4.0 INFRASTRUCTURAL AND OTHER ACTIVITIES

4.1 IOC/SCOR International Ocean Carbon Coordination Project ***Telszewski, Halpern***

International Ocean Carbon Coordination Project
Progress Report for SCOR, May 2018

Understanding and quantifying the role of ocean biogeochemical cycles in the global climate system requires efficient coordination of multi-platform observations of carbon and carbon-related biogeochemical variables, carried out on a myriad of spatial and temporal scales.

To this end, the International Ocean Carbon Coordination Program (IOCCP) promotes the development of a global network of ocean carbon and biogeochemistry observations as part of a multidisciplinary global ocean observing system which is fit-for-purpose, sustainable in the long term and globally feasible. IOCCP coordinates the development of globally acceptable strategies and provides technical coordination, developing methodologies and practices and standards, and homogenizing efforts of the research community and scientific advisory groups. IOCCP also provides communication services for the 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 June 2017 and May 2018 and outlines the actions planned for the near future.

Projects and Major Activities

Marine Carbon Think Tank

In April 2017, the Surface Ocean Lower Atmosphere Studies (SOLAS) and the Integrated Marine Biosphere Research (IMBeR) project disbanded their two carbon working groups that, based on the *Joint SOLAS/IMBeR Carbon Implementation Plan* (2006), were charged with coordination and synthesis of ocean carbon research related to both ocean surface and ocean interior. Seeking new science directions, SOLAS and IMBeR proposed an open discussion amongst all and any programs interested in ocean carbon research. Representatives of IOCCP, the Global Carbon Project (GCP), UNESCO's Intergovernmental Oceanographic Commission Ocean Science Section (IOC-OSS), the U.S. Ocean Carbon and Biogeochemistry (OCB) program, the Climate and Ocean: Variability, Predictability and Change (CLIVAR) project, the World Climate Research Programme (WCRP) C-challenge, and SOLAS and IMBeR expressed

interest in such discussion and an initial, scoping side-meeting during the 10th International Carbon Dioxide Conference (ICDC10) in Interlaken, Switzerland was organized in August 2017. You can find more information about the meeting on later in this report.

As a main outcome of the Interlaken meeting, it was agreed that there is an immediate need for international coordination in ocean carbon cycle research that goes beyond what is currently done. This need was expressed most strongly by IOCCP, which is currently lacking a scientific partner to develop and implement a science-based strategy related to the marine carbon cycle. But the gap left after disbanding of the SOLAS-IMBeR Carbon working groups 1 and 2 is felt by the other organizations, too. For example, the lack of coordinated ocean carbon cycle simulations was mentioned both with regard to the Coupled Model Intercomparison Project Phase 6 (CMIP6) and in the context of GCP's efforts to establish annual carbon budgets. Also, many new aspects (e.g., organic carbon) need to be included in such a global implementation strategy. Many programs are currently including ocean carbon-related activities in their science plans, but in none of these organizations does the ocean carbon cycle obtains adequate attention. This is neither efficient nor effective. Given the general trend to promote holistic marine observations, any new initiative would have to go beyond the (inorganic) carbon cycle, and include elements related to other biogeochemical properties such as nutrients, oxygen, and N_2O, that is, very much in the spirit of the biogeochemical suite of Essential Ocean Variables that were developed through IOCCP as the Global Ocean Observing System (GOOS) Biogeochemistry Expert Panel.

In the following months, IOCCP, SOLAS, IMBeR, GCP, U.S. OCB and IOC-OSS confirmed that they are very interested in furthering this issue as soon as possible. A synthesis of discussions is that perhaps a well-structured 2-3 days scoping meeting/workshop at IOC-UNESCO headquarters (similar to the Surface Ocean CO_2 Variability and Vulnerabilities (SOCOVV) workshop held in 2007, would be an effective next step. The meeting would be planned for 40-50 participants representing regions, sub-disciplines (fluxes vs storage for example), research types (observations vs models), end-users (assessments, status reports, local management etc.).

Key scientific questions will occupy the interface between biogeochemistry and physical oceanography as well as biogeochemistry and biology. Details are to be determined by community input. Exact meeting structure will also be determined, but the main goal is to clearly identify directions, niches, gaps, etc. and write it all up as a report with specific recommendations for actions. Individual sponsoring programs or specifically created task teams would then be able to concentrate on specific actions depending on the alignment of certain actions with respective terms of reference and mission statements. It is anticipated that such an implementation plan will help funding agencies direct their designated resources in an informed fashion.

Ocean Best Practices Working Group

According to the Terms of Reference, IOCCP is obliged, among other things, to:

> *4. Promote international agreements on measurement methodologies and best practices, primary and secondary data quality control and quality assurance procedures, data and metadata formats, and development and use of certified reference materials.*

Over the past 12 months, IOCCP has devoted significant efforts to fulfil this obligation towards the marine biogeochemistry community through a number of contributions, regionally as part of the EU Horizon2020 AtlantOS project and globally through GOOS and the WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM) Observations Coordination Group (OCG) in particular. All the recently launched initiatives were motivated by the fact that discoverability and sustainability of high-quality methodology is still limited by fragmented reporting and archiving. This is despite the fact that national, regional, and international observing networks have developed and adopted a tremendous amount of methodologies as their so-called best practices.

Central to addressing this issue is the creation of a new process, centered at the Ocean Best Practices repository (OBP; https://www.oceanbestpractices.net/). The OBP is a large-scale effort bringing together several international research communities, global observing system coordinating bodies, funding agencies and research projects. The final goal is to provide the ocean observing community with a structured, sustainable compendium of peer-reviewed best practices in ocean observing that can be used in training new oceanographers and data scientists, and also in providing references for experts. One important prerequisite in the process is reaching across science communities and networks to support multi-disciplinary applications.

In this context, a community best practice is defined as "a methodology that has repeatedly produced superior results relative to other methodologies with the same objective." Before any new promising method can be accepted as a best practice, it will have to be adopted and employed by multiple organizations. Best practices may come in any of a number of format types — best practices, standard operating procedures, manuals, operating instructions, etc. — with the understanding that the document content is put forth by the provider as a community best practice.

The ever-growing number of contributors to this effort have jointly undertaken a series of actions that constitute complementary efforts leading to the realization of the long-term objective. Below is a summary of a few of the key efforts in which IOCCP is directly involved and will continue to contribute over the next months and years.

AtlantOS Best Practice for Observing Systems: The AtlantOS Project, with support from the ODIP II project (www.odip.eu), has a Best Practices Work Group (BPWG), which is coordinating its activities with international and national agencies and which aims to improve access to documented best practices for ocean observations (https://www.atlantos-h2020.eu/project-information/best-practices).

As part of the BPWG, IOCCP has been collaborating with other AtlantOS partners in diverse ocean disciplines to populate the OBP repository and to address the utility of the best practices process for their communities. The AtlantOS partners in this effort currently include EuroGOOS/GOOS, GEOMAR, Ifremer, Marum, PML, UPMC; with a number of international projects other than IOCCP being involved as well.

The OBP is hosted and managed by International Oceanographic Data and Information Exchange (IODE) of the Intergovernmental Oceanographic Commission (IOC) of UNESCO for its partners: JCOMM, WMO and ICES. Any ocean-related best practice can be deposited by the community and the upgraded infrastructure will support all attributes of the flow process summarized in the diagram below.

JCOMM OCG Standards and Best Practices Task Team: Promoting the creation and timely updating of JCOMM best practice documentation is a key priority for the JCOMM OCG. The rationale for JCOMM OCG Standards and Best Practices (SBP) task team is that many of the observing networks have a focus on the development of best practices for their network (i.e., Argo, GO-SHIP). However, driven by the need to be able to deliver ocean observations by Essential Ocean Variables (EOVs), there is a need to be able to characterize and quantify the observational approaches and uncertainties across the networks, and there are also opportunities to capitalize on the best practice efforts of the individual networks to the benefit of the broader observing system. Therefore, many of the actions in this area are focused on the development and sharing of network best practice activities, and the coordination of best practice development and inter-comparison activities by EOV.

Peer-review of best practices in ocean observing – *Frontiers in Marine Science* Research Topic:
The OBP initiative encourages all BP methods to go through peer review, either in their originating community or through a journal peer-review system. To this end, members of the AtlantOS BPWG and JCOMM OCG SBP Task Team led to the successful establishment of the *Frontiers in Marine Science* Research Topic on Best Practices in Ocean Observing: https://www.frontiersin.org/research-topics/7173/best-practices-in-ocean-observing.

Lack of a forum to allow BP creators to describe and disseminate their developments was identified as a gap. This Research Topic is an opportunity for BP developers to expose their methods to the ocean community, and for that community to discover sustainably managed BPs to enable further progress in ocean observation.

In this Research Topic, the editors primarily solicit papers describing robust and high-quality methodologies over the entire range of ocean observing and addressing the challenges of improving observation capabilities (including data management) and interoperability. Papers can be linked to one or more fully documented protocols archived in a repository maintained by IODE. The Topic will also accept related submissions such as recommendations to expand the usage and reporting of methods and descriptions of major obstacles to their implementation.

> Developing ocean acidification indicators for SDG14.3 through the Global Ocean Acidification Network (GOA-ON)

IOCCP continues to play an active role in the activities of the Global Ocean Acidification Network (GOA-ON) through presence of its two SSG members Richard Feely and Benjamin Pfeil, and Project Director Maciej Telszewski on the GOA-ON Executive Council. Over the past year, a major undertaking of GOA-ON was to develop a robust and consistent framework for developing ocean acidification indicators to meet relevant targets set for the United Nations

Sustainable Development Goal (SDG) 14: Life Below Water, to conserve and sustainably use the oceans, seas and marine resources (https://sustainabledevelopment.un.org/sdgs). Of particular interest to our community is target 14.3: Minimize and address the impacts of ocean acidification, including through scientific cooperation at all levels.

In order for the global community to meet this target, an international group of experts (including four IOCCP SSG members and Project Director) was convened under the leadership of IOC-UNESCO to develop a harmonized and agreed indicator framework at the global level, allowing long-term monitoring and data management structures. In order for this activity to be successful all existing efforts by different groups of countries and organizations, including regional and international agencies, regional commissions, academia, civil society and other relevant international organizations have to be taken into account. This is not a trivial task as rigorous assessment of global ecosystem changes due to ocean acidification requires significant technical capacity building in many parts of the planet.

In January 2018, these experts met in Paris at the IOC-UNESCO Headquarters (see later in this report) to develop the indicator methodology for target 14.3 (average marine acidity measured at an agreed suite of representative sampling stations).

Establishing the surface ocean CO_2 observing network

The main rationale for establishing the Surface Ocean Carbon Observing NETwork (SOCONET) is to combine high-quality and intercomparable data from moorings and ships to determine what assets are in the water and to assure the quality of data delivered by these assets. The idea of coordinating surface water CO_2 observations has had a long history, with incremental implementation of certain aspects of the network such as data collation and distribution through the Surface Ocean CO_2 Atlas (SOCAT; www.socat.info) along with an independent effort of the Lamont-Doherty Earth Observatory (LDEO; https://www.nodc.noaa.gov/ocads/oceans/LDEO_Underway_Database/) database, or development of globally accepted standards and best practices for measurements and their metadata. However, there are still numerous aspects like the quality of measurements, collaboration with ship operators, design of the observing network globally, collaboration with other observing networks and more, which can only be improved or achieved globally through a coordinated structure. In spite of the fact that there are very successful data collation efforts in the form of SOCAT and the LDEO dataset, our knowledge of network status coming from these collations are 1 to 3 years after the fact.

As most of the global efforts in this field have been facilitated under aegis of IOCCP, the network was decided to be formed under auspices of IOCCP through a global partnership of investigators involved in ongoing efforts, both on ships of opportunity (SOOP-CO_2) and fixed-platforms (mooring-CO_2). To this end, IOCCP and U.S. NOAA held the kick-off meeting of the network on February 11, 2018. A group of invited participants who represented the largest operators of surface water CO_2 operations and/or activities relevant for network development met in Portland, Oregon, USA, just prior to the Ocean Sciences Meeting. See later in this report for more information on the meeting and its outcomes.

A goal of a surface ocean CO_2 observing network is to ensure that operators follow standard operating procedures (SoPs). Thus, the network will be a subset of SOCAT data. One of the next steps, after the official kick-off meeting was held, is to request JCOMM network status from JCOMM OCG. Another point on the surface ocean CO_2 observing network agenda is to quality control and use marine air boundary layer measurements of CO_2, which are measured but not processed by the instruments.

Global Ocean Observing System Biogeochemistry Expert Panel (GOOS BGC Panel) Towards the end of August 2017, IOCCP (as the GOOS Biogeochemistry Expert Panel) released GOOS Biogeochemistry EOV Specification Sheets version 2.0. The 2017 revision is the result of GOOS-wide dedicated efforts to better harmonize the EOV and associated concepts across all disciplines: physics and climate, biogeochemistry, biology & ecosystems; and to align the EOVs closer with the corresponding Essential Climate Variables (ECVs) developed by the Global Climate Observing System (GCOS - see the 2016 GCOS Implementation Plan for details). To view and download the most recent versions of all GOOS EOVs, please follow the link to the GOOS website: www.goosocean.org/eov.

The Specification Sheets were updated in terms of their structure and content in response to recommendations from GOOS expert panel members and thanks to feedback obtained from the community over the 18 months since the Specification Sheets were first published online in February 2016. These changes include revisions of several of the Biogeochemistry EOV names: Inorganic Carbon (formerly Carbonate System), Nutrients (formerly Inorganic Macronutrients), Oxygen (formerly Dissolved Oxygen) and Particulate Matter (formerly Suspended Particulates).

Though significantly updated, the 2017 Biogeochemistry EOV Specification Sheets should still be considered 'work in progress.' Acknowledging all the input already provided, IOCCP is looking forward to feedback from the community, which will be carefully considered prior to future updates. It is anticipated that the continuing revision process will result in annual or bi-annual updates over the next few years, with the frequency of the updates gradually decreasing as the Specification Sheets and their application mature. Through this 2017 update to the Biogeochemistry EOVs, performed alongside similar efforts on the Physics & Climate and Biology & Ecosystems EOVs, IOCCP has contributed to furthering the implementation of the Framework for Ocean Observing.

In the second half of 2017, IOCCP has also initiated the work of a Task Team on the Ocean Colour EOV. Consisting of members of the International Ocean Colour Coordination Group (IOCCG), GOOS Biogeochemistry and GOOS Biology & Ecosystems Expert Panels, as per recommendations of the GOOS Executive Council, the Task Team has successfully developed a first draft of the Ocean Colour EOV Specification Sheet. In February 2018, the draft was positively reviewed by the IOCCG Committee at its annual meeting. Currently, the final draft is being prepared, to be publically released through the GOOS and IOCCP websites within a few weeks.

Regular updates to the EOVs will hopefully trigger the ocean community at large to become even more engaged in building the multidisciplinary, fit-for-purpose global ocean observing system. However, there is much to do in that respect internally within the GOOS structures. In an

effort to strengthen the integration between the GOOS structures, as requested by the GOOS Steering Committee (see details of the GOOS-SC-6 meeting later in this report), the three expert Panels of GOOS committed to holding regular cross-panel meetings. Goals of these meetings are to advance the implementation of the Framework for Ocean Observing (FOO) through the EOVs and to harmonize the panels' efforts in delivering essential ocean information in response to user needs identified for the three themes of GOOS: climate, operational services, and marine ecosystem health. The IOCCP Office led the organization of the 2018 Cross-Panel meeting which took place between 28 February and 3 March in Hobart, Australia. You can read more about the meeting objectives and outcomes later in this report.

New IOCCP theme: Oxygen

In response to the need for playing a more active role in the global coordination of non-carbon EOV observations and the need for extending the relevant SSG expertise, IOCCP added a new Oxygen theme to its portfolio in early 2018. Approved by the two sponsors, SCOR and IOC-UNESCO, as well as the IOCCP SSG, Véronique Garçon has been appointed as a new SSG member responsible for coordination and communication concerning global ocean oxygen observations. Véronique has been involved with IOCCP in the work on oxygen-related coordination since the beginning of 2017. Since that time, a considerable number of relevant activities have taken place, either under her leadership or with her strong involvement.

The two most prominent ongoing global activities are related to the Global Ocean Oxygen Network (GO_2NE) and the Variability in the Oxycline and its ImpaCts on the Ecosystem (VOICE).

Raising awareness about ocean deoxygenation through the Global Ocean Oxygen Network (GO_2NE): IOCCP SSG member Véronique Garçon and IOCCP Director Maciej Telszewski have been members of the Global Ocean Oxygen Network (GO_2NE) Executive Council since its establishment in 2016 as an IOC-UNESCO Working Group. GO_2NE is committed to providing a global and multidisciplinary view of deoxygenation, with a focus on understanding its multiple aspects and impacts. The Network offers scientific advice to policy makers to counter this concerning trend and to preserve marine resources in the presence of deoxygenation. Currently, the members of the core working group represent 21 institutions in 11 countries.

A number of current and future GO_2NE actions was reviewed and discussed during the 2017 meeting of GO_2NE Executive Council (11-13 September 2017, Monterey, CA, USA). However, a major recent outcome of GO_2NE was an article published in *Science* in January 2018 entitled "Declining oxygen in the global ocean and coastal waters." The IOCCP Director was a co-author on this paper, which has received much attention among the press as well as the scientific community. Mentioned by 90 news outlets, 21 blogs, 2 policy sources and over 1,770 Tweets over a period of 5 months, the paper has been ranked in the top 5% of all research outputs ever tracked by Altmetric.

Variability of the Oxycline and its ImpaCt on the Ecosystem (VOICE): The international project VOICE (Variability of the Oxycline and its ImpaCt on the Ecosystem) was set up as a direct outcome of the Implementation of Multi-disciplinary Sustained Ocean Observations (IMSOO) workshop co-organized by GOOS and Ocean Research Coordination Network (RCN) in February 2017. IOCCP SSG member Véronique Garçon is a Co-Chair of

VOICE, and the IOCCP Project Office is providing coordination and communication services for this important and ambitious undertaking.

VOICE is an approach towards establishing a sustained observing system in Oxygen Minimum Zone (OMZ) regions, which are inherently multidisciplinary and complex, and likewise, are regarded as economically important areas (e.g., for fisheries). In order to encounter the complexity, VOICE will put an observing focus on the upper oxycline, which in an important "control surface" in OMZ regions. The goal of the initial stage of VOICE is to assess the current readiness level of the observing requirements, existing observing capabilities and availability of data products to deliver information on the variability in the oxycline and its impacts on the ecosystem in selected OMZ regions around the globe.

The first, preparatory, stage of VOICE consists of four phases:

- Phase 0: Communication and coordination efforts including definition of “societal issues” via stakeholder dialogue
- Phase 1: Literature review/historical data analysis to define science-driven observing requirements
- Phase 2: Identify existing and planned experiment/ocean observing opportunities in OMZ regions
- Phase 3: Develop the conceptual framework and observing system design for selected science cases related to oxycline variability

The key outcome at this stage of the project is to perform a preliminary assessment of the current readiness level with respect to all three categories distinguished by the Framework for Ocean Observing (FOO): (i) requirements setting process, (ii) existing observing capabilities, and (iii) data and information products management.

The goal of the VOICE Implementation Stage (Phase 4) would be to have in place an Ocean Observing System that measures EOVs and associated phenomena necessary to provide information about one selected key aspect of OMZ regions, the upper oxycline. The data will enhance the understanding of impacts, but also of dependencies of oxycline variability on intermediate and upper trophic levels, and improve modeling capabilities, across a number of OMZ systems.

Deliverables and milestones for the VOICE implementation stage, gradually refined through two consecutive VOICE workshops in 2017 and 2018, will focus on the following aspects:

- Optimal sampling strategy design
- Analysis of observing system gaps with respect to observations, data availability, sustainability and technology; and estimates on cost of their closing
- Technical enhancements and other observing system adaptations in response to the analysis of gaps
- Integrated data management
- Stakeholder engagement in evaluating fitness of information product generation for societal benefit applications

- Assessment of the observing system performance
- A blueprint of a multi-disciplinary, sustained and fit-for-purpose OMZ observing system, outlining a minimum set of observational and modelling requirements for global implementation

A successfully completed VOICE project would be a critical element in designing and implementing, as well as securing funding for, an observing system that is capable of addressing the overarching question of "How do changing OMZs affect the spatio-temporal distribution, productivity and trophic structure of the benthic and pelagic communities?" within a 10-year time frame.

The 1st VOICE Science Plan Workshop, a three-day event held on 13-15 September 2017, in Monterey, CA, USA, was an important milestone in the process. The workshop objectives were to enable or directly contribute to the delivery of anticipated outcomes of the VOICE preparatory stage, as defined in the IMSOO workshop report. The workshop was held back to back with the third annual meeting of GO2NE (11-13 September 2017, Monterey, CA, USA), and was attended by 22 scientists from around the globe. It was the first opportunity to establish communication and initiate coordination of efforts leading up to the implementation of the VOICE project. To this end, the first day of the meeting was organized as a joint event with the members of GO2NE, many of whom are also active in VOICE.

The VOICE workshop provided an excellent and in-depth summary of the regionally set requirements, observing capability, and data and information product management, forming a basis for comprehensive observing system readiness level assessment in accordance with the FOO guidelines. The information conveyed through presentations and during discussions has since then been documented and expanded upon through a spreadsheet questionnaire distributed among and filled out by VOICE regional champions. For more details on this and other important outcomes from the workshop, please see the workshop report available from www.goosocean.org/voice-mbari-report.

While the number of VOICE enthusiasts keeps gradually increasing, the group currently consists of more than 30 scientists and marine managers representing either their OMZ regions (appointed as VOICE regional champions) or serving as international experts in different aspects of OMZ dynamics observations, modeling and marine resource management. Critical to the success of implementing VOICE will be the role of regional champions who are not only responsible for assessing the regional observing capacities and gaps, but also are meant to survey the societal requirements with respect to VOICE-related observations and generated information products through regular communication with a broad range of regional stakeholders.

Data synthesis activities: Surface Ocean CO_2 Atlas (SOCAT) and the Global Ocean Data Assimilation Project (GLODAP)

SOCAT: Celebrating its 10th anniversary in 2017, SOCAT represents a milestone in biogeochemical and climate research, and in informing policy. SOCAT data are discoverable,

accessible and citable. SOCAT enables quantification of the ocean carbon sink and ocean acidification and evaluation of ocean biogeochemical models.

SOCAT Version 5, released in June 2017, has 21.5 million quality-controlled, surface ocean fCO_2 (fugacity of carbon dioxide) observations from 1957 to January 2017 for the global ocean and coastal seas. Calibrated sensor data are also available in SOCATv5. Automation allows annual, public releases of SOCAT.

The SOCAT website (www.socat.info) provides access to synthesis and gridded data products for version 5. Users can explore the data products via two powerful, interactive online viewers, the Data Set Viewer and the Gridded Data Viewer. Alternatively, users can download the synthesis and gridded products with MATLAB code available for reading these files. The paper by Bakker et al. (2016) documents the data products and quality control criteria in SOCAT version 3, which also apply to versions 4 and 5.

GLODAP: Following the formulation of Terms of Reference for GLODAP and the newly formed GLODAP Reference Group (RG), a new GLODAP website (www.glodap.info) was launched several weeks ago. The site holds information on GLODAP data in various formats, the GLODAP Reference Group membership, or the impact of GLODAP. The new web page is built on the same framework and is meant to serve a similar purpose as the SOCAT web page. The GLODAP website is hosted by the Bjerknes Climate Data Centre and the Integrated Carbon Observation System (ICOS) Ocean Thematic Centre (Bergen, Norway).

2017 nutrients intercomparison exercise

In 2017, IOCCP together with JAMSTEC co-funded the next edition of the inter-laboratory comparison of Certified Reference Material of Nutrients in Seawater. Outcomes of the very successful 2015 edition of the inter-laboratory comparison were documented and followed upon through the publication of the report available for download here: http://www.ioccp.org/index.php/nutrients/2-uncategorised/74-2014-inter-comparison-study-of-certified-reference-material-for-nutrients-in-seawater

Finally, 71 laboratories from 31 countries participated in the IOCCP-JAMSTEC 2017/18 inter-laboratory comparison exercise of Certified Reference Material of Nutrients in Seawater. A report is being prepared is expected to be published towards the end of June 2018.

Workshops and Meetings

IOCCP workshop on Marine Carbon and Biogeochemistry Data (ICDC10 side event): The core mission for IOCCP at the 10th International Carbon Dioxide Conference (ICDC10) in Interlaken, Switzerland, was to organize and run a half-day community workshop focused on IOCCP's activities related to data management and synthesis product development. The IOCCP side-event on "Marine Carbon and Biogeochemistry Data Management and Synthesis" took

place on Wednesday, 23 August 2017 as an official part of ICDC10, and was attended by more than 50 scientists from 15 countries.

The event highlighted the accomplishments, plans and challenges of communities engaged in delivering to and using existing and planned marine carbon and biogeochemistry data products, such as SOCAT and GLODAP. Representatives of terrestrial and atmospheric carbon cycle research communities actively participated in the event and we used this opportunity to exchange perspectives on presented subjects.

Based on lessons learned during the development of SOCAT and GLODAP, the aim was to discuss (i) the challenges and opportunities related to connecting the carbon and biogeochemistry data currently available from several sources, and (ii) the need to build an integrated access point for several carbon and biogeochemistry data types from various observing platforms (ships, moorings, floats, gliders). Moreover, the five thematic sessions (surface ocean, ocean interior, time series, sensors, and general data management) discussed a pathway towards extending the existing and planned data products beyond primarily carbonate chemistry measurements and into a full scope of biogeochemistry EOVs, which in many cases are measured using novel sensor technology.

A detailed summary from the event can be found on IOCCP website: http://www.ioccp.org/index.php/more/317-summary-of-the-ioccp-side-event-on-marine-carbon-and-biogeochemistry-data-management-and-synthesis-23-august-2017-interlaken-switzerland. The side event focused on five main topics, briefly summarized below:

SOCAT - update and road ahead: Some of the issues discussed concerned automated data upload to SOCAT, and progress on the automation of the SOCAT metadata upload. Moreover, discussions were continued around possible future inclusion of additional parameters to SOCAT. The SOCAT community agreed to include other surface parameters like nutrients, dissolved inorganic carbon (DIC), total alkalinity (TA) in SOCAT without quality control and release them in a separate file. This might start for version 7 (due for 2019). There are ongoing discussions regarding the inclusion of surface ocean CH_4 and N_2O in SOCAT or as a parallel data product using SOCAT infrastructure. There is a growing need for observing non-CO_2 greenhouse gases in marine environment, e.g. CH_4 and N_2O. During the past few years, instruments measuring these two gases with the same frequency as is common for CO_2 measurements by IR (infrared) instruments have become available. They can be used in existing setups for surface ocean CO_2 measurements without much additional effort. This results in data sets that have CO_2 and N_2O and/or CH_4 measurements combined. There is interest from the observational and modelling community to combine these data streams. Discussions are being held with MEMENTO (MarinE MethanE and NiTrous Oxide) scientists regarding the strategy and procedures for such a combined effort to become more globally implemented.

GLODAP – Update and road ahead: There were two issues presented and discussed during the GLODAP session: (i) data quality control, specifically the pH measurements, and (ii) the inclusion of sensors-based data from biogeochemical profiling floats in the future releases of the data product.

Regarding the first issue, there are at least two challenges related to this issue: (1) often unknown accuracy of the potentiometric pH measurements, and (2) unsatisfactory consistency of seawater CO_2 system calculations. To tackle the first challenge, the group decided to form a 'pH task force' within GLODAP, to focus on determining the quality of existing potentiometric pH data and work on their inclusion in the GLODAP data product. To tackle the second challenge, there is a need for a working group on the improvement of the seawater CO_2 chemistry dissociation constants. These discussions have resulted in a SCOR working group application being submitted earlier in 2018.

Regarding the second issue, while the Biogeochemical Argo network is yet to transition into a sustained funding mode, there are data already being produced in large quantities and global data collections like GLODAP need to start taking advantage of the new technologies allowing an increase in the spatial and temporal data coverage. Best practices manuals for data quality assessment need to be updated so that the existing, high-accuracy, bench-top, instrument-based data products could benefit from the ever-increasing sensor-based data stream.

Time Series – Data coverage and availability: Development of a global, time series-based data synthesis product was proposed as an activity promising to attract interest from most sites and therefore serving as an axis for coordination. Such a product would have to serve a (set of) specific science goal(s) that, in turn, would have to be within scientific interest of participating sites. The ability to observe long-term variability in physical, biogeochemical and biological phenomena and short- to long-term interconnectivity between the processes governing this variability, puts time series in a unique position within the global ocean observing system and makes the potential synthesis product(s) an extremely valuable perspective. Comments from participants were very positive; however, it was cautioned that such an effort would require a number of very dedicated champions across disciplines and some dedicated funding for coordination and technical infrastructure.

Autonomous Sensors – What happens between unpacking the box and providing a useful information product: This session looked at almost revolutionary change in requirements, specific needs and capabilities for biogeochemical measurements made with sensors. Widening the scope of sensor measurements beyond the traditional IOCCP focus centred on the carbonate system requires careful assessment of sensors' capabilities to provide measurements with required accuracy and precision. The development of international standards for sensor operation and data management is critical to assure the quality of the data output in order for the community to be able to develop confidence in the same way there is confidence in the traditional methods of analysing the variables of interest.

The role of the IOCCP and wider GOOS community was discussed in the context of focusing the requirements for sensor measurements of most biogeochemical EOVs. This requires active coordination efforts between sensor manufacturers, the wider scientific community and funding bodies.

Carbon Data Management – Challenges and solutions: Discussions regarding data interoperability and therefore integration of the community-wide data management efforts filled a considerable part of the session. Currently, data exchange in our community is predominantly

based on exchanging physical copies of individual data sets. As a result, seemingly endless number of versions of a given data set reside at various repositories, creating considerable confusion amongst users and making data curation a daunting task. Examples of interoperable data exchange systems working in other communities were briefly described and a schematic solution designed for use in marine biogeochemistry was proposed. When implemented, these services will not only address the version control challenges but, perhaps more importantly, will allow our community to instantly aggregate data from various sources moving our community to the age of Big Data.

It was emphasized that collaboration amongst elements of data management within our community must overcome the currently predominant competition. The key to success seems to be a community-wide agreement allowing individual data centres to focus and specialize in specific services for the community. In such a landscape, a combination of interconnected services provided by highly specialized elements (with modest digital overlap) would meet the community needs. Each element would clearly communicate its function and funding needs, and therefore funding streams would not be directed to support efforts duplicating existing service providers, as is often the case today.

SOLAS–IMBeR–IOCCP–GCP–CLIVAR–WCRP scoping meeting on future ocean carbon cycle research (ICDC10 side event), 24 August, 2017, Interlaken, Switzerland

IOCCP was also very active in preparing for and participating in a scoping meeting aimed at developing a community-wide consensus on the future needs of the marine carbon research community. Having disbanded two of their carbon working groups in April 2017 and seeking new science directions, SOLAS and IMBeR proposed an open discussion amongst all and any programs interested in ocean carbon research. IOCCP, GCP, CLIVAR, WCRP C-challenge and SOLAS and IMBeR representatives expressed interest in such discussion and an initial scoping side-meeting during the ICDC10 in Interlaken was organized. The meeting was attended by 13 participants representing the above mentioned programs and was chaired by Nicolas Gruber, a former chair of the SOLAS/IMBeR Carbon Working Group 2.

It was positively noted that most major international programs dealing with the ocean carbon cycle were represented at this meeting. The following questions were discussed: 1) is there a need for an international coordination in ocean carbon cycle research that goes beyond what is currently done? 2) If the answer to 1 is yes, then (i) how broad should such an activity be, (ii) what are the key questions that should guide this activity, and (iii) what kind of organizational setup do we envisage/is possible?

The answer to the first question was a clear yes, perhaps most strongly expressed by IOCCP, which is currently lacking a scientific partner to develop and implement a science-based strategy related to marine carbon cycle. But the gap left after disbanding of the SOLAS-IMBeR Carbon working groups 1 and 2 is felt by the other organisations, too. For example, the lack of coordinated ocean carbon cycle simulations was mentioned both with regard to CMIP6 and in the context of GCP's efforts to establish annual carbon budgets. Many programs are currently including ocean carbon-related activities in their science plans, but in none of these organizations does the ocean carbon cycle receive adequate attention. This is neither efficient nor effective.

There was a less clear consensus with regard to the question of how broad such a new initiative ought to be. Many participants were of the opinion that any new initiative would have to go beyond the (inorganic) carbon cycle, and include other related biogeochemical properties such as nutrients, oxygen, and N_2O, i.e., very much in the spirit of the biogeochemical suite of Essential Ocean Variables that were developed through the GOOS Biogeochemistry Panel (IOCCP). At the highest level, delineating an initiative from the perspective of ocean health was mentioned as a way forward, particularly since such a line of argument would be attractive for potential funders and Future Earth. A somewhat smaller fraction argued more in favour of a rather focused approach, staying mostly with inorganic carbon, that is, within the scope of the past SOLAS/IMBeR working groups 1 and 2. In terms of the key scientific questions that would drive such a new initiative, most mentioned issues at the interface between biogeochemistry and physical oceanography, while biological processes were not identified. This might have been due to the lack of relevant expertise in the room. Concrete examples included decadal variability, meso- and submesoscale processes, optimal observing system design, multiple stressors considerations, and the interaction of the fluxes of heat and carbon fluxes and their storage.

There was also a clear consensus that there should be a single entity dealing with surface and interior ocean carbon issues of interest. On an organizational level, no clear consensus has emerged yet, although it was strongly stated that a clear narrative about what this organization should represent and what its goals and ambitions should be, is needed. Associating a carbon-focused activity with CLIVAR was viewed as not feasible/desirable, although the large benefits of a close collaboration were uniformly recognized. RECCAP2 was identified as a potential seed project.

Furthermore, a couple of options for structuring of this new entity were proposed. On one hand there was a proposal that such an organization needs at its core people who run the office and are responsible for coordination who provide scientific leadership. The emerging Ocean Knowledge-Action Network (Ocean KAN) framework was identified as a potential avenue to move forward. The approach offers the stability of a project office and a clear organizational status. Challenges with such an approach include the need for fund-raising related to staff and operations of the program as well as the need to overcome potentially adverse reactions of the community to creating yet another layer of coordination.

An alternative proposed approach was to form an explicitly cross-program group (ocean carbon think tank) that would be supported jointly by some or all programs with links to but no direct focus on ocean carbon (CLIVAR and/or IMBeR and/or SOLAS and/or GCP) and IOCCP. Such a group would include interested members of the member organization SCs as well as others. The approach offers potentially immediate activity and clear and direct connection to all existing interested programs. Challenges with this approach include the need for all involved existing programs to agree to co-sponsor the activities of such a cross-program ocean carbon think-tank and to jointly agree on details of the implementation of developed future activities.

In response, the individual representatives were asked to bring these issues as a discussion items back to their respective organizations to further explore proposed options, while considering others as well. In conclusion, the need for a science development-focused, international ocean

carbon/biogeochemistry program was clearly articulated and supported by all present. As the issue is considered pressing, it is our intention to continue this scoping activity until the community will arrive at a feasible solution.

Sixth meeting of the GOOS Steering Committee (GOOS-SC-6)

The 6th meeting of the GOOS Steering Committee (GOOS-SC-6) was organized on 11-13 September 2017 at James Cook University in Singapore. Among many issues discussed, the presentation of a draft GOOS Strategy and feedback from the SC was a major objective for this meeting. Apart from that, the SC was informed about the current status of the global ocean observing system and discussed the ongoing and planned actions of the individual GOOS structures, including the GOOS Biogeochemistry Panel.

The SC was presented with the new Terms of Reference of IOCCP as the GOOS Biogeochemistry Panel. The Panel requested support for a number of its activities, including those focused on increasing the cross-disciplinary harmonization of GOOS Panel activities, and promoting a more integrated view of GOOS through various communication channels with its sponsors, stakeholders and the community at large.

The SC recommended that all GOOS Structures consistently refer to the set of GOOS EOVs in their activities and thus highlight their importance in building the multidisciplinary, fit-for-purpose Global Ocean Observing System. Furthermore, the SC requested the GOOS Secretariat to prioritize support for one GOOS cross-panel meeting per year, that is, to continue and improve the harmonization of EOV and associated concepts used by the three disciplinary panels of GOOS. The organization of such a meeting was later carried out by GOOS Biogeochemistry Panel office. The meeting was held between 28 February and 3 March 2018 in Hobart, Australia, and was attended by all Panel Co-Chairs, Secretariat as well as other invited experts.

Furthermore, the SC suggested that the Variability in the Oxycline and its ImpaCts on the Ecosystem (VOICE) project consider applying for status as a GOOS Project. IOCCP is in charge of facilitating the process of developing the VOICE project as it provides a direct implementation of some of the goals set up for the new Oxygen Theme led by Véronique Garçon who is both an IOCCP SSG member and a Co-Chair of VOICE.

With respect to expanding coordination of carbon-relevant observing systems, the SC suggested that the newly forming surface ocean CO_2 observing network consider using the network specification sheet template to apply for status of a GOOS-endorsed observing network, fulfilling the criteria set up by the JCOMM OCG. This recommendation was followed through at the recent 9th session of the JCOMM OCG (OCG-9) meeting in Brest, France.

Finally, a new Task Team was formed within the GOOS SC with the goals of:

1. formulating a decision process for GOOS approval of standards or best practice guidance material, and its additional resource requirements

2. identifying how these should be published (in an IOC Manuals and Guides series wrapper, for example?) and promoted (in EOV specification sheets, the IOC Best Practices catalogue, etc.).

While working closely with the JCOMM OCG and other entities engaged in synthesizing the ocean standards and best practices activities as part of the Ocean Best Practices initiative, this task team will report to the SC. The IOCCP Director is a focal point and a liaison as a representative in several of these groups.

Variability in the Oxycline and Its ImpaCts on the Ecosystem (VOICE) Science Plan workshop, 13-15 September 2017, Monterey, Calif., USA

The VOICE Science Plan Workshop was a three-day event held on 13-15 September 2017, in Monterey, Calif., USA. The workshop was held back to back with the Global Ocean Oxygen Network (GO_2NE) third annual meeting (11-13 September 2017, Monterey, CA, USA), and was attended by 22 scientists from around the globe. It was the first opportunity to establish communication and initiate coordination of efforts leading up to the implementation of the VOICE project.

To this end, the first day of the meeting was organized as a joint event with the members of GO_2NE, many of whom are also active in VOICE. The complete list of workshop participants can be found in the Appendix to this document. One of the aims of the workshop was to collect information on the current observing system status with respect to all three FOO categories across all VOICE OMZ regions. A specific focus was placed on the societal requirements, including gathering information on who the stakeholders and key players engaged in observing system design and/or operation are. To this end, the participants were thus expected to discuss

- Societal issues related to oxycline variability and motivations for current observing system designs, as well as selection of a common focus application for VOICE (e.g., Benguela Niño/El Niño impact on fisheries)
- Associated scientific approaches with respect to a common set of phenomena and Essential Ocean Variables identified
- Challenges and opportunities for data sharing and expertise exchange
- Current status of literature review and historical data analyses with respect to VOICE
- Revised VOICE time line and work flow

To facilitate the process of readiness level assessment, all participants were provided with a comprehensive spreadsheet questionnaire to be filled out based on the information exchanged during the workshop, but also based on information collected from all relevant players and stakeholders over the course of a few months after the workshop. The readiness level assessment ought to result in an identification of gaps that eventually prevent the current observing system to deliver the information the stakeholders are asking for.

The outline for a common roadmap for GO_2NE and VOICE presented in the workshop report was deemed an important outcome with respect to enhancing coordination of observation and modelling efforts, leading to a better understanding of OMZ functioning, and in particular of

deoxygenation and associated phenomena, as well as building awareness of their consequences. The development of the actual roadmap for OceanObs'19 and beyond will require refinements in the near future, in particular, through assigning persons responsible for implementation (that includes both coordination and fund-raising efforts) of individual recommendations and actions agreed upon.

The VOICE workshop provided an excellent and in-depth summary of the regionally set requirements, observing capability, and data and information product management, forming a basis for comprehensive observing system readiness level assessment in accordance with the FOO guidelines. The information conveyed through presentations and during discussions will be documented and expanded through a spreadsheet questionnaire distributed among the workshop participants, to be filled out before the end of 2017. Despite the fact that only a limited number of stakeholder groups could be represented at this workshop, the participants have agreed to assume the role of champions in their disciplinary and/or geographic domains, or in a few cases, pointed at other experts potentially available to play that role. It is thus through the institutional functions and well-established professional networks of the champions that a continued dialogue with all relevant stakeholders is meant to be ensured.

A central point in the established plan of actions is the realization of a global literature review for VOICE. Specific means of achieving these tasks were proposed and actions undertaken. Recognizing the importance of performing historical data analyses prior to a successful VOICE conceptual model development, it was agreed that steps will be taken to initiate such analyses. In some cases, the data are readily available, but additional resources and expertise are needed to carry out the work. In other cases, the focus will be on attempting to mobilize the existing data and information products, for example through unprecedented integration of oceanographic and higher trophic level data.

In order to enable progress of VOICE into its implementation stage beyond 2019, the group has agreed to review data-sharing agreements by September 2018. The regional observing system champions will therefore act on the potential opportunities to increase access to local information and eventually report on the level of data availability for VOICE and the global community.

The full workshop report (www.goosocean.org/voice-mbari-report) provides a detailed account of arriving at the outcomes above, and includes important information on many general as well as very specific issues that are critical to the development of the VOICE Science Plan and its future implementation.

GODAE OceanView International School: New Frontiers in Operational Oceanography

Maciej Telszewski was an invited lecturer during GODAE Ocean View International School "New Frontiers in Operational Oceanography", 2-13 October 2017, Mallorca, Spain.

The underlying objective of four lectures was to show the ever-growing capacities of the biogeochemical observations from sensors and their usefulness in data assimilation efforts, leading to relevant forecasting activities. However, the lectures provided a wider context and tried to connect the current societal (and scientific) needs for information with current

information delivery at the level of data products available for direct use (e.g., local management) and indirect use (e.g., local, regional and global model projections). One take-home message related to the above context was that technology (sensors) is only relevant if it becomes a part of a well-designed (driven by needs) multi-parameter and multi-platform observing system. Another one reflected on the fundamental need for absolute scrutiny with data quality assurance when it comes to sensors. The logistics of calibration and validation is often more difficult and troublesome with new sensors then with more traditional instruments; however, we will only be able to inform management decisions and model projections if we provide verified values and not registered numbers.

Combined lectures will be published as a chapter of a book to be published in late 2018. The book will be based on all the lectures given during the school.

Ocean Best Practices Workshop, 15-17 November, Paris, France

The Best Practices Workshop, held in Paris, in November 2017, was organized by the AtlantOS OBP WG in collaboration with the ODIP II project and the OceanObs RCN (http://sites.ieee.org/oceanrcn/) to better understand the needs of the ocean observing community in supporting the creation and dissemination of best practices. Over two and one-half days, thirty-seven participants representing a wide range of international organizations contributed insightful recommendations for the structure, processes and implementation of the OBP system.

The ocean carbon and biogeochemistry perspective were presented by IOCCP's Rik Wanninkhof and Maciej Telszewski. While focusing on repeat hydrography procedures employed by GO-SHIP, common protocols and standards, data/metadata documentation, clear accuracy and requirements, and robust data management and distribution system were noted. Furthermore, the group was made aware of a subtle difference between a GO-SHIP-required standard operating procedure (SOP) and a community best practice. Maintaining and updating SOPs as a volunteer effort is a challenge for GO-SHIP, and this challenge constituted a key discussion point at the workshop.

A wide range of challenges in moving forward with respect to Biogeochemistry OBPs were discussed, among which is the diversity of types of methodology documents (manuals, guides, standard operating procedures, standards and reference materials), as well as multiple steps and procedures often described in separate documents (best practices for deployment and sampling; data retrieval and formatting; calibration/validation; reference materials and standards; primary quality control and (near) real-time and delayed mode; secondary quality control). Moreover, completeness of documentation is rarely achieved and the mix of sensors with platforms may require different methods or practices.

IOCCP proposed a structure allowing the organization of the different types of best practices according to EOVs and observing networks on the one hand, and various observing steps/procedures involved in any ocean measurement on the other. Several practical recommendations for tackling the complexity in the ocean best practices realm were also provided:

- to agree upon and implement a structured, searchable and updatable database for existing web-based documentation;
- to develop a BP registration scheme; and
- to develop multilingual media resources allowing new users to follow practical and theoretical steps across vertical and horizontal categories in the proposed structure.

For more information on the workshop goals and outcomes, please see the full workshop report at:
https://www.oceanbestpractices.net/bitstream/handle/11329/410/BP_Workshop_Paris_2017_Proceedings.pdf?sequence=4&isAllowed=y

3rd AtlantOS General Assembly and associated workshops, 21-25 November 2017, Las Palmas, Gran Canaria, Spain

The General Assembly, 22-24 November 2017: The focus of the 3rd AtlantOS General Assembly (GA) was to present the achievements of individual AtlantOS working groups, with particular emphasis on the analysis of the effectiveness of cooperation of these working groups in order to optimize and improve the integrated ocean observation system in the Atlantic. Equally important was the need to develop a plan for the effective dissemination of research results and the resulting recommendations among a wide range of users of the observation system, mainly through the co-creation of the so-called Blueprint for Atlantic Ocean observing. Apart from presentations and discussions in plenary, a number of workshops were organized around the GA to meet the above mentioned objectives. A brief account of only a few involving IOCCP is provided below.

Review of observing system requirements: joint WP1-WP8 session, 21 November 2017: The goal of this session was to encourage members of WP8 and WP1 to discuss means of integrating the WP8 Data Adequacy Report approach with the WP1 strategic mapping approach to best capture the essential information about requirements in the final outputs of AtlantOS, including the Blueprint. Prior to a group discussion, the two approaches with initial suggestions for integration were introduced through short overview presentations:

- on "Evaluating AtlantOS fitness for the production of societal benefit products using the EMODNnet CheckPoint Data Adequacy reporting approach", and
- on "A strategic mapping approach to identifying AtlantOS requirements across the ocean observing value chain: from applications to phenomena to variables to observing networks," presented by the IOCCP Project Officer

The latter approach has been applied by WP1 to develop a strategy for a comprehensive capacity and gaps analysis, described in AtlantOS D1.3 report. As concluded in the report, "analysing the existing observing capacity in sampling appropriate EOVs in sufficient space/time resolution in the Atlantic Ocean can only be done in reference to each of the multiple observing objectives individually – and considering requirement (input) and observing products (output), informing society about ocean state." While the report provides examples of generic gaps in the system, it does not look at specific applications and societal benefit products in detail. It is in this area that the group can seek complementarity with the results of Data Adequacy reports produced by

WP8. Moreover, the opportunities for using WP1 outputs to expand on the data requirements of WP8 case studies beyond those identified through EMODnet CheckPoints could be explored.

A number of actions and recommendations were identified as a result of the discussions held during the workshop. These have important potential implications also in the global context for the work of GOOS Biogeochemistry Panel as it tries to better align the requirement setting process for coastal and open ocean end users alike.

- To pull the two glossaries of terms used by WP1 and WP8 in their respective methodologies into a single document, accessible to members of both WPs.
- To ensure that the EOV development/management is an iterative process
- To consider human impacts in existing and/or future EOVs as Human Activities
- To increase the consideration for the 'global coastal ocean' in the EOV framework

Atlantos OSSE workshop – 24 November 2017: AtlantOS WP1, WP2 and WP3 task leaders (and partners) participated in a workshop that on one hand provided a status update on Observing System Simulation Experiments (OSSEs) performed or yet to be performed within AtlantOS, and the other hand was a forum for providing detailed inputs (i.e., specifications) on metrics (e.g., integrated quantities such as transport, heat content) to assess the performance of the different observing system scenarios. Of particular interest were metrics related to societal benefits of ocean observations (WP1).

IOCCP contributed with recommendations for maximizing the benefit of running OSSEs targeting Biogeochemistry and multidisciplinary EOVs: Inorganic Carbon and Ocean Colour. Outcomes of the workshop helped set up the remainder of the OSSE scenarios and narrowed the list of metrics used to interpret the OSSE results for the benefit of reviewing the initial set of observing system requirements.

SDG 14.3.1 Methodology Development Workshop, 16-18 January, 2018, Paris, France

In January 2018, GOA-ON members and invited experts met in Paris at the Intergovernmental Oceanographic Commission of UNESCO to develop the indicator methodology for target 14.3 (average marine acidity measured at an agreed suite of representative sampling stations). IOCCP was represented by Dick Feely, Kim Currie and Maciej Telszewski.

The methodology provides guidance to scientists and countries in terms of what measurements are needed and how often, as well as how to report the collected information so it is transparent and traceable. In this way, the group is leveraging its scientific and policy expertise to develop a guiding vision for how ocean chemistry, and in future biological data, can be collected and shared worldwide in support of the Sustainable Development Agenda.

Once finalized and approved by appropriate partners in the process, the methodology will be implemented by the UN Member States and periodically assessed for its fitness-for-purpose. IOCCP Experts will continue to contribute to this important process.

Surface ocean CO_2 observing network kick-off meeting, 11 February 2018, Portland, Oregon, USA

IOCCP and U.S. NOAA held the kick-off meeting of the surface ocean CO_2 global observing network on February 11, 2018, just prior to the Ocean Sciences Meeting in Portland, Oregon, USA. The meeting was attended by invited participants who represented the largest operators of surface water CO_2 operations and/or activities relevant for network development. The following foundational points were addressed at the meeting:

- A listing of current assets of each group
- Creation of a network map
- The level of interest in forming a coordinated global network
- Discussion on targets, metrics, deliverables and products
- The ability and interest to provide real-time data display
- The repository and presentation of real-time data
- Delayed-mode data
- Standard operating procedures
- Resources required to establish a network (including "pay to play" options)
- Means to secure resources

The participants of the kick-off meeting decided that specific targets and metrics need to be developed to assess the efficacy of the network and its performance. Network participants will develop such network-wide targets and metrics, which will aid in the network's management and coordination. These targets and metrics will lead to deliverables that, to some extent, will mimic the successful Argo network. They will include real time transmission and dissemination of all data in the network, real-time tracking of assets, delayed mode quality controlled data including uncertainty estimates, and biannual releases of all data in the network in the form of collated data and maps. Participants of the network will confer on a regular basis to discuss data products and publications resulting from the data obtained in the network.

From a network and consistent data delivery perspective, it is desirable to have a single operator and uniform instrumentation, or at least strong top-down control to implement an observing system. However, this is seldom feasible for global ocean networks since the ocean is the global commons with many different independent observers and stakeholders. To this end, kick-off meeting participants decided to develop a framework that will use existing platforms and operations with specific focus on:

- Well-quantified accuracy and precision of measurements following established recommendations
- Rapid and consistent data delivery, including near real-time and delayed-mode data
- Inter-comparison and verification of different operations
- Recommendations on expansion of parameters that would be incorporated across the network

Initial focus on entraining the major groups with successful programs into the network and working with current multi-institutional efforts such as the marine element of the pan-European

Research Infrastructure: Integrated Carbon Observation System - Ocean Thematic Center (ICOS-OTC), NOAA SOOP-CO_2 and mooring-CO_2., for

- Addressing data gaps
- Mutual aid in maintaining operations and advocacy for sustained resources
- Assessing evolving needs of operators and stakeholders

A prospectus for the surface ocean CO_2 observing network will form the main outcome of the kick-off meeting. It will be shared with the marine biogeochemistry community after it is reviewed by JCOMM OCG.

Ocean Sciences Meeting, 11-16 February 2018, Portland, OR, USA

As usual, the Ocean Sciences Meeting gathered a critical mass of oceanographers from around the world and, in addition to being the most effective forum for information exchange in the field, it provided an opportunity for several meetings. IOCCP utilizes this critical opportunity to arrange face-to-face meetings of several relevant groups for coordination activities. A list of the more formalized meetings include:

- IOCCP/NOAA Session OC010: The Global Ocean Acidification Observing Network, GOA-ON: linking local information globally
- IOCCP and SCOR WG147 Session BN 007: Biogeochemistry and Nutrients in open ocean waters: Sustainable Ocean Observations and Time Series Efforts
- IOCCP and NOAA Session PL005: From WOCE through CLIVAR to GO-SHIP: Results from Global Repeat Hydrographic Surveys

Besides organizing and co-chairing the above sessions, IOCCP SSG members have attended several side meetings of many formal and informal Panels (OceanObs'19, GOOS Framework for Ocean Observing, COMPONUT, Marine Carbon Think-Tank).

GOOS Cross Panel and Executive Meetings

The rationale for the Cross-Panel meeting, held on 28 February – 3 March, and its objectives can be summarized with the four points below:

Objective #1: To reconcile the operational and scientific branches of the value chain to better present and communicate the value of the global ocean observing system

Objective #2: To harmonize the list of GOOS Applications and Scientific Questions to which information from observations should be delivered across the disciplines

Objective #3: To harmonize the list of GOOS phenomena in connection to GOOS Applications/Questions, and not just EOVs

Objective #4: To agree on a pragmatic approach and time plan to implement the meeting outcomes in the Strategic Mapping, and if relevant, in the revised version of EOV Spec Sheets

Central to arriving at these objectives was a critical gap (highlighted by the observing community and recognised by the GOOS Panels) in cross-panel integration and functional delivery to the three core outcomes/themes addressed by GOOS. This meeting was held in direct response to the outcomes of the 6th GOOS Steering Committee meeting (GOOS-SC-6) meeting in September 2017, during which GOOS Secretariat was requested to:

> *"prioritize support for one GOOS cross-panel meeting per year to continue and improve the harmonization of EOV and associated concepts used by the three disciplinary panels of GOOS. Moreover, SC agreed that there was a need to focus our work on applications/scientific questions, and relate these to top-level requirements; as well as integrate the concept of readiness in all areas of the Strategic Mapping."*

The meeting objectives, in particular the importance of the GOOS Strategic Mapping, were set in the context of the GOOS Strategy document through an introductory presentation. It was emphasised that there is a need to better connect and communicate to end users the links between observations and the suite of societal benefits GOOS aims to support. Building/Inviting "User Pull" and engagement with users outside the science community are high priorities of the GOOS Strategy. The detailed status and needs of the GOOS Strategic Mapping were also presented.

While only two of the four workshop objectives were fulfilled during the meeting, several actions were identified which will ensure that the remaining objectives will be met over the course of 2018. These actions and recommendations are listed in the workshop report available here:
http://goosocean.org/index.php?option=com_oe&task=viewEventRecord&eventID=2229.

During the workshop it also became apparent that there is a need for more frequent interaction between the GOOS Expert Panel Chairs and Secretariats. In the months following the Cross-Panel Workshop the frequency of such communication has increased, leading to an efficient realization of the actions identified both at the Cross-Panel and the GOOS Executive meeting.

It is the intention of GOOS Central Office to maintain a schedule of regular annual cross-panel meetings according to the request of the GOOS SC and in favour of implementing the vision and mission of an integrated, multidisciplinary GOOS delivering essential information to the society.

Integrated Carbon Observation System (ICOS) Ocean Thematic Centre (OTC) workshop on ocean CO_2 measurements, 7-8 March 2018, Bergen, Norway

The purpose of this meeting was to discuss experience with, and improvements of, three systems used by stations in the Integrated Carbon Observation System Ocean Thematic Center (ICOS OTC): the General Oceanics underway pCO_2 system, and Contros' HydroFIA TA and HydroC CO_2 systems. The goal was for participants to come away with a better understanding of the systems and for the companies to receive feedback and ideas to improve their systems. The meeting aimed also to foster better communication between the vendors and customers. Topics discussed also included improving atmospheric measurements and synergizing with the atmospheric community, new platforms and new sip recruitment, standardizing data processing and products, and alternative preserving methods for discrete samples.

9th Session of the JCOMM Observation Coordination Group (OCG-9), May 14-17, Brest, France

IOCCP represents the biogeochemistry community at this cross-platform cross-disciplinary observational forum. The needs, challenges and plans of the biogeochemistry community become an ever-growing proportion of OCG meetings, which reflects changes in our capacity, but also is a result of a decade-long advocacy by several international and intergovernmental organizations, including IOCCP. The outcomes of the 9th session from the biogeochemistry perspective are summarized below. All the meeting information, including the final meeting report, background documents and Power Point presentations, can be downloaded from the meeting website: http://www.ioc-unesco.org/index.php?option=com_oe&task=viewEventDocs&eventID=2120.

1. A comprehensive overview of biogeochemical observations on all platforms represented at the annual OCG meeting
    - Each observing network that aspires to conduct biogeochemical observations should report on the status, including number of assets in the water, sampling duration and frequency, which EOVs etc.
    - JCOMMOPS should serve as the information platform to derive the current status from.

2. Annual evaluation of TRLs of all observing networks conducting biogeochemical observations according to FOO TRL table from page 11.
3. Guidance to the Time Series community on how to organize into an observing network
    - This capacity is lacking. Scattered efforts by IOCCP, US OCB and IGMETS have dissipated since 2013.

Project Office

Kim Currie as new IOCCP Co-Chair

At the beginning of 2018, following the approval of SCOR and IOC-UNESCO, IOCCP announced that Kim Currie (NIWA, New Zealand) has joined Masao Ishii at the helm of the IOCCP SSG. In her day job, Kim is a scientist with NIWA and University of Otago in New Zealand, with a focus on marine carbon chemistry. She is responsible for surface ocean carbon programs and coastal ocean acidification observations in New Zealand, and is actively involved in a number of globally coordinated activities, such as SOCAT, GOA-ON and IOCCP. As the new Co-Chair, Kim has already demonstrated great energy and aptitude in pushing forward various IOCCP activities over the past several months.

Kim has replaced Toste Tanhua, who enriched IOCCP with his dedicated service for the past decade. Recognizing Toste's proactive attitude and visionary leadership, which benefited marine biogeochemistry and ocean observing in general, IOCCP very much looks forward to his continued community service in his new role as co-Chair of GOOS.

Website and newsletter

Over the past year, IOCCP put strong emphasis on maintaining a regular and timely communication of news, events and opportunities relevant to the marine carbon and biogeochemistry community. In the period of April 2017 to April 2018, the IOCCP Office released 3 issues of the *IOCCP Conveyor*, over 80 news items and posted a few dozen job announcements. Relative to the May 2016-May 2017 period, a growing number of website users was recorded for 8 out of 10 top countries ranked in terms of users' locations. The average number of users visiting the IOCCP website is currently around 500 per month, ranging from a few to more than 100 per day.

IOCCP has continued to hold individual teleconferences with SSG members responsible for their themes, to discuss and update the relevant pages on the IOCCP website, including careful analysis of existing and missing content, as well as connections to resources available elsewhere. The template for the thematic pages is currently being modified to allow a more visually appealing and easier to navigate content.

Funding for Project Officer

Over the past year, the IOCCP Office has engaged in several fundraising activities to ensure continued support for the second staff member in the Office. As a sub-contractor in an ECMWF tender C3S_511 (Quality assessment of ECV products), partial funds have been secured for the Project Officer to continue for another 2-year term from January 2019 onwards.

Publications

Breitburg D, ..., Telszewski M, et al. (2018). Declining oxygen in the global ocean and coastal waters, *Science* 359 (6371), doi: 10.1126/science.aam7240.

Future Directions

Influencing the next decade of oceanographic research by OceanObs'19 Community White Papers

IOCCP has been very active in responding to the call for submitting abstracts for OceanObs'19 Community White Papers (CWP). In its several contributions, IOCCP seeks to galvanize several ocean observing communities to improve coordination of regional and national efforts to better observe the global ocean, to better respond to the joint scientific and societal needs of a fit-for-purpose ocean observing system, and to maximize the overall benefit of more integrated observing. IOCCP SSG members and Project Officers are leading the following accepted contributions:

1. International Ocean Carbon Coordination Project: Enabling marine biogeochemistry observations for scientific and societal needs locally, regionally and globally.
   Lead author: Maciej Telszewski; co-authors include: all IOCCP SSG
2. The Global Ocean Observing System 2030 Strategy, building on a decade of progress

Lead author: Albert Fischer; co-authors include: Kim Currie, Masao Ishii, Maciej Telszewski, Artur Palacz

3. Demonstrating the value of enhanced multidisciplinary sustained observations for understanding variability in the oxycline and its impacts on the ecosystem (VOICE): a prerequisite for raising society awareness of ocean deoxygenation trends
   Lead author: Veronique Garçon; co-authors include: Maciej Telszewski, Artur Palacz
4. The Global Ocean Acidification Observing Network: a worldwide collaborative approach to address ocean change serving science and society
   Lead author: Libby Jewett; co-authors include: Richard Feely, Cristian Vargas, Benjamin Pfeil, Maciej Telszewski
5. Evolving ocean time-series: An eye toward integration and synthesis
   Lead author: Heather Benway; co-authors include: Bjoern Fiedler
6. Towards including atmospheric CO_2 data from the oceanic community into the global high-accuracy atmospheric CO_2 network
   Lead author: Penelope Pickers; co-authors include: Rik Wanninkhof
7. The Global Ocean Ship-Based Hydrographic Investigations Program (GO-SHIP): A platform for integrated multidisciplinary ocean science
   Lead author: Bernadette Sloyan; co-authors include: Masao Ishii, Rik Wanninkhof
8. A Future-facing and Sustainable System for Coordinating Best Practices during the Next Decade of Ocean Observation
   Lead author: Jay Pearlman; co-authors include: Maciej Telszewski

Surface CO_2 observations

There are two top priorities for near-future actions planned by IOCCP under this theme: (i) consolidation of the surface ocean CO_2 observing network, and (ii) validating and improving the quality of atmospheric CO_2 data from the ocean community CO_2 systems.

Establishment of the surface ocean CO_2 observing network is expected to have a high scientific impact as it responds to the need to provide high-quality data to constrain global and regional air-sea CO_2 fluxes on seasonal timescales, to determine trends and patterns in surface water CO_2 levels, and to elucidate the factors influencing the patterns on daily to decadal time scales, and to provide important elements of an OA monitoring system. IOCCP is looking forward to promoting the creation of new data-based products from the network, to be used for scientific analyses, development of indicators of the variability in ocean ecosystems, and allowing biogeochemical and socio-economic assessments. In particular, the products will be critical for determining the effects of OA on marine ecosystem health, and quantification of anthropogenic carbon uptake on a variety of scales.

Consolidation and further development of this effort over the coming months and years will rely heavily on implementation strategies, standard operating procedures and lessons learned of the smaller national and multi-national entities (e.g., ICOS-OTC in Europe, NOAA in the USA or NIES in Japan). In design and execution, it will look at protocols and procedures of other established networks such as Argo, GO-SHIP, the CMDL Atmospheric CO_2 network, and the Advanced Global Atmospheric Gases Experiment (AGAGE). At the same time, the network is envisioned to become part of JCOMM-SOT (Ships Observation Team) and report to the

JCOMM OCG (Observation Coordination Group). These are the relevant operational entities charged with implementing GOOS.

To realize the second priority for this theme, IOCCP will engage in dialogue with the atmospheric community, with a goal of organizing a technical workshop on quality of atmospheric measurements from ships. Although there are many ocean regions that are regularly visited by research vessels and commercial ships with systems that measure CO_2 in the surface seawater and in the overlying atmosphere, the atmospheric CO_2 data from these ocean community CO_2 systems ($SeaCO_2$) does not typically meet the rigorous accuracy standards of the atmospheric community, as set out in World Meteorological Organization recommendations.

Validating and improving the quality of $SeaCO_2$ data will provide mutual benefits to both the oceanic and atmospheric communities and, even more importantly, will better constrain the global carbon cycle in Earth System models used for climate and ecosystem assessments (IPCC, IPBES). For example, accurate $SeaCO_2$ data from ocean regions can be used by atmospheric scientists to constrain atmosphere-land CO_2 fluxes. And accurate $SeaCO_2$ data can be used by ocean scientists to calculate air-sea CO_2 fluxes with higher accuracy, rather than relying on interpolated atmospheric CO_2 data products, which can lead to significant biases.

IOCCP, in collaboration with WMO's Global Atmosphere Watch (GAW) and WMO/IAEA'a Greenhouse Gases and Measurement Techniques (GGMT) group, will provide support to the surface ocean carbon observational community centred around the newly forming surface ocean CO_2 observing network in order to develop dedicated instrument and gas-handling protocols allowing us to achieve sufficiently accurate $SeaCO_2$ data using existing measurement systems. Also, as a joint atmospheric-oceanic community effort, it is expected that a set of standard operating procedures that summarise best practice in shipboard atmospheric CO_2 measurements will be provided. This joint-community resource, combined with additional collaboration between the atmospheric and oceanic communities, should lead to more high-accuracy $SeaCO_2$ data over the coming decades. A long-term vision and strategy for how this effort will benefit a growing number of end users benefiting from information collected at sea will be presented in the form of an OceanObs'19 CWP, jointly led by members of GAW and IOCCP.

Data Synthesis Activities: Surface Ocean

Following the discussions held at a SOCAT session of the IOCCP side-event on "Marine Carbon and Biogeochemistry Data Management and Synthesis" (23 August 2017, Interlaken, Switzerland), the SOCAT community agreed to include additional surface parameters like nutrients, DIC and TA in SOCAT without quality control and release them in a separate file. This might start for version 7 (2019). There are ongoing discussions regarding the inclusion of surface ocean CH_4 and N_2O in SOCAT or as a parallel data product using the SOCAT infrastructure. The latest aspect of this issue concerns the inclusion of surface ocean fCO_2 calculated from other parameters most often based on sensor technology installed on floats and gliders. This issue will be taken further by SOCAT and relevant IOCCP groups, with the initial focus on the quality assessment of such data. After many years of development, all SOCAT data are being submitted through the Upload Dashboard. Despite several advantages of this solution, some challenges still exist and will be resolved over the coming years. Also despite significant

progress of the automation of the SOCAT metadata upload several issues still remain in the development phase. The aim of the activity is to automate quality control of the metadata, in order to improve the metadata quality and to reduce the annual quality control burden on individual PIs. The objective is to have the automated metadata upload in place for SOCAT version 8 (2020).

To this end, a 2-day SOCAT metadata Automation Team technical workshop will be organized in September 2018. The workshop will invite about 10-15 participants, and will be co-organized by the SOCAT Team, University of Bergen and NOAA PMEL. In addition, IOCCP plans to co-organize a session at the 2018 AGU Fall meeting initiating an international collaboration of researchers implementing machine learning in development of data synthesis products in marine biogeochemistry.

Ocean Interior Observations

A key priority for IOCCP's work under this theme is the necessary update of the GO-SHIP Repeat Hydrography Manual ("Hydro Manual") (http://www.go-ship.org/HydroMan.html). In its current edition (V1), a chapter dealing with the measurements of dissolved organic matter (DOM) is missing. The Hydro Manual also does not comprise Standard Operation Protocols for fluorescence or backscattering and they became urgently needed in the light of rapid development of the Biogeochemical Argo (BGC Argo). A rapidly increasing number of floats carry these sensors and operators often rely on GO-SHIP data for calibration and validation.

Data Synthesis Activities: Ocean Interior

GLODAP is the interior ocean data synthesis project of IOCCP and an important GOOS data product, reporting on a range of Essential Ocean Variables, as well as additional interior ocean variables. The GLODAP Reference Group (which includes several IOCCP members) will ensure the continuous provision of updated interior ocean biogeochemical synthesis products based on data from ship-based surveys. It will do this by adding data to GLODAPv2, after subjecting them to primary and secondary quality control. After completion of each round of the global repeat hydrographic surveys (the current round is scheduled for completion in 2023), this group will be responsible for instigating a new full version of GLODAP (the next one will be version 3), which will entail a full reevaluation of the entire product. Before then, cruises will be assessed for bias with respect to GLODAPv2 and the intermediate products released will be named GLODAPv2.YYYY where YYYY is year of release.

To this end, GLODAP RG has planned its first workshop for 24-28 September 2018 in Seattle, Washington, USA. The first half of the workshop is planned around developing automation software for processing. The other half will be a meeting of the RG aimed to reach agreement and populate the adjustment tables. It is likely that the outcome of this workshop will be a new GLODAPv2018 version published. The workshop will be partially funded by IOCCP.

As discussed at the GLODAP session of the IOCCP side-event on "Marine Carbon and Biogeochemistry Data Management and Synthesis" (23 August 2017, Interlaken, Switzerland), there are two main issues to be resolved by the GLODAP community. The first issue concerns

inclusion of pH data. The second issue concerns inclusion of sensor-derived data from profiling floats. Both issues will be widely discussed during the RG meeting in Seattle.

Time-Series Efforts

Development of a new, global, time series-based data synthesis product will be one of IOCCP's foci over the next 3 years. This activity promises to attract interest from most time-series sites and therefore has a large potential to serve as an axis for coordination. Such a product would have to address a set of specific science goal(s) that, in turn, would have to be within the scientific interest of participating scientists. The ability to observe long-term variability in physical, biogeochemical and biological phenomena and short to long-term interconnectivity between the processes governing this variability, puts time series in a unique position within the global ocean observing system and makes the potential synthesis product(s) an extremely valuable perspective. During discussions with several time-series operators and funders, ocean acidification emerged as one critical phenomenon lacking a data-based global synthesis product. The long-term vision for how time-series observations deliver essential information in response to societal needs will be presented in an OceanObs'19 CWP, to be written jointly by members of IGMETS, U.S. OCB, IOCCP, OceanSITES and other international coordinating bodies.

Undoubtedly, the successful creation of time-series data synthesis products will require further strengthening of joint coordination efforts of IOCCP, U.S. OCB, OceanSITES and others, as well as stronger engagement of the community. Early discussions among the international partners initiated efforts to revitalize the global time-series website and mailing list, currently managed by U.S. OCB. Moreover, plans for a first workshop on time-series data synthesis products are underway. The workshop, which will likely benefit from joint organization with GLODAP's RG meeting, would involve 10-15 participants representing the main ship-based and fixed-point time-series observatories around the globe.

One challenging aspect behind creating coherent data synthesis products is the pattern overload stemming from our ability to observe with ever-increasing frequency and coverage. In the age of big data from satellite missions, in situ campaigns, Earth System model simulations and high-resolution reanalysis products, machine learning tools provide increased capabilities for data mining, pattern recognition, trend detection and other applications. While their utility has been demonstrated in other areas of Earth Science, it is now also becoming apparent in marine biogeochemistry and other oceanographic disciplines. IOCCP plans to partner with most developed groups involved in "intelligent" mapping and create an active Exchange Forum aiming to assess the progress made to date, present current needs and opportunities for use of these techniques to create data synthesis products, foster collaboration and organize the community around new data synthesis efforts.

Ocean Acidification

As in the case of the Time Series theme, it is likely that the biggest impact that IOCCP might have on OA observations is to help with conceptualizing, developing and implementing OA-related synthesis product(s). The challenge is not only in getting financial support for data synthesis products, but also in obtaining adequate information from end users (e.g., policy

makers) on the exact requirements for such product(s). IOCCP is considering helping to organize a dedicated meeting to discuss issues like the types of the products we need, how they are going to be produced, and how this activity is going to be funded. For example, does a global map of pH and, eventually, a map of change in pH over time, meet the expectations of policy makers or national/regional managers? Such a workshop would ideally be combined with discussions on future time-series synthesis products, for which OA and its biological implications are a fundamental component.

Within GOA-ON there is capacity to produce data synthesis products for both water quality and climate study uses, but GOA-ON (with strong IOCCP leadership) must take responsibility for providing advice on requirements for such products based on several issues, for example, the quality of measurements which will determine the types of platforms and sensors with which we will try to augment the current observing system. IOCCP will rely strongly on its scientific partners (SOLAS, IMBeR, CLIVAR) and the Biology & Ecosystems Expert Panel of GOOS to take that step of driving the generation of new information products.

On the regional level, IOCCP will continue to support further development of the Latin American Ocean Acidification network (LAOCA), and together with GOA-ON and OA-ICC promote increased coordination and capacity building for OA observations in Africa. Priority will be given to activities leading to comprehensive, hands-on training courses that result in long-term legacy products (e.g., manuals, best practices, video lectures, instructions).

Framework for Ocean Observing (FOO)

The so-called FOO 2.0 project is designed to understand successes and challenges in applying the FOO, why it was adopted to support observing activities, and how it has assisted in development and implementation. While some community feedback on improving or expanding the FOO has already been collected, more structured consultations are needed, especially with the individual GOOS structures that pose the greatest experience in implementing the FOO, and thus can point at both weak and strong sides. At the same time, feedback from users of ocean data is needed to make sure that the proposed FOO cycle does in fact help increase the readiness level of the observing system in that it delivers the outputs according to the societal requirements. To this end, and as a first instance, IOCCP will contribute to an OceanObs'19 CWP on the vision for a FOO 2.0.

The development of first EOV Specification Sheets has been the core activity representing the efforts of GOOS to implement the FOO. Parallel to the FOO 2.0 project, it is critical that the structures of GOOS not only promote the use of EOVs and associated concepts, but also that they agree upon a consistent and reliable EOV curation procedure. IOCCP, as the GOOS Biogeochemistry Panel, has taken steps towards proposing such a procedure, which would enable regular annual to bi-annual updates of the EOV Specification Sheets based on new input and feedback from targeted experts as well as the ocean community. Such updates are critical considering still many gaps and inconsistencies can be found in the Specification Sheets, especially for EOVs with relatively low readiness levels. The proposed curation procedure will assume that IOCCP SSG members, though not necessarily experts on the EOVs, will take up the

roles of EOV curators, responsible for moderating community feedback and soliciting expert inputs and updates where and when necessary.

Apart from the regular updates, there are plans to translate EOV Specification Sheets from static PDF documents to interactive and searchable documents connected to a large database of observing system elements and structures collected within the so-called GOOS Strategic Mapping. It is anticipated that the Mapping database and associated input and output interfaces will be ready for public use in early 2019.

Another, more integrated and complex approach to implementing the FOO is through multidisciplinary pilot projects such as the ones originating from the IMSOO workshop in February 2017. Currently, there are two ongoing international initiatives which continue to develop the projects proposed during IMSOO: (i) the SCOR Working Group 154 Integration of Plankton-Observing Sensor Systems to Existing Global Sampling Programs (P-OBS), stemming from the IMSOO demonstration theme on "Plankton community changes", and (ii) the VOICE project, stemming from the IMSOO demonstration theme on "Oxygen minimum zones." As described extensively elsewhere in this report, IOCCP is strongly involved in leading the VOICE project through its preparatory phase and onto the implementation phase, envisioned to begin after the OceanObs'19 Conference. If successful, VOICE will demonstrate the added value of optimizing and enhancing the ocean observing systems through integrating the disciplinary components to better respond to societal requirements with respect to a given application, such as efficient marine resource management under decreasing oxygen conditions.

Instruments and Sensors

IOCCP plans to organize its second International Sensors Summer Course in June 2019. This is motivated by the very successful first edition, and numerous requests for more such comprehensive training opportunities. The venue for the Summer School will again be the Sven Loven Centre for Marine Infrastructure in Kristineberg, Sweden. The first half of 2019 will see IOCCP devote a substantial amount of resources to preparing the second edition of the Course. The facilities are already booked for 8-22 June 2019. The booking includes accommodation for 40 people and lab space to work in 4 separate groups, plus a lecture hall. All bookings are based on the experience with the first edition of the course.

The proposed course will tackle issues that span from basic usage of the technology including specific field advice from experienced users/lecturers to data quality assurance and reporting standards and protocols. The proposed course will target commercially or readily available biogeochemical sensors. This course also builds on other activities that have taken place in the recent past in the attempt to globally expand the correct usage of autonomous biogeochemical sensors (cited in the Relevant Publications section of this application). Some of this work includes the evaluation of the 'state of readiness' of the technologies, critical for the establishment of an integrated observing network.

The primary goal of the course will be to provide in-depth experience/training on the use of a basic suite of biogeochemical autonomous commercial sensors, and to discuss data and metadata reporting and quality. The sensors to be utilized include those that are "mature" and

commercially available, including oxygen, carbonate system (pH, pCO_2), and nutrient sensors. The main outcome of the training course will be a group of 25-30 initially trained sensor users who will apply their new skills for the benefit of the global ocean observing system. The non-trivial aspect of networking and community building will also be emphasised throughout the course so that the transfer of knowledge does not end on the last day of the course. The establishment of a fully integrated international network of biogeochemical sensor users, where colleagues can support each other, is highly desirable, and would further the establishment of a global ocean observing system. The secondary goals will be to establish an online forum for the Course participants to enable further networking as well as transfer of knowledge through access to recorded course materials. Total cost of the activity is estimated to be around 120,000 USD, most of which has already been ensured through a number of sponsor commitments.

Data and Information Access Services

Many central elements of the proposed Global Data Assembly Center for Marine Biogeochemistry (BGC GDAC) as proposed by the IOCCP in 2016 (http://www.ioccp.org/images/08dataANDinfo/IOCCP_position_paper_on_data_management_FINAL.pdf) are currently being developed in Europe by the European Research Infrastructure Integrated Carbon Observation System (ERI ICOS) and in the United States by the NOAA Ocean Acidification Program (OAP) and NOAA PMEL. Some proposed elements are not yet funded, but negotiations are ongoing and we envision the formal implementation into the IODE within 2-5 years. Standardised metadata forms are being developed and work progresses to make processing and quality control of underway inorganic carbon data fully operational. These efforts benefit from IOCCP's central role as a coordination hub providing communication platform and support.

However, as ocean observing systems evolve, and an increasing number of autonomous platforms and sensors are deployed, the volume of data increases dramatically. Therefore, in order to better serve forecast and prediction communities, more efficient turnaround of quality data in known formats and made available through web services is required to provide open access to the data and the creation of relevant data products. In particular, data automation workflows will be critical to reduce data friction throughout the whole data lifecycle. This increased efficiency is relevant for all data types in marine biogeochemical observations even if some EOV data are not currently routinely ingested by any end users.

IOCCP will continue to support the data management community in our discipline in order to fully realize the vision drawn in the IOCCP position paper in 2016. This process includes automated level 1 and 2 QC procedures. An additional benefit of such automated systems is the reduction of data management burdens to science projects when properly implemented. With such workflows, it becomes much easier to provide data in standard formats, ensure that data are fully documented, provide interoperable data access through appropriate web services and, in turn, ease the integration of the data with the WMO Information System (WIS). The process will also ensure that data complies with the Findable, Accessible, Interoperable and Re-usable (FAIR) data guiding principles, which are a community-driven effort to improve the infrastructure supporting the reuse of scientific data. Currently, negotiations with the GO-FAIR initiative (https://www.go-fair.org) are ongoing to highlight the steps already taken within the

global marine biogeochemistry community under the umbrella of IOCCP and to develop a showcase illustrating how FAIRness can directly support international bodies like IOC-UNESCO IODE in achieving their obligations towards the Sustainable Development Goals (SDGs) set by the United Nations (e.g. SDG 14.3. *'minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels'*).

While acknowledging the complexity of such a system, IOCCP believes that leveraging standard formats, conventions and existing tools makes it possible to build such systems in data management environments with reduced resources.

Oxygen

Considering that oxygen is the latest addition to the palette of IOCCP themes, there is an impressive number of activities planned for the near future, ranging from actions enhancing global coordination of observations and capacity building, to actions contributing to more efficient communication, awareness building and public outreach. A new page devoted to the Oxygen Theme is currently being finalized and will be made publically available on the IOCCP website within the next few weeks.

On the capacity building front, IOCCP members participating in the GO_2NE Executive Council are assisting in organizing the GO_2NE Summer School on oxygen, to be held in the summer 2019 in Xiamen, China. This short, 6-day school is planned as a mix of lectures and hands-on exercises for a few dozen participants. Scientists from small manufacturing enterprises (e.g., Anderaa and other oxygen sensor manufacturers) will also be present. The budget is estimated at 90,000 EUR. Funding commitments have been confirmed by the German SFB project, French CNRS, and the Chinese Xiamen University. IOCCP will also contribute financially to this event. More funding applications will be submitted to EGU, U.S. OCB, and UNESCO-IOC.

Moreover, it is expected that there will be a strong oxygen sensor component at the 2nd International IOCCP Sensors Summer Course, planned for June 2019. Detailed agenda and summer school scope will be worked out over the coming months.

Enhancing global coordination of oxygen observations and raising the readiness level of this particular component of the global ocean observing system will take place through the gradually developing project VOICE. The 2nd VOICE Science Plan workshop is due to take place on 8-9 September 2018 in Kiel, Germany**,** right after the International Conference on 'Ocean Deoxygenation: Drivers and Consequences – Past, Present and Future', to be held on 3-7 September 2018. The main point on the meeting agenda is to assess the readiness level assessment of oxygen measurements based on information collected from the various OMZ demonstration regions all over the world. To this end, VOICE prepared spreadsheet questionnaires, designed according to the three pillars of the FOO, which were distributed among the VOICE regional champions. While the majority of the questionnaires have already been submitted, a few more regions are expected to contribute with comprehensive information on the status of requirement setting, observing capacity and data management with respect to the questions of VOICE.

The main outcome of the workshop will be a near-final draft of an OceanObs'19 CWP written in response to an invitation from the OceanObs'19 Conference Program Committee. When published, the CWP will lay grounds for writing a research proposal aimed at mobilizing funds to move VOICE into its implementation phase, and thus enable a globally coordinated effort to address critical gaps preventing the current ocean observing system from delivering relevant societal benefit products. To learn more about the VOICE timeline and anticipated outcomes please see the report from the 1st VOICE Science Plan workshop available at www.goosocean.org/voice-mbari-report.

With respect to communication and public outreach, IOCCP SSG oxygen expert Véronique Garçon is in charge of writing a chapter on oxygen and land-air-sea interactions exacerbating ocean deoxygenation as part of the International Union for Conservation of Nature (IUCN) report on ocean conservation. Moreover, together with Johannes Karstensen, Véronique is writing a chapter for the Encyclopaedia of Oceans Science 3rd Edition.

At the coming 4th Symposium on Effects of Climate Change on World Ocean, in Washington, DC, USA, there will be two oxygen-related sessions convened by Véronique. IOCCP SSG members will also attend and convene sessions at the Ocean Deoxygenation International Conference, in Kiel, Germany. Finally, IOCCP SSG will be represented at the GO_2NE Executive Council at their next annual meeting on September 2, 2018, in Kiel, Germany.

4.2 GlobalHAB

United Nations Educational, Scientific and Cultural Organization

Intergovernmental Oceanographic Commission

International Council for Science SCOR Scientific Committee on Oceanic Research

Global HAB IOC-SCOR

GlobalHAB - the International SCOR-IOC Science Program on Harmful Algal Blooms

Program Activities 2017-2018 and Plans for the 2018-2019 period

GlobalHAB Scientific Steering Committee Membership
Elisa Berdalet, Institute of Marine Sciences, CSIC, Spain, Chair
Raphael Kudela, University of California, Santa Cruz, USA, Vice-chair

Other Members
Neil S. Banas, University of Strathclyde, United Kingdom
Michele Burford, Griffith University, Australia
Christopher J. Gobler, Stony Brook University, USA
Bengt Karlson, Swedish Meteorological and Hydrological Institute, Sweden
Po Teen Lim, University of Malaya, Kuala Lumpur, Malaysia
Lincoln Mackenzie, Cawthron Institute, New Zealand
Marina Montresor, Stazione Zoologica Anton Dohrn, Italy
Kedong Yin, Sun Yat-Sen (Zhongshan) University, China

Ex-officio Liaison Members
Eileen Bresnan, Marine Scotland Science, United Kingdom, ICES representative
Keith Davidson, The Scottish Association for Marine Science, United Kingdom, Ex-officio
Vera L. Trainer, National Oceanic and Atmospheric Administration, USA, ISSHA and PICES representative

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Gires Usup, Universiti Kebangsaan Malaysia, Malaysia, IPHAB representative

Sponsors' Representatives
Henrik Enevoldsen, IOC UNESCO/ University of Copenhagen, Denmark
Ed Urban, Scientific Committee on Oceanic Research, USA

The GlobalHAB Scientific Steering Committee (SSC) acknowledges the financial and logistic support received from SCOR during the 2015-2018 period. The funds have made possible the completion of the GlobalHAB Science and Implementation Plan, representation of the program at international meetings, and publications completing the work of the GEOHAB program. SCOR funds are also contributing to the implementation of some initiatives prioritized by GlobalHAB at short-term. The GlobalHAB activity is described next.

1. Finalization of the GlobalHAB Science and Implementation Plan

The *GlobalHAB Science and Implementation Plan* was initiated by the GlobalHAB SSC during its first meeting, held in Oban, UK (March 2016). The first draft version of the Plan was presented at the SCOR Annual Meeting in Sopot, Poland (September 2016) by Elisa Berdalet and at the 17th International Conference on Harmful Algae (ICHA) (http://icha2016.com/about/) attended also by most SSC members. At the ICHA meeting, the international community was invited to provide inputs to the *Science and Implementation Plan*. In January 2017, the complete draft of the Plan was evaluated by 9 external reviewers. The revised version of the plan was the focus of the second meeting of the SSC, held at the Stazione Zoologica di Napoli (SZN) in Naples (Italy) on March 28-30, 2017. In November 2017, the final Plan was edited and made free available at the GlobalHAB webpage (www.globalhab.info), which was active in January 2018.

Home page of the GlobalHAB website. This image illustrates in particular that, in the broader picture, GlobalHAB contributes to improved management of HABs as an ocean hazard through improved preparedness and early warning systems thus contributing to UN Sustainable Development Goal 11, target 11.5 and Priority 4 and to Global target 7 of the Sendai Framework on Disaster Risk Reduction (UNISDR) 2015-2020.

2. Meetings of the GlobalHAB SSC

GlobalHAB SSC members at the entrace of the LOV, April 2018. Participants (left to right): Henrik Enevoldsen, Ed Urban, Bengt Karlson, Vera Trainer, Chris Gobler, Elisa Berdalet, Raphe Kudela, Marina Montresor, Po Teen Lim, Neil Banas, and Kedong Yin.

The GlobalHAB SSC held its third meeting at the Laboratoire d'Océanographie de Villefranche (LOV) in Villefranche-sur-mer (France) on April 10 and 11, 2018 hosted by Dr. Rodolphe Lemée. His students, Anne-Sophie Marron, and Kévin Drouet offered a brief presentation of their PhD thesis and a tour through the LOV facilities was conducted with Dr. Lars Stemman. Dr. Lemée also presented the artificial substrate method for sampling benthic microalgae, which he had also introduced during the concurrent Regional Workshop on Monitoring and Management Strategies for Benthic HABs in Monaco, April 9-12, 2018. GlobalHAB acknowledges the LOV for its kind support.

The meeting addressed the following items:

1. Revision of the Implementation Activities identified in the former SSC meeting in Naples to address the objectives of the 12 GlobalHAB Themes and planned for the 2017-2019 period. Before the meeting, each SSC member was invited to provide a presentation addressing *what had been done*, *what will be done, what are the needs (funds, maturity of the action) for implementation actions, limitations, change of plans, etc.*
2. Information on HAB-related activities fostered by IOC/UNESCO and other entities (ISSHA, IPHAB, ICES, PICES, UNEP).
3. Communication strategies (endorsement procedure, website maintenance), budget, SSC membership renovation system.

The main completed/, ongoing and planned activities corresponding to each GlobalHAB Theme, and other key issues are presented in the next sections.

3. *Implementation activities in the 2017-2019 period*

Theme 1. Biogeography and Biodiversity. Responsible: Marina Montresor

Activity 1.1. *In progress*. Review paper on the taxonomy of selected harmful taxa and links with toxin production. Leader: **M. Montresor**. ICES is also considering an effort on this topic and HAB biogeography is a topic within ISSHA. Preliminary contacts have been made with E. Bresnan (ICES), U. Tillmann, N. Lundholm, S. Fraga, A. Kremp, D. Sarno, A. Zingone. Contents include cryptic species and pseudo-cryptic species, morphology and ultrastructure, molecular data, physiology, ecology and toxicity.

Activity 1.2. *October 2018*. HABs biogeography session within the 18th ICHA. **E. Berdalet** contacted the ICHA organizers and found out that biogeography is included in two sessions. An oral communication about GlobalHAB is scheduled (see section 4 in this Report).

Activity 1.3. *November 2018*. Workshop on dinoflagellate taxonomy. **M. Montresor** and **E. Berdalet** have fostered a workshop on this topic co-organized by EukRef of UniEuk (http://www.unieuk.org). *EukRef* is a standardized, open-source bioinformatics pipeline that allows taxonomic curation of publicly available phylogenetic marker sequences (starting with 18S rDNA), generating homogeneous sets of curated, aligned sequences and phylogenetic trees. *EukRef* is one of the modules of UniEuk, an open, community-based and expert-driven international initiative to build a flexible, adaptive universal taxonomic framework for eukaryotes, focused primarily on protists. The workshop will be held in Roscoff (France) on 5-9 Nov. 2018. The main organizers are Cedric Berney (taxonomy coordinator), Raffaele Siano, Laure Guillou, Javier del Campo, Christian Quast, Pelin Yilmaz and Colomban de Vargas.

Activity 1.4. - *In progress.* GlobalHAB Status Report coordinated by **Henrik Enevoldsen**.
In order to develop and launch the first Global HAB Status Report, a network of data providers for OBIS-HAB and HAEDAT has been established/reconfirmed and an Editorial Team for the First Global HAB Status Report has been established together with a data flow structure.

The network of data providers in ICES and PICES regions for OBIS-HAB and HAEDAT has been expanded in cooperation with IAEA in the South Pacific, Southeast Asia, the Caribbean and Africa. One joint WS was held in the South Pacific, one in the Caribbean, and one for Africa. Additionally, a training workshop for data editors across regions was held in Ostend on 25-28 September 2017. Reviewing the literature and other sources for HAB species' occurrences for entry into OBIS and compilation of data on HAB events for HAEDAT is ongoing. A data compilation template for HAB data in OBIS has been developed and reviewed and is in use (https://github.com/iobis/habtemplate/blob/master/habtemplate_a_v4.xlsx). This will allow HAB scientists to complement, and add value to, data already in OBIS with baseline observations recorded in the literature.

Establishment of a data flow with global coverage has taken longer than expected, but major progress has been achieved and all key regions are now covered, with only Southeast Asia pending full coverage. This is except regions/countries which are already regularly submitting HAB event data to HAEDAT (North Atlantic, North Pacific, China etc.).

During the second half of 2016 until the end of 2017, focus continued to be on data compilation and upgrades/adjustments to the data systems (HAEDAT as well as the OBIS-HAB data entry template). Additionally, the Editorial Team for the GHSR has developed the outline of the GHSR and chapters are drafted. Agreement has been reached with the Elsevier journal *Harmful* Algae for a special issue in 2019 with regional summaries on HABs based on OBIS, HAEDAT and the literature.

The planned online tools to create information products have yet to be developed and will focus on creating the products for the GHSR. Currently, a new data portal for HAEDAT is in development (http://dev.iobis.org/haedat/).

A first Editors-in-Chief (3) meeting for the Global HAB Status Report was held on 23-24 May 2015 in Sweden. An outline of the Global HAB Status Report was developed and a detailed timeline for the drafting was defined. The Editorial Team held its second meeting on 29-31

March 2016 in Monaco, co-funded by the IAEA as foreseen in the project document. The Editorial Team then held its third meeting on 27 September in Ostend, Belgium, during the above-mentioned data training workshop. An updated work plan and a revised outline of the Global HAB Status Report with chapters and authors was prepared and the draft chapter outlines were reviewed.

The GHSR is foreseen to be complete by end 2018 and to be launched early 2019.

Theme 2. Adaptive Strategies. Responsible: Michele Burford.
There was nothing to be reported on this theme, which is crosscuting other Themes. The SSC will follow-up on the content and implementation of this Theme.

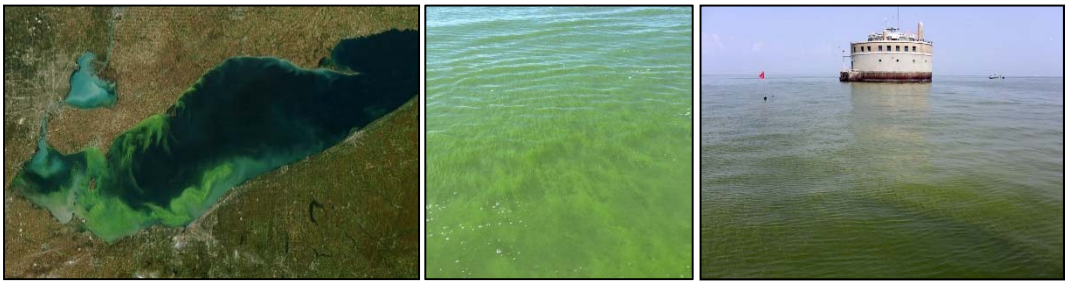
Theme 3. Toxins. Responsible: Po Teen Lim.

Activity 3.1. *In progress.* Develop plans for fish-killing HABs workshop (with Allan Cembella and Per Juel Hansen, in collaboration with ICES). There has been no progress yet during this year. The activity is followed by **Po Teen Lim**. See also *Activity 7.2.*

Activity 3.2. *In progress.* Develop plans for a Workshop and Summer school on analysis and interpretation of genetic data relevant to HAB toxicity. The activity is followed by **Po Teen Lim**, who is hosting a regional workshop on toxins for Southeast Asia, as well as the Xiamen Marine Environment Meeting.

Theme 4. Nutrients. Responsible: Kedong Yin.
There was nothing to be reported on this theme. **Kedong Yin** and the SSC will follow on the content and implementation of this Theme.

Theme 5. Freshwater HABs and CyanoHABs. Responsible: **Chris Gobler and Michele Burford**, that have been working on three main activities.



Activity 5.1. *In progress*. Manual for water managers on mitigation of cyanobacerial HABs. The goal is an aesthetically appealing, easy to understand document for drinking and recreational water managers on managing cyanobacterial HABs, available in print and on the web.

- **Outline**:
    - Background on cyanoHABs
    - Risks and standards for drinking water and recreational water
    - Options for mitigating cyanoHABs
        - Watershed management
        - Whole-ecosystem management
        - Drinking water treatment
        - Recreational water treatment
- **Materials**: Existing information from peer-reviewed literature and reputable governmental documents
- **Status**:
    - A summary document has been circulated to GlobalHAB steering committee. It can be endorsed.
    - Document has been outlined and partly written; will be circulated to the scientific community as well as managers for review.
- **Needs**: Logistical and financial support is needed for document design and lay-out, perhaps in a manner similar to the GEOHAB policymaker document (see http://unesdoc.unesco.org/images/0023/002334/233419e.pdf).

Activity 5.2. *In progress*: Webinar series on cyanoHABs for water managers, informational, one-hour duration, on cyanoHABs with a focus on management.

- **Topics:**
    - Background on cyanoHABs
    - CyanoHABs ecology
    - Risks and standards for drinking water and recreational water
    - Monitoring techniques, cells and biomass microscopic and molecular methods
    - Monitoring techniques, toxin analysis
    - Mitigating cyanoHABs: Watershed management
    - Mitigating cyanoHABs: In-water treatment
    - Mitigating cyanoHABs: Drinking water treatment
    - Webinars could be housed on GlobalHAB YouTube channel with links on GlobalHAB web site

The webinar series needs financial support the set-up logistics.

Activity 5.3. *In progress*: Global maps of cyanoHABs. Michele and Chris are working on several maps:

- Map of key problem cyanobacterial blooms and toxins globally, to be placed on GlobalHAB website.
- Maps for *Microcystis* and *Cylindrospermospis* (*Raphidopsis*): they are complete.
- Desire to make maps interactive with click and hover options for each country/incident with references, downloadable information, references.

Logistical and financial support is needed for to gather information for other cyanoHAB maps, to make them, and make them interactive with downloadable data and information. The maps could be added or linked to IOC-UNESCO Taxonomic Reference List of Harmful Microalgae.

Theme 6. BHABs. Responsible: Elisa Berdalet

Activity 6.1. *In progress.* GlobalHAB is collaborating in the coordination and implementation of the multiagency "IOC-IAEA-FAO-WHO Global Ciguatera Strategy". In particular, GlobalHAB SSC members participated in the workshop held during the Monaco's Ocean Week 9-12 April 2018, at the Oceanographic Museum of Monaco. The aims of the Workshop were to identify the main gaps that limit monitoring of BHAB species and their toxins in the most affected areas and define the best approaches to prevent and manage their impacts.

The workshop was structured on three major topics:

- Methods for Sampling benthic species, and to design an intercomparison experiment involving participants from about 30 countries.
- Methods for monitoring toxins, with cost effective and reliable methods in the afected areas
- Epidemiology studies on BHABs health impacts

Other activities that were planed at the launch of GlobalHAB are expected to be implemented in the 2019-2021 period. These include a PCR/qPCR *Gambierdiscus* identification workshop, the 2nd International Conference on *Ostreopsis* Development, and a meeting on BHABs, health and economy in coordination with Themes 10 and 11.

Theme 7. Aquaculture. Responsible: Lincoln Mackenzie.

Activity 7.1. *In progress, first results expected August 2018.* **Lincoln** reported on the GlobalHAB-endorsed project "International Collaborative Study for the Validation of a HILIC-MS/MS Method for Analysis of Paralytic Shellfish Toxins and Tetrodotoxin in Live Bivalve Molluscs". The workshop is led by Tim Harwood (Cawthron Institute, Nelson, New Zealand) and Andrew Turner (Centre for Environment Fisheries and Aquaculture Science (Cefas), Weymouth, United Kingdom). Twenty-four labs are involved in an inter-laboratory validation study and they have recruited three study advisors: Paul McNabb (NZ), Ana Gago Martinez (EURLMB Spain) and Jim Hungerford (FDA USA). The results will be available around the end of August 2018. GlobalHAB could help broadcast the results of the study. Lincoln suggested that GlobalHAB could help support a follow-up workshop. Bengt commented that this looks like a good effort. Chromatography columns were donated by a company.

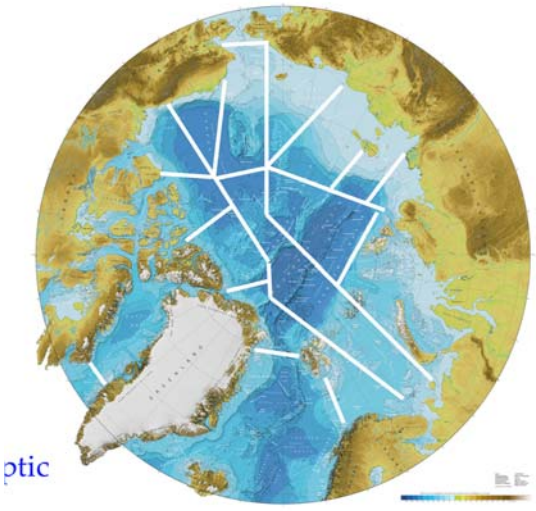
Activity 7.2. *February 2018.* Consider presenting a proposal for a SCOR WG on HABs and Aquaculture.

Activity 7.3. *In process*, *with certain changes.* Collaborate with the responsibles of Topic 3, Toxins, in order to implement the Workshop on Fish-killing algae.

Theme 8. Comparative ecosystems. Responsible: Bengt Karlson.

Activity 8.1. *To be explored.* The IOC Trends PO activity is related to this Theme 8 and it is also linked to Theme 1. Comparative work on different environments and harmful events have also been conducted by PICES and NOAA. Raphe Kudela suggested that there could be a group of PICES, ICES, TrendsPO, and GlobalHAB to discuss time series of HABs and climate change.

Activity 8.2. *To be explored.* Bengt suggested to write a proposal to add HABs on the Synoptic



Arctic Survey that will be conducted on 2020 or 2021, with the participation of at least 10 countries.

Theme 9 and Cross-cutting activities. Responsible: Raphael Kudela.

Activity 9.1. *To be explored.* GlobalHAB identified the potential links between ocean deoxygenation and HABs and there was an initial wish to interaction with IOC GO2NE (Global Ocean Oxygen Network, http://www.unesco.org/new/en/natural-sciences/ioc-oceans/sections-and-programmes/ocean-sciences/global-ocean-oxygen-network/). The GlobalHAB SSC will work in contact with Grant Pitcher to identify potential research on this topic.

Activity 9.2. *In progress.* GOOS Panel on Biology and Ecosystems. – The Essential Ocean Variable FEOV) for Phytoplankton Biomass and Diversity is online and it includes HABs. The information has been summarized in the paper "Essential ocean variables for global sustained observations of biodiversity and ecosystem changes", by Miloslawick et al. (2018), *Global Change Biology*, DOI: 10.1111/gcb.14108, coauthored by **Raphe Kudela**. A workshop will be conducted in June 2018 to try to begin implementing the EOV for phytoplankton and zooplankton, measuring everything as recommended in the EOV, including the HAB component (genus and species information), perhaps on a GO-SHIP cruise.

Activity 9.3. **Raphe Kudela** participated in the Alliance for Coastal Technologies workshop in Jan. 2017 on detection of HABs (see report). A second workshop and technology demonstration on toxin detection will be conducted soon. This organization is supported by U.S. companies, but is open to any vendor. There are a series of field sites, including Monterey, Lake Erie, and Long Island.

Activity 9.4. OCCG/GEOHAB Monograph. This activity is still continuing. A former student of Stuart Bernard has taken over production and is moving forward. The monograph should be finished soon, in 2018.

Theme 10. Health. Responsible: Elisa Berdalet

Activity 10.1. *April 2018.* Endorse and participate in the implementation of the coordinated IOC-IAEA-FAO-WHO "Global Ciguatera Strategy" and participate in the Regional Workshop on Monitoring and Management Strategies for Benthic HABs, Monaco, 9-12 April, 2018. This activity corresponds to Activity 6.1, here focused in the health aspects. **E. Berdalet** contributed to the organization of the questioanaires designed to better assess the existing capacity in benthic HAB management in relation to human poisonings surveillance programs, regulations, outreach campaigns, investigation procedures in case of epidemics, etc. The objective was, through relevant case studies, to discuss, during the workshop, existing programs, good practices, but also identify gaps, needs and propose adaptive solutions. The workshop was aimed to provide guidance for improved mitigation of HAB health effects on ciguatera and prevention of respiratory impacts related to *Ostreopsis* blooms. Accommodation of E. Berdalet was funded by Accord RAMOGE that co-sponsored the workshop with IAEA that covered invitation of about 30 participants, logistics, etc.

Activity 10.2. *March 2018 to October 2019.* **E. Berdalet** represented GlobalHAB at the CLEFSA workshop: Emerging threats on human health in Europe due to climate change. CLEFSA is a project of the European Food Safety Agengy (EFSA), that explores the risks of food intoxication in future climate change scenarios. CLEFSA included aquatic biotoxins in the European landscape. The event was held in Parma at the EFSA headquarters in March 2018. E. Berdalet is collaborating in the elaboration of reports and documents through online communication and in-person meetings.

Activity 10.3. *April 2018.* **Elisa Berdalet** was invited as External Expert in the SOPHIE project, a Coordination and Suport Action (CSA) of the European Commission aimed to develop a programme on Oceans and Human Health in Europe. Elisa represents GlobalHAB and the HABs and Health Theme. A first workshop was held in Dublin, on April 24-25, 2018, funded by SOPHIE.

Theme 11. Economy. Responsible: Vera Trainer and Keith Davidson.

Vera reviewed U.S. National HAB activities to estimate the economic cost of HABs and the existence of some fundamental problems with such a national estimate based on minimal data.

Activity 11.1. *To be explored.* **Vera Trainer** proposed a workshop on the economics of HABs at the 2017 annual PICES meeting (to be held later) and this seems like a good area of cooperation between GlobalHAB and PICES.

The goals would be to:

- Determine effective approaches for HAB economics research;
- Set priorities for HAB economics research based on highly impacted regional sectors;
- Develop partnerships between economists and HAB scientists; and

- Attract additional (resource) economists to the field.

Vera will work on the organization of the proposal, including identification of the steering committee; time, duration and location; funding; size of workshop; contributors; structure (example studies, specific questions to be addressed). The meeting could be held in Victoria, Canada in Oct. 2018 (prior to annual PICES meeting) or in Seattle, Washington, USA. There is a common interest in determining the socioeconomic impacts of HABs by PICES, NOAA (they have expertise also), the insurance industry, GlobalHAB, and some European efforts (for instance, conducted under the CoCliME project). The results of the workshop could be published online, as part of the "Good practices manual".

Theme 12. Climate Change. Responsible: Neil Banas.

Activity 12.1. Special issue on the journal *Harmful Algae* focused on "Climate Change and HABs". Responsible: Chris Gobler. The editors of the special issue are Chris Gobler and Mark Wells. 14 articles have been solicited, potential authorship is indicated in italics:

1. The Future of HAB Science: Directions and Challenges. *HAB-Climate Change Symposium Organizers and Breakout Discussion Leads.*
2. Projected Latitudinal Changes in Environmental Conditions Influencing HABs. *Fei Chai, Ernrique Curchitser (Temperate latitude), Phil Boyd lead (High latitude), Low latitude (TBD).*
3. Modelling HABs in a changing climate*. Kevin Flynn*, *Inga Hense, Neil Banas, Dennis McGillicuddy, Stephanie Dutkiewicz.*
4. Theoretical and Observed Effects of Dynamic CO_2 levels on HABs. *John Raven, Per Juel Hansen, John Bearall, Chris Gobler.*
5. The Use of OMIC Tools in HAB Research. *Authorship: Sonya Dhyrman, Student, Steve Wilhelm*.
6. Cyanobaterial HABs and Climate Change in Freshwater, Brackish and Marine Waters. *Michele Burford, Hans Pearl, Angela Wulff, Jef Huisman, Petra Visser.*
7. Toxic pelagic HABs and Climate Change. *Gustaaf Hallegraeff, Vera Trainer, Don Anderson.*
8. Benthic HABs and Climate change. *Pat Tester, Elisa Berdalet, Wayne Litaker.*
9. Fish-killing HAB and Climate change. *Charles Trick, Gustaaf Hallegraeff, Alan Cembella.*
10. High-biomass HAB and Climate change. *Bill Sunda, Grant Pitcher, Chris Gobler*
11. Future observing systems. *Bengt Karlson, Raphe Kudela, Stewart Benard*
12. HABs as a co-stressor in a changing world*. Chris Gobler, Sandra Shumway, Hannes Baumann*
13. Zooplankton grazing and HABs. *Hans Dam, Susan Menden-Duerer, Diane Stoeker, Matt Johnson*

Submission deadline of July 1 and GlobalHAB will support some open access, likely to the first article (to be decided).

The main key messages from the special issue will be used to elaborate a Scientific Summary for Policy Makers (SSPM) on HABs and Climate Change. It will be started on January 2019 to be presented at the 2019 IPHAB meeting in Paris. The SSPM could be linked to the two IPCC 1.5C special reports that are coming out this year and next year.

Activity 12.2. Best-practices Manual. Information from Marina Montresor.

The editorial team, constituted by Mark Wells (chair), Michele Burford, Anke Kremp, Marina Montresor, Grant Pitcher and Gires Usup met at the Stazione Zoologica di Napoli (Feb 26th - Mar 1, 2018) to work on the "Best Practice Guidelines for the Study of HABs and Climate Change". The outline of the chapters was defined (each chapter involves members of the editorial board and a lead external author) and the guideline for the authors was prepared.

The editorial board of the "Best Practice Guidelines for the Study of HABs and Climate Change" in their meeting at the SZN.

The tentative timeline of the Manual is

- April 2018: contact the lead authors, define the other authors
- June 2018: The outline of the chapters is submitted to the Editorial Board
- November 2018: Draft chapters are submitted to the Editorial Board, sent out for peer review
- Feb/March, 2019: Tentative plans for the Editorial Board to meet with the lead authors to discuss the reviews — decide on the necessary revisions.

- Summer, 2019: Release the proposed Best Practice Guidelines for community comments—via website—for 3 months
- Fall, 2019: Publish the final version of the Best Practice Guidelines

The initiative of the Best Practices Manual for HAB and Climate Change is in line with the activities of SCOR WG149, which has published the paper: Boyd, P.W., S. Collins, S. Dupont, K. Fabricius, J.-P. Gattuso, J. Havenhand, D.A. Hutchins, U. Riebesell, M.S. Rintoul, M. Vichi, H. Biswas, A. Ciotti, K. Gao, M. Gehlen, C.L. Hurd, H. Kurihara, C.M. McGraw, J.M. Navarro, G.E. Nilsson, U. Passow, and H.-O. Pörtner. 2018. Experimental strategies to assess the biological ramifications of multiple drivers of global ocean change—A review. *Global Change Biology* DOI: 10.1111/gcb.14102.

Activity 12.3. *June 2018*. Symposium on Effects of Climate Change on Worlds Ocean. A session on HABs chaired by E. Berdalet and K. Yin was organized in this symposium:

S17. Effects of climate change on ocean ecosystem health: Projecting occurrences of harmful algal blooms and disease outbreaks and assessment of the risk to ecosystem functioning, aquaculture, fisheries and human health (https://meetings.pices.int/meetings/international/2018/climate-change/program#S1). Raphe Kudela, Eileen Bresnan and Elisa Berdalet presented three oral communications and participated in the joint discussion of the session. GlobalHAB and IOC/UNESCO provided funds to cover the representation of GlobalHAB at the event.

S17: Effects of climate change on ocean ecosystem health: Projecting occurrences of harmful algal blooms and disease outbreaks and assessment of the risk to ecosystem functioning, aquaculture, fisheries and human health

Convenors:

Elisa Berdalet (Corresponding)
(*Institut de Ciències del Mar -CSIC-, Barcelona, Spain*)

Ryan Carnegie
(*Department of Aquatic Health Sciences, Virginia Institute of Marine Science, College of William & Mary, VA, USA*)

Alexandra Campbell
(*Faculty of Science, Health, Education and Engineering, University of the Sunshine Coast, Australia*)

Kedong Yin
(*School of Marine Sciences, Sun Yat-Sen (Zhongshan) University, Guangzhou, China*)

Plenary Speaker:
Iddya Karunasagar (Nitte University, Mangalore, India)

Invited Speaker:
Xuelei Zhang (First Institute of Oceanography (FIO), State Oceanic Administration, China)

Activity 12.4: *Potential future activity*. **Neil Banas** presented some possible workshops:

* *"Forecasting HABs: Best practices and emerging techniques"*
Goals:
- Share best practices and emerging techniques
- Improve communication between stakeholders and scientists, in particular educating scientists on what "decision support" actually means

The budget for 20 people (including teachers) and 2-day duration would be £25K (aprox). Some Scottish funding (£5-15K) would be available, from the SU2P Partnership (with California universities and industry).

* *"Understanding and predicting climate impacts on HABs"*
Goals:
- A strategy for answering the WoO question (Are windows of opportunity (WoO) for HABs expanding or merely shifting?)
- Designs for biological models for coupling to climate projections (How do we incorporate biological adaptive capacity into long-term projections?)
- Scoping of new research proposals + smaller-scale meta-analysis projects

The budget for 12 people and 3-day duration would be ≈ £18K.

The plans for these workshops will be developed in 2018.

New topic: *Sargassum* Blooms
The *GlobalHAB Science and Implementation Plan* noted that new emerging HAB-related issues could be incorporated to the program after its launch. This was the case of the blooms of green macroalgae and *Sargassum*. Elisa Berdalet and Henrik Enevoldsen have been in touch with Brian LaPointe about this topic since 2016. GESAMP has done a scoping paper on *Sargassum*, but it is not clear whether GESAMP will do a follow-up activity. GlobalHAB SSC will work during the coming months to clarify the organization of this theme.

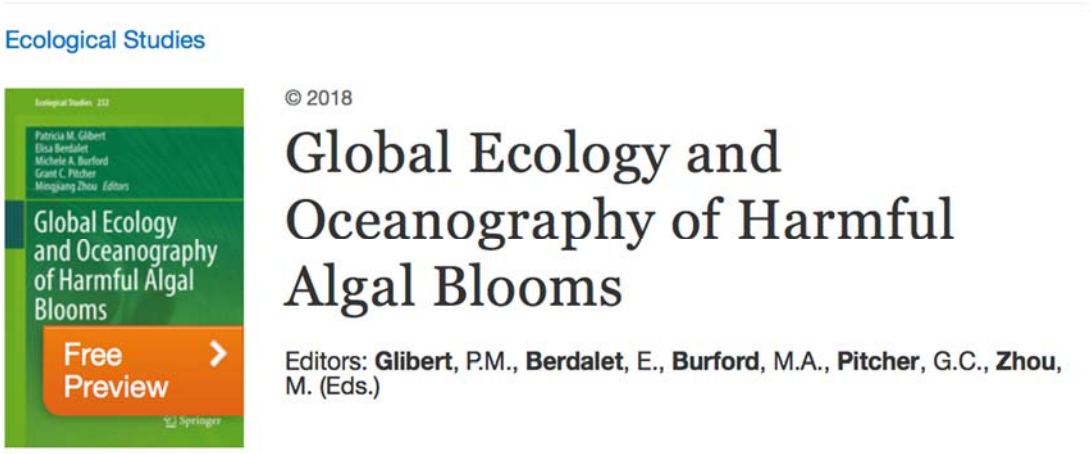
4. Representation of the program at international events.

Information about GlobalHAB has been or will be provided at the following events:

- The Regional Workshop on Monitoring and Management Strategies for Benthic HABs in Monaco, April 2018. E. Berdalet and H. Enevoldsen, representing the GlobalHAB SSC presented the oral communication "The IOC-UNESCO and SCOR programme GlobalHAB: International Coorindation to Advance in the Understanding and Management of Benthic Harmful Algal Blooms Impacts".
- The Symposium on Effects of Climate Change on Worlds Ocean, Washington, DC (US), June 2018. A session (S17) on HABs chaired by E. Berdalet and K. Yin was organized in this symposium. Raphe Kudela presented GlobalHAB with a special emphasis on the research priorities on HABs and Climate Change. See Activity 12.3.
- The International Conference on Harmful Algae, Nantes (France), October 2018. Progress on the GlobalHAB program will be presented in an oral presentation (*ICHA2018/616: "GlobalHAB (IOC-UNESCO and SCOR): International coordination for sound knowledge of HABs to manage their impacts"*, coauthored by the whole GlobalHAB SSC) at the Session "Networking activities around HABs: GlobalHAB, Global HAB Status report, ICES-WGs and other initiatives" chaired by E. Berdalet, A. Zingone and P. Hess. It is expected a publication in the *Proceedings.* See Activity 1.2.

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. On June 2018, the book was published by Springer, under their Ecological Studies series. The editors are Pat Glibert, Elisa Berdalet, Michele Burford, Grant Pitcher and Mingjiang Zhou.



This volume on the *Global Ecology and Oceanography of Harmful Algal Blooms* is aimed at synthesizing the broad range of research and activities that took place during the nearly two decades of the international programme bearing this acronym. The central challenge for GEOHAB was to "understand the critical features and mechanisms underlying the population dynamics of HAB species in a variety of oceanographic regimes." GEOHAB fostered research that was multi-faceted, multi-disciplinary, international and within an oceanographic context. With contributions from 69 authors from all over the world, this book reflects the global reach of the GEOHAB Programme. This volume aims to capture the key focus areas of research under the GEOHAB umbrella. It introduces readers to the overarching framework of GEOHAB, factors contributing to the global expansion of HABs, the complexities of HABs in different habitats, and the forward-looking issues to be tackled by the next generation of GEOHAB, GlobalHAB.

4.3 IAPWS/SCOR/IAPSO Joint Committee on Seawater — Smythe-Wright

From Rich Pawlowicz, the chair of the group:

"We have worked out a plan and a draft agenda or the Prague JCS workshops (see below).

"We are trying to bring in some new people (see agenda). One useful development is that Andrew Dickson, who is a member of JCS and also of SCOR WG 145, is bringing in some more WG145 people (Simon Clegg will talk at least). I think this is very positive; JCS would be assisting SCOR WG 145 in bringing their pH product "to market" (this was clearly a JCS goal as well)."

ICPWS BIPM/IAPWS Seawater Workshops (sponsored by JCS) – Prague, Czech Republic, Sept. 2-7, 2018

Monday Sept. 3 15:30-17:30	
(1) Salinity/Density Workshop	Chair – Pawlowicz
1530-1550 - Introduction	Rich Pawlowicz
1550-1610 Progress towards SI traceability	Steffen Seitz
1610-1630 Absolute density measurements of seawater	Yohei Kayukawa
1630-1730 Discussion: - likelihood of success - Anton Paar issues - Absolute density issues -	Rich Pawlowicz
Tuesday Sept. 4 08:30-10:30	
(2) pH Workshop	Chair - Dickson
0830-0850 Introduction	Andrew Dickson
0850-0910 Traceability of spectrophotometrically measured pHT values of TRIS buffered artificial seawater in the salinity range 5-20	Frank Bastkowski
0910-0930 A traceable thermodynamic speciation model, with quantified uncertainties, of pH in Tris buffers in artificial seawaters	Simon Clegg
Discussion:	Andrew Dickson
Tuesday Sept. 4 13:30-15:30	
(3) Relative Humidity Workshop	Chair – Hellmuth
1330-1350 Summary of Aims	Olaf Hellmuth
1350-1410 Progress in development of RH	Rainer Feistel
1410-1430Relationship between RH and SI metrology	Stephanie Bell
1430-1530 Discussion:	Olaf Hellmuth
Wednesday Sept. 5 8:30-10:30	
(4) JCS – where next?	Chair - Pawlowicz
0830-0850 Introduction	Rich Pawlowicz
0850-0910 Review - History and need for JCS: an oceanographers viewpoint	Trevor McDougall
0910-0930 JCS terms of reference	Rich Pawlowicz

Discussion: - software - updates to TEOS-10 - membership in different areas - roadmap for next 5 years	Rich Pawlowicz

Note (1)

- Workshops are part of the 17th International Conference on the Properties of Water and Steam (ICPWS – www.icpws2018.com)
- ICPWS Icebreaker Sunday Sep 2 18:00-21:00
- ICPWS group photo and Dinner Wednesday Sep 5 1900-22:00

Note (2)

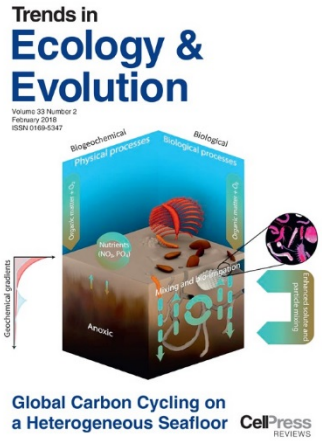
- The annual IAPWS SCSW workshop will be held in an abbreviated way on Sunday Sept. 2 (9-5). This is where any procedural issues with the development of IAPWS Releases, Guidelines, etc. are discussed, working groups formed, and final versions approved for submission to the Executive (meetings are abbreviated during ICPWS years as most talks are assumed to occur in the ICPWS).
- The IAPWS Executive meets on Friday but only Pawlowicz needs to attend this.

Attendance to workshops (tentative):

Pawlowicz, Feistel, McDougall, Dickson, Weinreben, Wolfe, Seitz, Bastkowski, Clegg, Pang+1, Stoica?, Camoes(maybe) Hellmuth, Lovell-Smith, Bell, Barker, (Williams? Laky?) Uchida, Kayukawa, NOT Millero

4.4 Workshop on Seafloor Ecosystem Functions and their Role in Global Processes Urban

The results of this workshop were published in the journal of *Trends in Ecology and Evolution* (see article following). The article was featured on the cover of this issue of the journal. This completes the activity.



CellPress
REVIEWS

Opinion

Global Carbon Cycling on a Heterogeneous Seafloor

Paul V.R. Snelgrove,[1,*] Karline Soetaert,[2] Martin Solan,[3] Simon Thrush,[4] Chih-Lin Wei,[5] Roberto Danovaro,[6,7] Robinson W. Fulweiler,[8] Hiroshi Kitazato,[9] Baban Ingole,[10] Alf Norkko,[11,12] R. John Parkes,[13] and Nils Volkenborn[14]

Diverse biological communities mediate the transformation, transport, and storage of elements fundamental to life on Earth, including carbon, nitrogen, and oxygen. However, global biogeochemical model outcomes can vary by orders of magnitude, compromising capacity to project realistic ecosystem responses to planetary changes, including ocean productivity and climate. Here, we compare global carbon turnover rates estimated using models grounded in biological versus geochemical theory and argue that the turnover estimates based on each perspective yield divergent outcomes. Importantly, empirical studies that include sedimentary biological activity vary less than those that ignore it. Improving the relevance of model projections and reducing uncertainty associated with the anticipated consequences of global change requires reconciliation of these perspectives, enabling better societal decisions on mitigation and adaptation.

Trends

Climate-change models hinge upon understanding how living ecosystems influence carbon cycling, but global models of oceanic systems produce carbon turnover estimates with a high degree of uncertainty.

Environmental conditions, and temperature in particular, strongly influence rates of carbon and nutrient cycling in the global ocean

Recent studies demonstrate a link between seafloor biodiversity and organic matter processing and nutrient efflux, suggesting that the functional group composition of biota is the most critical aspect of biodiversity for ecosystem functioning in the context of global biogeochemical cycles.

Strong spatial variability in carbon burial and recycling rates of organic material may relate to recognized variation in seafloor functional group composition.

Where Has All the Carbon Gone?

Rapid and well-documented environmental change over the past century has accelerated interest in quantifying the critical role of the ocean in global carbon and nutrient cycling [1]. As human pressures [e.g., climate change and **biodiversity** (see Glossary) loss] alter physical and biological processes, we must improve our capacity to predict the consequences of these alterations and their links to global cycles [2]. Divergent thinking in evaluating global cycles [3,4] and the role of biodiversity [5] has led most marine studies to compartmentalize biogeochemical versus biological approaches, with little effort to integrate alternative perspectives [6]. The functioning of most of the global seafloor depends largely upon the addition of oxygen and organic matter to the sediment–water interface [7] (Figure 1). Biogeochemical and ecological approaches both have value in assessing these processes, but remain poorly reconciled [8], an issue also noted in geological [9] and paleobiological [10] studies. Previous authors have highlighted the need for all types of model to improve how they represent sedimentary processes [8,11,12]. Here, we illustrate how different biases and/or perspectives associated with different world views (Figure 1) can lead to both different model projections and differential abilities to interrogate model outcomes to understand better the cumulative effects of drivers of change. The nature of the questions a model is expected to inform should influence the complexity of the model. However, the application of models to broad-global scale projections often requires simplification and averaging [13], which can lose key complexity or heterogeneity [14] essential in detecting all but the coarsest change. Biogeochemical modelers focus on the physical and chemical processes [15] that affect microbial activity in a way highly suited to developing global models [16], whereas ecologists focus on developing overarching themes governing ecosystems by studying different groups of organisms and how their activities

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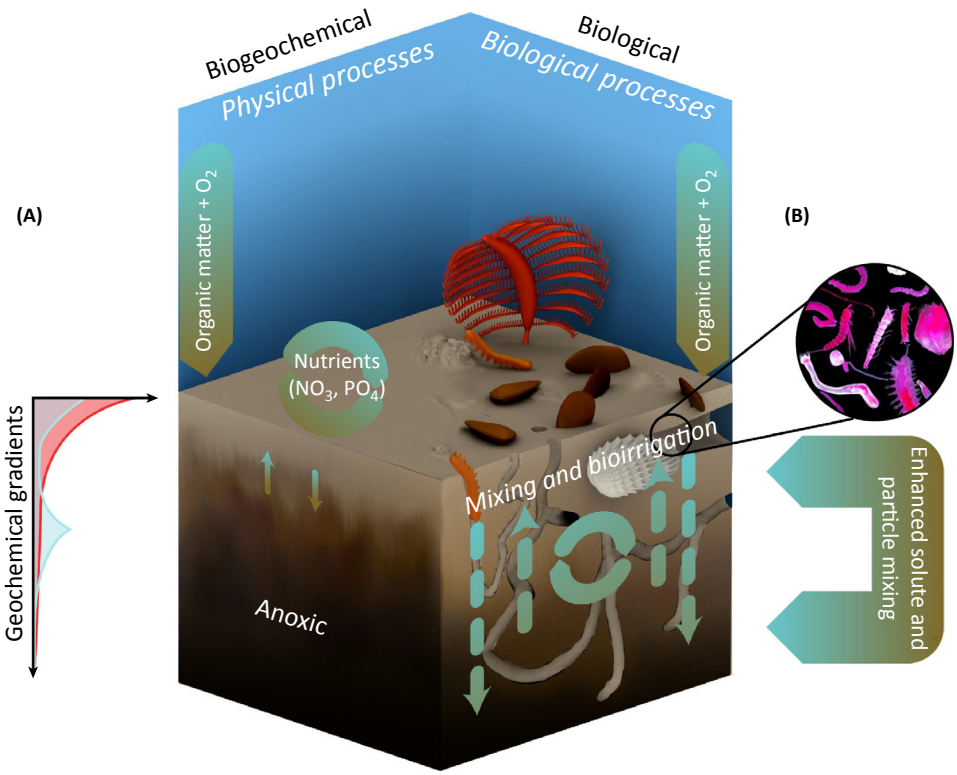

Figure 1. Summary of the Contrasting Geochemical (A) and Biological Views (B) of Organic Matter Decomposition, Illustrating Differences in Emphasis on the Predominant Processes and in the Relative Complexities of the Two Perspectives

For a Figure360 author presentation of Figure 1, see the figure legend at https://doi.org/10.1016/j.tree.2017.11.004

The fundamentally different roles of the functional groups, and the key elements that most models do not accommodate (i.e., feedbacks, habitat modification, horizontal bioturbation, large bioturbators, and different process rates) all contribute to major contrasts between the two approaches.

influence their environment [17] and, thus, processing of organic matter. Ecological studies tend to emphasize heterogeneity and variability as a functional component of the system, whereas many biogeochemists, despite emphasizing strong gradients in the sediment column, tend to 'average' seafloor rates and processes spatially [13]. Nevertheless, both approaches have advanced our understanding of how marine sediments influence global process. Highly productive coastal, shelf, and slope sedimentary seafloor ecosystems that cycle organic material rapidly contribute disproportionately to organic **mineralization** and nutrient processing [18]. In contrast in the deep ocean, regenerated nutrients can remain unused for many hundreds of years before transport into the photic zone and uptake by photosynthetic organisms occurs [19]. Despite low rates of carbon remineralization or sequestration and nutrient regeneration, integrating across the vast area of the deep ocean makes it a major contributor to global biogeochemical budgets and cycles. These deep-ocean contributions often have long lag times (up to hundreds of years) in how they influence the cycling of materials, which the short-time scales (e.g. hours–days) of many studies fail to capture [20]. Hence,

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constraining **carbon sequestration** and mineralization globally remains a major challenge, perhaps because of the difficulty in reconciling such marked differences in biological complexity [8]. Few studies have reasonably constrained the contribution of **continental shelf** sediments as a net source or sink for nutrients and carbon, or indeed for other elements, over regions of shelf habitat [21] and some deep-sea environments [22]. However, the underlying processes and players that lead to changes in the internal pool of dissolved and particulate nutrients are not well understood [23].

The Role of Seafloor Biota

Substantial evidence accumulated over the past few decades strongly links carbon remineralization, nutrient efflux, and the activities of the diverse seabed fauna [24–26]. The active redistribution of particles, water, and solutes by **bioturbation** [27] directly contributes to the spatial and temporal heterogeneity of oxic, anoxic, and oscillatory **redox zones** [28], as well as to the distribution of other electron acceptors [29]. These physical and chemical changes in sediments generated by faunal activity have important implications for microbial assemblages [14], and the ecosystem processes they affect (e.g., organic matter mineralization and burial [30], and nutrient transformation pathways [31,32]). Whereas **infaunal** activity inherently contributes to increased solute exchange between the sediment and the overlying water, the contribution of the underlying drivers varies among **functional groups** through increased diffusional fluxes, bioadvection, and animal excretion [29]. Seafloor heterogeneity itself can influence biodiversity–function relationships [33,34] (e.g., sedentary components of the seafloor fauna, including bivalves, corals, sponges, and cnidarians) and can add significant habitat complexity by providing **emergent structures**. Additionally, the rate and extent of filtering and suspension feeding can moderate local levels of **benthic**–pelagic coupling [35]. Most biogeochemical models simplify processes and average or approximate the substantial variability in biologically mediated processes that transform food (organic matter) into living tissue, respire oxygen, and release carbon dioxide [36]. However, evidence suggests that variation in the functional attributes of communities [37–39] can affect carbon- and nutrient-cycling processes more than species diversity can [40]. Anticipated changes in the abundance, distribution, and behavior of functionally important species in response to global environmental change [2,41,42] raise concerns about significant alteration of **ecosystem function** and services, given the strong interlinkages among seabed functioning [43] and ocean productivity.

Local–regional-level studies that consider faunal mediation of carbon cycling from shallow to deep seafloor ecosystems highlight the potential importance of including organisms in global carbon models and considering the contributions of different seabed environments [44]. Correlative studies across large-scale gradients in dissolved oxygen tend to use multivariate analyses to demonstrate strong linkages between seafloor biota, nutrient recycling, and remineralization. In the Baltic Sea, for example, the density of several macrofaunal functional groups that are important in affecting rates of bioturbation explain close to 70% of the variability in nutrient fluxes, including under hypoxic conditions [45]. Similarly, comparisons of oxygen and nutrient efflux in different coastal sedimentary regions of western Canada exhibit strong spatial variation, driven equally by environmental characteristics and macrofaunal functional group diversity [46]. Species contributions can vary between different populations and functionally important aspects of the behavior of individuals within a population can be context dependent [34]. Furthermore, short-term experimental addition of organic matter [40] reveals that higher species richness can explain most of the intersite differences in nutrient flux rates, even under high levels of environmental forcing [47] (acknowledging that chronic enrichment typically creates feedbacks that differentially depress diversity and function [48]). A nutrient budget based on long-term observations [22] and *in situ* measurements [49] in Sagami Bay, Japan

Glossary

Benthic: living in or on the aquatic seafloor. An operational classification based on sieve sizes used when sampling sediments subdivides benthos into megabenthos, visible in bottom photographs or video (e.g., crabs or fish), macrobenthos >300 μm (e.g., polychaete worms or small clams), and meiobenthos, which pass through a 250–500-μm sieve but are retained on a 20–30-μm sieve (e.g., nematodes or copepods).
Biodiversity: the extent of genetic, taxonomic, and ecological diversity over all spatial and temporal scales.
Bioturbation: the dispersal of particles by organisms reworking the sediment, typically by burrowing or feeding.
Carbon sequestration: the process of capture and long-term storage of atmospheric carbon.
Carbon turnover: the transformation of organic carbon to an inorganic form.
Continental shelf: the extended perimeter of the continents and associated coastal plain.
Continental slope: the slope extending from ~100 m to 3200 m bottom depth between the outer edge of the continental shelf and the deep ocean floor.
Denitrification: the microbial reduction of NO_3^- to N_2 and O, and of NO_2^- to N_2 or other N oxide.
Diagenesis: physical and chemical changes occurring during the conversion of sediment to sedimentary rock.
Ecosystem function: changes in energy and matter over time and space through biological activity.
Ecosystem service: the benefits people obtain from ecosystems.
Emergent structures: structures that protrude above the seabed, often produced by living organisms and providing habitat for other species.
Functional group: organisms with similar trophic, morphological, physiological, behavioral, biochemical, or environmental responses.
Infaunal: (animals) living within sediments.
Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES): an

resolved high inputs of organic material that were linked to key ecological and biogeochemical processes, including active sinks of carbon and nitrogen as well as regional hot spots of **denitrification**, anaerobic ammonium oxidation (anammox), and oxygen consumption (and, thus, carbon remineralization) in surficial sediment strongly linked to dense patches of infaunal polychaetes that transported chemically reduced sediments towards the sediment surface and laterally downslope via tidal and other currents [49]. Indeed, comparisons of multiple seabed ecosystems that vary in the flux of organic matter to the seafloor link exponential increases in the efficiency of carbon processing via prokaryote production and nutrient regeneration with the increasing functional diversity of small, abundant sedimentary meiofauna [37]. Thus, environments with a greater influx of organic material could support higher abundances of organisms, which, in turn, can increase remineralization when that abundance includes a greater portfolio of functional groups [46]. Nevertheless, researchers largely disregard the underlying reciprocal relationship between abiotic and biotic components that can explain much of the observed variability in ecosystem processes [50].

Bridging the Sampling Gap

Reasons why ecological information has not been prominent in ocean-based global process models relate to insufficient sampling of the seafloor [38] and the limited availability of data that describes the functional performance [51] of specific communities, particularly for deep ocean regions [52]. Moreover, sampling bias frustrates any clear resolution of the roles of different biota. For example, based on empirical measurements, many researchers assume that macrofauna have a greater role in coastal shelf and **continental slopes** than they do in the deep ocean [8], but, while comparatively robust data exist for these shallow regions, the issue remains unresolved at deeper depths. Nevertheless, these deficiencies in sampling design and data availability do not fully preclude ecological analysis of carbon remineralization on a global scale. By using estimates of biological turnover based on macrofaunal, meiofaunal, and microbial biomass for different seafloor biota, we can assess the role of ecological variation in determining the outcomes of alternative model scenarios. We hypothesize that the results of global-scale biogeochemical carbon modeling efforts that do not consider the roles of seafloor biota will diverge from those that do, resulting in key differences in predictions of the spatial locations of high and low **carbon turnover** rates.

Biogeochemical and Biological Model Estimates

Our comparison of carbon turnover utilizes two simple approaches. First, we used a widely employed geochemical model of carbon export to the deep ocean based on the equation of Lutz *et al*. [16] (Figure 2A), which considers production of organic matter near the surface of the ocean, and net remineralization during transit through the water column. We omitted the lateral transport of organic matter in our model, because other processes (e.g., declining organic carbon flux with depth, increasing carbon export with seasonality, and increasing carbon degradation with temperature) likely dominate the carbon turnover in our global-scale analysis. Nonetheless, we acknowledge the importance of lateral transport and its interaction with the biological pump that transports some 50% of organic carbon to the seafloor [53], and its particular importance in regional comparisons and downslope movement of material. Second, we developed a biologically based turnover rate, calculated as sediment oxygen consumption rate (based on ship-board or *in situ* sediment incubation) divided by seafloor standing biomass (Figure 2B). In the absence of appropriate data on the specific functional roles of organisms consuming organic matter that primarily determine its degradation, we assumed that total biomass and activity correlate strongly [54].

independent intergovernmental body established to strengthen the science-policy interface for biodiversity and ecosystem services for the conservation and sustainable use of biodiversity, long-term human well-being, and sustainable development.

Mineralization: the process of degrading organic material.

Multifunctional: the potential for individual organisms to contribute to more than one ecosystem function.

Niche: the ecological hyperspace occupied by an organism.

Redox zone: zone in sediments where the oxidation states of atoms are changed.

Trait: any morphological, physiological, behavioral, or phenological feature measurable at the individual level.

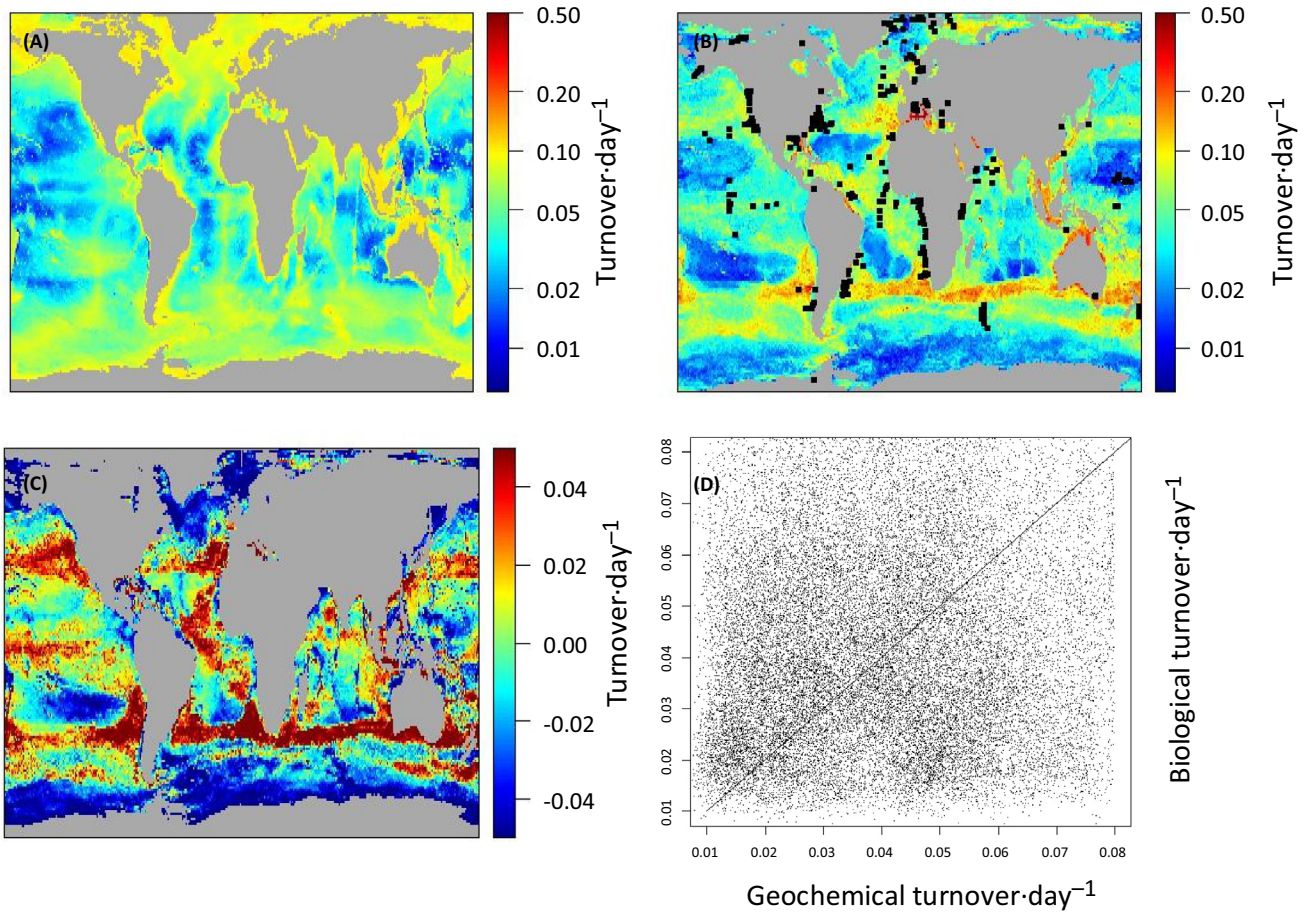

Figure 2. Global Map of Carbon Turnover on the Seafloor. (A) Turnover as estimated based on the equation of Lutz *et al.* [16], reproducing the aging of pelagically produced sinking organic matter. (B) Turnover of benthic organisms, estimated as the sediment community oxygen consumption (SCOC) rate divided by the infaunal biomass; dots represent SCOC data. Most of the SCOC data was estimated by whole-core sediment incubation under *in situ* temperatures. Contrasting estimates of carbon turnover based on biogeochemical and biological approaches. (C) Comparison of turnover rates based on biogeochemical and biological models where light-green colors indicate coherence between models, warm colors indicate higher estimates for the biogeochemical model, and cool colors indicate higher estimates for the biological model. (D) The density distribution of the biological and geochemical turnover estimates reflects the weak (R^2= 0.015) relationship between biological and geological turnover estimates (log-log scale) and the wide scatter around the line representing a 1:1 relationship. The apparent truncation results from reactivity in shallow water that is close to the reactivity of fresh organic matter.

Geochemical versus Biological Turnover Estimates

We estimated geochemical turnover (organic matter decay) as a function of organic matter deposition flux and organic matter decay rate (see the supplemental information online for details), and biological turnover (i.e., expressed as the proportion of organic carbon remineralized by respiration per day) by dividing sediment carbon mineralization rates (C/m^2/day) by total benthic biomass (C/m^2). The biomass (bacteria + meiofauna + macrofauna) approximately integrated to a depth in the sediments of 15 cm, and we estimated sediment carbon mineralization rates from oxygen fluxes, assuming a respiratory quotient (RQ) of 1 mol O_2/mol C and no burial of reduced product. Although the use of a marginally different RQ would change overall turnover rates [11], it would not alter relative values or spatial differences. Nonetheless, temporal and spatial differences in RQ add significant noise to our analysis that could eventually be refined with additional data. We integrated faunal and bacterial data over the upper 15 cm of

sediment, adjusting based on partial regression where necessary and noting that most biomass occurs within this layer (see also Figure S1 in the supplemental information online).

The Contrasting Tales of Two Models

Our two approaches to modeling carbon turnover produced very different patterns, with no clear relationship between the turnover estimates (Figure 2C,D). For example, the models predicted low biological turnover but high geochemical (flux based) turnover around Antarctica, in contrast to high biological but low geochemical turnover around 30°S. Moreover, high biomass and sedimentary community oxygen consumption in the Northern Oceans (e.g., near Alaska and Siberia) contrast low predicted biological turnover but high geochemical turnover. If seafloor biota were unimportant, then we would expect close congruence between the two types of estimate, both regionally and globally, which is not what we observed, These incongruences between approaches for key regions expected to change dramatically under many climate-change scenarios, such as those presented by the Intergovernmental Panel on Climate Change (IPCC) [55], illustrate a high degree of uncertainty when projecting the likely consequences of future change in major biogeochemical cycles. Our global estimate of sediment community oxygen consumption (SCOC) and biological turnover ranked as intermediate compared with previous comparable estimates achieved elsewhere (Table 1), adding confidence to our approach. Indeed, our analysis shows that adding even simple elements of seafloor ecology to the equation dramatically alters interpretation, potentially contributing to the five orders of magnitude variation in rate constants used in carbon models reported in the literature [34]. Importantly, researchers must evaluate the relative roles of microbial, meiofaunal, and macrofaunal contributions to carbon turnover across different habitats and seasons. Currently available data suggest similar spatial patterns in peak biomass for all size fractions, as well as similar patterns for size fractions across depth [56]. Moreover, recent correlative empirical studies confirm a clear role for sedimentary biota at larger regional scales [45,57]. Nonetheless, local manipulative process-based studies [24] offer the potential for more-detailed analysis, and to integrate meaningful data from locations (e.g. vents, seeps, upwelling regions, sponge, and coral habitat) where the rate, magnitude, or form of biogeochemical cycling differ distinctly from the surrounding habitat.

Many different types of biogeochemistry and biological models acknowledge that temporal variation in productivity and patchiness on multiple spatial scales add further complexity that complicates the prediction of rates of carbon cycling and that data availability limits our current capacity to account for this variation. Similarly, the strong gradients that living biota create in sediment vertical profiles at millimeter to centimeter scales can further influence biological

Table 1. Global Average Estimates of Sedimentary Processing of Organic Carbon in Terms of Sediment Community Oxygen Consumption (SCOC), Production of Dissolved Inorganic Carbon (DIC), and Biological Turnover[a]

Source	SCOC (Tmol O2·yr^{-1})	DIC (Gton C·yr^{-1})	Biological turnover (yr^{-1})	Biological turnover (day^{-1})
[63]	54.3	0.65	7.7	0.02
[64]	79.6	0.96	11.3	0.03
[65]	157	1.88	22.2	0.06
[11]	152	1.82	21.5	0.06
Our study	139.5	1.67	19.7	0.05

[a]Based on a respiratory quotient (DIC:O_2 exchange ratio) of 1.0 and a total seafloor biomass of 84.9 megaton C [56].

processes and interactions. Nonetheless, biogeochemical models routinely ignore the interlinked functions of bioturbation, trophic support, and enhanced microbial production. Yet, each of these elements includes an overlapping but distinct set of players as well as adding important complexity and heterogeneity to natural systems [58] that appropriate interdisciplinary collaboration can readily resolve [59]. These issues matter because the models we currently use to map and project changes in biogeochemical processes at global scales lack the capacity to look at unexpected outcomes and outlier data points that could link to seabed functioning, hampering our ability to predict the resiliency of systems and recovery trajectories following perturbations, and to account for natural variability.

Better Models for Future Ocean Scenarios

Rapid, ongoing transformation of global biogeochemical cycles demand improved models that produce not only more precise estimates of carbon degradation and burial, but also more accurate projections of change. Concerned by the mismatch between ecosystem processes measured at local to regional scales and the first-order approximation applied to global elemental models, we demonstrate here that the inclusion of seafloor biology in models likely changes global patterns appreciably and shifts regions of seafloor carbon processing. This conclusion is consistent with local and regional studies that link the actions of large sediment-dwelling organisms to ecosystem processes, although we recognize the potential importance of other aspects of biota (e.g., microbial biomass). This finding implies a need for particular caution in drawing inferences from current models that exclude, minimize, or oversimplify the contributions that biological communities make to ecosystem processes when projecting the effects and consequences of environmental change.

These global biogeochemical models do not fully accommodate important variables influential in determining the stocks and flows of biogeochemical cycles, or consider that changes in abiotic and biotic characteristics that are likely to produce nonadditive effects (e.g., changes in water temperature and functional group diversity produce combined effects that are less than their individual effects [46]). This gap identifies a need for case studies that specifically compare bottom-up approaches of ecologists with top-down approaches of biogeochemists, and which combine such information to generate a more-realistic evaluation of global carbon cycling [6]. Given that these biogeochemical models underpin many aspects of global climate change projections (e.g., IPCC) and **ecosystem service** assessments (e.g., **Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services**; IPBES), necessary improvements in predictive power will have important policy and socioeconomic consequences (Figure 1B). Estimates for carbon cycling in terrestrial systems would likely benefit from a similar approach that addresses ecosystem complexity and varying roles for biology.

Embracing the Complexity of Biodiversity

We urge our community to embrace ecological complexity, including the functionality and heterogeneity of seafloor biota in time and space that underpin the fate of carbon in our oceans, while also considering the 3D aspects of both the water column [4] and seafloor sediments [8]. Simultaneously, we need new concepts of **multifunctional** (e.g., sediment oxygenation, remineralization, and nutrient regeneration) ecosystems [58], where changes in carbon and nutrient cycling link to changes in the size, activity, density, and spatiotemporal arrangement of species that influence the functional performance, stability, and adaptive capacity of a system [43]. Specific arrangements of species dominance can exert greater influence than evenness in maintaining ecosystem process and function [34], and it is important to recognize that the functional role of an individual species is not static and can change with context [60]. We

suggest the following as key priorities for facilitating the next steps. First, we must generate credible maps of seafloor function that can accurately capture variation in organic matter processing in time and space. These efforts should include areas of seabed that contrast in relative performance, or where different biogeochemical pathways dominate, and eventually should consider the potential role of deep carbon wells below the redox layer [61] in global carbon models [59]. Second, we must merge models of geochemical **diagenesis** with meaningful estimates of biological turnover to reduce uncertainty in model outputs. Third, we must recognize the non-static nature of species–environment relations and account for the effects of physicochemical and biological interacting processes [40,41], including related changes in assemblage structure and adaptation capacity or alterations to geochemical cycles that accompany long-term environmental forcing [12]. Finally, the development of such combined models that couple the insights from both biogeochemistry and ecology can form the basis for realistic and defensible predictive models of global geochemical cycles and help those tasked with the management and governance of the marine environment to prepare for, or even possibly mitigate, climate-change impacts already evident in the most-remote ocean environments [26].

Concluding Remarks: A Path Forward

Massive amounts of new data on seafloor diversity and function will not appear in the foreseeable future, particularly for the deep ocean, so how can we improve estimates based primarily on available data? Our analysis illustrates how simple additions of biology can build from large-scale models, but further improvements could be achieved by working with abundance:biomass ratios, functional **trait** analysis, and spatial extrapolation of trait patterns based on environmental characteristics (e.g., grain size or bottom currents). Incorporating detailed regional data, where available, could help in this effort, particularly if oceanographic regimens (high productivity areas versus low productivity areas) are considered. Improved integration of geochemical and biological modeling approaches to refine regional and global predictions would benefit from studies that synchronize biological and geochemical measurements in time and space to examine the magnitude of difference between approaches in determining realized fluxes in and out of the seafloor. Food quantity and quality, which vary substantially over space and time in marine systems [62], add further aspects of complexity that both ecologists and biochemical modelers often ignore [8]. Biological and geochemical contributions to process rates both face the challenge of scaling measurements made at millimeter to centimeter scales upward to produce global estimates. In this respect, both aspects would benefit from stratifying data according to major habitat types with contrasting functional groups (e.g., bioturbators versus emergent structures) and environmental variables (e.g., oceanographic regimes, depth, or proximity to terrestrial input), and take advantage of natural environmental gradients to generate stronger predictive relationships [43]. Models could then build from stronger empirical data that explicitly incorporate spatial and temporal variation, improving the relevance of projections for underpinning management decisions and supporting policy options.

Outstanding Questions

Can collaboration between biologists and geochemists reduce the uncertainty regarding projections of global carbon dioxide concentrations?

Can environmental proxies or application of basic principles regarding traits provide a means of addressing major data gaps regarding seafloor diversity?

How can we effectively incorporate the dynamic nature of ocean systems, including seasonal and cyclic signals, such as El Niño or the North Atlantic Oscillation, to evaluate the role of the oceans in biogeochemical fluxes and, thus, in climate change and global productivity?

What is the likely impact of marine biodiversity change or loss on global biogeochemical cycles?

How can we extrapolate most effectively from small-scale measurements of biological and geochemical processes to produce defensible global-scale extrapolations, and then future projections?

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Supplemental Information

Supplemental information associated with this article can be found online at https://doi.org/10.1016/j.tree.2017.11.004.

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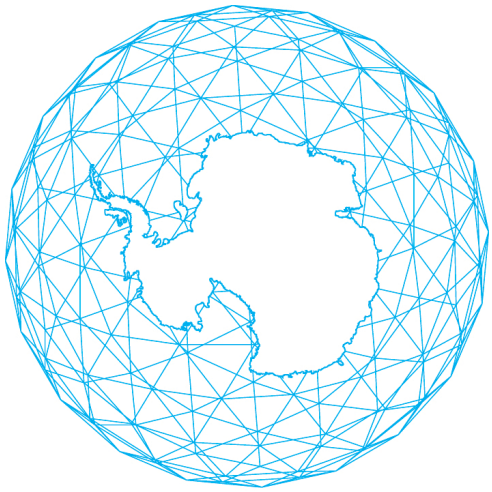


SOOS

SOUTHERN OCEAN
OBSERVING SYSTEM

The

Southern Ocean Observing System

2017 Annual Report

Summary

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 is 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.

The SOOS International Project Office core sponsorship

UNIVERSITY of TASMANIA
IMAS INSTITUTE FOR MARINE & ANTARCTIC STUDIES
ANTARCTIC GATEWAY PARTNERSHIP
A Special Research Initiative of the Australian Research Council
STATE OCEANIC ADMINISTRATION
UNIVERSITY OF GOTHENBURG

Content

2017 in review

By any measure, 2017 has been a great success for SOOS – the broader scientific community will now be benefitting from some major advances we have achieved.

If you have been following the SOOS website, you will have noticed two new tools that are important for all interested in the Southern Ocean. First, DueSouth has matured to provide a first point-of-access to plans for Southern Ocean voyages and projects, including deployments of observing platforms and research opportunities. It has long been sought by national Antarctic programs, oceanographic researchers and agencies, and programs relying on existing operations to support activities that only require a small amount of ship-time to undertake. Second, SOOSmap is a data discovery tool to help researchers find data in locations and at times of importance to their research programs. Built by EMODnet Physics in late 2017, it has already enabled one early-career researcher to find and use data essential to their thesis. It provides a central tool for finding integrated Southern Ocean datasets. It also provides SOOS with a mechanism for highlighting orphan data now made available through SOOS investment, such as the network of over 600 current and historical moorings in the Southern Ocean.

An additional measure of success is the engagement of our community in working groups, and 2017 has seen major steps forward in this area. SOOS has established and held the first meetings of three regional working groups, with two others now being formed. With international partners, such as GO-SHIP and ARGO, we now have groups covering all regions of the Southern Ocean, coordinating and filling gaps in our observational network. We are looking to further develop these groups and provide opportunities for all Southern Ocean researchers to participate at this important base-level, to define observing gaps and priorities, better coordinate, and collaborate in field programs.

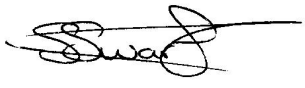
SOOS is actively encouraging and facilitating the development of observational capabilities for locations and for types of data difficult to obtain, such as observing under ice, the ocean-atmosphere interface, and the counting of marine mammals and birds. In these, 2017 has seen major steps forward. This year also saw increased support through sponsorship and investment. Publications over the last 12 months have shown the expansion of SOOS activities and how it underpins research in the region, including a special issue arising from a SOOS Symposium on the West Antarctic Peninsula.

2018 will be an exciting year for further enhancing SOOS as a hub of observational and data activities to support Southern Ocean research, your research. It will see an advancement in the design of the system through collaborations with modelling communities, and a consolidation of the essential ocean variables that will form the backbone of SOOS in the coming years.

We thank you for your support of SOOS and we encourage you to continue supporting it and to participate in our upcoming activities.

Signed: 

Dr. Andrew Constable; Biological Sciences Co-Chair
Australian Antarctic Division, Australia

Signed: 

Dr. Sebastiaan Swart; Physical Sciences Co-Chair
University of Gothenburg, Sweden

Performance Report

SOOS published its 5-Year Implementation Plan in 2016, which articulated the key problems driving SOOS, and resulted in the identification of 4 Objectives and specific Key Result Areas (KRAs) that will address the causes of these Key Challenges.

The annual report for SOOS is the mechanism through which we review progress against the KRAs, to ensure the Objectives are being met.

The 5-Year Implementation Plan is available from the SOOS website (http://soos.aq/activities/implementation).

Progress report against Objectives and Key Result Areas

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

Objective 1 will help to deliver a coordinated, integrated, efficient and sustained international program to deliver observations of essential elements of Southern Ocean Systems, following the Framework for Ocean Observing (FOO, 2010?) and the identification of Essential Ocean Variables (EOVs). Activity towards achieving Objective 1 will be predominantly carried out by the Regional Working Groups (RWGs) and Capability Working Groups (CWGs).

There are 4 KRAs that will focus work towards achieving this objective, however, only 2 (KRA 1.1 and 1.2) were identified for actioning in 2017. Progress for 2017 shown in the tables below.

Generally speaking, limited progress was made against Objective 1 in 2017, due mainly to the relatively immature status of the RWGs that will be delivering much of the activity. Looking forward, a much stronger statement by SOOS on the need for delivery of this information is required to ensure the RWGs and CWGs include it as an action for coming years. The addition of specific resources to support this KRA in 2018 is also expected to make a significant difference in its progress.

Key Result Area 1.1: Establish Criteria for adopting EOVs and communicate them

2017 Intended Actions	Progress Made (Y/ X)	Comment
Published, internationally defined criteria for EOVs	X	No progress was achieved in 2017, predominantly due to a lack of well-defined community to drive this initiative

Key Result Area 1.2: Southern Ocean EOVs are identified and the manner in which they satisfy the criteria are communicated

2017 Intended Actions	Progress Made (Y/ X)	Comment
Published table of status of EOVs	Y	Progress in 2017 has been initiated through some Regional Working Groups – see individual RWG reports (pages X – X) Resources to support this activity were sourced (State Oceanic Administration, China), and work will begin in March 2018 Identification of Essential Ocean Variables for Southern Ocean Fluxes, and advocacy for inclusion in the Global Climate Observing System's Essential Climate Variables
Compiled EOV descriptions and supporting documentation	Y	Resources were sourced (State Oceanic Administration, China) to deliver actions against this in 2018

Objective Two: Unify and enhance current observation efforts and leverage further resources across disciplines, and between nations and programs

Achieving Objective 2 will ensure regional implementation of long-term, sustained observations to achieve circumpolar coverage of Southern Ocean systems, built by integrating across internationally coordinated observation programs and existing efforts by national programs.

There are 3 KRAs that will focus work towards achieving this objective, and all were identified for actioning in 2017. Progress for 2017 shown in the tables below.

In 2017, activity towards achieving this objective was substantial, with delivery of several key products and networks. Looking forward, 2018 will likely be a year of consolidation and communication of these tools to the broader SOOS community.

Key Result Area 2.1: Working Groups and Task Teams that coordinate efforts across disciplines and programs, and between nations are developed to fill priority gaps

2017 Intended Actions	Progress Made (Y/ X)	Comment
Development of new WGs (as required)	Y	All 5 Regional Working Groups have been initiated Proposal accepted for new Capability Working Group (joint with IWC) "Acoustic Trends Working Group" Task Team on enhancing Observing System design and modelling efforts Task Team on defining requirements/scope of a Circumpolar Regional Working Group Issues – inability of IPO to provide required website, communication and coordination support for these groups

Key Result Area 2.2: Key products for the Southern Ocean that aid in information transfer and facilitate collaborative efforts are identified and produced

2017 Intended Actions	Progress Made (Y/ X)	Comment
Database of Upcoming Expeditions to the Southern Ocean	Y	Product was consolidated and delivered; Expeditions were populated manually by SOOS Data Officer; Automation of transfer of national expedition plan were initiated; Resources and personnel for further development of product were sourced; Engagement with COMNAP was developed Issues – Specific observational projects remain unpopulated; Inability to obtain user statistics; limited input of plans by community
SOOSmap	Y	Significant progress in delivering product; core portal designed and developed; new data layers added; future data layers identified; modifications to user interface initiated Issues – Low level of control over timing and delivery of enhancements and modifications to functionality due to in-kind delivery of product
Community annual calendar	Y	Product was delivered to the community and updated as required

Key Result Area 2.3: Collaborative, multidisciplinary and multinational workshops and meetings are undertaken, resulting in the SOOS mission being achieved

2017 Intended Actions	Progress Made (Y/ X)	Comment
Capability and Regional Working Group workshops	Y	OASIIS workshop; WAP WG workshop; Ross Sea workshop; Indian Sector workshop; Data Management Sub-Committee meeting
Capacity- or Community-building workshops	Y	SOOS-AWI Weddell/Dronning Maud Land symposium
International conference sessions, town-halls, side meetings, information sessions	Y	Southern Ocean Session at Asia Oceania Geosciences Society; Polar Connections Interoperability Workshop

Objective Three: 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

Achieving Objective 3 will enhance access to multidisciplinary, quality-controlled observational data from the Southern Ocean. Currently, such data is difficult and time consuming to access as there are many fragmented, mono-disciplinary or mono-platform data centres; a general lack of focused effort towards data sharing and platform interoperability; large variations in national/institutional data policies and data-sharing cultures; and a lack of general knowledge on the data that are being collected.

There are 4 KRAs that will focus work towards achieving this objective, and all were identified for actioning in 2017. Progress for 2017 is shown in the tables below.

In 2017, progress towards this objective was significant. Dedication to building strategic connections and networks within the data community over the last few years, resulted in enhanced opportunities to deliver against the KRAs in 2017. These connections are vital to maintain in the coming years. Several of the KRAs and specific actions towards achieving them are losing relevance or importance as priorities in data management shift. This is therefore reflected by a lower intensity of effort on these fronts.

Key Result Area 3.1: A multidisciplinary metadata portal is developed and populated and continuously updated with records. Efforts include archiving of orphan datasets and advocating for direct links to data in metadata records

2017 Intended Actions	Progress Made (Y/ X)	Comment
Maintenance of the SOOS NASA GCMD metadata portal	Y	Portal functionality maintained and number of records increased by 3% and the proportion of records with data links increased by 15% Issue: General recognition that the GCMD is no longer delivering what the community requires. Development of the Federated Data Search Tool will re-focus SOOS efforts away from the GCMD
International mooring network	Y	Significant effort in building network database of internationally deployed, retrieved and active moorings Delivery of mooring metadata to SOOSmap Management of BEDI mooring data rescue project and personnel

		Management and delivery of previously inaccessible data from 63 mooring deployments into NCEI repository Identification and management of new resources to enhance mooring data delivery (sponsorship by State Oceanic Administration, China)
Southern Ocean glider network	X	An international effort to manage and deliver global glider data was initiated by communities external to SOOS; SOOS will support this effort where needed but will no longer deliver a Southern Ocean glider network
NECKLACE data management	Y	Development of international data policy for NECKLACE (downward-looking radar for ice-shelf melt) data Maintenance of instrument deployment and retrieval data in SOOSmap
Argo Oxygen Data	Y	**This is a new addition to actions against this KRA, due to newly articulated community needs Identification of data holders of Argo oxygen data, issues with delivery of the data, and support for efforts to standardise data quality control for delivery of an integrated dataset
Sea-ice core chlorophyll database	Y	**This is a new addition to actions against this KRA, due to newly articulated community needs Opportunistic activity leveraging off the NOAA-BEDI funding of the SOOS Mooring data rescue effort to combine and deliver international sea-ice core chlorophyll data through the Australian Antarctic Data Centre and SOOSmap

Key Result Area 3.2: Up-to-date information on key Southern Ocean data programmes, centres and repositories is provided

2017 Intended Actions	Progress Made (Y/ X)	Comment
Catalogue of Southern Ocean data providers	Y	The online catalogue was updated and maintained on the SOOS website

Key Result Area 3.3: Web-based tools will be explored and, as needed, developed to aid data discovery and delivery; the wider community is encouraged to adopt and enhance tools that already exist

2017 Intended Actions	Progress Made (Y/ X)	Comment
Federated metadata search tool	Y	Proposed by SOOS for recognition as priority for the global polar community in coming years Development of focused Working Group jointly with SCADM and the Arctic Data Council on scoping of product requirements and pathway to delivery Management of WG meetings and publications
Brokering data discovery and interoperability	Y	Discussions initiated on integrating metadata from PANGAEA into GCMD Discussions initiated on integrating datasets from PANGAEA into EMODnet Benthic data from Polish research programs at King George Island documented and curated at NCEI. Possibility of developing data projects through the Alfred Wegener Institute investigated.
General data management advocacy and advice	Y	Support for development of Swiss Polar Institute data management Support for development of Antarctica New Zealand's data management Delivery of Australian Research Council's Antarctic Gateway Partnership data policy, including data management advice to staff, development of data policy for new observing platforms (AUV), and facilitation of model output publishing guidelines and workshop

Key Result Area 3.4: Data synthesis tools and products are made accessible

2017 Intended Actions	Progress Made (Y/ X)	Comment
Online catalogue of data products	Y	Scoping of requirements, initial products online Delivery of products as SOOSmap base layers

Objective Four: Provide services to communicate, coordinate, advocate and facilitate SOOS objectives and activities

Objective 4 provides the foundation for the work program of the International Project Office (IPO). It outlines the activities required to support the sustained implementation of SOOS, delivery of SOOS tools and products, and facilitate activities of the SOOS network.

There are 6 KRAs that will focus work towards achieving this objective, and all were scheduled for action in 2017. Progress for 2017 is shown in the tables below.

Although progress was made against all the KRAs of Objective 4 in 2017, required actions were limited in depth and quality of progress due to limited capability of the IPO staff to implement all required actions, in addition to supporting the SOOS network in actions against the other objectives.

Key Result Area 4.1: The need for sustained Southern Ocean observations is strongly articulated

2017 Intended Actions	Progress Made (Y/ X)	Comment
Endorsement of observational research projects	Y	Review and endorsement of international observational research projects as requested
High-level advocacy actions	Y	Letter of support for AMSR satellite observations Engagement with WMO Polar Space Task Group on advocacy for continued satellite observations Presentation at UN "The Ocean" Conference Presentation at the Asian Forum for Polar Sciences on the need for interoperable data sharing and discovery tools

Key Result Area 4.2: Engagement with international stakeholders, across all disciplines and nations, is maintained

2017 Intended Actions	Progress Made (Y/ X)	Comment
Reporting	Y	In 2017, annual reports were delivered for SCAR, SCOR, CCAMLR, COMNAP, ATCM-CEP, Australian Research Council's Antarctic Gateway Partnership, POGO, SCADM, and the SOOS SSC Issue: Reporting requirements are a significant overhead for the IPO, particularly given the lack of consistency between required information. Where possible, the general annual SOOS SSC report is delivered as the standard report to the above stakeholders.
Development of SOOS Engagement Strategy	X	This is a significant undertaking, and there is currently no capacity in the IPO to carry out this work
Community Engagement and conference presentations	Y	Direct engagement included (but not limited to): IICWG, CCAMLR, COLTO, EU-PolarNet, CEP, SORP, EPB, WDS, GEOSS, APECS, GOOS, OOPC, POGO, SCAR Programs, EuroGOOS, WCRP, CLIVAR, CliC, RDA, SCADM, COMNAP, ICED, IEEE, IMBER, IMOS, IAPSO, YOPP, SCOR All engagement/presentations were carried out directly by IPO staff or by a community member and facilitated by IPO
Engagement with core IPO sponsors and stakeholders	Y	Regular engagement was maintained through in-person meetings and email correspondence Engagement included: IMAS, UTAS, AAD, ACE CRC, CSIRO, AGP, IMOS, TPN, Tas. State Government, Antarctic NZ, University of Gothenburg, SOA-China

Key Result Area 4.3: A SOOS community bibliography is developed

2017 Intended Actions	Progress Made (Y/ X)	Comment
Scoping of requirements and delivery of product	X	No progress was achieved in 2017 but the database of SOOS publications was maintained on the SOOS website

Key Result Area 4.4: The SOOS Communication Strategy is implemented

2017 Intended Actions	Progress Made (Y/ X)	Comment
Sourcing of new website domain host; contact management system; transfer to standardised Joomla template;	X	No progress was achieved in 2017 **Issue**: This is a high priority but the IPO does not have the capacity and expertise to identify best options. External advice is required
Content of website is kept up-to-date	Y	Some aspects of the website were updated **Issue**: Website updates were done only when immediately required, rather than when they became out-of-date or when new information was available (e.g., reactive rather than strategic/pro-active). This is due to the growth in the SOOS network and activities, and lack of growth in IPO capacity and resources
Delivery of the SOOS Newsletter	Y	One issue was produced in December 2017 **Issue**: The newsletter has historically been produced quarterly, with production out-sourced by the IPO to a UTAS PhD student. In 2017, delivery was significantly delayed when the PhD student finished at the University and no alternative student was identified. Production is now out-sourced to a commercial communication company
Merchandise	X	**Issue**: Some merchandise remains from previous years' investments, however there are no stocks of up-to-date information fliers. There was no capacity within the SOOS IPO to develop new fliers in 2017. Newly agreed in-kind support by Australia's ACE CRC will ensure development of new fliers in 2018
Social Media	Y	Basic-level updates to SOOS Facebook and Twitter accounts was maintained and automated where possible **Issue**: Social media is not used strategically and is ad-hoc at best. Facebook posts are automatically delivered to Twitter irrespective of the different type of engagement that Twitter facilitates

Key Result Area 4.5: Support for SOOS International Project Office is maintained and enhanced

2017 Intended Actions	Progress Made (Y/ X)	Comment
Development of future IPO hosting Partnership Agreement	Y	Direct, regular and strategically-planned engagement with Partners was a significant action in 2017 Drafting of strategic and financial documentation in support of partnership development Management of partnership meetings and associated administration
Maintenance of existing IPO and SOOS sponsorship	Y	Regular engagement with existing sponsors Oversight of finance and budget Development of annual sponsorship agreements and project schedules Management of in-kind services and agreements Issue: Most direct sponsorship is agreed on an annual basis, requiring ongoing management of agreements, increased budget risk and inability to forward-plan Most in-kind services are agreed verbally without the ability to develop a Service Level Agreement on delivery of product/service
Actions on new sponsorship opportunities	Y	Connection to Hobart-based protein supplement company “BioFlex” for in-kind marketing support Initiation and delivery of newly agreed IPO sponsorship by State Oceanic Administration (China) for SOOS Project Officer

Key Result Area 4.6: SOOS Administration, facilitation of Strategic Plan activities and delivery of support services is maintained

2017 Intended Actions	Progress Made (Y/ X)	Comment
Maintenance and support of SOOS Governance	Y	Management and engagement with governing bodies SCAR and SCOR Management of Executive Committee (meetings, membership, activities, TORs) Management of Scientific Steering Committee (meetings, membership, activities, TORs) Management of Data Management Sub-Committee (meetings, membership, activities, TORs)
Management of Implementation Plan monitoring and progress review	Y	Weekly review and recording of activities against all KRAs
Administrative finance	Y	Development of 2017 budget Management of income and expenditure International sponsorship of SOOS representatives
Office administration and staff development/support	Y	Management of staff Professional Development updates and strategies Involvement of Executive Officer on International Scientific Advisory Board of the Swedish Marine Robotics Centre Weekly IPO workplan meetings Annual review of staff performance Development of new staff position of Project Officer

SOOS Key Products

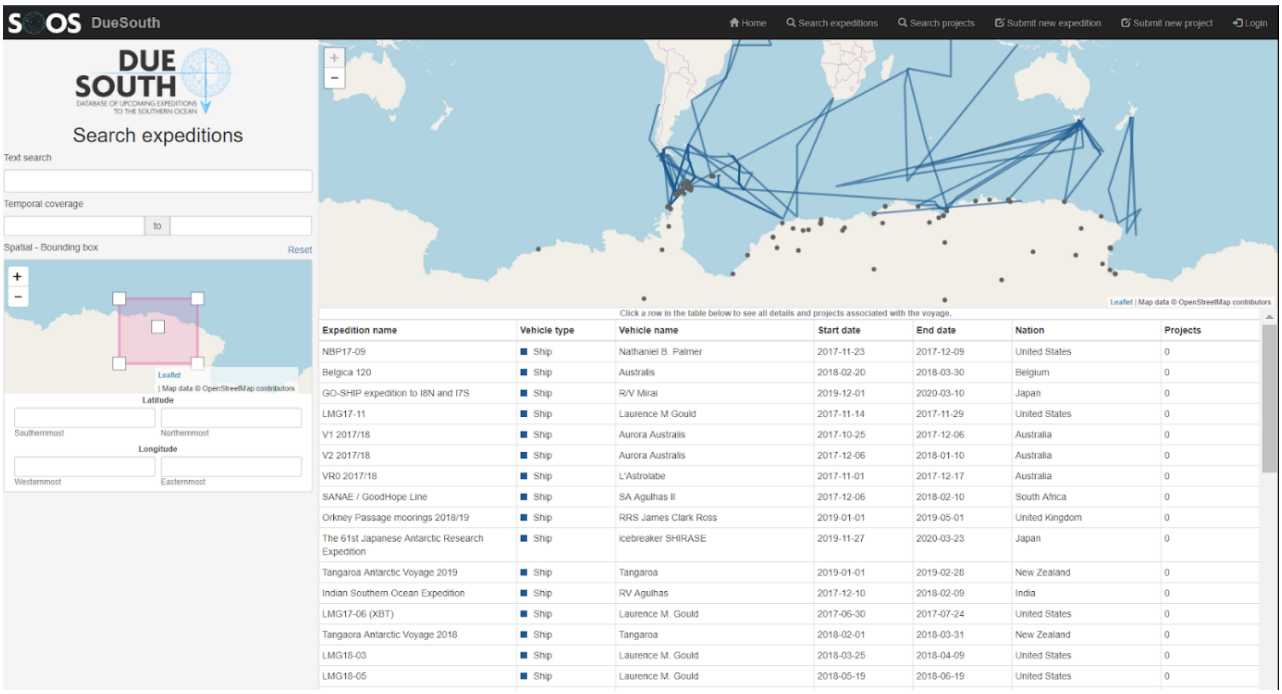
Database of Upcoming Expeditions to the Southern Ocean

DUE SOUTH
DATABASE OF UPCOMING EXPEDITIONS TO THE SOUTHERN OCEAN

DueSouth is a community-populated database for the sharing of information on upcoming field campaigns and expeditions. It enhances opportunities for collaboration and sharing of field resources.

Key Sponsors / People:

DueSouth coding and hosting is provided to SOOS by James Cusick of the Australian Antarctic Data Centre and DueSouth has been added to the project schedule between SOOS and AAD to provide long-term security. Antarctic Sea Ice Processes and Climate (ASPeCt) has provided funding to complete the coding.



DueSouth is available at https://data.aad.gov.au/duesouth/

2017 Milestones:

Initial construction of DueSouth was completed in early 2017 and the database was populated with key voyages from some large Southern Ocean projects. DueSouth was presented to the SOOS annual meeting in Bremerhaven, Germany in June 2017 and SOOS members encouraged to enter details of upcoming voyages and projects. This process highlighted limitations of the existing code and the need for some fundamental restructuring of the core functions. For example, the initial database design was predicated on a project being assigned to a single expedition or research facility, when many multi-year projects should be assigned to multiple expeditions.

During 2017, SOOS reached in-principle agreement with JCOMMOPS, CCAMLR, and the Alfred Wegener Institute (AWI) to automate the sharing of upcoming voyages with DueSouth. DueSouth was presented at scientific conferences throughout the year but the major focus of work on this product during 2017 was securing coding support to make the product stable and fully functional. Funding support for this coding work was secured from ASPeCt and DueSouth has been added to the Project Schedule with the AAD, giving it hosting and maintenance security in coming years.

2018 Plans:

- Complete the refactoring of the DueSouth code, including full administration rights for the SOOS data officer, allowing many-to-many relationships between projects and expeditions, and allowing record-authors to edit their records
- Add automatic data feeds from JCOMMOPS, AWI, and the Australian and New Zealand Antarctic science programs
- Ask the SOOS community to comprehensively populate DueSouth with expedition plans for 2018/19 and beyond.
- Implement site analytics to enable user statistics to be collected

SOOSmap

SOOSmap is an interactive web map that allows users to explore circumpolar datasets before downloading the data they need. SOOSmap was developed for SOOS by coders at the European Marine Observations and Data Network (EMODnet) Physics group, using the infrastructure they have created for aggregating and sharing data from disparate European and global oceanographic programs.

Key Sponsors/People

All development and hosting are provided by Antonio Novellino and Marco Alba at EMODnet Physics as part of their mandate to support regional ocean observing systems. The relationship between SOOS and EMODnet was negotiated by Patrick Gorringe from the EuroGOOS secretariat.

2017 Milestones

In early 2017, the SOOS data officer completed development of a prototype SOOSmap, populated with a few data layers showing key observing platforms for the Southern Ocean in an interactive web map. This map allowed users to explore the state of the observing system and produce maps for reporting. However, by mid-year. SOOS DMSC member, Taco de Bruin introduced the EMODnet Physics group to SOOS. EMODnet Physics had produced other portals showing the distribution of observing platforms in European waters and also providing access to the underlying data. Adding data access to SOOSmap would bring SOOSmap considerably closer to the SOOS vision of an interconnected cyber infrastructure.

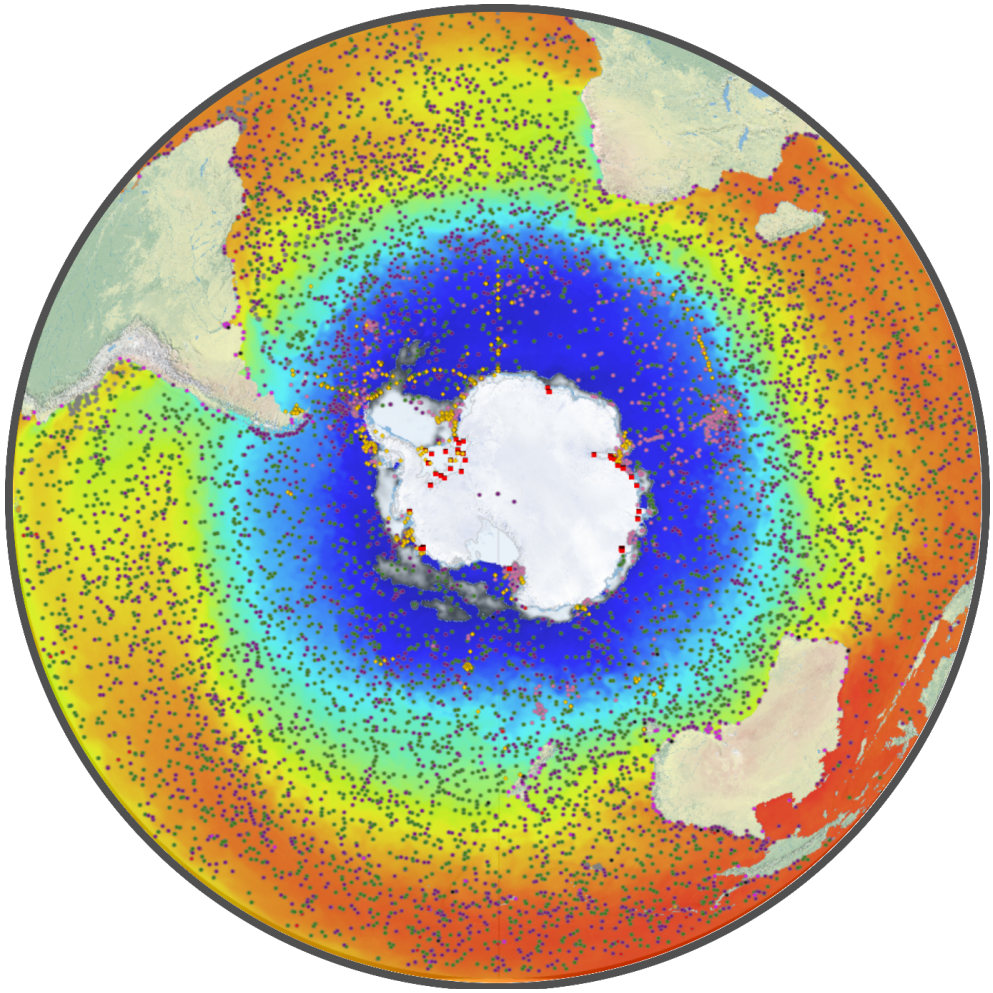
By the end of 2017, the core design and coding for SOOSmap was complete, the user interface had been amended and SOOSmap was publishing data from Argo, MEOP seals, ferrybox, drifting buoys, gliders, moorings, tide gauges, and COMNAP research facilities. Additionally, it displayed metadata from the SOOS mooring network and NECKLACE programs. It enables users to filter by time, place, platform type, parameters, or research program. The DMSC has identified target layers for inclusion in SOOSmap.

2018 Plans

In 2018, we plan to:

- Improve the user interface to make it more intuitive

- Add data from the following programs
- Southern Ocean Continuous Plankton Recorder program
- CCAMLR administrative boundaries (CEMP sites; MPAs; Research Blocks; and Areas, sub-Areas, and Divisions
- Bathymetry surveys
- Sea ice concentration
- Sea surface temperature
- Other programs as opportunity allows
- Investigate opportunities to produce high resolution maps for reporting purposes
- Implement site analytics to enable user statistics to be collected



All data layers available in SOOSmap as at January 2018

SOOS Sponsorship

General SOOS Sponsorship

In 2017, SOOS redefined its sponsorship categories to better articulate the types of support that we receive. SOOS Sponsors are identified by 4 categories:

1) SOOS Governing Bodies – the Scientific Committee on Antarctic Research (SCAR) and the Scientific Committee on Oceanic Research (SCOR) are the SOOS Governing Bodies and provide strategic and programmatic oversight and guidance to SOOS.

2) Core Sponsors – Core sponsors are those that support the salaries of IPO staff

3) IPO Operational Sponsors – Operational Sponsors are those that provide sponsorship monies in support of SOOS IPO activities. This support is for use by the IPO in delivery of communication products, support for workshops, IPO travel and other IPO-directed actions or products

4) Service Providers – This category is to give recognition to all providers of in-kind services for SOOS.

2017 saw significant growth in sponsorship of SOOS. The State Oceanic Administration of China (SOA) became a Core Sponsor, through their support of a Project Officer to work in the IPO in Hobart. Dr Yuhua Pei will work as the SOOS Project Officer until early 2019.

In addition to this, 3 organisations became new Service Providers for SOOS: the Australian Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC) now provides SOOS with ad-hoc administration and communication support; European Marine Observation and Data Network (EMODnet) provide SOOS with SOOSmap; and the Council of Managers of National Antarctic Programs (COMNAP) support SOOS in the delivery of DueSouth and other related information.

Sustained support for the IPO

In 2017, the SOOS IPO faced a funding cliff, with contracts for the IPO staff secure until end-2018 only. Therefore, a significant effort for the IPO in 2017 was engagement with Hobart-based organisations to develop a vision for sustained and enhanced support of the IPO in Hobart beyond 2018. The University of Tasmania, Australian Antarctic Division, CSIRO, Australia's Integrated Marine Observing System (IMOS), the ACE CRC and the Tasmanian State Government, all declared strong support for the SOOS IPO to remain in Hobart over the coming years. This support will form the foundation of a Partnership Agreement between the local organisations and SCAR and SCOR, to be developed in 2018.

IPO Sponsorship in 2017

The current sponsorship for the SOOS IPO is shown below.

SOOS Governing Bodies

Core Sponsors

Service Providers

IPO Operational Sponsors

Governance

Executive Committee

In 2017, the SOOS Executive Committee held one in-person meeting, and several virtual meetings. Membership also changed during 2017, with Anna Wåhlin finishing her term as Physical Sciences Co-Chair, and Oscar Schofield finishing his term as Biological Sciences Co-Chair. Following the recommendations of the SSC, the vice chairs, Andrew Constable and Sebastiaan Swart, were approved by SCAR and SCOR as the co-chairs for SOOS from mid-2017 to mid-2020.

At the same time, Mike Williams was elected Physical Sciences Vice Chair for a 3-year term, and Oscar Schofield remained on the Executive Committee as Biological Sciences Vice Chair for a 1-year term.

Scientific Steering Committee

The 2017 SSC meeting was hosted by the Alfred Wegener Institute (Germany) in June 2017. The minutes of this meeting are available online http://soos.aq/about-us/ssc/meeting-minutes

In November 2017, SOOS made an open call for nominations for new SSC members, with terms starting in May 2018 at the 2018 SSC meeting, when 5 members rotate off the committee.

The composition of the SSC in 2017 is shown below:

Name	Country	Expertise	2012	2013	2014	2015	2016	2017-Mid 2018	Mid 2019	Mid 2020	Mid 2021	Mid 2022	Mid 2023
Anna Wåhlin	Sweden	Physical	1	1^	1^	2^	2^						
Mauricio Mata	Brazil	Physical	1	1	1	2	2	2					
Mike Meredith	UK	Physical	1	1	1	2	2	2					
Dan Costa	USA	Biology	1	1	1	2	2	2					
Parli Bhaskar	India	Biology	1	1	1	2	2	2					
Oscar Schofield	USA	Biology	1^	1^	1^	2^	2^	2^					
SangHoon Lee	Korea	Biology				1	1	1	2				
Sebastiaan Swart	Sweden*	Physical	1	1	1^	2^	2^	2^	3^	3^			
Andrew Constable	Australia	Biology			1^	1^	1^	2^	2^	2^			
Matthew Mazloff	USA	Physical				1	1	1	2	2	2		
JB Sallee	France	Physical				1	1	1	2	2	2		
Mike Williams	NZ	Physical				1	1	1^	2^	2^	2^	3^	3^
Dake Chen	China	Physical						1	1	1	2	2	2
Burcu Ozsoy	Turkey	Sea ice						1	1	1	2	2	2
Anya Waite	Germany	Biology						1	1	1	2	2	2
DMSC Co-Chair													

*Note – These members have changed country of residence since joining the SSC
^EXCOM position (2 x 3 year terms)

Annual Scientific Steering Committee Meeting

The annual meeting for the SSC and Executive Committee took place in Bremerhaven, Germany (June 2017) hosted by the Alfred Wegener Institute. These meetings took place alongside the SOOS Data Management Sub-Committee meeting, a joint SOOS-AWI symposium on the Weddell Sea and Dronning Maud Land, and the workshop of the POGO Working Group "Observing and Understanding the Ocean beneath Antarctica's Sea Ice and Ice Sheet (OASIIS)".

In addition to reviewing progress against the Implementation Plan, a focus of the 2017 SSC meeting was broad stakeholder engagement. To this end, an additional 18 observers attended the SOOS meetings, representing 16 different external programs or national communities.

The minutes from the SSC meeting are available on the SOOS website. SOOS thanks the Alfred Wegener Institute for the significant organisation and financial support provided in hosting these meetings. SOOS also thanks SCOR and SCAR for their continued support of these annual meetings.

Participants of the 2017 SOOS SSC Meeting in Bremerhaven

SOOS Implementation Groups

Data Management Sub-Committee

The SOOS Data Management Sub-Committee (DMSC) has been engaged on a wide range of data activities, in addition to the development of DueSouth and SOOSmap (documented in Key Products section of this report).

Membership

Steve Diggs (CCHDO; Scripps Institution of Oceanography)	Mathieu Belbeoch JCOMMOPS
Joana Beja (British Oceanographic Data Centre)	Benjamin Pfeil Bjerknes Centre for Climate Research
Taco de Bruin (SCADM; Royal Netherlands Institute for Sea Research)	Roger Proctor Australian Ocean Data Network
Kenneth Casey (USA National Centers for Environmental Information)	Scott Ritz NASA Global Change Master Directory
James Cusick (Australian Antarctic Data Centre)	Stefanie Schumacher Alfred Wegener Institute
Bruno Danis Royal Belgian Institute of Natural Sciences	Petra Ten Hoopen British Antarctic Survey
Florence Fetterer (National Snow and Ice Data Centre)	Anton Van De Putte Biodiversity.aq
Hannes Grobe (PANGAEA)	Jie Zhang Chinese National Antarctic and Arctic Data Centre
Michael Morahan (NASA Global Change Master Directory)	

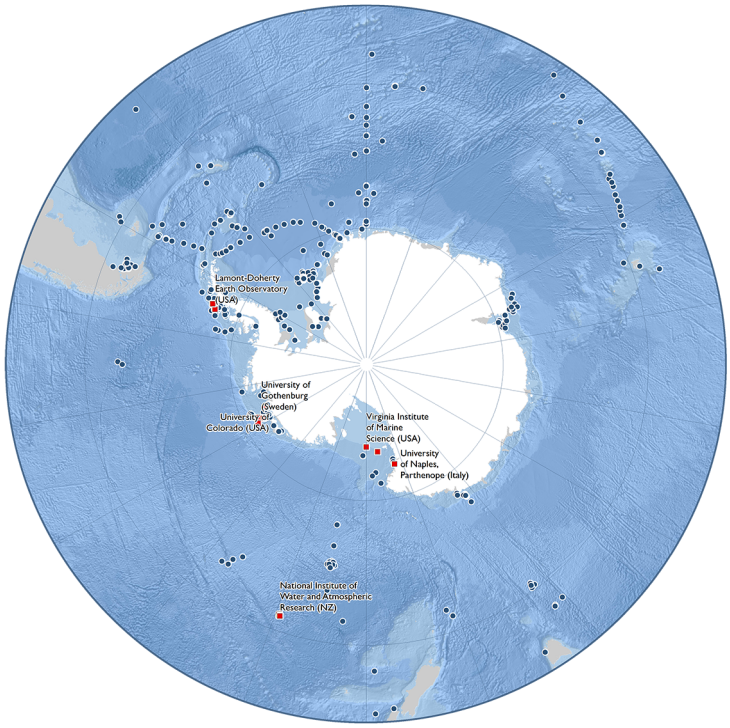
2017 Milestones

Federated search Tool

The DMSC is pursuing development of a federated metadata search tool, as a potential successor to the SOOS portal on the NASA Global Change Master Directory. Towards this end, a Polar Federated Data Search Working Group has been formed, drawing together members of the SOOS DMSC, the Standing Committee on Antarctic Data Management, and the Arctic Data Committee (ADC). SOOS data officer, Pip Bricher, and DMSC member, Taco de Bruin, are co-chairs, alongside Alexander Smirnov from (ADC). The group is preparing a journal article on federated search and investigating opportunities for funding its development and ongoing support. http://www.soos.aq/data/federatedsearch

Southern Ocean Mooring Network and other data rescue efforts

During 2017, the Southern Ocean Mooring Network continued to grow, with hundreds of additional moorings added to the spreadsheet of known deployments. Additionally, David Pasquale (NSIDC; NOAA Big Earth Data Initiative grant) has continued to transform and publish mooring data that was previously invisible to the broader community.



Other datasets were also discovered that had not yet been submitted to a data centre for curation and publication. David also: documented and prepared for publication physical data from the King George Island benthic intertidal zone (PI: Piotr Kuklinski, Poland); began standardising biological Argo data (PI: Robert Drucker, USA); converting 1300 sea-ice chlorophyll measurements into a standardised netCDF file for publication through SOOSmap (PI: Klaus Meiners, Australia). It is anticipated that these datasets will be published in 2018.

Data Management Advocacy

SOOS was active in advocating for stronger data management policies and activities in the Southern Ocean. In 2017, SOOS was officially approved as a Partner Member of the ICSU World Data System – an international body that certifies data centres that meet their high standards. As part of this membership, SOOS will advocate for partner data centres to apply for certification to demonstrate their high standards.

In addition, the SOOS data officer has provided advice to the Swiss Polar Institute and Antarctica New Zealand on development of National Antarctic Data Centres for their nations.

NECKLACE

The SOOS data officer has continued her support for data management in the NECKLACE program, a SOOS-endorsed collaboration of scientists collecting measurements of basal melt rates of ice shelves around Antarctica. A draft data policy has been prepared and in 2018, the data officer will work with the community for use of a new database to aggregate datasets.

Task Teams

SOOS Task Teams are developed to produce specific products, organise events, or solve a particular problem. Each Task Team is made up of a small group of experts and aims to complete its work within weeks or months.

Observing System Design Task Team

This Task Team was initiated in June 2017 and has the specific mission to advise methods for assessing observing system design for a given quantity of interest. This Task Team is an important contribution to SOOS Objective 1.

Members	Summary of Deliverables
Matthew Mazloff (Chair; mmazloff@ucsd.edu) Andrew Constable Oscar Schofield Anya Waite	1. Compile list of possibly useful methodologies 2. Determine scope of requirements 3. Recommend methods for estimating correlation scales 4. Recommend methods for estimating covariance scales and significance 5. Recommend methods for observing system design experiments (OSSEs) 6. Build user-friendly OSSE tools

2017 Milestones

Towards goal 3, “Establish a method to determine spatial and temporal correlation scales”, a manuscript has been published:

Mazloff, M. R., Cornuelle, B. D., Gille, S. T., & Verdy, A. (2018). Correlation lengths for estimating the large-scale carbon and heat content of the Southern Ocean. Journal of Geophysical Research: Oceans, 123, 883–901. https://doi.org/10.1002/2017JC013408

And press release: https://usclivar.org/research-highlights/designing-carbon-and-heat-observing-system-southern-ocean

This work describes the scales of variability for heat and carbon, and thus the scales the observing system is required to resolve. This can be extended to other EOVs (or QoIs) as they are identified.

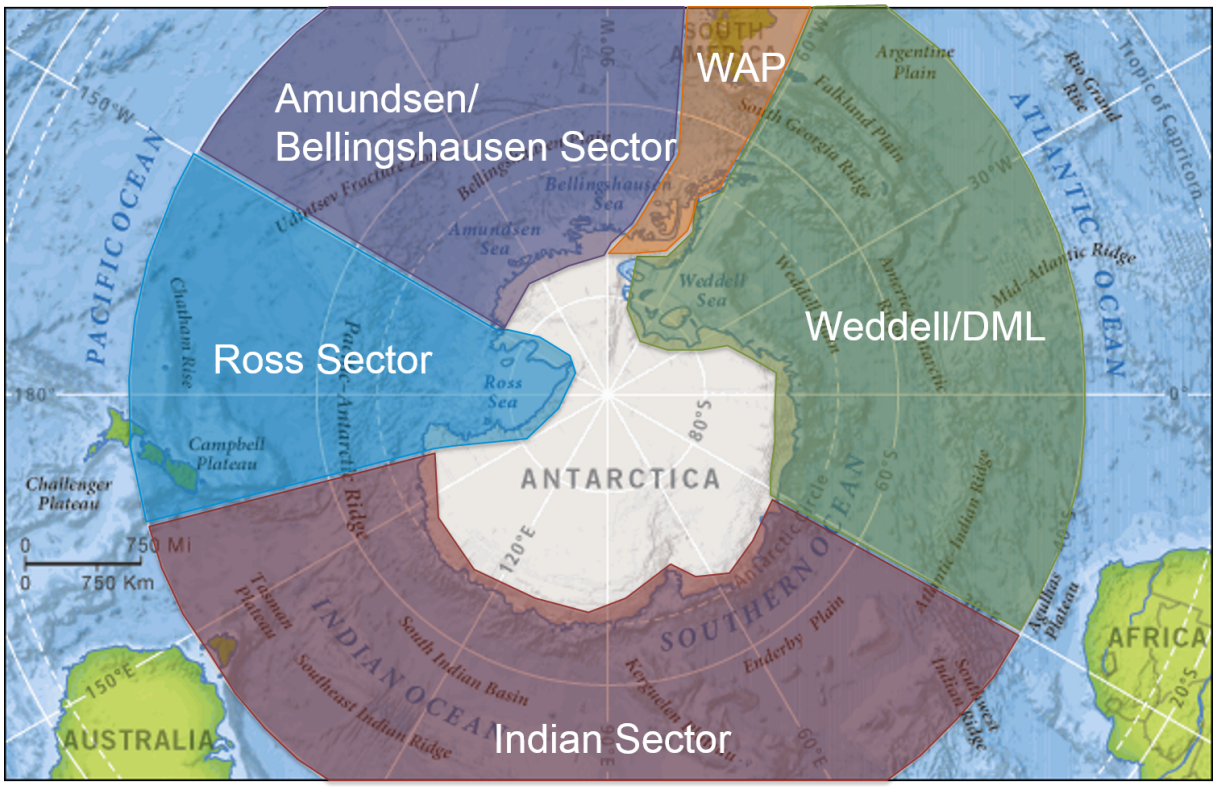
2018 Plans

Plans to accomplish or advance the other deliverables should be addressed at the 2018 SOOS modelling workshop and annual SOOS SSC meeting in May (Hangzhou, China).

Regional Working Groups

SOOS Regional Working Groups develop, coordinate and implement the observing system in their defined region. In 2015, the community identified five regions to be developed as regional groups: West Antarctic Peninsula; Ross Sea; Amundsen/Bellingshausen Seas; Weddell Sea and Dronning Maud Land; and the Indian Sector.

Three regional groups were active in 2017 and progress was made in initiating the development of the final 2 groups.



The above map shows the general area of focus for each Regional Working Group. Each group is working to define its specific boundaries.

West Antarctic Peninsula WG

Co-Chairs: Kate Hendry (UK), Oscar Schofield (USA), Sian Henley (UK)

2017 Milestones:

- 1st Workshop, hosted by British Antarctic Survey (May 2017). Over 80 participants from 13 countries helped to define observing priorities for the coming decade. This workshop resulted in a workshop report and a report published in *Eos*. This workshop was sponsored by BAS, SOOS, and SCAR.

- An international scientific workshop “The future of Marine biogeochemical research off the West Antarctic Peninsula”, sponsored by the UK Royal Society. This workshop of 30 participants resulted in a special issue on the status of the West Antarctic Peninsula, to be published in 2018.

The Ross Sea WG

Co-Chairs: Mike Williams (NZ); Walker Smith (USA)

2017 Milestones:

- 1st workshop, hosted by Shanghai Jiao Tong University, China (Sept 2017). Over 40 participants from 7 nations attended the workshop and identified existing observational efforts and recommendations for future priorities, including close collaboration with the CCAMLR Ross Sea MPA. This workshop resulted in a workshop report and was sponsored by the Institute of Oceanography, Shanghai Jiao Tong University; the US Ocean Carbon and Biogeochemistry (OCB) program; SOOS; Second Institute of Oceanography, China; and the National Laboratory for Marine Science and Technology, China

Southern Ocean Indian Sector (SOIS)

Co-Chairs: Andrew Constable (AUS); Tsuneo Odate (Japan); Phillippe Koubbi (France)

2017 Milestones:

- 1st workshop, hosted by NIPR and TUMSAT, Japan (Aug 2017). 20 participants from 5 nations attended the workshop to identify the status of multidisciplinary observations in the Indian Sector. This workshop resulted in a workshop report that will soon be available on the SOOS website, and was sponsored by NIPR, TUMSAT and SOOS.

Weddell/Dronning Maud Land

Co-Chairs: Julian Gutt (Germany); Sebastian Moreau (Norway); Laura de Steur (Norway)

2017 Milestones:

- A joint SOOS-AWI Symposium on the status of observational activities in the Weddell/DML region, hosted by AWI, Germany (June 2017). The outcome of this symposium was enhanced understanding and engagement of the research community in development of a regional working group for this region

- Initial co-chairs of the working group were identified and discussions held to plan development of the working group

Amundsen/Bellingshausen Sea

Co-Chairs: Tae-Wan Kim (Korea); Anna Wahlin (Sweden); others (TBA)

2017 Milestones:

- Initial co-chairs of the working group were identified and discussions held to plan development of the working group and expansion of leadership group

Capability Working Groups

SOOS Capability Working Groups enhance observational capabilities for SOOS.

The enhanced knowledge, technology and observing capabilities from these groups are intended to feed directly into the implementation plans of the Regional Working Groups. Capability Working Groups are, generally speaking, limited to multi-year efforts, with annual review of progress provided by SOOS governance.

Censusing Animal Populations from Space (CAPS)

Co-Chairs: Mark Hindell (Aus); Peter Fretwell (UK)

Members: Phil Tratham (UK); Dan Costa (USA); Kit Kovacs (Norway); Andrew Constable (Aus); Colin Southwell (Aus); Bill de la Mare (Aus); Andrew Lowther (Norway); Michelle LaRue (USA); Clive McMahon (Aus); Monica Muelbert (Brazil); Heather Lynch (USA)

2017 Milestones:

- Tomnod crowdsourcing platform to count seals in Antarctica has been successfully launched by Michelle LaRue. 16 300 km^2 images acquired from Prydz Bay. Visual counts have revealed a preliminary density estimate of 0.15±0.07 seals per km^2, which translates to 100,873 (range: 51,450 - 150,295)

- 2nd annual meeting held in Leuven, Belgium

- Two proposals to NERC, UK were funded to support 2 PhD students to contribute to the work of this Working Group; one to look at automation of the counting process, and the other to convert counts into a broader population structure.

Southern Ocean Fluxes (SOFLUX)

Co-Chairs: Sebastiaan Swart (Sweden); Sarah Gille (USA)

Steering Committee: Mark Bourassa (USA); Carol Anne Clayson (USA); Bruno Delille (Belgium); Simon Josey (UK); Andrew Lenton (Aus); Eric Schulz (Aus); Inga Smith (NZ); Brian Ward (UK). Over 30 additional community members from 8 nations are listed as members of SOFLUX.

2017 Milestones:

- 4 observational field programs during 2017, contributing to enhanced Southern Ocean fluxes observations
- Submission of SOFLUX community White Paper abstract to OceanObs19
- Regular community online newsletters to keep the SOFLUX network informed
- Organisation of SOFLUX meeting at Polar 2018 Conference
- Organisation of SOFLUX steering committee meeting at Ocean Sciences 2018
- Growth of membership to include 3 researchers from S. Africa and one from Brazil

Observing and Understanding the Ocean beneath Antarctic Sea Ice and Ice Shelves (OASIIS) – A POGO-Supported working group

Co-Chairs: Esmee van Wijk (Aus); Richard Coleman (Aus-POGO)

Steering Committee (from POGO institutes): Mike Meredith (UK); Jiuxin Shi (China); Alexander Brearley (UK); Oscar Schofield (USA); Lynne Talley (USA); Olaf Boebel (Germany); Susan Wijffels (USA); Steve Rintoul (Aus); Ben Galton-Fenzi (Aus); Anna Wahlin (Sweden); Seb Swart (Sweden); Fabian Roquet (Sweden); Craig Lee (USA); Dan Costa (USA); Kevin Speer (USA)

2017 Milestones:

- 1st workshop hosted by AWI, Germany (June 2017) with 70 participants from 17 nations. Outcomes of the meeting were shared field programs, strengthened collaborations for field planning, development of draft paper
- Submission of abstract for White paper at OceanObs19

Acoustic Trends in Antarctic Blue and Fin whales in the Southern Ocean (ATWG)

Co-Chairs: Flore Samaran (France); Kathleen Stafford (USA)

Members: Susannah Buchan (Chile); Ken Findlay (S. Africa); Dannielle Harris (UK); Brian Miller (Aus); Ilse van Opzeeland (Germany); Ana Sirovic (USA)

2017 Milestones:

- Serviced 2 existing recording stations; deployed 1 new station; continued data collection from 17 sites; deployment of 2 autonomous recorders in sub-Antarctic.
- Development of annotated library of acoustic detections (funded by IWC grant)
- Working Group meeting (May 2017, Slovenia) funded by IWC that focused on reviewing progress, identifying gaps in coverage, developing framework for standardised analysis of long-term acoustic data for call density and abundance estimates
- 3-year forward planning