1 % level) on the assigned value, and (2) a system for carrying forward in time the assignment of values which will be consistent over decades.

<u>We envisage that a SCOR working group would be the most effective method of developing the INSS concept, with, and for, the global oceanographic community.</u>

Terms of Reference

1. **The Working Group will develop and publish on the Internet the algorithm [the set of tools / the RMNS / the laboratory methods and the data reporting chain] needed to implement an international nutrients scale system.** A paper will be submitted to EOS or other publication to publicize the algorithm. This will thus begin the process to unify global measurements of nutrients in the marine environment based on the use of reference materials for nutrients in seawater (RMNS).
2. **The Group will submit a session to an AGU meeting (2013) to call for papers on the use of reference materials in the marine environment. This session will also inform the scientific community of the nutrient CRMs available and the developments and results so far for using these standards.**
3. **The Group will consider and report on how effective feedback loops would be established between data generators, database managers, and data users, so that effective alignment of and complete traceability of any future measurements of nitrate, nitrite, phosphate and silicate in seawater would be achieved.** This will require the development of standardized data-handling procedures, and common data vocabularies and formats across producers and users, and would also include the future linking of national data archives. The group will seek to involve several national and international data center representatives to assist with this task.
4. The Group will report on a plan for the promotion of the INSS in the global marine observing community. This will include (a) reporting of the results from previous global stability tests [see list at end for countries involved[1] in 2012, and also a world Map]; (b) promote the wider global use of RMNS by arranging training workshops to encourage their use and training in best practice in developing countries; (c) continuing regular global inter-comparison studies, to continue on from the previous exercises in 2003, 2006, 2008 and 2012.[2]
5. **The GO-SHIP nutrients measurement manual (Hydes et al., 2009, see http://go-ship.org/Manual/Hydes_et_al_Nutrients.pdf) will be updated to include detailed protocols for the use of the RMNS solutions and the reporting of the analytical results.**
6. **A plan will be developed and written for transitioning to a self-financing scheme after the end of Japanese Government research funding in 2014,[3] based on the experiences of other similar programs.**
7. **The Group will report a plan for continuing to (i) guide the work of the accredited Japanese company[1] currently producing the RMNS solutions, and (ii) work with the**

[1] Argentina, Australia, Belgium, Bermuda, Brazil, Canada, Cape Verde, Chile, China, Denmark, France, Germany, Iceland, India, Israel, Italy, Japan, Netherlands, New Zealand, Norway, Russia, Saudi Arabia, South Africa, South Korea, Spain, UK, USA, Venezuela.

[2] The frequency of the international collaborative inter-comparison exercises would be every five years.

[3] Michio Aoyama funded by grant in aid for scientific research of Japanese Government Grant number "Kiban-S 23221003" of Japan Society for the Promotion of Science (JSPS) entitled "A study of the inventory and distribution of seawater nutrients together with higher comparability" (April 2011 to March 2014)

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**National Metrology Institute of Japan on certification of the accuracy the RMNS solutions.**

History of the development of the RMNS

In the 1990s, a number of studies were organized under the ICES umbrella. These studies were well documented (UNESCO, 1965, 1967; ICES, 1967, 1977; Kirkwood, 1991; Aminot et al., 1995 and Aoyama, 2006). In Europe, this led to the establishment of the Quality Assurance of Information for Marine Environmental Monitoring in Europe (QUASIMEME: Topping, 1997). QUASIMEME is a useful programme for validating the procedures of individual laboratories for a wide range of determinands. However, this programme is inadequate for supporting the traceability that is required to link day to day measurements in order to improve the overall precision within a laboratory, or to achieve a known level of comparability between different laboratories.

In 2000 and 2002, the National Oceanic and Atmospheric Administration (NOAA), USA and the National Research Council of Canada (NRC) conducted two inter-comparison exercises to certify the MOOS-1 reference material (Willie and Clancy, 2000; Clancy and Willie, 2003). However, despite these individual efforts, adequate comparability and traceability of nutrient data have not yet been achieved. Various other efforts were made to attempt to improve the situation, but these were on too small a scale to meet the needs of the global community in measuring nutrients in seawater.

In 2003, Michio Aoyama of the Meteorological Research Institute (MRI), Japan, organized an inter-laboratory comparison study that included 18 laboratories (Aoyama, 2006, Aoyama et. al, 2007). In 2006 and 2008, Dr Aoyama, working with Hidekazu Ota of the General Environmental Technos Co., Ltd. (KANSO), Japan, organized the second and third inter-comparison studies that included more than 55 laboratories world-wide (Aoyama et al., 2008; 2010). These inter-laboratory comparison studies clearly showed that the global use of reference materials for nutrients in seawater would greatly improve the comparability of nutrients data in the world's oceans.

In early 2007, Michio Aoyama visited the National Oceanography Centre in Southampton, UK, to discuss the results of the 2006 inter-laboratory comparison study with the European participants in the exercise as well as other interested nutrient chemists. As a follow-up to this meeting, an International Workshop on Chemical Reference Materials in Ocean Science was held in Tsukuba, Japan, in late 2007. It focused on the measurement of nutrients and of ocean CO2 parameters, and the then-current status of available chemical reference materials, particularly for nutrients. The participants agreed to start a collaborative programme, called the International Nutrients Scale System (INSS), with the aim of establishing global comparability and traceability of nutrient data.

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[1] KANSO-TECHNOS Japan. KANSO achieved an accreditation as "Reference Material Producers" on 27 April 2011. The accreditation criteria are according to ISO Guide 34 + ISO/IEC 17025.

In February 2009, that INSS group held a workshop at UNESCO in Paris to advance international collaboration and to discuss future tasks with a wider group (2009 International Nutrients Scale System international workshop, Paris, 10–12 February 2009). An “International Nutrients Scale System (INSS)” in seawater was agreed as the appropriate way to achieve this goal. This led to the setting up of a Study Group on Nutrient Standards (SGONS) supported by IOC and ICES between 2010 and 2012. This IOC-ICES SGONS group has (i) worked alongside the Japanese Metrology Institute who are certifying the RMNS; (ii) collaborated with KANSO on testing the stability of the RMNS materials; (iii) Discussed results on work developing associated standards for (a) organic carbon, (b) organic nutrients, (c) dissolved oxygen, (d) mercury-free standards for the carbonate system; (iv) Organised an expanded (in terms of global coverage) inter-comparison exercise including 69 labs in 2012; (v) Initiated plans and applications for an at-sea inter-comparison study to take place in 2014, and (vi) Considered the steps necessary to encourage the global uptake of RMNS to the level that has been achieved by the IAPSO Standard-Seawater for the measurement of salinity, and measurements of total dissolved inorganic carbon and alkalinity.

The next phase in the progression to the global acceptance and use of these nutrient CRMs, would be by the establishing of a SCOR Working Group.

<u>Membership of Working Group:</u>
Full Members

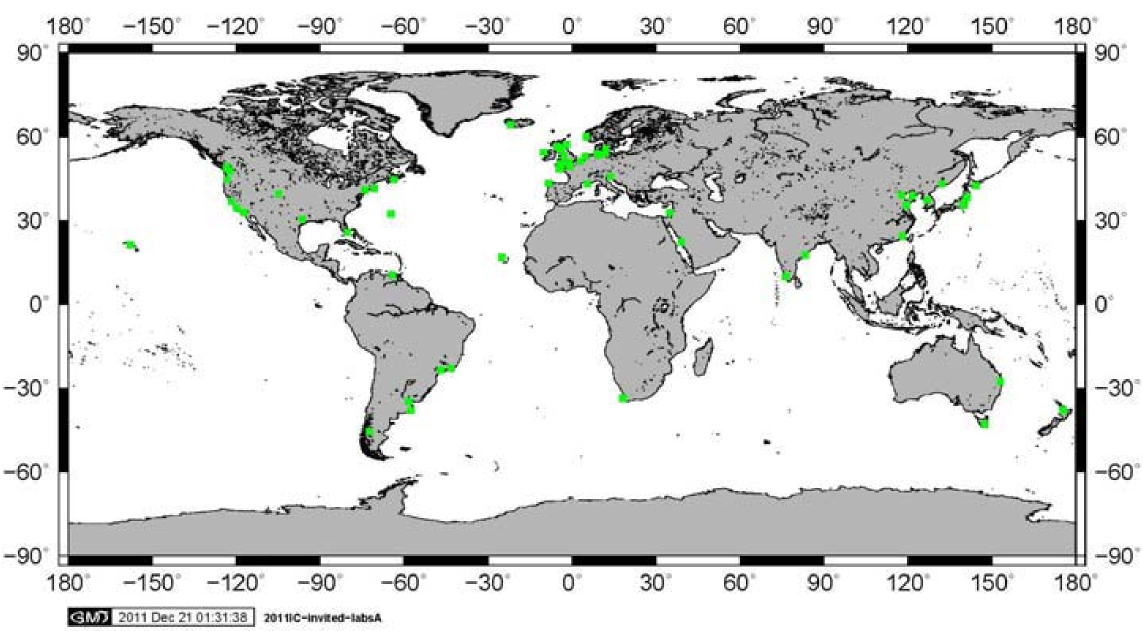
| | | | |
|---|---|---|---|
| 1 | Michio Aoyama | Japan | Chairman |
| 2 | David Hydes | UK | Co-Chairman |
| 3 | Jan van Ooijen | Netherlands | Measurement methods |
| 4 | Toste Tanhua | Germany | Comparability of deep sea data |
| 5 | Steve Diggs | USA | Standard data reporting, data vocabularies |
| 6 | Malcolm Woodward | UK | Low level measurements |
| 7 | Andrew Dickson | USA | CRM experience |
| 8 | Akiharu Hioki | Japan | Metrology & Certification |
| 9 | Minhan Dai | China | Large global (LOICZ and Chinese) programs |
| 10 | Susan Becker | USA | CLIVAR/GO-SHIP hydrography |

Associate Members:
Additional input to the group will be invited from a range of experts. Where necessaryfinancial support for attending meetings with the core SCOR group will be supported through MRI Japan (Grant number “Kiban-S 23221003“ of Grants-in-Aid for Scientific Research of Japan Society for the Promotion of Science (JSPS), made to Michio Aoyama). People involved would include: Masanobu Katagiri, KANSO Japan, on RMNS production; Alex Kozyr, USA, on experience of multiple user database access (e.g., SOCAT); Karel Bakker, Netherlands, and Anne Daniel,

France, on analytical methodologies; Jim Swift, USA and Bernadette Sloyan, Australia, Clivar-GO-SHIP; Mario Hoppema, Germany and Bob Key, USA, comparability of deep sea data; Takeshi Yoshimura, Japan, on organic nutrients; and Akihiko Murata, Japan, on related materials for carbonate work.

The group will be linked to the development of the FOO (Framework of Ocean Observations) effort by the input from Toste Tanhua (currently Chairman of the International Ocean Carbon Coordination Project: IOCCP). At a more local level, the group will also promote the activity with, for example, ICES and PICES (e.g., David Hydes' work as part of the ICES Marine Chemistry Working Group.)

Map showing the locations the laboratories taking part in the 2012 INSS inter-comparison exercise.





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### 2.3.3 Working Group on Marine ecosystem reorganisation under climate change *Costello*

Abstract

Marine ecosystems are responding to climate change[1], yet our ability to predict future ecosystem reorganisation is hindered by the lack of a standardised, integrated, comparative analysis. To date, global analyses of climate impacts are based on meta-analyses and include biases such as a focus towards terrestrial systems, the use of data derived from the published literature rather than primary data, a reliance on studies of individual species, and a focus on individual metrics of climate change (e.g. phenology, distribution) in isolation from other drivers of change. We will provide the first global integrated view of marine biological impacts of climate change by conducting standardised, robust, whole-system analyses across multiple taxa, trophic levels and regions. This proposed SCOR Working Group brings together climate change ecologists with expertise in a diverse suite of marine ecosystems, strong statistical skills, and access to key marine biological datasets from around the globe. We will: (1) provide unbiased estimates of impacts of climate change; (2) determine the fate of species that do not appear to respond to climate change in conventional ways; (3) determine impacts of climate change at the ecosystem level; and (4) understand how interactions with other human stressors drive ecological change. Our comparative analyses will overcome many of the existing limitations of current meta-analyses, leverage new understanding of the importance of climate change in marine systems (e.g. velocity of climate change), and produce a unique global synthesis. Most importantly, we will provide the understanding of ecosystem reorganisation under a changing climate needed by policy and decision makers.

Rationale and Background

*Scientific and societal importance:* Global emissions of greenhouse gases are tracking beyond the highest scenarios considered by the IPCC. Recent analyses by ourselves and co-authors suggest that marine systems are responding as faster than terrestrial systems despite less ocean warming, based on a meta-analysis of observed impacts[1]. This is because the rate that species need to respond to cope with a changing climate, the velocity of climate change (geographic shifts of temperature isoclines over time) and seasonal climate shift (shift in timing of seasonal temperatures) is greater in the ocean than on land2. However, there remains major gaps in our understanding of marine climate change, with <0.3% of the 28,671 biological changes synthesised in the IPCC 4th Assessment Report from marine systems[3,4]. We need to fill these knowledge gaps and incorporate our new understanding of velocity of climate change and seasonal shift so we can predict how ecosystems will reorganise. This understanding is the pre-requisite for incorporating impacts of climate change into our current frameworks for marine fisheries, conservation and multiple use management.

Currently global assessments of climate change are based on meta-analyses of the available published literature and have demonstrated ecological responses across species, regions and biomes consistent with those expected under anthropogenic climate change[1,5–7]. However, these analyses, including those in IPCC Assessment Reports, have not analysed primary datasets and are thus limited in their ability to answer critical questions. For example, a global meta-analysis of marine impacts of climate change led by us1 has shown that most studies are based on single species and thus could over-estimate the pervasiveness of impacts due to publication bias; that no studies analysed distribution change and phenology concurrently; that no studies analysed the viability of species not responding to climate change in terms of phenology or distribution change; that 95% of studies analysed only one taxonomic group in isolation; that only 15% of studies consider other human stressors (e.g. fishing) in their analyses1,8; and that statistical shortcomings of the original work is perpetuated into the meta-analysis. Using published studies to analyse climate change fingerprints therefore severely restricts our understanding of climate impacts and the capacity to investigate ecosystem reorganisation. We must therefore conduct standardised, robust, analyses on primary data that includes multiple taxa, trophic levels and regions and analyse these time series at the species level across multiple trophic levels and multiple responses to climate change to achieve a more robust understanding of impacts of climate change for marine biodiversity.

*Timeliness:* Given the rigorous meta-analyses[4,5,7,9] of impacts on terrestrial biology and the recent marine biological analysis1, it is now time to take the next step and analyse primary data of multiple trophic levels from several well-studied systems in a uniform way to assess different aspects of climate change impacts (phenology, distribution, abundance, demography). In addition, application of the recently developed velocity of climate change and the novel index for seasonal climate shift[2], will allow us to better interpret whether biological changes are keeping pace with climate change.

*Need for SCOR:* SCOR provides a unique opportunity to fund global comparative analyses that national and regional funding bodies rarely support. The proposed work requires an international team and international databases for a global analysis of climate change impacts and for regional interpretation of results. It needs an international comparative approach because we are not just collating published data, but bringing together world experts in data analysis and climate change ecology that have access to data from key marine systems for an integrated analysis. SCOR has the track record and international profile that has attracted a group of leading researchers to this proposal and encouraged researchers to make their time and data available for this global analysis. This work also follows nicely on from historical work on SCOR WGs focused on time series and particular ecosystem components (e.g. phytoplankton, zooplankton, micronekton). The new understanding and analyses in this project will be incorporated into assessments for IPCC and IPBES (Intergovernmental Panel for Biodiversity and Ecosystem Services).

*Other support:* Our institutions will provide in-kind support for WG members' time. Supporting funds have already been secured to run the proposed regional meetings within Australia (CSIRO), South Africa (Department of Agriculture, Forestry and Fisheries) and the UK (The Climate Change Consortium, Wales). Funding is currently being sort to support regional meetings in the US.

Terms of Reference
The proposed WG will answer the following questions:

1. *How pervasive are impacts of climate change?* Analysis of primary data will overcome the problem of publication bias, which artificially inflates the reported proportion of species responding to climate change. We will thus provide unbiased estimates of the proportion of species responding to climate change, and how this might differ among taxa and systems.
2. *What is the fate of species that do not appear to display conventional responses to climate change such as shifts in distribution and phenology?* Some species are able to make compensatory demographic changes that enable them to persist in sub-optimal habitats16, at least until threshold environmental change is reached; others may simply not be able to keep pace with a changing climate, while others may exhibit large lags in response time. Analyses will be undertaken to identify species falling into these categories and for apparent 'non-responders' determine whether compensatory changes in demography or abundance are occurring.
3. *How do impacts of climate change manifest at the ecosystem level?* Previous syntheses of climate change responses generally lack an ecosystem perspective. Analyses of collated primary datasets will allow us to investigate effects of climate change on species interactions and food webs.
4. *How does climate change interact with other stressors to drive ecological change?* Oceans globally are exposed to multiple interacting anthropogenic stressors11. We will apply consistent analytical approaches that include multiple stressors so we can tease apart the role of climate from other stressors and identify key interactions.

Approach and WG Activities
We will undertake three tasks: (1) the collation of multi-system, multi-species and multi-metric marine biological and oceanographic time series datasets; (2) the development of a toolbox containing a suite of customised statistical tools for time series analysis; and (3) the comparative analysis of impacts of climate change across systems and trophic levels by applying the toolbox to the collated time series.

**Task 1: Dataset collation.** Our recent literature-based meta-database showed that the most robust data, in terms of quality and length of time-series, came from a limited number of datasets (e.g. SAHFOS, CalCOFI and ICES). We have identified these primary datasets, along with other extensive datasets from around the globe, including areas under-represented in previous syntheses, as most suitable for analysis. These represent a wide range of marine species and habitats, from the poles to the tropics (Table 1). Primary datasets will be supplied by co-investigators, are freely obtainable, or have been made available by data custodians. Additional datasets will be included as access is negotiated. For example, negotiations are underway in Australia for access to >40-year datasets of marine turtle and seabird breeding and retrospective datasets of coral calcification rates.

Table 1 List of global primary datasets that will form the basis of the proposed analyses.

| Datasets | Dates | Biota | Region |
|---|---|---|---|
| SAHFOS | 1946 – | Chl a, phyto- zooplankton | NE Atlantic |
| ICES | 1960s- | Fish, seabirds, phyto, zooplankton | NE Atlantic |
| MarClim | 1950s- | Rocky intertidal | UK and Ireland |
| Seabird Monitoring Program | 1960s- | Birds, cetaceans | NE Atlantic |
| CSIRO fish time-series | 1970s- | Fish | Australia |
| AIMS | 1986-2004 | Coral (cover, composition); algal abundance, fish abundance, Chl a | Australia |
| Reefbase | 1971-2000 | Coral | Tropics |
| Reefcheck | 1997-2004 | Coral | Tropics |
| AGGRA | 1997-2004 | Coral (composition, disease, mortality, size); fish (biomass, density, abundance, size); algal abundance | Atlantic Gulf coast and Caribbean |
| CalCOFI | 1950s- | Hydrography, biogeochemistry, zooplankton; fish, birds and mammals | West coast USA |
| PISCO | 2000s- | Rocky intertidal | West coast USA |
| NansClim | 1970s | Hydrography, biogeochemistry, phyto, zooplankton, fisheries | Southern Africa |
| SCAR-MarBIN | 1960s- | Penguins* range of other data | Antarctic |
| Seabird.net | 1960s- | Birds | Circumpolar |
| BODC | 1961- | SST, hydrography, biogeochemistry | Global |
| Pacific CPR (Odate) | 2000- | Plankton | North Pacific |

**Task 2: Toolbox development.** We will develop a toolbox of robust statistical methods appropriate for the analysis of biological responses to climate change. Methods will emphasize approaches that allow direct use of all data. For example, generalised mixed-effects models[12] enable simultaneous analysis of data, including time-series, with different resolutions, durations or sizes, allowing quantification of effects of different climate and other human stressors consistently across datasets, taxa and regions[13]. This approach takes advantage of the hierarchical spatial structure of datasets, without losing information, as has often happened in literature-based meta-analyses[14]. The final toolbox will be an archive of the R code used for analyses, and include a comprehensive statistical guide for climate change ecologists, which we will make freely available outside the WG. This will be a lasting output and provide guidance for future analyses by the research community.

**Task 3: Impacts analysis.** Analyses will be undertaken at regional scales and combined to provide a global understanding of ecological change relevant to managers and policymakers. We will address our four Terms of Reference:

1. How pervasive are impacts of climate change? We do not know how many species are not responding to climate change. Studies that do report results for whole assemblages often find that some species have not responded in directions expected[15]. Using primary data, we will determine the proportion of species not responding to climate change across taxa and regions, thereby identifying hotspots of change and areas where few responses are expected, both spatially and taxonomically. Relationships between observed responses will be compared with the velocity that climate change is moving in space and time2 to determine whether regions experiencing more gradual change (Fig. 1) have more species not responding to climate change. Moreover, we will run velocity estimates for different time windows to determine whether periods of acceleration or deceleration of climate velocity correspond with observed biological responses.

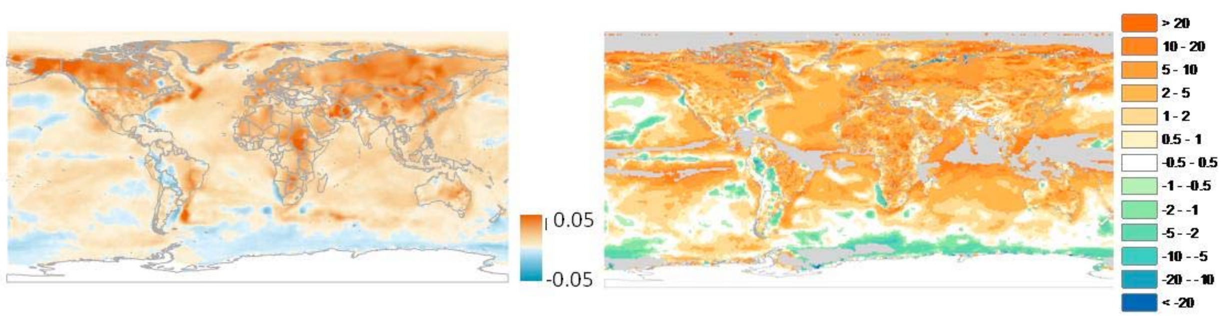


Fig. 1 (left) Trends in SST (HadISST1, °C.yr-1), and (right) velocity of climate change in the oceans 1960-2009 (km.yr-1) showing local reversals and areas of more rapid change[2].

2. What is the fate of species that do not appear to display conventional responses to climate change such as shifts in distribution and phenology? We will assess patterns in demography (e.g. growth, phenology, survival) through time to determine whether changes in demographic rates buffer some organisms from negative effects of climate change, as has been observed in some terrestrial (tundra) assemblages[16]. We will use the proportion of taxa responding to climate change and then compare rates of change in other patterns of demography for responders and apparent 'non-responders' to determine whether these 'non-responders' are compensating in different ways.
3. How do impacts of climate change manifest at the ecosystem level? Ecosystems are dynamic and shaped by physicochemical processes, species interactions, and external forces including climate[18]. Different components of the same ecosystem thus do not respond independently to climate change; instead responses may be idiosyncratic or influenced by interactions with other species[17,19,20]. For example, Beaugrand and Kirby20 showed that fluctuations in the abundance of plankton and cod recruitment in the North

Sea were not a result of the common influence of temperature on both trophic levels, but rather that cod recruitment was more strongly regulated by the indirect trophic effect of temperature on planktonic assemblages. We will determine the range of types and rates of responses of different taxa both within ecosystems and across regions. We will use causal modelling[21] and generalised mixed-effects models across multiple trophic levels and multiple climate and non-climate stressors (e.g. fishing, eutrophication) to determine types of control operating in different marine ecosystems[19,20]. By using this approach on a range of ecosystems and across multiple basins, we will generalise understanding of the complex direct and indirect trophic effects of climate change on the structure and functioning of marine ecosystems.

4. How does climate change interact with other stressors to drive ecological change? Other stressors will be considered in our analyses, as many marine species are exploited or subject to other human stressors such as eutrophication. Understanding consequences of multiple interacting anthropogenic stressors is vital to determine how marine managers must adapt regional stressors, such as fishing, to account for or manage climate change impacts[22]. We will use approaches such as mixed-effects models that incorporate both climate and non-climate stressors, and causal models that seek to explain complex patterns of causality among competing mechanistic hypotheses, to determine interactions of climate change with other stressors across taxa and ecosystems.

Time-scales and Products

We propose to run 3 intensive, in-person, 5-day meetings over 3-years, as well as 2 regional meetings in each of Europe, Australia, South Africa and North America. Regional meetings (regionally funded) will reduce the overall cost of the research and allow a focus on regional datasets and analysis with results feeding back into the main project. Regional meetings will also enable the membership of the WG to be expanded by including additional participants, particularly graduate students and early-to-mid career researchers, and it is anticipated that this inclusivity will also facilitate access to further datasets. Full members from outside these regions will also be able to link in via video-conferencing. Progress inter-sessionally will be monitored monthly via Skype.

Table 3 Timelines and products

| Workshop | Workshop aims | Task | Inter-sessional tasks and products |
|---|---|---|---|
| Mar 2013<br>UK | • Set up website for collation of datasets and identify other datasets to include<br>• Refine hypotheses<br>• Initiate toolbox development<br>• Initial analyses of individual datasets | 1<br><br><br>1<br>2<br>3 | • Continued analysis of datasets<br>• Paper: based on initial analyses |

| | | | |
|---|---|---|---|
| Oct 2013<br>Regional meetings* | • Compilation of initial results of primary analyses and paper outlines<br>• Further development of statistical toolbox<br>• Regional analyses | 3<br><br><br>2<br><br>3 | • Impacts analysis on questions 1-4<br>• Paper: Statistical toolbox for climate change analysis |
| June 2014<br>Australia | • Impacts analysis on TORs 1-4 | 3 | • Impacts analysis and paper writing<br>• Papers: TORs 1-4 |
| Nov 2014<br>Regional meetings* | • Impacts analysis on TORs 1-4<br>• Regional analyses | 3<br>3 | • Impacts analysis and paper writing<br>• Papers: TORs 1-4 |
| June 2015<br>US | • Impacts analysis on TORs 1-4 | 3 | • Impacts analysis and paper writing<br>• Papers: TORs 1-4 |

*Regional meetings will link via twice daily video conferencing

This first comprehensive global synthesis of climate change impacts using primary data will have a broad, global impact. Addressing the TORs will result in a suite of multi-authored papers in high-impact journals. A key outcome of the proposed project is to inform climate change policy. Findings will therefore be presented at international meetings aimed at policymakers (e.g. Greenhouse 2014 (AUS), Coastal Futures 2015 (UK) and Advancing Science, Serving Society 2015 (US)). An online description of the project will provide regular updates on progress and outputs.

Members

We have deliberately chosen a mix of male and female, and early, mid- and later-career researchers.

| Full Members | Sex | Affiliation | Contribution & expertise |
|---|---|---|---|
| 1. Anthony J Richardson+ | M | University of Queensland, Australia | WG Co-Chair, IPCC AR5 contributing author, plankton ecology, statistical analyses |
| 2. Pippa J Moore+ (Early career scientist) | F | Aberystwyth University, UK | WG Co-Chair, coastal ecology, ecosystem processes |
| 3. Elvira Poloczanska | F | CSIRO, Australia | IPCC AR5 lead author, coastal ecology |
| 4. Dawit Ghebrehiwet+ | M | Department of Agriculture, Forestry and Fisheries, South Africa | Fisheries ecology |
| 5. Sanae Chiba+ | F | Japan Agency for Marine and | Plankton ecology, phenology |

| | | | |
|---|---|---|---|
| | | Earth Science and Technology | |
| 6. Omar Defeo | M | Universidad de la República-Facultad de Ciencias, Uruguay | Marine policy, fisheries, sandy beach ecology |
| 7. David S Schoeman | M | University of Sunshine Coast, Australia | IPCC AR5 contributing author, sandy beach ecology, statistical analyses |
| 8. William Sydeman+ | M | Farrallon Institute, USA | IPCC AR5 contributing author, seabird ecology, Californian Current system |
| 9. Michael T Burrows | M | Scottish Association for Marine Science, UK | IPCC AR5 contributing author, coastal ecology, ecosystem modeling, spatial statistics |
| 10. Nick Dulvy+ | M | Simon Fraser University, Canada | Fisheries ecology |
| **Associate Members** | | | |
| 1. Ove Hoegh-Guldberg | M | University of Queensland, Australia | IPCC AR5 coordinating lead author, coral reefs |
| 2. Gregory Beaugrand+ | M | CNRS, France | Plankton ecology, statistical analysis |
| 3. Carlos Duarte | M | Mediterranean Institute for Advanced Studies, Spain | IPCC AR5 contributing author, stability and dynamics of aquatic habitats |
| 4. Chris Brown | M | University of Queensland, Australia | Ecosystem modelling, statistical analysis |
| 5. Tony Koslow+ | M | Scripps, USA | Plankton ecology, Californian Current system |
| 6. Keith Brander+ | M | Technical University of Denmark, Denmark | Fisheries ecology, climate impacts |
| 7. Mary O'Connor | F | University of British Columbia, Canada | IPCC AR5 author, coastal ecology, metabolic theory |

+ denotes data contributor

Endnotes

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### 2.3.4 Proposal for a SCOR Working Group on Sea-Surface Microlayers *Volkman*

Abstract

The sea-surface microlayer (SML) is the boundary interface between the atmosphere and ocean, covering about 70% of the Earth's surface. With a typical thickness of 40-100 µm, the SML has physicochemical and biological properties that are measurably distinct from underlying waters. Because of its unique position at the air-sea interface, the SML is central to a range of global biogeochemical and climate-related processes. Although known for the last five decades, the microlayer often has remained in a distinct research niche, primarily as it was thought to not exist at typical oceanic conditions. Recent studies now indicate that the SML covers the ocean to a significant extent, and evidence shows that it is an aggregate-enriched biofilm environment with distinct microbial communities. The redeveloped SML paradigm pushes the SML into a new and wider context that is relevant to many ocean and climate sciences.

The overall objective of the working group is to increase the awareness of the science community to the importance of the SML in a wide range of biogeochemical and climate-related processes. Specifically, the working group aims to (1) publish a unified definition of the microlayer in terms of physical, chemical and biological perspectives; (2) review sampling techniques and publish detailed sampling protocols; (3) outline the SML's role in a changing ocean; (4) initiate sessions on SML research during major meetings (e.g., Ocean Sciences Meeting); and (5) synthesize and publish available data on the SML as a book or a special issue of an open-access journal.

Rationale

The discovery that the SML is a widespread gelatinous and biofilm-like environment (Wurl and Holmes, 2008; Wurl et al., 2009; Cunliffe et at., 2009a; Wurl et al., 2011a) has created a new perspective of the air-water interface. Recent mass spectrometric measurements reveals unique and complex mixtures of biogenic molecules and polymers in the SML (Frew et al., 2006), complementing studies since the 1970s on enrichments of carbohydrates, protein and lipids in this layer relative to underlying waters. With recent advancement in the understanding of distinct microbial communities in the SML and their survival strategies (Cunliffe et al., 2011), it becomes clear that the SML is a microbe- and carbon-rich milieu with potentially unique transformation processes of organic material. Its role in biogeochemical cycling and the interactions between microbial diversity and ecosystem function are not yet fully understood. What is clear is that the SML has potentially significant effects within a global context, due to its unique position between the ocean and atmosphere including, for example, air-sea gas exchange processes (Upstill-Goddard et al., 2003; Salter et al., 2011) and production of organic-rich aerosols which develop into cloud condensation nuclei (Leck and Brigg, 2005; Russel et al., 2010; Orellana et al., 2011).

A SCOR SML working group will use a multidisciplinary perspective to suggest the future direction of SML research at an international level. The group will bring scientists from various disciplines together to consider chemical, biological and physical aspects of the SML, and to understand governing mechanisms in its formation and role in biogeochemical cycling and climate science. Deliverables of the group will include publications on the best practices in the sampling of the SML, consolidation of SML data sets and an updated SML review publication. SCOR as a non-governmental organization is an appropriate mechanism to promote future multinational and multidisciplinary fundamental SML research. A SCOR working group will ensure the involvement of scientists from developing countries and those at early career stages.

Scientific Background

The following is a summary of recent developments in SML research, which motivated the organization of the working group to submit this proposal. A complete review of research from the last five decades would be too extensive in the context of the proposal.

*SML coverage of the ocean's surface*

A misleading, but initially intuitive, assumption is that the SML is unstable under typical oceanic conditions. During a two-year long systematic study, however, it was shown that the SML is consistently enriched in surface-active organic matter at wind speeds of up to at least 10 m/s (Wurl et al., 2011b), which exceeds the global average wind speed over the ocean by 3.5 m/s (Archer and Jacobson, 2005). Higher enrichments found under oligotrophic conditions also suggest that the SML covers a significant fraction of the Earth's surface (Wurl et al., 2011b). Other studies support such conclusion with observed enrichment of organic matter at wind speeds of up to 10 m/s (Carlson et al., 1983; Kuznetsova et al., 2004; Reinthaler et al., 2008). Although temporarily disrupted by breaking waves, the SML is rapidly reformed through rising air bubble plumes, which are covered quickly with dispersed SML material during the ascent (Liss, 1975). In both laboratory (Dragćević and Pravdić, 1981) and field (Williams et al., 1986) experiments, surface films (i.e. SML) appear to reform within seconds after disruption. Zhou et al. (1998) showed formation of TEP by bubbling dissolved seawater through the aggregation of DOM at bubble surfaces. This result indicates that breaking waves can actually facilitate the production of TEP, which eventually accumulates in the SML with rising bubble plumes forming biofilm-like matrices on the ocean's surface under typical oceanic conditions (Wurl et al., 2011a).

*Effects on air-sea gas exchange*

The enrichment of naturally occurring organic compounds, such as carbohydrates, proteins and lipids, modifies the chemical and physical properties of the sea surface to form the SML film, which retards gas exchange processes (e.g., Broecker et al., 1978; Frew et al., 2004; Schmidt and Schneider, 2011). The SML is a laminar layer in the absence of turbulence, and gas transport is dominated by slower molecular diffusion as a limiting step. A release of an artificial surfactant film in the Atlantic Ocean confirmed the suppression of gas exchange by at least 25%, even at higher wind conditions (10 m/s) (Salter et al., 2011), similar to earlier observation in the North Sea (Brockman et al., 1982) and in a wind-wave tunnel (Broecker et al., 1978). Frew et al. (2004) found that enrichment of organic matter in the SML can reduce the wave slopes, and therefore reduce gas transfer velocities. Schmidt and Schneider (2011) reported seasonal variations of the gas transfer velocity in laboratory experiments, likely due to differences in the quantity and composition of organic material becoming enriched in the SML.

The direct involvement of the bacterioneuston in air-sea gas exchange has been examined experimentally in situ using free-floating gas exchange boxes (Conrad and Seiler, 1988; Frost, 1999) and with a laboratory gas exchange tank (Upstill-Goddard et al., 2003). Reinthaler et al. (2008) reported similar bacterial growth efficiency between communities in the SML and underlying water, but increased bacterial respiration in the SML, indicating that there could be bacterial control of O2/CO2 fluxes through the interface. These studies also highlight the complexity of air-sea gas exchange, and the need to address this research with an interdisciplinary approach.

*Production of organic-rich aerosols*

A biofilm environment at the air-water interface opens new directions in research on organic-rich aerosols. Several investigators have found gel-like matrices in marine aerosols (Leck and Brigg, 2005; Russel et al., 2010; Orellana et al., 2011) that could potentially form cloud condensation nuclei. Bubble bursting seems to be the primary vector for the production of marine-derived aerosol containing SML components (O'Dowd and Leeuw, 2007). It has been hypothesized that the enrichment of gel particles in the SML, the primary component of the biofilm-like ecosystem, is the source of gel-rich aerosols found in the Arctic atmosphere (Leck and Bigg, 2005). Such studies have initiated a hypothesis of a direct link between the SML and marine-derived aerosols; however, direct measurements remain for future research. Combined SML and aerosol measurement with good integrity seems to be challenging and requires various skills from different disciplines (chemistry, atmospheric, physics).

*SML's role in biogeochemical cycles*

Sieburth (1983) hypothesized that the SML is a hydrated gel-like layer formed by a complex structure of carbohydrates, proteins, and lipids. His hypothesis has been recently confirmed by finding that transparent exopolymer particles (TEP), abundant gel-like particles in the ocean, are enriched in the SML (Wurl and Holmes, 2008; Wurl et al. 2009; Cunliffe et al., 2009a; Wurl et al., 2011a). It can be concluded that the SML is a microbial- and carbon-rich milieu and Ellison et al. (1999) estimated that 200 Tg C /yr accumulates in the SML, similar to sedimentation rates of carbon to the ocean's seabed.

Although the total volume of the microlayer is small compared to the ocean's volume, Carlson (1993) suggested in his seminal paper that unique interfacial reactions may occur in microlayers that may not occur in underlying water or that may occur at a much slower rate, and therefore hypothesed that the microlayer plays an important role in the diagenesis of carbon in the upper ocean. For example, proteins spread on air-water interfaces undergo unusual configurations, including unfolding (MacRitchie, 1986) and orientation of the helical axis parallel to the interface (Fujita et al., 1995). Denatured molecules in the SML may expose reactive sites and thus undergo interactions with neighbouring molecules which were precluded in the bulk seawater. Molecular orientation also occurs in polymeric carbohydrate monolayers resembling natural films (Mao et al., 1996; J. Minones et al., 2002). Rotation of molecules within the biofilm matrixes may be hindered. Carlson (1987) provided evidence that the rotation of fluorescent probes was limit d in the SML. Reinthaler et al. (2008) reported high enrichment of dissolved amino acids in oceanic SML, which were, however, not readily available for bacteria. This may indicate that there is a high fraction of refractory organic material in the SML.

The enrichment of trace metals in the SML is another example of how the SML may influence biogeochemical cycles. Trace metals are essential, but often limiting, micronutrients for phytoplankton growth. Over the last decades the interests in the atmospheric deposition of trace metals to the ocean's surface has increased within the ocean science community, especially in the context of sand/dust storms. Interestingly, the SML has been widely ignored in this context, although bioavailability of trace metals may change within the SML due to SML-specific solubilisation or transformation processes. Hoffman et al. (1974) compared rates of atmospheric deposition with their findings on SML enrichments of trace metals offshore West Africa under the influence of the Saharan dust plume. They concluded that deposition rates were sufficiently great to explain the observed enrichment. Many studies followed on the enrichment of trace metals in the SML, but without detailed investigation of atmospheric inputs and chemical transformation within the SML. However, Jones (2011) recently suggested that dissolved trace metals in the SML undergo complex photochemical and scavenging processes.

*Sampling techniques*

Based on the current research literature, the SML can be summarized as being a microhabitat comprised of several layers distinguished by their ecological, chemical and physical properties with an operational total thickness of between 1 and 1000 µm. Based on the literature it is proposed that an SML of a thickness of 60 µm could be meaningfully used for studying the physicochemical properties of the SML (Zhang et al., 2003), and up to 1000 µm for biological properties, depending the organism, or ecological features, of interest. Cunliffe et al. (2009c) and Stolle et al. (2009) conducted a systematic comparison study of microlayer sampling techniques to investigate microbiological features. Cunliffe et al. (2009c) found that floating polycarbonate membranes are the best approach to detect differences in microbial structures between the SML and underlying water. Such differences could not be detected in microlayer samples collected by glass plate (Harvey and Burzell, 1972) or mesh screen sampler (Garrett, 1965). Different specificity and collection efficiency of sampling techniques are potential reasons of this observation (Stolle et al., 2009). On the other hand, glass plate and mesh screen sampler are most suitable for the chemical characterization of the SML (Hatcher and Parker, 1974; Momizkoff et al., 2005), but different sampling techniques challenges the linkage to microbiological parameters.

Despite the availability of several inexpensive sampling devices (reviewed by Huhnerfuss, 1981), collection of SML samples of an acceptable integrity remains a challenge. Reasons for this are: (i) the SML is physically, chemically and biological heterogeneous. For example, the thickness of SML changes according to wind speed, as a result of wave motion. The chemical composition also is subject to rapid alteration in areas of natural slicks, where surface tension is higher; (ii) operation of sample techniques requires experience to collect samples with high reproducibility and under higher sea states (Wurl et al., 2011b); (iii) different sampling devices collects layers of different thicknesses and selectivity (Carlson, 1982; Momizkoff et al., 2005; Cunliffe et al., 2009c); and (iv) typically sampling involves immersion and slow withdrawal of sampler device (e.g. glass plate, mesh screen) collecting only several mL of SML per withdrawal. Therefore the period of sampling may be excessive in order to collect an adequate volume of SML sample, for example, for trace contaminant analysis.

Terms of reference

The proposed sea surface microlayer working group will pursue the following terms of reference:

1. Review sampling techniques and provide best practice sampling protocols. Such protocols will support new scientists entering the field of SML research to produce reliable and comparable data among different research groups/oceanic regions.
2. Create a consensus definition of the SML in terms of physical, chemical and biological perspectives for a better understanding within the ocean science community.
3. Outline the SML's role in a changing ocean, delivered as a short communication publication, to support its implementation in future international projects concerning future changes of the ocean.
4. Initiate sessions on SML research during major meetings (e.g., Ocean Sciences Meetings), to increase the awareness of the importance of the SML within the general ocean science community.
5. Summarize and publish the latest advances in microlayer research (e.g., in the form of a book or a special issue of a peer-reviewed journal), including consolidation of existing sea surface microlayer datasets among different disciplines (chemistry, biology, atmospheric, physics). The publication will promote new research ideas and projects at an interdisciplinary level.

Capacity building

The proposed membership includes scientists from developing countries (Malaysia, Brazil and China) to promote scientific activities. The working group will meet for a 3-day workshop in 2014 planned to be held in China (Qingdao Ocean University). Additional students from this university or other national universities (depending on additional funding) will be invited for one day to the workshop. Working group members will give lectures and present their current SML activities. The working group plans to run a field trip for students to teach SML sampling techniques and simple measurements (i.e., surface film pressure). Inviting students will increase awareness and promote SML research among the next generation of oceanographers.

<u>Working group membership</u>
The proposed working group will include ten full members and six associate members. Additional associate members may be nominated after the first meeting. The proposed list of full members includes researcher from early stages (S.F., M.L., A.L and A.L.S.) to senior level, with expertise in SML research within the context to chemical, biological, fishery and physical oceanography, as well meteorology and aerosol chemistry. The proposed membership list ensures a wide geographic balance.
The following full members have agreed to serve on the working group to fulfil their terms of reference (M. N.-F. confirmation pending).

*Full members*

3. Michael Cunliffe, Marine Biological Association of the United Kingdom (UK) – co chair – Biological Oceanography (microbial ecology)
4. Oliver Wurl, Old Dominion University (USA) [(1)] – co chair – Chemical Oceanography (chemical composition)
5. Anja Engel, Leibniz Institute of Marine Sciences (IFM-GEOMAR) (Germany) – Biological Oceanography (link to SOLAS Scientific Steering Committee)
6. Sanja Frka, Ruđer Bošković Institute (Croatia) – Chemical Oceanography (chemical characterization)
7. Christopher Zappa, Lamont-Doherty Earth Observatory (USA) – Physical Oceanography (air-sea heat and gas exchange, modelling)
8. Caroline Leck, Stockholm University (Sweden) – Meteorology (aerosols, modelling)
9. Maria L. Negreiros-Fransozo, Universidade Estadual Paulista (Brazil) (2) – Marine Zoology (neuston biology)
10. Mohd T. Latif, Universiti Kebangsaan (Malaysia) – Environmental Science (surfactants, aerosols)
11. Bill Landing, Florida State University (USA) – Chemical Oceanography (trace metal chemistry, aerosols)
12. Gui-Peng Yang, Ocean University of Qingdao (China) – Chemical Oceanography (chemical composition, air-sea gas exchange)

*Associate members*

9. Robert Upstill-Goddard, Newcastle University (UK) - Physical Oceanography (air-sea gas exchange)
10. Blaženka Gašparović, Ruđer Bošković Institute (Croatia) – Chemical Oceanography (chemical characterization)
11. Kenneth Mopper, Old Dominion University (USA) – Chemical Oceanography (carbon cycling, photochemistry)
12. Anna Lindroos, University of Turku (Finland) – Biological Oceanography (bacterial communities)

13. Ana Louisa Santos, University of Aveiro (Portugal) – Biological Oceanography (bacterial communities)[(2)]
14. Alina Ebling, Florida State University (USA) – Chemical Oceanography (trace metal chemistry)
15. Miguel Leal, Skidaway Institute of Oceanography (USA) – Biological Oceanography (neuston communities)

[(1)]From 1st June 2012, Leibniz Institute of Baltic Sea Research Warnemunde, Germany
[(2)]Confirmation pending

Timeline and working group activities (including specific products to be delivered)
Upon funding, the working group will organize a first meeting in early to mid-2013, potentially in conjunction with an ASLO meeting (2013). During the first meeting, members of the working group will present their current scientific activities, and will discuss, establish and commit to the working group programme. The working group will share their experiences in sampling techniques, and produce a report, lead by the co-chairs, on the best practices in SML sampling (Product 1) to be finalized at a workshop held in 2014. The report will be available on the web for making it freely accessible to the international marine science community.

During the 2014 workshop, potentially to be held in China, the group will discuss a better definition of the SML for the science community, as well establishing first commitments to writing individual chapters of a book or special issue of a journal (to be published in 2016) upon agreement of its content. In 2015, the working group will also publish a short communication paper, preferably in an open-access journal, from the 2014 workshop incorporating the developed definition of the SML under the lead of the cochairs (Product 2).

The final meeting will be held in early-2016 in conjunction with a major meeting, potentially the 2016 Ocean Sciences Meeting. The members of the working group are expected to contribute to a session on SML research during this meeting, and the book publication or special issue of an open-access journal will be finalized (Product 3).

The co-chairs will approach other non-profit organizations for co-sponsoring the working group (i.e. IMBER, SOLAS) as they may share interests in this topic. The working group will also apply for additional funding from SCOR to support early-career scientists to attend the meetings and workshop.

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## 2.3.5 **Proposal for a SCOR Working Group on Quality Control Procedures for Oxygen and Other Biogeochemical Sensors On Floats and Gliders** *Feeley*

Rationale

The OceanObs'09 Conference (Venice, Italy, September 2009) brought together more than 600 scientists from 36 nations to build a common vision for the provision of routine and sustained global information on the marine environment sufficient to meet society's needs for describing, understanding and forecasting ocean variability. This common vision, as documented by 99 Community White Papers and 47 Plenary Papers, calls for significantly enhancing internationally coordinated provision of sustained observation and information of the world ocean, as a part of the larger Earth system observing effort, for public good and stewardship. The conference documented the state-of-the-art of observation technologies, highlighted the most promising observational approaches and provided concrete recommendations towards sustaining and enhancing the global ocean observation network.

Among the many breakthroughs in observational technology and capabilities the Argo float observatory is one of the most impressive and successful examples (Freeland et al., 2010). As Argo enters its second decade and chemical/biological sensor technology has improved significantly, it is becoming obvious that this observatory will be embraced by the ocean biogeochemistry community. An augmentation of the global float observatory, however, has to follow rather stringent constraints regarding sensor characteristics as well as data processing and quality control routines. Owing to the fairly advanced state of oxygen sensor technology and the high scientific value of oceanic oxygen measurements (Gruber et al., 2010), an expansion of the Argo core mission to routine oxygen measurements is perhaps the most mature and promising candidate (Freeland et al., 2010). But sensor technology also has reached a stage for other biogeochemical properties such as bio-optics (Claustre et al., 2010; Boss et al., 2008), nitrate (Johnson et al., 2009; 2010), pH (Martz et al., 2010) and CO2 (Fiedler et al., subm.) that makes these sensors suitable for future integration into the float observatory.

While in terms of sensor characterization, calibration and assessment of field performance many studies have been performed and a lot of published information has become or is becoming available—particularly for float-based oxygen measurements—a coherent assessment of the overall status is lacking and firm recommendations and protocols for sensor calibration, data processing and data quality control have not yet been made. This situation calls for action and an effort to improve the situation should be made by a group of international experts. The establishment of a SCOR working group on this issue is timely and arguably the best, if not only, way to bring available information and expertise together and develop community-based and accepted procedures. The WG will put its main focus on the "Oxygen on Argo" topic but will also address float and glider-based observations of other biogeochemically relevant properties that have the potential to follow oxygen and hence require a concerted approach.

Scientific and Technological Background

The challenge of understanding the impact of global change on ocean biogeochemistry and major elemental cycles of carbon, oxygen, nitrogen etc. and any potential feedback to Earth's climate cannot be met with traditional oceanographic sampling techniques but requires a major expansion of observation capabilities in time and space. This, in fact, is calling for a revolution in observation technology which already is, or soon will, be at hand (Johnson et al., 2009). The rapid progress in both observation platform technology and chemical/biological sensor technology made during recent years is impressive and it is time now to bring the two strains together in a concerted fashion.

There are compelling scientific arguments for the addition of robust oxygen sensors to the global Argo observing system. Gruber et al. (2010) have summarized many of these scientific reasons for undertaking detailed global-scale measurements of the temporal evolution of the ocean¡¦s oxygen distribution. These include:

- Detect and document the ocean¡¦s deoxygenation (Keeling et al., 2010);
- Predict and assess anoxic or hypoxic events (Stramma et al., 2008);
- Determine seasonal to inter-annual changes in net community and export production;
- Improve atmospheric O2/N2 constraint on the oceanic uptake of anthropogenic CO2;
- Aid interpretation of variations in ocean circulation/mixing;
- Provide constraints for ocean biogeochemistry models;
- Aid in interpretation of sparse data from repeat hydrographic surveys;
- Determine transport and regional air-sea fluxes of oxygen.

Quite a number of showcase studies employing oxygen floats have been performed successfully (e.g., Kihm & Kortzinger, 2010; Kortzinger et al., 2004; Martz et al., 2008; Prakash et al., 2012; Riser & Johnson, 2008; Tengberg et al., 2006) illustrating both the feasibility and the high and manifold utility of high-quality float-based oxygen measurements. However, several such studies (e.g., Czeschel et al., 2011; Fiedler et al., subm.; Kortzinger et al., 2005; Uchida et al., 2008) identified significant accuracy issues with the oxygen optode sensor that required dedicated post-calibration and correction exercises and call for the development of explicit pre-deployment calibration routines and facilities (e.g., Bittig et al., subm.). All this information needs to be cast into a coherent approach to data quality assurance and control procedures which then can be disseminated within the community and implemented into standard Argo routines. This is particularly important as a "global" system is developed. Each investigator needs to be able to compare oxygen data seamlessly from each float, just as is done with Argo temperature and salinity. To a large extent, that is not possible for oxygen today because of varying standard processes for sensor calibration and data reporting (Thierry et al., 2011).

The "Oxygen on Argo" initiative may in fact serve as a model case which provides the blueprint for data quality assurance and assessment procedures for other biogeochemical sensors. Some of these, for example, bio-optical (Claustre et al., 2010) and nitrate sensors (Johnson et al., 2010), are already available off the shelf in float-adapted versions, which have undergone serious testing and produced impressive showcases. Other sensors such as the DurafetR pH sensor (Martz et al., 2010) are approaching float-readiness and may soon provide much sought-after access to the marine CO2 system. Undoubtedly the implementation process of any of these other biogeochemical sensors into a float observatory will benefit from the lessons learned and the procedures established for the model case oxygen.

Statement of Work/Terms of Reference

The proposed working group would

1. Summarize and assess the current status of biogeochemical sensor technology with particular emphasis on float-readiness (pressure and temperature dependence, long-term stability, calibration accuracy, measurements time constant, etc.) → Year 1.
2. Develop pre- and post-deployment quality control metrics and procedures for oxygen and other biogeochemical sensors deployed on floats and gliders providing a research-quality synthesis data product → Years 2+3.
3. Collaborate with Argo and other data centers to implement these procedures in their standard routines → Years 3+4.
4. Disseminate procedures widely to ensure rapid adoption in the community → Year 4.

***Pre-Briefing:*** The 4th Argo Science Workshop (ASW-4), which is entitled “Argo — 10 Years of Progress — A new decade to prepare” and takes place in Venice, Italy on September 27- 29, 2012, would represent an ideal occasion for a pre-briefing among the members of the proposed SCOR WG and further discussion with the Argo community.

***Kick-off Meeting:*** In order to provide good international visibility (and assure high attendance) the idea would be to piggyback this meeting onto a major relevant international conference. A thematically suitable and internationally visible such platform could be the IMBER IMBIZO III (January 2013, Goa, India). An alternative and similarly appropriate meeting would be the 2013 EGU General Assembly (April 2013, Vienna, Austria).

***Further Meetings:*** Two further working group meetings will be held — one about half-way through and the other one towards the end of the WG lifetime. Potential candidates for the first meeting are the AGU fall meeting in 2014 or an expected 5th Argo Science Workshop in 2015. Candidate for the final meeting could be the 2016 Ocean Sciences Meeting or the 2016 AGU fall meeting.

***Products:*** The WG will write an article for EOS after its first meeting to inform the community about the objectives and further plans of the SCOR WG. Also, a written document will be produced from each meeting. As the final product some kind of "best practices" manual is envisaged which will provide the community with a consistent approach to data handling and quality control of oxygen data from autonomous platforms and form the basis for the implementation of oxygen measurements in the Argo program. The final product and recommendations from the group will also be highlighted within a group article.

***Capacity Building:*** Many of the major science issues of biogeochemical cycles in a changing ocean (e.g., ocean acidification, deoxygenation, eutrophication and changes in primary productivity) take place near and are socioeconomically highly relevant for developing countries. Modern autonomous observatories could potentially provide scientists from these countries with both cost-effective ways of mounting their own observational programs and open access to relevant high-quality data. This important aspect is reflected by having two distinguished scientists from developing countries on the list of proposed (full or associated) members. Also, a close contact will be established between this WG and the Argo capacity building activities. Building necessary capacities in developing countries can be fostered by providing access to ¡§best practices¡¨ documents which specifically address the often limited financial and infrastructural resources that are available to them. The aspect of capacity building could be further augmented by hosting a session (in conjunction with a WG meeting) to discuss the needs and capabilities of developing countries with respect to using the Argo observatory and other suitable programs. Similarly a group article on this topic could be written for and presented to the relevant audiences. Finally, the WG plans to get in contact with the Partnership for Observation of the Global Oceans, POGO, to see if the WG products and procedures could be added to POGO¡¦s portfolio of training & education activities.

<u>Working Group Composition (full members)</u>

1. Arne Kortzinger (Co-chair), GEOMAR, Kiel, Germany — chemical oceanography, oxygen minimum zones, oxygen & CO2 sensors and floats
2. Ken Johnson (Co-chair), MBARI, Moss Landing/CA, USA — chemical oceanography, nitrate and pH floats
3. Herve Claustre, Villefranche-sur-Mer, France — biological oceanography, bio-optical floats
4. Katja Fennel, Dalhousie University, Halifax/NS, Canada — marine biology, physical-biogeochemical modeling
5. Denis Gilbert, Institut Maurice-Lamontagne, Mont-Joli/QC, Canada — physical oceanography, oxygen minimum zones, oxygen floats
6. Steven Riser, UW School of Oceanography, Seattle/WA, USA — physical oceanography, Argo program & technology
7. Virginie Thierry, IFREMER, Brest, France — physical oceanography, Argo data quality control
8. Bronte Tilbrook, CSIRO, Hobart, Australia — chemical oceanography, oxygen floats
9. Hiroshi Uchida, Research Institute for Global Change, JAMSTEC, Yokosuka, Japan — physical oceanography, in-situ sensor calibration
10. Wajih Naqvi, National Institute of Oceanography, Goa, India — ocean biogeochemistry, ocean minimum zones & deoxygenation

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Working Group Composition (associate members)

1. Steve Emerson, UW School of Oceanography, Seattle/WA, USA — chemical oceanography, marine oxygen dynamics
2. Hernan Garcia, NOAA-NODC, Silver Spring/MD, USA — chemical oceanography, ocean climatology, data quality control
3. Nicolas Gruber, ETH Zurich, Switzerland — biogeochemical modeling, analysis of observational data
4. Osvaldo Ulloa, Universidad de Concepcion, Chile — marine biology, oxygen minimum zones, oxygen floats

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## 2.3.6 **Proposal for a SCOR Working Group to identify Ecosystem Essential Ocean Variables for measuring change in the biological properties of marine ecosystems**

***Costello***

Rationale

Indicators of marine ecosystem status have been an important focus of discussion for the last two decades, primarily arising from a need to better understand the impacts of fisheries and to develop indicators of when changes to fishing practices may be needed to retain or restore ecosystem health. Until recently, consideration of the effects of fishing assumed that the global oceans retained largely the same levels of productivity at lower trophic levels and that fisheries were the primary driver of long-term change in the sustainable harvest. Understanding has grown that present and expected changes in ocean climate and acidification could result in altered dynamics of marine ecosystems, which, in turn, will need to be considered when making decisions about how to maintain ecosystem health, services and robustness/resilience to future change. Marine ecosystem management will require indicators of the underlying status of marine ecosystems and how they may be changing, such as is highlighted by the UN World Oceans Assessment whose first cycle is scheduled by end 2014 (the Regular Process for global reporting and assessment of the state of the marine environment, including socieconomic aspects, St. Aimee and Sauvé 2011; see also UNEP 2007). Marine ecosystem indicators will also inform the science for assessment cycles of the emerging Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES - UNEP 2011) as a parallel to the IPCC. However, development of such indicators is not far advanced, particularly whole ecosystem indicators.

Recent attention to the development of field programs to measure change on large ecosystem scales has recognized deficiencies in understanding what biological parameters may be routinely measured to provide effective indication of the trajectories of change of those ecosystems (Murphy et al. 2008, Constable and Doust 2009, Rintoul et al. 2011). In particular, there is a growing recognition of the need to measure the background state of ecosystems to facilitate interpretation of indicators from fisheries, for example, the IndiSeas Working Group of the Eur-Oceans Network of Excellence (Shin and Shannon 2010), the North Pacific Marine Science Organization (PICES) assessment of the North Pacific marine ecosystem status (Jamieson et al. 2010), and in the Scientific Committee for the Conservation of Antarctic Marine Living Resources (SC-CAMLR) (SC-CAMLR 2011). Ocean observing systems are expanding worldwide and need assistance in identifying the biological and ecological variables that should be measured.

A SCOR Working Group in collaboration with other international groups, including the IMBER program's Integrating Climate and Ecosystem Dynamics (ICED) project in the Southern Ocean, the Southern Ocean Observing System (SOOS), and the Global Ocean Observing System (GOOS), will provide the best mechanism to bring together the international scientific community to identify the suite of Ecosystem Essential Ocean Variables (eEOVs) that need to be measured to assess status and change in whole marine ecosystems (here, we refer primarily to neritic and open ocean systems and do not include the interface between land and sea per se, although the results will benefit from some input from those specialists). Such variables build on the concept of Essential Ocean Variables for sustained monitoring of the ocean that are a part of the Framework for Ocean Observing developed out of the OceanObs'09 conference (Fischer et al. 2010), which has been adopted by GOOS and is being further developed as part of the EC-funded (2012-14) GEOSS interoperability for Weather, Ocean and Water project. This issue will require consideration of key biological attributes of marine ecosystems that underpin structure and function, how those attributes may be summarized and, in particular, the types of cost-effective measurements that will need to be taken simultaneously to capture those properties. As a result, it will require expertise ranging from ocean observations across the different biota of ecosystems to those with a theoretical understanding of the dynamics of ecosystems and the key drivers of their structure and function. Appropriate scientific expertise must be assembled with respect to the different types of global marine ecosystems. Scientists from developing nations should be included in the Working Group because of their proximity and experience in many important ecosystems, providing for opportunities to build capacity on this topic.

This topic is of fundamental theoretical importance to marine science as well as management, which are key goals for SCOR. SCOR already has experience in providing leadership in the development of indicators through its Working Group 119 (Cury and Christensen 2005), which provided foundations for further work on fisheries indicators (e.g., IndiSeas - Shin and Shannon 2010 - and PICES – Perry et al. 2010). Also, SCOR has current working groups considering time series of phytoplankton (Working Group 137) and zooplankton (Working Group 125), which together will provide important inputs to whole-ecosystem indicators and monitoring. The involvement of SCOR will provide the impetus for engaging with the wider community on this issue, including scientists from academic and government institutions as well as young researchers and those from developing countries.

Scientific Background

The development of ecosystem indicators is now fundamentally important to making statements about the state of the marine environment and, in particular, the rate at which marine ecosystems are changing (Millennium Ecosystem Assessment 2005, IPCC 2007, SC-CAMLR 2011). However, many of the indicators currently available for marine ecosystems relate to the physical environment or, for biology, only particular aspects of the ecosystem, most notably on the effects of fishing. In the latter case, biological indicators may range from size-spectra, trophic dominance and composition of fish communities as well as general attributes such as total biomass in a region (see references cited in Shin and Shannon 2010).

Many reviews of ecosystem indicators declare a need for assessments of whether the structure and function of an ecosystem is changing (e.g., Perry et al. 2010, Shin and Shannon 2010, Constable 2011). Such assessments may not require complete knowledge of exactly which elements have changed, but more to provide assessments that change in, say, primary productivity has occurred. This will enable managers to then alter their strategies to achieve sustainability objectives, for example, to adjust fishery strategies to be consistent with the present levels of productivity in the system.

A common difficulty with assessing change in biological components of marine ecosystems is that a sufficiently long time series of measurements is required in order to appropriately differentiate change from natural variability, which could include spatial and temporal variation in the biota of interest, but also in the natural variation associated with food web dynamics over many years. The identification of whole-ecosystem indicators has been a topic of considerable discussion over the last two decades but most indicators have been derived opportunistically from available datasets (e.g., Cury and Christensen 2005, Pauly et al. 2005, Coll et al. 2009, Perry et al. 2010). The utility of indicators for detecting change and the types of data that will be needed for estimating those indicators would ideally be designed so that important change is correctly detected when management action is required (de la Mare 1998, Perry et al. 2010, Constable 2011).

Essential indicators of the physical marine system are well developed, along with the appropriate interpretation and use in the development and application of models of the physical systems (e.g., Rintoul et al. 2011). Ecosystem Essential Ocean Variables (eEOVs) that indicate status and change in marine habitats and the biotic components of the ecosystem need to be developed in order to establish field programs concomitant to physical programs in order to begin monitoring and measuring change in marine ecosystems as a whole. The definition of eEOVs will need to balance their importance in monitoring ecosystem status and change, with the feasibility of their sustained measurement based on present and emerging observing technology. The readiness of eEOV observations will need to be assessed, to encourage research efforts aimed at a better ability to sustainably monitor ocean ecosystems.

Considerable progress has been achieved in developing individual methods for sampling marine ecosystems (Agnew 1997, Rintoul et al. 2011). Similarly, a large body of experience for assessing change in many marine ecosystems is now available (Perry et al. 2010, Shin and Shannon 2010). Importantly, this experience can be harnessed to develop cost-effective field designs for implementing methods to provide data on the eEOVs. Tools are now available for assisting with assessing and evaluating the efficacy of indicators and different spatial and temporal sampling approaches, both qualitatively (Dambacher et al. 2009, Melbourne-Thomas et al. submitted) and quantitatively (Fulton et al. 2005). A coherent plan for measuring indicative changes in marine ecosystems can now be developed on the basis of these advances.

Terms of Reference

The proposed Working Group would

1. **Identify composite indices that could be used to detect and track change in the structure and dynamics of marine ecosystems**. These indicators would be based on

current understanding of the key drivers of the structure and function of marine ecosystems. Priorities will be considered relative to different types of ecosystem services.

2. **Determine the Ecosystem Essential Ocean Variables (eEOVs) that would need to be monitored on a sustained basis to produce the composite indices identified in the first term of reference.** This determination will be based on an assessment of the importance of the variable in the context of the indices and the feasibility of sustained monitoring.
3. **Provide advice on the technical requirements for measuring these eEOVs**, including identifying available and emerging measurement methods and technologies, assessing the readiness for sustained monitoring, and, based on ecosystem simulation models and analyses of available datasets, specifying the spatial and temporal requirements for field sampling of the eEOVs.
4. Report on these outcomes through the development of a Web-based report, as well as a set of review papers submitted to the primary scientific literature on each of the three terms of reference above.

<u>Working Group activities</u>

Each Term of Reference (ToR) will be developed sequentially. The first term of reference (ToR 1) will be developed as case studies for major marine ecosystems around the world, including all the major oceans and subdivisions, as available, many of which have been considered in relation to fisheries impacts on those ecosystems and possible prognoses for impacts. This compilation is envisaged to rely on existing reviews, particularly in relation to indicators that relate to fisheries impacts. ToRs 1and 2 will use qualitative analytical methods (Melbourne-Thomas et al., submitted) to determine eEOVs for each of the major ecosystems that could underpin the development of assessments of change in those ecosystems.

The Working Group will hold its first meeting in 2013, following an initial compilation of material to satisfy ToR 1. This will be in conjunction with a meeting of ICED experts on food web modeling, which is an important part of considering the first term of reference. At this meeting, a work plan will be developed for undertaking a qualitative assessment of candidate eEOVs, including identification of which case studies have sufficient development of structure, function and the drivers of change to undertake such an assessment for that ecosystem. Also, experts will be identified for participation in the qualitative assessment and for participation in a workshop to clarify, test and decide on the best candidate eEOVs for further investigation.

The Workshop to conclude ToR 2 will be held in 2014, involving the WG and, as available, additional experts to consolidate the outcomes of the qualitative assessment and to provide recommendations for continued work on ToR 3. The Workshop will also consider the tools that need to be used to evaluate candidate eEOVs in terms of field sampling and the costs and benefits of the measurement of those eEOVs for estimating whether the structure and function of an ecosystem has changed. In preparation for the workshop, the WG will coordinate the qualitative assessment of the efficacy of different indicators for assessing change in ecosystems and the identification of potential eEOVs to contribute to those assessments. It will also coordinate the compilation of candidate field methods for measuring eEOVs and the tools (ecosystem models and analytical tools) that may be available for addressing ToR 3 in assessing the value of those methods in measuring change in different ecosystems. A primary outcome of this workshop will be a contribution to the process for UN Global Ocean Assessments, the second phase of which will begin in 2015.

The WG will, by correspondence, begin planning for a symposium to be held early in 2016. The WG will meet in 2015 to consider preliminary results and progress on ToR 3, and to continue the planning for the symposium in 2016.

The symposium early in 2016 will consider the outcomes the first three terms of reference, as well as invite participation through oral and poster presentations on the measurement of status and change in marine ecosystems. Any results on the first 3 ToRs will be made available to participants prior to the symposium to ensure that the greatest input possible to recommending eEOVs and their implementation. The symposium will provide an opportunity to finalize these outcomes amongst the international community as well as for exchanging views on how to integrate ecosystem studies with the long-term measurement and assessment of eEOVs and change in the status and dynamics of these ecosystems. These outcomes will then contribute to the second phase of the Global Ocean Assessment. The outcomes of the symposium will be published in a special issue of a suitable journal, such as Deep Sea Research II. The symposium will not use SCOR funds and if other funds cannot be raised for a symposium, the group will publish a small special issue containing only its own work.

The location of each meeting will be dependent on the costs of travel of the working group to a location. Where possible, the meetings will occur in conjunction with other meetings in order to minimise travel costs. The workshop and symposium are proposed to be in Chile and China to facilitate capacity building on these issues in South America and the western Pacific rim. The final locations will be considered at the first meeting of the Working Group and will depend on cost and feasibility.

A tentative schedule for these tasks is:

| | | | |
|---|---|---|---|
| 2013 | Meeting 1 | TBA | Review of structure and function of marine ecosystems, beginning planning of WG publications, including a short article for (EOS, PICES/ICES newsletter, or whatever venue is appropriate) |
| 2014 | Workshop (Meeting 2) | Chile | Consideration of efficacy of eEOVs for different ecosystems |
| 2015 | Meeting 3 | TBA | Review of progress on evaluating field designs for eEOVs |

| | | | |
|---|---|---|---|
| 2016 | Symposium, report & publication | China | Final commentary on each primary ToR and recommendations on eEOVs, including cost effectiveness of implementation |

Working Group Membership
The Working Group membership aims to include ecosystem theoreticians and modelers, as well as observational specialists for different biological levels across the different major marine ecosystems in the world. Where possible it will also maintain a balance between gender, age and the capacity and need of each country to participate in this work. The achievement of this balance will be through invitations for participation in particular tasks. A broader involvement of the international community will be achieved through the general invitation to participate in the discussions at the symposium and to give oral or poster presentations on the topic at the symposium.

The Working Group aims to build capacity, in this emerging field, in developing countries through participation in the Working Group by scientists from Chile (1) and China (2). These scientists will provide important linkages to oceanographic and ecosystem research institutions in their respective regions. Further opportunities for capacity building will be available by holding the workshop and symposium in these countries. We will be approaching SCOR and other funding agencies for funding to assist scientists from developing countries to participate in these events.

The proposed membership is as follows:

**Full Members:**

| Name | Country | Expertise |
|---|---|---|
| Sanae Chiba | Japan | North Pacific ecosystems, zooplankton, ecosystem indicators, Continuous Plankton Recorder, SCOR WG 125 |
| Andrew Constable (Co-Chair)[1] | Australia | Southern Ocean, ecosystems, sampling design, pelagic and benthic sampling, CCAMLR Ecosystem Monitoring Program, SOOS, Southern Ocean Sentinel (IMBER ICED) |
| Dan Costa (Co-Chair)[2] | USA | North Pacific, Southern Ocean, marine mammals and birds, tracking, SOOS |
| Philippe Cury | France | Fisheries, indicators, SCOR WG 119, European indicators for ecosystem approach to fisheries |
| Sophie Fielding | UK | North Atlantic, Southern Ocean, pelagic sampling, acoustics |
| Beth Fulton | Australia | All regions, ecosystem modelling & synthesis, ecosystem indicators |
| Sergio Neira | Chile | South-east Pacific, ecosystem ecology & indicators |

| | | |
|---|---|---|
| Oscar Schofield | USA | Southern Ocean, gliders, Northeast United States, remote sensing, SOOS |
| Yunne Shin | France | IndiSeas project (representative of coordinating group), OSMOSE modelling (lead) |
| Xianshi Jin | China | Ecosystem and fisheries ecology, PICES Fishery Science Committee, Yellow Sea/Bohai Sea Large Marine Ecosystem |

.

Co-Chairs:

[1]Dr. Andrew Constable
Leader, Southern Ocean Ecosystems Program, Australian Antarctic Division, Kingston, Australia; & Leader, Ecosystem Impacts Program, Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, Australia. Contact: andrew.constable@aad.gov.au

[2] Dr Daniel Costa
Distinguished Professor of Ecology and Evolutionary Biology, Ida Benson Chair in Ocean Health, Director Marine Vertebrate Physiological Ecology Group, University of California Santa Cruz, CA. Contact: costa@ucsc.edu

**Associate Members:**

| Name | Country | Expertise |
|---|---|---|
| Julia Blanchard | UK | Size-based indicators (lead), IndiSeas, QUEST-Fish |
| Antje Boetius | Germany | Microbial ecologist, GOOS - Deep Ocean Observing Strategy |
| Katja Fennel | Canada | Food web and biogechemical modeling, biological data assimilation techniques |
| Eileen Hofmann | USA | Atlantic, Southern Ocean, ecosystems, IMBER ICED project (co-leader) |
| Simon Jennings | UK | Marine ecosystems & fisheries ecology and management, indicators |
| Rudy Kloser | Australia | Bio-acoustic monitoring, Australian Integrated Marine Observing System, ecosystem indicators |
| Jason Link | USA | Atlantic, pelagic biota, indicators |
| Pat Livingston | USA | Ecosystem ecology and fisheries indicators |
| Olivier Maury | France | All regions, ecosystems, indicators, IMBER CLIOTOP Project |
| Eugene Murphy | UK | Southern Ocean, ecosystems, IMBER ICED project (coleader) |
| Todd O'Brien | USA | SCOR WG 125, 137, data management & synthesis |
| Tony Smith | Australia | Marine ecosystems, fisheries ecology and management, indicators |
| Xianyong Zhao | China | North Pacific, Southern Ocean, acoustics, SCOR-China |

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2.3.7 **Proposal for a SCOR Working Group on The reassessment of marine dinitrogen fixation methodology and measurements** ***Sundby***

Abstract

Biological dinitrogen (N2) fixation rate measurements are critical for determining the input of new fixed nitrogen to the oceanic nitrogen inventory. Recent development in N2 fixation research has identified that the method widely applied in the last 15 years has led to a systematic, significant, and variable underestimation of the real N2 fixation rates. Experimentally, the most widely applied method to measure N2 fixation in the ocean involves adding 15N2 gas to a water sample through a gas tight septum in a bottle, which is incubated in situ or under simulated in situ conditions, terminating the experiment by filtering the water onto a filter, and measuring the 14N and 15N isotopic abundances (or relative abundances) using a mass spectrometer. It has now been demonstrated that the rate of dissolution of the added 15N2 gas bubble is slow, taking between 6 to 12 hours to reach equilibrium (saturation) in the dissolved pool. Thus, the resulting rates are inherently in error, since the 15N percent in the aqueous phase is changing throughout the incubation rather than being constant, as assumed in the rate calculation. Both laboratory and field measurements predict on average a ~2 fold underestimation of the rates measured up to now. The research community needs to develop an acceptable alternative method for accurate measurements of N2 fixation. An initial workshop on this topic has already taken place on February 6-8 2012 in Kiel, Germany where a group of experts has come together to begin the initiation of a community attempt to rectify the problem. The outcome of the workshop indicates that there will be an additional requirement to meet periodically over the next 3-4 years to develop a widely accepted new method. The proposed SCOR group would continue this initiative of the SOLAS-sponsored workshop by coordinating the work of a group of international scientists that will develop a consensus methodology for N2 fixation rate measurements. The outcome of the working group would be 1) a short position paper explaining the problem and the possible solutions, 2) the planning of experiments and inter-calibration exercises to validate the new approach to N2 fixation measurements, 3) production of accepted and tested protocols for N2 fixation rate measurements, 4) publishing of a ‘Guide to Best Practice to Marine N2 Fixation Research’, and 5) evaluation of the historical data on N2 fixation to provide a best estimate of the magnitude of the underestimation and provide guidelines for the utilization of historical N2 fixation rate measurements in biogeochemical and global change research and models.

Rationale

The nitrogen cycle is intricately linked to the productivity of the ocean (Duce et al. 2008). The oceanic fixed nitrogen inventory is balanced by loss and gain processes, which are controlled by marine microbes (Gruber and Sarmiento 1997). Loss processes are diverse and include autotrophic and heterotrophic denitrification and anammox reactions, while N2 fixation is the only direct biological input of new fixed nitrogen to the ocean. Thus, biological dinitrogen fixation rate measurements are critical for determining the magnitude of new fixed N input to the oceanic N inventory (Karl et al. 2002, Luo et al. 2012, Duce et al. 2008). Since dinitrogen (N2) is a gas, these measurements require incubation of seawater samples with a gas, either isotopically labeled N2 molecules, or a N2 analogue (such as acetylene) (Capone 1993). In the last 15 years, the most widely accepted method to measure N2 fixation has been to incubate water samples containing natural microbial communities, including N2 fixing microorganisms, with tracer amount of the 15N (a stable isotope form of N) labeled N2 gas. The rate of N2 fixation is then determined by measuring the isotopic enrichment of the particulate nitrogen, which becomes enriched in 15N through the enzymatic conversion of N2 into ammonium, and subsequently into amino acids and other organic cellular material (Montoya et al. 1996). The calculations of the rates are based on measurements of the 15N in the particulate material and on the natural abundance of 15N in the particulate material, both measured with a mass spectrometer. A third critical parameter is the 15N isotope ratio of the seawater phase after the addition of the tracer, which is calculated assuming complete and instantaneous equilibration of the added 15N2 gas with the seawater, according to Weiss (1970), and Hamme and Emmerson (2004). It has recently been demonstrated experimentally that the latter assumption is not valid and therefore results in an underestimation of the real N2 fixation rates (Mohr et al. 2010a).

During a recent workshop where a group of 24 experts in marine N2 fixation research came together to discuss these problems, it was established that an improved method should be developed by the scientific community rather than by individual scientists. This will ensure thorough testing of the method, circumventing new problems such that the best possible alternative method can rapidly gain acceptance in the scientific community. Although several researchers have begun to adapt the method to circumvent the equilibration problem, working as a group rather than in isolation will ensure that the new method will be widely tested and benefit from the ideas and expertise of the scientific community involved in N2 fixation research. Coordination and discussion of the various individual efforts during the initial workshop, primarily sponsored by SOLAS, has already proven beneficial in terms of standardizing protocols and sharing information. During the initial workshop, a work plan has been proposed for the next 3-4 years. It was also discussed that a SCOR working group would be ideal to fulfill the goals of establishing the new method and assessing the consequences of the underestimation in the last 15 years of N2 fixation rate measurements, which are widely used in biogeochemical models and marine N cycle and global change research. The development and implementation of a new method which corrects for the underestimation will most likely lead to higher estimates of marine N2 fixation over the next few years and starting in 2012. It is very important that this time point (2012) is clearly documented in the peer-reviewed literature as the time when the method was readjusted to prevent misperception decades later that marine N2 fixation has increased due to natural or anthropogenic changes in environmental conditions that would favor N2 fixing organisms (diazotrophs).

In addition to designing a new method, it is important to recommend a strategy to regain a basic data set of N2 fixation rate measurements in the ocean, and assess the level of underestimation that may have taken place in the last 15 years of measurements. Additionally, the discovery of new diazotrophs in unsuspected regions calls for a systematic re-evaluation of N2 fixation in the ocean, requiring a strategic planning for oceanographic campaigns, where N2 fixation rate measurements will be carried out. A SCOR working group is the best mechanism to ensure a coordinated international scientific effort to develop, test and apply a N2 fixation method that circumvent the problems of the widely applied method, which currently underestimates N2 fixation rates. The scientific rationale for the working group is to distribute the tasks of designing and testing an improved method among the interested groups that cover different scientific backgrounds, ranging from chemists to ecologists. It will also provide a broad range of expertise and instrumentation that would otherwise not be readily available to individual groups (e.g., MIMS (membrane inlet mass spectrometry) measurements), which allows us to speed up the task of designing a new method and distributing it broadly.

Scientific Background

The importance of N2 fixation in the oceanic N cycle is well established (Duce et al 2008) and will not be reviewed in detail here. Marine N2 fixation has been the subject of recent reviews (e.g., Luo et al. 2012) and has been implemented in several coupled ocean-atmosphere biogeochemical models (Monteiro et al 2011, Monteiro and Follows 2009). Indirect estimates of N2 fixation based on geochemical approaches have so far been higher than direct field-based rate measurements (Gruber and Sarmiento, 1997, Gruber, 2008). Recent experimental work (Mohr et al. 2010a) indicates that the discrepancy may have arisen to a large extent because of a misconception in the assumptions involved in the direct measurements of marine N2 fixation as described above.

The N2 fixation measurements have typically been performed by injecting a gas bubble (typically a few milliliters) into a bottle filled with seawater, inverting the bottle to mix the bubble, and assuming that the injected gas rapidly equilibrates with the dissolved N2 pool (Montoya et al. 1996). Recent research has demonstrated that the dissolution of the gas bubble is slow, taking between 6-12 hours to reach close to equilibrium (saturation) in the dissolved pool, depending on the incubation conditions. Thus, the resulting rates are inherently in error, since the 15N % labeling is changing throughout the incubation time while a constant value is applied in the calculation of the N2 fixation rate leading to the underestimation. One additional consequence of the slow equilibration is that the time of initiation of the experiment is critical, as is the nature of the N2 fixing microorganisms. For example, some N2 fixing microorganisms fix only in the light period (e.g. Trichodesmium) and if the incubation is begun at the beginning of the light period, there will be a large degree of error, since the isotope will not be in equilibrium during the period that N2 fixation occurs. In contrast, if the incubation is begun the previous evening, the isotope has time to equilibrate prior to the daytime N2 fixation of Trichodesmium. Additionally, some organisms fix only during the dark (Mohr et al. 2010b), and some fix in both the light and dark (e.g. the UCYN-A cyanobacteria, Goebel et al. 2007). As a result, the bubble method is inconsistent in how it underestimates N2 fixation. The currently utilized method is therefore in violation of the principles of tracer experiments and a new method in which isotopic equilibrium is reached completely and rapidly at the beginning of the incubation is needed. Until we rectify the method and obtain a series of new measurements, we need to consider the current direct estimates of marine N2 fixation as lower estimates for this process. It is likely that with the development of the new methods the oceanic N cycle will need to be revised significantly to include higher estimates of N2 fixation. Given that N cycle is affected by anthropogenic activities, it is important to have an accurate method to directly measure N2 fixation at the local, regional and global scale in order to assess, for example, the relative contribution of atmospheric N deposition and N2 fixation to the N oceanic inventory as the contribution of atmospheric deposition is predicted to increase significantly in the future (Duce et al. 2008). Additionally, the recent discovery of new diazotrophs (Foster et al., 2006, Moisander et al., 2010, Rieman et al., 2010) and the long-term commitments of N2 fixation rate measurements at time-series sites such as HOT and BATS, where diazotrophs are known to be important members of the microbial community, all point to the urgent need to develop and apply accurate and standardized methods for measuring N2 fixation. During the initial workshop sponsored by SOLAS, we have already begun the task of designing a method without the drawbacks of the technique currently in use. At the initial workshop, it became evident that the process of establishing a more accurate method will require extensive testing and coordination of these activities through regular meetings would be the best way to reach our goals. As the work on N2 fixation is ongoing, a set of initial recommendations were made at the SOLAS workshop but the upgraded method will require more time to become established. Guidelines are needed for N2 fixation work and for interpreting previous measurements and for recommendations on the future plans for strategic measurements.

Terms of Reference

The working group will pursue the following terms of reference:

1. Write a short paper after the first meeting, to be submitted to Frontiers in Aquatic Microbiology-Perspective, explaining the inherent problems of the current N2 fixation rate measurement method, the associated consequences and the possible solutions.
2. Develop and test a more accurate method for the direct measurement of oceanic N2 fixation rates
    - Test method for producing 15N2 enriched water
    - Storage of standard enriched seawater
    - Test the effect of adding 15N2 enriched sea water to natural communities of microorganisms
3. Coordinate and execute an intercalibration exercise and a workshop to train people on the application of the new method
4. Review and assess the consequences of the underestimation in the historical measurements and provide a list of recommendation for their utilization.
5. Produce a series of protocols to measure marine N2 fixation, accepted by the group and distribute them to the wider scientific community. Eventually, also publish these in a peer-reviewed methods journal.
6. Produce and publish a document entitled 'Best practice guide to N2 fixation research' with chapters contributed by various members of the working group and complemented

(if necessary) from solicited contribution from additional members of the scientific community at large.

Working Group Membership

The work proposed here would be carried out by a group of 10 Full Members and 18 Associate Members, including the scientists that were involved in the initial workshop. The list of proposed experts includes all of the participants who attended the first workshop but has been extended to include scientists from other geographical areas. The full members all have ongoing programs to measure N2 fixation in the ocean or interest in the N cycle and are therefore highly motivated to carry out this task.

*Full Members*

1. Julie LaRoche (Canada) - Co-chair – Marine Biogeochemistry
2. Lucas Stal (Netherlands) - Co-chair – Marine Microbiology
3. Jonathan Zehr (USA)-Biological Oceanography
4. Eric Achterberg (UK)– Chemical Oceanography
5. Hongbin Liu (China) Biological Oceanography
6. Cliff Law (New Zealand) - Biogeochemistry
7. Anya Waite (Australia) – Biological Oceanography
8. Wajih Naqvi (India)- Biological Oceanography
9. Helle Plough (Sweden) - Biology
10. Wiebke Mohr (USA)-Marine Biogeochemistry

*Associate Members*

1. Sophie Bonnet (France) - Biology
2. Mark Altabet (USA)-Chemical oceanography
3. Margaret Mulholland (USA) - Biology
4. Lasse Riemann (Denmark) - Ecology
5. Ricardo Letelier (USA) Biological Oceanography
6. Ilana Berman-Frank (Israel) Biological Oceanography
7. Emilio Maranon (Spain) Ecology
8. Pia Moisander (USA) Biological Oceanography
9. Angelicque White (USA) Biological Oceanography
10. Mark Moore (UK) Marine Biogeochemistry
11. Matt Church (USA) Biological Oceanography
12. David Karl (USA) Marine Biogeochemistry
13. Gaute Lavik ( Germany) Marine Biogeochemistry
14. Maren Voß (Germany) – Biological Oceanography
15. Claire Mahaffey (UK) Biological Oceanography
16. Rachel Foster (Germany) Biological Oceanography
17. Daniella Böttjer (USA) Biological Oceanography
18. Sam Wilson (USA) Biological Oceanography

Working Group Activities

If approved, the working group would organize its first meeting in early 2013, potentially in conjunction with the ASLO meeting in New Orleans (February) or the annual EGU meeting (late April). At the first meeting, the members will present results from the activities that were carried out since the first meeting held in February 2012. The initial results will determine how to follow and fulfill the terms of references. As in the initial SOLAS meeting, tasks will be assigned to groups of individual scientists to insure that all of the terms of references will be covered during the 3-year period. The implemented task groups will discuss their requirements and work plans for the next year (e.g., how they will coordinate their activities and whether they will require an additional meeting or workshop to best achieve their goals). They will also plan a joint cruise that will serve both as a training and an intercalibration exercise, and additionally explore options to acquire additional funds for the field work.

The second meeting will be held at Dalhousie University in Halifax Canada in late 2013 or early 2014. A detailed outline of a publication entitled 'Guide to best practices to marine N2 fixation research' will be produced at the meeting with the various chapters of the book assigned to specific authors. This publication will be in a format similar to the successfully completed 'Guide to best practice to Ocean acidification research' (http://www.epoca-project.eu/index.php/guide-to-best-practices-for-ocean-acidification-research-and-data-reporting.html) which is widely accepted and used by the scientific community. In addition, the working group members will plan to write a method's paper (if possible to a journal such as Nature Methods, that encourages the synthesis of large experimental trials). We will also discuss at that time how to obtain the financial means to produce and distribute widely the publications either electronically or as printed material.

The final meeting in late 2014 or early 2015 will be to complete the best practice guide document and to produce a set of protocols for the methods paper, also collecting and reviewing the rate measurements made with the new method. In addition, the final meeting will be used to finalize the recommendations on 1) the utilization of the historical data and 2) the determination of a new series of N2 fixation rate measurements that can be used as a baseline for global change research on the oceanic N cycle from 2012 and beyond.

The topic and activities of the proposed group have already been judged important for SOLAS, as demonstrated from their support of an initial workshop. In addition, they will be useful to IMBER and GEOTRACES activities. The working group will ensure that links are established with these other programs.

Capacity Building

Nitrogen fixation measurements are made worldwide, in developed and developing countries. It will be important to ensure that the new methods are transmitted effectively to developing countries. This goal will be achieved through participation of developing country scientists on the working group and in the group's intercalibration and training activities. In addition, the publications of the outcomes of the SCOR group results will be made open access, including the best guide to N2 measurements and the potential 'Nature Methods' publication. The group will seek additional funding from SCOR and other sources for participation of developing country scientists in group activities.

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