

XV Session of the International Ocean Carbon Coordination Project Scientific Steering Group & Global Ocean Observing System Biogeochemistry Panel of Experts (IOCCP-SSG-15)

17-19 November 2020, online

REPORT

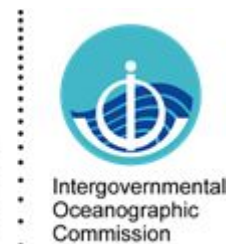


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SSG for 2020 and Participants List

IOCCP SSG Co-Chairs Masao Ishii and Kim Currie welcomed everyone to the XVth Session of the IOCCP SSG and GOOS Biogeochemistry Panel. They expressed gratitude to all for joining the meeting from across many time zones, some very inconvenient. Kim thanked all for extensive preparations for this meeting, including through pre-recorded narrated presentations. Kim introduced the agenda for the 3-day virtual meeting. This was followed by Maciej explaining the meeting etiquette. The full list of attendees is provided in Tables 1 & 2 below.

Table 1. 2020 SSG member composition and annual meeting attendance

Name (Gender)	Home institution	Country of residence	Expertize (Role)	Attendance
Kim Currie (F)	NIWA	New Zealand	Ocean acidification (Co-Chair)	attended
Masao Ishii (M)	JMA-MRI	Japan	Ocean interior observations (Co-Chair)	attended
Véronique Garçon (F)	CNRS-LEGOS	France	Oxygen	attended
Benjamin Pfeil (M)	UiB	Norway	Data & information access services	attended
Siv Lauvset (F)	NORCE	Norway	Synthesis activities	attended
Björn Fiedler (M)	GEOMAR	Germany	Time series efforts	attended
Rik Wanninkhof (M)	NOAA-AOML	USA	Surface CO ₂ Observations	attended
Cristian Vargas (M)	Univ. Concepcion	Chile	Ocean acidification	attended
Fei Chai (M)	SIO/Univ. Maine	China/USA	Observations - Modeling Interface	attended
Emmanuel Boss (M)	Univ. Maine	USA	Particulate Matter	attended

Table 2. Project Office staff and additional meeting participants

Name (gender)	Home institution	Country of residence	Role	Attendance
Maciej Telszewski (M)	IOCCP/IO PAN	Poland	Project Director	attended
Artur Palacz (M)	IOCCP/IO PAN	Poland	Project Officer	attended
Marie-Alexandrine Sicre (F)	CNRS-LOCEAN	France	SCOR Past President	attended
Patricia Miloslavich (F)	SCOR	USA	SCOR Exec Director	attended
Heather Benway (F)	WHOI	USA	OCB Executive Officer	attended
Sabrina Speich (F)	ENS	France	GOOS OOPC Co-Chair	attended
Gabrielle Canonico (F)	NOAA	USA	GOOS BioEco Co-Chair	attended
Lavy Ratnarajah (F)	Univ. Tasmania	Australia	GOOS BioEco Officer	attended
Albert Fischer (M)	IOC-UNESCO	France	GOOS Director	attended
Toste Tanhua (M)	GEOMAR	Germany	GOOS Co-Chair	attended
Richard Sanders (M)	NORCE	Norway	ICOS-OTC Director	attended
Tobias Steinhoff (M)	GEOMAR	Germany	ICOS-OTC Engineer	attended
Arne Körtzinger (M)	GEOMAR	Germany	SOLAS SSC Member	attended

Report

Major achievements and challenges since IOCCP-SSG-14

On behalf of IOCCP Executive, Maciej Telszewski presented an [Overview of major achievements and challenges since IOCCP-SSG-14](#). Maciej focused on two new themes introduced to the Panel which was made possible by two new SSG members joining our Panel: Emmanuel Boss to take the lead on Particulate Matter EOY, and Fei Chai taking the lead on the interface between observations and modelling. He described progress in developing a time-series synthesis product, and an oxygen atlas. He also talked about progress in setting up global coordination of IMDOS. Maciej highlighted the 2020 versions of SOCAT and GLODAP - flagship products of IOCCP. Other achievements mentioned by Maciej included the work of the IOC-UNESCO WG IOCR, and work on developing methodology for SDG indicator 14.3.1. In terms of adverse impacts of COVID-19, Maciej mentioned the need to postpone the IOCCP - ICOS OTC Training Course on a Suite of Biogeochemical Sensors until 2022. Deployment of autonomous platforms, buoys, floats and gliders were also significantly affected by cancellation of research vessel missions. Four GO-SHIP cruises were cancelled this year.

Perspectives from IOCCP sponsors

Scientific Committee on Oceanic Research (SCOR)

Patricia Miloslavich (SCOR Executive Director) thanked the SSG for the opportunity to attend her first IOCCP meeting. She gave an overview of the mission and activities relevant to IOCCP of the [Scientific Committee on Oceanic Research](#). Patricia highlighted the fact that there have already been 15 SCOR WGs which have dealt with ocean carbon in one way or another. SCOR's research projects also provide significant contributions to marine biogeochemistry. She focused on the SCOR WGs because this is where the interactions with IOCCP are most direct. Three new WGs were funded in 2020: OASIS (surface fluxes), ATOMIX (ocean turbulence), ReMO (Respiration in the Mesopelagic Ocean). Patricia also reminded the Panel that the current NSF/SCOR grant runs until 31 August 2021 and early in 2021 she will work with the IOCCP Project Director on documents needed for a full grant proposal to be submitted to NSF in the first half of 2021. Patricia also acknowledged the broad attendance at the recent SCOR Annual meeting, with a total of over 120 participants, indicating that some COVID-related impacts on the way we operate are beneficial.

It was noted that the SCOR Capacity Building Committee would accept a proposal to fund participation of developing country students at the Summer Course planned for 2022.

Recommendation: IOCCP to submit a proposal to the SCOR Capacity Building Committee to fund participation of students from developing countries to attend the 2022 IOCCP Sensors Training Course.

Responsible: IOCCP Office

Timeline: immediate

Global Ocean Observing System (GOOS), IOC-UNESCO

Albert Fischer (GOOS Director) represented IOC-UNESCO as the second sponsor of IOCCP. Albert gave an overview of the recent developments in the [Global Ocean Observing System](#) including IOCCP's role as the GOOS Biogeochemistry Panel of Experts. He summarized the GOOS 2030 Strategy and Strategic Objectives and talked about the role of IOCCP in the ongoing work on developing GOOS Implementation Plan. He emphasized the importance of staying engaged and aligned in terms of IOCCP Action Plan and GOOS Implementation Plan.

There was a brief discussion in plenary and an extensive chat discussion in response to a question on what efforts GOOS was undertaking to centralize access to biogeochemistry and ocean data in general. It was mentioned that the current plethora of data assembly centres (DACs), just in the US or in the EU, using different ways to deliver data, makes it hard for modelers to obtain a coherent global dataset but also hinders education and research of undergraduate students and early career researchers. While the carbon data seems to be most integrated, with CCHDO, SOCAT and GLODAP accounting for a coherent system, data for other biogeochemical EOVS require accessing many individual data collections in order to obtain a global picture.

The strategy of GOOS, as well as of WMO and IOC-UNESCO, is to advance interoperability of various data streams, rather than strive for their unification. The users should not be concerned which datastream they use as long as they have access to all data in the spirit of FAIR principles. Specifically, for the GOOS Observations Coordination Group (OCG), the strategy is to establish a consistent pattern of data delivery using ERDDAP, developed by Kevin O'Brien (NOAA PMEL, USA), which would allow many different systems to collect and harvest information in a consistent manner from different end points related to global observing networks. While this solution does not include many of the biogeochemistry data collected outside of the OCG networks, ERDDAP is an example of enabling federated systems characterized by machine-to-machine interoperability, based on DACs specialized in different data types. The ODIS architecture - an IODE project - is another example of a federated architecture. The EU funds several initiatives, such as H2020 Blue Cloud, EMODnet, CMEMS and others, which advance interoperability of data streams in an already very complicated European landscape of data. Global integration will require even more actors and dedicated resources to reach agreements on protocols and standards.

IOCCP has had a major focus on requirements for interoperability but major investments and agreements are needed, as well as long-term funding for establishment and maintenance. This is exactly why IOCCP has been working hard on sustaining SOCAT and GLODAP, and is now supporting the time-series data product and the oxygen atlas initiative - both of which will rely on interoperability rather than data centralization.

In response to a comment that the GOOS website has a link to 'Observations and data' that does not link to locations where data can be downloaded from, it was clarified that this page is being worked on right now to improve its technical and communication effectiveness. GOOS Steering Committee recently decided on an action around the mapping of data flow, in partnership with IODE and the WMO, as a start to: (1) identifying data flows for communications, and (2) identifying blocking points and gaps.

Presentations from IOCCP partner organizations

US Ocean Carbon & Biogeochemistry

The SSG listened to a pre-recorded presentation by Heather Benway (US OCB Executive Officer) on the [US Ocean Carbon & Biogeochemistry Program](#) and their recent and potential near future interaction with IOCCP. Among other things Heather referred to: the OceanObs'19 Community White Paper which included a gap analysis of data from shipboard time series, the EuroSea-IOCCP workshop on the time series synthesis product led by Nico Lange (GEOMAR, Germany), Bjorn Fiedler and Benjamin Pfeil, scheduled for the week after IOCCP-SSG-15, and the NSF EarthCube workshop and the resultant Marine Ecological Time Series (METS) NSF EarthCube Research Coordination Network. Heather introduced the three phases of the METS NSF EarthCube RCN:

- Phase 1. Spin-up and data model development: (i) steering committee, web presence, network building; (ii) consensus building workshop for common set of FAIR data solutions; (iii) METS data working group (scientists and managers).
- Phase 2. Broaden METS data users: (i) pilot regional user networks (observationalists, modelers, resource managers, educators, etc.); (ii) METS user workshop.
- Phase 3: METS data analysis capacity.

International collaboration across METS is critical to ensuring the success of this initiative, so US OCB is looking forward to working with interested members of the IOCCP and the international time series community.

In response to a question on whether the ship-based time series data synthesis effort was linked to the OceanSITES observing network, it was clarified that there is currently limited representation of principal investigators (PIs) running biogeochemistry ship-based time-series in OceanSITES. While some exchange with OceanSITES has been maintained, there is space for improved coordination.

Integrated Carbon Observing System - Ocean Thematic Center

The [EU Integrated Carbon Observing System – Ocean Thematic Center](#) was introduced by Richard Sanders, Director of ICOS-OTC. Richard explained the unique concept of ICOS as a Research Infrastructure (RI) and its legal meaning for EU member states. He summarized the key components of ICOS including the network of stations, the Head Office, the Carbon Portal, and specifically its ocean component, the OTC. It was mentioned that the recent evaluation of ICOS concluded that “The implementation of ICOS has been an astounding success and it is well underway to becoming fully operational.” Richard summarized key actions for ICOS in 2020 and beyond which include among other things: (i) continued efforts to simplify and support the process of submitting data to SOCAT (via QuinCE software); (ii) rolling out across the network gas standards from the ICOS CAL lab directly linked to NOAA standards; (iii) running a pCO₂ intercomparison with 30-40 people onsite at VLIZ in Ostend, Belgium in 2021. The presentation also shortlisted a few issues which ICOS will focus on in the next 5 years:

- ICOS continuous focus on expanding the subset of the European ocean observing stations that observe surface carbon cycle using one or more technologies
- ICOS role in developing a dialogue with Argo, other CO₂ observing systems, SOCAT
- ICOS as a reference network
- ICOS as part of the value chain, from funding observations to informing policies
- ICOS services - how to open them to the rest of the community

Discussions around these issues are summarized below:

Expansion of ICOS OTC

ICOS OTC is about 20 stations currently and will likely get to 30 or so if all the countries we are talking to will join. The cost for a station to join if their country is a member of ICOS, is about 10k EUR, which covers the supply of gas standards, help with data management, and a range of other services.

Integrating ICOS with GO-SHIP and other sustained ocean carbon observations

It has not been clear so far what ICOS can offer to GO-SHIP, Biogeochemical Argo and other networks measuring interior ocean carbon. One activity that is currently underway (led by Tobias Steinhof, GEOMAR, Germany) is leading the temporary production of 'emergency' (i.e. in response to COVID-19 related supply shortages) standards similar to Dickson's Lab CRMs. It is possible that production of gas standards will take place via one of the next Horizon Europe infrastructure calls.

The group discussed whether ICOS RI could support GO-SHIP reference laboratories. One of the challenges of including GO-SHIP style data in ICOS is that they do not fit the structure as ICOS is (mostly) focused on continuous, real-time (or near real-time) data flows. On the other hand, interior ocean carbon data provides critically important constraints on carbon fluxes, at least on a decadal time-scale. Integration of additional types of ocean carbon observations would also require interoperability of quality control (QC) operations. Integration efforts should include support for communities and archives performing QC as these operations are not handled by National Oceanographic Data Centres (NODCs) either.

GO-SHIP, SOCONET and Biogeochemical Argo networks are complementary in that they provide unique information on ocean carbon stocks and fluxes in different ways on different spatio-temporal scales. Biogeochemical Argo is critically dependent on the GO-SHIP reference data, and cannot be a substitute for ship-based observations. All in all, it remains an outstanding question to consider how the different observing approaches become properly integrated.

It was suggested that the issue of GO-SHIP reference laboratories and integration of the various ocean carbon observing networks could be brought up on various fora.

The need to reform the Research Infrastructure programme

In the context of discussions on GO-SHIP, the group commented on the likely need to reform the RI programme in Europe. RIs can be seen as great vehicles with longevity, stability and government level commitment. At the same time, some are focused on one element of the system, some on a single platform and others still on a specific domain of the ocean.

There was a suggestion to consider GOOS-like RIs funded at continental and global level, separate but linked to the idea of GOOS national committees seen as a forum for coordinating national ocean observations (currently fragmented for most nations).

Considering the attention on ocean observations from G7, SROCC and COP activities as well as the next round of RI funding in Horizon Europe called for 2021, the timing may be right for raising such issues internationally. For example, ICOS will be convening a meeting at JPI Oceans in 2021 where such a discussion point could be relevant.

Recommendation: Convene a virtual meeting about RI support for GO-SHIP reference labs among other aspects of integration between various ocean carbon observing approaches, with participation of ICOS OTC, GLODAP and GO-SHIP Co-Chairs, G7 GOOS Offices, and others as relevant.

Responsible: IOCCP Office

Timeline: early 2021

Revitalizing SOCONET

See discussion under the [Surface CO₂ Obs Theme](#).

Surface Ocean-Lower Atmosphere Studies (SOLAS)

Arne Körtzinger (GEOMAR, Germany) presented on behalf of the [Surface Ocean Lower Atmosphere Study](#), introducing how SOLAS is organizing its science into 5 core themes, many closely linked to IOCCP. SOLAS highlights from 2020 were also presented, including:

- Network of Integrated Air-Sea Observatories - Work to be linked with IOCCP and new SCOR WG OASIS.
- Geoengineering - SOLAS is putting together a proposal on a geoengineering programme for a UN Ocean Decade for Sustainable Development.
- Indian Ocean Integrated Topic - A workshop took place in September 2020. Fieldwork was halted due to COVID-19. The Indian Ocean remains a regional hotspot for SOLAS.
- Ship emission projects - Coordinated across 3 ongoing projects, a workshop on this topic is planned in 2021.
- Upcoming events - SOLAS Summer School has been postponed to 2022, same year as the SOLAS Open Science Conference in Cape Town South Africa (a hybrid meeting envisioned).

Two open questions were posted in the chat to consider for SOLAS:

1. Would SOLAS consider organizing a series of training webinars in 2021 so at least the community of early career researchers do not miss another full year of training?
2. What are the marine related activities in the geoengineering proposal for a UN Decade programme?

IOCCP will follow up on receiving a response to these questions and offer assistance if collaboration on these topics would seem useful.

Collaborative Activities with strong IOCCP involvement

A combined recording of presentations on the three topics discussed as collaborative activities with strong IOCCP involvement can be accessed from [here](#).

IOC-UNESCO Working Group on Integrated Ocean Carbon Research

Rik Wanninkhof gave a brief account of the origins of the IOCR WG, stemming from the void left after the disbandment of the SOLAS-IMBER Ocean Carbon WGs. IOCR, co-convened by the IOC-UNESCO, the IOCCP/GOOS Biogeochemistry, SOLAS, IMBeR, CLIVAR, and the Global Carbon Project (GCP), aims at:

- Identification of critical knowledge gaps in the ocean carbon cycle
- Identification of research activities in order to close these gaps
- 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 AR6 and subsequent AR's.

First IOC-R workshop took place in October 2019. Current and near-future focus stemming from Status Summary and Vision of Ocean Carbon Research:

- Strengthen sustained financial support for observing networks
- Enhance and coordinate the existing suite of carbon observing and synthesis projects
- Highlight regional priorities and need for process studies and experiments
- New technologies to enhance autonomous observations and analyses
- Integrate models and observations
- Boundary regions: Land-ocean continuum and air-sea Interface
- The changing role of biology in the ocean carbon cycle

The vision document, which should be published in early 2021, focuses on what are the pertinent research questions that the community should be addressing in the next 10 years.

- Will the ocean uptake of anthropogenic carbon dioxide (CO₂) continue as primarily an abiotic process?
- What is the role of biology in the ocean carbon cycle?
- What are the exchanges of carbon between the land-ocean continuum and how are they evolving over time?
- How are humans altering the ocean carbon cycle, and what are the feedbacks?

A forward look into the future, with the global society aiming to become carbon neutral by 2050, requires consideration of how the ocean will respond to such a change. 2.5 gigatonnes of carbon currently being taken up by the ocean provides a huge ecosystem service but the ocean could potentially even become a source rather than a sink.

Integrated Ocean Carbon Observing System (IOCOS)

Richard Sanders, Director of ICOS-OTC, presented the IOCOS initiative. IOCOS (<http://www.iocos.org/>) is a strictly time limited activity which aims to put pressure on the system to alter the funding for a very fragile carbon observing system. This inadequate funding situation prevents the responsible community from reporting the true state of the carbon cycle based on data on an annual basis – something we need to do to underpin carbon cycle management.

ICOS OTC has been talking to GCP, GOOS, G7 and recently also Copernicus and Saildrone to collectively propose how a significant investment for ocean carbon monitoring could be achieved. It is estimated that a return on such an investment would be 50:1. IOCOS has been preparing a paper to be released in 2021 which is likely to become a key year for ocean science.

SCOR WG 162: Observing Air-Sea Interactions Strategy (OASIS)

A new [SCOR WG 162 OASIS](#) was approved for funding by SCOR in 2020. OASIS stems from a multidisciplinary and multipurpose air-sea flux task team initiated by Meghan Cronin (GOOS OOPC), now led by Meghan jointly with Sebastiaan Swart (Gothenburg Univ, Sweden). This effort is an exciting example of combining recommendations from several dozen OceanObs'19 CWPs to enhance a specific element of the ocean observing system across disciplines.

OASIS proposed very ambitious [Terms of Reference](#), some of which intersect with IOCCP ToRs. There are four biogeochemists in the OASIS WG and IOCCP has collaborated with them before and will actively liaise with to help implement OASIS ToRs: Warren Joubert (SAWS, South Africa), Ute Schuster (Univ. Exeter, UK), Shuangling Chen (SIO, China) and Christa Marandino (GEOMAR, Germany).

It was commented that the OASIS SCOR WG 162 has a direct link to SOLAS Core Theme 2 and that close and direct interaction between OASIS and SOLAS is critical. This will be ensured by Crista Marandino who is both a SCOR WG full member and SOLAS SSC member.

IOCCP and the UN Decade of Ocean Science

This session aimed at reviewing and discussing how IOCCP is involved in transformative actions for the UN Decade to date and how it could be involved in the near future. The meeting participants were invited to watch ahead of the meeting a recorded presentation by Anya Waite (Co-Chair of GOOS) on [GOOS and the Decade](#). During the meeting, Maciej presented a brief overview of the UN Ocean Decade Action Framework based on a few introductory slides courtesy of Kirsten Isensee (IOC-UNESCO, France). This included a hierarchy of Decade Actions: from Decade Programmes, through Decade Projects and Activities, to Decade Contributions. The presentation was followed by an [Overview of IOCCP's initial involvement via: GOOS \(2 bids\), GO₂NE, GOA-ON](#) presented by Maciej and Kim on GOOS and GOA-ON programme bids, and by Veronique on the GO₂NE programme bid.

Open discussion around IOCCP's involvement at this stage:

In general, the IOCCP SSG pointed at the need to clarify and emphasize what the transformative aspects of the presented bid proposals are. Moreover, it was suggested that an estimate of the cost of the proposed programme needs to be clearly stated. More specific suggestions for the individuals bid were also provided.

Regarding the GOOS programme bid "Into the Coast" the following suggestions were made:

- It is critical to address water quality and aquaculture development. A truly transformative action could include making available a new generation of operational products derived from high resolution (10m footprint) ocean colour satellites (Landsat -8 and Sentinel 2A&B). Such products are currently not available to the public.
- Role of low-cost satellites which can advance high-resolution coastal observations.
- Addressing small scales of variability presents a major scientific challenge for ocean observations in the coastal zone.
- Stronger involvement of modelling groups, including expertise in biogeochemistry, was called for.
- IOCCP should maintain our focus on biogeochemistry and impacts on ecosystems. This will most likely complement input from CoastPredict which seems to be driven by issues related to ocean physics and climate.

Regarding the GOOS programme bid "Connect with Local Stakeholders" the following suggestions were made by the IOCCP SSG:

- Present use of ocean data by local stakeholders as the transformative aspect
- Include African representation on the group preparing the bid.

There was only one other programme bid mentioned in which IOCCP SSG members were involved: Bio GO-SHIP prepared by a US group. It was also suggested that IOCCP could play an active role in shaping any programme and/or project which considers ocean geoengineering solutions. There is a need to stress the importance of establishing an adequate baseline of the ocean carbon and marine biogeochemistry prior to proceeding with any geoengineering schemes.

IOCCP 3-5 Year Action Plan

Maciej gave an [Introductory presentation on the rationale and background for the initial proposal by IOCCP Exec](#) to generate a 3-5 Year Action Plan. The IOCCP Action Plan puts Action Items decided at annual and quarterly meetings at the foundation of IOCCP's delivery to longer-term (3-5 years) Actions developed to deliver IOCCP Terms of Reference.

Maciej introduced the three layered structure of the Action Plan, with IOCCP ToRs providing the top layer, long-term actions the middle layer, and specific action items operating on the shortest time frame (typically annual to sub-annual).

The overarching framework of IOCCP's mission are Terms of Reference developed by IOCCP SSG in response to community's need for specific services and approved by IOCCP sponsors. These ToRs serve as goals in the IOCCP Action Plan. Every decade or so, the

IOCCP SSG might decide to meet with executive bodies of its sponsors and perhaps representatives of major partners (observing networks, coordination programs, and selected high-impact stakeholders) to either confirm the ToRs for the next decade or to discuss potential changes in these ToRs resulting from the need to adapt IOCCP's mission to evolved needs of the community.

Actions might be developed by the IOCCP SSG in response to community needs expressed directly or indirectly (for example via high-level agendas and recommendations like SDG Goals or IOC WG on IOCR). Actions might also be proposed by sponsors and partners for approval of the IOCCP SSG. In either case they are delivered via implementation of related Action Items in a longer (2-5 years) period and might require contribution from several IOCCP Themes as well as close collaboration with several partners in the community.

Each Action Item has an assigned timeframe and gets reported on every one-fourth (25%) of the period between its approval and execution. Occasionally, when the timeframe for an action item is short (6-10 weeks or so), the frequency of reporting is decreased. Reporting (done in a variety of forms) will be uploaded to the shared drive and linked in the appropriate place of the Action Plan. This will allow panel-wide access to the status updates on decided Action Items, assure closure on individual action items and also provide legacy to be drawn upon when Panel rotations occur. Action Items usually span up to 12 months, and occasionally up to 18 months.

The IOCCP Action Plan is also intended to facilitate project management. It will be available as an online spreadsheet where the Office and the SSG monitor performance. Regular, transparent reporting on action items, with links to documents demonstrating progress and delivery of outcomes, will also provide a much needed legacy, e.g. passed on to new SSG members rotating onto the Panel.

IOCCP Co-Chairs expressed their hope that the Action Plan in the proposed form and structure will improve our long-term planning and better align with long-term strategies and implementation plans currently being developed by GOOS or the UN Decade.

IOCCP Themes

The IOCCP SSG members submitted written reports on the status of past year's action items and proposed future actions related to the theme(s) they are responsible for. For each theme, a narrated pre-recorded presentation was made available to all meeting attendees. During the virtual meeting, SSG members responsible for individual themes were asked to present a brief summary of the pre-recorded presentation with a strong emphasis on the proposed new action items. The presentations were followed with a discussion in plenary, carried out through oral interventions and through the chat.

Time Series Efforts

Björn Fiedler [presented the Time Series Efforts theme](#). Björn also announced his decision to step down from IOCCP SSG before the end of his second term due to an increasing number of commitments anticipated for 2021 and beyond. He will continue to coordinate IOCCP time series efforts until a new SSG member is nominated, likely in April 2021. An open call for his position was released at the beginning of December 2020.

Below is a report from past year's activities and discussion on the proposed future action related to international coordination of time series efforts.

Past Activities

Time-series data synthesis product

An actionable outcome of the last Earth Cube time-series workshop in Honolulu (2019) was the creation of a platform-focused ship-based time-series (TS) pilot data product on biogeochemistry (BGC) in general, and inorganic carbon in particular (similar to GLODAP). Achieving interoperable data among the TS sites and interoperability with the framework of related inorganic carbon data products (GLODAP, SOCAT, BGC Argo) to easier synthesize global trends and variability in (interior) ocean BGC, is the main driver behind. In order to facilitate this process, a pilot data product of ship-based BGC time-series data is being developed which is funded by the EU H2020 project EuroSea (www.eurosea.eu). A PhD position for this task was jointly funded by EuroSea and the German Digital Earth program. IOCCP SSG members (Benjamin Pfeil, Björn Fiedler), Prof. Dr. Arne Körtzinger as well as the GOOS Co-chair, Toste Tanhua (both from GEOMAR, Germany) are jointly supervising the student who is also involved in GLODAP QC (Nico Lange).

During the past year data from 12 ship-based biogeochemical time-series (see Tab. 1) were collected and transferred into a harmonized data set for further development of QC routines. The next step is to discuss with time-series PIs and external experts the development and application of QC routines in order to ensure inter-comparability of time-series data.

Table 3: Time-series stations participating in the development of the pilot data product.

Time-Series Site	Location	Time Range	Frequency	Depth
KNOT	North Pacific	1997-	1-3 cruises/yr	6000m
K2	North Pacific	2001-	1-3 cruises/yr	6000m
ALOHA	Tropical North Pacific	1988-	monthly	4800m
MOTS	South Pacific	1998-	6 cruises/yr	1000m
ESTOC	Subtropical North Atlantic	1994-	4 cruises/yr	3600m
BATS	Subtropical North Atlantic	1988-	15 cruises/yr	4500m
CVOO	Tropical North Atlantic	2006-	1-10 cruises/yr	3600m
A Coruña RADIALES	North Atlantic (coastal)	1989-	monthly	80m
CARIACO	Caribbean Sea	1995-2017	monthly	1300m
DYFAMED	Mediterranean Sea	1991-	monthly	2400m
Irminger Sea	Subpolar North Atlantic	1983-	4 cruise/yr	1000m
Iceland Sea	Subpolar North Atlantic	1983-	4 cruise/yr	1850m

Time-series community workshop

Due to the SARS-CoV-2 pandemic the planned in-person community workshop had to be transformed into a virtual event which took place on 23-25 November 2021. Overall 20 participants attended, thereby representing not only time-series PIs but also international programs and initiatives such as IOCCP, GOA-ON, US OCB, GLODAP, SOCAT, EU H2020 EuroSea and the newly formed Earthcube time-series Research Coordination Network (RCN) for Marine Ecological Time-Series (METS; see below).

Specific Goals of this meeting:

- Review analytical and QA/QC routines of each contributing TS site for the core parameters (S, T, O₂, nutrients, inorganic carbon) using the Bermuda 2012 outcomes as the basis
- Review data flow and management of each contributing TS site
- Agree on scope and format of the pilot data product, defining scientific objectives the pilot can address
- Discuss QC routines for the pilot
- Facilitate international time-series collaboration
- Form a group of experts that give advice to the development of the pilot and its later transformation into a product

The workshop built upon the two most recent (in total four) workshops focusing on BGC ship-based time series:

- BIOS, Bermuda (2012): Methodology of individual TS sites (“TS at a glance”) → TS-Selection, Basis for method sheet, Sources for offsets
- NSF Earth Cube TS workshop, Honolulu (2019): One of the actionable outcomes: An inorganic carbon focused TS pilot product

Furthermore, the workshop was closely tied to the long-term EarthCube RCN for Marine Ecological Time-Series (METS) project, which aims at developing a community- agreed FAIR METS data model. A workshop report will be available in the coming weeks.

Future Activities

Data product

The work on the time-series data product will continue within the framework of the H2020 EuroSea project. Depending on the expert feedback from the upcoming workshop the QC routines will be further refined. A second workshop with participating time-series PIs could be held in order to plan the release of the actual product in order to discuss a governing structure for a potential continuation of the product. Such a workshop could take place as a side event of a larger conference in late 2021 (assuming that travel would be feasible again) and should definitely be concerted with the METS RCN activities (see below).

METS RCN

Another actionable outcome of the Earthcube time-series workshop was the development of a proposal for the US Earthcube Research Coordination Network (RCN) to address issues of vocabulary, data/metadata reporting, citation, discoverability etc. to enable synthesis and broader applications. The proposal for a Marine Ecological Time Series (METS) RCN was submitted by a US OCB consortium and in October 2020 got funded for a 3-year period (see more details [in this section of the report](#)). The METS objectives are:

- Bring together members of the oceanographic, data science, and informatics communities to build consensus on key components of a FAIR data model for METS, including common vocabularies, metadata reporting standards, and data citation practices (METS data model consensus building workshop, METS data working group)

- Engage broader METS data users, including modelers, educators, and decision makers, to facilitate broader applications of METS data and foster collaborations and regional networks to address climate and environmental challenges (broadening METS data users workshop)
- Build community capacity for METS data analysis, statistical methods, and data-model integration (METS data hackathon)

A close coordination with the METS RCN is envisioned both with regard to the development of the pilot data product as well as the formation of a time-series PI and user community. An active engagement from IOCCP with the above-mentioned METS objectives and activities would be important for adding the global (GOOS) perspective to this initiative. Therefore, it was agreed that IOCCP will assist US OCB in agreeing on an adequate representation of time-series PIs on the METS RCN Steering Committee.

It was pointed out that advances on data and metadata standards are critically needed for ship-based time series observations to be recognized as a coordinated network in GOOS. Biogeochemical and biological time-series observations are currently not coordinated by the GOOS Observations Coordination Group (OCG) or reported on by OceanOPS. The [OCG network attributes](#) (adjusted for what is feasible for biological networks as well) were introduced to the time series community during the EarthCube workshop, and will provide guidance to METS RCN as well. IOCCP was asked to shepherd the conversations with OCG on how the ship-based time-series network can become better integrated into GOOS. The OceanSITES network, coordinating a different type of fixed-point observations, predominantly from moorings, has had a historical focus on physical observations and is only gradually expanding into biogeochemistry. SCOR WG 154 is working on a report on incorporation of biological measurements on OceanSITES platforms expected to be released for public comments before the end of 2020.

Additional interaction with GOOS BioEco Panel as well as the OceanObs RCN, led by Frank Muller-Karger (USF, USA) was recommended for METS RCN to further enable integration of biological data into the ocean observing system.

Recommendation: Ensure adequate international representation of time-series PIs on the METS RCN Steering Committee.

Responsible: IOCCP Office, a new SSG Expert for Time Series, Heather Benway

Timeline: immediate

Financial implications: none

Synthesis Activities

Siv Lauvset [presented the Synthesis Activities theme](#). Below is a report from past year's actions and a discussion on the future actions related to coordination of biogeochemical data synthesis activities: (i) SOCAT, (ii) GLODAP, and (iii) any other synthesis products.

SOCATv2020

In June 2020, SOCATv2020 was released. You can find details of this release in the poster posted at <http://www.ioccp.org/index.php/synthesis-activities>

It is worth noting that due to its automated online platform and support from data management teams in Norway and the US, and despite minimal funding, SOCAT is a surprisingly operational endeavor. Despite pandemic-related lockdowns in most countries involved, and enforced working-from-home for several critical months, the 2020 release of SOCAT happened on time, and with only minor problems. This speaks also to the dedication of the people involved in maintaining SOCAT updates. In 2020 Karl Smith, who has been instrumental for SOCAT since the beginning and particularly in the development of automated systems and platforms for data upload and QC, retired. He will be sorely missed by the SOCAT community.

The only big issue in 2020 was related to the assignment of DOI to the original data files. In previous versions, individual, SOCAT-enhanced (In addition to the submitted data, SOCAT-enhanced files include: recalculated fCO₂ plus woce flag, algorithm for calculations, bathymetry from ETOPO2, salinity from WOA, pressure from NCEP/NCAR, GlobalView xCO₂, and calculated ship speed) data files were archived at Pangea with a Pangea DOI. This solution is no longer viable and it is recommended that original versions of data should remain in national archives which would also assign the DOI. Thus, NODCs would gradually be given more responsibilities. NCEI (OCADS) can receive data and serve a copy according to the CC-BY license, but the original version of data should remain in a national archive. NODCs (with help from data PIs) should ensure that original data gets there.

The SOCAT global group made their recommendations at their meeting on 28 May 2020, and many of the changes were implemented in the SOCATv2020 update. In addition, members of the group presented their vision for future SOCAT releases - visions which require funding to implement. These include:

- Larger role for NODCs to e.g. provide DOI for relevant original datasets, and meet SDG14.3 criteria
- Standardize data and metadata format
- Single submission point for PIs
- SOCAT harvests data from a single submission point.
- In collaboration with SOCONET, to get in place a data center-independent interactive map for accessing data from various SOOP lines (i.e. clicking on a line in the map takes one to the data centre that serves the data)

IOCCP-SSG-14 Action Item #14: *Determine a strategy to include an uncertainty estimate in place for the QC flag approach in SOCAT. The strategy should include the interest, feasibility and resources required, and be reported to SOCAT Global Team and IOCCP SSG at IOCCP-SSG-15.*

A key requirement for observations, including surface water CO₂ measurements is to provide an estimate of accuracy. While data set accuracy estimates are provided in data collations such as SOCAT and GLODAP, there are increased requests from stakeholders, such as data assimilation modelers, to have an uncertainty estimate associated with each

measurement. In coordination with Siv Lauvset a strategy is being developed to include an uncertainty estimate in place of the QC flag approach in SOCAT.

Siv Lauvset and Rik Wanninkhof had a meeting at AGU Ocean Sciences in February 2020 to outline a plan with a goal to publish a white paper explaining the reasons for the changes and the need for including uncertainties in SOCAT products. The plan was briefly mentioned at a SOCAT global group meeting in April 2020, but was not discussed due to time constraints. Due to the pandemic, the work has not progressed very much since February 2020. The plan is as follows:

- Start with automatically adding a column, where QC flags A and B get an assigned uncertainty of 2 μatm , QC flags C and D get an assigned uncertainty of 5 μatm , and QC flag E gets an assigned uncertainty of 10 μatm .
- The QC flags should be retained since those are assigned for an entire cruise, while the uncertainty may vary based on the WOCE flag.
- Next steps will be to (i) allow changing the automatically assigned uncertainties if one can document that true uncertainty is different from that assigned; (ii) allow the uncertainty to vary with WOCE flag.
- Final step would be to build error propagation into QuinCe and LabView GO QC routines (the most commonly used routines for data processing)
- The output format in SOCAT would be adapted to include uncertainty and an uncertainty would be determined for the gridded product.

Specific notes on how to handle WOCE flag 3:

WOCE flag 3 indicates questionable data, but data in SOCAT with this flag are usually not questionable but out of standard gas range, have large uncertainties in measured temperatures, or large difference between intake SST and equilibrator temperature. All this indicates larger uncertainty, but not necessarily questionable data. We recognize that it may be difficult to quantify the additional uncertainty due to these factors, which is why building error propagation into the software is necessary. Some changes to the overall QC process will also become necessary.

During IOCCP-SSG-15 it was suggested that quantifying uncertainties robustly for every data point remains a major action for SOCAT and IOCCP. Although challenging to obtain, the prospect of assigning individual uncertainties might motivate researchers to submit more data and hence increase the coverage and density of data in SOCAT.

It was decided that the action item from IOCCP-SSG-14 should be carried forward and completed in 2021.

Recommendation: Determine a strategy to include an uncertainty estimate in place for the QC flag approach in SOCAT. The strategy should include the interest, feasibility and resources required, and be reported to SOCAT Global Team and IOCCP SSG.

Responsible: Siv

Timeline: IOCCP-SSG-16

Financial implications: none

SOCAT: Future Activities

SOCATv2021

Preparations for SOCATv2021 continue as planned, with submission deadline on January 15, 2021 and release in mid-June 2021. SOCATv2021 will already benefit from a standardized and automated metadata template for submission and quality control.

In addition to the SOCAT business plan and the issue of assigning DOIs (see above) there are some unresolved issues for SOCAT which the SSG briefly discussed:

- SOCAT QC remains vulnerable due to few volunteers being responsible for a major part of the process. The SSG was asked for suggestions on how to recruit new experts to perform QC. The responses emphasized the need for making SOCAT operational as soon as possible, as part of the initiative to make the entire value chain around ocean carbon observations operational (see discussions on IOCOS in this section of the report).
- The need for regular updates to the SOCAT ESSD paper was mentioned. Such an update is unlikely to be published until dedicated funding is secured.
- It was mentioned that the SOCAT metadata editor will be ready for SOCAT version 2021 which will adopt an IODE metadata format used for SDG 14.3.1 indicator data delivery, meaning a significant amount of new entries added to the metadata sheet. This will facilitate the data QC process.
- Behind SOCAT data there are research questions to be answered such as the one on the difference between using sea surface temperature measured at a few meters depth vs the actual temperature at the surface, i.e. skin temperature.
- More and more sensor data is and will be available through SOCAT. Currently, plenty of sensor data is not included in SOCAT but for example was included in a NOAA data product from 2019. There is a need to analyze similarities and differences between these two products.
- SOCAT is largely unfunded at the moment, but is able to keep going due to the high level of automation and large degree of volunteer effort. The retirement of Karl Smith at NOAA PMEL is already noticed, and could have consequences for the 2021 release which we are unable to foresee at the moment. I see no direct action IOCCP can take to help resolve the SOCAT funding crisis, apart from what is already done to communicate the issue broadly. Strong support and endorsement of any and all efforts to secure funding is greatly appreciated.

GLODAP: past activities

GLODAPv2.2020

Spring 2020 was spent preparing GLODAPv2.2020. There were a series of virtual meetings to discuss results of the crossover analysis and decide on adjustments for the new cruises. The updated product was released on June 23, and the living data ESSD paper submitted at the same time. The release poster, with details about the updated product, was published on IOCCP website here: <http://www.ioccp.org/index.php/synthesis-activities>

The ESSD paper is currently in revision after review. The revisions are all relatively minor and we expect the paper to be accepted and published in 2020.

In addition to the meetings to discuss GLODAPv2.2020 there was a meeting on GLODAP automation on October 1, attended by the GLODAP chairs and data people in Bergen and Seattle, and a full RG on October 13. Important topics covered at these meetings were how to raise funding for GLODAPv3, and a plan to write a so-called “GLODAP manifesto”.

In summer 2020, after the release of GLODAPv2.2020, Are Olsen announced that he is stepping down as co-chair of GLODAP. Siv K. Lauvset was chosen to take over, and will co-chair along with Toste Tanhua. Are Olsen continues as a member of the RG.

IOCCP-SSG-14 Action Item #13: Write and publicize a business plan for SOCAT and GLODAP

General budget for the GLODAP effort was created and presented at the GLODAP data meeting in San Diego, USA in February 2020. This initial budget estimate for GLODAP Annual Updates was prepared by Are Olsen and Benjamin Pfeil (University of Bergen, Norway) and Toste Tanhua and Nico Lange (GEOMAR, Germany) and is quoted below. Note that this budget assumes that there exists a LAS based system for data ingestion, which the community currently does not have. A wider “business plan”, including a more detailed work plan, was discussed at the GLODAP automation meeting on October 1, 2020.

GLODAP Initial Budget - version 11.02.2020

Overview of tasks involved

- Yellow data ingestion + primary QC
- Green secondary QC
- Blue make and publish product
- Gray system maintenance

Per cruise:

- Obtain cruise and metadata
- Get constant units and transform into exchange format
- Consistent 1st QC using AtlantOS (communication to PI!)
- Merge CTD and bottle data
- Run crossover analysis
- Eventually run MLR, carbon interconsistency and tracer analysis
- Evaluate cruise
- Select plots for upload
- Upload results to adjustment table

Per version:

- Reference group meeting
- Merge new version
- Double check new version
- Write/document paper

Infrastructure Maintenance:

- Adjustment table
- Front end
- Cruise summary table

- Running & updating ingestions system
- Running & updating QC system
- Overall coordination

Anticipated annual time consumption and budget

For handling approximately 40 cruises per year. Under the assumption that we have LAS based system for data ingestion that PIs use for uploading the data such that minimal time is used for formatting. GLODAP does primary and secondary QC (using LAS tools) and communicates with PIs regarding data issues.

What	PMs	Cost (k€/k\$)
Ingestion and 1 st QC	3	30
2 nd QC	3	30
Make product and check	1	10
Update paper	1	10
LAS Infrastructure maintenance	3	30
Adjustment table maintenance	1	10
Communication/coordination	1	10
Meetings to agree on adjustments ^a	1	10
TOTAL	14	140

^a3 days meeting, 10 people participating

Total estimated costs for one annual GLODAP update, assuming LAS tools are in place, 140 k€/k\$, not including time spent by PIs preparing and uploading data. Assuming a total cost of 1.5 million €/k\$ per cruise, this is ~0.23% of the costs involved for obtaining the data

During IOCCP-SSG-15 the importance of developing and publicizing business plans for GLODAP and SOCAT was reaffirmed. It was decided to carry this action item forward into 2021. The SSG recommended that we seek endorsement from all our stakeholders (in the broadest definition of the word) representing the entire value chain of observations. It was suggested to take advantage of the fact that a large number of users, including those benefiting from high-level products for policy makers (e.g. Global Carbon Budget), rely on the annual releases of both products without fully realizing where the data comes from. Support from IOCCP Office was requested for this activity with respect to communicating the importance of both products, and disseminating the business plans.

It was mentioned that this activity could benefit from the ongoing work under the IOCOS initiative. ICOS OTC submitted a request to JPI Oceans for a meeting to support planning the formation of an operational multiplatform carbon observing system including all elements of the value chain from technology innovation through to observations, data management, data synthesis, satellite integration and outreach. What is meant by operational here is that there are no critical single points of failure, including no volunteers, etc. The meeting aims to produce an overview of a blueprint on how to develop such a platform supported by the community, to be presented at the upcoming COP26 in the UK in November 2021.

Recommendation: Write and publicize a business plan for SOCAT and GLODAP.

Responsible: Siv Lauvset, IOCCP Office

Timeline: November 2021

Financial implications: none

GLODAP: Future Actions

GLODAPv2.2021

Preparing GLODAPv2.2021 continues as planned, with an expected release in June 2021. Deadline for submitting new cruises to GLODAPv2.2021 is set for the end of January 2021. Nico Lange (GEOMAR, Germany) is working on QC for the new cruises. The list of new cruises to be added in the 2021 release is [here](#).

It was clarified that currently there are no plans to move away from voluntary QC efforts. Even if 1-2 people worldwide could be funded to lead the annual data QC process, some volunteer assistance would likely be necessary. Obtaining funding for GLODAP QC, as was the case with Siv during the H2020 AtlantOS project, is strongly desirable and was discussed in the context of the wider GLODAP business plan (see above).

Towards GLODAPv3

The GLODAP effort has basic funding secured for the next 2 years, mostly thanks to the H2020 EuroSea project. However, there are plans to release GLODAP version 3 in 2024 and this large undertaking would require significant new funding. IOCCP was requested to help in fundraising efforts. Apart from funding, there are several near-term issues that should be resolved to enable production of GLODAPv3.

First, GLODAP needs an automated online platform for data upload and QC, similar to what SOCAT already has. This is needed if we are to achieve our goals of operational annual releases of the data product. Efforts continue to secure funding for this. As part of this we will expand on the current cost overview (see above) and detail the work flow and cost estimates contributing to relevant recommendations.

Second, there are pH-related issues in the data product which require fixing prior to release of GLODAPv3. GLODAP RG requested support from IOCCP to send 1-2 people to the 3rd US OCB [Ocean Carbonate System Intercomparison Forum \(OCSIF\) Working Group](#) meeting planned for early summer 2021, and which would address the pH-related issues.

Third, as in SOCAT, there are currently no uncertainty estimates included in GLODAP products. There is also no error propagation accounted for in the calculated parameters. Including uncertainties is high on the list of requirements but a strategy needs to be developed and resources found to enable this process.

Recommendation: Assist GLODAP RG in obtaining explicit funds to enable production and release of GLODAP version 3, including support for actions addressing outstanding issues related to an automated online platform for data upload and QC, pH calculations and quantifying uncertainty estimates.

Responsible: Siv Lauvset, IOCCP Office

Timeline: November 2021

Financial implications: low

Other Synthesis Activities

There are currently no synthesis activities supported by IOCCP other than SOCAT and GLODAP. However, the planned ocean oxygen synthesis is likely to receive IOCCP support from both the oxygen activity and the synthesis activity responsible persons.

Ocean Acidification

Kim Currie and Cristian Vargas jointly [presented the Ocean Acidification: from regional to global Theme](#). Cristian has announced his decision to step down from the IOCCP SSG (OA Regional), to concentrate on his work as Co-Chair of LAOCA (see below). Considering strong developments of GOA-ON Regional Hubs, and strong representation of IOCCP SSG members on the GOA-ON Executive Council, it is recommended to combine OA Global and OA Regional Focal Points and make that a responsibility of a single IOCCP SSG member.

Past Activities

IOCCP-SSG-14 #11: *Enquire about the next edition of the inter-laboratory comparison assessing the quality of seawater carbon dioxide measurements, and if relevant support the participation of LAOCA members.*

As of December 2020, there was no inter-laboratory comparison planned. IOCCP SSG recommended that this action should be retained and extended, and that when (if) such an exercise is held, IOCCP provides capacity building support, through an application process (see below).

IOCCP-SSG-14 #10: *Organize and co-sponsor a regional workshop for Latin America and other developing countries on carbonate chemistry data QC and submission into SOCAT.*

This activity has been expanded, and now involves development of an Ocean Acidification Data Quality Control Online Package. The joint GOA-ON – IOCCP Task Team is led by Adrienne Sutton (science) and Maciej Telszewski (initial project management), and will include:

- Community-developed best practices for level 1 QC of ocean acidification chemical data (pH, total alkalinity, pCO₂, dissolved inorganic carbon).
- Bringing together a combination of different types of resources from video to slideshows to written materials to interactive decision trees.
- Fully accessible online to aid in learning and putting into practice data QC techniques
- Downloadable resources to enable offline use for researchers in areas with unreliable access to the internet. Translation into several languages is planned.

Sustainable Development Goal 14, Life Below Water

The UN SDG Target 14.3 is to “Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels”. The first data submissions by UN member states opened in January 2020. The data portal, hosted by IODE, has been updated following user comments.

GOA-ON coordinated activities

A tight link between IOCCP and GOA-ON is ensured by the fact that IOCCP has a programme representative on the GOA-ON Executive Council (currently Kim Currie) and three other IOCCP SSG members also serve on the GOA-ON EC. GOA-ON membership currently includes 750 scientists from 100 countries who contribute to seven regional hubs. A distributed secretariat provides management and administrative services. The GOA-ON membership is linked and is informed via several active communication tools, including the website (www.goa-on.org), newsletters and social media. The OA-ICC manages the daily newsfeed, a bibliographic and a biological response database. The GOA-ON Data Portal

now includes data links, metadata and track visualizations from 71 Biogeochemical Argo Floats (BGC Argo). The OA Information Exchange is hosted by the US Interagency Working Group on Ocean Acidification.

In lieu of the postponed Oceans in a High CO₂ World Symposium, the inaugural OA Week was held in September 2020 by GOA-ON. A webinar series was launched with each Regional Hub hosting an online symposium and forum. In-person meetings were held by the North American Hub, and virtual meetings held by several of the other regional hubs. See below for more details on LAOCA activities, specifically.

Capacity Building continues to be a major initiative in the OA community, with mentoring, training, resource development and equipment provision activities taking place at the global and regional levels. The Pier2Peer mentorship programme assists with knowledge exchange and collaborations, with the opportunity for scholarships and financial assistance. Training workshops and the GOA-ON-in-a-Box programme are financially supported by a number of institutions including NOAA, IAEA, IOC and The Ocean Foundation.

Other international OA Activities

The OA Alliance and The Ocean Foundation co-hosted a virtual workshop on communicating OA science to decision and policy makers and other stakeholders, in October 2020. The Commonwealth Blue Charter - OA Action Group (New Zealand as the champion) has held a virtual coffee meeting and are developing an Ocean Acidification policy-makers workbook to assist policy makers in the identification of strategies to combat ocean acidification, specifically targeted at Commonwealth Member States, including small-island developing states.

Latin-American Ocean Acidification Network (LAOCA) activities

- The new Co-Chairs in LAOCA for the period 2020-2023 are Dr. Carla Berghoff (INIDEP, Argentina) and Cristian A. Vargas (UdeC, Chile). In consequence, Cristian Vargas is leaving the SSG IOCCP due to the multiple commitments associated with this new position.
- LAOCA has completed its Governance Plan. The first edition is available only in Spanish on ResearchGate. New LAOCA website is being finalized and the Governance Plan will be published there, hopefully in Spanish and English.
- The Latin-American community has been very active during 2019-2020. They have continued to focus on formalizing agreements and defining protocols for pCO₂ measurements in Latin-American countries in the framework of LAOCA. LAOCA has also been working actively to promote the inclusion of Ocean Acidification on political agendas of member countries and through the pursuit of cooperation agreements among LAOCA members. LAOCA is presently working on a proposal for a regional Data Portal for pH/pCO₂ data from buoys, research cruises, and time-series. From the beginning this effort is focused not only on the scientific community, but also on a variety of stakeholders such as the aquaculture industry.

Impact of the COVID-19 pandemic

- The 5th International Symposium on the Ocean in a High-CO₂ World, which was supposed to be held in Lima, Peru in September 2020, has been postponed until

September 2021. This postponement also impacted several planned side meetings including those of the GOA-ON EC, and the LAOCA Regional Workshop.

- Several research cruises and other type of field work was cancelled or postponed
- Several Labs experienced extensive lock-downs
- CRM supply severely interrupted (see below)
- Instrument purchase and maintenance hold-ups

Future Activities

OA data quality control online package

In response to initially proposed *IOCCP-SSG-14 Action Item #10 "Pending further information on the workshop scope and agenda, organize and co-sponsor a regional workshop for Latin America and other developing countries on carbonate chemistry data QC and submission into SOCAT"*, and based on the recommendations from IOCCP SSG VMQ1 in 2020, IOCCP along with GOA-ON and other partners discussed a new creative approach to providing training under global travel restrictions imposed for the foreseeable future. It was agreed that there is large demand in the ocean acidification observing community for training (and re-training) in data quality control techniques. In the course of several online meetings, a scope of work document was created by Adrienne Sutton (NOAA PMEL, USA) which describes a collaborative project to develop best practice documents and corresponding online training resources in data quality control for the ocean acidification observing community.

The OA data QC online package is proposed as a joint GOA-ON and IOCCP endeavour with Adrienne Sutton from NOAA-PMEL, USA, leading the task team. IOCCP has committed to providing office support and was asked to consider co-sponsorship of this initiative.

In the second part of 2020 IOC-UNESCO has confirmed its involvement, but the Task Team remains to be finalized. Invitations to several experts will be sent out soon. One of the immediate tasks will be to develop a draft budget and assess the timeline for developing the package.

During IOCCP-SSG-15 it was clarified that the online OA QC tool will only include inorganic carbon chemistry components and not the biological impacts of OA. Gabrielle Canonico informed the SSG that the GOOS BioEco panel and MBON have been in discussions with GOA-ON and also within the US OA Program about advancing standard approaches to biological data management for biological data collected alongside OA measurements. These discussions are ongoing but haven't yet advanced to address QA/QC. A separate but not unrelated conversation is taking place through the ESIP Biological Data Standards Cluster (https://wiki.esipfed.org/Biological_Data_Standards_Cluster) - a forum which includes US and global participants.

Recommendation: Co-sponsor and project manage the development of an OA data quality control online package

Responsible: IOCCP Office

Timeline: 2021-2022

Financial implications: medium

Support the participation of developing countries in an inter-laboratory comparison

In absence of any inter-comparisons currently planned by the Dickson Lab, the SSG discussed the possibility of contacting QUASIMEME (Quality Assurance of Information in Marine Environmental monitoring) - an interlaboratory intercomparison initiative. QUASIMEME are organizing a proficiency test for the analysis of Dissolved Inorganic Carbon (DIC) and Total Alkalinity (TA), as part of the ocean acidification research. This proficiency test will be organized in cooperation with the Royal Belgian Institute of Natural Sciences (RBINS), Ostend, Belgium. The effort is being led by the University of Wageningen in the Netherlands. Contact person is Steven Crum. More information can be found at": <https://www.wepal.nl/en/wepal/Home/Proficiency-tests/Seawater/S-water.htm>

It was mentioned that Tobias Steinhoff is already establishing contacts in relation to the ICOS OTC intercomparison exercise which was rescheduled for 2021. According to Siv, who received an invitation to participate, there is an anticipated cost of 500 EUR per year per lab. The SSG agreed to pursue actions to establish a link with QUASIMEME and discuss whether it was relevant for IOCCP to support participation of labs from developing countries in this intercomparison.

Recommendation: Establish links with QUASIMEME (Quality Assurance of Information in Marine Environmental monitoring), and if relevant, support the participation of developing countries.

Responsible: Kim, Siv, IOCCP Office

Timeline: early 2021

Financial implications: low

Addressing shortage of CRMs

A major issue faced by the marine carbon community in general, including those making ocean acidification relevant measurements, is the vulnerability to the supply of Certified Reference Material (CRM), currently produced and supplied by Andrew Dickson's lab at Scripps Institution of Oceanography. This vulnerability has been exacerbated by the temporary halt in CRM distribution due to COVID-19. It was suggested that the community should bid for funding to build capacity/facility to produce CRMs via the next Horizon Europe Programme as a comparable alternative to the only source of CRMs globally from the Dickson's Lab in the US. See also discussion on ICOS OTC efforts in that direction discussed [in this section of the report](#). These discussions should involve IAEA which has experience in producing RMs for other environmental variables.

Recommendation: Address the issue of CRM shortages in partnership with ICOS OTC, IAEA, US NOAA, Dickson's Lab and other interested parties.

Responsible: Maciej Telszewski, new SSG member for Ocean Interior

Timeline: throughout 2021

Financial implications: none

GOA-ON bid for a UN Ocean Decade Programme

IOCCP SSG discussed the potential role IOCCP should play in developing a program bid by GOA-ON under the UN Ocean Decade for Sustainable Development. See discussion under the [IOCCP and UN Ocean Decade section of this report](#). It was decided that IOCCP should approach GOA-ON leadership to inquire about our role.

Recommendation: Communicate with GOA-ON on how IOCCP should possibly be involved in developing a proposal for a programme under the UN Ocean Decade for Sustainable Development.

Responsible: Kim Currie

Timeline: immediate

Financial implications: none

Relevant new publications

On 10 March 2020 the World Meteorological Organization (WMO) published the Statement on the State of the Global Climate for 2019, including a chapter on ocean acidification, one of the Global Climate Indicators, concluding that OA continues to increase, with observed pH values at open ocean observing stations steadily decreasing. The report can be obtained from [here](#).

Oxygen

Veronique Garçon [presented the Oxygen Theme](#). She reported on actions carried out between November 2019 and November 2020, mentioning relevant actions related to coordination, communication and capacity building, including conference and workshop attendance, publications and outreach.

Past Activities

IOCCP-SSG-14 Action Item #8: *Publish the roadmap towards an oxygen data portal and data synthesis products as an outcome of the first scoping workshop on oxygen data.*

IOCCP-SSG-14 Action Item #9: *Organize a follow up oxygen data workshop.*

The Oxygen Data Platform Scoping Workshop took place on November 11-12, 2019 in Sopot with support from IOCCP, IOC, GO₂NE, NOAA and SFB754. Maciej Telszewski, Benjamin Pfeil, Cristian Vargas, Masao Ishii, Siv Lauvset, Véronique Garçon from the current IOCCP SSG have participated. The minutes of the workshop can be found [online under IOCCP meetings reports](#). The outcomes of the oxygen data platform scoping workshop have set a roadmap for progressing towards building this open access oxygen data platform for the world ocean, inspired by the SOCAT initiative. There has been a [white paper draft](#) prepared throughout the 2020, entitled “Building a Global Ocean Oxygen Atlas: a necessary requirement for assessing deoxygenation and ocean health in the open and coastal ocean.”

A virtual meeting was organized on 5-6 November 2020 to put into practice the road map defined in the manuscript and to finalize the manuscript for submission. Minutes from the meeting as well as meeting recordings are available online [here](#).

GO₂NE 5th Annual Meeting

GO₂NE 5th Annual Meeting took place as a virtual meeting on 31 August - 1st September, 2020. Marilaure Grégoire and Véronique Garçon presented a brief overview of the Sopot Scoping Workshop and the status of the White Paper on the Building of the Global Ocean Oxygen Atlas. It was advised to enforce the link with biodiversity and climate feedbacks thematics in the white paper. Frontiers in Marine Science could be the journal where to submit this community article. As for the implementation road map and business plan of the oxygen data platform, it was suggested to come up with a short brief for stakeholders, end-users and policy makers, and to approach national agencies as funding search actions, keeping in line with guidelines agreed upon internationally. Private foundations could also be approached. It would be useful to set up a project website if this effort is to be proposed as a UN Decade project under a UN Decade programme umbrella (see section 6 Actions/ideas for upcoming year below), it was questioned whether this website could be open for public contribution. All actions towards the roadmap implementation for this community effort have been discussed during the November 5-6, 2020 virtual meeting. Several avenues to ensure sustained funding are being pursued (e.g. Digital Twin Ocean proposal with Copernicus/EMODnet).

Summer School "Changes in coastal upwelling systems and their impact on marine resources"

The SOLAS co-sponsored SCOR Working Group on Eastern Boundary Upwelling Systems (EBUS) 155 [Summer School](#) "Changes in coastal upwelling systems and their impact on marine resources" was supposed to take place 4-12 May 2020 at the Ecole Supérieure Polytechnique (ESP), University Cheikh Anta Diop (UCAD), Dakar, Senegal. Due to COVID pandemia, it had to be postponed, and will hopefully take place in the second quarter of 2021. The Summer School should have brought together 40 attendees (Master/PhD students, postdoctoral scientists, and early career scientists/professionals from around the world) with the objective to provide an international training program and joint research opportunity for the next generation of ocean scientists focused on EBUS.

French LEFE/CYBER and CES ODATIS Workshop

Following the French LEFE/CYBER and CES ODATIS Workshop on Oxygen, Paris, 2-3 July 2019, ([agenda, pdfs of presentations](#)), it was planned to organize in spring 2020 (end of March-early April) an intercomparison experiment carried out at IFREMER in Brest, France, testing various oxygen sensors, along with Winkler titration by several French labs in a pre-configured, low oxygen concentration (close to anoxia) to define best practices for oxygen sensors work (calibration, deployment, data treatment and analysis). Due to COVID, it had to be postponed to some time in 2021.

Future Activities

Global Ocean Oxygen Atlas - next steps

Veronique informed the group about plans to hold an in-person meeting of the GO₂AT group to assess the progress in implementation of the roadmap, tentatively scheduled for the second half of 2021. Financial support of 5k EUR was requested from IOCCP. It should be noted that IOCCP SSG approved support for organizing such a workshop during IOCCP-SSG-14 but the funds were unused due to the need to adjust meetings to a virtual format.

Recommendation: Organize an in-person workshop to assess progress in implementation of the roadmap towards GO₂AT.

Responsible: Vero Garcon

Timeline: second half of 2021

Financial implications: low

Furthermore, building of the Global Ocean Oxygen Atlas is being considered as a proposal for the UN Ocean Decade Project as part of a larger UN Ocean Decade Programme proposal on oxygen/deoxygenation (see more at [IOCCP and the UN Decade of Ocean Science](#)). The overarching objective of the Programme umbrella could be to address the question: Is there a planetary boundary for marine oxygen? It fits with Objectives 1 and 3 of the UN Ocean Decade. Objective 1 is to identify required knowledge for sustainable development, and increase the capacity of ocean science to deliver needed ocean data and information. Objective 3 is to increase the use of ocean knowledge and understanding, and develop capacity to contribute to sustainable development solutions. The proposal will be multi-partner, multi-institutions, and will require an international effort, with multi-stakeholders groups, it will be cross generational combining early career scientists with senior scientists, and will be managed by IOCCP and GO₂NE, but also with other players such as IUCN, PICES, etc. paying a particular attention to capacity developments. So, if agreed by IOCCP SSG and the GO₂NE group, it could be proposed as a UN Decade project in response to the Call for actions setup by the Decade Coordination Unit to seek endorsement. Initial ideas and suggestions shared within the GO₂NE group can be found at: https://docs.google.com/document/d/1AoFaIgr9QLwytGARYFYkKnIh1_Vdtvfvmk2Rn-htyE/edit

Recommendation: Submit a bid for the UN Ocean Decade Programme on ocean deoxygenation on behalf of GO₂NE and IOCCP.

Responsible: Vero Garcon

Timeline: early 2021

Financial implications: none

Relevant new publications

Garçon V., Dewitte B., Montes I. and Goubanova K., 2019, Land-Sea-Atmosphere interactions exacerbating ocean deoxygenation in Eastern Boundary Upwelling Systems (EBUS), in “Laffoley D. and Baxter J.M.” (eds.) (2019). *Ocean deoxygenation: Everyone’s problem- Causes, impacts, consequences and solutions*, Gland, Switzerland: IUCN, 155-170, 562 pp

Garçon, V., Karstensen J., **Palacz, A.**, **Telszewski, M.**, et al., 2019, Multidisciplinary Observing in the world ocean’s Oxygen Minimum Zone regions: from climate to fish- the VOICE initiative, *Frontiers in Marine Science*, 6:722, doi: 10.3389/fmars.2019.00722

Bettencourt, J., Rossi, V., ... **Garçon, V.**, 2020, Effects of upwelling duration and phytoplankton growth regime on dissolved-oxygen levels in an idealized Iberian Peninsula upwelling system, *Non linear Processes in Geophysics*, 27, 2, 277-294

Dewitte, B., Conejero, C., Ramos, M., Bravo, L., and **Garçon, V.**, 2020, Understanding the impact of climate change in the oceanic circulation in the Chilean oceanic islands ecoregions, *Aquatic Conservation: Marine and Freshwater Ecosystems*, doi:10.1002/aqc.3506

Contribution to IPCC AR6 WG1 Chapter 5: Global Carbon and other Biogeochemical Cycles and Feedbacks, as Contributing author, Section 5.3.3.2 Ocean deoxygenation and its implications for GHGs, 2019-2020.

Surface CO₂ Observations

Rik Wanninkhof [presented the Surface CO₂ Observations Theme](#). Rik will have finished his 2nd term as IOCCP SSG member at the end of 2020. A new SSG member responsible for this theme will be selected from an open call, likely by April 2021.

The focus of the surface water CO₂ activity of IOCCP is to “facilitate coordination of current observational efforts and interactions with other observing efforts; advocates for common best practices; and facilitates incorporation of new technology with an overall aim to establish a global sustained surface ocean CO₂ network.” The implementation in the past year focused on encouraging the community to provide quality controlled data to SOCAT and facilitate use of surface fCO₂ data.

Past & Future Activities

During the period between SSG meetings of November 2019 and November 2020 activities revolved around 4 topics:

- 1) Addressing the outstanding action item: including uncertainties in fCO₂ data
- 2) Best Practices and intercomparisons
- 3) New technology
- 4) Scientific Connections (New opportunities)

All Action Items from IOCCP-SSG-14 relevant for this theme were also relevant to the Synthesis Activities Theme, thus a detailed report and discussion on 1) is found [elsewhere in the report](#).

Best Practices

Implementing procedures and protocols are cornerstones for improving quality of measurements. The documentation is commonly referred to as Best Practices. Surface water CO₂ measurements have benefitted from good documentation and standard operating procedures (SOP) (Pierrot et al, 2009; 2019) that are now being folded into the GOOS Framework of Ocean Observing (FOO), including attention to co-design of networks (multiple sensors on platforms) and interoperability. Activities in the past year include:

- Coordinating with VOS/SOOP groups through OceanOPS (formerly JCOMMOPS) in situ Observations Programme Support Centre to implement metadata and metadata standards (WMO/WIGOS).
- Improved connections with Ocean Best Practices to create a series of Best Practices for SOOP (TSG, UW O₂, UW pCO₂) (<https://www.oceanbestpractices.org/>).
- Coordinating best practices activities around the ICOS-OTC /IOCCP surface water CO₂ system intercomparison exercise in Oostende. The intercomparison was postponed but based on strong interest there has been a call for possible expansion of scope with discussion of implementing Best Practices when it does occur in 2021.

- The SOCONET (Surface Ocean Carbon Observing Reference Network) continues its progress of creating a multi-member reference network and with following programmatic collaborators:
 - OceanOPS: real-time tracking
 - GAW: Best practices for atmospheric measurement from ships
 - ICOS OTC: near-real time data reduction QUINCE
- Continued opportunistic intercomparison of instruments and publication of results in accessible literature. e.g. the comparison of three different instruments on the Irish GO-SHIP cruise A02 on Celtic Explorer (Arruda et al., 2019).

Recommendation: Determine which SOPs should be developed for the surface water CO₂ effort, including SOPs for other physical and biogeochemistry parameters (in consultation with the GOOS VOS/SOOP panel).

New Technologies

Improved and new technologies are essential to build up a comprehensive surface water CO₂ observing network. Several developments are of note. New analyzers are coming on the market that are laser-based (e.g. instruments from Los Gatos, Picarro, and the LICOR LI-7815). ICOS-OTC and US NOAA consortia are investigating installation of such analyzers in a General Oceanic (GO) underway pCO₂ system. The analyzers appear more stable, requiring less frequent standardization; they are more linear, requiring fewer standards; and they can provide accurate water vapor measurements, necessitating less drying and better correction to “dry” XCO₂. However, because of greater flow rates and low pressure in the analysis cavity they cannot be simply swapped out with current analyzers in GO systems. The analyzers are also significantly more costly.

Some new lower cost analyzers (such as the LI-COR 850) have come to market that are fully compatible with current GO systems. However, there appear to be issues with internal correction of water vapor interference and its temperature dependence that are being investigated by the engineering group at NOAA PMEL (Seattle, USA) who plan to use the analyzers in buoy based CO₂ (MAPCO₂) systems. The group is also converting MAPCO₂ to autonomous surface vehicles (ASVs) such as Saildrones.

There are other commercial systems on the market that are undergoing continued improvement such as those developed by Subseatec, Appollo Sci tech, Sunburst, Pro-oceanus. Of note are the Subseatech units that are being deployed on sailing yachts and used in transoceanic sailing races in partnership with race organizers.

Despite a number of producers of surface water CO₂ units there remains concern how to maintain commercial suppliers. Notably, the commercial supplier of MAPCO₂ mooring based systems (Battelle) discontinued selling units.

Recommendation: New technology intercomparisons should be an integral part of intercomparison exercises. A workshop/dialog on implementing new sensors/technologies into the current observing framework in coordination with the planned surface water CO₂ instrument intercomparison is suggested.

Inorganic carbon species conversions

With an increased interest in co-design and multi-use observing networks, the surface water CO₂ community is in a unique position to be leaders in the effort on inorganic carbon species conversions due to extensive experience operating on the different platforms. Moreover, surface water CO₂ measurements are gaining increased attention from a broader community of stakeholders and policy makers, notably for contributions to SDG 14.3.1 : “Average marine acidity (pH) measured at agreed suite of representative sampling stations”. In particular, using fCO₂ to determine pH for this SDG is receiving attention. As a corollary, profiling float based pH is being used as a fCO₂ proxy and the surface water fCO₂ measurements are an important component of the checks and validation. The proxy fCO₂ are a good opportunity to obtain more fCO₂ data in data poor regions but they will require validation with actual measurements (Bushinsky et al. 2019). A US OCB [Ocean Carbonate System Intercomparison Forum \(OCSIF\) Working Group](#) was established to look at inconsistencies in thermodynamic observations that will be of great utility to make conversions between inorganic carbon species including fCO₂.

References

Arruda, R., Atamanchuk, D., Cronin, M., Steinhoff, T., & Wallace, D. W. R. (2020). At-sea intercomparison of three underway pCO₂ systems. *Limnology and Oceanography: Methods*, 18(2), 63-76. <https://doi.org/10.1002/lom3.10346>. <https://doi.org/10.1002/lom3.10346>

Bushinsky, S. M., Landschützer, P., Rödenbeck, C., Gray, A. R., Baker, D., Mazloff, M. R., et al. (2019). Reassessing Southern Ocean Air-Sea CO₂ Flux Estimates With the Addition of Biogeochemical Float Observations. *Global Biogeochemical Cycles*, 33(11), 1370-1388. <https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2019GB006176>

Pierrot, D., Neil, C., Sullivan, K., Castle, R., Wanninkhof, R., Lueger, H., et al. (2009). Recommendations for autonomous underway pCO₂ measuring systems and data reduction routines. *Deep -Sea Res II*, 56, 512-522.

Pierrot, D., & Steinhoff, T. (2019). *Installation of Autonomous Underway pCO₂ Instruments onboard Ships of Opportunity*, <https://doi.org/10.25923/ffz6-0x48>.

Ocean Interior Observations

Masao Ishii [presented the Ocean Interior Observations Theme](#). It was noted that Masao will have rotated off the IOCCP SSG by the end of 2020, after serving three terms, including 4 years as IOCCP Co-Chair. Two new SSG members will assume responsibilities for this theme: Fei Chai will assume responsibility for autonomous interior ocean observations part starting in January 2021, and a new SSG member selected through an open call is expected to assume responsibility for the ship-based ocean interior observations in April 2021.

Ship-based observations: past activities

Impacts of COVID-19 on GO-SHIP cruises

Due to COVID-19 pandemic, all four GO-SHIP reference cruises that had been planned to conduct after March 2020 were cancelled. Other research cruises including those of

Associated GO-SHIP were also cancelled or postponed (Table 4). New cruise plans are yet to be compiled.

Table 4. Impact of COVID-19 on GO-SHIP and other cruises (as of 29 April 2020)[†]

Country	Status
Norway	75N next one under discussion
UK	3 recently done, SR1b, A23, A5 cruises now suspended, future uncertain
Japan	JMA 40N and JAMSTEC I7S, I8N (2019/20) were done. JMA P3W in July-August postponed. Future uncertain (P4W, P1).
Canada	No int. travel till September; AR7W (July-Aug), Davis Strait (Aug-Sep) and ARC02(Sep) cruises are still scheduled to go. GO-SHIP associated line Line P still scheduled in summer and fall (spring cruise was cancelled).
Germany	A12 and SR4 done in 2019, only partly due to medevac; cruise funded for A12 and SR4 in 2021/2022; MED01 done in 2018, data and cruise report available.
Australia	The ship request for I9 was not successful. There are plans to resubmit the proposal in the next funding call. This will push back the planned occupation to 2023 and will also impact plans for reoccupation of P15. Updated plans now: IO9 Planned 2023. P15S Planned 2024. SR3 still planned 2027
Ireland	No impact through Covid because no A2 repeat planned in close future
Korea	No regular GO-SHIP line, annual cruises in Indian Ocean postponed ~6 months
France	A25 should have been 2020 (2-year cycle), now hopefully 2021 (next cruise done by Spain, probably around June)
USA	I6 not fully done, A13.5 on Brown last minute cancelled in Cape Town, then steamed back to US (deploying floats and drifters but not more by crew), lockdown till min July. IO5 (Nov 2020) delayed indefinitely.
Spain	A10 COVID19-delayed pending ship schedule adjustment

[†] Information from GO-SHIP Committee Meeting (virtual) on 29 April 2020. (<https://www.go-ship.org/Docs/20200429-SC-Minutes.pdf>)

These impacts of COVID-19 on research vessel missions further impacted on the deployments of autonomous observing platforms such as drifters, Argo floats and underwater gliders (Table 5).

Table 5: Impact of COVID-19 pandemic on autonomous observing platforms.[‡]

Networks	Deployment 2020			Deployment required to maintain array	Predicted status of array (Dec 2020)	
	Mar	Apr	May		Monthly	50% normal deployments
Global surface drifter	58	41	25	80	-20%	-40%
Argo floats	51	21	10	81	-10%	-15%
Underwater gliders	10	1	5	20	-50%	-100%

[‡] From Heslop, E. et al., Briefing Note: Covid-19's impact on the ocean observing system and our ability to forecast weather and predict climate change, https://www.goosocean.org/index.php?option=com_oe&task=viewDocumentRecord&docID=26920

Best practice manuals

A draft of best practices manual for Dissolved Organic Matter (DOM) entitled “GO-SHIP Repeat Hydrography: Determination of dissolved organic carbon (DOC) and total dissolved nitrogen (TDN) in seawater using High Temperature Combustion Analysis.” was submitted by Halewood et al. and is now under review by GO-SHIP Committee members with the help of experts of DOM measurement.

Moreover, a working group on CTD-O₂ has been established within the GO-SHIP Committee and its best practice manual is to be prepared.

Autonomous observations: past activities

Status of Biogeochemical Argo

Total number of BGC-Argo floats in operation was 380 in September 2020, which increased from 329 in September 2018 and 366 in September 2019 but decreased from 402 in April 2020. The number of floats installed with a full suite of six sensors [oxygen, nitrate, pH, chlorophyll a, suspended particles (back scattering) and downwelling irradiance] is still limited. Oxygen sensor is the most mature sensor for BGC-Argo. It has been installed on the most (365) BGC-Argo floats currently in operation. Numbers of floats installed with nitrate sensors (158) and pH sensors (156) were increased but remain less than half of that with an oxygen sensor. The majority of BGC-Argo floats with nitrate and/or pH sensors have been in operation in the Southern Ocean for the SOCCOM (Southern Ocean Carbon and Climate Observations and Modeling) project.

Data quality control manual is yet to be prepared for variables other than oxygen and chlorophyll.

Table 6. Total number of BGC-Argo floats installed with respective sensors.

Sensor	9/2018	9/2019	9/2020
Oxygen	333	355	365
pH	117	136	156
Nitrate	131	148	158
Suspended Particles	208	206	205
Chlorophyll a	208	206	204
Downwelling Irradiance	70	63	55
Total	329	366	380

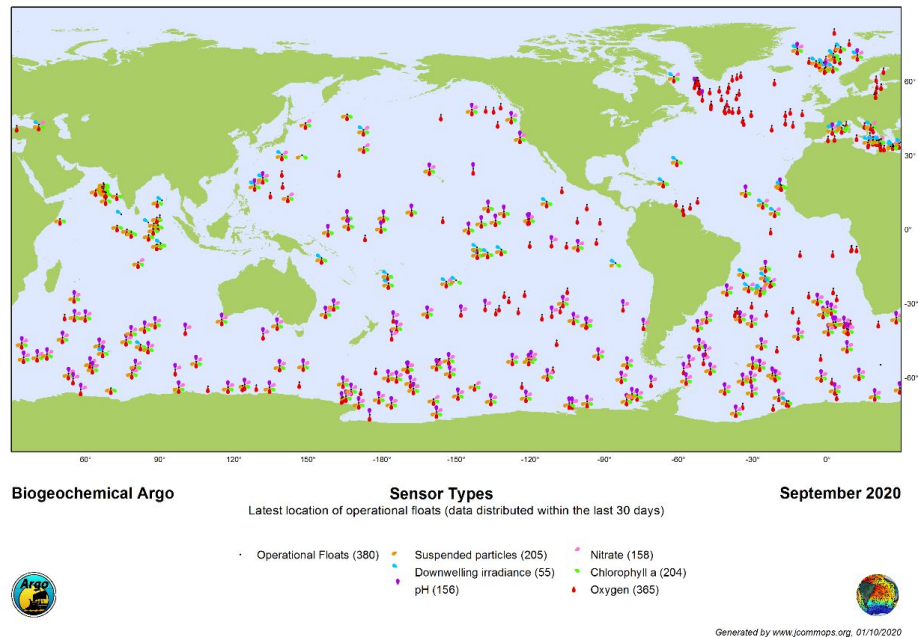


Figure 1: Status of BGC-Argo in September 2020.

<http://biogeochemical-argo.org/float-map-network-status-maps.php>

Highlights from Biogeochemical Argo SSC sub-meeting #1

During the meeting held on March 10, 2020, it was announced that a BGC-Argo project office was established after “Monaco Explorations” accepted to fund (60%) a BGC-Argo / OceanOPS project office at Sorbonne University, Paris, France. A contribution is expected from China to host a full-time position. BGC-Argo project office will be a good partner for IOCCP. The main activities of the BGC-Argo project office should be to:

- Develop/strengthen the awareness of BGC-Argo
- Help in the coordination of the network, support for meeting organization.
- Newsletters, website, social media, bibliography, organization of events.
- Organization of the interaction within the Argo community.
- AST meetings, ADMT meeting, and Argo science meeting.
- Organization/helping to develop collaboration/interactions outside the Argo community.
- Strengthen the relationship with other GOOS BGC-communities (Oceangliders, OceanSite, GO-SHIP): data format, data quality control
- BGC-Argo has developed a Data Management Task Team with specific terms of reference = > interactions with other communities required in the context of GOOS (and Ocean Best practice network)?
- Strengthen relationship with modeling community: GODAE, MERCATOR Ocean, etc.
- Strengthen relationship with the satellite (ocean color) community: IOCCG, NASA, ESA, EUMESAT
- Support meeting for training scientist, capacity building.
- Representation of the SSC/co-chairs at certain meetings

Several other issues were discussed during the meeting such as:

- Majority of BGC-Argo is equipped with an oxygen sensor only. There is a discussion on separating O₂-Argo from BGC-Argo.

- Price of a BGC-Argo float is rising thereby deploying floats equipped with all six BGC sensors is getting more costly (difficult).
- Low-cost OPUS (TriOS) nitrate sensor has been tested in Euro Argo, but Deep SUNA from Seabird shows better performance so far.
- A technical workshop for sensors and floats is being planned in China next year.

On 29 October 2020, US NSF announced a \$53 million grant to build a global network of BGC-Argo (Global Ocean Biogeochemistry Array) (~500 floats). Although this would constitute half of the planned 1,000 floats as described in the BGC-Argo Implementation Plan, international contributions are expected to double this number. See [here](#) for more details.

It was noted that the US NSF proposal does not include cost of data curation and dissemination. A separate proposal will be submitted to ensure adequate resources for data management are in place.

In China, a proposal for additional 400 core Argo floats was approved. Floats will be deployed over the next 2 year period. There is a potential to add a limited number of biogeochemical sensors, most likely oxygen, on top of the core measurements.

Recommendation: It is recommended that IOCCP strengthens the relationship with BGC-Argo SSC in terms of a variety of future activities related to ensuring data quality control, data management as well as capacity building.

Nutrients

Masao Ishii also [presented the Nutrients Theme](#), assigned to him as temporary responsibility at IOCCP-SSG-14. A new SSG member responsible for this theme will be assigned in April 2021.

Past Activities

IOCCP-SSG-14 Action Item #3: *Develop a strategy for curation of the Nutrients EOV and general coordination of inorganic nutrients observation.*

After Michio Aoyama (Tsukuba University, Japan) stepped down from IOCCP SSG at the end of 2018, we decided against inviting a dedicated SSG Expert, but rather try to fill this gap by combining expert knowledge of SSG Members primarily responsible for other tasks. With 5 new members joining the SSG in the first half of 2021 we are hoping to fulfil this gap by assuring that the newly selected SSG members will also be capable of working with the relevant nutrients community.

Future Activities

Proposal for the next IOCCP-JAMSTEC nutrients in seawater intercomparison exercise

Following the IOCCP-JAMSTEC intercomparison exercise implemented in 2018, a next intercomparison exercise, particularly for silicic acid, was proposed by Michio Aoyama. Due to COVID-19, further decisions and actions have not yet been taken. A virtual meeting

between organizers and selected IOCCP SSG members is planned prior to providing endorsement by IOCCP.

Information and Data Access Services

Benjamin Pfeil presented the [Information and Data Access Services Theme](#). At the end of 2020, Benjamin will have rotated off the IOCCP SSG after serving two terms. A new SSG member responsible for this theme will be appointed in April 2021.

Past Activities

IOCCP-SSG-14 Action Item #15: *Provide clear guidance on the procedure for reporting errors in data published in consecutive SOCAT products. Adequate information should be communicated on the SOCAT website and along with every product release.*

Clear guidance was added to the SOCAT website but the same information still needs to be provided on NOAA NCEI website.

IOCCP-SSG-14 Action Item #21: *Submit a formal GDAC application to IODE after BCDC and NOAA PMEL become approved as IODE Associated Data Units.*

The action has not been completed due to several issues related to the need to prioritize internal affairs at UiB and later external affairs due to COVID-19. Since March 2020, both NOAA PMEL and UiB limited their activities to business as usual in order to reorganize work practices (remote work by staff), delays in hiring, training or key personnel retiring. Therefore, this Action Item is carried forward to 2021.

Recommendation: Submit a formal GDAC application to IODE after BCDC and NOAA PMEL become approved as IODE Associated Data Units.

Responsible: ?

Timeline: end of 2021

Financial implications: none

SDG 14.3 data submission

Following the publication of SDG 14.3.1 indicator methodology (see IOCCP-SSG-14 Ocean Acidification Theme report), work focused on increasing the number of indicator data submissions worldwide. To this end, a dedicated IODE data portal was created (<https://oa.iode.org>). Acceptance of data requires adhering to the published [methodology](#) and filling out of a comprehensive metadata sheet covering over 200 entries.

IOCCP has been working with IOC-UNESCO and other partners to resolve several outstanding questions:

- Who is responsible for submitting data for the SDG 14.3 target?
- What happens if relevant data is already submitted to SOCAT and GLODAP?
- How do we achieve metadata and data alignment with SOCAT and GLODAP?

At the moment data has to be submitted on a national level but future integration via interoperable services is planned to enable one time submission through push and pull

streaming solutions, e.g using ERDDAP services. IOC-UNESCO plans to hire a person working on the integration.

Two major data centres at NOAA PMEL and UiB planned to implement SDG14.3.1 metadata and data needs to be machine to machine readable in 2020. However, the process got delayed due to retirement of key personnel (Karl Smith, University of Washington/NOAA PMEL, USA) and due to COVID-19 related issues. It is expected that SOCAT version 2021 will already benefit from an online metadata editor conforming with SDG 14.3.1 data standards.

The SSG discussed the consequences of the inaccurate or incorrect wording used to describe the SDG 14.3.1 Indicator “*Average marine acidity (pH) measured at agreed suite of representative sampling stations.*” The scientific community struggles to accept the meaning of “average acidity” or “designated sites”, causing confusion and being potentially detrimental to some established operations. Nevertheless, it was emphasized that the requirement to report carbon data on a national level is very advantageous to the marine biogeochemistry community. It was advocated that more responsibility and more visibility should be given to national (NODCs) and regional entities (e.g. EMODnet, Copernicus in Europe), not just for carbon, but for biogeochemical data collection as well. This recommendation is also included in the draft community white paper on the Global Ocean Oxygen Atlas (see [this section of the report](#)). In this context, the IOCCP will be required to work with many new partners which will bring us closer to other elements of GOOS. It was recommended that IOCCP focuses on enhancing interoperability of associated data streams (e.g. submitted data is machine to machine readable) and promoting high quality observations according to weather and climate targets established by GOA-ON.

Providing inorganic carbon data in NRT mode

An increasing number of Inorganic Carbon EOVS data is being made available in near-real time (NRT) mode. In addition to ship-based underway NRT data managed by ICOS and few other countries around the world, NRT data from autonomous surface vehicles (ASVs) such as SailDrone is now possible. In 2020, ICOS-OTC in collaboration with GEOMAR acquired and carried out a free SailDrone mission demonstrating the new capability for ingestion, automatic quality-control and data reduction of inorganic carbon NRT data provided as Level 1 data to Copernicus Marine Environmental Monitoring Services (CMEMS). After additional QC, the data is also submitted as Level 2 product to SOCAT and ICOS Carbon Portal, and through SOCAT also to CMEMS.

ASVs with carbon sensors will become more common in the future and it was recommended that the data flow used during this 2020 mission (Fig. 2) is reproduced in future missions.

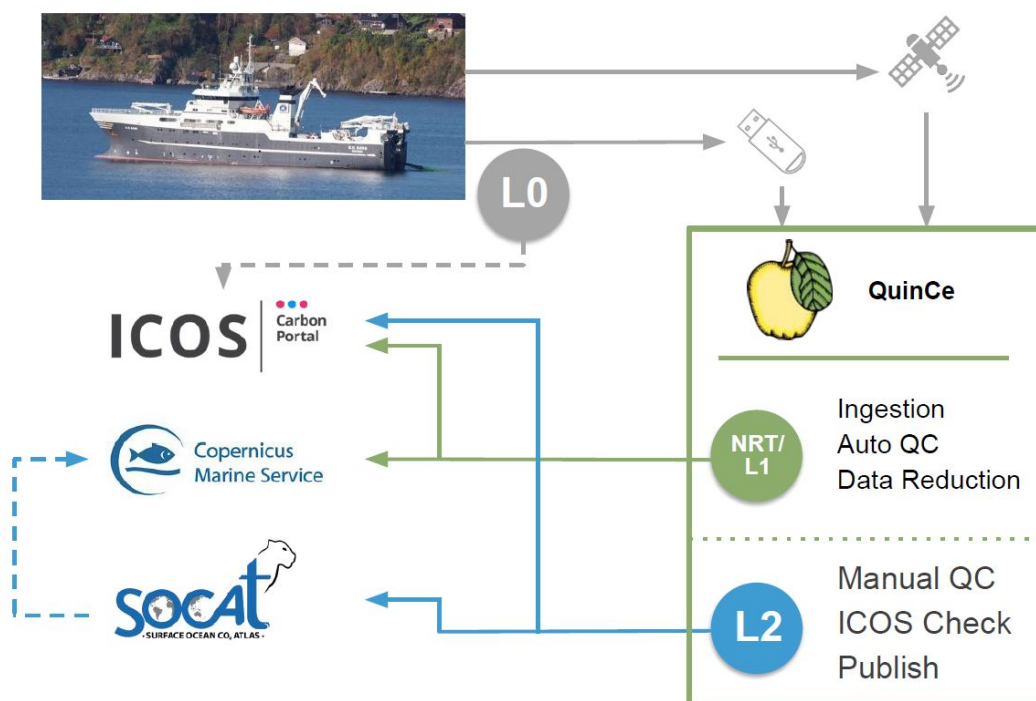


Photo by Steve Jones
Icons by Mavadee and Matthias Van Wambeke

Figure 2: A data flow scheme for acquisition of inorganic carbon data in NRT mode, from ship-based (SOOP underway) or autonomous (SailDrone) transects.

Collaboration with CMEMS and EMODnet

IOCCP has continued to strengthen collaboration with European data integrators and service providers. CMEMS and EMODnet are supported by different ministries in the European Commission: Directorate-General MARE (Maritime Affairs and Fisheries) and GROW (Internal Market, Industry, Entrepreneurship and SMEs). Towards the end of 2019, CMEMS and EMODnet signed a Memorandum of Understanding on a collaboration to combine data availability within Europe.

Recently, University of Bergen/ICOS became a Copernicus Thematic Assembly Centre (TAC) for carbon data. This includes providing NRT data and making available the SOCAT and GLODAP data products to the CMEMS users. Such a move is expected to make the two products more visible to users and stakeholders, and in the long-term, ensure sustainability of these community efforts. SOCAT and GLODAP are also available as products to EMODnet according to respective data usage licenses, while giving full credit to SOCAT and GLODAP.

Future Activities

Marine Carbon Indicator as a new service

There is an opportunity for new carbon related services to become available in the near future. Through participation in an EU H2020 Project BlueCloud, UiB/ICOS is contributing to the development of a marine thematic component of the European Open Science Cloud (EOSC) which “aims to provide a virtual environment with open and seamless services for

storage, management, analysis and re-use of research data, across borders and scientific disciplines.”

A Marine Carbon Indicator is being developed as a showcase for a future marine thematic EOSC. The output is intended as a harmonized and integrated carbon indicator providing state of the art data with uncertainties on sub-variables of the Inorganic Carbon EOVS, useful for modellers and other stakeholders (e.g. aquaculture, policy makers) concerned with phenomena such as ocean acidification, carbon fluxes and ocean carbon cycling in general.

Developing the indicator assumes the following steps:

- integrating existing data sources through ERDDAP services
- recomputing missing elements of the carbonate system
- assessing fitness of purpose of data
- providing data with uncertainties useful for cross-platform data QA/QC, e.g. for BGC Argo

It is estimated that by the end of 2020 there will be a federated ERDDAP server in place with a selection of the repositories as a test indicator. The system will (i) integrate data from various sources, (ii) harmonise data access and (iii) redistribute data. In early 2021 work will focus on (i) recalculation of EOVS Inorganic Carbon parameters, and (ii) providing uncertainty information for parts of the data (where possible). Such a service could in the future be picked up on a global scale.

Overcoming challenges for a digital twin ocean

It was recommended that IOCCP take or support coordinated actions to provide more clarity and transparency on the marine biogeochemistry data landscape, including efficient communication with funders of the observing system value chain. The current situation for accessing marine carbon data is complex, confusing, partly overlapping, not user friendly and not fit for purpose or sustainable. Understanding and communicating the difference between and interactions among an increasing number of projects, organizations, networks and data centres remains a challenge which needs to be addressed on an international level.

On the European level, an ICOS-led project proposal will be submitted in early 2021 to create a digital ecosystem for marine carbon data as a service. The goal will be to establish a transparent, integrated, fit-for-purpose European Ocean Observing Data Access System where marine carbon data are accessible with QC, uncertainties, provenance, giving visibility to all key players and increasing TRL for data access. The new service would be aligned with data inventories used for CMEMS, EMODnet and those informing SDG Target 14.3. The process is equally relevant to carry out on a global scale, with opportunities related to the UN Ocean Decade for Sustainable Development.

Particulate Matter

Emmanuel Boss, who has joined IOCCP SSG in mid 2020, [presented the new Particulate Matter Theme](#). With coordination activities around this theme only just beginning, the report

mostly contains future actions which were proposed by Emmanuel and discussed by IOCCP SSG during this meeting. As IOCCP SSG member, Emmanuel also serves as liaison to the International Ocean Colour Coordination Group (IOCCG), of which he is also a Steering Committee member. It is important to note that IOCCP has not had a direct link to IOCCG since Cyril Moulin (CNRS, France) completed his term as IOCCP SSG member in 2008. As remote sensing capabilities to monitor ocean biogeochemistry rapidly increase, IOCCP looks forward to working closer with the ocean colour community to support global coordination and communication efforts towards sustained and integrated ocean observations for biogeochemistry.

Particulate Matter EOVS Specification Sheet

An updated version of the Particulate Matter EOVS Specification Sheet was prepared by Emmanuel in October 2020. Compared to the previous version, published in February 2017, the document now contains references to recent reviews from OceanObs'19 and mentions use of imaging technologies for carbon fluxes. Some numbers under requirements were noted as being inconsistent with the literature.

The updated version will be posted online as part of the general EOVS Specification Sheet update planned for the first half of 2021.

Ocean Lidar and operational products from high-resolution coastal observations

Lidar is a tried and true satellite observing technology in use since the 1980s. Currently, there is no Lidar optimized for ocean observations. However, using existing Lidar instruments designed for ice cover and aerosol property measurements, it was possible to demonstrate that with sufficient resolution one can measure surface ocean particle distributions, can observe the ocean surface during polar winters, at night and through thin clouds, thus avoiding some of the biases characteristic of ocean colour measurements. What is more, an oceanic Lidar provides more direct measurements of particle abundance. Developing an Ocean Lidar would add the possibility of expanding the wavelength and number of detectors to provide additional information on particle size, chlorophyll fluorescence (as measure of plankton physiology) or coloured dissolved organic matter.

Another issue which IOCCP could help promote is the need to develop operational products from high resolution coastal observations. None of the biggest space agencies, NASA, ESA or JAXA, have so far invested in developing such products even though there is a tremendous opportunity to utilize existing high quality, high resolution coastal data to deliver new products to a range of stakeholders. Potential products (including temperature, suspended matter, chlorophyll and dissolved organic materials) would provide relevant information to inform policies in areas of marine biogeochemistry as well as biology and ecosystems. Societal application such as aquaculture and pollution monitoring would directly benefit from such products.

It was recommended that IOCCP as GOOS Biogeochemistry Panel promote the need for (i) an Ocean Lidar and (ii) operational products from coastal satellite observations as a contributor to the Global Climate Observing System (GCOS). It was agreed that these forward looking actions would be recommended for the next version of the GCOS Implementation Plan which IOCCP will be invited to contribute to beginning in 2021.

Recommendation: Contribute to the 2022 GCOS Implementation Plan with recommendations for actions aimed at developing (i) an Ocean Lidar and (ii) operational products from coastal satellite observations.

Responsible: Emmanuel Boss, IOCCP Executive

Timeline: end of 2021

Financial implications: none

Increasing capacity for in-line (flow-through) measurements

There are existing efforts to increase the capacity for in-line (flow-through) measurements of particulate matter in the ocean. Recently, an IOCCG report on best practices was published, also available through the Ocean Best Practices System repository. It is recommended that future actions in this area include training and capacity development.

A US NSF proposal for a 2022 summer workshop on teaching in-line measurements was successful. Details will be shared in due time. Moreover, Emmanuel is considering submitting a SCOR Visiting Scholar application to further promote use of best practices in in-line measurements in developing countries.

Comparison of methods to measure particle size distribution

It was suggested that as a longterm action IOCCP could spearhead a methods comparison to measure particulate size distribution - a property which provides important constraints on estimates of carbon fluxes in the ocean. An intercomparison would serve as means of bringing a community of practitioners using different methods together. Such a comparison is not feasible to organize until COVID-19 travel restrictions.

During the meeting, it was also mentioned that US OCB was trying to get omics intercomparison efforts underway to meet challenges associated with large-scale observing efforts, including [metaproteomics](#) and [Ocean nucleic acids 'omics intercalibration and standardization](#). Potential synergies or overlaps should be identified.

Training activities

In 2021 there are plans to hold a summer school in China on Argo data processing. Also in 2021, there are plans to hold the next edition of the Ocean Optics Class at University of Maine's Darling Marine Center in Walpole, ME, USA. In 2022, the Ocean Optics Class is due to be organized in Villefranche sur Mer, France. These several-week long courses provide comprehensive theoretical but mostly hands-on training sessions on calibration and validation for ocean colour remote sensing.

After successfully incorporating a bio-optics module in the 2019 IOCCP-BONUS INTEGRAL Sensors Training Course, it is suggested that the next edition of IOCCP Sensors Course, now postponed until 2022, also include an expanded module on in-line measurements. Detailed discussions and decisions will take place in the second part of 2021 as IOCCP begins to develop the agenda and convene the Scientific Advisory Committee.

Bio GO-SHIP as a UN Ocean Decade Programme bid

A proposal for US BIO GO-SHIP to US NSF submitted by a consortium of predominantly young scientists failed in the first round. It is anticipated that the proposal will be resubmitted in the future. This was meant to spearhead the efforts to establish a global BIO GO-SHIP

consistent with existing GO-SHIP protocols, as advocated for in the report with [Recommendations for plankton measurements on the GO-SHIP program with relevance to other sea-going expeditions](#) published by SCOR WG 154 in early 2020.

There is strong support for this proposal among both US and International GO-SHIP Co-Chairs. However, funding needs to come from individual countries for these additional measurements on repeat hydrography lines. There are other issues which need to be solved, such as insufficient human resources to take on additional sampling on some of these cruises, e.g. in the Pacific. It was noted that for imagery and optical methods expertise (Villefranche-sur-Mer, France), there are large collaborative communities which would be willing to send people and instruments to support global sampling. For Imaging FlowCytobot (IFBC), there is also a very large list-serve hosted at Woods Hole, USA, which is used to solve issues, increase capacities and share information. Nevertheless, there is a need to push for more international training and sharing of information on these biological observing methods.

Currently a bid is being proposed for BIO GO-SHIP as a Programme under the UN Ocean Decade for Sustainable Development. An international team was being assembled by an initial group of US scientists, including Emmanuel, Heather Benway (US UCB) and Lynne Talley (Scripps, USA). The plan is to use the UN Ocean Decade to mobilize a number of international organizations to raise the visibility and promote the need for comparable and sustained ship-based observations of biological parameters to provide a much needed baseline. The impact of establishing routine and comparable biological measurements on repeat hydrography lines around the globe would be significant, furthering our understanding of the biological pump and how its role in controlling ocean carbon fluxes will change in the future relative to the role of the solubility pump.

Observations-Modelling Interface

Fei Chai [presented the new Observations-Modelling Interface Theme](#). Fei joined IOCCP SSG in mid-2020. In his presentation, he focused on proposed future directions for IOCCP to support better integration of biogeochemical models and observations, including some specific actions which were then discussed by the SSG.

Better integration of biogeochemical models and observations

Global and basin-scale BGC modeling and uses of remote sensing products and global in situ survey observations

Fei highlighted a number of problems and issues that need to be solved in this area of work:

- Choice of multiple satellite products (SeaWiFS, MODIS, VIIRS, etc.) for modelling purposes
- Limitations of global surface ocean chlorophyll concentration for coastal applications
- Comparability and limitations of ocean colour derived quantities such as particulate organic carbon, phytoplankton functional types and primary production estimates
- Global in situ biogeochemistry observations and gridded products (GLODAP, SOCAT, WOA, BCO-DMO, etc.) are heavily used by the modelling communities but not for rate measurements

- Limitations of data from time-series observations (OceanSites)

In order for the modelling community to move beyond statistical evaluation of models with data, one must consider the following questions:

- How to use in situ observations to improve biogeochemical models?
- What remote sensing products are to be assimilated into biogeochemical models?
- Which data assimilation methods should be used (less advanced than for physics)?
- How to distribute the different model outputs for various uses?

Some of the issues were captured in a recent IOCCG report on “Synergy between Ocean Colour & Biogeochemical/Ecosystem Models” edited by Stephanie Dutkiewicz (MIT, USA), available from the OBPS repository:

<https://repository.oceanbestpractices.org/handle/11329/1194>

BGC-Argo and autonomous platforms BGC observations and its applications for improving physical-biogeochemical models on global and basin-scale

- BGC-Argo and autonomous platforms: offer extensive spatial coverage and resolution
- Sensors integration and data calibration: e.g. comparison of float-derived oxygen with direct in situ measurements; calibration of chl-a
- Spatial coverage and temporal sampling frequency:
- How to use the new observational data to improve models?

A [perspectives paper on “Monitoring ocean biogeochemistry with autonomous platforms”](#) discussing these issues was published by Chai et al. in Nature Reviews in 2020. The paper included a list of major observed biogeochemical properties vs a number of autonomous platforms. Capacity of platforms to address different marine realms was analyzed. Finally, the paper recommended how an integration of different platforms can be used through modelling to inform stakeholders about the current state of the ocean, ongoing changes, short-term and long-term forecasts or impacts of management policies, among other outcomes. See Figure 3 below for a schematic of the relationships between new observation technologies, biogeochemical models and ecosystem health management.

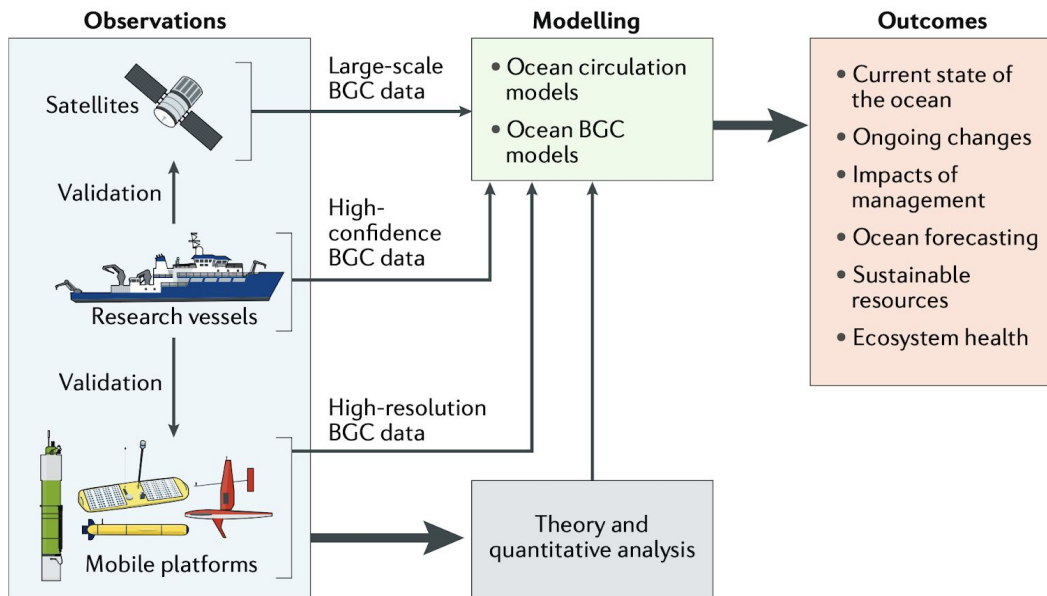


Fig. 5 | **Relationships between new observation technologies, biogeochemical models and ecosystem health management.** Mobile platforms, as an important component of global ocean-observing systems, provide high-resolution biogeochemical data. The data sets acquired by multiple platforms, including also ships and satellite sensors, are crucial to improving ocean biogeochemical models, and, in turn, to better evaluating the current state of ocean ecosystems and forecast its changes. BGC, biogeochemical.

Figure 3: From Chai et al. (2020); <https://www.nature.com/articles/s43017-020-0053-y>

During the meeting it was suggested that an additional feedback loop would be desirable in the schematic presented in the perspectives paper. Namely, outputs from modelling and any decision support tools should be used to determine lessons learnt for how to enhance and optimize the observing system so that it continues to meet the evolving end-user requirements.

It was suggested that IOCCP's observations-modeling theme could be closely linked with the work of the Expert Team on Operational Ocean Forecast Systems (ETOOFs) which is now a GOOS component.

Recommendation: Establish communication and align strategic goals between IOCCP Observations-Modelling Interface and the ETOOFs group of GOOS.

Responsible: Fei Chai, Albert Fischer

Timeline: early 2021

Financial implications: none

Connecting open ocean and coastal biogeochemical modelling communities

The second area of work which Fei has identified under this new theme considers the role that an integrated system needs to play in order to address the intensifying anthropogenic impacts on coastal ocean and connections between open ocean and marginal seas. Several overarching issues and problems connected to this theme are that:

- Human activities and anthropogenic impacts on coastal systems are increasing

- Intensification of associated phenomena of eutrophication, HABs, hypoxia and ocean acidification are monitored but there is limited capability for their forecasts
- There is a need to better understand and observe how the open ocean impact on boundary current systems (both eastern and western boundary systems) and marginal seas
- Models will also focus on marine heatwaves, extreme events, and their impacts on marine ecosystems

One of the goals for coordination work under this theme will thus be to address the question of how to connect land, estuarine, coastal seas, and open ocean through an integrated observing and modelling framework. This needs to consider the following aspects:

- What are the modeling frameworks needed to address this question?
- How do we connect different modeling communities?
- Global IPCC models downscaling and regional upscaling to the global ocean
- Hindcasts, short-term and seasonal forecasts, and future projections

Existing carbon model intercomparisons and iron model intercomparisons provide good examples of common modelling frameworks. However, it must be recognized that there is currently no systematic biogeochemical modelling comparison or coordination efforts. Such efforts could be feasible on a regional scale. Using targeted local knowledge and consolidated observations one could aim to bring together several modelling groups to compare and test a common set of parameters with particular applications in mind. The California region could provide one such testbed.

Plans and activities for the next 18 months

In response to the issues and questions presented above, Fei proposed a number of activities which he would like to be involved in over the coming 18 months period.

Involvement with other international programs:

- The organizing committee member for the Predicted Ocean theme for the UN Decade of Ocean Science kick-off meeting in Berlin
- The organizing committee member for the 5th High CO₂ World Symposium in Peru.
- Working with Herve Claustre (LOV, France) to coordinate BGC-Argo/OceanOPS office support

Specific tasks to address three overall goals for better integration:

- Hosting an international training workshop for “BGC-Argo and its applications” in Hangzhou, China during the fall of 2021. The training workshop will be led by Steve Riser (UW, USA) and Emmanuel Boss (UMaine, USA). It was recommended that a two-day small international conference on how to use BGC-Argo data to improve biogeochemical models on global and basin scale, and BGC modeling work could be held alongside the training workshop. While funding is already secured for the training workshop (mostly Chinese and South East Asian participants), additional funding would be needed to hold the 2-day conference.
- Plan an international training workshop and a small conference on how to better connect global ocean BGC models with coastal and nearshore modeling activities. Several potential scientists for the training workshop are: Enrique Curchitser

(Rutgers), Joseph Zhang (VIMS), Keith Rodgers (Pusan National University), Stephanie Dutkiewicz (MIT). The training workshop would take place in Hangzhou during the spring of 2022.

Recommendation: Organize a two-day international conference on integrating Biogeochemical Argo with biogeochemical models, convened back to back with a BGC Argo training workshop in Hangzhou, China in the second part of 2021.

Responsible: Fei Chai

Timeline: second part of 2021

Engaging more Chinese scientists to participate in international programs:

As one of four co-chairs for OceanObs'29 Chinese Organizing Committee, Fei will work towards engaging the Chinese scientific community in the global coordination of sustained ocean observations as well as modelling. This is aimed at organizing international activities leading up to the OceanObs'29 Conference. He will also help to coordinate Chinese activities within programmes of the UN Decade of the Ocean for Sustainable Development.

Framework for Ocean Observing

Maciej Telszewski and Artur Palacz presented the [Framework for Ocean Observing Theme](#), for which they are responsible along with IOCCP SSG Co-Chairs since IOCCP-SSG-13. This report is an update on actions with respect to several IOCCP Terms of Reference which are relevant to the Framework for Ocean Observing (FOO) Theme.

GOOS

In 2020, IOCCP and GOOS Biogeochemistry Panel took up the responsibility for coordination of a new EOVS: Particulate Matter, as part of our long-term commitment to increase the readiness level of sustained observations of all Biogeochemistry EOVS. With Emmanuel Boss joining the SSG, we are keen on further supporting the large and diverse community of scientists providing information on particulate matter from in situ as well as remote sensing, in partnership with relevant observing networks, IOCCG and other organizations. Please see [the other section of the report](#) on more details on proposed directions and future actions related to this theme.

The second part of our implementation of the FOO has to do with strengthening the interface between in situ observations and modelling. Adding a new theme to the IOCCP portfolio comes from the recognition of the fact that marine biogeochemistry is becoming [a new frontier in operational oceanography](#), and that there is currently a void in coordination of activities at the interface of two still rather distinct communities. For more details in initial directions and proposed actions, see [another section of this report](#).

It was noted that in general IOCCP is looking forward to strengthening its coordination of activities across the open ocean-coastal continuum, across many of the themes. The SSG remarked that IOCCP can rely on GOOS structures in the process which include mature GRAs such as EuroGOOS, IOOS and IMOS. It was noted that GOOS intends to be more responsive to national structures as well, for example from reinvigorating or establishing new

GOOS National Focal Points. It was suggested that IOCCP should not neglect the aspect of reviewing scientific requirements for coastal observing targets, a process which can be supported by such expert bodies as the IOCR WG which sets priorities for next decade's research at least with respect to carbon-related EOVs.

Most issues related to the FOO Theme, as well as specific directions for future actions, are regularly discussed during GOOS Steering Committee meetings. The 9th Session of the Steering Committee of GOOS took place virtually, with one session held in April and another in September. IOCCP CO-Chairs and Office attended. One of the issues tackled by GOOS was the continued need to better harmonize and improve the process of requirement setting through the EOV framework. During GOOS-SC-9, two decisions were taken which will have an impact on how IOCCP is asked to contribute to GOOS in the coming months or years.

The first is the decision to create a GOOS EOV Task Team which will be tasked with addressing (inter alia):

- What are the criteria for EOVs? What is the process for reviewing and adding new EOVs?
- Who is currently using EOVs / ECVs and for what purpose?
- How are EOVs used to review the status of observing system development or needs for new / better technology?
- How are stakeholders consulted about their needs for EOVs and EOV reviews?

The EOV paper, 'The Global Ocean Observing System Essential Ocean Variables (EOVs)' is to be relaunched with an expanded list of co-authors, including representation of IOCCP leadership. The focus of the forward-looking paper will be on explaining the value of the EOV concept in developing an observing system and how this differs from (but also supports) justification of measurements essential for research purposes.

Draft of EOV Task Team Terms of Reference as well as a revised outline of the paper were drafted by Maria Hood, hired as a part-time consultant in GOOS until end of 2020. The Task Team is expected to initiate its work in the first half of 2021.

The second decision regards the formation of a GOOS Task Team on an Evaluation & Review Framework. The composition of the Task Team should draw from the following stakeholders, and consult with all of them: relevant experts in the observing system community, the GOOS panels, CLIVAR and other scientific user communities, the ocean and coupled forecasting centers, OCG (including its networks and JCOMMOPS), other observing system networks, national funders, and GRAs, with a responsible lead appointed from the GOOS SC.

The Task Team will:

- take into account the discussions at GOOS SC-9 online meeting
- address questions posed in the GOOS SC 8 Background Document ["Should GOOS oversee a framework for ongoing evaluation of the observing system?"](#)
- prepare guidelines on when reviews should be triggered and how they should be done,
- prepare guidelines and best practices for observing system reviews,
- prepare guidelines and best practices for observing system design studies, and

- develop an evaluation framework along the value chain, assessing readiness, including FAIR data principles, sustainability of observations, governance, links to global networks, etc.

Formation of the Task Team is on hold, at least until a new OOPC project officer is hired.

Proposed actions for 2021 include:

- Assist in the development of the EOVS Task Team Terms of Reference
- Propose a uniform EOVS spec sheet template for all of GOOS
- Nominate GOOS BGC Panel rep on the EOVS Task Team
- Publish updated EOVS Specification Sheets

Global Climate Observing System (GCOS)

In 2020, IOCCP contributed extensively to the new Status Report of the Global Climate Observing System (GCOS). This included providing assessments of the current state of relevant Essential Climate Variables (ECVs) and the status of actions relevant to marine biogeochemistry as identified in the 2016 GCOS Implementation Plan.

In the long-term, IOCCP/GOOS Biogeochemistry wants to ensure that GCOS Implementation Plans, Status Reports and other related documents convey accurate information about the status of marine biogeochemistry observations and the requirements with respect to climate applications.

In 2021, IOCCP will be approached by GOOS to contribute to the 2022 GCOS Implementation Plan. IOCCP Exec is discussing with GOOS Office how to optimize timelines and methods of interacting with GCOS into the future.

Integrated Marine Debris Observing System (IMDOS)

Currently, half of IOCCP Office Staff is hired by EU H2020 project EuroSea, where we are working on behalf of GOOS on one of the tasks of the EuroSea project. Through EuroSea we are committed establishing sustained observations of marine plastic contaminants in the global ocean by bringing together technical experts leading individual global observing networks with leading authorities focused on marine plastic contaminants (including GESAMP, UNEP, MSFD Task Team on Marine Litter, GEO Blue Planet and initiatives involved in monitoring, sensor development, modelling, data management or ecosystem impact assessments).

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.

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.

In September 2020, IOCCP through EuroSea convened a Marine Litter Working Group during the IV Annual Workshop of the Ocean Best Practices System (OBPS). The WG gathered 14 world-leading experts who led 7 thematic sessions focused on best practices in a number of aspects related to marine litter monitoring, from environmental monitoring and remote sensing to modeling, citizen science, data management and knowledge co-creation. The outcome of the workshop was a series of recommendations which IOCCP through EuroSea will help implement. These recommendations will be published as part of the workshop proceedings.

In 2021, we will focus on establishing an international coordinating body for IMDOS, through a proposed joint partnership with UNEP. In parallel, work will commence on developing and publishing the first version of the new Marine Plastics Debris EOVS Specification Sheet, further support for harmonization and standardization of sampling methods, and establishing collaboration with the newly formed IOCCG Task Force on Remote Sensing of Marine Debris to strengthen the interface between in situ and remote sensing components of a future IMDOS.

Instruments and Sensors

Maciej Telszewski and Artur Palacz presented the [Instruments and Sensors Theme](#). After Doug Connelly stepped down from his SSG position in early 2020, there has been no SSG member formally responsible for this theme. Shortly after IOCCP-SSG-15, IOC-UNESCO and SCOR approved the nomination of Dariia Atamanchuk (Dalhousie University, Canada) as the new IOCCP SSG member responsible for this theme. Dariia will have started her duties as of January 2021.

The Office reported briefly on the status of the planned next edition of the IOCCP Sensors Training Course as the main action anticipated under this theme. Due to COVID-19 travel restrictions, the SSG approved the recommendation of the Office to postpone the course until June 2022. Previously confirmed co-sponsorship from ICOS-OTC will need to be confirmed. IOCCP Office will continue the fundraising efforts in order to secure the budget before the end of 2021. Because of the resource-intensive nature of this undertaking, early course planning will begin around June 2021 with the focus on developing the agenda, assembling the Organizing Committee and the Scientific Advisory Committee, and inviting lecturers.