International Ocean Carbon Coordination Project

Progress Report for SCOR, June 2020

PROJECTS AND MAJOR ACTIVITIES

IOCCP & BONUS-INTEGRAL Training Course on a Suite of Biogeochemical Sensors

In June 2019, IOCCP and EU BONUS INTEGRAL Project (Integrated carboN and TracE Gas monitoRing for the bALtic sea) held a 10-day international training course on "Instrumenting our ocean for better observation:a training course on a suite of biogeochemical sensors." As described in the 2019 annual report to SCOR, course organisation involved a significant amount of IOCCP human and financial resources, the allocation of which followed the decision of IOCCP SSG to strengthen our role in technical capacity building and thus better realize our Terms of Reference #7:

> *7) Develop and support training activities for users of observing technologies (instruments, sensors and platforms) for ocean carbon and biogeochemistry.*

The course took place on June 10-19, 2019 at the Sven Lovén Center for Marine Sciences, in Kristineberg, Sweden. Building on the success of the 2015 summer school, the course responded 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.

27 outstanding early-career scientists, including 18 women scientists, selected from almost 140 applicants, attended the course. The attendees were joined by 20 dedicated instructors, who shared their practical expertise with a variety of sensors:

- Multiple optode-type optical oxygen sensors
- Chlorophyll fluorescence and backscatter/turbidity sensors for bio-optical measurements
- Ion-sensitive field-effect transistor (ISFET)- and spectrophotometry-based pH sensors
- Membrane-based sensors and an underway system for measuring partial pressure of carbon dioxide (pCO_2)

This intensive course provided trainees with lectures and hands-on experience across the whole spectrum of operations—from deployment and interfacing, through troubleshooting and calibration, to data reduction, quality control, and data management. Insights into complementary use of remote sensing, modeling, and smart data extrapolation techniques not only broadened participants' perspectives, but also effectively opened new avenues for research ideas and collaborations that they initiated during the course. More information about the course goals, agenda, instructors and materials can be found on the course website at: http://www.ioccp.org/2019-training-course

In their post-workshop evaluations, the participants agreed that the course succeeded in teaching best practices for the selected biogeochemical sensors and autonomous measurement systems and provided ample guidelines and practical tips regarding specific reporting requirements (e.g., metadata, calibration, validation, error estimates). This training course was thus well suited for the next generation of users of large-scale biogeochemical ocean observation networks centered around profiling floats, moorings, and gliders, as well as around research and commercial vessels.

As also described in an *Eos* article published in November 2019, this course succeeded in forming a tight network of almost 50 biogeochemical sensor users, combining experts with beginners from 19 countries and six continents and representing a total of 26 nationalities. The benefits of networking enabled by this workshop are already evident through active communication maintained among the participants. The self-organised, informal network is used to pursue new research collaborations, exchange papers and technical advice, and organise course graduate meetings such as in San Diego after the 2020 Ocean Sciences conference.

Based on the course proceedings, and in collaboration with IOC-UNESCO IODE's Ocean Teacher Global Academy (OTGA), IOCCP prepared an online version of this course in an attempt to meet the overwhelming demand for such training opportunities. The comprehensive set of training materials divided into a number of topics, include video recorded lectures and/or lecture slideshows in PDF supplemented with links and references to various materials such as manuals, guides and best practices. The online course materials are open to all and are meant to expand the impact of the training beyond the initial group of 27 which could attend the course in Kristineberg in June 2019.

The online course materials can be accessed freely and openly by following this link: https://classroom.oceanteacher.org/course/view.php?id=394.

Next edition(s) of the IOCCP Sensors Training Course

Based on the very successful two editions of the sensors training course in 2015 and 2019, and in response to a great demand for such technical capacity building, the IOCCP SSG strongly supported organizing the sensors training course as a recurrent event. The SSG approved of the proposal to hold the course on a bi-annual basis, provided that we avoid overlap with other major international summer schools (IMBeR, SOLAS) to avoid competing for funding as well as participants. Overlap with SOLAS Summer School will happen in 2021, as SOLAS shifted their activity by one year. However, both SOLAS and IOCCP are in agreement that such overlap should be avoided at all costs in the future.

Arrangements have already been made to organize the 3rd IOCCP Sensors Training Course in June 2021, also in Kristineberg, Sweden. Currently, IOCCP is inquiring about funding opportunities with the goal of securing co-sponsorship by the end of boreal summer 2020.

Global data synthesis activities

New releases of Surface Ocean CO_2 Atlas (SOCAT) and Global Ocean Data Analysis Project (GLODAP)

On June 18th, 2019 SOCAT version 2019 was proudly released on behalf of over 100 contributors. SOCATv2019 has 25.7 million quality controlled surface ocean fCO_2 (fugacity of CO_2) observations from 1957 to 2019 for the global oceans and coastal seas. SOCAT enables quantification of the ocean carbon sink and ocean acidification, as well as evaluation of sensor data and ocean biogeochemical models. The product represents a milestone in biogeochemical and climate research, and it informs policy and high-profile climate negotiations. Importantly, SOCAT version 6, released in 2018, was mentioned in the IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC) IPCC report published in 2019.

Communication on SOCATv2019 took place through various channels, including, but not limited to, a release poster at OceanObs'19 Conference in September 2019, a presentation at the 2019 Challenger Advances in Marine Biogeochemistry meeting, and a webinar to the Community of Ocean Action on Ocean Acidification.

Preparations are ongoing for the release of GLODAPv2.2020, with Nico Lange (GEOMAR, Germany) taking the lead on work with quality control for data from over 100 new cruises which were submitted to GLODAP by the end of January 2020. A series of virtual meetings of GLODAP Reference Group was concluded in early 2020 to agree on adjustment tables for the new release. The new release is planned for boreal summer 2020.

A GLODAP meeting was held on 16 February 2020 ahead of the 2020 Ocean Sciences Meeting in San Diego, CA, USA. The meeting addressed issues related to the long-term functioning of the activity such as data submission and acquisition, automation, role of key people, as well as funding.

Development of a Global Ocean Oxygen Atlas (GO_2AT)

Following the discussions initiated at the joint VOICE & GO_2NE meeting in Monterey, CA, USA, in September 2017, and in line with one of the recommendations from the OceanObs'19 Community White Paper published by the VOICE initiative (Garçon et al., 2019), IOCCP (through its SSG member Véronique Garçon) has gradually been working towards enabling the development of an oxygen-related data platform and synthesis product, mimicking the process of developing SOCAT.

The overarching goal of this initiative 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.

To this end, in 2019 IOCCP engaged several international partners: IOC-UNESCO, Global Ocean Oxygen Network (GO_2NE), Collaborative Research Center (SFB 754), and US NOAA; to develop a roadmap towards creating a "SOCAT-like" synthesis data product for oxygen observations. An initial scoping workshop was held in Sopot, Poland, in November 2019. Please see the details of the workshop goals and proceedings under the Workshops and Meetings section of this report.

Currently the work is ongoing in several sub-groups, and an advanced draft white paper on the roadmap towards the proposed GO_2AT is being circulated for internal review. A second, follow-up workshop is tentatively planned for October 2020, pending sufficient progress within the sub-groups and removal of global travel restrictions.

Time-series biogeochemistry data product

Over the past 12 months progress has been made on the development of a biogeochemistry time-series data product - an effort led by IOCCP SSG member, Björn Fiedler, in collaboration with other international bodies coordinating time series observing and data dissemination efforts, primarily US OCB and IGMETS (https://igmets.net/).

As noted in the 2019 IOCCP report to SCOR, two main challenges need to be overcome in order to deliver the product: (i) establishing a community-based working group that defines requirements and steers the process, and (ii) funds need to be raised to enable the work on a pilot data product.

Much has been achieved to address the first challenge over the past 12-month cycle. First, Björn Fiedler in consultation with and on behalf of the IOCCP SSG, contributed to the OceanObs'19 Community White Paper (CWP) "Ocean Time Series Observations of Changing Marine Ecosystems: An Era of Integration, Synthesis, and Societal Applications" led by Heather Benway (US OCB). The paper outlines "near-term observing priorities and technology needs; explores potential mechanisms to broaden ocean time series data applications and end-user communities; and describes current tools and future requirements for managing increasingly complex multi-platform data streams and developing synthesis products that support science and society." Actionable recommendations which are put forward in this CWP would help develop "a robust, sustainable, fit-for-purpose time series network that will foster a predictive understanding of changing ocean systems for the benefit of society." The publication of this paper fulfills the action item from the 12th Session of IOCCP SSG which called for a 10-year strategy for internationally coordinated biogeochemistry time series observations.

The NSF EarthCube Time series workshop, held just prior to OceanObs'19 Conference in Hawaii, provided an excellent opportunity to discuss the needs of the community with respect to developing future data products, among other things. Workshop proceedings and outcomes are further described under the Workshops and Meetings section of this report.

The second challenge of fundraising has also been addressed very successfully with the EU H2020 EuroSea project providing funds for further development of multi-platform time series observations in the Atlantic Ocean, and a demonstration of a first time-series based data synthesis product. Funds have been allocated for a postdoc position at GEOMAR and partially for organisation of a large community workshop, which IOCCP has agreed to co-sponsor (see more information under Future Directions section of this report).

Most recently, the EuroSea effort was presented to the attendees of a time series workshop organized by the US Ocean Acidification Programme, held in February 2020 in Seattle, WA, USA. The workshop focused on creating consistent trends from time series data for particular applications, such as detecting anthropogenic trends, and fulfilling high level policy obligations, e.g. through SDG target 14.3.1 which calls for the "Average marine acidity (pH) measured at agreed suite of representative sampling stations". The undertaking requires discussions on deseasonalization and trend analysis routines, which will also be part of the EuroSea effort. Unlike the planned EuroSea workshop, the Seattle event focused specifically on surface ocean carbonate observations. Thanks to good communication between the two efforts in their early stages of development, as advised by IOCCP, maximum complementarity can be obtained.

IOC-UNESCO Working Group on Integrated Ocean Carbon Research (IOCR)

On 28 - 30 October 2019 the first Experts Workshop of the Integrated Ocean Carbon Research Working Group (IOCR) took place at the headquarters of the Intergovernmental Oceanographic Commission of UNESCO (IOC) in Paris, France. This expert workshop was co-convened by the IOC, IOCCP, SOLAS, IMBeR, CLIVAR and the Global Carbon Project (GCP). The objective of this workshop was to bring together the decades of collective experiences of the IOC, IOCCP, SOLAS, IMBeR, CLIVAR and GCP expert groups to inform the next generation of integrated ocean carbon research.

35 participants from 15 countries focused on three specific issues:

- Identification of critical knowledge gaps in the ocean carbon cycle;
- Identification of research activities in order to close this gap;
- Bridging between science and policy: the United Nations Decade of Ocean Science for Sustainable Development (2021-2030), the United Nations Framework Convention on Climate Change and its Paris agreement, the Intergovernmental Panel on Climate Change 6th Assessment Report.

During discussions leading to the workshop several key elements critical for the integration into the future ocean carbon research were identified and formed the basis of workshop discussions:

A. Policy and societal implications and applications of ocean carbon research and observations

Under this item, the societal value of ocean carbon research and observations was thoroughly considered from a UN and multilateral perspective. Specifically, the discussions dealt with relevant demands by the UN Framework Convention on Climate Convention, its Paris Agreement, and the Convention's Subsidiary Body on Scientific, Technical and Technological Advice (SBSTA). The discussions also identified research and observations needed to inform Sustainable Development Goal (SDG) 14, and the UN Decade of Ocean Science for Sustainable Development.

B. Integrating surface and interior and connecting coastal and open ocean carbon observations and products to enhance a 3D understanding of carbon distribution and variability

Currently existing connections and disconnections in research and products were highlighted. Surface fluxes relate to the pCO_2 of the water and air (evaluated by SOCAT) whereas storage of inorganic carbon is in the form of dissolved inorganic carbon (DIC; summarized by GLODAP). Given the temporal and spatial variability in pCO_2, SOCAT is evaluated at a much higher resolution (annually) than ocean inventories (once a decade). Evaluation of the fundamental question:"Do we fully understand the relationship between uptake and storage?" involved topics like water mass formation and the conversion of pCO_2 to DIC, which brought in aspects of the changing Revelle Factor. This session dealt with multiple dimensions of ocean biogeochemistry and changes therein: terrestrial influences on coastal biogeochemistry; biogeochemical and carbonate buffer factor feedbacks and tipping points that may shift ocean CO_2 net uptake and storage; understanding of how surface fluxes are connected to interior carbon storage;

C. Connecting carbon fluxes research with physical drivers, specifically heat and freshwater fluxes in the global ocean

Heat flux directly influences pCO_2 and fresh water fluxes directly influence DIC. We know reasonably well the relationship between temperature and pCO_2, but the question how tight is the relationship between heat flux and CO_2 fluxes remains open. Can the community constrain estimates of these fluxes? Also, can measurements of total alkalinity (TA) and DIC help constrain freshwater fluxes or vise versa? The most challenging aspects of the interconnections amongst these three flux variabilities (heat, freshwater, CO_2) link closely with themes B and D.

D. Interaction with biology including detection and impacts of ocean acidification

This was potentially the most complex theme discussed at the workshop as it requires insight into biological aspects of ocean carbon research, including the biological pump, the microbial carbon pump, and organic to inorganic carbon transformations in the ocean. Several specific issues were highlighted, for example our ability to definitively document any anthropogenic changes in the biological pump (including both the organic carbon pump and the inorganic carbonate pump). Can we as a community continue to support the claim that Total Alkalinity is and will always be constant with

time? Perhaps we are only in a position to start answering these and other relevant questions now, that our measurements are getting more integrated and accurate. Part of these divagations were naturally focused on impacts of ocean acidification on the ecosystem.

Each of the themes described above was thoroughly investigated for identification of existing knowledge gaps with focus on several aspects like different temporal and spatial scales of ocean carbon uptake from intra seasonal to decadal and from upwelling regions to other targeted sampling regions, the role of climate variability in ocean carbon uptake, targeted sampling of key regions, research gaps to improve the global and regional carbon assessments ie. the Regional Carbon Cycle Assessment and Processes (RECCAP). Also considered were gaps related to the use of the selected elements of the entire portfolio of observing platforms (underpinning aspects such as observing/analysis techniques, logistical challenges, feasibility and more). The adequacy of existing data streams and data syntheses products (if they exist) was also investigated in relation to currently existing modelling efforts. Specific research gaps and needs related to uncertainties in model predictions as well as data assimilation activities were also highlighted. Finally gaps related to standard protocols and best practices were discussed and highlighted.

Following the workshop, the Scientific Steering Committee of the IOCR WG (including IOCCP's Rik Wanninkhof and Maciej Telszewski) met to develop an exploitation plan allowing to influence a wide variety of community members, end-users and stakeholders. The SSC decided to focus the following 6-12 months on producing three documents based on the workshop proceedings:

- an Integrated Ocean Carbon Research Plan
- a high-level, short peer reviewed article illustrating the strategy of the IOCR plan to be submitted to Nature or Science by late 2020 to outline the major findings of the IOCR Plan
- a progress report highlighting the accomplishments of the IOCR Working Group to its main sponsor, the IOC.

Of these, the IOCR Plan is utterly the most important tool to advance ocean carbon research and give the ocean carbon community (and IOCCP) guidance on what specific activities are needed to do so. To that end a work plan was developed including the timeline, the structure of the Plan and an agreed list of chapter co-authors responsible for developing the first draft by mid-2020. The first draft will be shared with all workshop participants for input and then open for community review before formal approval by all co-convening organizations.

Providing authoritative guidance on observing system design

IOCCP contributes to many of the GOOS Strategic Objectives as described in the GOOS 2030 Strategy. GOOS Strategic Objective #5: "Provide authoritative guidance on integrated observing system design, synthesizing across evolving requirements and identifying gaps" puts a specific charge on the GOOS Panels of Experts, including IOCCP. To this end, IOCCP and other Panels have been involved in horizon-scanning and dialogue with the community over emerging areas of need for coordinated and sustained observations, and the subsequent development of EOVs.

In advance of the 9th Session of GOOS Steering Committee Meeting, IOCCP Office was asked to prepare a teleconference for members of GOOS Executive to discuss more efficient joint

implementation of GOOS Strategic Objective (SO) #5 on "Authoritative guidance on co-design" and to a large extent also the closely related SO#3 on “Observing System evaluation.”

The recent draft Roadmap to Implementation of the GOOS 2030 Strategy provided a much needed context for the discussions. The document describes our charge for the next few years in terms of what GOOS wants to achieve in dialogue with the many existing and future new partners. According to the Roadmap, authoritative guidance on observing system design (SO5) in this context is meant as:

“(...) undertaking of multidisciplinary assessment and synthesis across a range of evolving requirements, in order to guide and support implementation decisions from global to regional, and across platforms, networks and technologies.”

The objectives of the Call were not to discuss the partnership aspect per se, but rather to (i) decide on the shared role of GOOS Panels in providing authoritative guidance on observing system co-design, and (ii) agree on a consistent and transparent process of providing authoritative guidance, and its efficient communication.

The group acknowledged the urgent need for GOOS to show more effective leadership in providing guidance on the observing system design and evaluation to the community, and made a number of specific recommendations which will be put up for discussion by GOOS SC. It was agreed that while the core of the process should rely on tight collaboration between the GOOS structures, it is critical to eventually invite relevant stakeholders to co-develop guidelines for the global community. To this end, the Roadmap to Implementation of GOOS 2030 Strategy should ensure due acknowledgement of community and many stakeholder efforts, and ensure inclusivity in the future process.

It was recommended that an analysis of roles and responsibilities of all GOOS structures be performed, akin to e.g. what IOCCP carried out on a smaller scale for the panel. Equally important would be an analysis of the current vs required resources for successful implementation of GOOS actions, including decisions to re-allocate effort elsewhere to increase efficiency for the core business of GOOS.

The group further discussed how to revive the efforts initiated at GOOS-SC-8 with the proposed Task Team on System Evaluation and Task Team on EOVs. To deliver a document providing actual guidelines for observing system design and evaluation it was recommended to initiate a broader process which is based on co-development with stakeholders, and a process which ensures their buy-in. It was noted that from a broad perspective EOVs are of paramount importance for the global observing system, e.g. for satellite agencies justifying their operations based on whether a given parameter is an ECV/EOV. It was recommended that we continue to collect feedback on the current and potential usage of EOV/ECV by the community. In general, the priority is to document and publish a set of transparent guidelines for how GOOS sets and reviews requirements around EOVs, and how to communicate the process with the community. A peer-reviewed publication on the overall GOOS implementation of the Framework for Ocean Observing remains very much needed.

A proposal with estimates of human and financial resources needed to address the issues through two GOOS Task Teams was presented by IOCCP Project Officer during the virtual meeting of GOOS Steering Committee (20-24 April 2020), and subsequently endorsed by the Committee members.

Establishing global coordination of an Integrated Marine Debris Observing System (IMDOS) through the EuroSea Project

During the 7th Session of the GOOS Steering Committee (June 2018), it was recommended that IOCCP as GOOS Biogeochemistry Panel takes charge of scoping the community needs for international coordination of sustained ocean observations of marine plastics contaminants. GOOS acknowledges that Marine Plastics is not within the domain of expertise of IOCCP, but at the same time recognizes that IOCCP has a long and successful track record of building partnerships with expert working groups and dedicated institutions and organizations to initiate new elements of the observing system. Thus, GOOS hopes to build on this experience in its efforts to support the global coordination of an Integrated Marine Debris Observing System (IMDOS) and the development of Marine (Plastics) Debris as a new type of Human Pressure/Activity EOV. To this end, GOOS has offered to commit explicit funds for IOCCP Project Officer to overlook the coordination work within the new EU H2020 EuroSea project.

IOCCP SSG has very carefully considered this issue during its 13th Session in October 2018, and communicated its decision and put forward adequate recommendations for GOOS on how to proceed on this task. In summary, IOCCP SSG decided not to take this up as a long-term task, however in the short term, in its capacity as GOOS Biogeochemistry Panel of Experts, IOCCP would act on behalf of GOOS as a conduit for key international organizations and initiatives engaged in developing a coordinated observing system for marine debris. This short-term action, contributing to the GOOS Strategic Objective #10 "Impact of human activities on the ocean," involves collecting information on the status and needs of marine plastics monitoring towards creating a Marine Plastics Debris EOV; and support for the establishment of global coordination of IMDOS. What's more, IOCCP SSG concluded that taking up this activity directly fulfils Recommendation #20 from the IOCCP Sponsors Review Panel to "diversify the funding sources for IOCCP" as it allowed to secure the contract of IOCCP Project Officer for another 3 year term via EU Horizon 2020 EuroSea Project.

Formally, IOCCP's activities in this domain were initiated in the second part of 2019 in preparation for the OceanObs'19 Conference, and then intensified with the start of the EuroSea project (November 2019) and the task on establishing global coordination of marine plastics monitoring. After a series of meetings and individual consultations in late 2019 (see details under the Workshops and Meetings section), in early 2020 IOCCP on behalf of GOOS prepared a first draft of a proposed "Action Plan for establishing global coordination of the Integrated Marine Debris Observing System (IMDOS): Phase I (2020-2022)."

This document is a direct follow-up on the commitment expressed by GOOS during OceanObs'19 Conference which was made in response to a clearly articulated need for IMDOS as envisioned in the OceanObs'19 Community White Paper by Maximenko et al. (2019). The Action Plan is meant to identify specific actions which would enable implementation of ideas and recommendations from Maximenko et al. (2019), contributing to OceanObs'19 Living Action Plan, and being in concert with the related international initiatives led by UNEP, IOC-UNESCO, SCOR, Arctic Council, and GEO Blue Planet, among many others contributing to the mission of the Global Partnership on Marine Litter (GPML).

The design of IMDOS as a backbone observing system needs to ensure delivery of adequate data and information which could then be integrated and synthesized into indicators and decision-support tools via relevant data centres and knowledge platforms, in line with the proposed Global Platform for

Monitoring Marine Litter and Informing Action (Smail et al., draft) and more broadly a Digital Ecosystem for the Environment (UNEP, 2019).

Successful coordination of marine debris monitoring requires a complex approach that considers the entire life cycle of artificial debris in the marine environment. Currently, this Action Plan identifies actions which would focus on the backbone of such an observing system, to provide reliable information on the state of marine pollution due to artificial debris deposited into the marine environment, and to some extent, on its impacts on marine life. This backbone would not necessarily be able to answer all the questions which motivate maintaining a marine debris monitoring system, in particular those related to monitoring land-based sources of marine litter, or the dispersion and accumulation pathways.

As such, this Action Plan addresses only the sea-based (including shoreline) activities related to marine debris monitoring, and therefore, does not necessarily apply the entire concept of IMDOS as envisioned by Maximenko et al. (2019). The exact scope of IMDOS would be decided by the Steering Committee and described in the Terms of Reference.

Establishing a globally coordinated IMDOS would fill the need for a coordinating body providing authoritative guidance on how to develop and evolve a global sustained observing system providing adequate data and information on marine debris in response to diverse stakeholder needs. IMDOS would thus occupy an important niche in a very complex and full landscape of organizations and initiatives involved in tackling the problem of marine litter pollution.

The draft Action Plan proposes a two-phase process to establish global coordination and operational capacity of IMDOS as a system which enables monitoring and potentially also assessing the risk posed by marine debris, while leveraging global coordination mechanisms for data collection and dissemination set up by the UN system and other organizations.

As of May 2020, the document remains subject to initial consultations among leaders of marine debris monitoring efforts and lead authors of the IMDOS CWP, as well as members of selected GOOS structures. Details of the proposed Action Plan are described in the relevant section on IMDOS under the Future Directions section of this report. These plans will be modified pending the final revision of the Action Plan by the wider marine debris monitoring community.

Harmonization of requirements for EOV and ECV observations

In 2019, IOCCP worked closely with OOPC and the Biology & Ecosystems Panels of GOOS on improving how GOOS articulates requirements for the ocean observing system. The concept of setting requirements for EOVs has been evolving since their first drafting in 2013. More recent developments; particularly, clear articulation from Global Climate Observing System (GCOS) of their reporting needs, and the move towards strengthened engagement with the World Meteorological Organisation (WMO), which also means engaging in the WMO Rolling Review of Requirements process, meant it was timely to revisit the information included in the EOV Specification Sheets curated by GOOS Panels. The goal was to harmonize the GOOS EOV and GCOS ECV approach to setting requirements for what essentially is the same observing system. Recognizing discrepancies in definitions and formats used by GOOS and GCOS and lack of flexibility from GCOS to better adapt to the needs of the ocean community, we opted to further modify the table of requirements for EOVs to make it a source of all requirements information to be used for various reporting needs as the most efficient and consistent way to advocate for observation requirements.

The rationale for refining existing EOV requirements, the motivation for working with GCOS and the recommended process as outlined above was discussed at length with IOCCP SSG. The SSG decided that refining the requirements to the level of setting goals for coverage, resolution, uncertainty and timeliness of EOV sub-variable observations would be a worthwhile exercise. However, the SSG was strongly insistent on such refinement taking place through dedicated workshops engaging an adequate pool of experts. It was suggested that throughout 2020 we plan for one or two such type workshops, starting with EOVs on highest overall readiness level: inorganic carbon and oxygen. It was tentatively proposed that a workshop on Inorganic Carbon EOV requirements could take place in conjunction with the 15th Session of IOCCP SSG, while the workshop on oxygen EOV requirements be combined with the already planned oxygen data workshop.

In early 2020, GOOS Biogeochemistry Panel continued to support OOPC in their obligation to provide input into the GCOS processes. In particular the Panel engaged in the following activities:

- Reviewing progress against the 2015 GCOS Implementation Plan actions
- Reviewing any public comments on the new proposed ECV requirements as received by GCOS
- Evaluating the current adequacy of ECV products with respect to the 2015 requirements
- Drafting the 2021 GCOS Status Report

Coordination of global ocean acidification observations

IOCCP continues to play a very active role in coordination of ocean acidification (OA) observations on global and regional scales, through the work of two dedicated SSG members: Kim Currie and Cristian Vargas, respectively. Currently three IOCCP SSG members sit on the Executive Council of the Global Ocean Acidification Observing Network (GOA-ON) - an IOCCP spin off project which has quickly developed into an international partnership (to large extent thanks to huge support and dedication of the US NOAA OA Program and IOC-UNESCO Ocean Sciences Section) facilitating the documentation of the status and progress of OA, the understanding of the impacts and the forecasting of OA conditions. As a leading authority on OA observations requirements and status, it is also the vehicle through which IOCCP realises its mandate for implementing global coordination of sustained observations of OA as one of the key ocean biogeochemical phenomena.

Close collaboration between GOA-ON, IOCCP and GOOS (among others) brings high on the scientific and political agenda the need to understand ocean acidification (OA) conditions globally and the consequent need to expand OA monitoring. Recently, these efforts have been augmented thanks to WMO which established OA as a Global Climate Indicator in 2018, and published the WMO Report on the Global Climate in 2015–2019 in 2019. The report, with input from individual scientists, GOA-ON, IOC-UNESCO and other UN agencies, showed that ocean acidification continues to increase, with observed pH values at open ocean observing stations steadily decreasing. Moreover, a vision for the next decade of OA observations was presented jointly by GOA-ON and its partners during the OceanObs'19 Conference, based on a Community White Paper by Tilbrook et al. (2019), co-authored by IOCCP Project Director and published in Frontiers of Marine Science in advance of the meeting.

In that context, IOCCP is happy to report that the GOA-ON continues to grow in size and scope. As of 2020, there are over 730 scientists from 100 countries as members of the global network, though not all of these members are actively engaged in OA monitoring or research. The Regional Hub programme coordinates geographical groupings which enhances collaboration and the sharing of OA monitoring expertise and resources. There are now 7 active hubs – North America, NE Atlantic,

Mediterranean, PI-TOA, LAOCA, OA-Africa and Westpac. A representative from each Regional Hub serves on the GOA-ON Executive Committee, and a Regional Hub meeting is planned in conjunction with the up-coming Oceans in a High CO_2 World Symposium.

The growth of GOA-ON, especially into regions where there is currently limited expertise and infrastructure, is primarily made possible through widespread and comprehensive training and capacity building efforts. There are two main approaches to this: (i) mentoring, and (ii) direct training and equipment provision. The Pier2Peer mentorship programme assists with knowledge exchange and collaborations, with the opportunity for scholarships and financial assistance. A number of direct training activities were run in 2019, with significant input from IOCCP.

Thanks to a strong focus on the theory behind and best practices of using pH sensors, the 2019 IOCCP-BONUS INTEGRAL Training Course (described in a previous section of this report) made a unique contribution to the otherwise rich portfolio of capacity building efforts in this domain. IOCCP also contributed to the workshop on practical guidelines for OA research co-organized by OA-ICC, GOA-ON and The Ocean Foundation. Held on 29-31 May in Monaco, the workshop gathered 15 participants from 7 countries who assessed needs and issues faced when undertaking ocean acidification monitoring and research in different regions, and developed practical resources to help respond to those needs. A list of tools useful for "GOA-ON in a Box" users and those starting ocean acidification research will be released as a package for the community.

Access to resources and opportunities for training and re-training are among the priorities for increasing the readiness level in many of the GOA-ON regional hubs, and enhancing the delivery of high quality data to international databases for better informing SDG and other policy targets. Currently, IOCCP together with GOA-ON leadership have initiated efforts to develop a state-of-the-art online product to provide a universal and long-term solution for online training as an alternative to the costly and logistically challenging on the ground training carried out repeatedly across the globe.

Enhanced delivery of high quality pH data is critical to effectively respond to the UN SDG Target 14.3 which is to "Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels". The methodology associated with the SDG Indicator 14.3.1, now upgraded to Tier II, is available on the GOA-ON webpage, including the associated data and metadata files. GOA-ON has committed to expand the spatial and temporal coverage of ocean acidification observations around the world (Voluntary Commitment #OceanAction16542) in support of the Target 14.3. The UN Community of Action now has 267 OA relevant commitments.

In 2019, SDG 14.3.1 Data Portal (https://oa.iode.org) was launched as a tool for the submission, collection, validation, storage and sharing of ocean acidification data and metadata submitted towards the SDG 14.3.1 Indicator: Average marine acidity (pH) measured at agreed suite of representative sampling stations. The GOA-ON Data Portal (http://portal.goa-on.org/Explorer), has also been revamped in 2019 with multiple search and visualisation options, and links to data and data synthesis products. The GOA-ON Data Portal is not a data archive, but collates metadata on observing platforms with links to data repositories. Over 580 data assets measuring sub-variables of Inorganic Carbon EOV are registered. Real time data from several platforms are available, and more are currently being added, including from South American moorings, European ships of opportunity lines and most recently, Biogeochemical Argo profiling floats.

IOCCP contribution to OceanObs'19

IOCCP was heavily engaged in shaping the community vision and recommendations for sustained marine biogeochemistry and integrated ocean observations for the next decade. We had a marked presence during the OceanObs'19 Conference, co-organizing a series of breakout sessions on Integrated Ocean Observing (actionable details below), and actively participating in others, including as panel members in the one on Marine Debris. For several months in advance of the Conference and also just after the event, there were a number of Community White Papers (CWPs) published in the special issue of Frontiers in Marine Science, which IOCCP members either led or contributed to. The papers touch on a number of topics ranging from broad considerations of future ocean governance models, or challenges to more efficient implementation of the Framework for Ocean Observing, to review articles on more specific elements of the observing system which looked at challenges and recommendations from the GOA-ON, SOCONET, Argo networks or the time series community. A comprehensive list with full references to these CWPs can be found under the Publications section of this report.

Breakout Sessions on Integrated Ocean Observing

IOCCP along with representatives of other GOOS Panels has devoted a lot of time and effort to prepare a series of three breakout sessions on Integrated Ocean Observing for the OceanObs'19 Conference. Kim Currie and Artur Palacz represented IOCCP in the organizing team which met frequently online between June and September 2019 to prepare the breakout session agenda, provide a charge to invited speakers and panel members, and coordinate the process of synthesising recommendations from many relevant CWPs.

On Tuesday, Sep. 17, Jack Barth (Oregon State University, USA) and Sung Yong Kim (KAIST, South Korea) led the discussion on "Integrated Ocean Observations I: Across Geographic Scales." On Wednesday, September 18, Meghan Cronin (NOAA, USA), Eitarou Oka (University of Tokyo, Japan), Kim Currie (NIWA, New Zealand) and Artur Palacz (IOPAN, Poland) led the session "Integrated Ocean Observations II: Diverse Stakeholder Needs" to discuss how diverse stakeholders can work together to improve and build existing and emerging observing systems under the Framework for Ocean Observing in the next decade. The series was concluded on Thursday, Sep. 19, when Patricia Miloslavich (formerly University of Tasmania, Australia; Universidad Simón Bolívar, Venezuela) and Nic Bax (CSIRO, Australia) led the breakout session on "Integrated Ocean Observations III: Across disciplines and networks."

The goal of the 2-h breakout session on Integrated Ocean Observing: Across Diverse Stakeholder Needs, co-led by IOCCP members, was to discuss how diverse stakeholders can work together to improve and build existing and emerging observing systems under the Framework for Ocean Observing (FOO) in the next decade. During the session, 4 speakers were invited on a panel to present perspectives from communities they represent, and offer their recommendations.

Susan Wijfels (WHOI, USA), speaking on behalf of the research community, suggested that the ultimate responsibility for setting priorities for what to observe is with the national governments among other stakeholders. The process of setting requirements should aim at serving multiple uses, identifying critical cross-system interdependencies and closing critical gaps, and be based on an ongoing system-wide assessment of design efficiency and product adequacy. Acknowledging limited

resources, the system should promote implementing technological innovations and their gradual increase in readiness level from concept through pilot to mature.

Lisa Levin (SIO, USA), speaking on behalf of the deep sea stakeholder groups, described the challenges and opportunities of designing a multi-purpose observing system in the deep sea realm. She recommended that in this particular case the observing system design be cross-sectorial, should engage industry, managers, governments, educators, civil society as well as the future generations. To demonstrate the value of stakeholders converging in the process of requirement setting, Lisa recommended focusing on a specific region of interest to such a diverse group of stakeholders, e.g. the Clarion Clipperton Zone.

Nadia Pinardi (U. Bologna, Italy), speaking on behalf of the climate and operational services community, presented good working examples of generic and customized information services that succeed in realizing the so-called ocean value chain advocated for by the FOO. Her recommendations were to: (i) promote the development of multidisciplinary data sets available in near-real time, (ii) ensure state-of-the-art data management, (iii) develop standards for customized products, and (iv) establish a review process of the observing system and delivery of information as its outputs.

Sebastian de Halleux (Saildrone Inc.), speaking on behalf of surface ocean observers as well as private partnerships, talked about the need and proposed ways to simultaneously deliver diverse sets of data to diverse stakeholder groups in diverse regions. He emphasized the need for developing new business models capable of providing adequate ocean information on many levels of stakeholders and/or users, and argued for the important role of public-private partnerships in achieving that goal.

When drawing conclusions from the session discussions it should be kept in mind that: (i) there was limited geographical diversity among the breakout session participants, and (ii) that only a selected group of stakeholders could have been represented among the panel of speakers as well as in the audience. Based on a number of relevant Community White Papers and as a result of breakout session discussions with the panelists and the audience via slid.do, the following three recommendations were put forward:

Recommendation #1: Develop new mechanisms within the Framework for Ocean Observing (FOO) to ensure that the observing system is truly multi-purpose and multi-disciplinary and serves diverse stakeholders. This may include developing new categories of Essential Ocean Variables (EOVs) connected to human activities.

Regardless of whether the global ocean observing system already is multi-disciplinary and multi-purpose in nature or not, further significant integration efforts are needed to sustain and evolve it as the system grows more complex and needs to respond to more and ever changing user requirements. The success of these efforts depends on a proper recognition that there is both a direct cost (measurements) and an indirect cost (data management) in the observing system. The current funding reality prevents from building and sustaining a fit-for-purpose ocean observing system that would also be visionary in its design. It was thus recommended that:

- each observing system initiative needs to be accompanied by sufficient funding for both data production and distribution, and that
- new business models be explored, e.g. developed through public-private partnerships, to offset the total observing cost and ensure delivery of societal benefit products.

The process of observing system design needs to be cross-sectorial, and should therefore engage industry, managers, governments, educators, civil societies as well as the future generations. A system that serves such diverse stakeholders is bound to face stakeholder incompatibilities (e.g. oil/gas

regulators, fisheries managers, vs conservation) and/or competition (e.g. between companies) which hinders dialogue and collaboration among stakeholders to reach consensus on the required ocean observations, priorities therein, and joint responsibilities for adequate investment. These issues, particularly among the private sector, could be overcome if and when the industry becomes heavily reliant on the public goods provided by the academic and government bodies so that they too become important advocates for investment in ocean observing. It was further recommended to consider that ocean discovery, though distinct from the routine/operational measurements, is another aspect of ocean observing which may serve multiple purposes.

As the requirements space grows more complex, one of the challenges is to integrate and prioritize the various requirements under the conditions where multiple funding sources are used to drive observing efforts and where the budget is strongly constrained. The integration could first be done on a sector by sector basis, and then across the sectors, considering the need for stakeholder equity in the process. While global "high stakes" issues should be among the priorities, issues considered "less stakes" globally should not be neglected on regional scales where they have greater societal value.

While the current set of requirements expressed through Essential Ocean Variables is already comprehensive, it does not fully address the need for measuring the status and evolution of human activities and their impacts on the ocean. Similarly, there is a lack of data products informing on the human activities in the ocean. Therefore, it was recommended to:

- better link the existing EOV requirements to human activities in the ocean, and if needed, establish a separate set of requirements for measuring a new category of ocean variables related to human impacts.
- promote the development of new data products focused specifically on human activities in the ocean

Recommendation #2: Develop incentives to reward data providers, and invest in data assembly centres (DACs) and Integrated Data Services with expert curation, to ensure that data from all stakeholders are FAIR, open, and free, contributing to the ocean observing system value chain.

The discrepancy between involvement of developed vs developing countries in ocean observing is a major obstacle to an integrated observing system. Lack of data sharing practices will only further contribute to the inequality. Majority of the developing countries require better quality of data and easier access to data, especially in the coastal ocean regimes. Greater consideration of the requirements for coastal ocean data and derived services is needed in the global planning of GOOS and other bodies.

With respect to developing new mechanisms, incentives, policies, rewards and responsibilities among stakeholders and data providers, it was recommended that:

- The UN Decade of Ocean Science for Sustained Development becomes the main conduit for developing what these mechanisms should be, and how to implement them through governments and funding agencies.
- These mechanisms should develop professional metrics and rewards for good data sharing, similar to other measures of research impact, likely a mix of qualitative and quantitative measures.
- Traceability of data from its collection to inclusion in information products be established.
- Different levels of incentives are considered: high level endorsements, a system of royalty on data used for commercial (profitable) activities, inclusiveness in observing system design decision making, etc.
- In parallel to generating new ocean data, the system supports extracting novelty from existing data to facilitate their re-use, often for new purposes previously not envisaged. Such a

paradigm shift and dedicated funding is needed to establish and further develop data centres and data integrators capable of analyzing data and transforming them into generic and customized information products and services.

Recommendation #3: Develop tailored communication strategies for the integrated observing system, to encourage stakeholder feedback and engagement processes. The strategies should include prioritization of ocean information and ocean observation needs.

In order to meaningfully include diverse stakeholders in ocean observing system planning and evaluation, two levels of communication and engagement strategies are needed: one on the higher level of GOOS, and another more nuanced and tailored to specific needs of given stakeholder/user groups. It is recommended that stakeholder input be part of the formal process of an ongoing system-wide assessment of design efficiency and information product adequacy. This process requires developing performance metrics which are relevant to stakeholder needs and not only to observing network managers. Acknowledging limited resources, the observing system evaluation should include mechanisms of prioritization, and promote implementing technological innovations by gradually increasing their readiness level from concept through pilot to mature.

Breakout Session on Global observing system for marine debris

The goal of this session, held on Tuesday, September 17th, was to advance a harmonized approach to the design of regional/national programs and their integration in a global platform/repository. Participants discussed common approaches to data collection and management and proposed their unification and harmonization. The session also proposed post-conference activities and programs for the next decade and discussed marine litter observation governance. The Panel of speakers included representatives of many international organisations, institutions and expert working groups including UNEP, GEO Blue Planet, GESAMP WG 40, SCOR WG FLOTSAM, JAMSTEC, EMODnet and GOOS. IOCCP Project Officer was invited to the panel of speakers and presented the offer of GOOS to support the efforts to establish a globally coordinated Integrated Marine Debris Observing System (IMDOS) according to the vision presented in an OceanObs'19 CWP by Maximenko et al.

The breakout session concluded with the following recommendations, to the implementation of which GOOS will contribute as part of its 10th Strategic Objective on Observing Human Impacts in the Ocean.

- A comprehensive global observing & information system is necessary to evaluate sources/sinks, abundance, trends, risks and the efficiency of reduction measures and finally to get the problem under control.
- To achieve fundamental understanding of the issues of marine debris, develop efficient in situ observation technology, remote sensors, models and monitoring strategies, involving citizen scientists when possible.
- Build an integrated, standardized and harmonized collaborative network, using commonly accepted methods & definitions, whose structure (variables, coverage, and products) answers fundamental scientific questions and societal demands.

Within the scope of our ToR's, the IOCCP is now involved in follow-up actions leading to prioritising implementation of recommendations relevant to the biogeochemistry component of the integrated global ocean observing system.

Late Community White Paper on VOICE

In December 2019, the OceanObs'19 Community White Paper on "Multidisciplinary Observing in the World Ocean's Oxygen Minimum Zone Regions: From Climate to Fish — The VOICE Initiative" was published. The Variability of the Oxycline and its ImpaCt on the Ecosystem (VOICE; http://www.ioccp.org/voice) initiative, supported by IOCCP since its beginning in 2017, aims to demonstrate how societal benefits drive the need for integration and optimization of biological, biogeochemical, and physical components of regional ocean observing related to eastern boundary systems (EBSs). VOICE chose to focus on the upper oxycline (transition between high and low oxygen waters) which is fundamentally important for the ecosystem structure and can be a useful proxy for multiple observing objectives connected to EBSs that neighbour oxygen minimum zones. In this paper, we present a first, to our knowledge, comprehensive global readiness level assessment for ocean observing according to the principles of the Framework for Ocean Observing adapted to a particular observing objective related to oxygen minimum zones, drivers of change and impacts on ecosystems. The paper can be accessed at: https://www.frontiersin.org/articles/10.3389/fmars.2019.00722/full

WORKSHOPS AND MEETINGS

4th GO_2NE Annual Meeting, Paris, France, 13-14 June 2019

As with all Project's annual meetings, several strategic, administrative and logistical topics are covered and decided. From IOCCP's perspective the main issue discussed and decided at this meeting was one around development of a roadmap leading to establishment of an open access oxygen data platform for the world ocean.

The participants agreed that the oxygen data synthesis product should include ultimately all eulerian and lagrangian observations, i.e. Winkler titration measurements, sensor data from CTDs and from fixed moorings/time series, sensor data from BGC-Argo floats and gliders/wavegliders as well as any additional AUVs. It was also agreed that all data has to be quality controlled (data quality flags assigned based on consensus reached by data contributors and users), 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.

During this meeting, Hernan Garcia from NOAA (USA) presented the World Ocean Data Atlas and World Ocean Database. He invited GO_2NE members to assist with the quality control of data sets to obtain relevant data products and facilitate access to data. In addition, the map and data collection produced by Bob Diaz (VIMS, USA) focusing on hypoxic coastal zones was discussed. The group explored the possibility of a small international workshop, including interested GO_2NE members, ocean data experts, and experts focusing on second level data quality control for ocean oxygen measurements.

Participants agreed that a dedicated workshop including representatives of several involved groups should be held in boreal fall 2019. IOCCP, US NOAA and German SFB 754 agreed to co-sponsor this technical workshop. IOCCP offered to host it in Sopot, Poland.

Meeting on reconciling EOV-ECV Requirements, Geneva, Switzerland, 30 July-1 August 2019

In July 2019, IOCCP Project Officer travelled to WMO headquarters in Geneva to work with the OOPC Secretariat and GCOS Secretariat on improving how we articulate requirements and meet our various reporting responsibilities. The group was joined remotely by OOPC Chair Bernadette Sloyan and Patricia Miloslavich as GOOS BioEco Panel Secretariat.

The group recognized that in the GOOS approach, characteristic scales of phenomena provide the framework for articulating what the observing requirements are for EOVs, and provide authoritative guidance for the design of an integrated multi-scale, multi-disciplinary, multi-platform observing system. On the other hand, the reporting pathways both GCOS and WMO consider requirements for each ECV by sub-variables, or products, which has its own merits.

As an outcome of the work done during this meeting, it was recommended a two-step process be employed. The process would (i) determine the phenomena in the ocean we need to capture, and the scales (and regions) which they operate, and (ii) then use this information to determine the relevant requirements for individual sub-variables/products depending on the particular observing objective/application (e.g. climate vs operation services).

The first step was largely completed and required only an incremental update to the information already provided in Table 2 of the current version of EOV Specification Sheets. The second step meant that for every EOV a new table needed to be produced to encompass the resolution and uncertainty requirements for EOV sub-variables taken into account the need for potentially distinct requirements depending on the coverage (global vs coastal, surface vs interior vs deep ocean) and application if relevant.

The recommendations were presented to GOOS Executive and later presented to all three Panels of GOOS during respective panel meetings, including IOCCP-SSG-14. The new table with sub-variable requirements was initially filled out based on the information provided in 2015 for the previous GCOS Implementation Plan, using information from existing EOV Specification Sheet, and other available documents (e.g. GOA-ON Implementation Plan, Biogeochemical Argo Implementation Plan, GO-SHIP data requirements).

1st Global Ocean Oxygen Network (GO_2NE) International Summer School, Xiamen, China, 2 - 8 September 2019

The 1st International Summer School from the Global Ocean Oxygen Network (GO_2NE) from the IOC-UNESCO took place on 2 - 8 September, in Xiang'an Campus of Xiamen University, China. The summer school was sponsored by IOC UNESCO, GO_2NE, IOCCP, the Collaborative Research Center 754 (SFB754), the State Key Laboratory of Marine Environmental Science (MEL) of China, the French National Centre for Scientific Research (CNRS), the National Fund for Scientific Research

(FNRS), University of Liège, SOLAS, the European Geosciences Union (EGU), the US Ocean Carbon and Biogeochemistry (OCB) program, the National Oceanic and Atmospheric Administration (NOAA) and SCOR, and by several other individual advisors and institutes.

The GO_2NE Summer School 2019 offered a mix of lectures and practical workshops, and stakeholder engagement activities to a group of 37 PhD students and early career scientists from 19 countries coming from across all continents. The attendants were instructed by 14 world-leading international scientists from 12 countries. The topics covered included open ocean deoxygenation, closed seas and coastal waters deoxygenation, introduction to modelling ocean physics, introduction to modelling ocean biogeochemistry, ocean observing systems design in relation to the deoxygenation issue, effects of ocean deoxygenation including biological responses, etc.

There were also special sessions organised on "Ethics in Science" and "How to interact with the press and social media and NGOs." Attendants had ample opportunities to present their own research, and received feedback from a science communication perspective. During the cruise aboard the research vessel Tan Kah Kee from Xiamen University, students were introduced on how to use the most recent oxygen sensors of the market together with performing Winkler titrations and using a CTD with Niskin bottles, and plankton nets.

The event was reported on in detail in Issue 15 of the SOLAS Newsletter.

NSF EarthCube Workshop for Ocean Time Series Data (13-15 September 2019, Hawaii, USA)

On 13-15 September 2019, just prior to the OceanOb'19 Conference in Hawaii, IOCCP took part in the NSF EarthCube time series workshop. The rationale for the workshop stated that data synthesis and modeling efforts across ocean time-series represent an important and necessary step forward in broadening our view of a changing ocean and improving our return on investment in ocean time-series. Despite the advances achieved over the past decade, significant barriers remain that hinder work across time-series, including issues related to data access, discoverability, and metadata reporting. Furthermore, incorporation of ocean time series data into ocean and earth system models is currently limited due to the lack of a standardized data format and user interface. More details can be found at: https://www.us-ocb.org/earthcube-workshop-ocean-time-series-data/

Participants agreed to work on the following actions as outcomes of the workshop: (i) developing a pilot data product test case, (ii) developing an international time series working group to implement best practices and (iii) work on high-profile briefs and visualizations to increase awareness of time series stations.

IOCCP plays a leading role in addressing the first outcome through its role in the EU H2020 project EuroSea (see details in the Future Directions section of this report), while US OCB committed to addressing the remaining two outcomes.

OceanObs'19 Conference, 16-20 September 2019, Honolulu, Hawaii, USA

IOCCP made a significant contribution to the process of writing Community White Papers as a lead up to the OceanObs'19 Conference. This work, highlighted in the Major Activities, Publications and

Future Directions sections of this report, focused on identifying the vision forward and recommendations for its implementation within the field of marine biogeochemistry. However, IOCCP has also supported ideas of further evolving the entire integrated global ocean observing system in line with the new GOOS 2030 Strategy. To this end, we took part in organizing several breakout sessions which provided discussion fora for the 1000+ conference attendants.

Oxygen data workshop, 11-12 November 2019, Sopot, Poland

As part of the ongoing IOCCP efforts to further develop global coordination of oxygen observations, and in follow-up of recommendations from the VOICE project and the GO_2NE group, IOCCP co-organized the first scoping workshop on developing a global oxygen data product. The workshop, supported by IOCCP, IOC-UNESCO, GO_2NE, US NOAA and the German project SFB754, was a direct execution of Action Item #10 as agreed and detailed in the report from IOCCP-SSG-13.

The workshop took place on 11-12 November 2019 in Sopot, Poland, just prior to the 14th Session of IOCCP SSG. Co-location of the two meetings led to a significant reduction of travel costs and optimal use of time of the experts invited to attend both events: Maciej Telszewski, Benjamin Pfeil, Masao Ishii, Kim Currie, Siv Lauvset and Véronique Garçon from IOCCP SSG, as well as Fei Chai and Toste Tanhua who were invited as guests to parts of the IOCCP annual meeting.

The overarching goal of this 2-day scoping workshop was to bring a community of observationalists, modellers and data managers to develop a roadmap towards an open access oxygen data platform for the world ocean - an atlas akin to the Surface Ocean CO_2 Atlas (SOCAT). The atlas would be a quality controlled (data quality flags assigned based on consensus reached by data contributors and users) data synthesis product, with underlying raw data centrally archived, 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 oxygen data synthesis product would include ultimately all eulerian and lagrangian observations, i.e. Winkler titrations measurements, sensor data on CTDs and on fixed moorings/time series, sensors on BGC-Argo floats and on gliders/wavegliders and on any remote vehicle/platform. A strategy could be to first include additional eulerian (sensors on CTD data) then tackle the lagrangian oxygen data.

Workshop participants discussed several levels of improvements to current oxygen data management in order to enable such a product. First level improvements would be to gather data from the existing databases in which data is readily freely accessible in electronic format, without restriction, to remove duplicate data and to define consistent quality checks agreed by the community. Second level improvements are to identify and correct information from additional datasets for OMZs, coastal hypoxic sites and other ocean depths and regions based on experts' recommendation. Integration with the Argo, OceanGliders and coastal regional community is targeted through the efforts of GO_2NE, WESTPAC, VOICE, EBUS SCOR WG, EMODnet Chemistry, NOAA, etc.

Complete workshop report is expected to be published before mid-2020. Currently, a draft roadmap is being circulated internally among several task groups identified during the workshop. The roadmap is expected to be published as a community white paper in a peer-reviewed journal in late 2020, or early 2021.

14th Session of IOCCP SSG, 13-15 November 2019, Sopot, Poland

The meeting took place on 13-15 November 2019 at the Institute of Oceanology Polish Academy of Sciences in Sopot, Poland. Five IOCCP SSG members and Office staff attended the meeting in person, three SSG members attended remotely, and one SSG member was unable to attend the meeting due to other commitments. Two invited guests joined the first day of the meeting.

The meeting started with a summary of IOCCP accomplishments from 2018-2019, with a focus on key outcomes which had the biggest impact with respect to the IOCCP Terms of Reference. These are listed below. Each of these points was later elaborated on during sessions relevant to individual IOCCP themes, and documented in the meeting report available from IOCCP website. The different accomplishments and plans for their follow up, if relevant, are described in some detail across various sections of this IOCCP report to SCOR.

IOCCP ToR #7: Training Activities / ToR#8,9: FAIR data

- IOCCP & BONUS INTEGRAL Training Course on a Suite of Biogeochemical Sensors
- AtlantOS workshop on Underway and Sensor CO_2 Data and Metadata QC Procedures
- Global Ocean Oxygen Network (GO_2NE) Summer School

IOCCP ToR #8,9: FAIR, open and quality controlled data

- Supporting data synthesis of Inorganic Carbon EOV products through SOCAT and GLODAP
- Supporting the Global Ocean Acidification Observing Network Data Portal and phenomena-based products (ocean acidification)
- Developing a roadmap towards an Oxygen Data Portal and phenomena-based products (deoxygenation)
- Development of the Marine BGC Global Data Assembly Centre (GDAC)

IOCCP ToR #1,2: Observing system implementation

- Expansion of coordination activities onto new Biogeochemistry EOVs

IOCCP ToR #2,6: Fit-for-purpose BGC observing system

- IOCCP partnership with the modelling community
    - Surface Ocean pCO_2 Mapping intercomparison (SOCOM)
    - Towards ocean biogeochemistry data model assimilations
    - Contribution to the synthesis and intercomparison of ocean carbon uptake in CMIP6 models
    - IOC WG on Integrated Ocean Carbon Research (IOCR)
- Contribution to the Global Climate Observing System (GCOS)

IOCCP ToR #3,4: Goals, Metrics, Standards and Best Practices

- SDG Target 14.3: Minimize impacts of ocean acidification

Significant contribution to the OceanObs'19 Conference and Community White Papers - pertaining to virtually all IOCCP Terms of Reference.

EU H2020 EuroSea Project Kick-Off meeting, 27-29 November 2019, Brussels, Belgium

The EU Innovation Action "Improving and Integrating European Ocean Observing and Forecasting Systems for Sustainable Use of the Oceans (EuroSea)" officially started on 1 November 2019. The kick-off meeting took place at the Royal Belgian Museum of Natural Sciences (RBINS) in Brussels on 27-29 November 2019, co-organized by GEOMAR, RBINS, and EuroGOOS.

The kick-off meeting offered a unique opportunity to plan the project's success from the outset, bringing together representatives of most partners making up the interdisciplinary and international consortium of 55 partners who will work together for the next 4 years, with an allocated budget of almost € 12.6M. IOCCP was represented by Maciej Telszewski, Artur Palacz, Benjamin Pfeil, Bjorn Fiedler, all of whom are assuming roles of work package or task leads in this project.

EuroSea is part of "The Future of Seas and Oceans Flagship Initiative" funded through the Horizon 2020 Blue Growth call (BG-07-2019-2020). EuroSea brings together key European actors of ocean observation and forecasting with key end users of ocean observations. The kick-off meeting was also the 1st General Assembly of EuroSea during which decisions on the Steering Committee, Gender and Equality Committee and other project governing bodies were made. The meeting was also an opportunity to discuss work plans within individual work packages, present initial plans for cross-project aspects such as data management plan, communication and results exploitation plans, as well as strategies for engaging stakeholders - a critical aspect of this project.

Detailed agenda and proceedings can be found in the kick-off meeting programme and in a list of meeting presentations.

Ocean Best Practices Workshop, 2-3 December, Oostende, Belgium

The Ocean Best Practices Workshop III (OBP Workshop III) was held at the International Oceanographic Data and Information Exchange (IODE) of the Intergovernmental Oceanographic Commission of UNESCO, Project Office for IODE, Oostende, Belgium, 2-3 December 2019.

It was organized with support from IODE, GOOS and IEEE Oceanic Engineering Society with the objective of better understanding the future needs of the ocean observing community. Specifically, also to provide recommendations to the IOC Ocean Best Practices System Steering Group for its inaugural meeting that followed the workshop. The workshop outcomes were defined as: (1) an articulated strategic direction for ocean best practices; (2) recommendations for best practice synthesis and 3) recommendations for further Ocean Best Practices System development/implementation, embedding outcomes from community input.

Over the 2 days, 50 international ocean experts from 20 countries representing international agencies, Programmes, Projects and Organizations participated in presentations and panel discussions. The workshop encouraged maximum audience participation and was structured with several thematic, hour-long Panels followed by plenary discussion. This format was effective in stimulating ideas and discussions to lay out a future vision of ocean best practices and how OBPS will contribute to improving ocean observing in the decade to come. Breakout Sessions were also a major part of the agenda, to provide opportunities for participants to share insights and importantly to make

recommendations to the Panel on Vision for the Next Decade and ultimately the OBPS Steering Group.

Maciej Telszewski lead the Panel on Capacity Building and Training. Maciej was joined by 5 panelists representing IODE - Ocean Teacher Global Academy, POGO, GEO-Blue Planet, SCOR, Nippon Foundation and national efforts. The Panelists described in detail several types of training/capacity development modes focusing on their attributes related to the feasibility of each modality for global implementation. Panelists also highlighted challenges related to individual modalities as well as suggested types of outcomes which might be expected when certain modality is implemented.

After a brief presentation from each Panelist a long and vigorous plenary discussion started leading to the major conclusion suggesting that a highly anticipated outcome of this session would be for the OBPS Steering Group to develop a Work Package on Capacity Development. Ideally such a package would come in a form of a comprehensive product (paper, best practice, training module) which would describe various types of capacity development activities (with their pros and cons) in relation to various types of best practices in OBPS.

Full proceedings from the meeting are available from the OBPS website: https://www.oceanbestpractices.org/

Marine debris indicators-What's next?, 16-18 December 2019, Brest, France

On December 16-18, 2019, IOCCP project officer attended the workshop on "Marine Debris Indicators: What is Next?" held in Brest, France. Building on the first workshop in a series held in November 2018 also in Brest on "Technologies for Observing and Monitoring Plastics in the Oceans" this workshop aimed to strengthen the link between observation, extracted information, and decision and policy making related to the problem of marine litter. Participation in the workshop meant that IOCCP took part in further development of a community focusing on monitoring and measuring of marine debris, thus enhancing our capacity to establish global coordination of an Integrated Marine Debris Observing System (IMDOS) as part of the EuroSea project, and in fulfilment of obligations as GOOS Biogeochemistry Panel.

Building on the recommendations and draft road map of the 2018 Workshop, the main goals for this activity was to further develop a community of stakeholders around marine debris and to further detail the road map towards a joint goal. The overarching goal for this community is to achieve a comprehensive description of observation means (underwater, satellite-borne, in situ, crowdsourcing, Big Data analyses) and assess their technological readiness, as well as their availability for relevant indicators, including the SDG Indicator 14.1.1, and to ensure that a range of emerging efforts to address the global challenge of marine debris can be based on sufficient observational evidence.

In that context, the workshop explored the potential for a platform linking the data to actions and for development of an implementation strategy for observing networks and modeling platforms to support co-creation of knowledge needed by those addressing all aspects of marine debris.

The first part of the workshop included several sessions with invited presentations and brief discussions. This part aimed at reviewing the current state in monitoring marine debris and relevant modeling, and aimed at an overview of the knowledge needed for societal decision making on

mitigating the threat marine debris poses to the ocean and human beings. The second part took a participatory approach in which the participants worked together to improve the draft road map that resulted from the first workshop in 2018. Initially, several groups collected sets of relevant terms and developed graphics of their vision for the next five years.

In a collaborative effort, input for a case study on "Reducing Plastics in the Ocean within a Growing Global Economy: Understanding the Data Needs to Inform Actions" was compiled for the following sections of the case study report: Introduction, Wicked Problem, Conceptual Model, Decision Space, Hazards, Vulnerabilities, Foresight, Interventions, and Recommendations. It was agreed to carry out this case study over the six months prior to the Third Workshop planned at the end of May 2020.

The planned third workshop, Linking Data to Actions on Marine Debris for the Ocean Decade, was postponed due to COVID-19 and will be rescheduled according to the new venue and date of the UN Ocean Conference.

GLODAP data meeting, 16 February 2020, San Diego, USA

As part of its commitment to support the ongoing efforts of GLODAP, several IOCCP SSG members attended a GLODAP Data Meeting which took place on 16 February 2020 in San Diego, CA, USA just prior to the 2020 Ocean Sciences Meeting.

The purpose of this meeting, attended by 19 participants, was to address the effects and possible solutions to Bob Key's 2019 retirement, in particular with respect to the process of acquisition, flow, and quality control of data for GLODAPv2020 and beyond. Participants reviewed the current state of the GLODAP (and GO-SHIP) data, from in situ measurements to final products, formalized the data flow for 2020 and beyond, and discussed a software data system, based on SOCAT, to normalize the submission of GO-SHIP quality data.

What is more, suggestions were made as to the vision for optimal coordination between different entities engaged in collection and dissemination of hydrographic biogeochemistry data, and clarifying the roles played by each among NOAA NCEI, CCHDO, GO-SHIP, GLODAP, IOCCP and national contributions from Germany, Norway and others. Following the meeting, a preliminary budget estimate has been made for GLODAP, in response to the need for a resource plan outlining the personnel and other needs to sustain these important efforts as recommended by IOCCP and GOOS. IOCCP will support the GLODAP community in finalizing and publishing the resource plan, ideally by the end of 2020.

OceanObs Research Coordination Network (RCN) Annual Meeting, 16 February 2020, San Diego, CA, USA

The OceanObs Research Coordination Network (RCN) hosted its annual meeting on February 16, 2020, in San Diego, CA, just prior to the 2020 Ocean Sciences Meeting. Several members of the global ocean research and observation communities joined the meeting responding to the RCN invitation to join discussions aiming to synthesize threads and recommendations emerging from the OceanObs'19 Conference, including planning for the implementation of initiatives emerging from OceanObs'19.

The objective of the RCN meeting was to provide avenues for these communities to discuss and advance outcomes and priorities that emerged from theOceanObs'19 Conference of September 2019. The challenge following the OceanObs'19 Conference is to integrate the diverse activities of the ocean research and application communities into focused and sustained efforts that address important societal priorities, and that help inform international initiatives such as the UN Decade of Ocean Science for Sustainable Development and others, as well as important national priorities.

The February 2020 RCN meeting was structured to encourage dialogue and clear definition of next steps. In one day, the meeting could address only a subset of the OceanObs'19 themes and outcomes. Five Breakout Sessions were organized for the community during the RCN meeting. Each of the breakouts defined specific actions and identified leads to carry these forward. Some of these actions are substantive new directions, and some are expansions of current efforts.

Three major themes emerged from the February 2020 OceanObs RCN meeting:

1. Expansion of coordinated observing systems and global scale measurements relevant to a Global Ocean Observing System. Some of these are the Deep Ocean Observing System, Integrated Surface Ocean Observing System, Seabed mapping, a HABs Initiative and Smart Cables and integration across parallel observing capabilities (e.g. VOS, SOT and SOOP, all ship observing efforts). There are some that have not yet fully emerged such as a coordinated global effort for biological observations.
2. Cross-cutting efforts that underpin ocean observing across the value chain from observations to applications and policy. Examples of there are data management, interoperability, community building, best practices, open science/open access and capacity development.
3. Resources, the blue economy and the need for expanding collaboration across the ocean research community and engagement with industry, sponsors and policy organizations.

The RCN meeting produced specific actions with assigned leads in areas covered at the meeting. From IOCCP perspective, theme 1 was of major interest, with Meghan Cronin specifically proposing and describing the Integrated Surface Ocean Observing System (ISOOS, currently SCOR WG proposal OASIS). Rik Wanninkhof and Maciej Telszewski attended the related parts of the meeting and the resulting developments are described under Surface ocean observations of biogeochemical parameters in the Future Directions section of this report.

One of the major issues raised during the discussions were partnerships. There were many examples where partnerships are happening in a successful manner: across international organizations (e.g. IOC and WMO), across research and the private sector (e.g. maritime operators), with research science and citizen science and across national funding agencies. Further efforts are needed as the ocean community takes a global perspective. Participants recognized that major international ocean research efforts need to better link research and operations, for example in support of agreements such as UN Agenda 2030 (the UN Sustainable Development Goals). Finally, the participants recognized that the successful outcomes of this meeting are another step in shaping the research for the next decade. Full proceedings with detailed discussions, action items and plans forward were distributed in early May 2020. Current global situation is impacted by COVID19 pandemic and related limitations will continue to impact the implementation of these actions and plans but the community will continue to move forward even if at a slower than optimal pace.

PROJECT OFFICE

Open calls, nominations for new IOCCP SSG members

During the XIV Session of the IOCCP SSG in Sopot, Poland (13-15 November 2019), the Panel discussed the fact that according to the current Terms of Reference for members of the IOCCP SSG, our co-Chair (Masao Ishii) should rotate off the group at the end of 2019 due to the fact that the total service on the Panel is limited to 9 years. However, since Masao has only been the Co-Chair for the past 3 years, having served as a "regular" member for 6 years prior to becoming a co-Chair, the SSG suggested that it would be more beneficial for IOCCP now and into the future, if Masao (and every new co-chair) had the choice of serving two terms on this position regardless of the duration of their earlier service as an IOCCP SSG member. The suggestion was grounded on the fact that it takes a considerable amount of time to acquire sufficient level of understanding and experience needed to efficiently steer the group. Therefore, SSG approved the notion to update the Terms of Reference for members of the IOCCP SSG to allow a co-Chair to serve for up to 6 years. This proposal was presented to our Sponsors who did not approve of this notion. While SCOR and IOC expressed their understanding of the value of maintaining Masao Ishii in the SSG due to his experience and to provide continuity, SCOR and IOC are not inclined to approve a change in the ToRs to allow for an extension of service to 12 years. Our sponsors feel strong about rotation and renewal being healthy practices for a project to build capacity for the next generation of leaders. SCOR and IOC agreed, as an exception, that the current co-chair Masao Ishii continues to serve until the end of the calendar year (total of 7 years as co-Chair). Our sponsors recommended that the process to nominate the new co-Chair to succeed Masao Ishii starts in due time considering the new co-Chair will commence duties on 1 January, 2021.

The SSG approved the IOCCP Executive proposal to extend by 1 year the second term of Benjamin Pfeil as SSG member. This decision was motivated by the fact that the work on creating the Biogeochemistry Global Data Assembly Centre (GDAC), initiated and coordinated by Benjamin for the past several years, is nearly complete and that it would be highly beneficial for both IOCCP and the GDAC effort to ensure Benjamin's position as IOCCP SSG member until the end of 2020. This decision was approved by IOCCP Sponsors.

Following the decisions from the XIII Session of the IOCCP SSG, an open call for new SSG members was drafted and released to the public in October 2019 via several communication channels. The news was shared widely through our partner organization newsletters, Twitter channels, and even through the ECO Magazine. Based on the submitted applications, the IOCCP SSG identified two outstanding candidates who were subsequently nominated to IOCCP sponsors, who approved our nominations. These new SSG members will take charge of (among other things): (i) coordination of Particulate Matter EOV observations, and (ii) coordination between marine biogeochemistry observationalist and modelling communities. It is anticipated that the new themes will be added to the IOCCP portfolio by mid-2020.

In February 2020, Douglas Connelly announced his decision to step down from IOCCP SSG. This decision motivated IOCCP SSG to re-evaluate the criteria for selecting his replacement prior to releasing an open call for this position (see discussion under Future Directions section of this report). A new open call for an IOCCP SSG member was advertised in March 2020. By the deadline of April 10th, IOCCP Office received four applications for the position. Currently, the applications are being reviewed by the Panel, and nominations will be presented to the sponsors by mid 2020.

Communication services

Twitter

During the 2019 Sensors Training Course in June 2019 IOCCP Project Office launched its Twitter account, thus fulfilling *Action Item #36* from IOCCP-SSG-13. You can now follow news relevant to marine biogeochemistry through @ioccp_org. This new communication service responds to the needs of the predominantly younger generation of marine biogeochemists who seem to prefer short and frequent updates to be distributed via social media. We do not only share but also receive important news through Twitter which is gradually replacing daily to weekly email communications used by other international projects of a similar profile, such as IMBeR, SOLAS, or US OCB.

The IOCCP Twitter account received plenty of attention right from the start thanks to an enthusiastic crowd of #2019SensorsTraining course attendees and course instructions, many of which are frequent Twitter users. By the end of April 2020, after almost 12 months of Twitter activity, we have 218 followers. During this period we posted 122 tweets, many of which were re-tweeted by our followers, eventually reaching an estimated 2,000 - 8,800 users per tweet.

It is worth pointing out that daily news on job postings, training courses, workshop reports and scientific publications, are currently more easily (and often exclusively) available from Twitter. We perform daily filtering of information shared by individuals and organizations strategically "followed" by IOCCP, and often instantly share with our followers (and their followers) any unique information acquired by the Project Office through more traditional communications means. We reckon that thanks to the new (for IOCCP) Twitter service we have greatly expanded our capability to timely and efficiently reach out to the global community of marine biogeochemistry observationalists and thus better serve as a communication hub.

Website and email newsletter

The Office is committed to using the IOCCP website and (sub-)weekly email newsletter as its primary means of communicating with the core of the marine biogeochemistry community, i.e. those who explicitly subscribe to our services (currently 600 subscribers). Over the past 12 months, we have distributed over 70 news pieces through our newsletter. We consider the new Twitter service as complementary to this core communication activity. Currently, we use Twitter for short, rapid and/or urgent communications, followed by or linked to a more extensive news article posted on the web and shared via the email newsletter.

The IOCCP Conveyor

The shift towards more frequent and short communications shed new light on our quarterly newsletter The IOCCP Conveyor. An internal analysis revealed several reasons to suggest that this particular communication service might be obsolete.

Firstly, there is a lack of input from the community on what topics and articles that could be of interest to those on the receiving end of this service. Secondly, the majority of the articles written for the past issues heavily relied on news already communicated via website and email weeks or months prior to the publication of the Conveyor. Thirdly, the purposefulness of communicating on a quarterly to bi-annual time scale seems questionable considering the daily to weekly Twitter and email communication on one end, and the annual reporting from IOCCP SSG meetings on the other end. Fourth, it is difficult to estimate who reads the newsletter, or which sections of it. Finally, in an environment that is supersaturated with lengthy newsletters on one hand, and tweets designed for the new generation characterized by an average 8-second attention span (Microsoft Attention Span Report, 2015), IOCCP's strength and communication niche could be the weekly email newsletter.

After a comprehensive discussion, the SSG endorsed the suggestion from the Office to discontinue the quarterly newsletter service, to maintain the weekly to monthly website updates and email newsletters, and shift the efforts towards the shorter, frequent and up to date messages distributed via Twitter.

Funding for Project Office and activities

Since 2012, upon request by NSF, IOCCP continues fundraising efforts for salary support for the Project Officer. Since 2015, these efforts have been successful enough to maintain the position of Project Officer with 100% external (to NSF award through SCOR) funding. Successful collaborations related to the previous funding source (2015-2019, EU H2020 AtlantOS Project) allowed our participation in a bidding consortium responding to the EU Horizon2020 call in early 2019. This required tremendous effort at the end of 2018 and in the first half of 2019, however our bid was successful again and will allow the Project Office to focus on implementing the Project ToRs in the next 3 years (2020-2022). The funding secured for the Project Officer comes from the EU H2020 EuroSea Project. It's important to note that our participation in the Project consortium has been assured directly by the GOOS co-Chair and the GOOS Head Office.

For almost a decade now, IOCCP has also been able to significantly diversify funding sources for a great majority of its activities. There are many examples of activities which were led or co-organized by IOCCP and which were in fact carried out with >50% external sponsorship. This is achieved almost exclusively via successful and long-lasting partnerships with several organizations, where mutual benefit is obtained and often the impact of an activity is more prominent than what would have been expected without partnering. Several specific examples of such partnerships were given in a recent IOCCP Sponsor's Review 2012-2022. Recent (2019) examples of more prominent activities initiated and coordinated by IOCCP include:

- 2019 IOCCP & BONUS Integral Training Course on a Suite of Biogeochemical Sensors

    - Total budget: US$ 105,000; IOCCP contribution: US$ 40,000
    - Co-sponsors: BONUS-INTEGRAL Project, US Ocean Carbon and Biogeochemistry Program, European Research Infrastructure: Integrated Carbon Observing System Ocean Thematic Center and EU RINGO Project
- 2019 Oxygen Data Platform Scoping Workshop
    - Total budget: US$ 35,000; IOCCP contribution: US$ 10,000
    - Co-sponsors: US NOAA, US NCEI, German SFB754 Project

Every year there are also several activities initiated and coordinated by our partners, where IOCCP plays a co-sponsor role helping the main organizer meet its budgetary requirements and at the same time fulfilling IOCCP's ToR's which we would not be able to do otherwise. Recent (2019) examples of these type of partnerships around specific activities include:

- 4th GOA-ON International Workshop
    - IOCCP contribution: US$ 5,000
    - Main sponsor and organizer: Global Ocean Acidification Observing Network
- GO_2NE Oxygen Summer School
    - IOCCP contribution: US$ 7,500
    - Main sponsor and organizer: Global Ocean Oxygen Network
- Experts Workshop of the Integrated Ocean Carbon Research Working Group
    - IOCCP contribution: US$ 10,000
    - Main sponsor and organizer: Intergovernmental Oceanographic Commission of UNESCO

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FUTURE DIRECTIONS

Developing an IOCCP Strategy

Over the next 12 months IOCCP aims to compile a comprehensive set of observing strategies for biogeochemical EOVs by forming effective partnerships with relevant interested players. To initiate this process we plan to submit a White Paper laying out these individual strategies and call on relevant partnerships. The complexity of the marine biogeochemical cycles with numerous connections to their atmospheric and terrestrial pathways means that a wide range of approaches have to be used in order to embed marine biogeochemistry observations into globally integrated earth system observing networks. In order to fulfil the 2030 vision for a mature, sustained marine biogeochemistry observations being a part of a global, integrated system delivering essential information to the society, we will expand on the following draft recommendations:

- To reconcile the societal and scientific requirements for biogeochemistry observations by strengthening or establishing new partnerships between observing networks and relevant expert working groups (in particular IOC-UNESCO WGs such as GO2NE and IOCR, SCOR WGs such as P-OBS and newly proposed OASIS, and UNEP expert communities).
- To establish partnership between IOCCP and GEOTRACES to support the implementation and increase of readiness level of sustained observations of EOVs, such as Particulate Matter and Nutrients.
- To actively guide the co-design of the observing system by engaging expert WGs and observing networks to determine phenomena-based observing targets and jointly agree on implementation plans for all EOVs for the period 2025-2030.
- To increase the comparability of measurements and thus increase the quality of information products and generated knowledge by:
    - establishing globally agreed-upon standards and protocols;

    - whenever possible, support producing Certified Reference Materials for EOVs, e.g. through establishment of central calibration facilities and regular inter-laboratory comparison studies;
    - enforcing strict requirements for use of globally-accepted standards, protocols and CRMs in all observing networks recognized by the GOOS Observations Coordination Group.
- To support centralized monitoring and performance evaluation of all observing networks carrying out biogeochemistry EOV observations (i.e. through JCOMMOPS).
- To increase the observing capacity by adding routine biogeochemistry (and biology) EOV measurements on existing observing networks, in particular GO-SHIP and OceanSITES.
- To strengthen existing and promote creation of new EOV-based observing networks that would facilitate implementation of EOV requirements across platforms
- To create new data synthesis products based on multi-EOV and multi-platform observations needed to fulfil the end user product requirements for various applications globally (e.g. SDG14 indicators, Global Carbon Budget, IPCC and World Ocean Assessment) and regionally (e.g. harmful algal bloom forecasts, regional carbon budgets, integrated ecosystem assessments).
- To increase the availability, discoverability and interoperability of marine biogeochemistry data and to enable product development by end users. To this end we recommend creating and maintaining a Global Data Assembly Centre for Biogeochemistry EOVs, and where relevant (e.g. Particulate Matter EOV) designing new data repositories capable of integrating EOV data from many heterogeneous sources.
- To support observing networks and communities in regularly assessing the potential of newly developed observing techniques to better elucidate changes in key ocean phenomena, (e.g. ventilation, biological carbon uptake, deoxygenation).

New coordination activities of GOOS Biogeochemistry Panel

Partnership with the modelling community

During IOCCP-SSG-13 it was recognized that IOCCP would like to strengthen its dialogue with the modelling community and through partnership foster the delivery of observational data required for the development and evaluation of biogeochemical forecasts as a new frontier in oceanography.

During IOCCP-SSG-14, the IOCCP dedicated a separate session to this issue to better identify what biogeochemical observations are needed to support model development, and at the same time how models can be used to optimize the observing system design. Through an open call in 2019, IOCCP has successfully recruited a new IOCCP SSG member who, pending SCOR's approval, would take on this responsibility. Fei Chai (SIO, China / University of Maine, USA), is a modeller and observationalist in one, who is in an excellent position to provide a perspective and represent global community views as a member of the OceanPredict Marine Ecosystem Analysis and Prediction Task Team (MEAP-TT) and a Biogeochemical Argo Steering Committee member.

When reviewing the observing system requirements, there will be a strong need to engage various model developing communities as users of ocean data. There are multiple modelling communities operating on national and regional levels, as well as groups with truly global representation and focus (e.g. OceanPredict (GODAE), CMIP).

One of the challenges the modelling community needs to address is the need to account for multiple stressors in models, even when operating on a local scale. Phenomena such as hypoxia, ocean acidification, eutrophication, harmful algal blooms and others often control the marine environment. There are examples of successful forecasts of nutrients, pH, oxygen and other parameters at sites where nested models and observational assets from multiple platforms were assimilated and used to constrain the models. These models provide information in response to ocean health applications, and so can be used to derive observing requirements for ocean health monitoring.

The Argo 2020 program, with a significant expansion of deep Argo and Biogeochemical Argo is an essential source of oceanographic data describing multiple stressors in a given location, thus being useful for climate, operational and ocean health applications. However, there are still many issues with assimilating profiling float data, strictly related to inorganic carbon data analysis - which IOCCP can ensure are well documented, communicated and eventually resolved by consensus efforts.

Overall IOCCP's main role in coordination with the modelling community will be to promote the availability of metadata and quality control information to benefit modellers building or evaluating their ocean forecasts. On the other hand, there are examples of the modelling community successfully providing guidance to the observing networks/programs. For instance, the design of the SOCCOM array of profiling floats was based on the results of Observing System Simulation Experiments (OSSEs).

Partnership with remote sensing community for Particulate Matter EOV coordination

Particulate matter concentration and fluxes play a major role in regulating cycling of organic matter, and thus affect carbon sequestration, biological production and deoxygenation among other ocean phenomena. Yet their routine observations remain limited and insufficient to determine with any certainty even the direction of future changes in the biological carbon pump - a significant knowledge gap according to the IPCC AR5. Currently, very few ship-based monitoring efforts include routine measurements of particulate matter, although these have been given greater priority by satellite observing networks and recently also by networks of autonomous observations from gliders and profiling floats. There is a growing need to better coordinate global efforts related to setting requirements, observing and managing data related to the Particulate Matter EOV, which IOCCP is a custodian of.

Estimates of particulate material concentration are based on empirical relationship between optical properties and concentration of different particulate pools. These relationships have typical uncertainties on the order of +/-50%, are mostly limited to the sun-lit surface ocean, and most often do not separate living and non-living particles. Furthermore, they most frequently provide no information on particles' micro-physical properties such as composition, size, shape and degree of aggregation, all necessary to understand their role in the carbon cycle. With respect to biological particles, we lack information regarding partition into groups (e.g. bacteria, phytoplankton, detritus and zooplankton) and within groups with respect to function (e.g. nitrogen fixing, DMS producing, toxic etc'). These are critical for the development and to provide constraints on biogeochemical or ecosystem models, in which particles are important state variables. These models are key to develop our understanding about how the ocean cycles elements and for predicting its evolution under different climate change scenarios.

To improve over the gaps identified in the above paragraph, it is critical that the community:

- develops internationally agreed-upon protocols to measure particulate properties,
- expand our capacity to make these observations, and

- design data repositories where these data can be readily accessed (including single particle analysis data such as from cameras and cytometers).

In the aftermath of the 2019 Open Call for IOCCP SSG members, IOCCP nominated Emmanuel Boss (University of Maine, USA) to join our Panel to more effectively realize our Terms of Reference with respect to coordination of Particulate Matter EOV while addressing the gaps mentioned above. Dr Boss would bring valuable experience and programmatic connections which would help re-establish the once prominent relationship between IOCCP and the International Ocean Colour Coordinating Group (IOCCG), with both organisations likely to play a key role in strengthening the interface between sustained in situ and remote sensing observations of particulate matter and related EOVs (e.g. Ocean Colour, Phytoplankton Biomass and Diversity).

Developing Marine Debris (Plastics) Essential Ocean Variable

The EU Horizon 2020 project EuroSea, aimed at improving and integrating European ocean observing and forecasting systems for sustainable use of the oceans, provides explicit resources to develop Marine Debris as a new type of Human Activity/Impact EOV, and pursue initial selected global coordination activities. Further resources will need to be identified to fully implement the proposed Action Plan for Establishing Global Coordination of IMDOS - introduced under the Major Activities section of this report.

In Phase I, extending from 2020 to mid-2022, the goal would be to initiate a global coordination of IMDOS by:

- establishing an international Steering Committee and approved Terms of Reference (ToR) for IMDOS;
- developing Marine Debris as a new type of Human Activity/Impact EOV, while also integrating relevant requirements in the existing framework (e.g. Particulate Matter EOV);
- developing first platform-specific standard operating procedures (SOPs) based on GESAMP 'Guidelines for the monitoring and assessment of plastic litter in the ocean' (GESAMP, 2019);
- interfacing in situ and remote sensing observations according to EOV requirements.

In Phase II, extending from 2022 to 2025, the goal would be to increase the readiness level of selected elements of IMDOS and their data management streams by integrating them into the global system of coordinated observing networks. This would improve the global coverage, resolution, accuracy and interoperability of marine debris data and thus better inform indicators and sub-indicators of SDG target 14.1 and any regional policy targets set, e.g. by the European Union (Marine Strategy Framework Directive, Marine Plastics Directive), the Arctic Council (Arctic Monitoring & Assessment Programme), other identified governing bodies. Emphasis would also be placed on improving the coordination on the interface between in situ and remote sensing operations (e.g. ESA, NASA, NOAA, JAXA), based on a common set of observing requirements. Exact objectives for Phase II would be determined in the Terms of Reference for IMDOS.

Below is a list and timeline of activities suggested to be carried out as part of this Action Plan during Phase 1 of the project, from 2020 to 2022. The list of activities and their scope will ultimately be refined according to the Terms of Reference adopted by the IMDOS Steering Committee pending its suggested initiation in 2021.

1. **Establish an international Steering Committee and ToRs for IMDOS**

Developing the right governance model for IMDOS requires careful consideration. In this Action Plan we propose to establish a Scientific Committee composed of members of international organizations and regional initiatives spearheading the process of regional to global coordination of marine debris monitoring focused on sea-based activities, representing expertise in various observing approaches, data management, and considering geographic balance among other criteria.

The Committee would be an independent coordination body, responsible for overseeing the execution of ToRs approved during their first in-person meeting scheduled tentatively for early 2021. In order to foster the interaction with other coordinating bodies and structures of GOOS, it is proposed that IMDOS would apply to be an affiliated project of GOOS. Most of the GOOS project requirements could be met in time for the 10th Session of the GOOS Steering Committee (April 2021) to consider such an application.

2. **Develop the concept of Marine Debris as a Human Activity/Impact EOV and publish the Marine Debris EOV Specification Sheet**

This process will build on an early draft of a Plastics Contaminants EOV Specification Sheet which was based on initial input provided by Peter Kershaw (GESAMP) during an AtlantOS workshop on setting targets for the Atlantic ocean observing system. The document should contain a summary of the observing requirements for marine debris as an EOV, including which parameters/indicators to measure, and if possible, specify at what coverage, resolution and accuracy. The document should also list any coordinated monitoring efforts on regional to global scale, as well as those at concept stage but with potential to emerge as vital elements of IMDOS. Key established data streams, databases and information synthesis products will be described, along with a list of monitoring guidelines, best practices, and if available any SOPs among other reference documents.

The document would be published on the GOOS website (www.goosocean.org/eov) and be subject to periodic updates aligned with updates to all other EOVs. IMDOS SC would be the formal curator of the Marine Debris EOV.

3. **Synthesize currently available information on requirements for in situ and remote sensing components of IMDOS**

There are ongoing guidelines and recommendations for setting requirements for marine debris monitoring to provide adequate data to realize policy targets, such as SGD 14.1. 'Guidelines for monitoring and assessment of plastic litter in the ocean' is provided in the GESAMP (2019) report. Requirements should carefully consider the needs of the modelling community, in particular as global model projections inform the SDG 14.1.1b indicators on a global scale. Additional recommendations are already being put forward for remote sensing measurements of marine debris and the processes affecting the distribution, e.g. based on characteristic scales of the processes/phenomena (Martinez-Vicente et al., 2019) – taking an approach which is fully in line with the phenomena-based approach adopted by the GOOS Panels of Experts.

A combination of policy, scientific and user-defined requirements provide the basis for setting specific observing targets expressed in terms of coverage, resolution, accuracy and latency. For the benefit of designing an integrated ocean observing system which is fit for many purposes and for ease of performance tracking, setting observing targets for marine debris will be a long-term process but one which should be part of a coordinated process across ocean disciplines and across observing networks.

4. **Develop and promote the use of first SOPs for marine debris monitoring estimated at pilot or mature**

This activity would build on the guidelines and recommendations from GESAMP (2019). Focus will be given to those observing approaches and methodologies with highest impact and feasibility, but which lack global standardization of methodology and data interoperability. This could include human observations (beach and river mouth surveys), visual imagery and video surveillance of the seafloor (SCUBA, ROV), or in-line/underway sampling (net tows, pumps, CPR). IMDOS SC would determine the priority for addressing standardization of the methods recommended for global monitoring, in close alignment with recommendations from GESAMP.

Where possible and relevant, SOPs should be aligned with existing coordinated observing network and program protocols (e.g. SOOP for ships of opportunity, ICES for bottom trawl surveys) or co-developed with similar initiatives leading to expansion of current sustained efforts (e.g. SCOR WG P-OBS for water sampling on ship-based and fixed-point open ocean observatories).

The draft SOPs developed will be shared for input with a much larger representative group from each research community of practice. Developing and promoting the use of SOPs would benefit from collaboration with Ocean Best Practices (OBP), including from technical workshops potentially co-organized by OBP and GOOS.

5. **Integrate elements of IMDOS into the existing coordinated observing networks, and enhance platform sharing**

While the development of a dedicated global sustained observing network for marine debris is a long-term development, Phase 1 of this Action Plan recommends an analysis of feasibility and cost of adding a marine debris component to established (e.g. GO-SHIP, SOOP, OceanSITES, GACS) and/or emerging globally coordinated observing networks (e.g. OTN, ASV fleets). A recent model of such analysis is provided by the report from SCOR WG 154 P-OBS on 'Recommendations for plankton measurements on the GO-SHIP program with relevance to other sea-going expeditions'.

One aspect of such analysis considers addition of new sensors and instruments designed specifically for marine debris monitoring. For instance, it might be relevant to scope the possibility of expanding video camera observations of marine litter (e.g. littercam) on autonomous platforms (e.g. wave gliders) and ships. Similarly there is interest among the sailing community to contribute to marine debris monitoring. However, there are no formal contact points and documents providing guidelines on technical specifications and cost estimates for yachts (racing and recreational) willing to support sampling and delivering data to international databases (such as EMODnet).

Another aspect of enhanced platform sharing concerns minimal adjustments to existing data collection methods and protocols to enable collection of data for multiple-applications, e.g. from visual and bio-optical observations from existing in-line/underway surveys used for particulate matter and biological sampling.

GOOS is currently supporting efforts leading to enhanced coordination of Particulate Matter EOV observations. Several of the observing approaches used for particulate matter observations, traditionally focused on estimating particulate carbon and nutrient pools and fluxes, are similar to those used for marine debris. Moreover, the International Ocean Colour Coordination Group (IOCCG) has been developing technical reports and protocols for both in situ and remote sensing observations of ocean colour and its applications, with possible high relevance to marine plastics and other debris observations. A joint technical workshop between experts from particulate carbon and debris

observations could provide a useful step in cross-checking and potentially harmonizing best practices for water column particulate monitoring in situ and from space.

Global Data Assembly Centre for marine biogeochemistry and data synthesis products

Global Data Assembly Centre (GDAC) for marine Biogeochemistry

Developments are ongoing and funding was secured in Europe and in the US for future GDAC partners. After US NOAA Pacific Marine Environmental Laboratory (PMEL) and the Bjerknes Climate Data Centre (BCDC) at the University of Bergen signed a Memorandum of Understanding in 2018, the two organizations will apply to become official IODE Associated Data Units (ADU) in 2020 - thus completing one of the last steps prior to a formal GDAC application.

BCDC at the University of Bergen made an assessment of related tasks for an operational GDAC, which is covered by current and future activities. Technical Readiness Levels for data management activities are continuously increasing, and becoming a formal part of IODE will help to increase the visibility and usability of biogeochemical data. BCDC representatives attended several IOC UNESCO IODE meetings and will apply to become an official IODE GDAC in 2020. NOAA NCEI is interested in becoming a partner as well - an idea discussed during a visit to BCDC in November 2019. The overall concept of streaming data through the GDAC and how the effort relates to the needs for national data reporting and reporting into the UN system is briefly introduced below.

While the GDAC is primarily funded from European sources, it is a global effort based on the existing national data management structures and regional hubs or assembly centres. In most countries, data can be submitted via a National Oceanographic Data Centre (NODC). If a country does not have an NODC, one can submit the data via a regional DAC or hub. For instance, NOAA NCEI would be considered a hub in North America, and an Integrated Carbon Observing System (ICOS) would be a hub in Europe. For scientists working e.g. in South America, the simplest way would be to put an ERDDAP on the datastream used, which would then get picked up by the GDAC. In some instances, data providers might prefer to bypass the NODC and still be able to deliver into the UN system. In response to IOC requests, they can submit their data directly through the regional DAC or the GDAC which has the status of an IODE unit. Regardless of how the data providers choose to submit the data, it must be clear that GDAC is only responsible for streaming data, and not for reporting the data. The actual reporting takes place through the national bureau of statistics, and this need not go through the GDAC.

Operational data flow developments

While operational data flow including NRT (Near Real-Time) data distribution has been established for decades for mainly physical oceanographic parameters like temperature and salinity – the entire field of operational data flow is relatively new to many of the parameters in the field of marine biogeochemistry. Data obtained from biogeochemical sensors is often obtained in NRT mode (e.g. Biogeochemical Argo) made available to portals e.g. GOA-ON, but data is often not automatically quality controlled or integrated in global/regional NRT data products. There are many valid reasons, one major is the non-standardized system setups with a variety of measurement devices which makes it challenging to automate data flow and QC. Higher financial resources are needed to overcome this burden. At the same time data is often obtained in research projects with limited resources where the major focus is on science with and not on establishing an operational data flow. Activities in the US

(e.g. IOOS, NOAA), Australia (e.g. IMOS) and in Europe (e.g. ICOS, EMODnet) are moving towards making the data flow for the EOVs that are of interest for IOCCP (e.g. Inorganic Carbon EOV) operational, and to speed up data availability.

Addressing lack of sustained funding for SOCAT and GLODAP projects

Both GLODAP and SOCAT, two IOCCP flagship products, are community efforts that have become "brand names". Both data products are much used and well cited in literature. Both efforts are great successes and show the dedication of the ocean carbon cycle community to produce high-quality data. Efficient communication of the high impact of the products is the successful part of the "branding" process. However, both efforts remain practically unfunded, and rely on volunteer contributions.

There is an urgent need for the community to abandon the misconception that SOCAT and GLODAP are funded projects, and instead recognize the immense vulnerability of these voluntary efforts. While IOCCP continues to support SOCAT and GLODAP to a limited extent, e.g. to organize meetings, our priority is to help bring both efforts to a self-sustained mode.

In early 2020 IOCCP has taken initial steps in coordinating and galvanizing the community to assure stronger financial footing for global synthesis efforts such as SOCAT and GLODAP. A first step will be to provide a clear picture of the elements and resources needed for robust operations. This could be done through a report outlining the scope of the efforts, voluntary contributions to the SOCAT enterprise, and required resources for the core effort. It could include a view of the evolution of SOCAT to include more parameters, linking to other datasets and improved automation and visualization, and the resources needed for this. This report would provide a holistic view and offer funding agencies a clear picture of how they could contribute to the sustainability of the effort. A similarly scoped report could potentially be produced for GLODAP within the EU EuroSea project.

IOCCP SSG suggested committing adequate resources to realizing this proposed action, and recommended that the report should have a form of a business plan that could be used to successfully communicate both the value and needs of SOCAT and GLODAP efforts. IOCCP will coordinate the effort, ensuring that a common template is used for SOCAT, GLODAP and future data synthesis initiatives such as the one initiated for oxygen data, and ship-based time-series data.

Ship-based time-series product including development of QC routines

As already described elsewhere in the report, IOCCP SSG members Björn Fiedler and Benjamin Pfeil are leading the effort of developing a new pilot time-series data product. Within the EuroSea project, existing EOV synthesis products from in situ biogeochemical observations and high quality and long-term ship-based time series data will be optimally fused to obtain optimal estimates of EOVs and derived quantities in support of ocean climate and ocean health monitoring. This task will focus on the Inorganic Carbon EOV with all four of its sub-variables (Dissolved Inorganic Carbon (DIC), Total Alkalinity (TA), Partial pressure of carbon dioxide (pCO_2) and pH) and potentially the Oxygen EOV, including how to operationalise data flow and availability. The effort will develop quality control procedures for data from certain platforms e.g. ship-based time series stations, and subsequently integrate those quality controlled data with data from the GLODAP data product. As part of the tasks led by University of Bergen, European SOCAT and GLODAP quality control efforts will be operationalised, and the implementation of the quality control routines for ship-based time-series EOV data will be tested.

The next step towards the creation of the product will be a workshop which would discuss procedures for quality control of bottle data. It was decided that the work would not consider quality control of

sensor data, indicating strong complementarity between this workshop and the oxygen atlas undertaking where a task team was created to deal with mooring and other sensor oxygen data for the purpose of data management and synthesis product development.

IOCCP has recommended that the time series workshop be run back to back with the second workshop on oxygen data product in order to better align the two efforts, and reduce travel and logistics costs for experts likely to attend both events. IOC-UNESCO has tentatively agreed to host both events in Paris, France, likely to be held towards the end of October 2020.

As of February 2020, PIs of nine ship-based open-ocean time series sites have confirmed their interest in the workshop and data product development. While there is already a wide geographical coverage included, other station managers will need to be re-approached to maximize the community involvement. The initial focus will be on the open-ocean sites only because issues with quality control and comparability between coastal sites would be too challenging and beyond the scope of the initial demonstrator planned under EuroSea.

Technical capacity development, standards and best practices

Online training tool for ocean acidification data quality control

During IOCCP-SSG-14, Crisitan Vargas proposed to partially fund and organize a regional workshop on data quality control and data management for ocean acidification research in Latin America and other regions. Cristian requested co-sponsorship from IOCCP and mentioned the possibility of additional funding to be requested from the International Atomic Energy Agency's Ocean Acidification International Coordination Centre (IAEA OA-ICC), and multiple local funding partners, such as the Millennium Institute of Oceanography (IMO), in Chile. The workshop would give us the opportunity to incorporate a community of new ocean observers from, among others, Colombia, Costa Rica, Mexico, and Ecuador, which were funded by The Ocean Foundation for implementing carbon chemistry (pH mostly) monitoring in their respective countries, and whose instruments will have been deployed by the time of the workshop.

In order to better streamline such regional technical capacity building efforts related to ocean acidification, IOCCP decided to consult with GOA-ON prior to approving sponsorship and organisation of the workshop. Such a consultation involved GOA-ON Co-Chairs and Adrienne Sutton who has been involved in developing quality control guidance for the ocean acidification community through IAEA.

During a virtual meeting held in March 2020, the group agreed that there is a need for finding a creative approach (e.g. an online training platform / virtual user guide) to providing adequate online training (and re-training) resources in response to such a large demand among the community, and especially in light of restricted travel for an unforeseeable future. A potential project could involve a portfolio of online resources, including best practice documents, video instructions, discussion fora, webinars, etc.

Cristian confirmed that a project resulting in widely distributed manuals and protocols and associated training resources for carbonate system measurements would be suitable for the needs of the Latin American and supposedly other regional communities from developing countries. However, he also stressed that the basic information would need to be provided in at least a few languages, not just in English. Cristian agreed with the recommendations to invest resources into developing such a

comprehensive online product instead of organising one or more dedicated in-person training workshops.

It was further recommended to consult with members of existing working groups the main themes of which are related to ocean acidification observations, both to avoid overlap and to identify potential synergies. These include:

- IAPSO WG on Best Practice Study Group to identify approaches to be recommended for seawater pH measurement
  Co-led by Andrew Dickson (Scripps) with Kim and Bronte as members;
  http://iapso.iugg.org/images/stories/_working_groups/Best_practice_study_groups/pH_Best_Practice_Study_Group_2019-proposal.pdf
  Initial meeting took place after OSM 2020. The work of the WG would likely be too theoretical to fit into the proposed project but a link is clearly needed.
- SCOR WG 149: Launch of the Multiple Environmental Driver Design Lab for Experiments (MEDDLE; www.meddle-scor149.org), led by Phil Boyd.
  Kim Currie is to contact WG member Christina McGraw
- US OCB Working Group on Ocean Carbonate System Intercomparison Forum,
  Led by Brendan Carter (NOAA PMEL)
  https://www.us-ocb.org/ocean-carbonate-system-intercomparison-forum/
  Scope of the work likely does not consider quality control of pH measurements.

Consequently the decision for IOCCP was not to sponsor the regional workshop but instead engage in a broader collaborative project to develop best practice documents and corresponding online training resources for the ocean acidification observing community. In the next few months IOCCP and GOA-ON members will jointly develop an action plan and seek to obtain adequate financial support.

Sensors Training Course 2021 planning

Based on the very successful two editions of the sensors training course in 2015 and 2019 and in response to a great demand for such technical capacity building, the IOCCP SSG strongly supported organizing the sensors training course as a recurrent event. The SSG approved of the proposal to hold the course on a bi-annual basis, provided that we avoid overlap with other major international summer schools with which we might compete for funding as well as participants.

Tentative plans have been made to organize the 3rd IOCCP Sensors Training Course in June 2021, also in Kristineberg, Sweden. IOCCP SSG recommended supporting the organization of the course at a level of ca. 30,000 USD. IOCCP Co-Chairs and the Office have started a fundraising campaign in late 2019 in order to identify partners interested in co-sponsorship of the event allowing to secure 80% of the approximate budget of 100,000 USD by mid- 2020. By mid-May 2020 we managed to secure 50% of the total budget, with several ongoing co-sponsorship discussions.

1st ICOS OTC pCO_2 instrument inter-comparison

As announced by IOCCP through the communication channels, the 1st ICOS OTC pCO_2 instrument inter-comparison exercise was scheduled to take place on 24 Aug - 4 Sep 2020, at VLIZ in Oostende, Belgium. Tobias Steinhoff (GEOMAR, Germany) and Thanos Gritzalis (VLIZ, Belgium) are leading the effort. IOCCP was invited to join the Organizing Committee and provide know-how and experience related to organizing similar scale events. Organizers are committed to making this intercomparison global and to invite explicitly those colleagues who work at laboratories submitting their data to SOCAT.

The SSG approved the request to support travel for participants from developing countries, with a total contribution of 5,000 USD. The organizers ensured that there will be a final report with the results of the intercomparison published under the IOCCP umbrella. The IOCCP Director met the organizers at VLIZ in December 2019, a few weeks after the IOCCP SSG meeting in Sopot, to discuss the details and agree on IOCCP commitments as co-organizers of the event.

Due to COVID-19, the inter-comparison has been postponed until July 2021.

Surface ocean observations of biogeochemical parameters

SOCONET and OASIS

IOCCP will continue coordination efforts to operationalize surface ocean biogeochemical observations. Scientific evidence of the critical role that carbon dioxide (CO_2) levels in (and fluxes between) the ocean surface and atmospheric marine boundary layer (MBL) play in sequestering the anthropogenic CO_2 and therefore mitigating man-made climate change, has been overwhelming. The need for long-term sustained and accurate monitoring of those levels and fluxes has been called upon to enable accurate assessments for policy and decision making at regional and global levels. However, the measurements enabling monitoring surface ocean CO_2 and CO_2 ocean-atmosphere flux continue to be driven by scientific curiosity and is achieved mainly via research funding. IOCCP has already started engaging with several partners to work out a more suitable model where the need for monitoring is fulfilled by infrastructural support rather than piggybacked on research proposals, consuming our capacity (human and in terms of resources) to engage in other types of observations-based research.

In late 2018 and first half 2019, IOCCP experts contributed to the vision for surface CO_2 observations in the next decade by a review of the challenges and recommendations for the Surface Ocean CO_2 NETwork (SOCONET) and the wider community in an OceanObs'19 Community White Paper led by Rik Wanninkhof, published in July 2019 in Frontiers in Marine Science. The paper can be accessed at: https://www.frontiersin.org/articles/10.3389/fmars.2019.00400/full

SOCONET is a partnership of many investigators that have a major goal measuring surface ocean CO_2 and MBL CO_2 levels on an operational basis following agreed upon procedures. The accurate measurements will be disseminated within a year of measurement. Platform and instrument metadata tracking would occur in near-real time. The current list of platforms and participants that expressed interest in being part of SOCONET can be found at www.aoml.noaa.gov/ocd/gcc/SOCONET. The measurements are key inputs to products addressing important social, policy, and economic issues of our time as they pertain to marine health and anthropogenic carbon sequestration. While the surface ocean and MBL measurements are automated, the data reduction and quality control for the level of accuracy required for SOCONET are labor intensive, adding to the challenges of timeliness and cost of operation of the network. From an organizational perspective, securing and maintaining resources in these international distributed networks is critical, and means need to be explored to accomplish this. This holds true particularly for the communal aspects, including network design, data tracking, and coordination.

IOCCP is devoted to implementing individual recommendations from the Community White Paper over the next several years, working with several national, international and intergovernmental partners. Simultaneously, we will work closely with surface observing communities across disciplines to co-design, or rather adapt existing elements of the surface ocean observing system for maximum

efficiency, fitness for purpose and flexibility in terms of temporal and spatial coverage and a suite of parameters measured in any given time and space.

This work has also already started, triggered by several CWP's published in preparation for the OceanObs19. Cronin et al., Wanninkof et al., Centurioni et al., Muller-Karger et al., Pinardi et al., Steinhoff et al., just to name a few. Intense communication in the last 6-8 months resulted in a well described strategy for harmonization of proposed recommendations aimed at working towards an Integrated Surface Ocean Observing System. The concept of integrating, coordinating, and leveraging across disciplines (physics, biogeochemistry and biology and ecosystem observations) will hopefully be part of the UN Decade of the Ocean Science for Sustainable Development, allowing this multidisciplinary and multifunctional part of the observing system to fully develop.

In May 2020, a proposal to create a SCOR Working Group to harmonize the recommendations from the OceanObs'19 CWPs into a unified Observing Air-Sea Interaction Strategy (OASIS) has been submitted with the following initial core drivers:

- monitoring and predicting the ocean's influence on global weather and climate on timescales of days-seasons-decades
- monitoring and predicting marine weather in the ocean and atmosphere
- tracking ocean uptake of carbon dioxide and oceanic deoxygenation and denitrification
- studying how biology, biodiversity, and the surface ecosystems relate to changes in surface concentrations and fluxes of CO_2, DMS, and N_2O

Regardless of the outcome of the SCOR Working Group selection process, there are almost a hundred individuals committed to making an operational OASIS a reality and IOCCP as an organization as well as its individual members are part of this process. Specific proposed implementation timeline is described in the proposal which is available for review at https://scor-int.org/events/2020-scor-annual-meeting/

Autonomous surface vehicles

During IOCCP-SSG-14 the group discussed some new technological developments which should be on the radar of IOCCP. For instance, Saildrone Inc. has greatly increased the readiness level of the autonomous surface vehicles (ASVs) as an observing approach, performing important demonstrations of successful marine biogeochemistry surface measurements in both open ocean and regional seas through partnerships with leading research institutes such as NOAA, GEOMAR and University of Bergen.

A new model of data collection and dissemination, based on private-public partnerships (see OceanObs'19 CWP by Meinig et al., 2019), is opening up new opportunities for sustained marine biogeochemistry, not only in terms of coverage and resolution but also cross-platform data validation and multidisciplinary information product creation. IOCCP will consider whether a person familiar with running an ASV fleet sampling campaign be potentially invited to the IOCCP-SSG-15 meeting.

Meeting the needs of the coastal observing community

The Panel has discussed the current gap in Nutrients EOV expertise and whether there is a need to nominate another SSG member who would fill this gap. This position has remained vacant since the start of 2019 and related issues are tentatively a responsibility of IOCCP co-Chair, Masao Ishii. During 14th Session of IOCCP SSG, IOCCP Executive was asked to perform a thorough analysis of

the IOCCP Skills, Roles and Responsibilities Matrix (see report from IOCCP-SSG-13) and provide recommendation(s) on IOCCP's approach to future curation of the Nutrients EOV and identify criteria for subsequent open calls for new SSG members.

On one hand, it should be considered that the SCOR Working Group 147: Towards comparability of global oceanic nutrient data (COMPONUT) has already been dissolved and that there is currently no group conducting work related to coordinating nutrient observations in seawater. It was mentioned that there are a lot of issues with nutrient observations at the land-ocean interface and in the coastal zone. These would require application of sensors which were not considered by COMPONUT at all. A large increase in their deployment around the world for various applications is accompanied by challenges related to data quality control procedures, best practices and technical training. Nutrient sensors applications reach beyond climate studies, and are increasingly used for ocean health (e.g. water quality) purposes.

Developing indicators of nutrient pollution in marine waters to inform SDG targets has been on the agenda of UNEP as the custodian agency for the relevant targets. UNEP is responsible for promoting standards and methods applicable for national and regional monitoring efforts, including many parameters common to the Nutrients EOV. However, there has been no interaction between IOCCP and UNEP in this domain. As GOOS is looking to establish strong partnerships with UNEP on aspects of water quality and environmental monitoring requirements and capacities, IOCCP could play a vital role in joint coordination of standards and best practices as well as data management activities for nutrients measurements in both open ocean and coastal waters.

In effect of Douglas Connelly stepping down from IOCCP SSG in February 2020, the group decided to issue an early open call for a position which would not only maintain our capacity to coordinate and communicate with users of instruments and sensors in the open ocean domain, but also expand our focus onto nutrient and other inorganic biogeochemistry measurements performed routinely in the coastal environments, for various applications. The candidate would moreover need to take charge of technical capacity building initiatives, in particular organizing next editions of the training course on a suite of biogeochemical sensors.

Considering the excellence of all applications received in response to the March 2020 open call for a new IOCCP SSG member, we are confident that the nominated expert, once approved by the sponsors, will significantly improve IOCCP's capacity to better fulfill our Terms of Reference, and thus serve the growing needs of our community.