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## International Ocean Carbon Coordination Project Progress Report for SCOR, May 2016



The complexity of the marine carbon cycle and its numerous connections to carbon's atmospheric and terrestrial pathways mean that a wide range of approaches have to be used in order to establish its qualitative and quantitative role in the global climate system. In addition, an inter-correlation with carbon-related biogeochemical parameters requires a coordinated, comprehensive biogeochemistry observing system that is fit-for-purpose, sustainable in long term and globally feasible.

The International Ocean Carbon Coordination Program promotes the development of a global network of ocean carbon and biogeochemistry observations, coordinates the development of globally acceptable strategies and provides technical coordination developing methodologies and practices and standards, homogenizing efforts of the research community and scientific advisory groups. IOCCP also provides communication services for marine biogeochemistry community as well as advocacy and links to a multidisciplinary sustained global observing system. This report highlights main activities of the IOCCP between September 2015 and May 2016.

### PROJECTS AND MAJOR ACTIVITIES

#### IOCCP Position Statement on Data Management

Triggered by adverse developments in the DOE/USA related to funding of data management activities lying in the center of global ocean marine biogeochemistry observing community and based on the long-lasting need to update several protocols and procedures utilized by data management system, a Position Statement was written by members of the IOCCP SSG and the former IOCCP SSG Chair, Dr. Christopher Sabine. Some emphasis in this document is placed on our current situation but the major focus is on providing the initial direction for the way forward into the future. The Panel unanimously endorsed the Position Statement provided below and supported the data and information team in their activities aimed at finding a short-term and long-term solutions so that no legacy is lost and the future data management system, while modernized, can benefit from the existing infrastructure and personnel.

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*The international ocean biogeochemistry community is mainly using and depending upon one global data center, the Carbon Dioxide Information Analysis Center ocean trace gases section (CDIAC-Oceans) at the U.S. Department of Energy's Oak Ridge National Laboratory, USA. CDIAC-Oceans provides data management support for ocean carbon measurements from Repeat Section cruises, VOS/SOOP lines, time series and moorings data, has accommodated most community requests for data archival and data access and has also actively engaged with the science community, supporting large synthesis projects like SOCAT, the LDEO Database, GLODAP, CARINA, PACIFICA and GLODAPv2. The cut of funding support for the ocean trace gases section of CDIAC puts in jeopardy the uninterrupted data management that the ocean biogeochemical data community has come to rely upon as well as the trust and recognition from the scientific community that CDIAC-Oceans has built through decades of interactions. The loss of CDIAC-Oceans will have a negative impact on ocean carbon data submissions and reduction in value added products.*

*The uncertainty of funding for CDIAC highlights the vulnerability of a system that relies too heavily on individual data managers or institutions. At the same time, it provides an opportunity to review the requirements for modern data access and data management systems that have evolved significantly during the last decades and which currently are not being met through the CDIAC infrastructure. Operational data management systems that (a) provide automated data ingestion, (b) conform to modern standards for data and metadata, (c) utilize standard vocabularies, (d) have easy-to-use data access tools, and (e) provide stable data citations are driven not only by user requirements, but also by funding and government agencies as they promote open access to data. In the discussion of CDIAC funding and the vulnerability of ocean biogeochemistry data, we see a strong opportunity to implement a data management infrastructure that can thrive in the modern world of integrated science data.*

*A modern data management infrastructure needs to be established in which existing data centers (e.g. CDIAC, CCHDO, BCO-DMO, PANGAEA, NCEI) and data from various other networks (e.g. OceanSites, Argo) can be integrated through interoperable discovery and access services. This is essential for providing access to data, while at the same time ensuring that credit for data creation and data synthesis products is appropriately assigned. We propose to mimic the successful data management approach implemented for the Argo profiling float network (<http://www.argodatamgt.org>). The Argo network addresses national funding agency requirements of having data housed in specific locales by setting up two Global Data Assembly Centers (GDACs), one in the US and one in Europe. Data holdings are mirrored between the data centers and can be accessed through either one. This redundancy makes access to the data collection, by nature, more resilient.*

*We suggest establishing a system of Global Data Assembly Centers for ocean biogeochemistry (e.g. GDAC-OBGC) where two initial GDACs are established, each with specific roles and responsibilities. The two GDACS will be complementary systems that will leverage the unique capabilities of each, to provide a complete solution for data ingestion, data quality control, data access, data citation and data archival.*

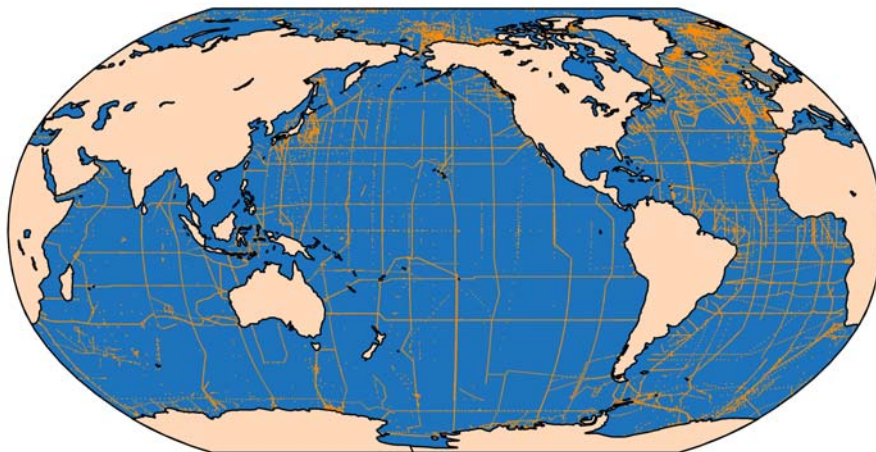
*A strong focus will be on interoperable access of standards compliant carbonate system data and metadata, irrespective of where they are archived. In addition, it is paramount that support for*

*automated data ingestion, both for real time and delayed mode sources, be integrated into the data management workflow. This is crucial to being able to keep pace with the higher volume of data now being generated by autonomous platforms. First order quality control checks built into the automated ingestion streams can further reduce the quality control burden. By providing interoperable access, and adhering to standards and conventions, this framework will make future data synthesis products and activities much more efficient than with the current non-centralized data management system.*

*Another important emphasis of the GDAC will be an external review process by ensuring that (a) data are being quality assured and controlled according to community agreed standards, (b) direct feedback is given to the data source, (c) duplicates are being identified and resulting issues are resolved, (d) metadata are complete according to community agreed best practices or existing standards, (e) data and metadata are available through interoperable services, (f) reports are made to IODE and JCOMM Committees on data management status and activities, (g) data citation practices as outlined by the Research Data Alliance (RDA) and DataCite are incorporated, (h) data requests and searches from users can be reproduced and (i) there is clear tracking of the complete data lifecycle for each dataset. The last three bullet points are often overlooked but are increasingly becoming more important to ensure that PIs get credit for data they create and that users/reviewers can reproduce the exact data requests for data that is referenced in scientific publications.*

*The implementation of the above framework will facilitate continuation of the data synthesis and assessment products such as GLODAP, SOCAT and create a foundation for additional data products, including the integration of data such as time series data and coastal data. In addition, the implementation of such a framework will support compatible efforts internationally, providing a cohesive process toward more uniform data management strategies within the ocean biogeochemistry community. In the long term, such efforts will provide a significant cost savings by reducing data management overhead as well reducing the data management burden on individual scientists.*

#### Global Ocean Data Analysis Project version 2 (GLODAPv2)



*Figure: Locations of stations included in the GLODAPv2 data product*

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In January 2016, the GLObal Ocean Data Analysis Project version 2 (GLODAPv2) was released. Over the past few years, IOCCP was heavily involved in compiling of this new interior ocean data synthesis product. GLODAPv2 includes all data from the original GLODAP, data from CARINA and PACIFICA, and data from 168 new cruises – all in all data from 724 cruises covering 1972 to 2013 (Figure above).

All data included in GLODAPv2 have been evaluated for measurement bias and adjusted appropriately, using a consistent method. The end result is the most comprehensive and rigorously quality controlled ocean interior data product for marine biogeochemistry studies.

GLODAPv2 consist of three elements:

- a database with original cruise data, as submitted by individual data providers but updated to WOCE Exchange format,
- a merged data product, with measurement biases removed for key biogeochemical variables, and
- a mapped climatology of the merged data product consisting of global 3D fields of the seawater distribution of CO<sub>2</sub> chemistry and other parameters.

Analysis of GLODAPv2 parameters will allow for quantitative assessment of biogeochemical changes and feedbacks between climate change and the ocean system. GLODAPv2 is the result of a multi-year global team effort funded by EU-IP CARBOCHANGE, US NSF, US-NASA, US DOE, IOCCP and many other projects, programs and organizations.

The procedures and results are extensively documented in the three publications listed in this report under IOCCP publications.

### The Surface Ocean CO<sub>2</sub> Atlas (SOCAT) Project

The Surface Ocean CO<sub>2</sub> Atlas (SOCAT) is an activity coordinated by IOCCP on behalf of the ocean carbon international community. Its goal is to improve access to surface water CO<sub>2</sub> measurements by regular releases of quality controlled and documented, synthesis fugacity of carbon dioxide (fCO<sub>2</sub>) data products for the global oceans and coastal seas. The SOCAT data products are of great benefit to the ocean carbon and biogeochemistry community as they enhance our capability to: (i) accurately detect global and regional changes in the ocean carbon sink, (ii) quantify ocean acidification, and (iii) validate climate, biogeochemical and ecosystem models.

SOCAT Version 3 was launched at a workshop held prior to the SOLAS Open Science Conference in Kiel in September 2015 (details under Meetings and Workshops). Version 3 contains an additional 4.4 million data points and extends the time span of the data included in SOCAT to 1957 – 2014. As in prior versions, version 3 includes individual data sets, synthesis and gridded data products.

A revamped upload dashboard which integrates data upload, data submission and subsequent quality control on a single platform is currently being used for SOCAT Version 4. Data

submission for version 4 closed at the end of January 2016 (1171 new and updated datasets submitted), the QC process is underway, and the release is scheduled for June 2016. The data submission, QC and release of subsequent versions will become an annual activity.

Since its initial release in 2011, SOCAT products were used in 7 influential international reports (e.g. IPCC, CBD, GOA-ON, ICES and OceanObs'09), in more than 100 peer-reviewed publications, and many PhD theses and book chapters. Still, the impact of SOCAT could be strengthened, for example by making sure that SOCAT data products are utilized in all national and international reports and science plans, and that relevant stakeholders are informed about SOCAT activities, e.g. GCOS, GOOS, UNFCCC, and GCP. SOCAT and SOCAT-based scientific assessments provide stakeholders with information allowing them to meet societal requirements. Verification of the fitness-for-purpose of the ocean carbon observing system for informing policy is the final part of the cycle, something in which SOCAT can play a major role in.

An important discussion related to non-CO<sub>2</sub> parameters measured alongside CO<sub>2</sub> developed during the past several months. These parameters are currently accepted but not quality-controlled. Very recently a decision was taken to convene a working group consisting of MEMENTO (MarinE MethanE and NiTrous Oxide; <https://memento.geomar.de/>) scientists, SOCAT data providers and SOCAT data managers to discuss these issues further, starting with N<sub>2</sub>O and CH<sub>4</sub> surface water data. The aim being a combined, fully quality-controlled data set compiled by disciplinary experts and data providers.

Considering the Fair Data Use Statement, the decision was recently made for a Working Group to consider if the wording of the SOCAT data policy can be improved and whether data providers can be made more visible. This action is now in fact complete, and available on the SOCAT website at: [http://www.socat.info/SOCAT\\_fair\\_data\\_use\\_statement.htm](http://www.socat.info/SOCAT_fair_data_use_statement.htm).

It is important to acknowledge the large community that is involved in the SOCAT effort: data providers, quality-controllers, IT managers, funders and SOCAT users. 53 organisations from 18 countries contribute either explicitly, or with in-kind support. Notably, Dorothee Bakker (Chair of SOCAT Global group; UEA, UK) received an award at the SOLAS conference for her ongoing lead and coordination of this project.

The long term funding and viability of SOCAT continues to be an issue. As means of seeking long-term funding and assuring sustainability of SOCAT, a budget outlining the annual costs of SOCAT with breakdown of individual components will be prepared. In the future, the Integrated Carbon Observing System (ICOS) might assist with long-term support by identifying SOCAT as a science area for national contributions. ICOS is preparing a proposal to the EU (INFRADEV), which may include an activity for ICOS to become the European pillar of SOCAT, and a proposal has been put forward for post-doc time for SOCAT assistance for Dorothee Bakker.

*SOCOM (Surface Ocean pCO<sub>2</sub> Mapping inter-comparison)*

It should also be mentioned that the SOCAT workshop in Kiel included a SOCOM (Surface Ocean pCO<sub>2</sub> Mapping inter-comparison; <http://www.bgc-jena.mpg.de/SOCOM/>) session where the results from the mapping inter-comparison were presented. The first SOCOM results and the

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methodology were published by Rödenbeck et al. (2015). Other recent publications, e.g. Landschützer et al. (2015), in high-ranked journals demonstrate both the need for development and the power of application of the new approaches to  $p\text{CO}_2$  mapping with the goal of better constraining the global carbon budget. IOCCP in collaboration with NIES, Japan has initiated the SOCOM effort in 2011 when the first version of SOCAT was released.

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### The Global Ocean Acidification Observing Network (GOA-ON)

The major focus for IOCCP continues to be the coordination of activities related to biogeochemistry observations in the Global Ocean Acidification Observing Network. 3 IOCCP SSG members and the IOCCP Project Directors are members of the GOA-ON Executive Council. During this reporting period the GOA-ON focused on the following efforts (only activities with active IOCCP engagement are described):

#### *Creating a joint portal for access to global ocean acidification data*

GOA-ON organized two expert meetings to advance the development of data portals for easy access to ocean acidification data. Both meetings were hosted by the Ocean Acidification-International Coordination Centre (OA-ICC) based at the International Atomic Energy Agency (IAEA) Environmental Labs in Monaco. The first meeting (Monaco, 1-2 June 2015) focused on ocean acidification biogeochemical data, whereas the second (Monaco, 17-18 November 2015) focused on experimental data on the biological response to ocean acidification. Both meetings brought together scientific and technical experts actively involved in the use or archiving of ocean acidification data. These two expert meetings explored possibilities to create a joint portal for access to global ocean acidification data within the GOA-ON framework. Invited experts discussed the way forward to (i) extend and update the current GOA-ON inventory and (ii) propose a web portal interface for ocean acidification metadata retrieval. Both groups discussed the advantages and shortcomings of existing data portal systems, the use of common controlled vocabularies, useful search filters, metadata standards and interoperability between different data providers. The longer-term goal of creating a one-stop portal to ocean acidification data with adequate search facilities was also discussed.

*Development of a set of global ocean acidification synthesis products*

With the above developments in mind the GOA-ON Executive Council during an extended working meeting in Monaco, (19-20 November 2015) agreed on developing a central site for products of the variability in ocean acidification (primarily carbonate mineral saturation states and pH) across a range of temporal and spatial scales, including: (i) decadal trends in pH and aragonite saturation state from long-term time series sites, (ii) seasonal changes in pH and aragonite saturation state at the growing number of observing sites in recent years (moored and ship-based time series), and (iii) global distributions focused initially on aragonite saturation state of the kind produced by Jiang et al (2015).

*Organizing the 3<sup>rd</sup> GOA-ON Science Workshop*

IOCCP co-sponsored and was actively involved in the organization (on all levels from logistics to agenda development) of the 3<sup>rd</sup> GOA-ON Science Workshop. The workshop was held in Hobart, Australia (8-10 May 2016), following the 4<sup>th</sup> International Symposium on the Oceans in a High CO<sub>2</sub> World (3-6 May 2016), aimed to further the development of the network. The Workshop intended to cover the following issues:

- Update the GOA-ON community on GOA-ON status and linkages to other global programs
- Build communities to develop regional hubs that will facilitate capacity building
- Update requirements for biology and ecosystem response measurements
- Discuss modeling connections, observational challenges and opportunities
- Present advances in technologies, data management and products
- Gain input on data products and information needs
- Gain input on regional implementation needs
- Launch the GOA-ON Mentorship Program

For more details about the Workshop proceedings and key outcomes see the Meetings and Workshops section.

*Latin American Ocean Acidification (LAOCA) Network*

IOCCP through its involvement in GOA-ON and in close collaboration with OA-ICC supported the launch of the Latin American Ocean Acidification Network (LAOCA Network) - a regional counterpart of GOA-ON. On December 15<sup>th</sup>, 2015, a group of 24 scientists from seven Latin-American countries, including Argentina, Brazil, Chile, Colombia, Ecuador, Mexico and Peru, met at the city of Concepcion in Chile to establish the LAOCA.

This regional workshop was co-funded by IAEA through OA-ICC, the Intergovernmental Oceanographic Commission (IOC-UNESCO), the Center for the Study of Multiple-Drivers on Marine Socio-Ecological Systems (MUSELS), and the Millennium Institute of Oceanography (IMO) from Chile. During two days the group of scientists discussed the strengths and weaknesses of each country in relation to ocean acidification research, and also defining the mission and goals of the LAOCA Network:



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- to synthesize the information about ocean acidification impacts in Latin-America,
- to encourage the implementation, maintenance, and calibration of long-term data-sets of carbonate chemistry in Latin-America,
- training of LAOCA members in various aspects of research (e.g. observation, experimentation, and modelling),
- to standardize chemical analytical techniques and protocols for experimentation in order to enhance data quality and homogeneity,
- to establish a regional node for the articulation and communication amongst local, regional, and global research and coordination programs (e.g. [Brazilian Ocean Acidification Network \(BrOA\)](#), IMO, GOA-ON and IOCCP),
- to determine and evaluate local and regional scenarios of Ocean Acidification for different types of marine ecosystems (e.g. estuaries, coastal area, open ocean, etc.),
- to enhance student exchange and to facilitate access to infrastructure and equipment among institutions and LAOCA member countries,
- to design an outreach strategy for communicating ocean acidification-related issues to various audiences,
- to promote the development of cooperation projects between member countries of LAOCA, and,
- to promote the inclusion of Ocean Acidification to the political agendas of member countries, and even through the pursuit of cooperation agreements among LAOCA member countries.

Finally, scientists defined the LAOCA Executive Council, which will be co-chaired by Leticia da Cunha, (Universidade do Estado do Rio de Janeiro – UERJ, Brazil; Co-leader of BrOA); Nelson A. Lagos (Centro de Investigación e Innovación para el Cambio Climático (CiiCC), Universidad Santo Tomás, Chile; Member of the OA–ICC advisory board and SOLAS-IMBER WG in Ocean Acidification, SIOA) and Cristian A. Vargas (Universidad de Concepción, Chile; Member of the Executive Scientific Council at GOA-ON and IOCCP).

In addition, the Executive Council includes representatives from each country participating in LAOCA: Rodrigo Kerr (Universidade Federal de Rio Grande (FURG), Brasil), Patricio Manríquez (Centro de Estudios Avanzados en Zonas Aridas (CEAZA), Chile), Patricia Castillo-Briceño (The Escuela Superior Politécnica del Litoral (ESPOL), Ecuador), Alberto Acosta (Universidad de Bogotá Jorge Tadeo Lozano (UTADEO), Colombia), Michelle Graco (Instituto del Mar del Perú (IMARPE), Perú), Alejandro Bianchi (Servicio de Hidrografía Naval (SHN), Argentina) and José Martín Hernández-Ayón (Universidad Autónoma de Baja California (UABC), México).

A first meeting, which will be focused on scientific plans and development of the on-the-ground collaboration scheme during the first year of operation of LOACA was held in early June 2016.

One of early tasks ahead of the LAOCA community, recommended by the IOCCP, is for LAOCA to adopt a complete open data-sharing policy in order for the international community to benefit from IOCCP's efforts to support LAOCA.

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The Global Ocean Ship-based Hydrographic Investigations Panel (GO-SHIP)

The 5<sup>th</sup> Session of the GO-SHIP Committee held in Galway, Ireland, in September 2015 brought about an important change to GO-SHIP's Repeat Hydrography Program. Namely, a criterion of "associated GO-SHIP" section was defined as:

- High quality – some full depth stations below 2000m (at least every 240 nm)
- Repeated on decadal frequency or more often, on GO-SHIP line or not
- Not necessarily coast to coast
- 60 nm resolution minimum
- At least once per decade full Level 1 parameters (see go-ship.org for parameter description)
- Comply with data access policy

Moreover, the GO-SHIP cruise plan was updated (<http://www.go-ship.org/CruisePlans.html>) based on the information provided by national representatives. The map of GO-SHIP sections was also updated accordingly (November 2015). It now includes several proposed "associated GO-SHIP" lines as well as reference sections and high-frequency sections. In 2016, cruises are planned for seven reference sections (A12, A28, I08S, I09N, P09, P15S, SR04) in addition to several high-frequency sections. JCOMMOPS maintains and serves an up-to-date listing of proposed and completed GO-SHIP cruises.

*A Review of the First Decade of GO-SHIP Global Repeat Hydrography*

In a review paper by Talley et al. (2016) scientific outcomes from the first decade of international GO-SHIP Global Repeat Hydrography were reviewed for anthropogenic climate change, ocean temperature change, salinity change, ocean carbon cycle, ocean oxygen and nutrients, ocean chlorofluorocarbons, ocean circulation change, ocean mixing. Preliminary results on the global anthropogenic CO<sub>2</sub> inventory change over the last decade based on the second repeat occupation of reference lines yield an uptake of  $2.6 \pm 0.5$  PgC yr<sup>-1</sup> on average for years 1994-2006.

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### Global Ocean Observing System Biogeochemistry Expert Panel (GOOS BGC Panel)

Leadership in GOOS Biogeochemistry Panel gradually merges with the core IOCCP themes through integration of topics like development of Essential Ocean Variables (EOVs) for biogeochemistry and related technical EOVS Specification Sheets, strategic work on observing system design and development of targets and metrics for the observing system in relation to EOVs. All these become essential part of IOCCP's mission. However, some activities require very wide overview in terms of EOVs, observing networks and observing requirements as well as good working understanding of activities undertaken by GOOS Physics Panel and GOOS Biology and Ecosystem Panel. Such activities were accomplished by calling on expertise from outside the IOCCP SSG (modelling, experts on EOVs currently not "covered" by the SSG, communities of practice around certain observing network or platform and more) and included tasks which traditionally were not included in IOCCP's mission. These tasks are logistically and financially supported by the GOOS Office. One of the key contributions of IOCCP to GOOS activities over the past year has been the Global Climate Observing System (GCOS) 2015 Status Report and 2016 GCOS Implementation Plan.

### *Global Climate Observing System (GCOS) 2015 Status Report and 2016 Implementation Plan*

During the past 12 months the IOCCP significantly contributed to the Status Report on the Global Observing System for Climate (available from <http://www.wmo.int/gcos>). Several IOCCP SSG members took the responsibility to lead individual sections of the Report. IOCCP's input is most significant in sections describing oceanic Essential Climate Variables (ECVs) related to biogeochemistry (nutrients, ocean acidity, carbon dioxide partial pressure, oxygen and tracers) and sections dealing with the observing networks that carry out biogeochemical observations (SOO network, GO-SHIP, biogeochemical floats, mooring arrays and ship-based time series). Additionally, IOCCP made important contributions to an overall ocean observing section introduction and summary.

This Report tries to provide a full account of how well climate is currently being observed in support of IPCC and UNFCCC. It provides a basis for identifying the actions required to reduce gaps in knowledge (expression of which will be published as a GCOS Implementation Plan in 2016), and to assess where progress is being made, and where progress is lacking (progress against 2010 GCOS Implementation Plan is assessed). Since 2012, when the Framework for Ocean Observing identified the need for more integrated marine biogeochemistry observations, IOCCP was asked to lend its expertise and community-wide network to contribute to this multi-domain effort. Past year was when the actual report writing took place and the final product was presented during the COP 21 in Paris in December 2015.

Specific details on individual parameters and networks can be found in the Report but the very general conclusion is that observation of the ocean has progressed substantially through deployment of buoy networks, autonomous sub-surface measurement systems and space-based remote sensing, which complement longer-established and still-essential ship-based programs. It is now taking place under revised arrangements for scientific guidance and advice, provided by GOOS and its three panels, including one for biogeochemistry (led by IOCCP). The last few years have seen rapid development of chemical and bio-optical sensors, with increasing levels of

readiness for deployment on Argo floats, gliders and moorings. Currently 7% of floats are equipped with oxygen sensors and a smaller number of floats measuring nitrate and pH.

Progress in recent years has also been made on data collection and support, for example through establishment of SOCAT and work towards GLODAPv2. Organization of observing activities has taken place through formation of the GOA-ON. The considerable progress made in establishing observational capabilities and systems provides a basis for reconsidering the specification of the related ECVs during preparation of the 2016 Implementation Plan (GCOS 2016 IP).

The GCOS 2016 IP is where the importance of this activity lies for biogeochemistry community. The Implementation Plan will be published in mid- to late 2016 and it is already clear that much stronger emphasis will be placed on marine biogeochemical observations for the system to be able to truly observe climate variability globally. IOCCP has a major role to play there as almost revolutionary progress was made in our observational capacity in terms of marine biogeochemistry, and a strategic utilization of these technological developments needs to be structured and aligned with the rest of global climate observing system.

The writing process has started with the first two writing meetings which took place in Italy in February and May 2016. Toste Tanhua (IOCCP Chair) and Bernadette Sloyan (CSIRO, Hobart, Australia) are leading the ocean part of the GCOS 2016 IP, with support from the OOPC Office and very soon from IOCCP SSG and other biogeochemistry experts. An initial draft of the ocean biogeochemistry part of the 2016 GCOS IP has been circulated amongst the SSG members, with request for input. The GCOS 2016 IP will be published for open community review by the northern hemisphere summer 2016, and for solicited expert review before that.

#### Optimizing and Enhancing the Integrated Atlantic Ocean Observing System – AtlantOS

European Commission funds one IOCCP Project Officer through the Horizon 2020 project AtlantOS. During the last 12 months the new Project Officer was primarily responsible for delivering tasks listed below. Although the tasks have to be initially regionally focused, their scope is by all means global and the idea is to apply newly developed procedures and ideas to the global coordination efforts and vice-versa.

IOCCP has played an active role in AtlantOS over the past year with efforts mainly focused around Task 1.1 “Identification of major scientific and societal challenges that require sustained ocean biogeochemistry variable observations in the Atlantic Ocean region,” and Task 1.2 “Identification of biogeochemical Essential Ocean Variables (EOVs) for the Atlantic Ocean observing system and multidimensional feasibility assessment of the observing system capabilities based on proposed EOVs and available infrastructure.” Much of the progress on Task 1.1. and planning for Task 1.2 was achieved during the WP1 Workshop in Copenhagen in January 2016. The proceedings and outcomes of the first WP1 Workshop are described in detail under the Workshops and Meetings section.

At the end of June 2016, IOCCP will take part in the 2<sup>nd</sup> AtlantOS General Assembly and several associated workshops. Special attention will be given to strengthening the links between societal

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requirements set in WP1 and the specific data requirements for product development set in WP8. Moreover, IOCCP will participate in the discussions on Observing System Simulation Experiments (OSSEs) to be completed within the AtlantOS project time line, contributing with its oversight and coordination experience for the benefit of designing an optimal multidisciplinary observing network in the Atlantic.

## Inter-comparison of global observing capacity for inorganic nutrients in seawater and status report on certified reference materials (CRMs) for inorganic nutrients in seawater

### *Inter-comparison of global observing capacity for inorganic nutrients in seawater*

In 2014, IOCCP and JAMSTEC co-organized an inter-laboratory comparison study of nutrients in seawater using:

- four lots of recently certified RM by KANSO,
- former RMNS produced by KANSO, which has already shown an excellent homogeneity of within 0.2% and long shelf-life of 6 years (Aoyama et al., 2012), and
- three CRMs by National Metrology Institute of Japan, which were certified in March 2014 .

Additionally, the Korean Institute of Standards offered to provide their recently developed RMs to be utilized in the inter-laboratory comparison study and the Royal Netherlands Institute for Sea Research (NIOZ) offered to provide a silicate stock solution to contribute to the overall assessment of results.

Based on that, a set of four samples of CRMs was distributed to all 71 participating laboratories around the globe (28 countries) free of charge, and NMIJ CRMs were sent to the laboratories who agreed to pay for them. Korean RMs were also distributed to laboratories who agreed to analyze them. NIOZ stock solutions were sent to selected laboratories focused on open ocean deep waters which agreed to perform the analysis. Results were received from 58 participating laboratories, which included partial reporting from some laboratories. 24 laboratories reported results from analysis of Korean RMs.

Early analysis of obtained results compared with the results obtained previously (i.e. 2012) makes it clear that the level of internal consistency is high for laboratories participating in both inter-comparison experiments. However, poor inter-laboratory comparability emerged from the same analysis and still significant discrepancies between results from different laboratories exist, at least for some of the participants.

Standard deviations of determinants are one order of magnitude larger than homogeneity of the samples distributed. One major conclusion from this analysis is that the use of CRMs will greatly improve comparability of nutrient data among the laboratories in the world. Another positive conclusion is that although standard deviations are relatively large, median/mean of each sample for all groups showed good agreement with certified values of the samples within their SDs. This implies that majority of the participating laboratories have good capability to measure nutrients concentration in seawater, and using CRMs will further improve the consistency of obtained data of different groups worldwide and will allow for the results to be SI traceable.

Despite the positive outcome of the recent inter-comparison study, there is more progress to be made to ensure comparability of oceanic nutrients data in the world. Therefore, he proposes that IOCCP in collaboration with JAMSTEC will co-organize another inter-comparison study using SCOR-JAMSTEC CRMs. Proposed timeframe would be late 2016 – early 2017 and organizational structure would mimic that employed in the 2014/2015 inter-comparison study.

Based on the report, which will be published in the first half of 2016, it was suggested that participating labs be contacted for feedback on the inter-comparison experiment. Perhaps a short questionnaire should be developed where participating labs could (perhaps anonymously) provide feedback on the usefulness of the exercise, suggest improvements, comment on the logistics etc. IOCCP agreed to support the organization of and contribute financially to the follow-up inter-comparison activity to be performed about 1 year after publication of the report from the 2014 inter-comparison.

There are some issues which IOCCP is concerned about. For example, a rather sudden rise in the number of available CRMs for nutrients might cause confusion amongst users. Also the quality of some materials is not very well verified. There might be more interest in developing CRMs in the future and the community might end up with a whole suite of nationally developed materials and no way to compare them or cross-reference them. A discussion within the COMONUT was proposed and a joint activity between interested organizations might have to be developed in order to ensure consistency and clarity.

#### REFERENCES:

Aoyama, Michio, Ota, Hidekazu, Kimura, Munehito, Kitao, Takashi, Mitsuda, Hitoshi, Murata, Akihiko, Sato, Kenichro, et al. (2012), Current status of homogeneity and stability of the reference materials for nutrients in seawater, *Analytical sciences: the international journal of the Japan Society for Analytical Chemistry* **28** (9): 911-6.

#### *Certified Reference Materials for nutrients in seawater*

The National Meteorology Institute of Japan (NMIJ) started to provide three lots (batches) of nutrients Certified Reference Material (CRM) in March 2014 for nitrate and silicate. NMIJ are currently working on certification of phosphate concentrations. KANSO-produced CRMs were certified for nitrate, nitrite, phosphate and silicate by joint analysis performed simultaneously by JAMSTEC and KANSO and since April 2015 are 100% SI traceable. Seven lots of KANSO-produced CRMs have already been certified. The Korea Institute of Ocean Science and Technology (KIOST) Nutrient Reference Materials for Seawater (KNRMS) were also recently produced and they were evaluated during the 2014/15 inter-comparison experiment. Phosphate and nitrate concentrations in Seawater Certified Reference Materials for Nutrients (MOOS-3) produced by the National Research Council Canada showed lower and unstable values when they were measured during certification process at JAMSTEC and KANSO in 2015.

In April 2016 the SCOR Working Group 147 announced that JAMSTEC will start to provide CRMs with the new SCOR-JAMSTEC logo, with a new cost structure making them more accessible for the global science and research community. These will be available for sale in

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early boreal summer 2016, based on the framework objectives of SCOR WG147.

## Enhancing the coordination of underway surface ocean observations

On a global scale, there is currently no formal coordination of the different groups maintaining CO<sub>2</sub> systems on ships, which means that the current status of this observing network at any given time is estimated. This is in spite of the fact that underway CO<sub>2</sub> observations are to a large extent a monitoring effort and the outcomes it produces support our understanding of long-term climate and ecosystem dynamics. With the vast majority of resources coming from national research funding, the global underway carbon and biogeochemistry observations remain proposal-based and hypothesis-driven, and are thus an effort that is still far from sustained and operational. IOCCP focuses on communication activities for general inquiries, capacity building and developing best practices, operating protocols and data quality procedures.

Currently two documents are being prepared to facilitate underway CO<sub>2</sub> measurements:

- A “pCO<sub>2</sub> system installation guide on ships” led by Tobias Steinhoff (GEOMAR, Germany) and Denis Pierrot (NOAA-AOML, USA) with target delivery date in boreal summer 2016. This document focuses on the considerable challenges of installation on ships and will provide guidance on do's and don'ts when installing. It will both cover installation on research ships and on commercial vessels.
- A “Prospectus for ship's officers and crew, and ship owners” led by Ute Schuster (Uni. Exeter, UK) with target delivery date in boreal summer 2016. This will serve as a "sales brochure" to inform on the reason for installation and overall scope. It will build on the efforts of several individual groups to provide this information in an appealing form to the prospective ships hosting underway systems.

IOCCP maintains the map of the network status with varying success mainly due to limited manpower in the office in previous years. SOCAT effort takes care of data submission, quality control and publication but as these data streams are delayed mode (several months to years) they only give an indication of the status of the network with 12-24 months delay depending on the timeliness of data submission and the SOCAT publishing frequency.

Regionally (European waters), appreciable advances have been made through the Integrated Carbon Observation System, an EU Strategic Research Infrastructure (ICOS-RI), to set up a systematic, sustained and coordinated surface pCO<sub>2</sub>-observing network in the Atlantic with 9 ships of opportunity in operation. There remain differences in nomenclature as ICOS lists them as volunteer observing ship lines (Carbo-VOS lines) instead of the nomenclature used in JCOMM which refers to them as ships of opportunity (SOOP). Dr. Truls Johannessen is leading the ICOS-ocean effort. ICOS names IOCCP as its global partner and IOCCP will continue to work closely with the European community in order to coordinate activities. Furthermore, in January 2016 funding for the ICOS Ocean Thematic Centre (OTC) was approved – the OTC is a joined effort between Norway and the UK, and the ICOS OTC head office is located in Bergen, Norway. This activity will increase European capacity in ocean carbon and biogeochemistry data management and will lead to easier and faster access to quality controlled data by allowing for much more flexibility in staff employment and dedicating funds for infrastructure. Version

tracking, implementation of controlled vocabulary, detailed documentation of quality control, NRT data visualization are just some parts that will become the norm and European developments will effect and feedback to the global marine carbon community. Additional data management personnel will be hired in Bergen and will continue to work towards global data synthesis efforts in our field.

Based on the current lack of formal coordination of the ever-changing existing fleet of SOOP-CO<sub>2</sub>, the IOCCP decided to work with and benefit from the services provided by the WMO-IOC Joint Technical Commission on Oceanography and Marine Meteorology - Observing Platform Support Center (JCOMMOPS). JCOMMOPS provides technical metadata-based coordination at the international level for oceanographic and marine observations for the following global programs and networks:

- The Data Buoy Cooperation Panel (including drifting and moored buoys),
- The Ship Observations Team
  - Ship of Opportunity Program (SOOP) currently coordinating the collection of the upper ocean thermal oceanographic data collected by XBTs, XCTDs and TSGs.
  - ASAP&VOS – coordinating meteorological observations from commercial ships
- Global Sea Level Observing System (GLOSS)
- OceanSITES
- The Argo profiling float program.
- Global Ocean –Ship-based Hydrographic Investigations Panel (GO-SHIP)

Teaming up with the SOOP Implementation Panel and creating additional category: SOOP-CO<sub>2</sub> has been proposed in April 2016 to optimize and harmonize coordination efforts related to surface ocean carbon observations. JCOMMOPS support after initial, to certain extent manual, stock-taking would allow constant, meta-data-based program planning and implementation and more effective operations. Specific benefits include but are not limited to:

- Pre-deployment interdisciplinary planning
- Deployment opportunities and advanced warning for network decreases
- Co-location with other observations under SOOP
- Observational meta-data requirements
- Constant operational status of observing network (e.g. identification of data sparse regions)

Services provided by JCOMMOPS require each participating program to contribute to their staffing cost in proportion equivalent to FTE required by each program. IOCCP would not be able to provide such support and as with other programs using JCOMMOPS' services, the service would have to be supported by national funding agencies from participating countries. IOCCP would actively seek such support via its members and partner organizations.



## WORKSHOPS AND MEETINGS

### Surface Ocean CO<sub>2</sub> Atlas (SOCAT) and Surface Ocean pCO<sub>2</sub> Mapping Intercomparison (SOCOM) Event at the SOLAS Open Science Conference, Kiel, Germany, 7 September 2015

During this event, SOCAT and SOCOM came together to jointly review the past and ongoing activities as well as to discuss the agenda and longer term strategy for future developments within the two projects. From the perspective of SOCAT, this event had the following aims to fulfil:

- Release of SOCAT version 3
- Launch of the SOCAT automation system
- Showcase SOCAT science
- Update the SOCAT community on recent progress
- To welcome new members
- To enable discussion of SOCAT strategy
- To set the SOCAT agenda for the next 24 months.

The goals of the Surface Ocean pCO<sub>2</sub> Mapping Intercomparison (SOCOM) are complementary to those of SOCAT in that SOCOM is a comparison of data-based air-sea CO<sub>2</sub> flux estimates, many of them using SOCAT. Within SOCOM a range of methods are applied for interpolating sparse partial pressure of CO<sub>2</sub> (pCO<sub>2</sub>) data in time and space. Approaches include neural networks, multiple linear regressions and model-based regression with tuning. The methods vary in terms of statistical characteristics, making individual approaches suitable for mapping in specific specific space- and/or time scales. The SOCOM initiative aims to quantify uncertainties and to identify common features in the mapping methods. From the perspective of SOCOM, the aims for this joint event were to:

- Showcase SOCOM science
- Enable discussion on combined work with SOCAT (e.g. within the Global Carbon Project) and improved coordination activities

Fifty-four participants from 18 countries attended the SOCAT and SOCOM Event. Attendees included: data providers, data managers, data quality controllers, data users, SOCOM algorithm developers, and project managers and coordinators. A detailed list of participants and the meeting agenda can be found in the Event's report found on the SOCAT website under the following link:

[http://www.confmanager.com/communities/c2778/files/downloads/SOCAT\\_SOCOM\\_Event.pdf](http://www.confmanager.com/communities/c2778/files/downloads/SOCAT_SOCOM_Event.pdf)

Meeting participants decided that the data submission deadline for SOCAT Version 4 will be January 31 2016 and the QC deadline was set to March 31<sup>st</sup> 2016. SOCAT Version 4 is expected to be released on June 30<sup>th</sup> 2016, and thanks to the automation system, the subsequent versions should be released regularly every summer.

GAIC 2015: "Sustained ocean observing for the next decade" A combined GO-SHIP/Argo/IOCCP conference on physical and biogeochemical measurements of the water column, Galway, Ireland, 14-18 September 2015

A combined GO-SHIP/Argo/IOCCP conference on physical and biogeochemical measurements of the water column was held in Galway, Ireland on 14-18 September 2015. Three IOCCP SSG members and the Project Director were on the Scientific Organizing Committee assuring a balanced input from the biogeochemistry community. More than 150 participants from 18 countries attended the workshop with 85 presenting authors accepted.

The three sponsoring programs for this conference promote and coordinate sustained observations of the water column to reveal the changing physics, chemistry and biology of the ocean. This conference brought together these programs showcasing the existing and upcoming synergies among them. An additional focus of the conference was on the future opportunities presented by rapid sensor development especially in the field of marine biogeochemistry, with technological development of Argo into the realms of Deep and Bio-Argo. Deep and Bio Argo measurements will supplement GO-SHIP and other IOCCP-coordinated observations in new ways. In turn, these new measurements will depend on ship-borne programs for calibration and data quality assurance of the new float data. It was very timely to bring together scientists from the communities that will enact the next phase of this technological evolution.

Studies combining data from these programs will very soon be addressing new research questions and adding value to the individual programs. New technology means there is growing overlap in the research questions that each program can now address. It also presents challenges for how to implement and utilize the ever-increasing volumes of data.

Several so-far informal working groups were initiated or called-upon during the workshop. Formalization of some of those will generate cross-program and cross-platform synergies increasing the efficiency of the global ocean observing system.

GOA-ON Executive Meeting on Data Portal and Synthesis Products, Monaco, Monaco, 19-20 November 2015

The Executive Council of the [Global Ocean Acidification Observing Network \(GOA-ON\)](#) met at the IAEA Environment Laboratories in Monaco, 19-20 November, to discuss the development of ocean acidification data portal and data synthesis products. Three members of the IOCCP SSG and the Project Director are members of the GOA-ON EC.

Discussions related to ocean acidification data portal were based on an earlier meeting (1-2 June 2015) held in Monaco's IAEA labs. This two-expert meeting explored possibilities to create a joint portal for access to global ocean acidification data within the framework GOA-ON. Invited experts discussed the way forward to (1) extend and update the current GOA-ON inventory and (2) propose a web portal interface for ocean acidification metadata retrieval. The group discussed the advantages and shortcomings of existing data portal systems, the use of common controlled vocabularies, useful search filters, metadata standards and interoperability between different data

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providers. The longer-term goal of creating a one-stop portal to ocean acidification data with adequate search facilities was also discussed.

With the above developments in mind the GOA-ON Executive Council agreed on developing a central site for products of the variability in ocean acidification (primarily carbonate mineral saturation states and pH) across a range of temporal and spatial scales, including: (i) decadal trends in pH and aragonite saturation state from long-term time series sites, (ii) seasonal changes in pH and aragonite saturation state at the growing number of observing sites in recent years (moored and ship-based time series), and (iii) global distributions focused initially on aragonite saturation state of the kind produced by [Jiang et al \(2015\)](#).

The Executive Council also discussed planning of the [Third GOA-ON Science Workshop](#) held in Hobart, Australia, 8-10 May 2016. The workshop was planned in conjunction with the [Fourth Symposium on the Ocean in a High CO<sub>2</sub> World](#) in Hobart. The two meetings posed a significant opportunity to bring together the international community to further the development of regional collaborations, data products, and closer integration of key biological and ecological variables into GOA-ON.

## REFERENCES:

Jiang, R.A., Feely, B.R., Carter, D.J., Greeley, D.K., Gledhill, K.M., Arzayus (2015), Climatological distribution of aragonite saturation state in the global oceans, *Global Biogeochemical Cycles* **29** (10), pp. 1656–1673, doi: 10.1002/2015GB005198.

### Planning of global Biogeochemical Argo network, Villefranche-sur-Mer, France, 11-13 January 2016

“Planning a global BioGeoChemical-Argo network” meeting, organized by Hervé. Claustre (LOV, France) and Ken Johnson (MBARI, USA) was held on January 11-13, 2016, in Villefranche-sur-Mer, France. 30 persons, including Argo/BGC-float experts, ocean biogeochemists, modelers etc. from 9 countries attended the meeting. IOCCP was represented by Masao Ishii.

The goal for the meeting was to create a Science and Implementation plan for a global BGC float array. The Plan (to be open for public consultation in mid-2016) will include:

- Major science questions revolving around ocean carbon cycle, ocean carbon uptake, ocean acidification, ocean deoxygenation and ecosystem processes.
- Major societal applications such as carbon treaty verification, ecosystem modeling and link to management.
- Formalization, to the extent necessary and possible, of the relationship with other major programs such as GO-SHIP, IOCCP, Satellite Ocean Color and more.
- Conceptualization of the required system design for an array size, sensor array needed to meet the mission, integration with models, international structure for operations, implementation strategy allowing to build the array, plan for global capacity building to

- deal with BGC sensors data.
- Reliable estimates of cost

EU Horizon 2020 AtlantOS Project WP1 Workshop, Copenhagen, Denmark, 14-15 January 2016

On January 14-15<sup>th</sup> 2016, leaders of AtlantOS Work Package 1 (WP1): [Observing system requirements and design studies](#), met at the headquarters of the [International Council for the Exploration of the Sea \(ICES\)](#) in Copenhagen, Denmark, to discuss progress on the outstanding tasks laid out in front of WP1 for the initial phase of the project.

For 11 participants from several institutions from around the Atlantic, including two from IOCCP Project Office, the first task was to agree on the requirements for sustained ocean observations of the Atlantic. Major societal drivers of sustained ocean observing in the Atlantic basin were identified, together with the major Atlantic phenomena that are required to be monitored to achieve these societal goals. It was agreed that requirements for sustained ocean observations are to be described through the concept of Essential Ocean Variables (EOVs), expressed separately for the physical, biological and biogeochemical realms. Among other things, IOCCP is providing specifications of biogeochemical EOVs and the associated observing elements operating in the Atlantic.

On the second day of the meeting, the focus was shifted to the other task at hand, namely planning the analysis of the capacities and gaps of the present Atlantic Ocean Observing System. Here IOCCP is taking the lead on identifying the critical gaps that need to be filled on the level of biogeochemical observations.

As a direct outcome of the workshop, members of WP1 produced a deliverable report on the initial description from ongoing work of the societal imperatives for sustained Atlantic Ocean observations, the phenomena to observe, EOVs, and contributing observing networks; as guidance for other WPs within the AtlantOS project.

Measurement of  $p\text{CO}_2$  on ships of opportunity (SOOP- $\text{CO}_2$ ) operations meeting, Miami, Florida, USA, 21-22 January 2016

The establishment of a coordinated global surface  $\text{CO}_2$  observing system including ships of opportunity (SOOP) is challenging as the operation of the sophisticated instruments and data reduction is personnel intensive, and requires high levels of skill. Rather than having a single entity maintaining the systems, the *ad hoc* network is comprised of many investigators. To facilitate information exchange and facilitate best practices the NOAA sponsored SOOP- $\text{CO}_2$  consortium held an operations meeting in Miami FL in January 2016. The IOCCP was represented by Rik Wanninkhof. The exchange was deemed very worthwhile with a consensus that these meeting should be held biennial and be inclusive to all operators of underway  $p\text{CO}_2$  systems. The IOCCP agreed to support this workshop in the future to allow for global participation

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The SOOP-CO<sub>2</sub> operations meeting was focused on training in system hardware and software, and data reduction procedures of the underway *p*CO<sub>2</sub> systems. The venue also served for information exchange between the different groups that ended up taking center stage with fruitful discussion of intricacies of operations, issues encountered and "tricks of the trade".

A series of action items were suggested that will be addressed in the coming year and shared with the community at large to improve interoperability and consistency in operations, servicing and quality control.

- Conformity of analyses
  - Decide whether to use time and location at the point the water enters the ship or time of equilibration when reporting data
  - Formalize standard ranges of reference standards that will be used
  - Use same analysis sequence
  - Document routine maintenance and replacement schedules
  - Set protocol for air sampling and air QC
- Improve documentation of procedures
  - Document procedures for checking and QCing sea surface temperature and sea surface salinity
  - Produce a video of startup procedures
  - Produce video on use of data reduction software
  - Complete installation manual
- Increase communication and recommendations with the manufacturer of systems
  - Advise the manufacturers on hardware modification (e.g. ability to adapt cable and tubing runs into dry box by installing mounting plates)
  - Go over the FAQ list on manufacturers websites, and suggest additions and corrections
  - Improve understanding of issues and expectations that operators have
- Establish routine, fixed interval servicing and replacement of components:
  - Replacing internal and external desiccant (magnesium perchlorate) and CO<sub>2</sub> scrubber Malcosorb® [sodium/calcium hydroxide] in the IR analyzers
  - Replacing Nafion® drying tubes
  - Replacing Acrodisc® filters
  - Replacing or cleaning and drying Airline
  - Cleaning underway water line.
- Work with IOCCP to have a follow-up meeting including the global community

The workshop was the first formal interaction of the system operators and was deemed highly effective in exchanging knowledge and forging a common path ahead. It was recommended to have the meetings (at least) biennial and inviting all groups involved in SOOP-CO<sub>2</sub> measurements, possibly seeking travel funds from the NOAA program office and IOCCP. Other means of exchanges on operating issues and lessons learned were encouraged such as establishing a message board/blog post to share common issues in operation.

GOOS Biology and Ecosystem Panel Meeting, New Orleans, LA, USA, 20 February 2016

The IOCCP was invited to join the GOOS Biology and Ecosystem Panel meeting in order to strengthen the coordination between the two disciplinary communities. Over the past 3 years the GOOS Bio/Eco Panel has made an outstanding progress in coordinating the relevant community in order to include their observing and monitoring strategies into the implementation of the Framework for Ocean Observing and GOOS in general. Several presentations and discussion sessions allowed the attendees to grasp the whole suite of efforts the Panel had been able to accomplish in the previous 12 months. Specific actions related to IOCCP:

- The BioEco Panel asked for more communication and coordination across panels, including sharing of how support had been built for panel activities.
- The BioEco Panel asked for more monitoring of whether the panel and secretariat work was meeting the wider goals of GOOS integration amongst the three disciplines

The question of how human pressure variables would be coordinated within the FOO efforts was raised, and the BioEco Panel asked to propose a concept approach to the GOOS Steering Committee at the next meeting in Sopot, Poland in June 2016.

2<sup>nd</sup> Meeting of the Global Ocean Observing System Steering Committee Executive (GOOS Exec), New Orleans, LA, USA, 21 February 2016

The IOCCP SSG Chair and the Project Office Director are members of the GOOS Exec. The meeting agenda focused on deliverables for the upcoming GOOS Steering Committee meeting in Sopot, Poland in June 2016. Draft GOOS Implementation Plan for the next 3 years (OceanObs'19 perspective) was assessed as was its already accomplished part for years 2014-2016. The following are the major points discussed:

- Status of the Framework for Ocean Observing (FOO) processes including EOV definitions and the GOOS Strategic Mapping
- GOOS Structures and Functions
- The Exec identified the following major functions of the GOOS program that should be captured in a new structure:
  - Governance/oversight
    - SC
    - 3 Panels (IOCCP leads one of them)
    - GOOS Regional Council
  - Implementation
    - JCOMM Observations Coordination Group, JCOMMOPS
    - Observing elements: networks
    - GRAs
    - IOCCP, Biology and Ecosystem Panel
  - Innovation
    - Projects
    - But really all GOOS structures
  - Capacity Development
    - Through GRAs

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2016 Ocean Sciences Conference, New Orleans, LA, USA, 21-26 February 2016.

During the Ocean Science Meeting in New Orleans in February, IOCCP co-organized two Town Hall meetings with the aim of informing the community of recent developments and to get community input. One of the town-hall meetings were on the Global Ocean Ship-based Hydrographic Investigations program (GO-SHIP) where Bernadette Sloyan (GO-SHIP co-chair) informed about recent developments, including the possibility to participate in the GO-SHIP program on shorter lines that are repeated at high frequency but without full depth or full suite of level-1 variables; such cruises are now welcome to join the GO-SHIP community as either associate GO-SHIP lines, or High Frequency GO-SHIP, details of which can be found on the GO-SHIP website, <http://www.go-ship.org/Documents.html>.

During another town-hall meeting, the GOOS panels; i.e. the physics panel (OOPC), the Biogeochemistry panel (led by IOCCP) and the biology / ecosystems panel, presented work performed during the last couple of years aiming at defining and agreeing on a set of Essential Ocean Variables (EOVs). Particularly the new bio/eco panel had a lot of new research in that field to report on with an initial first take on some key EOVs for that panel. The town-hall was reasonable well attended and valuable input from the community was received by the panels. This will be valuable for the future development of the EOV concept, that is generally well accepted by the ocean community, at least that is my impression, although it is also clear that the increasing complexity of observing the ocean from physics to biogeochemistry to bio/eco is reflected in the complexity of how to define an EOV. This is a very active field of research for the GOOS panels, in which IOCCP is playing a leading role for biogeochemistry.

The latest versions of the biogeochemical EOVs can be found at the IOCCP website; <http://www.ioccp.org/index.php/foo>. Note that these are still being modified, mainly for consistency between EOV specifications across EOVs and panels. We are, as always, interested in getting feedback on the work EOVs; if you have any comments please contact the IOCCP.

GCOS Science Conference: The Road to the Future, Amsterdam, the Netherlands, 2-4 March 2016

To further the development of a comprehensive GCOS IP 2016 and leading up to the second writing team meeting that took place later in May 2016, an open science conference was held in Amsterdam in early March 2016 where input from the climate observation community feed into the writing process. The agenda, with downloadable presentations, is available here: <http://www.gcos-science.org/pg/programmedetails.aspx>.

The IOCCP was presented by Toste Tanhua that gave a presentation on “A New Look at the Ocean Biogeochemistry ECVs”. In addition, all the talks were streamed live and these talks are available for download or viewing here: <http://www.gcos-science.org/livestream/Videostreams.aspx>. There were also a number of talks focused on various aspects of climate observations in the ocean and, obviously, on all kind of climate observation themes.



The 7<sup>th</sup> Session of the WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM)'s Observation Coordination Group (OCG), Esporles, Spain, 4-6 April 2016

The 7<sup>th</sup> session of the JCOMM OCG provided an opportunity for representatives of various observing networks (Argo, Ocean SITES, GLOSS, Gliders, GO-SHIP, SOOP) to interact, provide updates and cross-fertilize amongst the programs. An overriding focus of the meeting was the continued interaction and integration of JCOMM with the GOOS framework with updates on essential ocean variables and network specification sheets along with a performance tracking system using key performance indicators (KPI). Of particular note were the favorable developments in the glider and OceanSITES networks towards improved coordination, infrastructure, and metadata reporting.

The venue in Majorca hosted by the Mediterranean Institute for Advanced Studies, IMEDEA was a good backdrop for the discussions of the GRAs (GOOS Regional Alliances) that have a coastal focus. Investigators from IMEDEA provided presentations on their effort around the Balearic islands including outreach activities geared to the local island populations. They contribute to the Balearic Islands Coastal Observing and Forecasting System SBIC which is an integrated, distributed, cross-platform system which supplies a flow of ocean data, numerical simulation services and new technology to support operational oceanography within the European and International framework, contributing to the marine and coastal research needs in the context of global change. Its web presence is through "the Mediterranean in one click" medcliv ([www.medcliv.es/en/](http://www.medcliv.es/en/)). The presentations highlighted the unique utility of gliders and HF radar observation in the coastal zones.

Of particular interest to the ocean carbon and biogeochemistry community were the discussions on the new global climate observing system (GCOS) implementation plan that will include a focus on ocean biogeochemistry and ecosystems. A proposal was put forward to include surface CO<sub>2</sub> observations from ships as part of the JCOMM ship observations team (SOT) to facilitate tracking, closer global collaborations, and network design. The work of the SOT involves voluntary observing ships that perform meteorological observations and ships of opportunity focused on surface observations. In subsequent discussions some of the challenges currently encountered in SOT were brought up and the overall recommendation was to look at the overall structure of the SOT and for the SOT group to make recommendations on improvements to the OCG at its next scheduled teleconference. As part of the recommendations Martin Kramp of the JCOMMOPS office will be distributing a questionnaire to the SOT community on current protocols and needs.

A proposal was put forth by the Regional Marine instrument center RMIC at the South China Sea Environmental Monitoring Center (SCSEMC) to create an inorganic nutrient standard and perform an intercomparison exercise following their intercomparison of salinity measurements ([http://www.jcomm.info/index.php?option=com\\_content&view=article&id=326](http://www.jcomm.info/index.php?option=com_content&view=article&id=326)). A discussion ensued regarding the lack of information exchange and discussion between the RMIC and similar intercomparison studies supported by the IOCCP and other entities. A recommendation was made for the RMIC and IOCCP to discuss possible collaborations and avoid redundancy for these critical but costly efforts.



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As IOCCP biogeochemical interests intersect many of the program areas of JCOMMOPS continued coordination and exchange with JCOMM through the OCG is imperative and the OCG facilitates and encourages these interactions.

## EGU General Assembly, Vienna, 17-22 April 2016

In the Session EOS21 “Geoscience for Society: Collaborative research management and Communications Strategy”, the IOCCP Office Director Maciej Telszewski presented a talk entitled: “Global Ocean Carbon and Biogeochemistry Coordination.”

The aim was to update IOCCP’s partners across disciplines and domains on the program’s short- and long-term strategies as well as learn from their combined experience and knowledge so that individual activities align more with those undertaken by our counterparts in biological and physical oceanography as well as in terrestrial and atmospheric domains. Project managers (mostly European) of 18 projects of various funding schemes, sizes and thematic compositions were involved in this first project management session ever at EGU.

AtlantOS Project Manager was amongst the presenters which allowed for informal discussions related to execution of the first reporting period coming very soon for AtlantOS partners. Also an informal working meeting of task 6.4 of AtlantOS was organized and significant progress was made towards finalizing the deliverables for the first reporting period. Finally, a meeting-organizing meeting for the *Promoting Implementation of Multi-Disciplinary Sustained Ocean Observations* meeting planned for February 2017 in Miami, took place where the agenda was drafted for distribution to a wider committee.

## 3<sup>rd</sup> GOA-ON Science Workshop, Hobart, Australia, 8-10 May 2016

The third science workshop for the Global Ocean Acidification Observing Network (GOA-ON) was held following the 4th International Symposium on the Ocean in a High-CO<sub>2</sub> World. 135 participants from 37 countries spent three days furthering the development and implementation of an integrated network for the detection and attribution of ocean acidification and ecosystem response. IOCCP co-sponsored and was actively involved in the organization of the workshop on all levels from logistics to agenda development to running of the meeting.

The observational and modelling needs that are required in order to distinguish between natural and anthropogenic variability were discussed. The parameters required for the detection of the chemical signals of ocean acidification were defined at previous GOA-ON science workshops, however designing the biological component of a global observing system proved far more difficult. Key biological variables, and the theoretical framework linking physical –chemical changes to biological responses were introduced, along with input from the GOOS Biology and Ecosystems Panel and the GOOS Biogeochemical Panel. Breakout groups, based on specific environments discussed and recommended components of a biological monitoring system that is practical, but would meet the GOA-ON detection and attribution goals.

Extending the monitoring capacity to regions that are currently under-represented is a major challenge, specifically in coastal regions. Through plenary presentations and break-out

discussions the organizers attempted at identifying the regional needs for ocean acidification information products, particularly for policy makers in Africa, large areas of Asia, and South America. Participants discussed the existing observing efforts within geographic regions, in the context of the science, societal and policy needs of each region. The formation of regional hubs for the ongoing coordination of effort was encouraged, using the Latin American Network (LAOCA) as a case study. Technical groupings (e.g. specific instruments) and ecosystem groupings (e.g. coral reefs) were also discussed. These hubs could provide regional coordination, sharing of resources and expertise, and capacity building opportunities.

The GOA-ON Pier2Peer mentoring programme was launched. Participants signed up as either mentors or mentees and were matched so as to form a global collaborative network for sharing expertise and experience. Such sharing consists of consultation over scientific questions or techniques, discussion of experiment/study design, sharing of relevant scientific articles and opportunities.

More information is available from the GOA-ON website <http://www.goa-on.org/> and on the Workshop-dedicated page at <http://www.goa-on.org/3rdWorkshop/>

## PROJECT OFFICE

### IOCCP Scientific Steering Group Meeting

The Eleventh IOCCP Scientific Steering Group meeting was held on 20 February 2016 in parallel with the Ocean Sciences Conference in New Orleans, LA, USA. Toste Tanhua (Chair) was joined by eight members of the SSG, the Project Director and one guest representing IOC-UNESCO and GOOS. Two SSG members could not attend the meeting. Two of the new SSG members, Douglas Connelly and Björn Fiedler, were welcomed and introduced to the SSG. The Chair provided a brief overview of the many on-going activities that IOCCP was engaged in over the previous 10 months since the Tenth Session. He mentioned the SSG Quarterly Virtual Meetings (teleconferences) as important tool for the members to coordinate activities in short term and hinted that in-person meetings should concentrate primarily on long term planning and developing/shaping the long term strategy for the community. The rest of the meeting focused on presentations and discussions divided according to different themes of IOCCP activity, as well as the project office business.

Full meeting report with specific action items is published and available for download as PDF from the IOCCP website at:

[http://www.ioccp.org/images/D3meetingReports/IOCCP%20SSG%2011th%20Session%20Report\\_Final.pdf](http://www.ioccp.org/images/D3meetingReports/IOCCP%20SSG%2011th%20Session%20Report_Final.pdf)

### Employment of IOCCP Project Officer

After three years of fundraising efforts, and thanks to funding from the EU Horizon2020 AtlantOS Project, the IOCCP was able to employ a Project Officer. The position was announced in August 2015 and within a month of application period a large number of outstanding

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applications was received. The final decision was made in early October 2015 and Dr Artur Palacz has been appointed effective 1 January 2016.

Artur holds a B.Sc. in Geosciences & Astrophysics from Jacobs University in Bremen, Germany (2006) and a Ph.D. in Oceanography from the University of Maine in Orono, Maine, USA (2011). He took advantage of this transdisciplinary education to explore innovative approaches to combining multi-platform ocean observations with ecosystem model results while contributing to numerous national and international, regional and global projects. His scientific interests and contributions range from cold-water coral biology and trace metal biogeochemistry, through ecosystem modeling, to the development of decision-support tools for marine resource management. As an oceanographer he gained a broad perspective on a critical issue of data collection and synthesis, which often hinders the development of reliable biogeochemical and ecosystem model projections needed to provide scientific advice to local, regional and global ocean management – a perspective lacking so far from the IOCCP Project Office.

In his most recent employment as a researcher at the National Institute of Aquatic Resources, Technical University of Denmark (DTU-Aqua), Copenhagen, Denmark (2012-2015), Artur gained experience in coordinating international and cross-sector data synthesis efforts (EU VECTORS project) or designing decision-support tools (EU EURO-BASIN project for the North Atlantic). He has also been providing scientific advice to three working groups of the International Council for the Exploration of the Sea (ICES).

Very broadly, at IOCCP Artur will contribute to the mission of coordination and communication services for carbon and biogeochemistry observing community.

Below you can find Artur's contact details:

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## Rotations of SSG members

The following members rotated off at the end of 2015:

- Laura Lorenzoni (Time Series Efforts)
- *Decided to step down at the beginning of the second term due to over-commitment and change in employment status.*
- Todd Martz (Instruments and Sensors)
- *Decided to step down at the beginning of the second term due to over-commitment.*

The following colleagues accepted our invitation and joined the SSG in January 2016:

- Dr Björn Fiedler (Kiel, Germany) assumed responsibilities related to Time Series Efforts.
- Dr Douglas Patrick Connelly (Southampton, UK) assumed responsibilities related to Instruments and Sensors.
- Dr Cristian A. Vargas (Concepcion, Chile) to strengthen IOCCP's coordination in Latin and South America through Ocean Acidification – related activities.
- Dr Siv Kari Lauvset (Bergen, Norway) to strengthen IOCCP's coordination in Ocean Interior Synthesis Activities allowing for an overlap with Are Olsen who will rotate off at the end of 2016.

#### IOCCP website and newsletter

The IOCCP will in the next few months put emphasis on updating the dedicated thematic pages on IOCCP website. Individual teleconferences will be scheduled with respective SSG members to discuss and update the relevant page on the IOCCP website including careful analysis of existing and missing content as well as connections to resources available elsewhere. The standards and methods page will also be carefully reviewed and updated.

Moreover, IOCCP has returned to producing material for its 4 quarterly newsletters a year. The IOCCP office will try to introduce a couple of thematic series in IOCCP Conveyor and one will include an overview of a selected IOCCP theme. A new section introducing the profiles of new SSG members will also be included.

## PUBLICATIONS

Following is the list of IOCCP publications, with IOCCP SSG members marked in blue:

- Global Ocean Biogeochemistry Data Management IOCCP Position Paper
- Olsen, A., R.M. Key, S. van Heuven, S.K. Lauvset, A. Velo, X. Lin, C. Schirnack, A. Kozyr, T. Tanhua, M. Hoppema, S. Jutterström, R. Steinfeldt, E. Jeansson, M. Ishii, F.F. Pérez & T. Suzuki: An internally consistent data product for the world ocean: the Global Ocean Data Analysis Project, version 2 (GLODAPv2), Earth System Science Data Discussions, doi:10.5194/essd-2015-42, in review, 2016
- Lauvset, S.K., R.M. Key, A. Olsen, S. van Heuven, A. Velo, X. Lin, C. Schirnack, A. Kozyr, T. Tanhua, M. Hoppema, S. Jutterström, R. Steinfeldt, E. Jeansson, M. Ishii, F.F. Pérez, T. Suzuki & S. Watelet: A new global interior ocean mapped climatology: the 1°x1° GLODAP version 2, Earth System Science Data Discussions, doi:10.5194/essd-2015-43, in review, 2016
- Key, R.M, A. Olsen, S. van Heuven, S.K. Lauvset, A. Velo, X. Lin, C. Schirnack, A. Kozyr, T. Tanhua, M. Hoppema, S. Jutterström, R. Steinfeldt, E. Jeansson, M. Ishii, F.F. Perez, and T. Suzuki, 2015, Global Ocean Data Analysis Project, version 2 (GLODAPv2), ORNL/CDIAC-162, NDP-093, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee, US.
- Talley, L.D., R.A. Feely, B.M. Sloyan, R. Wanninkhof, M.O. Baringer, J.L. Bullister, C.A. Carlson, S.C. Doney, R.A. Fine, E. Firing, N. Gruber, D.A. Hansell, M. Ishii, G.C.

Johnson, K. Katsumata, R.M. Key, M. Kramp, C. Langdon, A.M. Macdonald, J.T. Mathis, E.L. McDonagh, S. Mecking, F.J. Millero, C.W. Mordy, T. Nakano, C.L. Sabine, W.M. Smethie, J.H. Swift, T. Tanhua, A.M. Thurnherr, M.J. Warner, and J.-Z. Zhang, 2016, Change in Ocean Heat, Carbon Content, and Ventilation: A Review of the First Decade of GO-SHIP Global Repeat Hydrography, *Annual Review of Marine Science*, 8: 185-215, doi: 10.1146/annurev-marine-052915-100829.

- Bakker, D.C.E., Pfeil, B., Landa, C.S., Metzl, N., O'Brien, K.M., Olsen, A., Smith, K., Cosca, C., Harasawa, S., Jones, S.D., Nakaoka, S., Nojiri, Y., Schuster, U., Steinhoff, T., Sweeney, C., Takahashi, T., Tilbrook, B., Wada, C., Wanninkhof, R., Alin, S.R., Balestrini, C. F., Barbero, L., Bates, N. R., Bianchi, A. A., Bonou, F., Boutin, J., Bozec, Y., Burger, E.F., Cai, W.-J., Castle, R.D., Chen, L., Chierici, M., Currie, K., Evans, W., Featherstone, C., Feely, R.A., Fransson, A., Goyet, C., Greenwood, N., Gregor, L., Hankin, S., Hardman-Mountford, N.J., Harlay, J., Hauck, J., Hoppema, M., Humphreys, M.P., Hunt, C.W., Huss, B., Ibáñez, J.S.P., Johannessen, T., Keeling, R., Kitidis, V., Körtzinger, A., Kozyr, A., Krasakopoulou, E., Kuwata, A., Landschützer, P., Lauvset, S.K., Lefèvre, N., Lo Monaco, C., Manke, A., Mathis, J.T., Merlivat, L., Millero, F.J., Monteiro, P.M.S., Munro, D.R., Murata, A., Newberger, T., Omar, A.M., Ono, T., Paterson, K., Pearce, D., Pierrot, D., Robbins, L.L., Saito, S., Salisbury, J., Schlitzer, R., Schneider, B., Schweitzer, R., Sieger, R., Skjelvan, I., Sullivan, K.F., Sutherland, S.C., Sutton, A.J., Tadokoro, K., Telszewski, M., Tuma, M., Van Heuven, S.M.A.C., Vandemark, D., Ward, B., Watson, A.J., and Xu, S. (2016), A multi-decade record of high quality  $f\text{CO}_2$  data in version 3 of the Surface Ocean  $\text{CO}_2$  Atlas (SOCAT), *Under review in Earth System Science Data Discussions*, 55 pp. doi:10.5194/essd-2016-15.

## FUTURE DIRECTIONS

IOCCP will execute specific actions developed during the Eleventh Session of the Scientific Steering Group (20 February 2016, New Orleans, LA, USA). In addition, more general actions will be taken to meet new challenges dictated by changing needs of marine biogeochemistry community. During the course of the next year IOCCP priorities will include:

### Underway $\text{CO}_2$ observations

Next steps in the process of SOOP- $\text{CO}_2$  fleet coordination utilizing JCOMMOPS will be undertaken. Up to now, Rik Wanninkhof and Maciej Telszewski attended the JCOMM Observation Coordination Group meeting and outlined IOCCP's proposal. In the next step, an initial implementation strategy for SOOP- $\text{CO}_2$  joining JCOMMOPS will be drafted.

IOCCP will coordinate the efforts to write and make publicly available the surface ocean underway data-reduction software developed and improved by Dennis Pierrot, as described in the outcomes of the NOAA operations workshop held in Miami (FL, USA) in January 2016.

Finally, two more ongoing activities will continue over the next months in support of better coordination of underway  $\text{CO}_2$  observations. First, IOCCP will support the development of auto-sampling technology and best practices (for auxiliary measurements) as well as sample

preservation strategies for the underway system. Second, IOCCP will support the developments (i.e. an inter-comparison experiment, and a workshop) leading to higher quality atmospheric observations from SOOP-CO<sub>2</sub> which would be highly relevant to the atmospheric community.

#### Data Synthesis Activities: Surface Ocean

The IOCCP SSG decided that promoting recognition of SOCAT and GLODAP as global infrastructure for both surface and interior observations is of very high importance. It is an optimal way for national funding agencies to be able to contribute to these efforts at a global, long-term level. It has been suggested that a small meeting should be organized focused on promoting SOCAT and GLODAP as global infrastructure. Funding agencies representatives should be included and SOCAT Implementation Plan (technical and science-related) should be developed in order to aid fund-raising initiatives.

Therefore, future plans for IOCCP under this theme will be centred around two actions:

- To co-organize and co-sponsor the SOCATv4 release event/workshop by late 2016.
- To coordinate with SOCAT and GLODAP teams to develop an Implementation Plan for both activities.

#### Ocean Interior Observations

Future work under the Ocean Interior Observations theme will be focused on establishing a closer coordination and communication with the Biogeochemical Argo network. Draft of "The Rationale, Design and Implementation Plan for Biogeochemical-Argo" is currently under review. It will be sent to the Argo Steering Team in June 2016 for comments and will go out to the ocean science community for consultation soon after.

#### Data Synthesis Activities: Ocean Interior

One of the key future actions for IOCCP with regard to the interior ocean synthesis efforts should be to support the transition towards regular releases of the GLODAP updates. IOCCP has decided to support the establishment of a GLODAP International Reference Group (IRG). The composition and terms of reference for such group are to be established but general mandate of this group will be to: (i) ensure that data are submitted to GLODAP; (ii) carry out secondary QC and (iii) vouch adjustments that are recommended following the secondary QC.

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Therefore, the main future work planned under this theme is to coordinate and support the activities of soon-to-be-formed GLODAP International Reference Group. Initial tasks are composition and terms of reference for this group.

At the same time, IOCCP will continue to facilitate activities increasing ocean interior data consistency and improved data quality, in collaboration with Steven van Heuven (NIOZ, Netherlands).

## Time Series Efforts

An ongoing task that will continue over the next several months is to collate, and process for basic visualization, metadata information about biogeochemical (based on BGC EOVs) time-series measurements done across programs and projects. This action was instigated after IOCCP had been approached by the OceanSITES with a request to suggest location(s) of potential new sites globally in relation to the existing network and scientific and societal needs for time series observations. IOCCP's response was based on brief analysis of existing OceanSITES locations with biogeochemistry observations and initial and regionally limited gap analysis performed by Henson et al 2016. The former proved to be very difficult and un-earthed rather surprising lack of knowledge even within OceanSITES technical team about types of measurements taken at particular sites, details of data flow and other aspects crucial for informed and efficient observing system design. The latter, even though very informative in terms of the approach, proved to be limited in scope and not adequate to provide global, multi-platform based analysis. This state of knowledge thus requires an assessment of time series observing biogeochemical EOVs with regards to enhancing the global observing system design.

The vision for IOCCP's future work under the Time Series Efforts theme could be divided into three tasks, each of which could take a different approach varying from a white paper, through organizing a relevant survey, to organizing a focused workshop or a science meeting, to multi-year community-driven data-related effort. Suggestions for the following three actions were proposed at IOCCP SSG 11<sup>th</sup> Session:

- Creating a 10-year strategy for future ocean time series observatories by strengthening the connection between time-series science and socio-economic aspects and including the use of novel cost-effective technologies, In collaboration with major related programs and projects. This task could be presented as a white paper submitted for the next OceanObs Conference (to be held in 2019).
- Co-organizing (jointly with the instruments and sensors panel) next edition(s) of the IOCCP Sensor Summer Course (held in summer 2015) within the context of time-series observations, educating the next generation of operators fluent in autonomous sensors technology operations and maintenance
- Working towards a time-series data synthesis product (similar to or combined with SOCAT and/or GLODAP).

The three activities need further discussions and coordination and were proposed by the IOCCP SGG to become action items with the initial emphasis on developing a deeper description of rationale, targets and outcomes as well as a timeline and budgetary requirements.

Furthermore, a gap in the time-series related capacity building in Africa has been identified and it has been suggested that IOCCP together with its relevant partners (SCOR, IOC-UNESCO, US OCB, OA-ICC (of IAEA), IGMETS, GOA-ON) is perfectly placed to develop and implement a suitable strategy to help mitigate this problem. A striking lack of observations along most of the African coast emerges from an analysis of the metadata compilation of global ship-based time series stations assembled for the Bermuda workshop in 2013. Two reasons might cause this deficit: A lack of observational as well as knowledge capacity and an insufficient integration of the African scientific community with the international time-series community. Synergies with the GOA-ON initiative as well as with POGO could be used to better integrate this region into international ocean carbon research. The form, extent and specific targets of proposed capacity building in Africa will have to be considered with relevant partners (GOA-ON, IGMETS, GOOS) and discussed in more detail amongst the IOCCP SSG during one of the quarterly teleconferences. As an immediate action, IOCCP will investigate how it could complement existing capacity building activities in Africa aimed at increasing the observational coverage around the continent.

#### REFERENCES:

Henson, S., A. C. Beaulieu and R. Lampit (2016). Observing climate change trends in ocean biogeochemistry: when and where, *Global Change Biology*, **22**: 1561–1571, doi: 10.1111/gcb.13152.

#### Ocean Acidification

IOCCP's near future work under the Ocean Acidification theme will be centered around GOA-ON as well as capacity building activities in Latin America. For GOA-ON, IOCCP will continue to support the efforts related to the creation of the OA data portal and OA synthesis products. Both, the data portal and a set of synthesis products should be connected to existing activities like SOCAT and GLODAP. IOCCP and GOOS data management teams should be involved to avoid duplication and allow future convergence of existing data products for marine biogeochemistry regardless of the EOV covered or main platform used. In order to better tailor the OA synthesis products, further clarification of the target user groups is required. Currently, it is anticipated that these products will have numerous user groups (scientific, policy making, local management, local industry) and that the information should be available in "layers" depending on the intended use.

As far as IOCCP's role in OA capacity building is concerned, IOCCP was approached by the LAOCA community with a request to help organize and fund a small, focused workshop for leading PI's in Latin American community concentrating on specific, hands-on activities such as: sensor calibration, data sharing, manual and autonomous measurements methodology and best practice. Initial discussions within LAOCA indicate that about 15 participants would be interested in attending such a workshop and they are keen to have it organized in late 2016, in Mexico (location dictated by the fact that the group there owns several instruments and sensors critical for running an efficient hands-on workshop).

The obvious need for building stronger capacity in the region was confirmed and IOCCP has an important role to play there. An alternative to the workshop which could be more efficient is a



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few “placements” in more developed labs. More specific description of the workshop has been requested and discussions on how to establish the most efficient modus operandi are ongoing. Regardless, IOCCP will engage in closer work with and support for the Latin American community.

In conclusion, IOCCP will in the near future work closely with GOOS, OA-ICC and GOA-ON to actively support the Latin American capacity in OA observations. Focus will be placed on the requested workshop activity allowing for knowledge transfer on specific technical aspects, pending a more substantial description of current needs from LAOCA and a decision on mutually acceptable form of support.

## Nutrients

### *Nutrient Inter-comparison studies*

Considering that all the results of the 2014 Nutrient Inter-comparison study are already available, the first task for IOCCP is to publish the study report. At the same time, planning requests for the follow-up inter-comparison experiment have already been made. IOCCP recommended to develop and distribute a questionnaire asking laboratories participating in the two most recent inter-comparison studies for feedback on various aspects of the exercise. It was also decided that IOCCP will support the organization of and contribute financially to the follow-up inter-comparison activity to be performed about 1 year after publication of the report from 2014 inter-comparison.

### *GO-SHIP manual re-write by SCOR WG 147*

One of the full members of the SCOR WG147 (COMPONUT) has been leading a re-write of GO-SHIP nutrients manual published by Hydes et al. (2010). An outline was already accepted by the SCOR WG 147 and draft of the manual will be prepared before October 2016. The main updates will be presented at the CLIVAR Open Science Conference in Qingdao, China in September 2016 and will be discussed during an annual meeting of SCOR WG147 taking place during the CLIVAR meeting.

## REFERENCES:

D.J. Hydes, M. Aoyama, A. Aminot, K. Bakker, S. Becker, S. Coverly, A. Daniel, A.G. Dickson, O. Grosso, R. Kerouel, J. van Ooijen, K. Sato, T. Tanhua, E.M.S. Woodward, and J. Z. Zhang (2010), Recommendations for the Determination of Nutrients in Seawater to High Levels of Precision and Inter-Comparability using Continuous Flow Analysers, *IOCCP Report No. 14, ICPO Publication Series No. 134, Version 1*, pp. 87.

### Framework for Ocean Observing

As far as Framework for Ocean Observing is concerned, the main focus for IOCCP in the future will be to promote the implementation of multidisciplinary sustained ocean observations based on the concept of EOVs.

With advances in observing technology, and the definition of EOVs, clear opportunities exist to improve the coordinated planning and implementation of observing activities measuring EOVs across the three major disciplines (biogeochemistry, physics and biology). Working with GOOS Physics and GOOS Biology & Ecosystem Panels, JCOMM-OCG, GCOS, GOOS and NSF-RCN, IOCCP proposed to hold a workshop in early 2017 (in Miami, USA) where specific actions will be developed for implementation of a truly multidisciplinary observing system.

The workshop will identify priority steps forward by bringing together users of established observing networks and experts in EOVs and science in all three ocean observation disciplines.

The major aims of the workshop are:

- Building on the established societal and scientific requirements expressed in EOVs, identify the key applications and phenomena that will benefit from co-located multi-disciplinary sustained observations
- Identifying near-term innovation priorities for observing platforms and sensors to enable multi-disciplinary observations, and
- Identifying programmatic and professional connections between existing and emerging observing networks that will increase multi-disciplinary observations

These will contribute to long-term objectives of improving the capability of the global observing system to serve specific information needs, and to raise awareness of the foundational role of sustained ocean observations in delivering societal benefit.

Outcomes from the workshop, based on specific exemplars, will be a clear series of actions with related milestones and metrics for efforts of collaborations across disciplines and observation platforms. These will be focused through actions that fall within current funded activities or actions with clear paths for resources and consistent with identified EOVs. These will be documented in proceedings.

Following are the names of members of the Organizing Committee in alphabetical order:

Nic Bax (GOOS Bio-Eco Panel), Mark Bourassa (GOOS Physics Panel), Albert Fischer (GOOS Director), Katherine Hill (GOOS Physics panel, GCOS), Bob Houtman (NSF), David Legler (JCOMM-OCG, NOAA), Eric Lindstrom (GOOS Co-Chair, NASA), Jay Pearlman (NSF-RCN), Samantha Simmons (GOOS Bio-Eco Panel), Bernadette Sloyan (GOOS Physics Panel), Toste Tanhua (IOCCP), Maciej Telszewski (IOCCP).

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## Instruments and Sensors

Ocean observations are entering an exciting time for sensors and technology that are particularly relevant to the work of the IOCCP, and IOCCP activities related to coordination of relevant developments are highly needed. Specifically, aspects like data quality protocols, observing system design, metrology and incorporating of the sensors data into already established data streams should be considered. IOCCP also plans to provide ongoing support for training of the next generation of users of biogeochemical sensors. A regular task for the Instruments and Sensors team is to continue to report on existing technologies currently on the market and endeavour to link to the newly developing technologies in sensors, platforms and observing systems.

There are a large number of existing and upcoming regionally-funded collaborative projects in the field of marine technology that are aiming to develop the next generation of marine sensors. These projects are not limited just to pH and the other carbon system parameters but nutrients, contaminants and optical properties. These projects are either specifically aimed at sensor development; such as those funded under the ‘Oceans of Tomorrow’ call for action issued by the EU, or projects with a high level of technology development in them e.g. AtlantOS and the upcoming STEMM-CCS project. Whilst the projects funded under the ‘Oceans of Tomorrow’ are broad ranging there is one topic that is specifically directed towards marine sensing technology. From this topic four projects: Common Sense, NEXOS, SCHeMA and SenseOCEAN, are developing sensors for the carbon system. The overall aim of each project is to produce sensors that have been demonstrated in ‘real-life’ environments by the end of the project, and have a clear path to commercial production. In the EU Horizon2020 AtlantOS project, IOCCP will pay particular attention to the development of roadmaps for biogeochemical networks, both sensors and instruments. The “Strategies for the environmental monitoring and measurement of marine carbon capture and storage” (STEM-CSS) project has a large component of technology development around sensors for carbon system parameters and nutrients. The project started on 1<sup>st</sup> March 2016 and will run for 4 years.

Specific action items were listed under the Instruments and Sensors theme to be completed prior to the next IOCCP SSG meeting in early 2017.

- To finalize and publish a Sensors User Guide based on the input compiled during and after the First Sensor Summer Course. The intention is that the User Guide will provide a key asset for participants of the Second Sensor Summer Course tentatively planned for 2018.
- To prepare a proposal for the 2<sup>nd</sup> edition of the IOCCP Sensor Summer Course to be held in summer 2018. Scope, general agenda, planned outcomes and logistics and initial description of partners need to be included. It’s proposed that also oceanographic platforms utilizing autonomous sensors (fixed-point vs. mobile platforms) would become part of the scope so that a system design becomes part of the skill-set in the next generation of autonomous sensors’ operators.
- To develop an engagement strategy for IOCCP focusing on connections between sensors developers’ and sensors users’ communities. Specifically, aspects like data quality protocols, observing system design, metrology and incorporating of the sensors data into already established data streams should be considered.

Data and Information Access Services

The driver for future work under the Data and Information Access Services theme is the need to support and contribute to the development of activities aimed at implementing strategies described in the IOCCP Data Management Position Statement which was unanimously endorsed by the IOCCP SSG. Support will be given to activities aimed at finding a short-term and long-term solutions so that no legacy is lost and the future data management system, while modernized, can benefit from the existing infrastructure and personnel.



## THE SOUTHERN OCEAN OBSERVING SYSTEM

## ANNUAL REPORT

## TO THE SCOR EXECUTIVE COMMITTEE

2016

The Southern Ocean Observing System (SOOS) is a joint initiative of the Scientific Committee on Antarctic Research (SCAR) and the Scientific Committee on Oceanic Research (SCOR), and endorsed by the Partnership for Observations of the Global Ocean (POGO), and the Climate Variability and Predictability (CLIVAR) and Climate and Cryosphere (CliC) projects of the World Climate Research Programme (WCRP).

SOOS was launched in 2011 with the mission to facilitate the collection and delivery of essential observations on dynamics and change of Southern Ocean systems to all international stakeholders, through design, advocacy, and implementation of cost-effective observing and data delivery systems.

#### *A) SOOS Activities and Milestones from May 2015 to May 2016*

In 2015/2016, SCAR and SCOR facilitated an international review of SOOS progress and the new 5-Year Implementation Plan. SOOS has provided a response to the review comments, and will also be making significant changes to the 5-Year Implementation Plan as a result of the review. The updated plan will be made available in July 2016, and will be presented to SCAR Delegates at the 2016 meeting.

All milestones and activities herein are reported against SOOS' six key objectives as defined in the [interim Strategic Plan](#).

### **Milestones**

#### **Objective 1: Facilitate the design of a comprehensive and multi-disciplinary observing system for the Southern Ocean:**

- Publication on ecosystem Essential Ocean Variables (eEOVs) for the Southern Ocean (<http://soos.aq/resources/recent?view=product&pid=38>)
- Outreach with the global ocean observing community on Southern Ocean EOVs
- Coordination of Southern Ocean contribution to the Global Ocean Observing System (GOOS) Biology Panel's survey of sustained biological monitoring towards identification of global eEOVs
- Discussion of OOPC-GCOS-GOOS EOVS specification sheets for Southern Ocean requirements

**Objective 2: Advocate and guide the development of new observation technologies**

- Implementation of a new Endorsement Category that supports technological research and development of observing techniques, platforms and sensors
- Development of a working group to drive observations under ice ([OASIIS](#)) with a core focus on use of new advances in ice-capable technologies

**Objective 3: Compile and encourage use of existing international standards and methodologies, and facilitate the development of new standards where required**

- Organisation of a [workshop](#) for the SOOS-endorsed [NECKLACE project](#)
- Development of Regional and Capability WGs that contribute to Objective 3

**Objective 4: Unify and enhance current observation efforts and leverage further resources across disciplines, and between nations and programmes**Regional Working Groups ([RWG](#)):

- West Antarctic Peninsula Working Group ([WAP WG](#)): Has preliminary SOOS approval and is building membership. An information session will be held at the SCAR 2016 OSC, and a proposal has been submitted to the Royal Society (UK) for a focused WAP WG workshop.
- Southern Ocean Indian Sector WG ([SOIS WG](#)): This WG has preliminary approval and is currently building membership. An information session will be held at the SCAR 2016 OSC.

Capability Working Groups ([CWG](#)):

- Southern Ocean Air-Sea Fluxes ([SO-FLUX](#)): This WG was officially approved at the 2016 SSC meeting. A meeting was held alongside Ocean Science Meeting to discuss key requirements for the pilot study. A [workshop report](#) was published in EOS.
- Censusing Animal Populations from Space ([CAPS](#)): CAPS was officially approved by SOOS in Oct 2015 and is developing a detailed action plan. A [workshop](#) is planned alongside SCAR OSC.
- Ecosystem Essential Ocean Variables ([eEOVs](#)): This WG has preliminary approval and is currently building membership. An information session will be held at the SCAR 2016 OSC, a [community paper](#) has been published, and a community presentation was given (IMOS Planning, March 2016)
- POGO's Observing and Understanding the Ocean below Antarctic Sea Ice and Ice Shelves WG ([OASIIS](#)): SOOS facilitated a successful proposal to Partnership for Observation of the Global Ocean (POGO) for support of a working group that focused on implementation of the 2014 SOOS international strategy for observations under ice ([Seeing Below the Ice](#)).

Task Teams ([TT](#)):

- Southern Ocean Satellite Data Task Team ([Satellite TT](#)): A community report has been accepted in *Antarctic Science*, pending revision. It will be made freely available once published.

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- Field Projects Database ([Here](#)): This product has had a number of challenges and progress has been hindered by a strong reliance on in-kind donation of time/resources. SOOS is currently reassessing the best way to progress with delivery of this important product.

## Key Products:

- Field Projects Database (see above)
- Satellite Data Report (see above)
- National Capabilities ([Here](#)): Currently available on the SOOS website, and will soon be provided in a more user-friendly format.

## Meetings/Workshops:

Since May 2015, SOOS has presented or been represented at 22 meetings/workshops. In addition, SOOS has held the following workshops:

- Implementation of a Southern Ocean Observing System ([more info](#); June 2015, Aus)
- Assessing the State of the Climate of the Southern Ocean ([more info](#); June 2015, Aus)
- Southern Ocean Air-Sea Fluxes ([more info](#); Oct 2015, Italy)
- SOOS Executive Committee meeting (May 2016, Scripps, USA)
- Joint SOOS-SOCCOM [Workshop](#) (May 2016, Scripps, USA)
- 2016 SOOS Scientific Steering Committee [meeting](#) (May 2016, Scripps, USA)
- 2016 SOOS Data Management Sub-Committee [meeting](#) (May 2016, Scripps, USA)

### **Objective 5: Facilitate linking of sustained long-term observations to provide a system of enhanced data discovery and delivery, utilising existing data centres and programmatic efforts combined with, as needed, purpose-built data management and storage systems**

- Establishment and initial population of [SOOS Metadata portal](#) (NASA GCMD), support for community use of portal, driving national data centre connections to GCMD
- Community consultation on and design of [Field Projects Database](#) (see Obj 4)
- Initiation of efforts towards a Southern Ocean mooring data repository (with OceanSITES) and NECKLACE data management
- Involvement in SCADM (Canada, Oct 2015), Polar Data Forum (Canada, Oct 2015), and Ocean Sciences (USA, Feb 2016)

### **Objective 6: Provide services to communicate, coordinate, advocate and facilitate SOOS objectives and activities**

- New SOOS website launched ([www.soos.aq](http://www.soos.aq))
- SOOS network grown from 40 to 46 [Affiliated Organisations](#), 3 successful [endorsed projects](#), and a new [national representative](#) from Japan.
- 2015 SOOS Scientific Steering Committee meeting (June 2015, Aus, Minutes available [here](#)). 2016 SSC meeting minutes will be posted on the website in July 2016.

- 2015 SOOS Data Management Sub-Committee meeting (June 2015, Aus, Minutes available [here](#)). 2016 DMSC meeting minutes will be posted on the website in July 2016.
- Inaugural Southern Ocean chapter in BAMS ([State of Climate 2014](#)), and recently submitted, 2015 Southern Ocean chapter for BAMS State of Climate 2015.
- 3 [Workshop Reports](#), 2 [newsletter issues](#), 4 [publications](#),
- Development of the SOOS Report Series for white papers, position statements, and community reports. These are published in the [SOOS Collection](#) in Zenodo, ensuring they are citable and openly accessible. [Three reports](#) were published in 2015.
- Agreement by all existing [IPO sponsors](#) for continuation of existing level of sponsorship for 2016
- The Institute for Marine and Antarctic Studies at the University of Tasmania (IMAS-UTas) funding of the Executive Officer will end in August 2016. Through the University of Tasmania, the Australian Research Council's Special Research Initiative for [Antarctic Gateway Partnership](#) (Project ID SR140300001), which currently funds the SOOS Data Officer, has agreed to support both the Executive Officer and Data Officer until mid-2018. The IPO office will continue to be located at IMAS-UTas, with on-costs for this hosting to be supported by IMAS.

#### ***B) Planned Activities for April 2016 - Onwards***

Implementation activities in 2016-2017 will focus on achieving the objectives and deliverables outlined in the SOOS 5-year Implementation Plan. Specific activities already planned for this period include:

- 1) SOOS involvement in or organisation of the following meetings;
  - SCAR OSC SOOS Session, Delegates meeting, 2 x topical Town Hall meetings (Aug 2016, Malaysia)
  - SCADM Meeting (Aug 2016, Malaysia)
  - CLIVAR Open Science Conference (Sept 2016, Qingdao, China)
  - CLIVAR-CliC-SCAR Southern Ocean Region Panel (Sept 2016, Qingdao, China)
  - SCOR Executive Committee Meeting (Sept 2016, Sopot, Poland)
  - International workshop on [NECKLACE](#) standards and data (Network for the Collection of Knowledge on Melt of Antarctic Ice Shelves)(Oct 2016, Sweden)
  - Implementing an Under Ice Observing System (TBC, AWI Germany)
- 2) Revision and finalisation of the 5-Year Implementation Plan
- 3) Publication of a data vision for SOOS
- 4) Delivery of Key Products and Working Group milestones
- 5) Development of a Funding Strategy to support SOOS implementation

For further and more detailed information see [www.soos.aq](http://www.soos.aq) or contact the SOOS Executive Officer Louise Newman [newman@soos.aq](mailto:newman@soos.aq).



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## *C) Sponsorship*

SOOS thanks the following sponsors for their support over the last few years, and for their continued assistance into 2016/2017:

- 1) SCOR
- 2) SCAR
- 3) IMAS-Gateway, University of Tasmania,
- 4) Australian Antarctic Division
- 5) Antarctica New Zealand
- 6) University of Gothenburg
- 7) Integrated Marine Observing System
- 8) Tasmania Partnership for Advanced Computing
- 9) NASA Global Change Master Directory
- 10) NSF - CLIVAR and Carbon Hydrographic Data Office

SOOS also acknowledges the support provided to our SSC and DMSC members by their institutions.

## *D) Issues/Challenges*

SOOS is at a point of significant growth and activity and existing IPO resources are insufficient to support this growth. The SOOS IPO needs to enhance capability, particularly with regard to communication activities. The communication effort required to support the *existing* network is an 80% position and this is currently not being met by IPO staff. In 2016/2017, the IPO will need to prioritise efforts further and it is likely that more aspects of the communication strategy will need to be put aside. An additional limitation to SOOS growth is our dependence on voluntary and in-kind efforts. It is hoped that the development of a funding strategy for SOOS will clarify options to address these issues.

## *E) Importance of SCOR Support*

SCOR has been a staunch supporter of SOOS since our development, and we greatly appreciate the guidance and assistance provided by the SCOR Executive Director. We thank SCOR for this vital support.

We also acknowledge the SCOR support for the SOOS SSC meeting. The annual SSC meeting is core to the strategic planning of SOOS implementation. This support is greatly appreciated by SOOS and is vital for ensuring participation from all committee members.

SOOS requests that the SCOR support of 10,000 USD is continued for the 2017 SSC meeting (location TBA, likely EU). A similar request has been made to SCAR, and will be considered at their annual Delegates meeting (August 2016).

Further, SOOS has gained valuable input from the involvement of the SCOR Executive Director at four of the five SSC meetings. SOOS therefore invites the SCOR Executive Director to attend our 2017 SSC meeting, likely to be held in the EU in May/June (location to be confirmed).

#### 4.3 IAPWS/SCOR/IAPSO Joint Committee on Seawater

*Smythe-Wright*

The Joint Committee on Seawater is a group that resulted from SCOR/IAPSO Working Group 127 on Thermodynamics and Equation of State of Seawater, which developed a new equation of state of seawater (TEOS-10), which has been widely accepted.

### Report to SCOR and IAPSO on JCS Activities July 2015-June 2016

#### Membership

##### Executive

|                                  |           |
|----------------------------------|-----------|
| Rich Pawlowicz (Chair)           | Canada    |
| Rainer Feistel (Vice-chair)      | Germany   |
| Trevor J. McDougall (Vice-chair) | Australia |

##### Salinity/Density Subgroup

|                  |         |
|------------------|---------|
| Frank J. Millero | USA     |
| (Rich Pawlowicz) | Canada  |
| Steffen Seitz    | Germany |
| Hiroshi Uchida   | Japan   |
| Stefan Weinreben | Germany |
| Youngchao Pang   | China   |
| Henning Wolf     | Germany |

##### pH Subgroup

|                       |          |
|-----------------------|----------|
| Maria Filomena Camoes | Portugal |
| Andrew Dickson        | USA      |
| Daniela Stoica        | France   |

##### Relative Humidity Subgroup

|                     |             |
|---------------------|-------------|
| Olaf Hellmuth       | Germany     |
| Jeremy Lovell-Smith | New Zealand |

##### Thermodynamics

(Rainer Feistel)

##### Numerical Modelling and Applications

(Trevor J. McDougall)

##### Software

|             |           |
|-------------|-----------|
| Paul Barker | Australia |
|-------------|-----------|

**Industry Representatives**

Richard Williams (OSIL)  
Barbara Laky (Anton Paar)

UK Proposed  
Austria

NB: Former member Paul Ridout (OSIL) has retired.

*Meetings*

JCS did not meet as a full group in 2015-2016. However, 7 JCS members did attend the 2015 IAPWS Annual Meeting in Stockholm, Sweden (June 29-July 2, 2015), as described in last year's report, and it is anticipated a similar number will attend the 2016 IAPWS Annual Meeting in Dresden, Germany (September 2016), including the new OSIL representative R. Williams, who is also the new head of the Seawater Service.

*Web site*

JCS maintains a web site at [www.teos-10.org](http://www.teos-10.org). This site gets 1,500-2,000 visitors per month (12,829 in the past year, with 46,965 "unique views" since Oct. 2010). Annual downloads have been stable over the past two years.

| <b>Web site Item</b> | <b>Unique<br/>downloads<br/>June 2011-<br/>June 2013</b> | <b>Unique<br/>downloads<br/>June 2013-<br/>June 2014</b> | <b>Unique<br/>downloads<br/>June 2014-<br/>June 2015</b> | <b>Unique<br/>downloads<br/>June 2015-<br/>June 2016</b> |
|----------------------|--|--|--|--|
| Manual               | 920  | 360  | 535  | 552  |
| Getting Started      | 879  | 362  | 558  | 547  |
| Slides               | 704  | 284  | 374  | 318  |
| Primer               | 584  | 197  | 289  | 297  |
| GSW_MATLAB_v3_0      | 1920   | 1102   | 1485   | 1814   |
| GSW_FORTRAN_v3_      | 366  | 222  | 171  | 162  |
| GSW_C_v3_0           | 202  | 84   | 133  | 151  |
| GSW_PHP              | -  | 55   | 61   | 43   |
| SIA_VB_V3_0          | 72   | 100  | 46   | 45   |
| SIA_FORTRAN_V3_0     | 59   | 118  | 58   | 44   |

*Other Progress*

1. The major event was the publication of the *Metrologia* review papers (see refs 4-7 below) Since publication in January 2016, these have been heavily downloaded. As of May 31, 2016:

Part 1: Overview – 2,452 downloads  
 Part 2: Salinity – 1,524 downloads  
 Part 3: pH – 1,522 downloads  
 Part 4: RH – 2,772 downloads  
 total: 8,270

2. After encouragement from JCS, members of the Chinese delegation to 2015 IAPWS meeting published a paper on Chinese Standard Seawater, which provides an independent test of PSS-78 (see ref 8 below).
3. TM is working with several modelling groups to add TEOS-10 support to their code base. It is now available in NEMO.
4. RP/FM carried out a second set of density anomaly measurements in N. Pacific (Line-P program, June 2016) to check on anomalies found in first survey.
5. RP/HU carried out density anomaly measurements in Canadian Arctic Archipelago (w/ K. Brown, WHOI – Aug. 2015), with a second set of samples to be acquired (July 2016).
6. FM carried out density anomaly measurements in the deep Arctic (Aug. 2015).
7. DS is spearheading an ERMP proposal for pH, pCO<sub>2</sub>, salinity and chlorophyll calibration standards that went through a pre-selection and is now being developed into a full proposal (also involves SS, MFC).
8. HU carried out density anomaly measurements in N. Pacific (Izu-Ogasawara Trench to 9,500 m).
9. SW continued a decadal series of measurements of density anomalies in the Baltic Sea.
10. HU, FM, HW are continuing measurements of density in SSW batches; this information will be collated in a planned publication.
11. HW, HU, SW, RP are still writing the ‘Best Practices Guide for seawater Density Measurements’ (now at version 13).
12. SS is still investigating instrument effects on conductance measurements.
13. AD continues to provide seawater buffers for pH, and is also a member for SCOR WG147 on speciation (discussing a seawater Pitzer model).

#### *Papers published*

1. McDougall, T.J. and P.M. Barker, Comment on “Buoyancy frequency profiles and internal semidiurnal tide turning depths in the oceans” by B. Kind et al., *J. Geophys. Oceans*, 119, doi:10.1002/2014JC010066, (2014).
2. Feistel, R.: Salinity and relative humidity: climatological relevance and metrological needs, *Acta Imeko* 4, 57-61 (2015)
3. Pawlowicz, R., *Electrical Properties of Seawater: Theory and Applications*, Reference Module in Earth Systems and Environmental Sciences, Elsevier, 11pp, doi:10.1016/B978-0-

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12-409548- 9.09578-6 (2015)

4. R Feistel, R Wielgosz, S A Bell, M F Camões, J R Cooper, P Dexter, A G Dickson, P Fiscaro, A H Harvey, M Heinonen, O Hellmuth, H-J Kretzschmar, J W Lovell-Smith, T J McDougall, R Pawlowicz, P Ridout, S Seitz, P Spitzer, D Stoica and H Wolf: Metrological challenges for measurements of key climatological observables: Oceanic salinity and pH, and atmospheric humidity. Part 1: Overview. REVIEW PAPER. *Metrologia*, 53 (2016) R1–R11, doi:10.1088/0026-1394/53/1/R1
5. R Pawlowicz, R Feistel, T J McDougall, P Ridout, S Seitz, H Wolf: Metrological challenges for measurements of key climatological observables, Part 2: Oceanic salinity. REVIEW PAPER. *Metrologia*, 53 (2016) R12–R25, doi:10.1088/0026-1394/53/1/R12
6. A G Dickson, M F Camões, P Spitzer, P Fiscaro, D Stoica, R Pawlowicz and R Feistel: Metrological challenges for measurements of key climatological observables, Part 3: Seawater pH. REVIEW PAPER. *Metrologia*, 53 (2016) R26–R39, doi:10.1088/0026-1394/53/1/R26
7. J W Lovell-Smith, R Feistel, A H Harvey, O Hellmuth, S A Bell, M Heinonen, J R Cooper: Metrological challenges for measurements of key climatological observables, Part 4: Atmospheric relative humidity. REVIEW PAPER. *Metrologia* 53 (2016) R40–R59 doi:10.1088/0026-1394/53/1/R40
8. Li Y., Y. Luo, Y. Kang, T. Yu, A. Wang, C. Zhang, Chinese Primary Standard Seawater: Stability checks and comparisons with IAPSO Standard Seawater, *Deep Sea Res. I*, 113, 101-106 (2016).
9. R Feistel, J W Lovell-Smith, P Saunders and S Seitz: Uncertainty of Empirical Correlation Equations. Submitted to *Metrologia*, 26 May 2015, in press.

R. Pawlowicz

JCS chair, June 23, 2016

#### 4.4 GlobalHAB



*Berdalet, Sun*



### **GlobalHAB - the International SCOR-IOC Science Programme**

#### **on Harmful Algal Blooms**

#### **Program Activities 2016**

The GlobalHAB programme was launched in January 2016. The GlobalHAB Scientific Steering Committee (SSC) held its first meeting at the Scottish Association for Ocean Sciences (SAMS) in Oban (Scotland, UK) on March 8-10, 2016.

The SSC is constituted by Elisa Berdalet (Chair, Spain), Neil Banas (UK), Michele Burford (Australia), Chris Gobler (USA), Bengt Karlson (Sweden), Raphael Kudela (USA), Po Teen Lim (Malaysia), Lincoln Mackenzie (New Zealand), Marina Montresor (Italy), and Kedong Yin (China). The SSC includes liaisons from the International Council for the Exploration of the Sea (ICES) Working Group on Harmful Algal Bloom Dynamics (WGHABD), the IOC International Panel on Harmful Algal Blooms (IPHAB), the North Pacific Marine Science Organization (PICES) HAB Section, and International Society for the Study of Harmful Algae (ISSHA), the GOOS Biology and Ecosystems Panel and representatives of the sponsoring organizations, Henrik Enevoldsen from IOC and Ed Urban from SCOR.

The main objective of the Oban meeting was to design the general plan of the program over the next decade and map out specific activities for the next three years. In particular, the meeting focused on the definition of the Mission and Goals of GlobalHAB, the elaboration of a Science and Implementation plan, identify approaches for collaboration with other international entities, and addressing logistic and structural questions of the program. The main outcomes of the meeting are summarized below.

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## 1. GlobalHAB Goal and Mission statements

GlobalHAB is a cutting edge scientific programme on HABs.

### GOAL

*To improve understanding, prediction, management and mitigation of HABs in aquatic ecosystems.*

### MISSION

*GlobalHAB will*

- ✓ *address the science and societal challenges of HABs, including the environmental, human health and economic impacts, in a rapidly changing world,*
- ✓ *consolidate linkages with broader scientific fields and other regional and international initiatives relevant to HABs,*
- ✓ *foster the development and adoption of advanced technologies,*
- ✓ *promote training, capacity building and communication of HAB research to society, and*
- ✓ *serve as a liaison between the scientific community, stakeholders and policy makers, informing science-based decision-making.*

## 2. Science and Implementation Plans

The Scientific Plan (SP) of GlobalHAB follows the legacy of the former GEOHAB program, but will incorporate new themes. It will be augmented by a new Implementation Plan (IP) for the coming 10 years. The international scientific community at the GEOHAB Open Science Meeting (OSM) in Paris, April 2013, recommended this approach.

During the meeting in Oban, the GlobalHAB SSC members analyzed the Programme Elements that structured GEOHAB to identify the relevant aspects still valid for GlobalHAB, as well as the new themes identified at the OSM. Before the meeting, several documents were developed by the GlobalHAB SSC members in order to facilitate the meeting discussions.

It was decided to carry forward the 5 GEOHAB Program Elements (Biodiversity and Biogeography; Eutrophication; Adaptive Strategies; Comparative Approach; Modeling, Observation and Prediction) and to define new Program Elements. Based on the GEOHAB SP, the addendum will be more synthetic and will probably be merged with the new Implementation Plan in a single 20-25-page document.

New draft documents were produced that will assist in the elaboration of the SP and IP, to be finished in June 2016. Each document included the following:

- a brief introduction about the importance of the topic,
- the overall and specific objectives,
- potential implementation activities with different time horizons,

- outcomes for the scientific community and policy makers, and
- funding opportunities.

A summary of the draft documents for the new themes follows next, with indication of the names of the SSC members and liaisons that are leading on development of the documents.

*a.- HABs and Fish Farming (led by Lincoln McKenzie and Keith Davidson)*

The overall objective is to determine the potential effects of nutrients, shifting nutrient ratios, and/or organic matter from aquaculture in promoting HABs in different regions.

Implementation activities will include a comprehensive review workshop and position paper to identify the gaps in knowledge on this issue, and to define further research strategies.

*b. CyanoHABs (cHABs) and Freshwater HABs (led by Michele Burford, Bengt Karlson and Chris Gobler)*

The overall objective is to take a global perspective in advancing the science and management of freshwater and cyanobacterial HABs in benthic and pelagic habitats.

Implementation activities will include the development of a user-friendly electronic manual on mitigation strategies for freshwater cHABs across the world; an Open Science Meeting on cross-cutting issues and challenges for cHABs in marine, freshwater and brackish systems; and targeted workshops on emerging species and toxins, and methodological challenges.

*c. Climate Change and HABs (led by Raphe Kudela, Neil Banas, Kedong Yin and Chris Gobler)*

The overall objective is to understand global patterns in HAB responses to common drivers (thermal windows, stratification, nutrients, changing levels of CO<sub>2</sub>).

Implementation activities will include identification of super-sites for time-series observations of HABs and related oceanographic parameters to track the potential impact of climate change on HABs, in coordination with GOOS.

*d. Human Health (led by Elisa Berdalet, Marina Montresor and Gires Usup)*

The overall objective is to minimise the risk of HAB impacts on human and ecosystem health, exploring traditional and new toxin exposure risks.

Implementation activities will include a regional workshop or forum bringing together HAB and medical specialists to identify the main needs and tools to jointly address this objective.

*e. Toxins (led by Po Teen Lim, Chris Gobler and Gires Usup)*

A fundamental overall objective will be characterization of the genetic and environmental basis for toxin production and determination of the mode of action of selected toxins. An overall applied objective will be the development, evaluation and regulatory validation of toxin analyses.

Implementation activities will include a workshop to summarize the state-of-the art and to identify further experiments about the mode of action of fish-killing events, and an inter-laboratory validation study on mass spectrometry methods of (e.g. PSP-toxin analysis).

*f. Benthic HABs (Elisa Berdalet, Gires Usup)*

The overall objective is to improve the knowledge on the ecology, physiology, toxin transfer mechanisms through marine food webs, and to obtain fundamental parameters for modeling BHAB dynamics, with a special interest on climate change scenarios.



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Implementation activities will include a training workshop on methods for sampling BHABs organisms, intercomparison exercises focused on new analytical techniques for ciguatoxins, palytoxins and analogues, and an open science meeting on BHABs.

*g. Economy (Keith Davidson, Michele Burford, Vera Trainer)*

The overall objective is to develop tools and criteria for the comprehensive understanding of the economic impacts of HABs.

Implementation activities will include an interdisciplinary workshop targeted to (re)evaluate the economic impacts in key regions affected by HABs.

### 3. Collaboration with other international bodies

Several ToRs specify the essential link of GlobalHAB with other international entities that have HABs among their scientific research interests (Figure 1). At the first GlobalHAB SSC meeting, some of these entities were already represented by their liaisons that indicated possible collaborations, such as:

**IPHAB** (Gires Usup) – IPHAB identifies needs related to HABs and addresses IOC high-level objectives (e.g., the development of a Global HAB Status Report, a UN interagency strategy on ciguatera for improved research and management). Support to GlobalHAB from IPHAB could include training workshops (e.g., on taxonomy), interaction with member states and regional grouping on HAB issues, technical support through IPHAB Task Teams on Toxins and economic costs of HABs, and encouragement of countries to support their scientists to engage in GlobalHAB activities. The IOC liaison also includes links to IOC regional programmes such as IOC/WESTPAC/HAB (represented by Po Teen Lim) which could contribute to GlobalHAB, for instance, by creating outreach materials and sending regional experts to GlobalHAB-related meetings.

**PICES** (represented by Vera Trainer) has a Section on Ecology of Harmful Algal Blooms in the North Pacific. PICES could collaborate with GlobalHAB in future studies, through the alignment of PICES work with certain GlobalHAB objectives, providing ex officio status for GlobalHAB representatives on PICES Expert Groups that organize special meetings, workshops, and symposia, etc.

**ISSHA** (represented by Vera Trainer) – At the ICHA-16 conference in Brazil, co-sponsored by ISSHA, GlobalHAB will have a booth, an abstract about the program and a Town Hall session **to facilitate the engagement of the international community on the implementation of GlobalHAB, essential for the success of GlobalHAB.**

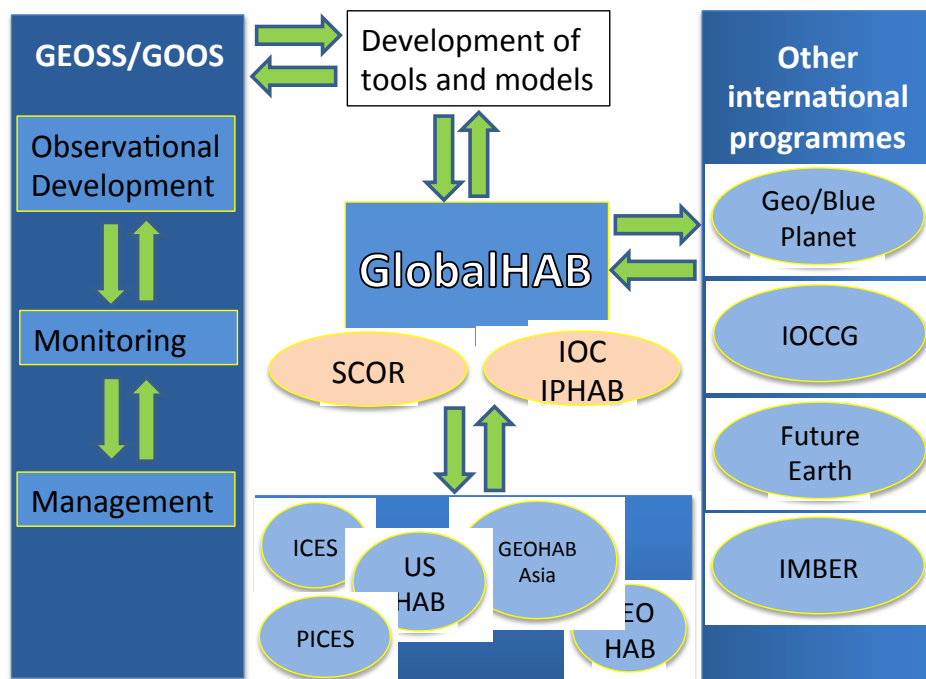


Figure 1. Links of GlobalHAB with other international entities that include HABs in their ToRs or objectives.

**ICES** (represented by Eileen Bresnan) - The ICES/IOC WG on Harmful Algal Bloom Dynamics (WGHABD), which concerns the ecology of HAB species within the ICES area, was pivotal in the development of GEOHAB. The new ToRs of the WGHABD in 2017 will incorporate “GlobalHAB” as a new descriptor. Furthermore, GlobalHAB could co-sponsor a 2017 workshop on novel methods for HABs species detection.

**GOOS Biology and Ecosystems Panel** (represented by Raphael Kudela) has identified HABs as an Essential Ocean Variable (EOV). GlobalHAB could help develop this EOV and the GOOS webpages can raise the visibility of GlobalHAB.

**EuroGOOS** (represented by Bengt Karlson) – Traditionally focused on physical oceanography processes, the incorporation of FerryBox systems may facilitate research on HABs. EuroGOOS also supported the proposal for UK funding of a GlobalHAB IPO.

**IOCCG** (represented by Raphe Kudela) – The joint working group between GEOHAB and IOCCG (now finishing a monograph) can continue with GlobalHAB.

**GEO/Blue Planet** (represented by Raphe Kudela) – The relationship with GEO/Blue Planet and GlobalHAB will be fostered.

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**IAEA** (presented by Gires Usup) – IAEA developed a receptor-binding assay method for PSP and is now focusing on ciguatera (CTX detection method). IAEA participates in monitoring (sampling devices), provides support for lab equipment, is producing reference materials, and is incorporating epidemiology on the Pacific Island Countries and Territories (PICTs). All these aspects are relevant for the implementation of GlobalHAB objectives.

## 4. Other logistic and structural aspects

Other agreements concerned the general design of the logo (Figure 2), the webpage, revision of the Endorsement procedure, dissemination of the meeting in Harmful Algal News #53, future meetings, etc.



Figure 2. Draft of the GlobalHAB logo. To be refined.

## 5. GEOHAB Synthesis Products

At the official end of GEOHAB, some synthesis products were still in progress and GlobalHAB has taken responsibility to see them completed. These products include the following:

- A special issue to be published in *Oceanography* magazine (The Oceanographic Society), Volume 30, March 2017. [Deadline for submission: June 30, 2016]

**Title:** *International Cooperation in Harmful Algal Blooms Science*

**Guest Editors:** Raphael Kudela, Henrik Enevoldsen and Ed Urban

**Papers:**

1. *Past to future in the International Cooperation in HABs research.* Kudela, Berdalet, Enevoldsen, Magnien, Urban.
2. *Advances and new challenges on HABs in Upwelling Systems.* Pitcher, Kudela, Moita.
3. *Recent progress in understanding BHABs and manage their impacts.* Tester, Berdalet, et al.

4. *HABs in Stratified Systems, and Fjords and Coastal Embayments: tools and knowledge for future improvements.* Berdalet, Roy, Reguera, Cembella, Montresor and Raine.

5. *HABs in Eutrophied Systems.* Burford, Glibert, et al.

6. *Technology and modelling for the advances of the research on HABs.* Kudela et al.

- A monograph on the application of Ocean Colour satellite techniques for the study of HABs is planned for publication in the *IOCCG Report* series. This book is the result of the collaboration between GEOHAB and the International Ocean Color Coordination Group (IOCCG), with Steward Bernard, Raphael Kudela and Grant Picher as editors. The document will be structured on several representative case studies of HABs.

- A book published by Elsevier, under their *Ecological Studies* series.

*Editors:* Pat Glibert, Elisa Berdalet, Michele Burford, Grant Pitcher and Mingjiang Zhou.

*Expected date of publication:* End of 2016.

*Chapters (expected):*

|  |                                     |
|--|-------------------------------------|
| 1. Preface: Introduction to the GEOHAB Synthesis   | PG and all editors                  |
| 2. Introduction to HABs and their impacts  | PG, GP et al                        |
| 3. The Global Ecology of Oceanography and Harmful Algal Blooms Programme (GEOHAB): History and Impacts | Kudela, Berdalet, Urban, Enevoldsen |
| 4. Changing landscape, seascape of nutrients and relationship with HABs                                | Glibert, Bouwman, Beusen et al.     |
| 5. HABs and Climate change   | Wells, Karlson, Kudela              |
| 6. Nutrients and HABs  | Glibert et al.                      |
| 7. Life cycles and HABs  | Azanza et al                        |
| 8. Mixotrophy and HABs   | Flynn et al.                        |
| 9. Swimming and motility and HABs-turbulence   | Berdalet et al.                     |
| 10. HABs in Stratified Systems   | Raine, Reguera, Berdalet, Gentien   |
| 11. HABs in fjords and coastal embayments  | Roy, Cembella, Montresor            |
| 12. HABs in eastern boundary upwelling systems   | Pitcher et al.                      |
| 13. HABs in eutrophic systems  | Glibert et al.                      |
| 14. HABs in benthic systems  | Berdalet, Tester et al.             |
| 15. Expansion of HABs in Asia  | Lu songhui, Yu Rencheng, Dongyan,   |
| 16. Expansion of HABs continued  | part 2                              |
| 17. GEOHAB Asia: Development, successes and future steps   | Furuya, Usup, Azanza Mingjiang      |
| 18. Expansion of HABs in Arabian Sea and Arabian Gulf  | Goes, AL-Azri, Glibert              |
| 19. Developing global capabilities for observation and prediction of HABs                              | Babin et al.                        |
| 20. Advances in modeling HABs-1  | McGillicuddy, Allen, Fernand        |

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| 21. Advances in modeling HABs-2  | Peter Franks                          |
| 23. Assessing utility of global ocean color for HAB research                                 | Bernard et al.                        |
| 24. Emerging HAB issues in freshwater  | Burford, Glibert et al.               |
| 25. Emerging techniques for managing and preventing HAB impacts: regional operation models   | Magnien                               |
| 26. Clay mitigation  | Zhuming Yu, Kim et al.                |
| 27. Establishment of the GlobalHAB international coordination effort: research to mitigation | Berdalet, Magnien, Enevoldsen, Kudela |

#### 4.5 Workshop on Seafloor Ecosystem Functions and their Role in Global Processes

*Urban*

Processes that occur at, immediately above, and just below the seafloor play an important role in global biogeochemical cycles, from coastal areas to the deep ocean. SCOR supported a workshop convened by several seafloor ecologists (Paul Snelgrove, Simon Thrush, and Alf Norkko) to consider seabed ecosystem functioning on a global scale. The workshop brought together the interdisciplinary expertise necessary to address this issue and identify priority research topics. Twelve experts in seabed biology, chemistry, and geology from North America, Europe, Asia and New Zealand met for 2.5 days, hosted by Roberto Danovaro at the historic Stazione Zoologica in Naples, Italy in September 2015. The group began to develop a set of priority research questions on the role of seafloor processes in ocean functioning. Discussions began with short presentations on modelling ecosystem functions how to go about it, processes and key functions, available data and gaps, scaling functions, approaches to generating large-scale metrics of biological activity, and model systems that have been well sampled. Workshop participants then discussed links between seabed processes, functions, and services and quickly zeroed in to ask how we can evaluate and predict seafloor ecosystem functions in the global ocean, to the extent that this assessment can inform debate on the consequences of environmental change. The group focused primarily on carbon cycling and nutrient regeneration, and the role that sedimentary organisms from microbes to megafauna play in those key processes. Next, they considered how to build maps—or at least define testable functional relationships—that might allow extrapolation of a sparsely sampled seabed to regional and global scales. The goal of the workshop was to produce an article for a peer-reviewed journal that could form the basis for a more inclusive discussion by interested scientists, and the workshop places the group in an excellent position to do just that.

The paper has been drafted and the plan is to submit it to *Nature Geosciences*.