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International Ocean Carbon Coordination Project Progress Report for SCOR, May 2019



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 promotes the development of a global network of ocean carbon and biogeochemistry observations as part of a multidisciplinary global ocean observing system that 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, practices, and standards, 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 2018 and May 2019 and outlines the actions planned for the near future.

Projects and Major Activities

IOC-UNESCO Working Group on Integrated Ocean Carbon Research (IOCR) Over the past months, IOCCP has been actively participating in the development of the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO) Working Group on Integrated Ocean Carbon Research (IOCR WG). The IOCR was formally recognized as an IOC-UNESCO Working Group at the 51st Session of the IOC Executive Council on 3-6 July 2018, in Paris, France. The creation of the IOCR WG marked a successful conclusion of the process initiated by a number of international organizations engaged in informal discussions of the Marine Carbon Think Tank. The Think Tank was a community response to an immediate need for an international coordination in ocean carbon research following the disbandment of two IMBER-SOLAS carbon working groups. Details of the process leading up to the creation of the IOCR WG, were described fully in IOCCP's report to SCOR last year.

IOCCP tends to focus on ocean carbon observations, assisting in the development of new needed technology, and developing relevant capacity. However, we recognized a continuous need for an integrative platform on ocean carbon research.

The global ocean carbon research community constitutes of several initiatives carried out by the Surface Ocean - Lower Atmosphere Study (SOLAS), the Integrated Marine Biosphere Research (IMBeR) project; the Global Carbon Project (GCP); WCRP's core project on Climate and Ocean Variability, Predictability and Change (CLIVAR), and relevant activities of IOC. Relevant national efforts on carbon research, as exemplified by the U.S. Ocean Carbon & Biogeochemistry (OCB) program under the U.S. Carbon Cycle Science Program, contribute directly to such global efforts on ocean carbon research.

The current scope of the IOCR WG was consulted across all of these international projects and programs, and acknowledged IOCCP's strong advocacy for this initiative to go beyond the inorganic component of the carbon cycle, and include other related biogeochemical properties such as nutrients, oxygen, and N₂O, that is, consistently with the biogeochemical suite of Essential Ocean Variables (EOVs) developed through IOCCP as the GOOS Biogeochemistry Panel. The new focus on integrated ocean carbon research would deal with issues related to decadal variability, meso and sub-meso scale processes, scientific requirements for optimal observing system design, integrating ocean carbon biology considerations, and the interaction of the fluxes of heat and carbon fluxes and their storage.

Moreover, it was agreed that the WG would consider relevant new developments in ocean carbon research. For example, innovative work initiated in the context of SCOR Working Group 134 on the Microbial Pump in the Ocean in 2008, and leading to the publication of a number of established studies in 2011, have emphasized the importance of the microbial pump in the global carbon cycle and in related models; its relation with eutrophication levels in coastal areas; and the need to combine established knowledge and research on the biological pump with research on the microbial pump.

The decision to form the IOCR WG was also enabled by the increased policy demand for ocean carbon research. The need for ocean research and systematic observations, in particular with respect to the carbon cycle, was discussed by the United Nations Framework Convention on Climate Change (UNFCCC) and one of its two permanent subsidiary bodies: Subsidiary Body for Scientific and Technological Advice (SBSTA).

Furthermore, the work of the IOCR WG will contribute to and benefit from the UN Decade of Ocean Science for Sustainable Development and the Agenda 2030. Details of the policy-enabling framework providing context for future IOCR WG activities can be found in the working document IOC/EC-LI/2 Annex 5, presented for approval to the IOC Executive Council: http://ioc-

unesco.org/index.php?option=com_oe&task=viewDocumentRecord&docID=21841

With the approval of the IOCR WG by the IOC Executive Council, the following Terms of Reference were adopted. These were drafted with significant input from the IOCCP.

Terms of Reference of the IOC Working Group on Integrated Ocean Carbon Research

- 1. The IOC Working Group on Integrated Ocean Carbon Research (hereinafter referred to as 'the Working Group') aims at filling knowledge gaps in relation to ocean carbon by designing and promoting the implementation of the new generation of integrated ocean carbon research
- 2. The Working Group, coordinated by IOC, will foster active collaboration and synergies amongst IOC, the International Ocean Carbon Coordination Project (IOCCP), the Surface-Ocean Lower Atmosphere Study (SOLAS), the Integrated Marine Biosphere Research (IMBeR), the Global Carbon Project (GCP), the core project on Climate and Ocean Variability, Predictability and Change (CLIVAR) of the World Climate Research Programme (WCRP), and relevant national efforts on carbon research. The Initiative is open to any other relevant international efforts on ocean carbon research with a demonstrated scientific record
- 3. The Working Group will be composed of approximately 20-25 experts. The core of the Group will be constituted by two experts designated by each partner (IOC, IOCCP, SOLAS, IMBeR, GCP, WCRP/CLIVAR), which will act as the Working Group's Steering Committee (SC). The SC will identify additional experts for their inclusion in the Working Group. The SC will identify and appoint two members of the Working Group as Co-Chairs of the Group. Membership of the group will last two years; while members of the Working Group could be prolonged for a second two-year term, it is envisaged that at the end of the first term, one third to half of the group be renewed by appointing new members
- 4. The Working Group will have a geographic and gender balanced representation, reflecting inter alia the following disciplines and areas of ocean carbon research: ocean physics, chemistry, biochemistry, biology, ecology and technology
- 5. Depending on scientific needs, the Working Group may establish task teams around specific themes or crosscutting issues related to various aspects of ocean carbon research. These task teams would be co-chaired by two members of the Working Group, taking into due account geographic and gender balance
- 6. The Working Group will build upon the multiple relevant synthesis activities for ocean carbon and promote coordination across these efforts. These syntheses will inform the organization of research efforts on ocean carbon research at multiple levels national, regional and global
- 7. The findings of the Working Group may contribute to the sixth assessment report of the IPCC (IPCC AR6) and other IPCC reports, as appropriate, and according to the IPCC rules of procedure (e.g. through the peer-review process of the AR6 and other IPCC reports). The Working Group, in coordination with the UNFCCC Secretariat, may also assist in facilitating informal consultations among science organizations invited to contribute to research dialogues convened by the UNFCCC
- 8. The Working Group will develop a yearly work plan, review it on a yearly basis, and report, through the IOC Secretariat, to the IOC Governing Bodies on progress made in the discharge of its functions
- 9. The Working Group will produce its findings in the form of meeting reports, scientific articles, science plans and implementation plans. It will also assist the IOC Secretariat in producing policy briefs and public awareness materials, as appropriate, including dedicated web pages as part of the IOC website
- 10. A Working Group secretariat will be provided by the Ocean Science Section of the IOC Secretariat. Collaborating organizations, programmes and initiatives may also provide staff or in kind contributions, including secondment of experts, to support the Working Group secretariat
- 11. The Working Group will operate on the basis of voluntary financial and in-kind contributions of IOC Member States, other governments, and international organizations

IOCCP will advocate for a science strategy for future marine carbon research as a needed outcome of this WG. Such a strategy would become an important asset for the community, used for example to lay out long-term planning for bodies such as the Global Ocean Acidification Observing Network (GOA-ON). However, in order to produce a strategy that is relevant for these structures, the structures need to be involved in the strategy design itself. There is a clear need to take into account the perspective of the coastal ocean and not just the open ocean in a strategy for future ocean carbon research.

Currently, the IOCR WG Steering Committee includes two IOCCP members: Director Maciej Telszewski and SSG member Rik Wanninkhof. One of IOCCP's roles will be to ensure that GOA-ON community is adequately represented in the process, though they are not formally part of the Steering Committee. IOCCP also nominated Prof. Christopher Sabine (former IOCCP Chair) to join the Steering Committee. Chris accepted this nomination. Maciej Telszewski will be replaced by an active scientist after the initial 2-year period.

Initial activities of the WG were foreseen to start in the last quarter of 2018 and were to entail:

- An inception meeting of the Working Group in early 2019
- Coordinated contributions to WCRP Coupled Model Intercomparison Project (CMIP6) activities as a follow-up to the CMIP6 workshop on ocean carbon uptake (AGU, 2018), in coordination with CMIP.
- Inputs to relevant ocean acidification activities in relation to the work plans of GOA-ON and the IAEA Ocean Acidification International Coordination Centre (OA-ICC), in coordination with GOA-ON
- Inputs to the GCP's 2nd REgional Carbon Cycle Assessment and Processes (RECCAP2) meeting (Japan, March 2019)

The tentatively planned first meeting of the group was cancelled and replaced by an idea to hold a larger scoping workshop. IOCCP was asked to suggest 5 names of experts to a larger workshop (40-50 participants) to represent areas we think should be taken up as the future carbon research directions of the WG. Based on the ensuing discussions, the IOCCP Executive (Co-Chairs and Office) came up with a list of five proposed themes for which expertise would be needed at the workshop. The proposed themes will be discussed and elaborated on in consultation with the IOCCP SSG.

- 1. Integrating surface and interior ocean carbon observations and products, i.e. SOCAT and GLODAP, accounting for the need to develop a better understanding of how surface fluxes are connected to interior carbon storage.
- 2. Inclusion of observing system review of carbon fluxes alongside the ongoing review of heat and freshwater fluxes carried out by the Ocean Observations Panel for Climate (OOPC).
- 3. Ocean acidification (OA), perhaps the development of an OA data synthesis product.
- 4. Terrestrial influences on coastal biogeochemistry.
- 5. Promoting time series activities towards data synthesis products.

As part of the IOCR activities, IOCCP participated in the community workshop on "Synthesis and intercomparison of ocean carbon uptake in CMIP6 models" organized by U.S. OCB on 8-9 December 2018, in Washington, DC. IOCCP was also invited to represent the ocean carbon community at the 1st All-RECCAP2 Workshop held on 18-21 March 2019, in Gotemba, Japan. For details on the meeting proceedings, please see the reports under the Workshops and Meetings section below.

Further activity of the IOCR WG is expected in late 2019 and early 2020, parallel to the final preparations and kick-off of the UN Decade for Ocean Science for Sustainable Development starting in 2020.

Technical capacity development in marine biogeochemistry

A significant amount of IOCCP human and financial resources were devoted to technical capacity building in 2018 and early 2019, in line with IOCCP SSG decision to strengthen our role in this domain (see more under the Future Directions section). All in all, IOCCP has been involved in organizing, co-sponsoring and running three training events, described in detail below. Based on our activities in the past 12 months, it is clear that IOCCP has also diversified its training offer to include a new workshop style specifically dedicated to promoting best practices in data management-related aspects, thus realizing not one but two of our Terms of Reference at the same time:

- 7) Develop and support training activities for users of observing technologies (instruments, sensors and platforms) for ocean carbon and biogeochemistry.
- 9) Promote the integration of ocean carbon and biogeochemistry information into research and assessments including the use of relevant data synthesis products (e.g., SOCAT, GLODAP).

IOCCP – BONUS INTEGRAL Training Course on a Suite of Biogeochemical Sensors

Building on the success of the 2015 IOCCP International Summer School and in response to a large demand for a repeated offer of this course, IOCCP and EU BONUS INTEGRAL Project (Integrated carboN and TracE Gas monitoRing for the bALtic sea; https://www.iowarnemuende.de/integral-home.html) have organized a 10-day international course on "Instrumenting our ocean for better observation: A training course on a suite of biogeochemical sensors." The course has a total budget of ca. 110,000 USD and is funded by IOCCP and BONUS INTEGRAL with generous co-sponsorship from U.S. OCB, the Integrated Carbon Observation System–Ocean Thematic Centre (ICOS-OTC; https://www.icos-ri.eu/icos-central-facilities/icos-otc), EU H2020 RINGO project (Readiness of ICOS for Necessities of Integrated Global Observations; https://www.icos-ri.eu/ringo), and EU H2020 AtlantOS project (https://www.atlantos-h2020.eu/).

The course will be held on 10-19 June 2019 at the Sven Lovén Center for Marine Sciences, in Kristineberg, Sweden. This course responds to the growing demand of the global ocean observing system and the marine biogeochemistry community for expanding the correct usage and generation of information from a suite of autonomous biogeochemical sensors. The goal of the course is to train a new generation of marine biogeochemists in the use of a suite of commercially available biogeochemical sensors and to assure the best possible quality of the data produced. The suite of sensors will include those that measure pCO₂, pH, dissolved oxygen and selected bio-optical parameters, related to four EOVs: Inorganic Carbon, Oxygen, Particulate Matter, and Ocean Colour.

This intensive training course will provide trainees with lectures and hands-on field and laboratory experience with sensors (deployment, interfacing, troubleshooting and calibration), will provide in-depth knowledge on data analysis, quality control, and further

processing. This course will also provide an overview on the use of remote sensing, modelling, and intelligent data extrapolation techniques. Complete information on the course, along with a draft agenda and list of course instructors, can be found at the course website: http://www.ioccp.org/2019-training-course.

The main outcome of the training course will be a group of 28 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 emphasized 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, and transfer of knowledge through open and free access to recorded course materials.

Course applications were open from mid-December 2018 to 1 February 2019. Twenty-eight participants at a PhD/early postdoc level were selected from among more than 130 applicants from all over the world through a competitive process. The selection committee consisting of 7 reviewers (female and male, from Europe and North America) considered criteria such as personal motivation, academic excellence and potential, and ability to apply and distribute acquired knowledge for the benefit of expanding the ocean observing community. Gender and geographic balance were also considered. Ultimately, the Organizing Committee invited 18 females and 10 males, resulting in 64% female participation. Out of the 28 participants, 8 were invited from Europe, 7 from North America, 6 from South America, 3 from Asia, 3 from Africa and 1 from Australia – reflecting very well the geographic distribution of all eligible applications received.

IOCCP intends to video record most lectures and make them available to the wider community towards the end of 2019. There are also ongoing discussions between the Organizing Committee, the International Oceanographic Data and Information Exchange (IODE) Ocean Teacher Global Academy (OTGA) and the Ocean Best Practices (OBP) initiative regarding whether components of the training course could be used as a new pilot for a best practices video course available through the advanced e-learning platform of OTGA, popular especially among the countries of the developing world.

Global Ocean Oxygen Network International Summer School (GO₂NE SS2019)

Also in 2019, IOCCP is contributing to and co-sponsoring the GO₂NE Summer School, to be held on 2-8 September in Xiamen, China. The IOC- GO₂NE SS2019 will bring together 40 PhD students and early-career scientists with 16 world-leading international scientists. The school aims to connect young researchers with leading scientists from the academic and small & medium enterprise world who are working on oxygen. The information will be delivered not only in a theoretical framework, but also through practical sessions on laboratory experiments, field work, modelling and special sessions on communication, ethics, and engagement with stakeholders.

IOCCP SSG member Véronique Garçon is one of the 3 Directors of the School, as well as a member of the Organizing and the Scientific Committee. She will teach four lectures and/or practical sessions, and IOCCP Director Maciej Telszewski will also deliver two lectures on ocean observing system design in relation to the deoxygenation issue, and on data management covering local to global perspectives.

For more details please access the Summer School website: https://mel.xmu.edu.cn/summerschool/go2ne/index.asp.

Workshop on Underway and sensor CO2 data and metadata quality control procedures

On 1-3 April 2019, IOCCP organized a small technical workshop on "Underway and sensor CO₂ data and metadata quality control procedures" at the Institute of Oceanology of the Polish Academy of Science (IO PAN) in Sopot, Poland. The workshop was sponsored by the EU project AtlantOS and EU BONUS INTEGRAL project. The goal of this workshop was to update participants on the protocols enabling globally coherent quality control of surface ocean CO₂ data, using a series of lectures and practicals given in the context of the most comprehensive surface ocean CO₂ data set: the Surface Ocean CO₂ Atlas (SOCAT; www.socat.info).

The workshop gathered 10 participants from Ireland, UK, Sweden, Poland and Estonia. Siv Lauvset (IOCCP SSG member), Maciej Telszewski (IOCCP Director), and Bernd Schneider from the Leibniz Institute for Baltic Sea Research Warnemünde (IOW) in Germany, designed and successfully carried out this new model of a workshop. The participants, representing a mixture of open ocean and coastal observationalists, expressed their appreciation of the mix of theoretical and hands-on training they received, indicating that IOCCP should strongly consider adapting this workshop model in a few other regions of the world where there is interest but gap in knowledge with respect to submitting quality controlled biogeochemistry data to SOCAT, GLODAP, or other emerging data synthesis products.

Having a small size group fostered interactions during the workshop, resulting in a number of useful recommendations to the SOCAT community. Responding to these will not only potentially increase the number of data providers, but also help increase the impact of SOCAT data for a growing number of applications.

Coordination of global ocean acidification observations

IOCCP continues to play an active role in the activities of GOA-ON through participation of its three SSG members Kim Currie, Cristian Vargas and Benjamin Pfeil, and Director Maciej Telszewski on the GOA-ON Executive Council. GOA-ON is a network currently comprised of more than 600 members from 94 countries.

Over the past year, there were two major developments on which we would like to focus in this report. First, GOA-ON organized its 4th International Science Workshop in Hangzhou, China. Second, the indicator methodology for UN Sustainable Development Goal (SDG) Target 14.3 has been officially welcomed by the IOC Executive Council. In addition, we report on the GOA-ON Executive Council meeting in April 2019, in Hangzhou, China. Proceedings from the meeting are available under the Workshops and Meetings section of this report.

SDG Indicator 14.3.1 Methodology accepted by the IOC-UNESCO Executive Council IOC-UNESCO acts as a custodian agency for specific SDG 14 indicators, particularly under targets 14.3 and 14.a:

[SDG 14.3] Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels.

[SDG 14.a] Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular Small Island Developing States and least developed countries.

This means that the IOC is responsible for the methodological development and measurement of these SDG indicators at global scale. The SDG Target Indicator 14.3.1 calls for "average marine acidity measured at an agreed suite of representative sampling stations." The process of developing suitable methodology has taken place with significant involvement of IOCCP, primarily through the expert meeting in Paris in January 2018, as reported in IOCCP's report to SCOR last year.

The Methodology, along with the associated data and metadata files, are now available on the new GOA-ON Resources webpage: http://www.goa-on.org/resources/sdg_14.3.1_indicator.php. The documents provide guidance to scientists and countries about how to carry out measurements following the best practices established by

countries about how to carry out measurements following the best practices established by experts in the ocean acidification community, including members of the GOA-ON and IOCCP, and explains how to report the collected information. It was officially welcomed by the Member States of the IOC during its 51st Executive Council Meeting in July 2018. You can view the accepted Methodology, available in English, French, Spanish and Russian from here.

A few months later, the SDG Target Indicator 14.3.1 was upgraded from Tier III to Tier II by the Inter-agency and Expert Group on SDG Indicators (IAEG-SDG) of the United Nations Statistical Commission following a presentation by the IOC-UNESCO. Tier II classification means that the "Indicator is conceptually clear, has an internationally established methodology and standards are available, but data are not regularly produced by countries."

As part of the continued efforts to stimulate adequate data production to bring the SDG Target Indicator 14.3.1 to Tier I, GOA-ON and IOC-UNESCO also invited the community to take part in a survey on OA research and observation data. The survey responses, collected until 20 December 2018, will help trace where OA data are being collected, and where they are stored and served, to facilitate reporting on this Indicator.

4th GOA-ON International Workshop, Hangzhou, China, 14-17 April 2019

IOCCP was strongly engaged in the organization of the 4th GOA-ON International Workshop, held on 14-17 April 2019 in Hangzhou, China, and which brought together scientists from around the world to discuss emerging aspects from the coupled effects of ocean acidification with multi-stressors, review global ocean acidification status and forecast capabilities, and explore opportunities for capacity development.

The workshop was the fourth in a series that aims to build a sustained observing system for ocean acidification and the related biological responses that extends from local to global scales. These workshops bring together the international community and are important for developing collaborative networks and for building capacity to address the threat of OA to marine ecosystems. Previous workshops have been held in the USA (Seattle, 2012), United Kingdom (St. Andrews, 2013), and Australia (Hobart, 2016).

Goals of the 2019 workshop included (i) opening a dialogue towards a better understanding of ocean acidification's impacts on industry, (ii) increasing coordination across nations and

stakeholders, and (iii) highlighting the widespread recognition of the threat of ocean acidification to the health and sustainability of marine ecosystems.

The workshop was organized by the State Key Laboratory of Satellite Ocean Environment Dynamics (SOED) in Hangzhou and by the Second Institute of Oceanography (SIO), Ministry of Natural Resources, China. Apart from being a co-sponsor of the event, IOCCP was represented by its Director and several SSG members, who contributed tremendously to shaping the agenda, reviewing applications, convening and moderating one of the sessions, and actively engaging in the discussions.

The organizers were impressed to receive 196 abstracts for the four thematic sessions. The agenda of the meeting was structured to maximize time for discussions whilst enabling selected participants to highlight research achievements, which stimulated the discussions during and after the workshop.

A detailed workshop report is being compiled and will be available from GOA-ON website and distributed by IOCCP and others. The main focus of this report will be recommendations from each thematic session, which will be incorporated as action items in the GOA-ON Implementation Strategy.

Release of the GOA-ON Implementation Strategy

Taking the opportunity that many of GOA-ON members were present at the Science Workshop in Hangzhou, GOA-ON launched its new 2019 Implementation Strategy. This document outlines how to implement the GOA-ON Requirements and Governance Plan, including expanding OA observations, closing human and technology capacity gaps, connecting scientists regionally and globally, and informing about the impacts of OA. The aim was also to provide guidance that will allow for comparability across the Network, while considering the potentially different requirements and impediments within different regions. The Implementation Strategy also offers practical information prompting members to approach GOA-ON's goals. The GOA-ON Executive Council is looking for feedback about this document until **1 July 2019**. The Strategy will be also updated to incorporate action items stemming from the Science Workshop recommendations.

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

A significant accomplishment related to the implementation of the Framework for Ocean Observing (FOO) was the publication of the Ocean Colour EOV Specification Sheet, which is available for viewing and download from: http://www.ioccp.org/images/10FOO/BGC-EOV-Spec-Sheets_Aug-2017/EOV_Ocean-Colour_20180924.pdf. The document has been prepared as a joint effort by the International Ocean Colour Coordination Group (IOCCG) and GOOS Panels, under the coordination of IOCCP Project Office. The challenge of describing the multidisciplinary requirements and applications of ocean colour measurements was met by a task team of dedicated experts from the IOCCG Committee and GOOS Expert Panels: Emmanuel Boss (University of Maine, USA), Frank Muller-Karger (University of South Florida, USA), Rosalia Santoleri (Consiglio Nazionale delle Ricerche, Italy), Simon Bélanger (Université du Québec à Rimouski, Canada) and Taka Hirata (Hokkaido University, Japan). Extensive feedback was obtained through two rounds of review provided by the IOCCG Committee, which consists of members drawn from national space agencies and the ocean colour community.

Although IOCCP as GOOS Biogeochemistry Panel is formally responsible for curation of the document, the Ocean Colour EOV should be seen as equally owned by and applicable to the work of all three Expert Panels of GOOS: Physics & Climate, Biogeochemistry, and Biology & Ecosystems. As in the case of other EOVs, GOOS (in consultation with IOCCG) will ensure that the document remains up to date in the future. The IOCCP Office developed a timeline and procedure for curation and regular update of all Biogeochemistry EOV Specification Sheets. The process will rely on timely input from SSG members as well as external experts, if needed. The next update is scheduled for August/September 2019.

During the past 12 months, IOCCP Co-Chairs and Office took part in two sessions of the GOOS Steering Committee: in Santa Marta, Colombia, in June 2018 and in Kiel, Germany, in May 2019. On both occasions, a comprehensive report of Biogeochemistry Panel activities and future plans was presented. As the GOOS Strategy is scheduled for public launch in mid-May, at the UN Decade Planning Meeting in Copenhagen, the efforts of GOOS are now shifting towards finalizing a new Implementation Plan. The document will outline planned activities in a 1-3-year time frame, and is intended to be updated regularly. IOCCP continues to advocate for more efficient collaboration among the GOOS structures (Expert Panels, JCOMM OCG, and GOOS Regional Alliances) and helps strengthen existing and build new partnerships for GOOS (e.g., GODAE OceanView modelling community, IODE, UN Environment), significantly contributing to the realization of the Strategic Objectives of GOOS.

Among the specific requests for our Panel was the recommendation to scope out the requirements for sustained ocean observations of marine plastics contamination. In the interim period between the 7th and 8th Session of GOOS SC, IOCCP together with the GOOS Office have engaged in dialogue with key organizations and expert working groups interested in pursuing coordinated action towards better mapping the status as well as impact of this growing human pressure. While IOCCP does not intend to lead this activity, it will continue to play the role of a conduit in the process to the extent made possible by currently available human and financial resources. Please see the Future Directions section for a detailed discussion of the notion.

Surface Ocean CO₂ Reference Observing Network (SOCONET)

The Surface Ocean CO₂ Reference Observing NETwork (SOCONET) was established to combine high-quality and intercomparable Inorganic Carbon EOV data from moorings and ships to determine what assets are in the water and assure the quality of data delivered by these assets. Following the network kick-off meeting in February 2018, the network was formed under auspices of IOCCP through a global partnership of investigators involved in ongoing efforts, both on ships of opportunity (SOOP-CO₂) and fixed platforms (OceanSITES). Goals of surface ocean CO₂ observing network are to make sure that operators of CO₂ measuring instruments on ships of opportunity and fixed platforms follow standard operating procedures (SOPs), strengthening the quality of data collection efforts of the wider SOCAT community.

A prospectus of SOCONET is available online at a skeleton webpage: http://www.aoml.noaa.gov/ocd/gcc/SOCONET/. Implementation of SOCONET is slower than anticipated in large part because the regional construct that consortia (EU, USA, Japan, Southern Ocean (Australia, New Zealand, and South Africa)) would comprise SOCONET was not embraced. Rather, individual participants wanted to be directly acknowledged and engaged in the SOCONET effort. The readiness level of several participants to accomplish some of the goals (telemetry, near real-time distribution of data) was such that full implementation will likely take several years. The first steps of registering the different ships is well underway, with over 40 platforms that appear to meet SOCONET criteria. The next step will be establishing protocols for air CO₂ measurements and QC. To this end, a community white paper (CWP) is being reviewed for the OceanObs'19 Conference that covers SOCONET and the associated Marine Boundary Layer CO₂ ("air CO₂") measurements. The paper presents the joint vision of the atmospheric and oceanographic community for taking full advantage of shared use of platforms through overcoming the existing hurdles over the next decade.

Coordination with WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM)

As part of WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology-Ship Observations Team (JCOMM-SOT), key performance indicators and specification sheets have been developed for the CO₂ part of the Ships of Opportunity Program (SOOP-CO₂). Efforts are underway with the JCOMM in situ Observations Programme Support Centre (JCOMMOPS) to list all platforms in their appropriate program. Discussions took place on how to best integrate SOCONET, which is an EOV-based approach, to the platform-based structure of JCOMM. At the 10th Session of the JCOMM Observation Coordination Group (OCG) held in May 2019, the decision was made that all SOCONET pCO₂ sensors will be listed in JCOMM under its relevant platform-based program (e.g., mooring under OceanSITES and the Data Buoy Cooperation Panel (DBCP); SOOP-CO₂ under SOOP-SOT).

Publication of the pCO₂ installation manual

An important and long-awaited outcome of the SOCONET was the publication of the manual which helps guide the community on "Installation of autonomous underway pCO₂ instruments onboard ships of opportunity." The manual was produced by Dennis Pierrot (NOAA-AOML/Univ. Miami-CIMAS, USA) and Tobias Steinhoff (GEOMAR, Germany) and is full of good tips based on real experience from the authors and several other members of the community. The information contained in this technical document pertains specifically to the installation of the system built by General Oceanics, Inc. in Miami, Florida, USA. However, most of the instructions and issues discussed should apply to any type of autonomous system. Different sections of the manual describe the different phases of the installation process, from hardware requirements and necessary preparations to the installation and testing of the system.

The document can be accessed from the IOCCP site here:

http://www.ioccp.org/images/D4standards/NOAA-Technical-Report_OAR-AOML-50.pdf, and it should be cited as:

Pierrot, D., and T. Steinhoff, 2019: Installation of autonomous underway pCO₂ instruments onboard ships of opportunity. NOAA Technical Report, OAR-AOML-50 (doi:10.25923/ffz6-0x48), 31 pp.

Global data synthesis activities Surface Ocean CO₂ Atlas (SOCAT)

In June 2018, on behalf of more than 100 contributing scientists worldwide, we proudly announced the release of Version 6 of SOCAT - a synthesis activity by international marine carbon scientists with annual public releases. SOCAT version 6 has 23.4 million quality-

controlled in situ surface ocean fCO₂ (fugacity of carbon dioxide) measurements from 1957 to 2017 for the global ocean and coastal seas, as well as additional calibrated sensor fCO₂ measurements. Early in 2019, data submission and quality control for SOCAT version 7 was also completed. The release of SOCATv7 is planned for June 2019.

SOCAT has also released an updated "cookbook" for secondary data quality control procedures. The updated cookbook, which applies from version 7 onward, was prepared by a team led by IOCCP SSG member Siv Lauvset. There is no intention to retrospectively implement the revised quality control criteria for data sets in SOCAT versions 1-6. The updated cookbook can be downloaded from the SOCAT site: https://www.socat.info/index.php/2010/09/01/socat-cookbook-revised/; and also from the IOCCP Standards and Methods page.

Global Ocean Data Assimilation Project (GLODAP)

On 26 March 2019, IOCCP also informed the community that the GLODAPv2_2019 data product had been released during the First International AtlantOS Symposium in Paris (see details under Workshops and Meetings). The Global Ocean Data Analysis Project (GLODAP) is a data synthesis activity of carbon-relevant ocean interior data by a consortium of international marine scientists. The EU project AtlantOS supported the new release, together with the IOCCP and numerous national funding bodies, universities, and research institutes.

GLODAPv2_2019 is an incremental update of the GLODAPv2 data product released in 2016. Data from 116 new cruises have been added and small errors in the previous GLODAPv2 data product have been corrected. GLODAPv2_2019 contains data from 840 cruises with more than 1.1 million Niskin bottle sample analyses from all ocean basins, from 1972 through 2017. The original data, their documentation and doi codes are available at the Ocean Carbon Data System of NOAA/NCEI

(https://www.nodc.noaa.gov/ocads/oceans/GLODAPv2_2019/). This site also provides access to the merged data product, which is provided as a single global file or as four regional ones – for the Arctic, Atlantic, Indian, and Pacific oceans – under the doi: https://doi.org/10.25921/xnme-wr20 (Olsen et al., 2019). The product files also include significant ancillary and approximated data. These were obtained by interpolation of, or calculation from, measured data.

There is currently work underway to publish a scientific paper documenting the GLODAPv2.2019 methods and providing a broad overview of the secondary quality control results. Several IOCCP SSG members and the Project Director are co-authors on the paper. Until the review is completed, the community may access the discussion version of the paper via this link: https://www.earth-syst-sci-data-discuss.net/essd-2019-66/.

Capturing the legacy of the EU H2020 AtlantOS project

There are currently two large ongoing projects endorsed by GOOS and providing information on how to (re-)design basin-scale observing systems: TPOS2020 in the Equatorial Pacific and EU H2020 AtlantOS in the Atlantic. Through dedicated AtlantOS funding for the IOCCP project officer in 2016-2019, IOCCP has been providing significant input into a number of regional activities in the Atlantic related primarily to setting requirements for observations via the EOV process, but also for improved knowledge of the current status of coordinated marine biogeochemistry observations and data accessibility. These efforts have been complementary to the strategic objectives of GOOS and helped progress the work of GOOS Biogeochemistry Panel.

From AtlantOS the project to AtlantOS the system

From the onset of the EU AtlantOS project, efforts were put in place to avoid sharing the fate of many EU projects that failed to provide a clear legacy for the future. The vision for what AtlantOS the system would look like was outlined in the high-level strategy document put together through a process known as the Atlantic Ocean Observing BluePrint (http://atlanticblueprint.net/). Recognizing the importance of continuing the unprecedented basin-scale coordination actions instigated by AtlantOS the project, the BluePrint process has therefore been supported from the very beginning not only by the project by also by GOOS. The document "Vision for an All-Atlantic Ocean Observing System (AtlantOS)" provides a structural framework for guiding the development of the Atlantic Ocean Observing System in the North and South Atlantic. It outlines a baseline of core platforms, networks and systems that make up AtlantOS and a path from initial capability at the beginning of the UN Decade of Ocean Science for Sustainable Development in 2021, to full operating capability at the end of the decade in 2030. The AtlantOS BluePrint benefited from active engagement from all interested parties and partners.

On 25-28 March 2019 at the IOC headquarters in Paris, the 1st International AtlantOS Symposium was organized as a high-level event bringing together scientists, policy makers, users, funders and other stakeholders, to articulate and refine the joint All-Atlantic ambition for ocean observing. The four-day long symposium was not only an occasion to celebrate the success of the H2020 AtlantOS project, but more importantly marked the beginning of the international AtlantOS (All-Atlantic Ocean Observing System) programme, which benefits from the Galway and Belém Statements and is the Atlantic contribution to GOOS. More information on the Symposium proceedings can be found under the Workshops and Meetings section of this report.

The legacy of AtlantOS as a GOOS project

GOOS has been considering how to capture the legacy of its two regional projects while considering their outcomes/advances in all steps of the FOO, as well as the approach taken to exercising the FOO process. In addition, GOOS looks to the projects for some guidance on notions not covered by the FOO, including governance, prioritisation and facilitating change.

The need and the best way to capture the legacy of these projects was discussed during the 8th Session of GOOS Steering Committee in May 2018. In a document prepared in advance of the meeting, IOCCP highlighted specific AtlantOS accomplishments, lessons learnt and recommendations that could be considered as legacy in the context of a future integrated Global Ocean Observing System.

With respect to setting requirements for observations, analysis of the societal requirements for Atlantic Ocean observations can be found in deliverable report 8.1, currently under revision. The project also analysed the adequacy of selected information products to meet user requirements (e.g., deliverable reports 8.9, 8.11 and 8.16). The European Strategy for All-Atlantic Ocean Observing System, produced by the AtlantOS project with IOCCP's co-authorship, points at the need to map the requirements of European users "on a biannual basis via dedicated user meetings focussing specifically on delivering information for operational services, climate and marine ecosystem health applications." This goal could be

realized through actions proposed by the European Ocean Observing System (EOOS) as specified in the 2018-2022 Strategy and Implementation Plan.

The AtlantOS workshop on setting phenomena-based targets for biogeochemical observations in the Atlantic Ocean provided a valuable trigger to discussing a phenomena-based approach to co-design of a multi-platform observing system. The full potential of exploring this approach on a basin to global scale remains to be explored. The full report from that workshop is available from here.

AtlantOS also contributed strongly to other aspects, such as technology development, data management, and ocean information product delivery. A ten-year roadmap for strategic development of sensor and instrument technology for Integrated Atlantic Ocean Observing Systems and GOOS was developed (AtlantOS Sensors and Instrumentation Roadmap) under the leadership of IOCCP SSG member Douglas Connelly. GOOS should ensure that a strategy for keeping the roadmap alive is in place. Assessment of networks and gap analysis that highlights opportunities for development over three- and ten-year timescales was included in the AtlantOS Emerging Networks Roadmap, which likewise requires regular updates to remain a useful resource for the ocean observing community.

An integrated data system that harmonizes work flows, data processing, and distribution across in-situ observing network systems, and integrates in-situ observations into existing European and international data infrastructures was presented by the project in the AtlantOS Data Services Report, to which IOCCP SSG member Benjamin Pfeil also contributed. The challenge will be to support further across-basin data integration efforts which could provide a backbone for a more efficient global ocean data management system. Such considerations are taking place in parallel with other partnerships built by GOOS, for example, with the World Meteorological Organization (WMO) as described in the report from a recent Technical Workshop on "Enhancing ocean observations and research, and the free exchange of data, to foster services for the safety of life and property." IOCCP's efforts to set up a Global Data Assembly Centre for Marine Biogeochemistry offer a pragmatic global solution at least for one of the ocean disciplines.

Delivery of essential ocean information products and downstream services relies on close partnership with the modelling and forecasting community. GOOS aims to enhance product delivery for applications related to weather and operational ocean forecasting, climate prediction and projection, as well as climate analysis and assessment, hazard response and early warning systems, sustainable fisheries and aquaculture management, marine spatial planning, biodiversity and environmental assessments, and other. By partnering with the modelling and forecasting community, GOOS can help transfer information product ideas and solutions to other regions; turn pilot projects into operational products; and engage with the private sector to advance the delivery of adequate ocean observations. In AtlantOS specifically, the following targeted products benefited from the use of forecasts and reanalyses made available by the European Centre for Medium-range Weather Forecast (ECMWF) and Copernicus Marine Environment Monitoring Service (CMEMS), among other.

- North West European Shelf Seas Reanalysis and Forecasting
- <u>Ship routing hazard mapping</u>
- Harmful algal bloom warning bulletins
- Operational forecast system for Atlantic albacore tuna

POGO-AtlantOS collaboration on ocean products

Strengthening the partnership with the modelling community is also high on the IOCCP agenda. With marine biogeochemistry recognized as a new frontier in ocean forecasting and data assimilation, we see both a need and a benefit to engage stronger with GODAE OceanView, CMIP6, ECMWF, Copernicus and other intermediate data users.

Workshops and Meetings

8th Session of the GOOS Steering Committee (GOOS-SC-8), 1-3 May 2019, Kiel, Germany

The 8th Session of the GOOS Steering Committee (GOOS-SC-8), guided by a new GOOS 2030 Strategy, focused on implementation planning related to major objectives. These include: developing partnerships for delivery; advocacy, visibility, and communications about the observing system; authoritative design guidance and the incorporation of results from projects; core observation coordination actions and the promotion of best practice; open data; capacity development; and governance of the observing system.

The meeting took place in Kiel, Germany, on 1-3 May 2019, and was hosted by SC co-Chair Toste Tanhua. There were 36 attendees, including SC members, sponsor representatives, GOOS staff members and invited experts. IOCCP was represented by Kim Currie and Artur Palacz, who also attended the GOOS Executive meeting on Saturday, 4 May 2019, also in Kiel, Germany.

The 3-day meeting had a strong focus on future developments of the global ocean observing system and GOOS, the program, in particular. Several forward-looking documents were prepared in advance of the meeting, with contributions from IOCCP. A restructuring of the GOOS SC was outlined in a proposal which will be further discussed and modified before presenting for approval at the IOC Executive Council meeting in 2020. A significant part of the meeting was devoted to debating the optimal governance models for the integrated ocean observing system, with due consideration to the right theoretical governance models (e.g., polycentric), their organizational scope and geographic scope (e.g., global vs basin scale). The debates benefited from a dedicated governance workshop held the day before the start of GOOS-SC-8.

Other areas of discussion included the strategy for observing system evaluations, capturing the legacy of GOOS projects, and strategies for effective partnerships in data management, societal benefit product delivery and capacity development, among others. The extent to which IOCCP as GOOS Biogeochemistry Panel will contribute to them will be determined by their overlap with IOCCP Terms of Reference and the successful partnership building over the course of coming years. Our proposed input will be reflected in the GOOS Implementation Plan, which is expected to be finalized by early 2020.

All the meeting documents and presentations from GOOS-SC-8 are available at goosocean.org/goos-sc-8. The full meeting report is expected to be published over the next several weeks.

Global Ocean Acidification Observing Network Executive Council Annual Meeting, 13 & 18 April 2019, Hangzhou, China

The GOA-ON held its 6th Annual Executive Council (EC) meeting in Hangzhou, China on the 13 and 18 April 2019 and 13 EC members attended. The objectives of this meeting were

for the group to provide updates on GOA-ON's activities since the last in-person EC meeting held in Sopot, Poland, 28-30 May 2018, as well as to discuss upcoming activities, current needs for the global ocean acidification community, and future priorities. This meeting was held the day prior to, and the day following the 4th GOA-ON International Workshop, where more than 250 scientists and industry representatives from more than 60 countries attended, and therefore the GOA-ON EC meeting included discussions on the outcomes from this workshop. The Executive Council addressed several important issues, such as the SDG 14.3.1 data reporting process, advancements of regional hubs, newly announced GOA-ON Implementation Strategy, further development of the Data Portal, status of capacity-building activities, communication products, and the network's participation at upcoming international meetings, including OceanObs'19, the Oceans in a High CO₂ World 2020 meeting, and the UNFCCC COP25.

A detailed meeting report with all action items and major outcomes listed and described will be soon available from the GOA-ON website.

1st International AtlantOS Symposium, 25-28 March 2019, Paris, France IOCCP Project Office staff and several IOCCP SSG members attended the 1st International AtlantOS Symposium held on 25-28 March 2019 at the IOC Headquarters in Paris, France. The event celebrated the success of the EU Horizon 2020 Research and Innovation Action AtlantOS and simultaneously marked the beginning of the international AtlantOS (All-Atlantic Ocean Observing System) programme, which benefits from the Galway and Belém Statements and is the Atlantic contribution to the Global Ocean Observing System (GOOS).

There was broad participation with 29 countries and many pan-European initiatives. A major outcome was agreement for further Atlantic Basin integration, data aggregation and societal awareness of the ocean observations. The symposium showcased successes of four years of work involving 62 partners from 18 countries and the investment of 20 million Euros. It also articulated opportunities, needs, and benefits from the work of the EU-H2020 AtlantOS project feeding into the implementation of the AtlantOS system and its role of enabling a wide range of societal benefits. How will AtlantOS contribute to ocean policy processes? How does it connect to the wider ocean observing context? What are national and regional ocean observing ambitions and contributions? And how does AtlantOS respond to user needs, from the scientific, private sector, and civil society perspective?

The symposium concluded by articulating the path forward to sustain and grow the All-Atlantic Ocean Observing System (AtlantOS) during the next decade. Moreover, ocean experts assembled at the First International AtlantOS Symposium gave their support for an All-Atlantic Ocean Observing System by issuing the Paris Declaration on All-Atlantic Ocean Observing which called on all nations, scientists, ocean stakeholders and citizens to join together to:

- Raise global awareness of the importance of the ocean and of fit-for-purpose ocean information for increased prosperity and sustainable management.
- Work to expand ocean observing, ocean forecasting, interdisciplinary research, innovative outreach, science ethics, early careers and ocean education training and capacity building.
- *Ensure that this Atlantic Ocean observing system is sustainably and adequately resourced.*
- Realize and foster ocean observing benefits through international collaboration, innovation, sharing of observing platforms, infrastructure and systems.

- *Share ocean data freely without restriction, grow interoperable data infrastructures.*
- *Ensure integration of ecological and biological observations with the physical and biogeochemical systems, for the coastal, seafloor and water column regimes.*
- Promote the engagement of the ocean observing community with natural and social sciences, engineering, civil society, private sectors and citizens who rely on this information.
- Support adherence to global standards, best practices and joint ambitions articulated through GOOS, the Partnership for Observation of the Global Ocean, and GEO's Blue Planet Initiative.

Full text of the Declaration is available at: https://www.atlantos-h2020.eu/first-international-atlantos-symposium/paris-declaration-on-all-atlantic-ocean-observing/.

First All-RECCAP2 (2nd Regional Carbon Cycle Assessment and Processes) Workshop, 18-21 March 2019, Gotemba, Japan

The second Regional Carbon Cycle Assessment and Processes (RECCAP2) is the second exercise to evaluate regional and global carbon budgets being organized by the GCP. Nicolas Gruber (ETH, Switzerland) and IOCCP Co-Chair Masao Ishii are currently responsible for leading the ocean component of RECCAP2. As first RECCAP had a very strong observational focus, IOCCP SSG members were heavily involved in the process of its development and publication of regional and global assessment papers.

The First All-RECCAP2 Workshop took place on 18-21 March 2019 in Gotemba, Japan. The event gathered scientists with expertise on regional and global budgets of greenhouse gases (GHG: CO₂, CH₄, N₂O), including atmospheric inversions, vegetation, soils and ocean models, existing and emerging observations, data mining and synthesis, from different regions of the globe. The main goal was the planning to deliver (and explore the feasibility for regular updates) of regional assessment of GHG budgets based on scientific evidence, considering uncertainties, understanding of drivers, and retrospective analysis of recent trends. Additionally, key global assessments will be developed for their own value and in support to the regional GHG budgets. This meeting was partly supported by the National Institute for Environmental Studies, the European Space Agency (ESA), and the GCP.

Apart from IOCCP Co-Chair Masao Ishii, who is a member of the RECCAP2 Science Committee, IOCCP was represented by Rik Wanninkhof.

During the planning stages of RECCAP2, IOCCP has been keen to:

- Act as an efficient link to the ocean carbon community with the RECCAP2 effort, also via the IOCR WG of IOC-UNESCO.
- Ensure that RECCAP2 planning needs are consulted with the ocean carbon community – critical to obtain the support of the community, to collect ideas, and thus lead to a successful exercise.
- Suggest that core members engaged in RECCAP2-ocean include a group of participants of SOCOMv2 (Second Surface Ocean CO₂ Mapping Intercomparison) led by Peter Landschützer (MPI-M, Germany) and Christian Rödenbeck (MPI-B, Germany).

For more details on RECCAP2 and the workshop, please see the site here: https://www.reccap2-gotemba2019.org/.

Global Climate Observing System (GCOS) All Panels Meeting, 18-22 March 2019, Marrakesh, Morocco

More than 80 experts from the Global Climate Observing System (GCOS), the World Climate Research Programme (WCRP) and the CEOS-CGMS Joint Working Group on Climate (WGClimate) came together in a series of interlinked meetings from 18 to 22 March 2019 in Marrakech, Morocco. The overall aim was to achieve a common understanding of the needs of stakeholders for climate observations and of how GCOS and WCRP should achieve their strategic goals.

IOCCP, represented at the meeting by Co-Chair Masao Ishii and Director Maciej Telszewski, contributes significantly to GCOS Implementation Plans making sure that climate-relevant observations in the ocean are appropriately highlighted and included in budgetary, management and political agendas benefiting from the GCOS IP recommendations.

From the perspective of IOCCP, there were some interesting developments in the carbon working group report. Global temperatures are steadily increasing, driven primarily by emissions of carbon dioxide, which are projected to increase by 2.8% between 2017 and 2018. The fossil fuel emissions overlie and interact with highly dynamic natural carbon cycle that itself is sensitive to climate. Carbon sinks have continued to grow with increasing emissions, but based on measurements and model results, there remains a large and unexplained variability in the global carbon balance caused by uncertainty; lack of understanding hinders independent verification of reported CO₂ emissions of about 0.5 Gt/year. Errors in the land and ocean sinks are likely to be the main cause for this budget imbalance. Lateral transport between the land, ocean, and atmosphere likely has implications for estimates of the land budget.

Discussions in the Carbon breakout group identified two reasons to continue observing the carbon cycle at high temporal and spatial resolution: diagnostic –to monitor how well/badly we are doing and prognostic – to understand and predict how the cycle will likely change. Large gaps in ocean observations with poor spatial and temporal resolution of stocks and fluxes were acknowledged and the resulting recommendation will be to enhance the ocean monitoring efforts. Other (than carbon) parameters are deemed necessary to proxyparameterize models such as surface properties and a good transport model to link fluxes and stocks. More regional understanding will also be advocated to better quantify regional variability.

All documents and presentations can be accessed from the meeting website: https://gcos.wmo.int/en/gcos-joint-panels-meeting.

A detailed meeting report will be published in June 2019.

Ocean Best Practices Workshop, 4-6 December 2018, Paris, France IOCCP continues its strong commitment to the development of the Ocean Best Practices (OBP) initiative, in line with our Terms of Reference:

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.

The second annual Best Practices workshop was held at UNESCO-IOC in Paris on 4-6 December 2018. The focus of the workshop was the implementation of the OBP System operations and the future directions for technology insertion and community interactions. The meeting was well attended with broad representation, including IOCCP SSG member Rik Wanninkhof and IOCCP Director Maciej Telszewski.

The group looked at current practices in observations and applications, then discussed the needs of the community. With that, the participants then mapped out a plan for the next two years. Of the many activities that were discussed, several were (i) inclusion of ocean observations from space in the OBP System; (ii) the need to address the full value chain from observation to information to policy; and (iii) increased interaction with ocean biology.

IOCCP as the GOOS Biogeochemistry Panel was also asked to provide input into the development of a process by which selected best practices documents from the OBP repository would be endorsed by GOOS. The issue was further discussed during GOOS-SC-8. The process will likely be developed throughout late 2019 and early 2020, with some pilot cases already identified for each of the three ocean disciplines.

Synthesis and intercomparison of ocean carbon uptake in CMIP6 models, 8-9 December 2018, Washington, DC

A CMIP6 (Coupled Model Intercomparison Project Phase 6) community workshop was held 8-9 December 2018, in Washington, DC, USA just before the Fall 2018 American Geophysical Union (AGU) Meeting, organized by U.S. OCB. Following our commitment to strengthen our partnership with the modelling community, and as an early activity of the UNESCO-IOC IOCR WG, IOCCP contributed to achieving the meeting goals through active participation of IOCCP SSG members Rik Wanninkhof and Richard Feely.

The objectives of this workshop were as follows:

- Summarize high-profile CMIP5 Ocean Carbon Uptake analyses and challenges, as well as the planned suite of CMIP6 experiments
- Summarize new observational constraints, including GLODAPv2, SOCAT, SOCCOM, GO-SHIP, community observational synthesis efforts such as Obs4MIPs, ocean carbon inversions, and atmospheric observations of CO₂and oxygen
- Modelling center reports on model formulation and preliminary analysis of simulated regional and global patterns in heat/carbon/tracer uptake in CMIP6 experiments
- Discuss mechanisms of heat/carbon/tracer uptake differences across models and observations towards linking physical and biogeochemical drivers and their impact
- Discuss tools and techniques that can lower barriers to analysis

Participants highlighted the availability of several new decadal-scale synthesis products on air-sea CO₂ flux and ocean carbon storage and the urgent need within the OCB community for more comprehensive and efficient computational tools to make optimal use of 'big data' resources such as the CMIP6 model archive. Additionally, the group emphasized that the timeline of CMIP6 model analysis is extremely tight; modelling centers are planning to supply their data publicly in March-June 2019, and the manuscript submission deadline for contribution to the sixth assessment of the Intergovernmental Panel on Climate Change (IPCC) is 31 December 2019. Workshop participants made several recommendations to facilitate and coordinate community use of the CMIP6 model archive:

Standardize tools for the estimation of ocean biomes

- Explicitly separate river/coastal factors from open-ocean syntheses for air-sea CO₂ flux and ocean storage
- Incorporate pre-1850 carbon cycle changes
- Improve understanding of ocean carbon cycling under reversibility and sustainability scenarios

A full workshop report and information about community follow-on activities will be available in the next couple of months.

Variability in the Oxycline and Its ImpaCts on the Ecosystem (VOICE) 2nd Science Plan workshop, 8-9 September 2018, Kiel, Germany

The 2nd VOICE (Variability of the Oxycline and its ImpaCt on the Ecosystem; http://www.ioccp.org/voice) Science Plan workshop took place on 8-9 September 2018 in Kiel, Germany, in conjunction with the International Conference on 'Ocean Deoxygenation: Drivers and Consequences – Past, Present and Future', held on 3-7 September 2018. The main objective of the meeting was to perform the readiness level assessment based on information collected from the various Oxygen Minimum Zone demonstration regions all over the world. During the meeting, members of the VOICE initiative reviewed the answers to spreadsheet questionnaires that were distributed among the VOICE regional champions in order to collect information on current status and gaps in requirement setting, observing capacity, and data and information product management.

The main outcome of this workshop was the submission of VOICE Community White Paper in response to an invitation from the OceanObs'19 Conference Program Committee. The core writing team consisting of VOICE Co-Chairs and IOCCP Project Office submitted the CWP on behalf of the VOICE initiative in November 2018. Below we provide the abstract as submitted. The paper is currently in revision.

<u>OceanObs'19 CWP abstract on "Multidisciplinary Observing in the World Ocean's Oxygen</u> <u>Minimum Zone regions: from climate to fish- the VOICE initiative":</u>

Multidisciplinary ocean observing activities provide critical ocean information to satisfy ever-changing socio-economic needs, and require coordinated implementation. The upper oxycline (transition between high and low oxygenated waters) is fundamentally important for the ecosystem structure and can be a useful proxy for multiple observing objectives connected to Oxygen Minimum Zones (OMZs). The VOICE (Variability of the Oxycline and its ImpaCt on the Ecosystem) initiative demonstrates how societal benefits drive the need for integration and optimization of physical, biogeochemical and biological components of regional ocean observing. In liaison with the Global Ocean Oxygen Network, VOICE creates a roadmap towards observation-model syntheses for a comprehensive understanding of selected oxycline dependent objectives. Local to global effects, such as habitat compression or deoxygenation trends, prompt for comprehensive observing of the oxycline on various space and time scales, and for an increased awareness of its impact on ecosystem services. Building on the Framework for Ocean Observing (FOO), we initiated readiness level (RL) assessments for ocean observing of the oxycline in highly productive and economically important OMZ waters. VOICE determines ocean observing design based on scientific and monitoring activities in selected OMZs, namely the California Current System (US West Coast, the Southern California Current system off Mexico), the Equatorial Eastern Pacific off Ecuador, the Peru-Chile Current system, West Africa off Senegal and Cape Verde Islands, the northern Benguela off Namibia and in the Northern Indian Ocean (Bay of Bengal,

Arabian Sea). Regional champions aided in assessing FOO design elements for the respective OMZ, namely: requirements processes, coordination of observational elements, and data management and information products. The RL for FOO elements is derived for each region and points at system bottlenecks which prevent delivering information and products for end users with a goal of motivating consistency across regions. We found that fisheries and ecosystem management are a societal requirement for all regions, but maturity levels of observational elements and data management and information products differ. Identification of relevant stakeholders, developing strategies for RL improvements, and building and sustaining infrastructure capacity to implement these strategies are fundamental milestones for VOICE initiative over the next 2-5 years and beyond.

IOCCP SSG member Véronique Garçon is a Co-Chair of VOICE, and the IOCCP Project Office is providing support for this international initiative. Although IOCCP continues to provide its coordination and communication services for VOICE until the OceanObs'19 Conference, we anticipate that this activity will become a stand-alone effort with dedicated funding likely derived from several distributed sources, contributing to the realization of the CWP recommendations in form of pilot/demonstration projects, and/or regionally-focused efforts.

To learn more about VOICE, please see http://www.ioccp.org/voice.

Ocean Deoxygenation Conference, 3-7 September 2018, Kiel, Germany The International Ocean Deoxygenation Conference (https://conference.sfb754.de/event/1) was held on 3-7 September 2018 in Kiel, Germany. The conference was organised by the Collaborative Research Center (SFB 754) which addresses the threat of ocean deoxygenation, its possible impact on tropical oxygen minimum zones, and implications for the global climate-biogeochemistry system. The conference brought together the global scientific community working on ocean deoxygenation and aimed to identify drivers and consequences of ocean deoxygenation in the past, present, and future. IOCCP was represented by SSG member Véronique Garçon and Director Maciej Telszewski, who convened and contributed to sessions, respectively.

Following the appointment of Véronique Garçon as IOCCP SSG member responsible for the Oxygen Theme, IOCCP continues to support efforts leading to coordinated observations and data management in response to growing concerns over the problem of global deoxygenation in the ocean. Similar to our partnership with GOA-ON with respect to ocean acidification, we partner with the Global Ocean Oxygen Network (GO₂NE) to set the requirements for, coordinate observations and deliver essential information adequate to monitor and predict the status, trends and impacts of ocean deoxygenation.

This Conference was a unique opportunity to gather the global community of observationalists, modellers, and stakeholders interested in sharing and advancing the stateof-the-art knowledge of the phenomenon and at the same time committed to further promoting societal awareness of this global issue. Accordingly, one outcome of the conference was the 'Kiel Declaration', in which the scientists call for more marine and climate protection and more international awareness of oxygen depletion. The declaration is available HERE.

Global Ocean Oxygen NEtwork (GO₂NE) annual workshop, 2 September 2018, Kiel, Germany

IOCCP SSG member Véronique Garçon and IOCCP Director Maciej Telszewski are members of the Global Ocean Oxygen Network (GO₂NE) Executive Council since its establishment in 2016 as an IOC-UNESCO Working Group. GO₂NE 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.

The GO₂NE Executive Council held its annual meeting on 2 September 2018, in Kiel, Germany, just prior to the Ocean Deoxygenation International Conference. In 2018, GO₂NE continued to issue high-impact publications with the policy brief "The ocean is losing its breath: Declining oxygen in the world's ocean and coastal waters" released in July 2018. The document seeks to inform policy makers of the latest scientific data and conclusions, to ensure informed decision-making to counter this rising threat to ocean health.

A significant part of the 2018 Annual Workshop was devoted to the GO₂NE Summer School planned for September 2019 in China. IOCCP is a co-sponsor of the activity, and is sending two instructors to the course. The details of the school are described under the Major Activities section of this report.

To learn more about the current and planned activities of GO₂NE, please visit their website at: https://en.unesco.org/go2ne.

A European Vision for an Atlantic Ocean Observing System - AtlantOS workshop, 4-5 June 2018, Brussels, Belgium

At the 3rd General Assembly of the H2020 AtlantOS project, in Las Palmas, Gran Canaria in November 2017, the community discussed 'How can and will Europe contribute to an integrated Atlantic Ocean Observing System?' Since the kick-off of AtlantOS in 2015, different initiatives have developed to strengthen regional coordination. These include the international BluePrint for Atlantic Ocean Observing, an international basin-scale initiative and the European Ocean Observing System (EOOS) which focuses on Europe's capability in ocean observation worldwide.

To align these two initiatives and further strengthen European input, the AtlantOS community decided to initiate a process of drafting a European Strategy for Atlantic Ocean Observing – a forward-looking document that defines a vision for 2020 and 2030. The strategy serves as a European perspective to the BluePrint and as a basin-scale (Atlantic Ocean) contribution to EOOS. Regional examples demonstrate current European capabilities as well as the potential of ocean observing in the Atlantic Ocean.

A workshop with 25 ocean observing experts took place in Brussels from 4 to 5 June 2018. IOCCP Project Officer Artur Palacz was among the invited experts. During the workshop, three main subjects were discussed:

- Requirement setting to meet the user needs / Ocean Observation Networks
- ---- Data Infrastructure and New Technologies
- Capacity Building / Resource Mobilization

Throughout the workshop, participants were also encouraged to consider existing and new innovative partnerships and coordination activities that could help achieve progress in these areas and drive greater sustainability in the future Atlantic Ocean Observing System.

Over the following months, the group was involved in drafting the strategy. The final version was completed in early 2019 and published ahead of the 1st International AtlantOS Symposium. Artur Palacz contributed as a lead co-author on two chapters of the European Strategy For All-Atlantic Ocean Observing System, which is available both as a brochure and a full document.

7th Session of the GOOS Steering Committee (GOOS-SC-7), 13-15 June 2018, Santa Marta, Colombia

The 7th Session of the GOOS SC took place on 13-15 June 2018 at INVEMAR in Santa Marta, Colombia. A major theme of the meeting was the GOOS Strategy and how we move towards implementing it. During GOOS-SC-7, IOCCP outlined its current and near-future priorities with respect to the GOOS Strategic Objectives and Implementation Plan. These included but were not limited to:

- Expand IOCCP coordination and communication services for up to 3 additional biogeochemical EOVs: oxygen, nitrous oxide and dissolved organic carbon, currently beyond panel's expertise and capacity.
- Develop new marine carbon research directions through the IOC-UNESCO Working Group on Integrated Ocean Carbon Research in partnership with SOLAS, IMBER, IOCCP, GCP, U.S. OCB, CLIVAR, WCRP and IOC
- Continue to develop and promote the use of standards, reference materials, manuals, best practices, etc. among the marine biogeochemistry community
- Continue to support the existing data synthesis products (e.g., SOCAT and GLODAP) and lead the development of new data synthesis products based on community needs in particular ocean acidification and time series communities
- Promote and organize new training activities on biogeochemical instruments and sensors
- Strengthen the dialogue with UN Environment and other international bodies and initiatives engaged in monitoring marine plastics contamination as a potential emergent EOV

The GOOS Biogeochemistry Panel was congratulated for working across many GOOS Strategic Objectives and also cross-IOC (e.g., work with GOA-ON, GO₂NE, IOCR WG). It was suggested that IOCCP continue to work actively with GOA-ON and that GOOS could look at GOA-ON as an example of development of successful, active regional networks. It was recognized that GOOS should be supportive of IOCCP in seeking sustained funding for the project officer.

Complete reports and presentations are available on the meeting website: goosocean.org/goos-sc-7.

The meeting was preceded by a Regional Workshop for Latin and South America on 12 June 2018, also at INVEMAR. The workshop was attended by around 50 participants, including INVEMAR Director, Captain Francisco Arias Isaza, Martha Arteaga from the Office of Marine and Coastal Affairs and Aquatic Resources (DAMCRA) of the Ministry of Environment and Sustainable Development (MADS) of Colombia, Vladimir Ryabinin, the

Executive Secretary of IOC, John Gunn and Toste Tanhua, the co-chairs of GOOS, other GOOS SC members, and a large group of regional stakeholders representing ocean observations, modelling and research. IOCCP was represented by Co-Chairs Kim Currie and Masao Ishii, and Office: Maciej Telszewski and Artur Palacz.

Goals of the workshop were to:

- To strengthen and build links across Latin American ocean observing stakeholders: scientific community, observing networks, industry, navies, and GOOS Regional Alliances (GRAs)
- To showcase examples of monitoring projects in the region and discuss the national strategies as drivers of coordinated observations
- To promote development of GOOS multidisciplinary projects in the region focused around Essential Ocean Variables (EOVs) and responding to national strategies

The regional workshop was acknowledged as an historic event that gathered key players and communities from across South America who share a common interest in realizing the vision and mission of GOOS, and whose plans are well aligned with the decadal strategy of GOOS. It was stated that workshops such as this should act as catalysts for engaging local and regional scientific communities in the work done by GOOS on a global level. Participants were encouraged to think across the disciplines and in terms of promoting regional networks capable of enhancing and optimizing sustained ocean observations that are fit for purpose. It is critical that such engagement on the scientific level occurs in parallel to messages delivered by IOC on a national representative level. However, a greater sense of urgency is needed to swiftly move across the science-policy-society interface and ensure that the South America region actively takes part and fully benefits from the upcoming UN Decade of Ocean Science for Sustainable Development.

Regional workshop information is available at: goosocean.org/regional-workshop-2018.

Project Office

Restructuring of the IOCCP SSG

Prior to the 13th Session of the IOCCP SSG, each SSG member was requested to self-assess their skills with respect to a number of roles and responsibilities that IOCCP SSG members are asked to perform. The need for this exercise was driven primarily by the continued expansion of IOCCP onto the GOOS Biogeochemistry Panel, and the entailed need for larger in-house expertise and capacity for partnership building.

One of the applications of the analysis of our skill assessment exercise is to make better-informed decisions on SSG members' rotations, so that in the future we will not only try to replace the key expertise of an outgoing member, but will make sure that new members have additional set of skills needed.

The results of this exercise were discussed in plenary and were instrumental in taking some of the key decisions regarding how IOCCP will approach the execution of action items in 2019 and prepare for achieving its goals on the longer, 5- to 10-year time frame. Below is a summary of key conclusions derived from the combined assessment of skills, role and responsibilities:

- The information regarding the level of expertise relevant to individual EOVs and platform-specific observations, modelling, policy interaction and other dimensions will be used by the Office to call upon relevant SSG members when dealing with requests for IOCCP action.
- In its current composition, the IOCCP SSG has a strong expertise in all observing platforms. However, in many cases this strong expertise might be limited to carbon parameters, and be significantly weaker with respect to other Biogeochemistry EOVs.
- There are a few gaps in expertise that IOCCP SSG should be alerted to, considering our Terms of Reference and obligations towards GOOS. These include for example the interaction with GCOS, and implementation of Transient Tracer and Nitrous Oxide EOVs.
- It was noted that when appointing a new member onto the Panel, the person should have interest and some expertise in most aspects of IOCCP's portfolio, especially various observing platforms.
- There are strong programmatic connections to national agencies leading the global sustained observing efforts, with the exception of China which is expected to play a growing role in the system, particularly in the development of the Biogeochemical Argo network. These connections should be maintained and expanded.
- The SSG is well positioned to act at the science-policy interface, but only within the countries we are residents of.
- All SSG members indicated a similar level of time commitment to IOCCP activities, with several looking forward to invest more time in 2019 compared to the 2017-2018 period.
- It was noted that any changes to the SSG should additionally consider the recommendation from SCOR to further increase the ratio of female members, and to maintain a wide geographical coverage among the members.

The above points have been considered when creating the open call for new IOCCP SSG membership (to be released by Fall 2019), and evaluation of the applications received.

Regarding restructuring of the Panel Themes, IOCCP has decided to appoint only 1 member responsible for both synthesis activities: surface ocean and interior ocean. It was noted that this SSG member would be responsible not only for SOCAT and GLODAP but also for future synthesis products. Siv Lauvset agreed to be responsible for this merged Synthesis Products theme. Regarding collaboration with SOCAT and GLODAP, IOCCP will maintain close interaction with Dorothee Bakker (University of East Anglia, UK) and the GLODAP Reference Group, respectively.

IOCCP also decided not to combine the newly merged Synthesis Activities Theme with the Data Access and Information Services Theme. This decision was dictated by recognition that specific expertise is needed to understand the complex realm of oceanographic data flow, which is different from knowledge of quality control procedures and synthesis production.

While the other Themes will not be affected by restructuring, IOCCP would like to avoid individual SSG members being responsible for only a single IOCCP Theme, but rather, be able to share responsibility for a number of cross-cutting activities. This transition will likely occur over a few years' time span, and depend on the ability to attract new SSG members with an appropriate set of skills.

It is noteworthy that the positive outcome of IOCCP's skills and roles analysis has triggered similar exercises to be undertaken by the other two expert panels of GOOS, as well as the GOOS Steering Committee.

Communication services Internal communication

At the 13th Session of IOCCP SSG it was decided that new measures will be undertaken to strengthen internal communication between IOCCP Office and the SSG. The most important measure is to introduce regular, quarterly updates on the status of Action Items by SSG member assigned as lead responsible for a given action. Also, all action items with their current status will be maintained as a living document shared and updated by the IOCCP SSG.

With respect to the monthly IOCCP Executive meetings, which started in 2017, they have proved extremely helpful for boosting internal communication and decision making. The SSG recommended that the Executive group consider inviting one of the SSG members on the call if and when this would be relevant for making progress on a given action item.

The SSG was also asked to set a fixed time in the year in which the annual in-person SSG meeting could take place on a regular basis in order to help anticipate the yearly event scheduling. After a quick poll, it was decided that in general the 2nd and 3rd week of November would be a suitable time to meet.

External communication

The Conveyor

Considering the workload that goes into each issue and the fact that the community is overloaded with frequent newsletters, the SSG decided to change the Conveyor status from a quarterly to a biannual newsletter. The newsletter was perceived as a useful archive of most important news in a given time period, being complementary to the more rapid communication service provided by the near-daily email news and website updates.

The website usage statistics

Our Jobs page remains the most popular, with more than 1,200 unique page views a year (i.e., not counting repeated visit of same user during a single session) giving an average of ca. 100 per month. The most popular theme sites were those dedicated to: Instruments and Sensors, Nutrients, Framework for Ocean Observing, Ocean Acidification and Surface CO_2 Measurements - each with more than 300 unique page views per year.

The number of subscribers to IOCCP email newsletter has been growing slowly but steadily since 2016. As of mid-May 2019, there are 574 confirmed subscribers. Regular email news distribution was picked up in early 2016, and since then, we have been distributing between 60 and 80 announcements per year.

We estimate that our website receives on average around 150 unique page views per week, with a minimum of ca. 80 in the boreal summer months and up to 800 in response to particularly important announcements. It is difficult to assess the value of these results as we do not have a long data record, nor can we compare our data with other coordinating programs. Still, we would like to attract more visitors, and more frequent updates to the thematic pages is one action that the Office and the responsible SSG members will undertake.

Social media

IOCCP decided to open a Twitter account to reach out to an even greater pool of users and provide a very rapid news communication service. The activity is likely to start in the second half of 2019.

Funding for Project Officer

Over the past year, IOCCP Office has engaged in several fundraising activities to ensure continued support for the second staff member in the IOCCP Office. Current funding from the EU AtlantOS project terminates in June 2019. Considering the substantial amount of new requests and responsibilities passed onto IOCCP from GOOS, it is expected that GOOS takes the responsibility for continued funding of the project officer beyond June 2019. Currently, GOOS has secured salary for project officer until the end of 2019.

With IO PAN acting as a sub-contractor in an ECMWF tender C3S_511 (Quality assessment of ECV products), partial funds are likely to be available for the IOCCP Project Officer to continue for another 2-year term. However, due to changes in the timeline for contractual obligations and delivery, no funds are expected before June-August 2020. This presents a gap of 6-8 months which is currently being addressed via alternative fundraising options (i.e., two EU H2020 proposals under evaluation).

Publications (IOCCP SSG and Staff in **bold**)

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- Lauvset S, Currie K, et al. (2018). SOCAT Quality Control Cookbook for SOCAT version 7. https://www.socat.info/wp-

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- Telszewski M, Palacz AP (2019). A report from the XIIIth Session of the International Ocean Carbon Coordination Project Scientific Steering Group and the Global Ocean Observing System Biogeochemistry Expert Panel. IOCCP Report No. 1/2019, GOOS Report No. 233; http://www.ioccp.org/images/D3meetingReports/XIII-IOCCP-SSG_report_FINALv2.pdf

Future Directions

In the past, IOCCP has reported on its future directions and planned activities primarily according to its individual themes. However, several actions over the past months have provided a strong incentive to look at our strategic and tactical plans with respect to several broader notions that very often cut across several IOCCP themes, and which require close collaboration between several SSG members to deliver the desired outcomes. The overarching future directions were first determined and described in IOCCP's report to its sponsors who commissioned an official review of the IOCCP in 2018. Furthermore, future directions on both short and long-term perspectives were discussed at length at the 13th Session of IOCCP SSG in October 2018. It was recognized that along with the adoption of new Terms of Reference in 2017 and the new mandate of IOCCP to act as the GOOS Biogeochemistry Panel, structural changes are necessary to match the requirements for new and extended functionality of the IOCCP.

IOCCP has been exposed to and provided significant contributions to a 2030 vision for integrated ocean observing through its numerous contributions to OceanObs'19 Community White Papers. Our role will be 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 will strongly influence the Conference proceedings as a co-organizer of a series of 3 breakout sessions on the future of integrated global ocean observations, distributed over three days of the Conference.

The long-term, 5-10-year strategic thinking that has driven the OceanObs'19 Community White Paper writing process, combined with IOCCP's internal review of its function and structure, has also determined much of IOCCP's short-term agenda. Therefore, below we present IOCCP's future directions for the next 1-2 years in the context of the broader, overarching themes employing IOCCP as a whole, as well as a few other themes still led primarily by individual SSG members assigned specifically to them.

New coordination activities as part of the GOOS Biogeochemistry Panel As the GOOS Biogeochemistry Panel, the IOCCP will gradually expand its coordination and communication activities in order to help the ocean observing community implement individual EOVs. Over the past 6 years we led the community to establish a set of biogeochemistry EOVs and provided coordination support for three out of nine EOVs (inorganic carbon, nutrients, and oxygen). We now work to develop a careful strategy and conservative time plan to further expand our portfolio and perhaps add another three EOVs over the next 5-10 years.

IOCCP Executive selected three candidate EOVs to choose from for the implementation into the Panel's activities: nitrous oxide, dissolved organic carbon and particulate matter. Prior to the SSG discussion on priorities and strategies for these EOVs, it was noted that the Oxygen Theme was only added to the IOCCP portfolio in 2018 and that the coordination and communication efforts related to oxygen observations have likely not yet reached their full capacity. With respect to the Ocean Colour EOV, any implementation activities will continue to be a joint venture of IOCCG, IOCCP, and the GOOS Biology & Ecosystems Panel. IOCCP's main role is to curate the Ocean Colour EOV Specification Sheet, not to lead all coordination and communication efforts related to this EOV.

Several criteria were put forward to judge the impact and feasibility of taking up new responsibilities with respect to EOVs: size and leadership in the observing community (if any), connection to observing networks (and satellite agencies), technological advancement, use of standards and best practices, data availability and quality, societal drivers and value for data users (scientific and non-scientific), and importance for constraining mass balance of biogeochemical cycles. Please see the 13th Session IOCCP SSG report for a summary of the arguments for all three EOVs.

Estimates of personnel costs and volunteer hours will be made to verify feasibility of taking up the three EOVs. The IOCCP Executive will determine the exact order and timing of adding new EOVs to IOCCP's portfolio of activities. It should be noted that these activities will not be initiated until the project officer position is secured beyond December 2019. An open call for nominations for new SSG members will then be released to seek the right level of expertise to carry out new coordination activities.

Technical capacity development

During the 13th Session of the IOCCP SSG, there was a clear agreement to retain a strong focus on IOCCP's involvement in technical capacity development initiatives. In order to best match the evolving requirements for training services with the ongoing rapid technology development, the IOCCP SSG decided to combine the responsibility for technical capacity development with that held for the Instruments and Sensors Theme. At the same time, broader involvement of other SSG members will be considered for future training events, depending on their individual expertize and availability. Strong support will continue to be provided by the IOCCP Office.

The decision to re-focus the activities under this theme was based on the analysis of the past several years of IOCCP's services performed under the Instruments and Sensors theme. Doug Connelly pointed at the futile efforts of addressing marine sensor developers as a community. The developers tend to interact loosely through short-term research and development projects, and have little incentive to form a strong community. In the offshore domain, the market is small and competition is the only force for further development.

In the coastal domain, however, the observer community has a strong interest in the services offered by IOCCP. While well aware of the requirements for measurements (i.e., what to measure and why), they lack the capacity and knowledge on how to perform measurements. And that is especially true outside of academia, where most of coastal measurements for management purposes are taken. They thus appreciate having a central repository with a sensors and instruments hardware directory, Alliance for Coastal Technologies (ACT) evaluation reports, technical workshop reports, or standards and best practices documents. Therefore, complementing these existing services with comprehensive training courses was deemed as the most efficient use of IOCCP's resources with regard to this theme.

It was clear that IOCCP's role is in international development, which is critical in enabling specific capacity building efforts to be tied in with existing regional and national projects. The goal is then for IOCCP's services to be relevant for large observing systems in the United States and in the European Union (e.g., to support the implementation of Marine Strategy Framework Directive monitoring), but also for observations in developing countries keen on continuing technical capacity development. The IOCCP SSG recommended that a partnership model be developed, akin to the one successfully used in ocean acidification research where joint capacity building efforts by GOA-ON, IOCCP, IAEA and others led to the rapid expansion of OA-related observing capacity.

Quality control of sensor measurements was suggested as a key aspect of capacity development that IOCCP could provide. This is important not only because of the growing use of sensors, but also in the context of generating data that is of sufficient quality to support the development of thematic synthesis products, such as on ocean acidification and its impacts. IOCCP recognized this need and during the 2019 training course will devote 1.5 days to quality control issues. In addition, as part of the AtlantOS project, the IOCCP Office organized a dedicated workshop on quality control of pCO₂ sensors in April 2019. Such a new workshop model could be implemented in other regions with potential for new data providers to SOCAT and/or GLODAP.

Perhaps the most effective means of improving quality of data is through follow-up activities, such as providing access to reference materials, after introducing new technology in a given environment. The issue of maintaining technology and its proper application is widespread among countries that do not have local manufacturers.

Supporting data synthesis products through the Global Data Assembly Centre for marine biogeochemistry

While the two flagship synthesis products supported by IOCCP: SOCAT, and GLODAP have become standalone activities with significant accomplishments, it is important to note that both activities will continue to rely on and benefit from the support of IOCCP for funding and coordination of their activities (i.e., 1 meeting each year for SOCAT and 1 for GLODAP). IOCCP will continue to advocate for stable support to secure core funding for both the SOCAT and GLODAP communities' efforts. IOCCP financial support would be focused on supporting specific activities.

A parallel goal for IOCCP is to determine what are the requirements for future synthesis products, and to anticipate how to advance their development, using a pragmatic approach to designing and developing these products. In order to best respond to the community's requests for new synthesis products, IOCCP has decided to restructure the current themes of the panel by merging the 'Surface synthesis products' with 'Ocean interior synthesis products' themes (see also under the Project Office section of this report).

Central to these considerations was a discussion on the current status and future prospects of the Global Data Assembly Centre (GDAC) for Marine Biogeochemistry, as envisioned in the IOCCP position paper on Global Ocean Biogeochemistry Data Management. The first important conclusion was that the community already has the capacity to have a GDAC functional for high-quality Inorganic Carbon EOV measurements, thus sustaining data management for SOCAT and GLODAP products. However, more efforts and resources were needed in order for the GDAC to account for all biogeochemistry EOV data, regardless of the quality and intended applications. If the BGC GDAC was to support the development of new synthesis products based on time-series observations, there is a lot improvement necessary to bring management of these data onto the level of a GDAC.

Significant funds were collected so far to complete the implementation of the BGC GDAC. However, it was not reasonable to expect that central funding will be available to sponsor this activity entirely. Instead, it was recommended that IOCCP joins efforts with ICOS, the NOAA Ocean Acidification Program and Pacific Marine Environmental Laboratory, IODE and Copernicus in order to fully develop the GDAC. IOCCP will support the efforts to seek dedicated funding for the final implementation of the BGC GDAC which is aimed for 2020-2021.

An important step in this direction was the meeting between Benjamin Pfeil (IOCCP SSG) and Peter Pissierssens (Head of IOC Project Office for IODE) related to the requirements of IODE Associate Data Units (ADUs) – contributing to the objectives of National Oceanographic Data Centres (NODCs), and about adding visibility to the contribution of ADUs into the GDAC. With respect to supporting time series-based synthesis products, it would be beneficial to establish a stronger connection with OceanSITES which already has two GDACs in place (in France and in the United States). This connection would not only highlight the outstanding issues preventing time-series data synthesis, but also likely help secure additional funding for the BGC GDAC.

While the intention is not to interfere with how countries deal with original data management as part of their NODCs, it was recognized that many countries do not have national data management centers and researchers submit data to regional and international databases in an often uncoordinated manner, or oftentimes, receive no clear guidelines on what to do with the data at all. Therefore, it cannot be expected that IODE's network of NODCs accounts for the integration of all oceanographic data. In order to respond to the needs of users, actions need to be taken on a larger scale, integrating data from across the NODCs. IOCCP is in position to play such a role through the development of the BGC GDAC.

Towards new data synthesis products for marine biogeochemistry

The process of developing new data synthesis products ought to start with identifying endusers and opening a two-way dialog to identify specific needs for such products. Equally critical is the identification of who will provide the actual product, what the specifications and limitations will be, and what is the long-term (10-year) goal for any given product. A specific example could be that of a synthesis product on ocean acidification and its impacts developed from time-series observing efforts, including ship-based and moored observatories. Anthropogenic CO_2 in the ocean could be a product if provided on decadal

time scales, but not on monthly. The community has also expressed interest in developing oxygen-related synthesis products. It was apparent that any development of a product must start with organizing a workshop which would bring together expert observationalists and anticipated users. As new requirements for these products come up, IOCCP will need to have a strategy for engaging the right group of experts to join the effort to support various activities, such as data quality control, web-based GUI, etc.

Time-series observations support new biogeochemistry data products

In order to initiate the development of a biogeochemistry time-series data product, two main challenges need to be overcome: (i) establishing a community-based working group that defines requirements and steers the process and (ii) raising funds to enable work on a pilot data product.

To achieve the first objective, an international scoping workshop for a biogeochemistry timeseries data synthesis product is envisioned that would involve representatives of shipboard time-series sites, other programs like IGMETS, GOA-ON, etc. and experts with a background in GLODAP. The workshop would formulate a roadmap for the development of a pilot data product that should form the basis for a more sustained product in the end. The workshop could be co-sponsored by IOCCP and OCB as a follow-up initiative of the 2012 time-series workshop in Bermuda. Funds will be sought through OCB's open call for workshop proposals to be released in late 2019. Tentative plans are made to organize the workshop in 2020.

The second objective could be implemented by incorporating this topic into a national or international research proposal to acquire funds for a dedicated postdoctoral researcher who would work on the implementation of a first pilot product. In January 2019, an EU H2020 proposal was submitted under the call "BG-07-2019-2020: The Future of Seas and Oceans Flagship Initiative", which included a dedicated task to develop a pilot biogeochemistry time series data product.

Development of OA data-synthesis products

IOCCP recognizes need for OA-related data-synthesis products in the context of SDG14.3 and the new WMO OA indicator, among others. A wide community consultation in partnership with GOA-ON and other interested coordinating bodies was suggested to identify the most pressing needs for such products and to assess the current and needed capabilities in the community.

A global map of OA with temporal variability, visualized over various relevant timescales, was considered as the most effective tool for "upward" communication with local and regional governmental managers and policy makers. Biologists and ecosystem scientists rely on the availability of such information to examine and project future impacts of OA on ecosystems. For instance, if you know what the carbonate system thresholds for oyster larvae are, and know how often this threshold was/is/will be crossed depending on the current atmospheric CO₂ levels and related marine levels, then you could design an interactive decision support tool for stakeholders interested in assessing risks related to oyster farming.

As mentioned above, better coordination of time-series observations and data management is a critical step towards developing OA-related products. This includes developing standards and operating procedures for better quality and inter-comparability of data. ICOS OTC has been working towards those goals for fixed ocean stations. ICOS and GOA-ON are learning from each other's experiences and are natural partners in the process. Moreover, there is a need for agreed procedures for discerning anthropogenic signal from the data – a task that is challenging recognizing the difficulty in de-seasonalizing the signal in coastal time-series stations.

IOCCP is looking for wider community consultation on these issues as part of the preparation and organization of the time series workshop planned for 2020.

Oxygen data platform and synthesis product on deoxygenation

Following the discussions at the joint VOICE & GO₂NE meeting in Monterey, CA, USA, in September 2017, IOCCP (through its SSG member Véronique Garçon) has gradually been working towards enabling the development of an oxygen-related data platform and synthesis product. Such a product would be a very valuable addition to the World Ocean Atlas oxygen climatology – currently the only global oxygen data product. The overarching goal is to obtain more reliable climate and ecosystem models and gaining a better understanding of the ecology of the marine systems. Model evaluations and IPCC-type assessments provide just two types of examples motivating improved global oxygen data availability, quality, and comparability. The importance of pointing at the societal benefits of submitting and quality controlling data in general is critical in regions where data is not being submitted anywhere, or is inaccessible beyond a single institution.

An initial 2-day scoping workshop was proposed to develop a roadmap among the community interested in the issue of ocean deoxygenation towards an open-access oxygen data platform for the world ocean. By this, it is meant a quality-controlled (data quality flags assigned based on consensus reached by data contributors and users) data-synthesis product, with underlying raw data available in one place or, if impossible, then distributed but available, with metadata clearly defined and available for each data and with a DOI assigned to each data set.

The proposed workshop would gather ca. 35 participants, including representatives of different observing networks performing O₂ measurements, both Eulerian and Lagrangian style, that is, Winkler titrations measurements, sensors data on CTDs and on fixed moorings/time series, sensors on Biogeochemical Argo floats and on gliders/wavegliders and on any remote vehicle/platform. The initial proposed strategy is to first focus on Eulerian sensor (on CTDs) measurements and then tackle Lagrangian oxygen data. The process will strongly benefit from the lessons learned by SOCAT, as a community-driven effort to generate information for many user groups.

Apart from IOCCP's sponsorship, tentative funding support is being sought from Future Earth – Belmont Forum Collaborative Research Action – Oceans, and the U.S. NOAA. The workshop will likely take place in Sopot, Poland, around mid-November 2019.

Standards and best practices

With the onset of the idea to develop the Ocean Best Practices (OBP) repository (https://www.oceanbestpractices.net/), there has been a proliferation of activities related to promotion, availability, and standardization of standards and best practices in all ocean domains. The GOOS BGC Panel was asked to make sure that marine biogeochemistry best practices are (i) visible, (ii) well documented, and (iii) searchable. For the benefit of our community, our work should take place via the OBP. The goal for IOCCP is to achieve

standards and best practices for all EOVs, all platforms and stages of the data cycle, from data acquisition to processing. To this end, IOCCP will continue to actively participate in relevant international meetings, the first of which took place in December 2018 in Paris.

It was noted that, so far, all the activities related to requests related to best practices come through the IOCCP Office and through individual requests to IOCCP SSG members as experts in their fields. At the 13th Session of IOCCP SSG, an idea was discussed to establish Standards and Best Practices as a separate theme in the Panel's portfolio, with a dedicated SSG member responsible for related coordination and communication activities.

In response, the group argued that the theme of standards and best practices is intrinsic to the work of the entire Panel, and that the responsibility for it should span across all SSG members. Thus, the SSG decided that it will not create a new theme dedicated to standards and best practices. The SSG also recommended that it does not take on an overwhelming amount of tasks related to the work of the OBP. Instead, we should offer our support to activities otherwise led and executed by the very capable OBP working group, members of which are also on the IOCCP SSG.

Ocean acidification

IOCCP's future work in the domain of ocean acidification observations will continue to be catalysed by a close collaboration with the GOA-ON. IOCCP's role will continue to be related to specific issues regarding chemical and biological EOVs, to developing and updating relevant best practice documents and also providing a connection between the scientific community and high-level agendas such as UN SDG 14, WMO Indicators, and GCOS Implementation Plan. Parallel to this, there is an ongoing interaction with the GOOS Biology & Ecosystems Panel through GOA-ON's panel on biological observations of OA.

Support for global and regional activities

IOCCP was asked to support GOA-ON with leadership and vision on future carbon science, which would help steer the long-term strategy for ocean acidification observation and research. Continued IOCCP support for ongoing and planned GOA-ON activities will be important as the network continues to grow. These include the further development of the data portal and web site, capacity building, Pier2Peer mentoring program, and ongoing support to developing countries. IOCCP will also ensure that GOA-ON is adequately represented in the IOCR WG, both in terms of experts present in the meeting rooms and thematically on the agenda.

Access to affordable certified reference material for researchers in countries setting up OA monitoring and research continues to be a challenge and IOCCP will assist the process to the extent possible. A couple of recently discussed partial solutions include exploring the development of IAEA-produced reference material and centralizing shipments, which account for a very significant portion of the overall cost. Another ongoing issue, which could benefit from a more centralized solution backed by IOCCP is related to safety issues with mercuric chloride.

Through Cristian Vargas and the Latin American Ocean Acidification Network (LAOCA), IOCCP is determining the needs and activities of the Latin American marine biogeochemical community. IOCCP recognized the need for developing best practices (for data collection and data management), and including Latin American colleagues in any intercalibration efforts in the future. Best practices would help the community evaluate whether the sensor calibration was performed accurately, and would allow the regional and global data analyses, which would further assess whether the given data uncertainty is within an acceptable range.

Acknowledging numerous complementary activities of IAEA in the region, IOCCP will support the organization of a regional meeting on data quality control and management for OA research in Latin America and beyond. The proposed workshop would aim to produce a strategy for adequate quality control and help connect regional observationalists to global synthesis products. IOCCP will consult and collaborate with the Ocean Teacher Global Academy (OTGA), GOA-ON, and IAEA.

Surface ocean CO₂ observations

Protocols for marine boundary layer air CO₂ measurements and quality control Establishing protocols for marine boundary layer air CO₂ measurements and quality control is high on the agenda of SOCONET. IOCCP has endorsed the need to further develop the collaboration with the atmospheric community.

To determine air-sea fluxes. the NOAA Boulder product GlobalView is currently being used. A quasi-assimilation product CarbonTracker CT2017 is also available. As air measurements of CO₂ are becoming increasingly important, details of how to develop a high-quality product without regional bias needs to be worked out. It was recommended to carry out an investigation into the feasibility and the need for comparison/validation of products.

IOCCP is keen to strengthen the collaboration with the atmospheric observationalists, who as a community are also gathered in Global Atmospheric Watch (GAW). GAW requirements cannot be currently met with our ship-borne measurements. However, these ship-based measurements could be of value if the uncertainty is better constrained. Otherwise a special sensor for atmospheric CO₂ measurements would be needed. A useful application could be the validation of satellite retrievals of column CO₂.

Apart from the contribution to the OceanObs' 19 Community White Paper on the topic of marine boundary layer air CO₂ measurements, IOCCP will make sure that its representative attends the Biennial WMO/IAEA Meeting on Carbon Dioxide, Other Greenhouse Gases and Related Tracer Measurement Techniques (GGMT), with the next one taking place in Korea, Jeju Island, on 1-6 September 2019.

Investigating utility of SOCONET data for surface water and profiling float pH measurements

Autonomous pH sensors are reaching a maturity level where they are low maintenance, precise, and have minimal drift. There is strong interest to use these sensors to determine surface water pH. As the accuracy of the sensors and conversion of pH to pCO_2 is not well known, the SOCONET quality data will be of great utility to validate or calibrate these units. If successful, this will greatly augment the current surface pCO_2 dataset.

IOCCP is planning to support and organize a technical workshop to explore this utility in detail. The workshop has tentatively been scheduled for the second part of 2019, potentially as a side event to a larger SOCAT community event.

Ocean interior observations

IOCCP will continue contributing to the development of all ocean interior observations in many aspects, such as dissemination, preparation of best practices, capacity building and
negotiation with intergovernmental organizations through our work with GO-SHIP Committee, Biogeochemical Argo Steering Committee, JCOMM OCG, GOOS Steering Committee and others.

GO-SHIP

For the years 2019-2022, ten GO-SHIP cruises have been planned (nine funded) for reference sections. Among these, five cruises have been funded for the sections in the Indian Ocean and Indian sector of the Southern Ocean.

A review of the U.S. GO-SHIP (significant conclusions for international GO-SHIP) is planned for 2019. Topics discussed include expanding onto more biogeochemistry and biology; and relationship between GO-SHIP and Biogeochemical Argo. IOCCP's advice in the process will be instrumental. GO-SHIP is also keen on obtaining advice from IOCCP on which EOVs should be included in the expansion of the network's capacity.

Coordination among Biogeochemical Argo, GO-SHIP, and IOCCP

Calibration/validation of data collected by Biogeochemical Argo sensors is fundamental in order for these very large sets of data to be used in the context of long-term trends quantification as required when discussing climate variability. This argument is specifically highlighted in the OceanObs'19 CWPs submitted by both GO-SHIP and Argo. This argument is as valid for calibration/validation of data from other autonomous ocean observing networks such as that of gliders equipped with biogeochemical sensors.

During the 13th Session of IOCCP SSG, discussions revolved around the growing importance of Biogeochemical Argo in ocean interior observations and the extent to which IOCCP should support it alongside the current support given to GO-SHIP. The SSG exchanged information on the prospects for future funding of the ongoing components of the Biogeochemical Argo float array and for the expansion of the fleet towards the goal of 1,000 floats with all six biogeochemical sensors as detailed in the Biogeochemical Argo implementation plan (http://biogeochemical-argo.org/). The group agreed on the importance of supporting the program on the international level, recognizing the fact that current support is mostly national and project-based, with a growing number of countries committing to create national operational Biogeochemical Argo programs (China, Canada, Japan, Norway).

The SSG remarked on a number of open issues regarding the strategy and implementation of Biogeochemical Argo from an international perspective. One such issue is the possibility and cost-benefit analysis of having additional oxygen sensor measurements on core Argo floats, implemented on top of the Biogeochemical Argo float array with a full-blown suite of sensors.

While the 6th Argo Workshop held just prior to the 13th Session of IOCCP SSG was intended to approach some of these issues, it did so only to a very limited extent. Hence, there was a suggestion to organize an international workshop on Biogeochemical Argo but with IOCCP's role as facilitators and with a clear strategy and implementation plan published. Further progress was made at the Argo Science Team meeting in China in March 2019, in particular, regarding the establishment of Argo Mission 2020 (Argo-2020). Dick Feely has been responsible for scoping the need and possibility for pursuing this activity further.

Sustained observations of marine plastics contamination

During the 7th Session of the GOOS Steering Committee (June 2018), it was recommended that GOOS Biogeochemistry Panel takes charge of scoping the community needs for international coordination of sustained ocean observations of marine plastic contaminants.

The IOCCP SSG agreed that the issues of marine plastic monitoring are vital from the societal perspective, as recognized by the regional and global conventions (e.g., EU Marine Strategy Framework Directive, UN Agenda 2030) and as reflected in the GOOS Strategic Objectives. The SSG also recognized the challenges related to even identifying what part of this highly complex variable should and could be measured. Aspects such as monitoring various species of plastic, various fractions (micro vs macro), and whether in situ or spaceborne observations are more feasible and why, are just a few examples of fundamental questions that need addressing as soon as possible. Recognizing these challenges, the group suggested that it is likely premature to establish standard operating procedures for monitoring marine microplastics. However, developing common methodology would be a priority for the global community involved in plastics monitoring efforts. It was also mentioned that IOCCP, in its form, could not comfortably advise on data management issues related to marine plastics. The Biogeochemistry Global Data Assembly Centre could potentially be considered, but it is premature to make any recommendations, as data management practices in marine plastics community have very low maturity level. It was recognized that GESAMP, UN Environment and lately also SCOR have expert working groups dedicated to this topic and they would be more suited to herding the relevant members of the community.

Ultimately, IOCCP decided in the short-term to be involved in collecting information on the status and needs of marine plastic monitoring, acting as a conduit for some other organizations on behalf of GOOS and not assuming any leadership role in the process.

At the GOOS-SC-8 meeting (May 2019) IOCCP recommended as a long-term solution to create a dedicated expert panel of GOOS, or a development program aiming towards calling such a panel, which would in partnership with the relevant organizations (e.g., UN Environment, GESAMP WG 40, EU EuroSea project, if funded) and expert working groups take up the challenge of coordinating ocean observations of marine plastics. This Panel need not be limited to marine plastics, but would account for all "Human Pressure Variables", as per original idea put forward by GOOS in 2016.

At GOOS-SC-8, it was decided that currently there are insufficient resources available to establish a new GOOS Expert Panel dealing with so-called human pressure variables. However, the SC recognized the need for treating such variables separately from other EOVs using the current Framework for Ocean Observing approach. The SC also noted that the process would require expertise beyond the scope of existing panels of GOOS. It was agreed that IOCCP will continue the scoping activities to a limited extent, pending additional dedicated funds are acquired, e.g., via the EU proposal EuroSea.

Coordination of marine plastics observations in the EU proposal EuroSea

Participation in the EU proposal EuroSea is one of the options which IOCCP is pursuing to secure funding for the Project Officer beyond 2019. One of the proposed tasks in EuroSea deals with "Developing capacity and coordination for a sustained ocean observations of marine plastic contaminants." If funded, this task would be led by IOCCP Project Office at IO PAN, and it would bring together technical experts leading individual global observing networks with leading authorities focused on marine plastic contamination (e.g., GESAMP,

UN Environment and initiatives involved monitoring, sensor development, and ecosystem impact assessments in marine plastics) with the long-term aim to establish global coordination of sustained observations of marine plastic contaminants as a "Human Pressure" EOV. A subtask will aim to establish a common sampling protocol, support implementation among European observing network partners, and establish the capacity to map out marine plastic contaminant monitoring.

4.2 GlobalHAB

Berdalet



Dr Ed Urban, SCOR Executive Director

May, 27th 2019

Dear Dr Urban,

The GlobalHAB Scientific Steering Committee is glad to present the Report to SCOR. It is a good opportunity to acknowledge the SCOR support to the program. As you know, this program, launched in 2016, was born from the need to coordinate research on harmful algal blooms (HABs). It was established on the legacy of the previous IOC/UNESCO and SCOR program GEOHAB, as a bottom up initiative from the research community working on HABs in an open science meeting held in Paris, April 2013 at the sunset of GEOHAB. The ultimate goal of GlobalHAB is to improve understanding and prediction of HABs in aquatic ecosystems, and management and mitigation of their impacts.

Since its launch in 2016, the GlobalHAB SSC worked on the elaboration of the Science and Implementation Plan, the webpage structure, some activities and end products of GEOHAB and new GlobalHAB initiatives. **Without an international program office**, GlobalHAB is being implemented by the SSC working on line, three scientific meetings with the support of IOC UNESCO and SCOR (including funding from the U.S. National Science Foundation) and by in-kind contributions from ICES and PICES, and with the invaluable support of Ed Urban (SCOR) and Henrik Enevoldsen (IOC UNESCO). Additional funds have been received from other institutions when hosting the SSC meetings and for the implementation of the specific activities indicated in this and previous Reports to SCOR.

As it is shown in this 2019 Report (section 4) some new scientific activities are planned and scheduled for the 2019-2021 period, whose implementation depends on obtaining the necessary funds. At present, the SSC members are in contact with interested researchers and institutions to co-organize and co-fund these activities, and some support is already secured. In all cases, scientific outcomes in form of papers, new knowledge, training and coordination will result.

Furthermore, GlobalHAB has been present in relevant international scientific and stakeholder *fora* where the challenges posed by HABs have been visualized and incorporated in key documents defining the road map of international agencies. **The work of GlobalHAB is becoming increasingly relevant as climate change begins to have worldwide discernible effects on coastal marine ecosystems along with major HAB impacts on resources (e.g., HAB induced salmon mass mortalities in Chile and Norway in the last three years). Nowadays, research on HABs goes beyond the traditional HAB arena and is entering into a new era of coordination initiatives. In all these initiatives SCOR has always been visible and acknowledged.**

For all the exposed, it is extremely necessary that the utilization of the US NSF earmarked contribution to SCOR allocated to GlobalHAB is extended beyond August 31st, 2019, specifically for 18 months, until February 28th, 2021.

The GlobalHAB SSC requests that SCOR investigates with NSF all options to extend this deadline. This extension will allow conducting the planned activities and produce the scientific outcomes that implement GlobalHAB goals. As stated in the GlobalHAB webpage, "In the broader picture GlobalHAB contributes to improved management of HABs as an ocean hazard through improved preparedness and early warning systems contributing to UN Sustainable Development Goal 11, target 11.5 and Priority 4 and Global target 7 of the Sendai Framework on Disaster Risk Reduction (UNISDR) 2015-2030." And the GlobalHAB SSC is committed to it.

When closing this Report, I am asking, respectfully, for this consideration to the SCOR President, Executive Director and Committee, on behalf of the GlobalHAB SSC and the international community working on HABs.

Elisa Berdalet, Chair of the GlobalHAB SSC

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

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

Joe Silke, Marine Institute, Ireland, IPHAB representative



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

Program Activities 2018-2019 and Plans for the 2019-2021 period

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

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Henrik Enevoldsen, IOC UNESCO/ IOC Science and Communication Centre on Harmful Algae at the 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 and IOC during the 2015-2019 period. The funds made possible the development 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 short-term initiatives prioritized by GlobalHAB. GlobalHAB activities are described next.

1. Meetings of the GlobalHAB SSC members

Since the last meeting at the Laboratoire d'Océanographie de Villefranche (LOV) in Villefranche-sur-mer (France) on 10-11 April 2018, GlobalHAB SSC members have worked on implementation of the GlobalHAB by communication through email and virtual meetings of small groups. In addition, most SSC members (including representatives of ISSHA, IPHAB, ICES, PICES) had an opportunistic meeting during the 18th International Conference on Harmful Algae (ICHA) held in Nantes, France, 21-26 October 2018. Among other items, the SSC reviewed the status of ongoing activities and prioritized new ones. Given that many activities are in progress, the SSC decided not to meet in 2019 and to continue coordination remotely. This will save funds to be used for specific activities and products.

2. Science highlights in the 2018-2019 period

2.1. Communications about the GlobalHAB program, from GlobalHAB-endorsed projects and other programmes related to GlobalHAB in international scientific events:

- Regional Workshop on Monitoring and Management Strategies for Benthic HABs, Monaco, April 2018 - E. Berdalet, H. Enevoldsen and the GlobalHAB SSC. *The IOC-UNESCO and SCOR programme GlobalHAB: International coordination to advance in the understanding and management of benthic harmful algal blooms impacts.*
- The Effects of Climate Change on the World's Oceans, 4th International Symposium, Washington, DC, USA, June 2018 - Raphael Kudela, E. Berdalet, C. Gobler, B. Karlson, N. Banas, E. Bresnan, M. Burford, K. Davidson, Po Teen Lim, L. Mackenzie, M. Montresor, V. Trainer, G. Usup, K. Yin, H. Enevoldsen and Ed Urban. *GlobalHAB: International coordination to ascertain the effects of Climate Change on the occurrence of Harmful Algal Blooms*.
- ICHA 2018, Nantes, October 2018 E. Berdalet, N. Banas, E. Bresnan, M. Burford, K. Davidson, C. Gobler, B. Karlson, R. Kudela, P. T. Lim, L. Mackenzie, M. Montresor, V. Trainer, G. Usup, K. Yin, H. Enevoldsen, E. Urban. *GlobalHAB (IOC-UNESCO and SCOR): International coordination for sound knowledge of HABs to manage their impacts.*
- ICHA 2018, Nantes, October 2018 L. Mackenzie, J. Banks, K. Smith. *Application of gel-formatted qPCR assays for rapid diagnosis of shellfish toxin producing and fish-killing micro-algae in seawater*. Communication of the GlobalHAB endorsed projects of the authors.
- Global Ocean Observing System Bio/Eco Panel Meeting. St Peter's Beach, FL, USA, October 2018 R.M. Kudela. *An update on development and implementation of the Phytoplankton EOV*.
- PICES 2018, Yokohama, Japan October 2018 V.L. Trainer Progress of GlobalHAB including Best Practices Manual. PICES Annual Meeting, HAB Section report, https://meetings.pices.int/publications/annual-reports/2018/2018-S-HAB.pdf
- UN DOALAS, Multi-Stakeholder Dialogue and Capacity-Building Partnership Event, New York, January 24-25, 2019. Kedong Yin was invited to give the presentation

Science-Driven Management Decision Making in Formulating Sewage Treatment Strategy.

- UN DOALAS, Regular Process for The Global Reporting and Assessment of the State of the Marine Environment, Including Socioeconomic Aspects. Kedong Yin also participates in writing *Chapter 10. Changes in inputs to the marine environment of nutrients*.
- International Conference on Toxic Cyanobacteria, Krakow, Poland, 2019, Poster presentation on GlobalHAB program and activities associated with cyanobacteria research. Presenter Michele Burford.

2.2. Sessions chaired by GlobalHAB in international meetings:

• International Conference on Harmful Algae, Nantes (France), October 2018. Session "Networking activities around HABs: GlobalHAB, Global HAB Status report, ICES-WGs and other initiatives" chaired by E. Berdalet, A. Zingone and P. Hess.

2.3. GlobalHAB endorsed Workshop funded by EukRef of UniEuk, Roscoff, (France), 5-9 Nov 2018 (http://eukref.org/roscoff-workshop/).

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* (www.unieuk.org), an open, community-based and expert-driven international initiative to build a flexible, adaptive universal taxonomic framework for eukaryotes, focused primarily on protists. E. Berdalet and M. Montresor participated in the organization of the workshop and M. Montresor attended it as an advisor, with UniEuk financial support.

The workshop focused on diatoms, dinoflagellates, and green algae. The working group integrated the curation efforts on individual eukaryotic groups into a biological data warehouse consisting of curated sequences, flexible taxonomy, and phylogenetic trees and their underlying sequence alignment. EukRef will integrate with PR2, a reference database for protists, with plans to push forward and expand ongoing curation efforts that are crucial for the interpretation of metabarcoding datasets (http://eukref.org/eukref-pr2-integration/).

2.4. 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", jointly led by Dr Andrew Turner (Centre for Environment Fisheries and Aquaculture Science-CEFAS, Weymouth, United Kingdom) and Dr Tim Harwood (Cawthron Institute, Nelson, New Zealand). Twenty-four labs were involved in the inter-laboratory validation study, with support of a private company and participation of independent advisors: Dr Paul McNabb (NZ), Dr Ana Gago Martínez (EURLMB Spain) and Dr Jim Hungerford (FDA USA).

The project is in the final stages of report preparation and publication, and will mark a very important milestone in the global adoption of instrumental method of analysis of marine biotoxins. The validation study will be published in the *Journal of Official Analytical*

Chemists (JAOAC), after which it can be formally accepted as the official standard method for the analysis of paralytic shellfish toxins and tetrodotoxins in New Zealand and other jurisdictions that may wish to adopt this method.

2.5. Workshops of GlobalHAB endorsed project "Assessment of the risk of benthic life stages of toxic dinoflagellates to the Seafood Sector of New Zealand and France", led by Dr Kirsty Smith (Cawthron Institute, Nelson New Zealand) and Dr Kenneth Mertens Ifremer, Concarneau, France). The specific aim of this project was to identify benthic life stages of three high-priority toxic dinoflagellate groups, *Alexandrium, Azadinium* and *Vulcanodinium*. Two workshops, held in New Zealand (12-14 February 2018) and France (coinciding with ICHA 2018 in Nantes, 21-26 October 2018) demonstrated morphological and novel molecular methods for cyst identification and provided international training for monitoring programmes.

2.6. GlobalHAB endorsed project "Innovative technologies for the early detection of Harmful Algal Bloom threats", led by Dr Lincoln MacKenzie (Cawthron Institute, New Zealand) with participation of Drs Kirsty Smith and Jonathan Banks (Cawthron, NZ), Dr Raphael Kudela (University of California Santa Cruz, USA), Mr Mark Vanasten (Diagnostic Technologies, Australia), and Dr Jason Acker (Diagnostic Systems Inc. Edmonton, Canada).

The project aims to apply innovative technologies for detecting harmful phytoplankton species in near real time, thereby enabling rapid response of the aquaculture industry and other stakeholders to the onset of HABs and, where possible, mitigate their impacts.



Drone footage of a 'red-tide' of *Alexandrium pacificum* in the Marlborough Sounds, New Zealand.

Specifically, the project involves field and laboratory trials of three complementary technologies: the HydrogelTM qPCR assay, the DinoDTec Saxitoxin gene qPCR assay and the Imaging FlowCytoBot (IFCB) instrument for the detection and monitoring of harmful planktonic micro-algae. This project is applied research aimed at improving the effectiveness, and lowering the cost, of current harmful algae monitoring methods for aquaculture. The HydrogelTM assay is a field-deployable qPCR assay developed by Aquila Diagnostic Systems that can provide a fast and effective screening tool competitive with the current microscopy methods for detecting problem algae species. The assay is sensitive, simple, and robust and able to be carried out in a basic laboratory at sea or in an on-shore

seafood processing facility. The research involves the transfer of developed qPCR assays to the HydrogelTM format targeting HAB species most important to the aquaculture industry in New Zealand. The assays specifically target DNA sequences unique to the ichthyotoxic species *Pseudochattonella verruculosa*, *Heterosigma akashiwo* and *Karenia brevisulcata*, and the paralytic shellfish toxin producers *Alexandrium pacificum* and *A. minutum*. Parallel trials of the commercially available DinoTec STX gene assay are being carried out alongside the HydrogelTM assay when screening for toxic *Alexandrium* spp.



Portable equipment required for DNA extraction and the Hydrogel qPCR assay of seawater samples.



IFCB *in situ* imaging of phytoplankton showing two chain-forming *Alexandrium* species (*A. pacificum* and *A. fraterculus*) in the assemblage.

The Imaging FlowCytobot (IFCB) is an-autonomous submersible, *in situ* imaging flow cytometer, manufactured by McLane Labs, USA (<u>http://mclanelabs.com/imaging-flowcytobot/</u>). It combines flow cytometry and video technology to capture images of individual cells. After training the software, the images can be automatically classified to provide identification, abundance and bio-volume estimates. Through collaboration with Dr Raphael Kudela, the instrument is being evaluated for the detection and quantification of HAB species in aquaculture regions in New Zealand. The IFCB is currently being deployed

from various aquaculture installations (e.g., salmon farms) and on monitoring vessels and its capabilities demonstrated the aquaculture industry.

2.7. Intercomparison of methods to detect harmful species and toxins.

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.

2.8. Paper on HAB Observing System: Scaling Up From Regional Case Studies to a Global Harmful Algal Bloom Observing System. Clarissa R. Anderson, Elisa Berdalet, Raphael Kudela, Caroline Cusack, Joe Silke, Eleanor O'Rourke, Darcy Dugan, Molly McCammon, Jan Newton, Stephanie K. Moore, Kelli Paige, Steve Ruberg, John R. Morrison, Barbara Kirkpatrick, Katherine Hubbard and Julio Morell. Frontiers in Marine Science May 2019, doi: 10.3389/fmars.2019.00250, https://www.frontiersin.org/articles/10.3389/fmars.2019.00250/full

2.9. Inclusion of data on cyanobacterial blooms and toxins in HAEDAT database which presents reporting of HAB blooms globally (http://haedat.iode.org/index.php).

3. Implementation activities in the 2018-2019 period

In addition to the Science Highlights in the previous Section 2, other activities have been conducted by GlobalHAB:

• A brochure was produced on October 2018 and distributed at the ICHA2018 and at the *Marine Environmental Science Symposium (XMAS IV)* 6-9 Jan. 2019, in the HABs session convened by Po Teen Lim and colleagues from Xiamen, China.



GlobalHAB Endorsed Workshops & Projects

http://www.globalhab.info/about-us/ globalhab-endorsed-projects

This list will be enhanced with your participation in GlobalHAB!

- . EukRef: The 18S Annotation Initiative, 3rd Workshop, November 5-9, 2018
- International Collaborative Study for the Validation of a HILIC-MS/MS Method for Analysis of Paralytic Shellfish Toxins and Tetrodoxin in Live Molluscs
- Effects of climate changes on harmful algal and cyanobacterial blooms along the South Atlantic Ocean
- Predicting Risk and Impact of Harmful Events on the Aquaculture Sector (PRIMROSE)
- Source and fate of ciguatera fish poisoning-toxins and its implication on coral reef ecosystem health and seafood safety. Training courses and Workshop .
- AZTI EEAcademy Summer School 2019: Does Human health and Wellbeing depend on a Healthy Ocean? .
- Assessment of Risk of Benthic Life Stages of Toxic Dinoflagellates to the Seafood Sectors of New Zealand and France (CystRisk)
- Co-development of Climate services for adaptation to changing Marine Ecosystems (CoCliME)
- Innovative technologies for the early detection of Harmful Algal Bloom threats



GlobalHAB Themes

tegrated in GlobalHAB range from and climate-based processes. Gli tegrated in GlobalHAB range from - and climate-based processes. G multidisciplinary, integrating physic d biology and addressing the impu-imment and humans. Terms shown d as individual GlobalHAB theme tegrated into HAB research. sics, acts of HABs

Coordination with International and

- Regional Programs on HABs, such as ISSHA, ICES, PICES, IAEA, CIESM, POGO, WHO, FAO, IWC, IOC-IPHAB, IOC Regional Groups, SCOR Working Groups
- GOOS Bio/Eco HABs are a major component of the Phytoplankton EOV
- IOC-NOAA-FAO-WHO to implement the Global Ciguatera Strategy
- OceanObs19 GlobalHAB will foster HAB multidisciplinary and innovative observation systems

Opportunities & Outcomes

- GEOHAB final product: Oceanography special issue (2017) Harmful Algae special issue "Harmful Algae and Climate Change" (2019) M. Wells & C. Gobier, Editors
- Global Harmful Blooms Status Report
- "Best Practice Guidelines for the Study of HABs and Climate Change" (2019) M. Weis, M. Buford, A. Kreyn, M. Montresor, G. Pitcher, G. Usup, Editors
- GlobalHAB participates as External Advisor in the EU H2020 SOPHIE project aimed at Linking Oceans and Human Health (2018-2020)
- Workshop on the economic impacts of HABs coordinated with PICES (2019)
- A Webinar series on cyanobacter for water managers and maps of cyanobacterial species occurrent
- Open Science Meeting on HABs and deoxygenation in coordination with IOC-GO2NE
- Open Science Meetings, Workshops and Summer Schools focused on HAB related topics

Acronyms

- · HAB: Harmful Algal Bloom
- · EOV: Essential Ocean Variable
- GO2NE: Global Ocean Oxygen Network PICES: North Pacific Marine Science Organization

- Coordination between GlobalHAB and TrendsPO (IOC) to analyse occurrence of HABs in response to climate change and global change, TrendsPO meeting (12-16 November 2018, UCSC, USA). Efforts are underway to conduct a comparative analysis across multiple ecosystems of trends in HAB organisms. Following from this analysis would be exploration of the underlying drivers (i.e., if a trend exists, is it clearly linked to climate change?). Comparative work on different environments and harmful events is also conducted by PICES and NOAA. As part of this effort a manuscript describing the link between climate change and HAB events has been submitted to *Harmful Algae* (Trainer et al., 2018).
- A workshop was organized by IOC WESTPAC-HAB at Chulalongkorn University (Thailand) on 25-27 February 2019 to review the status of fish-killing Raphidophytes species in Western Pacific region. A review paper on Raphidophyte species and its impacts in the region is expected from this activity.
- A session on HABs will be conducted within the 7th European Phycological Conference (<u>http://epcseven.biol.pmf.hr/</u>) to be held in Zagreb (Croatia) on 25-30 August 2019. The session is by S. Accoroni and P.M. Visser, and M. Montresor is member of the Organizing Committee.
- 4. New implementation activities in the 2019-2021 period
- 4.1. Ongoing and confirmed activities
- June 5-7, 2019. AZTI-SOPHIE project Summer School: "Does human health and Wellbeing depend on a healthy Ocean?" Aquarium of San Sebastian (Spain). This is a GlobalHAB-endorsed project. Elisa Berdalet will give a lecture, representing GlobalHAB (https://www.azti.es/eventos/azti-sophie-project-summer-school-2019- doeshuman-health-and-wellbeing-depend-on-a-healthy-ocean/). The activity is linked to the World Oceans Day (http://www.worldoceansday.org/Default.aspx?CCID=31759&FID=343862&ExcludeBo olFalse=True&PageID=17466397).
- June 10-11, 2019. As already initiated within GEOHAB (lead by Grant Pitcher and Raphe Kudela) GlobalHAB included fostering research on the potential links between ocean deoxygenation and HABs through 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/). A joint GO2NE GlobalHAB workshop is being organized to identify potential research on this topic in 2019, to be held in Paris immediately prior to the next GO2NE workshop (http://hab.ioc-unesco.org/index.php?option=com_oe&task=viewEventRecord&eventID=2469).
- October 17-19, 2019. An international workshop, "Evaluating, reducing and mitigating the cost of harmful algal blooms: a compendium of case studies", which will be held in Victoria, British Columbia, Canada as part of the Annual Meeting of the North Pacific Marine Science Organization (PICES). The workshop co-convenors are Drs Vera Trainer (USA), Keith Davidson (UK) and Kazumi Wakita (Japan) and it is jointly sponsored by GlobalHAB (SCOR and IOC), PICES, NOWPAP, ISSHA, NOAA, FAO and private companies. The goal of the 2.5-day workshop is to bring together international experts in

economics, social sciences, and the study of harmful algal blooms (HABs) to develop a compendium of case studies to guide future research on the economic and social costs of HABs. The intent is that this compendium will identify priorities and unify methods for future collaborative assessments of HAB impacts. More information can be found at https://meetings.pices.int/meetings/annual/2019/PICES/Program.

- October 2019. A fish-killing HABs workshop is planned, co-funded by GlobalHAB, IOC UNESCO and the government of Chile. The activity is coordinated by Leonardo Guzmán and the IOC/IPHAB Task Team on Fish-killing algae. The workshop will include a) plenary lectures by invited experts to provide a synthesis of current state-of-knowledge and to point the way forward in furthering our understanding of fish-killing HABs; b) presentation of case studies of particularly dramatic crises in Chile and other areas; c) participation of Chilean national scientists, monitoring and regulatory agencies and the local industry viewpoints; d) laboratory demonstrations (if feasible). The outcomes of the workshop will be published as an ebook. Note: the date has not been confirmed yet, and due to agenda issues it could be delayed for a few weeks.
- Fall 2019. *Manual for water managers on mitigation of cyanobacterial HABs* elaborated by Michele Burford and Chris Gobler. 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 web. The first draft already finished. GlobalHAB is co-funding this product.
- March 2018 to October 2019. E. Berdalet is participating, in representation of GlobalHAB at the CLEFSA project activities "*Emerging threats on human health in Europe due to climate change*". CLEFSA is a project of the European Food Safety Agency (EFSA) that explores the risks of food intoxication in future climate change scenarios. CLEFSA included aquatic biotoxins in the European landscape. E. Berdalet is collaborating in the development of reports and documents through online communication and particular meetings (funded by GlobalHAB).
- Fall 2019. *Special issue of the journal* Harmful Algae *focused on "Climate Change and HABs"*. The editors of the special issue, Chris Gobler and Mark Wells, have solicited 14 articles. Papers were submitted in summer 2018; some are under revision and others will be in press as of April 2019:
 - The Future of HAB Science: Directions and Challenges. *HAB-Climate Change* Symposium Organizers and Breakout Discussion Leads.
 - Projected Latitudinal Changes in Environmental Conditions Influencing HABs. *Fei Chai, Enrique Curchitser, Phil Boyd et al.*
 - Modelling HABs in a changing climate. *Kevin Flynn, Inga Hense, Neil Banas, Dennis McGillicuddy, Stephanie Dutkiewicz.*
 - Dynamic CO₂ and pH levels in coastal, estuarine, and inland waters: theoretical and observed effects on harmful algal blooms. *John Raven, Chris Gobler, Per Juel Hansen.*
 - Progress and promise of omics for predicting the impacts of climate change on harmful algal blooms. *Gwenn Hennon, Sonya Dhyrman.*

- Advancing the research agenda for improving understanding of cyanobacteria in a future of global change. *M.A. Burford, C.C. Carey, D.P. Hamilton, J. Huisman, H.W. Paerl, S.A. Wood, A. Wulff.*
- Pelagic harmful algal blooms and climate change: lessons from nature experiments with extremes. *Vera L. Trainer, Stephanie K. Moore, Gustaaf Hallegraeff, Raphael M. Kudela, Alejandro Clement, Jorge Mardones.*
- Climate change and benthic harmful algae. *Pat Tester, Elisa Berdalet, Wayne Litaker.*
- Fish-killing HAB and Climate change. *Charles Trick, Gustaaf Hallegraeff, Alan Cembella*.
- High biomass HAB and Climate change. Bill Sunda, Grant Pitcher, Chris Gobler.
- o Future observing systems. Bengt Karlson, Raphe Kudela, Stewart Bernard
- HABs: a climate change co-stressor in marine and freshwater ecosystems. *Andrew Griffith, Chris Gobler*
- Zooplankton grazing and HABs. *Hans Dam, Susan Menden-Deuer, Diane Stoeker, Matt Johnson.*
- Harmful algae at the complex nexus of eutrophication and climate change. *Pat Glibert*.
- **GlobalHAB will support some open access**. 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. The SSPM could be linked to the two IPCC 1.5C special reports that are coming out this year and next year.
- May 2020. Planning is underway for a workshop on "*Modelling and prediction of harmful algal blooms, from event response to multi-decadal projections*" to be held in Glasgow, UK. The organising committee consists of Neil Banas, David McKee, Bingzhang Chen, Paul Udom (University of Strathclyde), Bengt Karlson (Swedish Meteorological and Hydrological Institute), Keith Davidson, Dmitri Aleynik (Scottish Association of Marine Science), Clarissa Anderson (Scripps / SCCOOS), Dennis McGillicuddy (Woods Hole Oceanographic Institution), Beatrix Siemering (Marine Institute, Galway), and is also coordinating with Katja Fennel and Marion Gehlen, chairs of the Marine Ecosystem Analysis and Prediction Task Team (MEAP-TT) of the GODAE OceanView programme.
- The organizers hope to secure enough funds from different institutions, including cofunding from GlobalHAB, to invite a substantial number of early-career and developingworld scientists. A programme of summer school-like tutorials will be woven into conference-style presentations and discussions. The draft programme is organised into four parts:
 - o Exploring the diversity of HAB modelling approaches
 - o Emerging technologies and platforms to support HAB monitoring
 - o Linking models, observations, and stakeholder needs
 - o Scaling up: the global impact of global change on HABs

- Summer 2020. *Symposium on automated in situ observations of plankton.* In recent years, novel in situ instrumentation has been developed for automated high-frequency HAB detection in near real time. Also instruments for observing grazers, e.g. microzooplankton and multicellular zooplankton are becoming available commercially. These instruments are now being adopted in research and also in monitoring programmes. The aim of the minisymposium is to bring together experts on, and users of, in automated in situ imaging systems, novel sampling equipment etc. to present methods, recent results and to share experiences. Another aim is to carry out a comparison of results when analysing plankton communities quantitatively. Young scientists is one target group of the symposium. After the main symposium a young scientist's data workshop for data processing and report/article writing is planned. The symposium is planned for summer 2020, pending the results of several applications for funds (e.g., recently sent to the European network EuroMarine www.euromarinenetwork.eu), besides some potential support from GlobalHAB.
- **2020.** A "*Best Practice Guidelines for the Study of HABs and Climate Change*", editorial team constituted by Mark Wells (chair), Michele Burford, Anke Kremp, Marina Montresor, Grant Pitcher and Gires Usup started on March 2018 with a tentative deadline for the submission of the draft chapters was the month of May 2019.

The Manual includes the following chapters: Overview

(Editorial Board)

Chapter 1 - Rationale and Introduction (Editorial Board)

Chapter 2 - Observing changes in HABs over time — Long Term Observations (Richardson AJ, Eriksen R, Hallegraeff GM, Rochester W, Pitcher G, Burford M)

Chapter 3 - Understanding Responses of HAB Species to climate change through experimentation

A) General Recommendations (Burford M)

B) Culture Experiments (van der Waal D, Kremp A)

C) Acclimation and Adaptation (Dyhrman S, Godhe A, Hennon G, Sefbom J)

D) Toxin Measurements (McCarron P, Deeds J)

Chapter 4 - Databases (Zingone A, O'Brien T, Enevoldsen H, Provoost P, Lorenzoni L, Yin K, Bresnan E, Richardson A, Kruck A, Hallegraeff G)

Chapter 5 - HAB modelling and forecasting chapter (Hense I)

Funds for the first working meeting of the editorial team were provided by GlobalHAB. *The initiative of the Best Practices Manual for HAB and Climate Change is in line with the activities of SCOR WG149 that is focusing on Changing Ocean Biological Systems (COBS) and particularly on "How will biota respond to a changing ocean?" (https://scor149-ocean.com/)*. A second writing - editorial meeting could be necessary to finish the Manual.

4.2. Other potential activities ongoing and under exploration by the GlobalHAB SSC members and other collaborators:

Global Harmful Algal Bloom Status Report

The first Global HAB Status Report is an initiative of IOC UNESCO with the support of IAEA, ICES, PICES and ISSHA. The GlobalHAB SSC is following and supporting the initiative where it can. 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 and an Editorial Team for the First Global HAB Status Report was established together with a data flow structure. 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 submitting scientists to complement, and add value to, data already in OBIS with baseline observations recorded in the literature. Focus continues to be on data compilation and upgrades, and 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. Regional summaries on HAB based on OBIS, HAEDAT and the literature will constitute a special issue of the Elsevier Journal Harmful Algae in late 2019. 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/). The GHSR is foreseen to be completed by end 2019/early 2020.

• New GlobalHAB Theme: Sargassum Blooms.

The GlobalHAB Science and Implementation Plan identifies that new emerging HAB-related issues can be incorporated into the program after its launch. This is the case of the blooms of green macroalgae and *Sargassum*. **Elisa Berdalet** and **Henrik Enevoldsen** have been in touch with several researchers about this topic since 2016. The SSC have, with Brian Lapointe (USA), developed a short overview paper and the GESAMP Group of Experts have prepared a longer scoping paper on the *Sargassum* issue. The SSC proposed to GESAMP at its 2018 session to organize a joint open science meeting to identify the main research questions to understand the population dynamics of *Sargassum*. Several of the GESAMP sponsoring agencies have shown interests in the topic. **The GlobalHAB SSC will work during the coming months to progress in the organization of this theme jointly with GESAMP**, herein included to identify and engage additional experts with experience on *Sargassum*.

• Workshop and a Summer school on analysis and interpretation of genetic data on HABs.

The activity is followed by Po Teen Lim who hosted regional workshops/training courses on HABs species and detection using molecular techniques for Southeast Asia in 2017 and 2018. More details of these activities are available in Harmful Algae News 58 and 61 (<u>http://hab.ioc-unesco.org/index.php?option=com_content&view=article&id=22&Itemid=0</u>). National and regional workshop will be planned in collaboration with other international and regional agencies interested in HABs.

• 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.

- A PCR/qPCR *Gambierdiscus* identification workshop.
- A 2nd International Conference on *Ostreopsis* Development, including ecology, toxicology, health and economy issues.
- A harmful species (*Gambierdiscus, Ostreopsis, Prorocentrum*, cyanobacteria) sampling workshop is under exploration with different Spanish institutions in the Canary Islands in 2020 early 2021.

5. Representation of GlobalHAB at the Fourteenth Session of the IOC Intergovernmental Panel on Harmful Algal Blooms (IPHAB)

The session was conducted in Paris, UNESCO Headquarters, Paris, 24-26 April 2019. SSC Chair, Elisa Berdalet, presented the Report on the activities contributing to the GlobalHAB Implementation Plan between May 2017 (XII IPHAB session) and April 2019. The IPHAB is the IOC governing body to which the SSC reports for IOC. The IPHAB welcomed the developments and had a discussion on how to ensure broader engagement geographically in as many of the GlobalHAB activities as possible. The Panel also discussed strategies and means for announcing GlobalHAB events, for engaging younger scientists and to strengthen the perception of ownership to GlobalHAB in the scientific HAB community. IPHAB recommended broader, wider, and earlier communication of all events and developments, even in cases where there may be few seats available, as it is a way to make visible what GlobalHAB does and how it contributes to advance science. The IPHAB recognized that IPHAB members can serve an important role in doing so.

6. Funding considerations and future funding plans

The scientific meetings of the GlobalHAB SSC have been supported by IOC UNESCO and SCOR (with funding from the U.S. National Science Foundation), and by in-kind contributions from ICES, PICES and SAMS. Additional funds have been received from other institutions to conduct the specific activities indicated previously.

As it is shown in this 2019 Report (section 4) some new scientific activities are planned and scheduled for the 2019 - 2021 period. In all cases, scientific outcomes in form of papers, new knowledge, training and coordination will result. The implementation of these activities depends on obtaining the necessary funds. At present, the SSC members are in contact with interested researchers and institutions to co-organize and co-fund these activities.

It is also important to note that GlobalHAB has been present in relevant international scientific and stakeholder *fora* where the challenges posed by HABs have been visualized and incorporated in key documents defining the road map of international agencies. **The work of GlobalHAB is becoming increasingly relevant as climate change begins to have worldwide discernible effects on coastal marine ecosystems along with major HAB impacts on resources (e.g., HAB induced salmon mass mortalities in Chile and Norway in the last three years). Nowadays, research on HABs goes beyond the traditional HAB arena and is entering into a new era of coordination initiatives. In all these initiatives SCOR has always been visible and acknowledged.**

For all the exposed, both SCOR and IOC members (states) are encouraged to contribute to the operation of the GlobalHAB SSC as well as to the implementation of the specific activities. This is particularly needed as the US NSF earmarked contribution to SCOR will be exhausted on August 31st, 2019. **The GlobalHAB SSC requests that SCOR investigates with NSF all options to extend this deadline** specifically for 18 months, **until February 28th, 2021.** This extension will allow conducting the planned activities and produce the scientific outcomes that implement GlobalHAB goal. As stated in the GlobalHAB webpage, "*In the broader picture GlobalHAB contributes to improved management of HABs as an ocean hazard through improved preparedness and early warning systems contributing to UN Sustainable Development Goal 11, target 11.5 and Priority 4 and Global target 7 of the Sendai Framework on Disaster Risk Reduction (UNISDR) 2015-2030.*" And the GlobalHAB SSC is committed to it.

When closing this Report, I am asking, respectfully, for this consideration to the SCOR President, Executive Director and Committee, on behalf of the GlobalHAB SSC and the international community working on HABs.

Elisa Berdalet, Chair of the GlobalHAB SSC

4.3 IAPWS/SCOR/IAPSO Joint Committee on Seawater

McDougall

Joint SCOR/IAPWS/IAPSO Committee on the Properties of Seawater (JCS) Report to SCOR on JCS Activities June 2017- Jun 2019

JCS Exe	cutive		
Rich Pawlowicz (Chair)	Canada		
Rainer Feistel (Vice-chair)	Germany		
Steffen Seitz (Vice-chair)	Germany		
Salinity/Densit	y Taskgroup		
(Rich Pawlowicz) (Chair)			
Frank J. Millero	USA		
(Steffen Seitz)			
Hiroshi Uchida	Japan		
Stefan Weinreben	Germany		
Youngchao Pang	China		
Ryan Woosley	USA		
Yohei Kayukawa	Japan		
pH Taskgroup			
Andrew Dickson (Chair)	USA		
Maria Filomena Camoes	Portugal		
Daniela Stoica	France		
Simon Clegg	UK		
Frank Bastkowski	Germany		
Relative Humid	ity Taskgroup		
Olaf Hellmuth	Germany		
Jeremy Lovell-Smith	New Zealand		
(Rainer Feistel)			
Stephanie Bell	UK		
Export subgroup: Thermodynamics			
(Rainer Feistel)			
Expert subgroup: Numerical I	Modelling and Applications		
Trevor J. McDougall	Australia		
Expert subgroup: Software			
Paul Barker	Australia		

Industry Representatives		
Richard Williams (OSIL)	UK	
Barbara Laky (Anton Paar)	Austria	

Background

The Joint SCOR/IAPWS/IAPSO Committee on the Properties of Seawater (JCS) is a permanent group with limited membership whose purpose is to act as an international "point of contact" for seawater questions. It is jointly sponsored by organizations directly concerned with the properties of seawater: the Scientific Committee on Oceanic Research, the International Association for the Properties of Water and Steam, and the International Association for the Physical Sciences of the Ocean.

JCS acts as a permanent source of expertise to its parent organizations, maintains a repository of knowledge and software for the scientific community (via a web-site, <u>www.teos-10.org</u>), and is also a conduit for any desired communications between its parents, and out to other international organizations like the BIPM (Bureau International des Poids et Mesures), the WMO (World Meteorological Organization), and IUPAC (International Union of Pure and Applied Chemistry). In addition, JCS may from time to time summarize progress in seawater-related issues to the community at large, and suggest areas where gaps exist in the available knowledge.

Meetings

JCS does not meet annually as a full group. However, individual members represent the group at other meetings. For example, in 2017-2019, 6 JCS members attended the 2017 IAPWS Annual Meeting in Kyoto, Japan (Sept 2-7, 2017), and 3 members attended the 2018 Ocean Sciences meeting (Portland, Feb 1, 2018).

However, at a five-year interval from the time of a full set of workshops that initially formed the committee, JCS held a second series of workshops at the 17th International Conference on the Properties of Water and Steam (Sept., 2018, Prague, Czech Republic). These included a workshop on the aims and purpose of JCS, as well as meetings of a) the Salinity/Density taskgroup, b) the pH Taskgroup, and c) the RH Taskgroup, with an attendance of 14-19 scientists for each.

As a result of these discussions, JCS recommended to SCOR, IAPWSO, and IAPWS that JCS continue as an organization sponsored by these organizations, that the JCS Terms of reference remain unchanged for the next cycle, and that the membership of the various JCS taskgroups, which are largely independent of one another, be increased slightly to assist them in their work, by including a number of scientists who are currently contributing to the tasks of JCS Taskgroup chairs were also appointed. These recommendations were accepted and the current membership is listed above. In addition, a series of goals was developed to guide taskgroup activities over the next few years.

Web site

JCS maintains a web site at <u>www.teos-10.org</u>. This site gets 1,600-2,300 visitors per month (8,574 in the past year, with 64,304 "unique views"¹ since Oct. 2010). Annual downloads are stable.

Web site Item	Unique downloads June 2011- June 2013	Unique downloads June 2013- June 2014	Unique downloads June 2014- June 2015	Unique downloads June 2015- June 2016	Unique downloads June 2016- June 2017	Unique downloads June 2017- June 2018	Unique downloads June 2018- Apr 2019
Manual	920	360	535	552	418	427	349
Getting Started	879	362	558	547	427	475	349
Slides	704	284	374	318	219	248	204
Primer	584	197	289	297	222	217	187
GSW MATLAB_v3_	1920	1102	1485	1814	1235	1552	1233
GSW FORTRAN_v3	366	222	171	162	127	116	82
GSW_C_v3_0	202	84	133	151	85	96	59
GSW_PHP	-	55	61	43	29	60	28
SIA_VB	72	100	46	45	45	48	43
SIA_FORTRAN	59	118	58	44	36	42	37

Other Progress

- A new "European metrology network" (EMN) on Climate and Ocean has been formed, with several JCS members involved (however, the network is open to all to participate). The first AGM will be held on 20-21 June 2019 at the National Physical Laboratory (UK). In essence, this is a network for creating and disseminating knowledge, and building coordinated infrastructure. It has Sections dedicated to atmosphere observation, ocean observation, and land and earth observation, and will have activities in these areas.
- 2) Progress in the pH taskgroup is being carried out under the auspices of SCOR WG 145. An effort is being made to identify the limitations of Harned cell measurements through an intercomparison exercise between AD's laboratory and the national standards laboratories in France, Germany, Japan, and the USA; a new postdoctoral researcher is involved in making these measurements.
- 3) SC has almost completed coding of a speciation model that will allow for the estimation of uncertainties in pH.

¹The method of computing "unique views" changed in 2019.

- TEOS-10 is now the equation of state in the two main community climate ocean models (MOM6 and NEMO). It is also optional in two other widely used models (MITgcm and ROMS).
- 5) HU has carried out density anomaly measurements in the Bering Sea and Gulf of Alaska (2017), HU/FJM are carrying out an interlaboratory comparison with measurements in the Arabian Sea (May/June 2018).
- 6) FJM/RP continue analysis of East Pacific Rise density anomaly data.
- 7) RP is working on understanding the diffusion of seawater and possible fractionations that result from this (MSc thesis scheduled for completion fall/2019)
- 8) SS is working towards making high-pressure measurements of conductivity traceable to the SI system.
- 9) RF and JLS continue working towards procedures for making systematic error estimates.
- 10) RW is continuing with development of the 'best practices in density measurements' document.
- 11) The 2016 *Metrologia* papers have now been downloaded 15,422 times (Overview 4,587, Salinity 2,371, pH 2,387, RH 6,067)
- 12) OH has written 2 book chapters to appear in a textbook on meterological measurements, and is working on a long paper: Real-Gas Effects in Humid Air: Possible Implications of the Advanced Seawater Standard TEOS-10 for Hygrometry at Atmospheric Pressure (authors OH, RF, JLS and 3 others).

Papers published

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- Y. Li, Y. Kang, H. Yu, Y. Pang, Linearity corrections for laboratory salinometer measurements: IAPSO Standard Seawater linarity pack vs. weight diluted samples, Deep Sea Res I, 137, 13-19 (2018) doi.org/10.1016/j.dsr.2018.04.011
- 3) R. Feistel, Thermodynamic properties of seawater, ice and humid airL TEOS-10, before and beyond, Ocean Sci., 14, 471-502 (2018) doi.org/10.5194/os-14-471-2018 [*Invited paper by winner of EGU Fridtjof Nansen Medal 2018*]
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R. Pawlowicz

JCS chair, Jun 8, 2019

4.4 Southern Ocean Observing System (SOOS)

Miloslavich





The Southern Ocean Observing System

2018 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 2018 core sponsorship







2018 in review

2018 was a strong year for SOOS. Particularly exciting was recognition of the impact of SOOS in the broader community; evident through strong engagement at key meetings. Measured success was also possible. More than 41,000 individuals used SOOSmap in 2018, with six new data layers added and more than 300 direct downloads of data. Furthermore, DueSouth, a first point-of-access for information on upcoming Southern Ocean voyages and projects, has initiated automated data feeds to deliver an up-to-date directory.

Advocacy for Southern Ocean observations was also central in 2018. In collaboration with the CLIVAR-CliC-SCAR Southern Ocean Regional Panel, SOOS led a review paper to be published in *Frontiers in Marine Science* for OceanObs'19. This had broad community input and revealed eight future priorities for Southern Ocean observations. SOOS made contributions to other OceanObs'19 review papers, and also contributed the Southern Ocean chapter of the *Bulletin of the American Meteorology Society* State of the Climate for 2017.

All 10 SOOS working groups were active in 2018, and the detailed achievements of these groups can be viewed in this report. Importantly, two new regional working groups were developed and first workshops organised for early 2019. This fulfils requirements to deliver a fully circumpolar observing system for the Southern Ocean. The development of cooperation with other programs was also front and centre in 2018, with enhanced collaboration and data-sharing efforts between SOOS and CCAMLR, as well as strengthened connection to the Southern Ocean modelling community, through the SOOS Modelling workshop and the Marine Ecosystem Assessment for the Southern Ocean (MEASO).

In 2019, core efforts will focus on consolidating sustained funding for the SOOS Project Office, the first review and update of the SOOS Science Plan, and activities aimed at finalising the current 5-Year Implementation Plan and drafting of the next 5-year plan. Importantly, through SCAR, SOOS will also strengthen its engagement with the Antarctic Treaty and Committee on Environmental Protection.

Thank you for your continued support and interest in SOOS. We encourage you to engage with our on-line platforms by submitting field plans to DueSouth and discovering data through SOOSmap, and to collaborate through our working groups. We look forward to engaging with you at upcoming events.

Calden Cott 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 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 at 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 support delivery of a coordinated, integrated and efficient program that provides sustained observations 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 carried out by the Regional Working Groups (RWGs) and Capability Working Groups (CWGs).

There are four KRAs that will focus work towards achieving this objective, and all four were identified for action in 2018. Details of the progress are shown in the tables below.

During 2018, a concerted effort was made to address KRA 1.1 and 1.2; however, there are significant discrepancies in how EOVs and their criteria are documented, and how they are used by the community. The KRAs are not necessarily priorities for the implementors of the observing system, and thus pushing for significant community effort on these is not a practical priority. Instead, SOOS will be working through CWGs, RWGs, and specific Task Teams, to identify, prioritise, and document EOV coverage and requirements (KRA 1.3), which will result in a more "organic" delivery of KRA 1.1 and 1.2.

2018 Intended Actions	Progress Made (Y/X)	Comment
Published table of status of EOVs	Y	EOVs were published on the website: <u>http://soos.aq/activities/system-</u> <u>design</u>
Published, internationally defined criteria for EOVs	Х	No progress was achieved in 2018, predominantly due to a lack of a well-defined community to drive this initiative

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

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

2018 Intended Actions	Progress Made (Y/X)	Comment
Compiled EOV descriptions and supporting documentation	Y	Concerted efforts were made to address this Action in 2018. As a result, it was identified that this Action will be a more organic outcome of the RWGs rather than a separate, focussed effort.

Key Result Area 1.3: Spatio-temporal, system-level EOV sampling requirements are identified, documented and agreed, and strategies for implementation developed if needed

2018 Intended Actions	Progress Made (Y/X)	Comment
Development of 5 international networks for regional coordination of SOOS implementation	Y	All 5 Regional Working Groups (RWGs) have been developed: - West Antarctic Peninsula + Scotia Arc - Weddell Sea/Dronning Maud Land - Southern Ocean Indian Sector - Ross Sea - Amundsen/Bellingshausen Sea
Reviews of current status of EOV coverage, key gaps and requirements	Y	EOV Heatmaps have been developed by the Indian Sector RWG and will be delivered by all RWGs in 2019/2020. These identify existing coverage of EOVs, gaps and requirements, as well as support discussions on standards and data management. The Co-Chairs of all RWGs together form a <i>consortium</i> that meets semi-regularly to ensure alignment between RWGs where appropriate
International strategic plan for observing the ocean beneath Antarctic sea ice and ice shelves (OASIIS Working Group)	Y	A POGO Fact Sheet has been drafted and will be made available on the SOOS website. The strategy document is planned and will be delivered in 2020. Issues – Products from this group are delayed but will be delivered by end-2020

Key Result Area 1.4: A strategy for the uptake of EOVs within the RWGs is developed

2018 Intended Actions	Progress Made (Y/X)	Comment
Regional Implementation Strategies developed	Y	RWGs have developed an overview of observational coverage. This information will be standardised into EOV Heat-maps, and each RWG will identify strategies for implementation – to be delivered 2020. 2018 products contributing to this action include: Indian Sector Workshop <u>report</u> West Antarctic Peninsula/Scotia Arc <u>publication</u> Ross Sea Workshop <u>Report</u>

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

Delivering 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.

Three KRAs will focus work towards achieving this objective, and all were identified for action in 2018. Progress for 2018 shown in the tables below.

In 2018, Objective 2 activities focused on consolidation and communication of key products and networks. In this process, issues with integration and alignment across regional networks were identified and structures put in place to enable better communication and

connection. IPO support for Capability Working Groups is an ongoing issue, with websites, workshops and other communication efforts lagging significantly. At present, there is no clear pathway to enhancing the IPO support for these groups.

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

2018 Intended Actions	Progress Made (Y/X)	Comment
Continuation of active Working Groups against WG-specific TORs	Y	SOOS has 10 Working Groups and all were active in 2018.
Development of new WGs (as required)	Y	The Observing System Design Task Team was approved as a new Capability Working Group.
		The POLDER Task Team is a joint working group between SOOS, SCADM and the Arctic Data Committee established in 2017 and fully developed in 2018.
		Issues—inability of IPO to provide required website, communication and coordination support for existing groups. This puts into question the continued growth in WG numbers.

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

2018 Intended Actions	Progress Made (Y/X)	Comment
Database of Upcoming Expeditions to the Southern Ocean	Υ	Product was consolidated and a final version almost completed; Expeditions were populated manually; Automated transfer of expedition information from JCOMMOPS; the CCAMLR Science Committee approved the inclusion of new, exploratory, and krill fishing expeditions; COMNAP provided Regional Information Exchange reports for manual entry into DueSouth; and negotiations with IAATO for tourist vessel movements were begun. Negotiations also began with Geoscience Australia to use DueSouth for Australian bathymetric survey planning.
		Issues – Specific observational projects remain unpopulated; Inability to obtain user statistics; limited input of plans by community; Low level of control over timing and delivery of enhancements and modifications due to in-kind delivery of product.
SOOSmap	Y	Significant progress in delivering product; improvements to core functionality; 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	Υ	Product was maintained 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

2018 Intended Actions	Progress Made (Y/X)	Comment
Capability and Regional Working Group workshops	Y	SOFLUX Workshop; CAPS Annual Workshop; Regional Working Group Consortium workshop; Data Management Sub-Committee meeting; POLDER meeting
Capacity- or Community-building workshops	Y	Southern Ocean Data Hack; Southern Ocean Modelling workshop; CCAMLR-SOOS Synergies workshop; OceanObs'19 Community White Paper preparatory workshop;
International conference sessions, town- halls, side meetings, information sessions	Y	Polar2018 Data Townhall, Polar 2018 conference session "Big data, small data, your data: What does good data management look like to you?"

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 are 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 four KRAs that will focus work towards achieving this objective, and all were identified for action in 2018. Progress is shown in the tables below.

In 2018, progress towards this objective was considerable, based on strategic community consultation in recent years. These connections are vital to maintain in the coming years. In the past two years, as the SOOS data vision has developed, the focus of activity shifted away from a few KRAs and this is reflected by a lower intensity of effort on these fronts. In particular, KRA 3.4 "Community-developed data synthesis tools and products for the Southern Ocean are accessible through the SOOS website", was identified as being beyond the capability of the IPO to make appropriately comprehensive and useful at this point in time.

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

2018 Intended Actions	Progress Made (Y/X)	Comment
Maintenance of the SOOS NASA GCMD metadata portal	Y	The portal was rebuilt to maintain functionality with the GCMD's new Common Metadata Repository. Between the two portals, there were 1,720 unique visits, with 11,916 page-views. Due to differences in the portal query, it does not make sense to compare the number of records in the portal (3,675) with previous years.
		Issue: The GCMD is no longer delivering what the community requires. Development of the Federated Data Search Tool (POLDER) will shift SOOS efforts away from the GCMD.
SOOS mooring network	Y	The original actions identified in the Implementation Plan have been modified following community consultation.
		The major activity in 2018 was to enrich the metadata for moorings published through SOOSmap to include links to the thousands of datasets at BODC that are linked to Southern Ocean moorings. Minor additions and corrections from other nations were added as well.
Chinese CTD data sharing	Y	DMSC members, Chinese researchers and data managers, and CCHDO staff have begun exploring ways to calibrate historic Chinese CTD observations and negotiating a path to incorporating these datasets in international aggregations of CTD data.
Southern Ocean glider network	Y	Funding was obtained to improve the management of Swedishglider data and a project to aggregateglider datafrom EGO, IOOS, and IMOS through the SOOS map portal was scoped out.

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

2018 Intended Actions	Progress Made (Y/X)	Comment
Catalogue of Southern Ocean data providers	Υ	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

2018 Intended Actions	Progress Made (Y/X)	Comment
Federated metadata search tool	Υ	Adopted by the polar community as a high priority, on the basis of SOOS' proposal
Brokering data discovery and interoperability	Υ	Initial metadata harvest from PANGAEA into EMODnet, with discussions advanced on integrating CTD data harvests. SOOS mooring network updated to provide full links to all BODC mooring datasets
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
		Establishment of a simple data sharing mechanism for the SCAR Plasticin Polar Environments Action Group for publishing in SOOSmap.
		Delivery of Australian Research Council's Antarctic Gateway Partnership data policy, including data management advice to staff, implementation 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

2018 Intended Actions	Progress Made (Y/X)	Comment
Online catalogue of data products	Х	This KRA involves considerable resources to develop and maintain. Following several efforts to scope a useful product that is sustainable, SOOS has put this KRA aside until more resources are found and/or higher priority is given

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.

Six KRAs will focus work towards achieving this objective, and all were scheduled for action in 2018. Progress is shown in the tables below.

Although progress was made against all the KRAs of Objective 4 in 2018, 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

2018 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	Report to Antarctic Treaty Consultative Meeting Presentation to International Arctic Science Committee on SOOS data sharing activities

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

2018 Intended Actions	Progress Made (Y/X)	Comment
Reporting	Y	In 2018, annual reports were prepared for SCAR, SCOR, CCAMLR, COMNAP, ATCM-CEP, Australian Research Council's Antarctic Gateway Partnership, POGO, SCADM, and the SOOSSSC
		Issue: Reporting requirements are a significant overhead for the IPO, particularly given the lack of consistency between required information.
Development of SOOS Engagement Strategy	Y	This is a significant undertaking and has been an action for the IPO for several years. In 2018, the IPO identified a way forward using AirTable and began the process of developing the strategy. It will be delivered in 2019.
Community Engagement and conference presentations	Y	Direct engagement included (but not limited to): IICWG, COMNAP, CCAMLR, SORP, IAATO, WDS, GEOSS, GOOS, APECS, POGO, OOPC, SCAR Programs, RDA, SCADM, ICED, IASC, IPAB, IEEE, IMBER, IMOS, IAPSO, YOPP, SCOR, Ocean Sciences 2018, OceanSITES, EGU, ADC
		All engagement/presentations were carried out directly by IPO staffor by a community member 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

2018 Intended Actions	Progress Made (Y/X)	Comment
Scoping of requirements and delivery of product	Y	The need for this product has changed and a bibliography will no longer be developed. The IPO will continue to track all published references to SOOS using AirTable, which was initiated in 2018.

Key Result Area 4.4: The SOOS Communication Strategy is implemented

2018 Intended Actions	Progress Made (Y/X)	Comment
Sourcing of new website domain host; contact management system; transfer to standardised Joomla template;	Y	The IPO sought external advice on the best way forward. A plan was developed in 2018 for implementation in 2019.
		Issue: This is a high priority but the IPO does not have the capacity to implement in appropriate timeframes
Online database of presentations, posters, publications and other products	Y	Keyproducts, such as publications, were updated to the products database. Other, less important products (e.g., posters, presentations) have yet to be updated to the website
		Issue: Lack of IPO resources to update website as 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 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 April 2018
		Issue: The newsletter has historically been produced quarterly, however requires significant IPO effort, which has reduced its delivery
SOOS Publications (not including WG- specific publications)	Y	Southern Ocean OceanObs' 19 community paper; Fair Data OceanObs' 19 Community Paper; Southern Ocean chapter of BAMS State of the Climate in 2017
Other communication activities	Y	SOOS products were highlighted in the SCOR and SCAR newsletters and listed as SCAR Data Products
Merchandise	Y	New in-kind sponsorship by the Turkish Polar Institute and the ACE CRC supported the delivery of updated fliers and SOOS stickers
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

2018 Intended Actions	Progress Made (Y/X)	Comment		
5-Year Business Plan and funding strategy	Y	The Business Plan was developed and provided to all stakeholders and sponsors as required		
Development of future IPO hosting Partnership Agreement	Y	Significant IPO effort was directed towards this action in 2018		
Maintenance of existing IPO and SOOS	Y	Regular engagement with existing sponsors		
sponsorship		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	Significant effort was made to formalise new sponsorship with CSIRO, Tasmanian Government DoSG		
		New in-kind sponsorship was provided by the Turkish Polar Institute and the ACE CRC		

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

2018 Intended Actions	Progress Made (Y/X)	Comment
Maintenance and support of SOOS Governance	Y	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	Υ	Weekly IPO review and recording of activities against all KRAs	
Administrative finance	Y	Development of 2018 budget Management of income and expenditure	
		Sponsorship of 6 international SOOS events	
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	
		Executive Officer completion of Australian Institute of Company Directors professional development course on "Company Directors"	

SOOS Key Products

Southern Ocean community review publication

In 2018, SOOS led the development of a large community review paper² as a contribution to the decadal OceanObs'19 Conference. This paper presented a community statement on the major scientific and observational progress of the last decade, since the 2009 OceanObs conference that was integral in scoping and shaping the development of SOOS. The paper also provides an assessment of key priorities for the coming decade, towards achieving the SOOS vision and delivering essential data to all end users. These issues were identified as major data bottlenecks in addressing the six SOOS Science Themes. The issues identified include the following:

- Observing Antarctic Bottom Water production processes
- Reducing uncertainties in air-sea and air-sea-ice fluxes of heat, momentum, freshwater and carbon
- Understanding the contribution of oceanic heat to ice-shelf basal melt
- Towards a better understanding of processes controlling Antarctic sea-ice variability and change
- Observing sea-ice thickness and volume
- Constraining the seasonal carbon cycle
- Constraining biological energy pathways
- Assessing status and trends of key Southern Ocean taxa

Additionally, the above disciplinary priorities share common needs for observation systemlevel priorities:

²Newman L., et al., 2019 (in press): Delivering sustained, coordinated and integrated observations of the Southern Ocean for global impact. *Frontiers in Marine Science*.

- Observations from all seasons, as well as focused autumn/winter observational programs
- A strong relationship between implementation of new technologies and development of internationally agreed standards for the collection, QC and management of the data
- Standardisation and aggregation of similar observations
- Development and use of robust observing system design efforts that can be used to quantify observational needs of all end-users
- Incorporation of models into the observing system design and evaluation process
- Better community-wide coordinated articulation and advocacy of remote-sensing data requirements to Space Agencies

The community paper underwent review in 2018, and will be published in *Frontiers in Marine Science* in 2019.



Database of Upcoming Expeditions to the Southern Ocean

DueSouth is a community-populated database for sharing 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.

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		22 Tangaora Antarctic Voyage 2018	Tangaroa	Ship 0	2018-02-01 2018-	03-31 New Zealand
		23 Tangaroa Antarctic Voyage 2019	Tangaroa	Ship 0	2019-01-01 2019-	02-28 New Zealand
		24 IDEAL Beagle Channel 2017	FORREST	Ship 1	2017-07-17 2017-	07-28 Chile

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

2018 Milestones:

The prototype portal underwent significant redevelopment in 2018 to create a stable platform that

- Can be easily maintained by staff at the AADC
- Allows many-to-many mappings of projects and expeditions so that multi-year projects could easily be mapped to all relevant expeditions and Antarctic research stations
- Provides a polar-projected map for better visualisation of expedition plans
- Enables automated data transfers from partner organisations
- Enables bulk uploads from tables of planned expeditions
- Allows users to edit their contributions
- Gives the SOOS Data Officer greater administrative powers to edit submitted expeditions and projects

The renewed portal is not yet complete but considerable work was undertaken during this year. In 2018, the portal was largely manually populated by the SOOS Data Officer, with a small number of submissions from community members.

Major developments in DueSouth community collaboration in 2018 are the following:

- Agreement from Council of Managers of National Antarctic Programs (COMNAP) to share Regional Information Exchange documents with SOOS for manual upload into DueSouth
- Agreement from COMNAP to share the COMNAP ships database and research stations database with DueSouth as master lists for ships and research stations available for Southern Ocean research
- In-principle agreement from COMNAP to share outputs from their Asset Tracking System of real-time ship movements with the SOOS community, through DueSouth and/or SOOSmap
- Negotiations with the International Association of Antarctica Tour Operators (IAATO) project office to develop a potential method for sharing planned movements of tourist vessels, while concealing commercially sensitive information.
- Agreement from the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) Scientific Committee to share information on planned krill fishing, and new and exploratory toothfish fishing expeditions.
- In-principle agreement with the AAD to automatically share planned Australian research expeditions with DueSouth
- Negotiations with Geoscience Australia for them to develop a separate front-end access point to DueSouth for use by Australia's bathymetric survey community to plan upcoming surveys

2019 Plans:

- Finalise 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
- Seek approval from the CCAMLR Scientific Committee for publication of the bulk-uploaded planned expeditions from their krill and new and exploratory notification systems
- Continue negotiations with the IAATO community to allow automatic ingestion of their planned vessel movements
- Present DueSouth to the Antarctic Treaty Consultative Meeting (ATCM) and request high-level support from National Antarctic Programs in sharing their research expedition plans in a more directly useful format
- Ask the SOOS community to comprehensively populate DueSouth with expedition plans for 2019/20 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.

2018 Milestones:

During 2018, 6 new data layers were added to SOOSmap, displaying data and metadata on CCAMLR Ecosystem Monitoring Program sites, CCAMLR Statistical Areas, CCAMLR research blocks, marine protected areas, CPR tows, micro- and macroplastics observations, KrillBase, and penguin colony count data from the Mapping Application for Penguin Populations and Projected Dynamics (MAPPPD) database, seaice cores with chlorophyll observations, sea-ice concentration, sea-surface temperature, bathymetric survey effort, and high-resolution bathymetric data. Additionally, the SOOS Regional Working Group layer and the SOOS mooring network layer were updated and improved. There was considerable development on SOOSmap background components to improve processing speed, and a landing page for SOOS-specific datasets, to enable those datasets to be visualised in the web browser, was partially developed.

2019 Plans:

In 2019, we plan to

- Finalise a tool to allow high-resolution map printing for reporting purposes
- Move SOOSmap to a new web domain that will enable the sharing of specific map views
- Finalise development of a landing page for SOOS-specific observations so that these can be plotted and explored similarly to the global data feeds that were already being served through EMODnet
- Work with PANGAEA to publish CTD data from PANGAEA in SOOSmap, as a pilot for publishing other data types from PANGAEA and other data centres with large holdings of Southern Ocean data
- Add data from the Agreement on the Conservation of Albatrosses and Petrels, MESOPP and SONA, as well as Southern Ocean frontal locations and geographic names



All data layers available in SOOSmap as at January 2019

SOOS Sponsorship

SOOS Sponsorship in 2018

In 2018, SOOS maintained its broad sponsorship base. Core sponsors remained the Australian Research Council's Antarctic Gateway Partnership (AGP); the University of Tasmania, Australia; the State Oceanic Administration of China; and the University of Gothenburg, Sweden. Operational sponsors were the Australian Antarctic Division, Antarctica New Zealand, and the AGP.

In-kind Service Providers are important and enable SOOS to achieve outputs and outcomes that would not be possible if they had to be funded directly by SOOS. The figure below shows the Service Providers for SOOS in 2018, and includes the new sponsorship by the Istanbul Technical University Polar Research Centre, which provided SOOS with support of communication products.

SOOS is grateful to all sponsors for the contribution they make to ensuring the efficient and sustained delivery of SOOS for the community.



Sustained support for the IPO

A significant effort for the IPO in 2018, was to secure sustained hosting for the SOOS office beyond the agreed end-2019 contract with AGP. Many discussions took place with existing Australian host sponsors, as well as international institutes. The SOOS Business Plan was developed and circulated within the community. As a result, the University of Tasmania, Commonwealth Scientific and Industrial Research Organisation and the Tasmanian State Government Department of State Growth, will form a partnership to secure funding to support the IPO to remain in Hobart for 2020-2022. Additionally, the State Oceanic Administration of China will continue its support of the SOOS Project Officer in Hobart, currently agreed until mid-2020.

Sponsorship of SOOS Activities

Sponsors of SOOS events provide a vital service in enabling the delivery of SOOS activities. In 2018, the following institutes sponsored SOOS events, and we thank them for their important support.

Event	Sponsoring Institute/Organisation
SOOS-CCAMLR Synergies Workshop (Hobart, Australia; April 2018) /soos.aq/resources/reports?view=product&pid=60	Australian Research Council's Antarctic Gateway Partnership, UTAS
Marine Ecosystem Assessment for the Southern Ocean (Hobart, Australia; April 2018)	The PEW Charitable Trusts World Wildlife Fund Antarctic Climate and Ecosystems Cooperative Research Centre, Australia Australian Antarctic Division Integrating Climate and Ecosystem Dynamics Information on other sponsors here <u>http://www.measo2018.aq/</u>
SOOS Scientific Steering Committee Meeting (Hangzhou, China; May 2018) <u>http://soos.ag/about-us/ssc/meeting-minutes</u>	SCAR SCOR State Oceanic Administration, China State Key Laboratory of Satellite Ocean Environment Dynamics, China Second Institute of Oceanography, SOA, China College of Oceanography Hohai University, China Institute of Oceanography, Shanghai Jiao Tong University, China
SOOS Data Management Sub-Committee Meeting (Hangzhou, China; May 2018) http://soos.aq/data/dmsc/dmsc-minutes	State Oceanic Administration, China State Key Laboratory of Satellite Ocean Environment Dynamics, China Second Institute of Oceanography, SOA, China College of Oceanography Hohai University, China Institute of Oceanography, Shanghai Jiao Tong University, China
Southern Ocean Modelling Workshop (Hangzhou, China; May 2018) Report: <u>http://soos.aq/resources/reports?view=product&pid=57</u>	State Oceanic Administration, China State Key Laboratory of Satellite Ocean Environment Dynamics, China Second Institute of Oceanography, SOA, China College of Oceanography Hohai University, China Institute of Oceanography, Shanghai Jiao Tong University, China
SOOS Executive Committee Meeting (Hangzhou, China; May 2018)	State Oceanic Administration, China State Key Laboratory of Satellite Ocean Environment Dynamics, China Second Institute of Oceanography, SOA, China College of Oceanography Hohai University, China Institute of Oceanography, Shanghai Jiao Tong University, China

POLDER Annual Meeting	SCAR
(Davos, Switzerland; June 2018)	SCAR Data Management Committee
Data Town Hall	SCAR
(Davos, Switzerland; June 2018)	Arctic Data Committee

Governance

Executive Committee

In 2018, the SOOS Executive Committee (EXCOM) held one in-person meeting, and several virtual meetings. Andrew Constable (Australia) and Sebastiaan Swart (Sweden) continued as Co-Chairs, and Mike Williams (New Zealand) continued as Vice Chair. After 7 years, inaugural SSC member Oscar Schofield (USA) rotated off EXCOM and the Scientific Steering Committee (SSC)—we thank Oscar for his significant contribution to SOOS in this time, and are glad that he will continue to be involved through as co-chair of the West Antarctic Peninsula/Scotia Arc RWG!

At the same time, we welcomed Eileen Hofmann (USA) to the EXCOM as Vice Chair.

Scientific Steering Committee

Five inaugural members rotated off the SSC in 2018: Mauricio Mata (Brazil), Dan Costa (USA), Parli Bhaskar (India), Mike Meredith (UK) and Oscar Schofield (USA). We thank these members for their contribution to SOOS! At the same time, we welcomed four new members: Sarah Fawcett (South Africa), Eileen Hofmann, Irene Schloss (Argentina) and Andrew Meijers (UK). 2018 was also the first year that RWG chairs had ex-officio status on the SSC. This status was initiated to ensure strong communication between the groups and the SSC. The composition of the SSC in 2018 is shown below:

Name	Country	Expertise	2015	2016*	Mid 2017	Mid 2018	Mid 2019	Mid 2020
SangHoon Lee	Korea	Biology	1	1	1	2	2	
Sebastiaan Swart	Sweden	Physical	2^	2^	2^	3^	3^	
Andrew Constable	Australia	Biology	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^
Dake Chen	China	Physical			1	1	1	
Burcu Ozsoy	Turkey	Sea ice			1	1	1	
Anya Waite	Germany	Biology			1	1	1	
Eileen Hofmann	USA	Biology				1^	1^	1^
Irene Schloss	Argentina	Biology				1	1	1
Andrew Meijers	UK	Physical				1	1	1
Sarah Fawcett	S. Africa	Biogeoch				1	1	1
DMSC Co-Chairs								
IPO Exec. Officer								

*Note – Membership terms changed from calendar year, to mid-year rotations in alignment with SSC meeting times

^EXCOM position (2 x 3-year terms)

Annual Scientific Steering Committee Meeting



The annual meetings of the SSC and Executive Committee took place in Hangzhou, China (May 2018), hosted by the Second Institute of Oceanography, State Oceanic Administration. These meetings took place alongside the SOOS Data Management Sub-Committee meeting, and a workshop focused on Southern Ocean Modelling.

In addition to reviewing progress, a focus of the 2018 SSC meeting was "maintaining momentum". This was in acknowledgement of the significant advances achieved in 2017, and in support of ensuring that efforts are maintained, where required. This meeting also focused on the need to ensure an integrated, circumpolar system by drawing together the separate efforts of working groups and communities.

The minutes from the SSC meeting are available on the SOOS website. SOOS thanks the many Chinese sponsors, and our host Prof. Dake Chen 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 2018 SOOS SSC Meeting in Hangzhou, China.

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 other sections of this report).

Southern Ocean data rescue efforts

In 2018, the SOOS Mooring Network grew by an additional 198 datasets, which we expect to be published in 2019. Further, SOOS Project Officer, Yuhua Pei, worked with the DMSC to substantially improve the metadata held in the Network, by developing links to the thousands of relevant datasets at BODC. Additionally, 1,300 sea-ice chlorophyll measurements collected by the ASPeCt community, collated by Klaus Meiners, and aggregated by SOOS intern, David Pasquale in 2017, were published through SOOSmap.

The DMSC facilitated a collaboration between the Chinese National Arctic and Antarctic Data Centre, CLIVAR and Carbon Hydrographic Data Office, and the Ocean University China, to calibrate historic Chinese CTD data against other co-located observations. This collaboration also intends to publish these datasets alongside other international CTD observations, to improve access and use. Initial calibration trials were successful and negotiations on re-publication of the data through CCHDO or other CTD data aggregators is now underway.

Data Management Advocacy

In 2018, the DMSC advocated for stronger data management policies and activities in the Southern Ocean. In particular, the SOOS Data Officer provided advice on establishing data centres to the Swiss Polar Institute and Antarctica New Zealand. Further, the SOOS Data Officer and DMSC established a data-sharing system for the SCAR Plastics in Polar Environments Action Group, enabling micro- and macro-plastics observations in SOOSmap. To date, more than 100 observations from 13 sources have been published through SOOSmap.

Federated Search Tool

The Polar Federated Data Search Working Group that was formed in 2017 was renamed POLDER (Polar Data Discovery Enhancement Research) and continued its work in 2018. Details of this working group are highlighted in Task Teams section below.

Task Teams

SOOS Task Teams are developed to produce specific products, 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.

POLDER

Name	Institution	Affiliation
Pip Bricher	Southern Ocean Observing System	SOOS, SCADM
Taco de Bruin	NIOZ Royal Netherlands Institute for Sea Research	SOOS, SCADM, ADC
Alexander Smirnov	Arctic Portal	ADC
Anton Van de Putte	Biodiversity.aq, SCADM	SOOS, SCADM
Brendan Billingsley	Billingsley Custom Software	
Halldór Jóhansson	Arctic Portal	ADC
Marten Tacoma	NIOZ Royal Netherlands Institute for Sea Research	SCADM, ADC
Peter Pulsifer	Nat. Snow & Ice Data Centre, Arctic Data Committee	
Stein Tronstad	Norwegian Polar Institute	SCADM, ADC
Thomas Vandenberghe	Belgian Marine Data Centre	
William Manley	Institute of Arctic and Antarctic Research	ADC
Lynn Yarmey	Research Data Alliance	
Matthew Jones	Arctic Data Centre, DataONE	ADC
Gabrielle Alix	Polar Data Catalogue	SCADM
Stefanie Schumacher	PANGAEA	SOOS, SCADM, ADC
Jenny Thomas	Swiss Polar Institute	
Kathryn Meyer	Arctic Data Centre	
Yubao Qiu	Big Earth Data for the Three Poles, GEOCRI	
Adam Leadbetter	The Marine Institute of Ireland	
Cindy Chandler	Woods Hole Oceanography Institution	

Mission statement

The Polar Federated Search Working Group (POLDER) is a collaboration between the Arctic Data Committee (ADC), Standing Committee on Antarctic Data Management (SCADM) and SOOS, to develop tools and resources to support metadata aggregation, and federated search tools to improve the discoverability of polar science data.

Progress

POLDER has made considerable progress and also evolved its focus during 2018. POLDER helped organise and convene polar data management meetings in Boulder, Davos, and Geneva in 2018. It led development of a survey of metadata standards and

software tools in use in the polar data community, as well as a survey of metadata harvesting relationships in this community. These results are being developed into a research paper.

The unveiling of Google's Data Search Tool in late 2018 resulted in a change of focus for POLDER. This tool searches the web for schema.org formatted header text on individual webpages to find metadata records that describe scientific datasets. While schema.org is comparatively basic compared to richer metadata standards, the presence of Google in this space is encouraging many organisations to adopt it in addition to their own metadata standards. If the schema.org standards are implemented in a uniform way across polar metadata centres, this will simplify the effort required to develop federated search by an order of magnitude. In late 2018, POLDER halted work on seeking funding and scoping the needs of a federated data search tool until it becomes apparent whether the initial interest in schema.org will translate into widespread implementation. In the meantime, POLDER is encouraging polar data centres to adopt the recommendations of the Science on schema.org community on best practices in implementing schema.org.

POLDER members also contributed to the OceanObs Community White Paper on FAIR data principles in oceanographic data management. For further details on POLDER activities, please visit <u>https://polder.info</u>.

2019 Plans

- To finalise and publish the research paper associated with the survey of metadata repositories
- To publish the results of the survey of metadata repositories as a dataset for the broader community
- To advocate for the adoption of the Science On Schema.org best practices by the polar data community
- To review whether schema.org will be adopted sufficiently widely in the polar community to make a basis for federated search.

Regional Working Groups

SOOS Regional Working Groups will develop, coordinate, and implement the observing system in their defined region. The regions align with the natural areas of focus of nations involved in Southern Ocean activities (although some activities will be coordinated at a circumpolar scale e.g., Argo). Given the long-term requirements for coordination and implementation, the SOOS Regional Working Groups are viewed as ongoing efforts, whilst still undergoing annual reviews by SOOS governance.

Building on the significant developments of 2017, the final two regional groups— Weddell Sea/Dronning Maud Land (WSDML) and the Amundsen/Bellingshausen Sea (ABS) (see map below)—were developed in 2018. The network now provides circumpolar coverage of the Southern Ocean.



The above map shows the extent of the five Regional Working Groups, as well as the Partner Observing Area

In addition to development of the final two groups, the SSC agreed that the approach taken by the Southern Ocean Indian Sector (SIOS) group (highlighted in their workshop report) was one that should be implemented across all groups to enable a semi-quantified understanding of regional observational coverage and key gaps. In addition to this, a number of the boundaries between groups were shifted. The Scotia Arc region was moved from the WSDML group to the West Antarctic Peninsula group—henceforth called the West Antarctic Peninsula/Scotia Arc RWG (WAPSA); and the Balleny Islands region was moved from the SOIS to the Ross Sea group. Additionally, the Ross and ABS groups reduced their northerly boundary to 60°S, leaving the South Pacific region uncovered by the network. This large region is generally not covered by national programs, and observational efforts include predominantly Argo floats, remote sensing and decadal GO-SHIP Reference Sections (Partner Observing Area in map above). SOOS will support these international efforts where required, to ensure that adequate observational coverage of the South Pacific is maintained.

With development of the network complete, communication and alignment between the groups is imperative to ensure an integrated circumpolar system, rather than 5 disparate communities. In support of this, the chairs of each group will meet regularly through a Regional Working Group "Consortium". Sian Henley (WAPSA) and Sebastien Moreau (WSDML) will lead this consortium for 2019.

West Antarctic Peninsula and Scotia Arc (WAPSA) WG

Leadership:

K. Hendry (Co-Chair, UK); O. Schofield (Co-Chair, USA); S. Henley (Co-Chair, UK); I. Schloss (Argentina); M. Mata (Brazil); J. Arata (Chile); D. Abele (Germany); In-Young Ahn (Korea); A. Buma (Netherlands); A. Meijers (UK); E. Hofmann (USA); B. Ozsoy (Turkey); J. Hofer (APECS, Chile); P. Trathan (CCAMLR, UK)

2018 Milestones:

- Special issue of the *Proceedings of the Royal Society* was published, titled "The marine system of the West Antarctic Peninsula: status and strategy for process in a region of rapid change".
- A WAPSA-led scientific review and horizon scan manuscript was submitted to *Progress in Oceanography* (published in 2019)
- o WAPSA held a small meeting at Polar2018 (Davos, Switzerland)
- A representative from the Association of Polar Early Career Scientists (APECS) was selected from an open call, and now serves in the leadership group

Ross Sea WG

Leadership:

M. Williams (Co-Chair, NZ); W. Smith (Co-Chair; USA); M. Zhu (China); G. Budillon (Italy)

2018 Milestones:

• Continued oversight of field activities in the region (e.g., mooring deployments (NZ, Italy), Chinese time-series assessments, Australian MPA cruise)

Indian Sector WG

Leadership:

T. Odate (Co-Chair, Japan); A. Constable (Co-Chair; Aus); P. Koubbi (France)

2018 Milestones:

- Completion of the report from the 2017 Indian Sector workshop
- Support for other Regional Working Groups in the development of regional heatmaps for observational activities and coverage

Weddell Sea and Dronning Maud Land (WSDML) WG

Leadership:

J. Gutt (Co-Chair, Germany); L. de Steur (Co-Chair; Norway); S. Moreau (Co-Chair, Norway); M. Janout (Co- Chair, Germany); JB Sallee (France); A. Meijers (UK); L. Biddle (Sweden); S. Fawcett (S. Africa); M. Wege (APECS, S. Africa); U. Nixdorf (COMNAP, Germany); OA Bergsad (Norway)

2018 Milestones:

The WSDML WG was developed in early 2018. Activities for the year focused on:

- Development of leadership group
- Development of Terms of Reference for the WG
- Overview of upcoming field campaigns to the region
- Planning and detailed organisation for 1st WSDML workshop (held Jan. 2019, hosted by NPI Norway)
- Participation in the SOOS Regional Working Group consortium meeting at Polar2018 (Davos, Switzerland)
- Selection of a representative from APECS
- Identification of key national contacts (Argentina, Belgium, Brazil, France, Germany, India, Norway, Poland, S. Africa, Sweden, UK, USA)

Amundsen-Bellingshausen Sea (ABS) WG

Leadership:

B. Queste (Chair, UK); A. Wåhlin (Sweden); T-W Kim (Korea); T. Yager (USA); P. Abrahamson (UK); Y. Nakayama (APECS, Japan)

2018 Milestones:

The ABS WG was developed in mid-2018. Activities for the year focused on:

- o Development of leadership group
- Selection of a representative from APECS
- Planning and detailed organisation for 1st ABS workshop (held May 2019, hosted by KOPRI, Korea)

Capability Working Groups

SOOS Capability Working Groups enhance observational capabilities for SOOS, such as:

- o Developing and implementing technologies
- o Improving observational design, efficiency, and coverage
- o Developing associated methods for managing and disseminating information.

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) WG

Leadership:

M. Hindell (Co-Chair, Aus); P. Fretwell (Co-Chair, UK); H. Lynch (USA); D. Costa (USA); K. Kovacs (Norway); A. Lowther (Norway); C. Southwell (Aus); B. de la Mare (Aus); M. LaRue (USA); C. McMahon (Aus); H. Bornemann (Germany)

2018 Milestones:

- Ground truthing field campaign (AWI, Germany)
- Launch of Tomnod crowdsourcing platform "counting seals in Antarctica"
- Initial release of SealNet framework for automating detection of pack-ice seals in imagery
- Model development and improving manuscript in development
- Data Study Group challenge (supported by BAS and Alan Turing Institute) to automate sea-ice type classifications and link to seal distribution
- 3rd CAPS meeting (Davos, Switzerland)
- Several conference presentations
- Two new PhDs (funded by NERC)
- Honours student (funded by UTAS)
- Post-doc (funded by Uni Pretoria)

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

Leadership:

F. Samaran (Co-Chair, France); K. Stafford (Co-Chair, USA); S. Buchan (Chile); K. Findlay (S. Africa); D. Harris (UK); B. Miller (Aus); I. van Opzeeland (Germany); A. Sirovic (USA)

2018 Milestones:

No annual report provided at this stage

Southern Ocean Fluxes (SOFLUX) WG

Leadership:

S. Gille (Co-Chair, USA); S. Swart (Co-Chair, Sweden); B. Delille (Belgium); M. Bourassa (USA); C-A. Clayson (USA); S. Josey (UK); A. Lenton (Aus); I. Smith (NZ) E. Schulz (Aus); B. Ward (UK); M. du Plessis (APECS, S. Africa)

2018 Milestones:

2018 was the 3rd year of action for SOFLUX, and included:

- Growth in membership (from 51 to 65)
- Selection of a representative from APECS
- Overview and communication of flux observational field and modelling activities in the Southern Ocean
- Support for SOOS post-doc researcher (Dr. Yanzhou Wei), funded by the State Oceanic Administration of China, and delivering a research project jointly with the Observing System Design WG, on determination of priority locations for flux moorings in the Southern Ocean
- SOFLUX side meeting at Polar2018 (Davos, Switzerland)
- Endorsement of 3 flux research proposals
- Development and submission of Southern Ocean fluxes OceanObs19 publication, and input into other flux-related manuscripts (including the SOOS OceanObs19 community paper)
- Regular communication to all members through newsletters (every 1-3 months) to update on key events, papers, field activities etc.)

Observing and Understanding the Ocean beneath Antarctic sea ice and ice shelves (OASIIS) WG

Leadership:

E. van Wijk (Co-Chair, Aus); R. Coleman (Co-Chair, Aus); A. Breierly (UK); L. Herraiz-Borreguero (Aus); P. Dutrieux (USA)

2018 Milestones:

This is a joint WG of SOOS and POGO. 2018 milestones include:

- A short info-sheet prepared for POGO
- Contribution to the SOOS OceanObs'19 Community White Paper

Delivery of other key outputs for this WG have been delayed due to extenuating circumstances. Efforts are being revived and the "Under-Ice Observations strategy" will be delivered by mid-2020.

Observing System Design (OSD) WG

Leadership:

M. Mazloff (USA); N. Hill (Aus); A. Waite (Canada)

2018 Milestones:

This working group was proposed in mid-2018, builds on the priorities identified in the Observing System Design Task Team (2017):

- Development of leadership group
- Support for SOOS post-doc researcher (Yanzhou Wei), funded by the State Oceanic Administration of China, and delivering a research project jointly with the Observing System Design WG, on determination of priority locations for flux moorings in the Southern Ocean
- Contribution to the SOOS OceanObs'19 Community Paper
- Organisation and running of the 2018 Southern Ocean Modelling workshop (Hangzhou, China; May 2018) and production of workshop report

4.5 Changing Ocean Biological Systems (COBS)

Miloslavich

Annual report from COBS

Accomplishments from the past year (in the context of our terms of reference)

In the last 12 months, we have made substantial progress in achieving the goals and objectives set out in our Terms of Reference (ToR, see Appendix). The major achievement in 2018/2019 was the development and launch of a www-based multi-driver Best-Practice Guide (BPG) – (ToR #4). This BGP is available at <u>https://meddle-scor149.org/</u> and comprises three components – decision support for design, MEDDLE (Multiple Environmental Driver Design Lab for Experiments) experimental simulator, and a library of video tutorials. A handbook is available to step the reader through the BPG (<u>https://doi.org/10.25959/5c92fdf0d3c7a</u>).



The BPG was publicised via a News and Views article in *Nature Climate Change* (see <u>https://doi.org/10.1038/s41558-019-0475-z</u>) in April 2019, and also on sites such as Ocean Carbon Biogeochemistry in the United States and by the OA-ICC in Monaco (Lina Hanssen). The BGP has been popular, based on data from both Google Analytics (400 visits in 30 days) and You-Tube (>1000 visits to the video tutorials since its release).

We have mentored early-career scientists in the design process for complex multiple-driver manipulation experiments (including the BPG, ToR 5) at a course run in Monaco through the International Atomic Energy Agency (IAEA) in May 2019 by three members of COBS (Sam Dupont, Christina McGraw and Marcello Vichi) for more details see <u>https://news-oceanacidification-icc.org/2019/06/27/training-course-on-best-practices-for-ocean-acidification-experiments-in-multi-stressor-</u>

scenarios/?utm_source=feedburner&utm_medium=email&utm_campaign=Feed%3A+wordpress %2FlRgb+%28Ocean+acidification%29).

In 2018/2019 we have also made advances in completing other ToRs such as #6 (short articles on multiple drivers) and #7 (guide for policy-makers). COBS member Sinead Collins has a Perspective in review at *Nature Climate Change* entitled "Novel experimental frameworks are essential to reveal the rules shaping ocean global change biology". This Perspective (ToR #6) was written with both other COBS members (Hutchins, Boyd, Havenhand) and with other scientists from a range of disciplines such as Francis Chan (coastal ecology), Naomi Levine (biogeochemical modelling), and Tatiana Rynerson (molecular biology) and so helps us attain ToR 2 (Raise awareness across different scientific communities). We have been working with the IOC (Salvatore Arico and Kirsten Isensee) to develop a Guide for Policy-makers on multiple drivers (ToR #7), that will form part of the UN Decade on Ocean Science of which multiple drivers will be a key theme (see "About" on <u>https://en.unesco.org/ocean-decade/</u>).

In addition to advancing ToRs #4-7 towards completion, we continue to develop ToRs #2 and #3 as evidenced by the following achievements in 2018/2019:

- Outreach to other groups working in the field of multiple drivers such as GOA-ON, GO₂NE, and IMBER (see <u>https://scor149-ocean.com/partners</u>). Outreach has included invitations to present (by video-conference) at our annual COBS meetings (2018, Denise Breitburg (GO₂NE), Salvatore Arico (IOC)); (2019, Carol Robinson (IMBER), Denise Breitburg (GO₂NE), Salvatore Arico (IOC)). We have also reciprocated by attending their events (Kiel GO₂NE conference, Ulf Riebesell lab; IMBER SSC, Philip Boyd). We also ran a 1-day workshop and hosted a session at the IMBER Ocean Science Conference in Brest in June 2019 (convened by Marion Gehlen, Sinead Collins, Christian McGraw).
- Bridge-building with disparate disciplines including eco-toxicology, epi-genetics, and paleo-oceanography continues through a number of fora, including the Ocean Global Change Biology Gordon Research Conference (<u>https://www.grc.org/ocean-global-change-biology-conference/2020/</u>) and Early Career event (Gordon Research Seminar) that will be chaired by COBS member Sinead Collins. COBS is also forging close links with the proposed IOC WG on Multiple Stressors, with Boyd and others having regular video-conferences with Salvatore Arico.

We also maintain and regularly update our website (<u>https://scor149-ocean.com/</u>) by adding new research papers and partners every 3-4 months to provide a useful repository of information on multiple drivers.

Plans for the coming year

Plans for the coming year were made at the annual COBS meeting that took place just before the IMBER Open Science Conference in Brest:

• A change in the composition of COBS, with several members rotating off to allow us to inject some new ideas and energy for the next 2 years (NSF funding means that we can

continue at least until August 2021). We hope to contact three new members in the coming month.

- Revision of our original terms of reference, with several of the original goals such as #4 (www BPG now complete) to be replaced with new activities and other more generic ToRs such as #2, #3 and #6 to be continued. The new suite of ToRs are currently being reviewed by COBS members.
- Major efforts in 2019/2020 include raising awareness of the availability of the www-based BPG through a suite of national, regional and international presentations and 1-day workshops. In particular, we are pleased to have secured a 30-minute tutorial session at the 2020 Ocean Sciences meeting (attended by ~5000 researchers in 2018) in San Diego. The tutorial on the www-based BPG will be led by COBS member Dave Hutchins. Resources for tutorials (such as the talk given by Christina McGraw at IMBER) will be made available to both the COBS members and other interested parties.
- The view from our annual meeting was that the www-based guide can also serve as a valuable educational resource and this will also be developed in the next 12 months.
- We also will continue to work closely with the IOC as they develop multiple drivers as a key strand of their UN Decade of Ocean Science.
- Additional video tutorials will be uploaded onto our You-Tube site that is linked into the www-based BPG. We will also seek constructive criticism through a portal in the www-based BPG site (managed by Sinead Collin's lab).

Thanks to Ed Urban for continued support and advice, to NSF for ongoing support, to Axel Durand (IMAS) for maintaining the www site, and to the members of COBS who have been so generous with their time and energy in 2018 and 2019.

Philip Boyd

Appendix

Terms of Reference of the current working group

- Assess the current status of emerging research themes by reviewing the literature to assess the dominant research foci, their relative coverage, and identify any major gaps and/or limitations. Publish this review in an open-access peer-reviewed journal. (Completed in 2017/18, Boyd et al., Global Change Biology Review paper)
- 2. Raise awareness across different scientific communities (evolutionary experimental biologists, ecologists, physiologists, chemists, modelers) to initiate better alignment and integration of research efforts.
- 3. Co-ordinate thematic transdisciplinary sessions to attract and assemble experts from other fields such as paleoceanography and marine ecotoxicology to learn from the successful approaches their fields have developed to address multiple drivers.
- 4. Develop a multi-driver Best-Practice Guide (BPG, or other tools) as one potentially valuable way to help this research field move forward in a cohesive manner.

- 5. Mentor early-career scientists in the design process for complex multiple driver manipulation experiments, familiarize them with BPG, and teach them practical methodologies for the analysis of their experimental findings.
- 6. Publish a series of short articles in both the scientific media and with scientific journalists to disseminate the challenges and opportunities surrounding multiple drivers and ecosystems.
- 7. Engage with policy-makers and science communication experts to produce a glossary of terms and an implementation guide for policy-makers to better understand the role of multiple drivers in altering marine living resources and ecosystem services.