XVI Session of the International Ocean Carbon Coordination Project Scientific Steering Group & Global Ocean Observing System Biogeochemistry Panel of Experts (IOCCP-SSG-16)

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REPORT

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Report

Meeting format and participants

The 16th Session of the IOCCP Scientific Steering Group was held on 22-24 November 2021 as a hybrid meeting. There were 6 IOCCP SSG members and two IOCCP Office members who attended in person at the IOCCP Office Headquarters at the Institute of Oceanology of the Polish Academy of Sciences (IOPAN) in Sopot, Poland. The rest of the IOCCP SSG and guests connected remotely via GoToMeeting during most if not all sessions. Full list of meeting participants is provided in Appendix A.

The meeting was opened by the IOCCP Co-Chairs, Kim Currie and Véronique Garçon, who welcomed all IOCCP SSG and guests. The Co-Chairs expressed their joy at the possibility of meeting in-person at least for part of the SSG, and thanked all remote attendees for their participation despite having to occasionally connect at very inconvenient hours.

Special welcome was given to the six new SSG members who joined in May 2021 and for whom this was the first IOCCP Annual Meeting: Sana Ben Ismail, Adrienne Sutton, Maribel García-Ibáñez, Keyhong Park, Steve Jones and Richard Sanders. The new members had an opportunity to briefly introduce themselves to the rest of the group, present their interests and major career activities through dedicated sessions planned over the first two days of the meeting.

This year's meeting agenda was constructed differently from previous years, partially to respond to the challenges of a hybrid meeting, and partially to foster more discussions replacing the past presentation-heavy meeting format. As a result, the bulk of the agenda included so-called mini workshops, ca. 2h sessions dedicated to specific issues or actions for IOCCP SSG members. Such a format also enabled us to invite a greater number of guests, mostly attending one or two mini-workshops where their input was specifically needed. Complete meeting agenda can be found in Appendix B.

The last day of the meeting was organised jointly with G7 FSOI as a 1st Planning Meeting of the Surface Ocean CO_2 Monitoring Strategy. A report from this workshop was prepared by Maria Hood from the G7 FSOI, and can be accessed from here.

Overview of IOCCP accomplishments

The meeting agenda began with an overview of the IOCCP accomplishments over the past annual cycle, introduced by the IOCCP Director. Maciej noted the significant change in the Panel make-up which occurred in 2021. He also commented on IOCCP's active role in developing successful programme bids for the UN Decade of the Ocean for Sustainable Development (henceforth, the Ocean Decade) and highlighted a number of key developments and completed action items, such as the publication of the roadmap towards an ocean oxygen atlas, the Integrated Ocean Carbon Research (IOC-R) report, IOCCP-G7 collaboration towards operationalizing the surface ocean carbon value chain, development of the Integrated Marine Debris Observing System (IMDOS), the 1st ICOS pCO_2 instrument intercomparison exercise and continued support for recurring (SOCAT, GLODAP) and new

(Ship-based Time-Series) data synthesis products, among many other activities and accomplishments. Many of the topics were presented and discussed in detail during the remainder of the meeting, as described below in this report.

IOCCP and the Ocean Decade for Sustainable Development

IOCCP SSG members play leading roles in a number of endorsed programmes of the Ocean Decade, and represent IOCCP contributions to a number of others as well. This session of the meeting included several presentations on the current status of these programmes, and the role of IOCCP in their future evolution was subsequently discussed.

GOOD

Veronique presented the Global Ocean Oxygen Decade (GOOD) program goals and objectives and first accomplishments, such as the GOOD Factsheet, the contribution to the 2021 OceanOPS Report Card, or the high-level GOOD poster presentation at COP26. It was mentioned that the VOICE project (www.ioccp.org/voice), which had received significant IOCCP support in its initial phase during 2017-2019 and constitutes GOOS Implementation Plan Action 6.1, will receive support for regional implementation in association with the Chilean CLAP project. GOOD will also support the development of the Global Ocean Oxygen Data Atlas (GO2DAT) discussed in more detail under the data synthesis mini-workshop part of this report.

OARS

Kim presented the Ocean Acidification Research for Sustainability (OARS; http://www.goa-on.org/oars/overview.php) programme, led by the Global Ocean Acidification Observing Network (GOA-ON). Among the proposed projects under OARS is the OA Data QC Online Package which IOCCP and GOA-ON discussed in greater detail in a dedicated mini-workshop during this meeting, and described below in this report.

GOOS Programmes

Kim also introduced the main rationale behind the three UN Ocean Decade programmes of GOOS. Kim announced that both she and Molly Powers would be stepping down from their roles as co-leads of the “Observing Together” program to which they had been contributing since its inception. While new Co-Chairs are being identified, IOCCP is advised to contact Mairead O’Donovan who is the new Communications Specialist at GOOS Central Office in case of interest in the programme. It is worth noting that the One Argo project belongs to the Observing Together programme, with Fei Chai and Emmanuel Boss providing contributions as Biogeochemical Argo Mission Team members. Current discussions in One Argo programme are on how to merge Core Argo with BGC Argo and Deep Argo to reach a very clear goal for 2030 to have 4600 Argo floats, 1000 BGC Argo floats and 1200 Deep Argo floats, following from the OceanObs’19 CWP recommendations. A new Sailing for Science project is also part of the Observing Together programme. Synergies between this initiative and the Odyssey project of OceanOPS were discussed in detail during the meeting in the

context of IOCCP's increasing involvement in coordinating citizen science observations of biogeochemical EOVs (and the emerging Marine Plastics Debris EOV).

OASIS

Much discussion was sparked by Adrienne's presentation of the Observing Air-Sea Interactions Strategy (OASIS; https://airseaobs.org/) programme which included explicit requests for IOCCP SSG to consider during the meeting. First, IOCCP SSG members were invited to join the OASIS community in order to broaden the expertise related to air-sea biogeochemistry interactions. Interested parties can do so by going to the community webpage at https://airseaobs.org/airsea-community, and/or joining the Slack workspace at: observingairsea.slack.com. It was clarified that this invitation is for individual researchers to join an open community, and that no official IOCCP representation was expected. Currently, Adrienne and Richard from IOCCP SSG are part of the OASIS community, and Artur monitors OASIS activities through Slack membership. Second, IOCCP was asked to consider submitting a request for endorsing the Surface Ocean CO2 Reference Network (SOCONET) as one of the OASIS projects, and possibly propose other relevant projects. For endorsed projects OASIS would provide advocacy, visibility and connections to a wider network. In return, OASIS would want help in influencing harmonisation and coordination across platforms, i.e. to leverage off of what SOCONET is providing as a coordinated observing network. The SSG concluded that further discussion was needed to decide whether it was worthwhile to submit SOCONET as an OASIS project in order to avoid generating coordination overhead or duplicating efforts. In particular, it was noted that cross-platform coordination and co-design is the role of GOOS Observations Coordination Group (OCG) of which SOCONET was already a part. The SSG discussed what the transformative element of making SOCONET contribute to OASIS would be, and requested more information on the level of synergies between OASIS plans and those of existing programmes (e.g. SOLAS Air-Sea theme) or projects (e.g. JPI Oceans and Climate EUREC4A-OA). Third, IOCCP was asked to contribute to a series of webinars planned in the scope of OASIS best practices theme, with a webinar on surface ocean pCO_2 measurements.

The SSG **recommended that IOCCP:**

- **Communicate with OASIS to clarify their request for SOCONET to become an endorsed project under OASIS (as opposed to an OCG network), and respond to the request to organise a webinar around pCO_2 observations.**

Other programmes

The IOCCP SSG members provided additional information on their involvement or knowledge of progress of other UN Ocean Decade programmes. Fei informed the SSG about his involvement in the Coastal SOS regional project led by Minhan Dai (Xiamen University, China), a project which combines observations and modelling. Fei is also part of the Digital Ocean (DITTO) Programme. Steve Jones, Richard Sanders and Siv Lauvset indicated their interest in and plans to contribute to DITTO. DITTO was in the process of getting its governing structure together, hoping to complete that by the end of 2021. It was mentioned by Dariia that the North Atlantic Carbon Observing (NACO) initiative is also considered to be submitted as an UN Ocean Decade project. As far as Korea is concerned, first discussions on the national level have recently occurred to generate more involvement

of Korean scientists in the UN Ocean Decade activities. Keyhong is following the discussions. Finally, Maribel on behalf of IOCCP contacted a few groups behind relevant endorsed Ocean Decade programmes, but noted that neither of them were nearly as advanced as the programmes mentioned above. A meeting between Maribel, Artur and Felix Janssen from the Biogeochemistry Task Team of the Deep Ocean Observing Strategy (DOOS) remains on the list of outstanding actions, put forward into 2022.

IOCCP and the Integrated Marine Debris Observing System

Artur introduced the current status of work towards establishing global coordination of IMDOS, carried out under the auspices of the EU H2020 EuroSea project. IOCCP's efforts in this domain focused on gradually implementing the Action Plan for IMDOS (latest version from March 2021), in particular focusing on promoting global coordination of surface floating plastics as a key component of IMDOS. Throughout 2021 IOCCP managed to initiate a number of close collaborations for the benefit of IMDOS, most notably with the UNEP Global Partnership on Marine Litter (GPML), the Ministry of Environmental Government of Japan (MOEJ), JAMSTEC, GEO Blue Planet and the newly formed International Ocean Colour Coordinating Group (IOCCG) Task Force on Remote Sensing of Marine Litter.

IOCCP contributed as co-organizers to public events such as the Macroalgal Community Workshop to promote augmenting coastal biodiversity surveys with litter monitoring, and the high level Satellite Activity of the UN Ocean Decade Clean Ocean Laboratory on IMDOS to promote the implementation of the IMDOS vision as part of the UN Ocean Decade. In addition, IOCCP held internal meetings with collaborators and partners, as well as contributed with presentations at project meetings, conferences and department seminars.

Framework for Ocean Observing and IOCCP's interaction with other GOOS structures

The main aim of this session was to introduce new SSG members to the Framework for Ocean Observing (FOO), review IOCCP's responsibilities in the implementation of the FOO as the GOOS Biogeochemistry Panel of Experts, as well as to highlight the nature of our relationship with other structures of GOOS. Beyond the informational aspect, the session also resulted in constructive discussions and recommendations which are divided below according to which GOOS structures they pertain to.

FOO

In the broader discussion about the efficiency of implementing the FOO, the SSG pointed at the fact that any economic valuation of what is required vs. available to meet the demands of a truly integrated global ocean observing system was currently still missing, both at the conceptual level of the FOO and programmatic level at GOOS. It was noted that the many different elements of the ocean observing system and value chain don't recognize each other, and at the same time that they do not have mid- to long- term support secured, and often even short term support is provided in the form of "in kind" time of individuals. The SSG discussed known attempts to evaluate the return investment on ocean observing, in particular carbon observing, and referred to other fields of natural science which are able to

capitalise on the known value of observations, including the element of discovery as in astrophysics. Reference to existing work at Woods Hole in the US, and under WP7 of the H2020 EUroSea project were mentioned.

The SSG **recommended for IOCCP to:**

- **Prepare and lead an agenda block (1h discussion) on economic valuation of what is needed to maintain and develop an integrated GOOS as part of the 11th Session of the GOOS Steering Committee in April/May 2022.**
- **Propose economic valuation to be included under the Terms of Reference for the GOOS Task Team on Restructuring and/or Governance.**

Ocean Best Practices System (OBPS)

Much of the discussion focused on the value of the BP repository, the GOOS endorsement process and its response to evolution of the technology. It was noted that the repository is packed with very useful information but at the same time there is little capacity to filter for the state-of-the-art information. Issues with the GOOS endorsement process, mostly the excessive bureaucracy around it, were discussed. It was mentioned that the peer-review process conducted via the Frontiers of Marine Sciences Research Topic on OBPS does not help the community identify which BPs should be followed in which situations.

The SSG agreed that IOCCP should provide the authoritative guidance on what the current GOOS endorsed BPs are with regard to measuring biogeochemical EOVs, and oversee the required changes in time in response to the evolution of the technology.

The SSG **recommended** the following:

- **Include the GOOS endorsed BPs in the respective EOV Specification Sheets as they are updated periodically.**
- **Discuss with OBPS establishing a regular liaison in OBPS to be responsible for regular interaction with each of the GOOS Panels of Experts. These liaisons would need to have some expertise in a given domain.**
- **Convene a meeting with Co-Chairs of GOOS Panels to agree how to interact with the OBPS repository to ensure its future functionality.**

ETOOFS

The SSG noted a very weak connection to the Expert Team on Operational Ocean Forecasting Systems **(**ETOOFS). Considering that the observations-modelling interface is a new theme at IOCCP and that biogeochemical and ecosystem forecasting is the new frontier, the SSG **recommended to:**

- **Establish a working relationship between the responsible IOCCP SSG member (currently Fei Chai) and ETOOFS, and include ETOOFS needs in the IOCCP Action Plan where relevant.**

Updates to Skills, Roles & Responsibilities Matrix

While updating the Matrix, the SSG noted three areas where we currently have gaps. First, we have limited expertise in some phenomena such as marine pollution and benthic fluxes. With IOCCP working at the frontline of establishing IMDOS, it is unlikely that we need to

have stronger expertise in marine pollution internally in the panel. Benthic (biogeochemical) fluxes are mentioned in the context of converging on requirements for Deep Ocean Observing Strategy (DOOS) proposed EOVs. Again, by linking closer to DOOS, the expertise would come from their group of biogeochemistry experts.

Second, the SSG noted the need to account for estuary and coastal water measurements in intermediate salinity values. IOCCP has focused so far entirely on the open ocean, but the latter are needed to address the SDG 14.1 indicator measurement needs, and thus also the Nutrients EOV. A closer link to UNEP Global Environment Monitoring System (GEMS) Oceans is being developed at the high level in GOOS.

Third, the SSG noted a gap in connections at the science-policy interface, particularly with UNFCCC.

The IOCCP SSG **recommended** adding this element to the matrix to be considered in the future selection of IOCCP SSG members.

Technical Capacity Building

IOCCP Sensors Summer School 2022

Maciej and Artur presented the current situation regarding plans to run the IOCCP Sensors Summer Course 2022. Based on the current COVID-19 situation and global travel restrictions or hesitancy, the SSG decided to postpone the course until 2023. A similar decision was taken by SOLAS to postpone their in-person Summer School to 2023 in Cape Verde, and run a virtual course in June 2022. A realistic assessment suggested that any course run in June 2022 would likely be limited to European participants, which did not win approval of the majority of the SSG. We discussed whether some components of the course could be run as interactive online components, as preparation for the in-person course, but it was decided that the value of the course would be limited without the dominant hands-on part.

A suggestion was put forward to explore the potential of combining the SOLAS and IOCCP summer schools in 2023, while considering how to reconcile course length with a joint agenda and fatigue of lecturers. In addition, the SSG suggested that SOLAS and IOCCP may consider convening a group which could discuss the future of ocean carbon training in the post-covid times.

The SSG discussed possibilities of providing elements of technical capacity building through other means. It was proposed that such an element could be added to the regional capacity development workshop planned by IOCCP for North Africa in 2022.

The SSG also decided that we will use 2022 to recap the agenda and scope of the next IOCCP Sensors SUmmer Course under the leadership of Dariia. In order to better align with other capacity building efforts in marine biogeochemistry, it was for example suggested to bring the *GOA-ON in a Box* kit to the next edition of the course.

The session was concluded with **recommendations to:**

- **Announce the postponement of the IOCCP Sensors Course to 2023**
- **Recap the agenda and scope of the IOCCP Sensors Summer Course**
- **Discuss jointly with SOLAS the future of ocean carbon training.**

Thematic Mini-Workshop: Ocean Acidification Data Quality Control Online Tool

This session was attended by the following guests: Christina McGraw, Katherina Schoo, Jan Newton, Kirsten Isensee. Adrienne Sutton, the scientific lead of this effort since its inception in 2020, introduced the goals of the session, and her presentation can be found here.

The following questions were posed for the SSG to discuss:

1) Is IOCCP or IOC taking the role of the management lead for the tool development?
2) Is the proposed scope of work appropriate?
3) What are the potential sources of funding which are needed for contracting the communications and programming group, and travel to promotion at meetings or conferences?

Regarding 1), it was decided that IOCCP and UNESCO-IOC will team up to lead the management and coordination of this work. Terms of Reference will be developed for both organisations in early 2022.

Regarding 2), the proposed scope of work was deemed appropriate. The SSG had a question about whether the tool would in any way tackle the issue of OA calculations at intermediate salinities, but Adrienne pointed at the US OCB Ocean Carbonate System Intercomparison Forum, led by Brendan Carter (NOAA PMEL, USA), as the group addressing that problem.

Regarding 3), the SSG was informed that the OA Data QC Online Tool is included in the resource assessment for the UN Ocean Decade Programme OARS, as indicated on the OARS website: http://goa-on.org/oars/overview.php Furthermore, IOC offered to provide limited financial support, including Katherina's time for coordination work. Similar contributions will be made available from the IOCCP Office providing coordination support.

In the remainder of the session the SSG heard a presentation from Christina McGraw about a recent development of an online interactive tool MEDDLE, done by SCOR WG 149 "Changing Ocean Biological System"; and discussed the potential role of the Ocean Teacher Global Academy (OTGA) as a platform to host the OA Data QC Tool.

Christina's presentation outlined the entire process, from development of scope of work, to production and ongoing dissemination and promotion, thus offering important lessons-learnt perspective as the onset of the OA Data QC Online tool development. Below is a list of few pointers based on the MEDDLE experience:

On resource needs and their allocation

- Most efficient use of MEDDLE for those Early Career Ocean Professionals (ECOPs) trained in person and then following up remotely with the tools provided.
- It took a year to work out the content of MEDDLE, and then about six months to set up the website and the simulator.
- The SCOR WG 149 was quite big but with a handful of people dedicating up to a few hours every week. The group met at least once a year.
- The group now became an infrastructure group which means a lot more can be done with the available resources. The SCOR Infrastructural Project has a really good engaged team. When you are busy it takes a day a week, when not, it is maybe an hour a week. This is voluntary work done in personal time in the evenings and weekends, not a day job.
- Modelling simulation was provided by two WG members. The website design was outsourced to Ionata (https://ionata.com.au/).
- Poor internet connection in some areas of the world motivates running in-person workshops. There is nothing in MEDDLE that requires huge internet resources, videos can be downloaded and watched later offline.

Other suggestions

- Suggest to get website analytics from the get go to know how many users and who is using the resources. Bulk number of MEDDLE users: under 2,000 for video downloads. Comes in pulses, maybe around 50 after a class was given.
- Promoting the use of such tools could be optimised through volunteer ambassadors. MEDDLE explores ECOPs taking on such a role, and running online workshops for various audiences.
- Identifying the audience is very important, as is the ability to provide an engaging and interactive experience in such an envisioned online format.

UNESCO-IOC introduced the OTGA course on OA which was set up almost like a massive open online course (MOOC). It contained 7 modules, with typical long lectures cut down to 15/17 minutes of material, thanks to support from OTGA staff. There are no videos with practical demonstrations. This was meant as a preparation for the subsequent hands-on training. The production of this course was sponsored by OTGA (approximate cost was indicated at 1500 EUR for such a course). When asked about the advantage of building an OTGA course over a tool like MEDDLE, Kirsten mentioned that registered attendees can obtain a certificate for completing an OTGA course, that they receive access to many other existing courses, including in-person courses offered periodically at 17 regional training centres scattered around the world (many of them in developing countries). Moreover, OTGA gives you a chance to track the use of resources

The session was concluded with recommendations to:

1. **IOCCP and IOC/OARS to form the management team. Write down ToRs for each. Put together a group by December 2021.**
2. **Assemble the team and execute the scoping document timeline.**

In addition, Christina McGraw agreed to work as an advisor for this group.

Thematic Mini-Workshop: Time Series

This mini-workshop on Time-Series was led by Adrienne, Kim, Siv and Keyhong with guest attendance by Nico Lange (GEOMAR, Germany). The goal of the session was to review the current status of various international efforts related to time series coordination and synthesis product development. Kim started with a presentation on METS RCN given on behalf of Heather Benway (US OCB). This was followed by a presentation of the H2020 EuroSea project activity and planned work around a pilot ship-based time-series data product for inorganic carbon EOV measurements. Adrienne provided a perspective on the connection between OceanSITES OCG network and IOCCP coordination of fixed-point/moored observations. The second part of the mini-workshop saw a presentation from Adrienne on the best practices of analysing trends in biogeochemical time-series data (see also a corresponding Eos article), and hearing a perspective on future activities by Siv.

The bulk of the discussions focused on the scope and progress of the pilot time-series product and how it fits into the long-term goals of METS RCN. Nico informed the SSG that there are excellent synergies between the two initiatives, with Nico serving on the METS RCN Data Working Group. The ultimate goals are to (i) deliver a sustained ship-based data product and for the observing community to (ii) obtain GOOS recognition as an OCG observing network, either under OceanSITES or otherwise. The pilot data product is expected to be published by mid 2022. Current tasks include assigning uncertainties, defining minimum requirements, archiving unpublished datasets, applying post quality control and eventually implementing data usage licence and tracking on the synthesised dataset.

The SSG pointed at the relatively low number of time-series stations participating in the pilot. Nico clarified that this was the result of imposing stringent requirements upon invitation but also the result of limited responsiveness among the invited PIs. Nico noted a good geographical representation of the stations, including big and small efforts, and the inclusion of historical time-series, such as those from Cariaco Basin and the Kerguelen Islands. Nevertheless, future work includes reaching out to engage more time series stations. Separate discussions will concern transect time series, such as from AMT cruises, after verifying relevance of these observing efforts for GLODAP.

The SSG cautioned against taking the issue of uncertainty assessment/quantification lightly. Recognizing the difficulty of this process, Siv recommended including that from the initial stages of the product development. In the case of SOCAT and GLODAP, it proved even harder to implement uncertainty assessment with time. Moreover, secondary analysis, such as cross-over analysis or similar, was recommended to examine comparability between the time-series stations. Performing such checks against SOCAT or GLODAP is again not trivial but an important step towards ocean data integration. While PIs tend to be reluctant to have a third person look over and assess data quality, the long-term benefits of such an exercise are very large.

Nico responded that such a cross-over analysis had to be removed from the pilot requirements because the majority of PIs did not agree. However, in the planned ESSD paper, Nico aims to demonstrate the value of performing such cross-over analysis with GLODAP, e.g. for a selected time-series site.

Regarding the time-series work in OceanSITES, Adrienne and other SSG members mentioned the following developments and issues:

- There is a need to accelerate data transfer to GDACs
- The OceanSITES Flux Data is there to help extract data from the GDACs
- Too frequent updates to manuals (e.g. Data Format Reference Manual, Data Provider's Guide, Data User's Guide) are becoming an issue to the network contributors.
- An OceanSITES newsletter is now also available by contacting Long Jiang at OceanOPS.
- Data from one of the ICOS buoys is planned to be available through ERDDAP services
- It was recommended to clarify if the European Marine Seafloor Observatory (EMSO), which is an EU ERIC, is part of OceanSITES.

The following key messages were put forward by Adrienne regarding the time series trends detection analysis, following up on the 2019 workshop held in Seattle:

- Paper and associated open-source code in development for spring 2022
- Poster to be presented at Ocean Sciences Meeting (session OC24).
- Recommend establishing a formalised community of practice that would meet regularly (every 2 years?) to share results and new techniques in trend analysis and modify the best practices accordingly. This recommendation identifies a potential future role for IOCCP and GOA-ON

The session was concluded with **recommendations to:**

- **Support Nico Lange in efforts to incorporate other ship-based time series sites in the EuroSea task on developing a synthesis data product.**
- **Support coordination between EuroSea and METS RCN to jointly reach an ultimate outcome which is to obtain GOOS recognition for a coordinated observing network on ship-based time series, either under OceanSITES or another.**
- **Once the best practices are published, explore the potential of IOCCP and GOA-ON to help establish a formalised community of practice that would meet regularly (every 2 years?) to share results and new techniques in OA trend analysis and modify these best practises accordingly**

Thematic Mini-Workshop: Data Synthesis Products

This thematic mini workshop was organised and led by Maciej, Siv and Vero with the objective of deciding how the IOCCP should continue its support the established data synthesis products (SOCAT and GLODAP), and to what extent IOCCP should support the development of new and emerging data synthesis products.

SOCAT

The session started with considering what are the needs for SOCAT carbon data, and whether operationalizing SOCAT was needed in order to allow for more effective long-term high-level fundraising. Dorothee Bakker (UEA, UK) - SOCAT Global Group Leader - gave an

overview presentation of SOCAT, current status and needs with a strong focus on the planned development of the SOCAT business plan.

The SSG discussions focused on several outstanding issues hampering the SOCAT effort:

- Lack of pCO_2 measurements in EEZs where sampling equipment needs to be turned off
- Concerns with the cost of quality control operations
- Challenges in automation as demonstrated by the recent ICOS #pCO2compare exercise
- Reconciling the need for SOCAT automation and technology progress in pCO_2 instrumentation development
- Need for a "known uncertainty" to be specified for SOCAT data to ensure high quality data (NB: high quality is not data with smallest uncertainty but data with KNOWN uncertainty).
- Assigning DOIs by SOCAT vs by NODCs.

The main conclusion of the discussion was that there is a need to inherently consider the issue of an operational SOCAT as part of the broader community and funding agency support for the entire ocean carbon value chain. To this end, the SOCAT business plan discussions were placed in the context of developing the new strategy for surface ocean CO_2 observations which among its goals includes to establish funding to support operational data management centres and the data synthesis activity SOCAT.

Participants agreed and **recommended that:**

- **The surface CO_2 monitoring strategy must highlight both the needs and ambitions for data management and data synthesis, both in terms of operational costs and support for personnel but also for necessary innovations required to streamline and automate workflow to transition towards a sustained, operational system.**
- **The issues of assigning DOIs should be explored, beginning by consulting the existing operational system such as Argo GDACS and DOI attributions.**

Please see details of the discussion and further recommendations on pages 8-11 of the separate report from the joint IOCCP-G7 FSOI first planning meeting which took place in conjunction with IOCCP-SSG-16.

GLODAP

The discussion on GLODAP was introduced by Siv, who in her "GLODAP: vision for the future" presentation among other things referred to the latest release of GLODAP and the so-called GLODAP Manifesto which was published in Nature Communications in 2021.

Similar to SOCAT, the discussions on GLODAP focused around the budgetary needs of GLODAP which were presented already in the report from IOCCP-SSG-15.

GO2DAT

The current status and next steps for the Global Oxygen Data Atlas was introduced by Véronique. This effort, which has been supported by IOCCP from its inception and is recognized in IOCCP's 2020-2023 Action Plan, saw many important developments over the past year. The roadmap towards GO2DAT implementation was published in Frontiers in Marine Science, completing an action item around that. Veronique also pointed at the successful presentation of the GO2DAT concepts as part of the GOOD poster at COP26. The GO2NE/GOOD Meeting held at IOC Headquarters in Paris, France, on 21-22 October 2021, also provided the opportunity to address another action item from IOCCP-SSG-15, namely to organise an in-person workshop to assess progress in implementation of the roadmap towards GO2DAT.

Based on the lessons learnt from the SOCAT and GLODAP experience, GO2DAT sets out with estimating their budgetary requirements from the onset. Included in the UN Ocean Decade Programme GOOD resource assessments from August 2021, GO2DAT implementation would require that:

- 150 K€/year be secured over the first 3 years of GOOD lifetime for hiring 2 developers/engineers as dedicated GO2DAT staff
- Staff to be hosted ideally at an established data centre (NOAA, CMEMS, Bjerknes Climate Data Centre, other?)
- Ultimate GO2DAT global ocean data base and atlas to be stored at IODE

The SSG agreed to further support GO2DAT in those efforts, although no specific new action items were put forward for 2022.

Other data synthesis efforts

The question of other data synthesis efforts was discussed in connection with adopting a strategy to replace Siv Lauvset as the outgoing SSG member, responsible for Synthesis Data Activities, completing her second term by the end of 2022.

Based on the analysis of the skills, roles & responsibilities matrix, it was suggested that the call for a new SSG member should reflect the dynamically evolving field of biogeochemical product development.

In particular, the SSG suggested the possibility to take on coordination of the Nitrous Oxide EOV through providing support for the MEMENTO database (https://memento.geomar.de/) and related data products on N_2O concentration and flux - two products already recognized by GCOS as essential to addressing critical climate knowledge gaps around greenhouse gases.

The recent community effort around a synthesis product on dissolved organic matter, led by Cristian Lonborg from Aarhus University (Denmark), could also be considered in the expanded scope of IOCCP's support.

The IOCCP SSG **recommended to:**

- **consider the needs of new data synthesis products when drafting the open call for a new IOCCP SSG member responsible for Synthesis Activities.**

Thematic Mini-Workshop: Ocean Carbon Monitoring

The aim of this thematic mini-workshop, led by Maciej, Richard, Adrienne, Dariia and Kim, was to review and discuss a number of actions pursued by IOCCP in the broad realm of ocean carbon monitoring. The session was divided according to several issues described below.

Surface Ocean CO_2 Monitoring Strategy

Maria Hood, coordinator of the G7/FSOI Office at Mercator International, introduced the joint IOCCP & G7/FSOI activity to develop “a global surface ocean CO_2 monitoring strategy,” officially launched the following day, on November 25th, through a dedicated workshop organised by IOCCP and G7/FSOI, in conjunction with IOCCP-SSG-16.

This activity, endorsed by the G7 Future of the Seas and Oceans Initiative at its working group meeting in June, will run for 2 years to develop an internationally-agreed strategy and implementation plan for a global network that can be used by governments for coordinated investment actions. The activity will establish a scientific steering group and an International Mission Team, will build on the existing Surface Ocean CO_2 reference Observing Network (SOCONET), and will include plans for a full-time coordinator, potentially as part of the OceanOPS Centre but based at IOCCP Office, and support plans to operationalize the data management centres and the data synthesis project SOCAT. Please see the scoping paper for more background information.

This activity gained momentum at COP 26 following the announcement by NOAA Administrator Dr. Richard Spinrad to establish a globally operational Surface Ocean CO2 Reference Network (SOCONET): "The network will integrate established and proposed national and regional surface ocean carbon dioxide (CO2) research and monitoring efforts into a global framework, enabling countries to track changes in global ocean uptake of CO2 over time. Through international engagement, NOAA will facilitate the development of the global network and produce high-value products, such as observation-based annual updates of ocean carbon uptake and changes in ocean acidification, that are critical for decision making about ocean-based mitigation options and marine ecosystem health."

Through the discussion with the SSG, it was clarified that the strategy document was not going to rewrite the science requirements for surface CO2 observations, but rather focus on the nuts and bolts of building an observing network. Two-year target goals for this activity are to:

- Establish an International Mission Team
- Secure funding for a full-time coordinator as part of the OceanOPS Centre but preferentially based in Sopot
- Secure funding to operationalize data management structures and processes necessary for SOCAT

Maria further clarified the concept of the Mission Team, modelled after the Argo programme, where there is one person per country for all of the countries that are part of the observing

network. Every member of the mission team is then responsible for coordinating operations with colleagues responsible for individual observations in their country.

The need for and ways to reactivate SOCONET became the main focus of this part of the mini-workshop, and provided a much needed context and background discussion to the broader surface CO2 strategy discussions held during the IOCCP & G7/FSOI workshop. The rationale, goals and current status of SOCONET was presented, with strong references to the published OceanObs'19 Community White Paper.

Two issues came to the spotlight: (i) the concept of SOCONET being a reference (i.e. fulfilling strict reporting and data quality criteria) network vs a network open to any members, and (ii) the meaning of the word "operational" vs sustained in the context of ocean observations and data management operations.

All the relevant discussions, including any resulting recommendations and decisions, were included in the final report from the Surface CO2 Strategy workshop which can be accessed from here.

IOC Working Group on Integrated Ocean Carbon Research (IOC-R)
This part was introduced by Maciej with contributions from several of the IOCCP SSG members who also co-authored the first IOCR report: "Integrated Ocean Carbon Research: A Summary of Ocean Carbon Knowledge and a Vision for Coordinated Ocean Carbon Research and Observations for the Next Decade", which sets out to accomplish the vital task of indicating the current gaps and future directions for the integrated ocean carbon cycle research.

As introduced by Maciej in his presentation, IOCCP was one of the five international research and coordination programmes on ocean-climate interaction, which have been working together since 2018 in the IOC Working Group on Integrated Ocean Carbon Research (IOC-R). The other organisations are: the Integrated Marine Biosphere Research Project (IMBeR), the Surface Ocean Lower Atmosphere Study (SOLAS), the Climate and Ocean Variability, Predictability and Change (CLIVAR) project and the Global Carbon Project (GCP).

The report presents a synthesis of the state of knowledge about the oceans' role in the carbon cycle and points to the way ahead. Its objective is to provide decision-makers with the knowledge needed to develop climate change mitigation and adaptation policies for the coming decade. It also emphasises the importance of scientific knowledge to the taking of informed decisions within the United Nations Framework Convention on Climate Change in order to achieve the goals of the Paris Agreement and build more resilient societies. Through continued collaboration amongst IOC-R WG co-conveners, we hope to develop an innovative joint programme of medium- and long-term integrated ocean carbon research to fill the gaps in this field.

Several detailed research questions and recommendations in support of the integrated ocean carbon research which IOCCP SSG discussed in the context of follow-up actions are found in Appendix to the report. These identified gaps in our knowledge are linked to the overarching questions which will be addressed by the IOC-R WG co-conveners:

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

The SSG discussed the fact that activities aimed at addressing the IOC-R report recommendations have been very limited and not interlinked amongst convening partners. It was suggested that IOC should initiate a stocktaking exercise to better account for ongoing and planned activities aimed at implementing the recommendations agreed upon in the report. As an alternative, it was proposed to have a discussion about proposed key actions in response to the recommendations which would then be proposed to be taken up by relevant groups and organisations. While the SSG agreed that implementing parts of the IOCR strategy are critical for IOCCP, IOCCP should not take the responsibility for coordinating all actions related to IOC-R recommendations. IOCCP's contribution to the process could be aided by adding a suitable task to the Terms of Reference of the proposed new OceanOPS/IOCCP Officer responsible for the surface CO2 observing strategy.

ICOS-OTC pCO_2 Intercomparison Exercise

Dariia presented an overview and preliminary results of the first Integrated Carbon Observation System - Ocean Thematic Centre (ICOS OTC) pCO2 intercomparison exercise which was led by Tobias Steinhof (NORCE, Norway) and six other members of the team working at the venue. The intercomparison helped answer the question of how comparable the measurements of the ICOS-Oceans network are, and in the global context. The long-term motivation was to improve the data comparability and lower the uncertainty of pCO2 data delivered into SOCAT.

IOCCP supported the exercise throughout the first half of 2021. On June 25, ICOS OTC together with the IOCCP held a public webinar to kick off the 1st ICOS OTC pCO2 instrument inter-comparison which took place at the Flanders Marine Institute (VLIZ) in Oostende, Belgium, on 28 June - 11 July 2021. The webinar introduced the structure and goals of the exercise but also provided a historical overview and legacy of past pCO2 inter-comparison exercises which took place between 1995 and 2010. The second webinar in a series was organised on 12 July to provide a quick summary of the inter-comparison exercise outcomes. The third and final webinar is anticipated for the near future and will deliver a synthesis of the results and give an opportunity for community discussions prior to the final report publication. Recordings of the webinars are available on the IOC-GOOS YouTube channel:
https://www.youtube.com/watch?v=ksjPIobyuoA (kick-off webinar)
2021 ICOS-OTC pCO2 instrument inter-comparison: preliminary results

Despite the COVID-19 challenges, the intercomparison brought together 29 instruments from 18 different manufacturers, divided into 3 groups: submersible, buoy and underway systems. Nearly all data was processed using Quince (online tool for data reduction) to facilitate daily meeting discussion on preliminary results. Preliminary results revealed clear differences between the 3 groups of sensors and instruments. The group also focused on identifying factors responsible for the observed differences. Participants agreed on the data sharing

policy and planned to complete data processing by December 2021, including making the process transparent and public, and compared with Quince. It was agreed that Quick Start Guides will also be revised, along with sensor data processing routines.

The final outcome will be a summary publication with a full documentation and free and open access to data collected through the intercomparison. The report, authored by all intercomparison participants, will publish the data and information without providing any recommendations for which instruments or sensor is better for a given interpretation. It will be up to the reader to determine what is suitable for their application. The SSG emphasised the need to ensure the legacy of the intercomparison through the publication of results - something which had not been achieved by the latest intercomparison exercise.

The SSG also discussed the importance of publishing the Quick Start Guides which are planned as an annex to the final publication, and which likely would also be published on the IOCCP Instruments & Sensors webpage as critical best-practice type of documents.

Seawater Carbonate System Reference Materials

Kim presented the issues with seawater carbonate system Certified Reference Materials (CRMs) and led the discussion on how IOCCP should continue its support to address the present and future challenges related to the global supply of CRMs in general. Kim thanked Micheal Aquafreda from the GOA-ON Secretariat for providing an up-to-date report on the CRM issues.

Building resilience in the production and distribution of CO2-in-seawater CRMs continues to be an issue for the global marine carbon community because there is a single source of reference materials for total alkalinity, dissolved inorganic carbon, and pH in seawater and a calibrated HCl titrant for seawater alkalinity analysis (A. Dickson Laboratory, Scripps Institution of Oceanography, UC San Diego, USA).

The SSG were given background information on global efforts to address the current shortage of supplies and vulnerability of the long-term provision of RMs ahead of the meeting, through access to a recording of OA Community Discussion Around CO2-in-Seawater Certified Reference Materials (CRMs) recorded on 16 September 2021, as part of the Global Ocean Acidification Observing Network (GOA-ON) Week. Apart from introducing the results from over 240 responses to the "CO2-in-seawater Reference Material Community Survey" organised by the US Interagency Working Group on Ocean Acidification, the session informed and discussed about the status of CRMs and updates on resilience building globally and regionally in the US, Europe and for developing and lesser resourced laboratories.

Kim informed the SSG that the Dickson's lab restarted production of CRMs, and is working through a significant backlog. The major bottleneck in the process surprisingly is the supply of bottles. The specific bottles needed have been backordered since July 2021. This is an opportunity to further encourage the international community to send bottles back to Andrew Dickson and highlight its importance as a means of overcoming the backlog. The Dickson Lab will be funded until March 2024.

Ensuring resilience in the supply of CRMs continues to be a major objective of the IWG-OA, which has been working on the issues since 2020. The agency is working on a white paper outlining the proposed vision. IWG-OA currently views the CRM problem as having three equally important issues that must be addressed in parallel, with IOCCP's support is envisioned for the latter two issues:

- Develop a more resilient US node of CRM production, most likely transition to the model of the US National Institute of Standards and Technology (NIST) which expressed a strong interest to contribute to the certification but NOT production of the CRMs.
- Develop standard operating protocols (SOPs) for making secondary standards, which any lab in the world can apply.
- Work with the international community to develop auxiliary nodes of CRM production.

In Europe, ICOS-OTC (Tobias Steinhoff) ran an emergency secondary CRM production, however it is too early to remark on the results. A cost-analysis of setting up a secondary CRM production within ICOS-OTC was considered, although it should be noted that such a process would not involve any certification. There are plans to develop and publish the protocols for making "in house" secondary standards (already pursued by many groups in an uncoordinated manner) via a research proposal focused on enhancing European GO-SHIP node.

Moreover, JPI Oceans Action Plan included a suggestion that Europe should invest in a standards laboratory. In addition to the concern about long-term supply, the EU recognized that the existing CRMs are not very well calibrated for the Mediterranean Sea. A much broader range of calibrated water samples would be beneficial for many other regions.

Elsewhere in the world, Japan has indicated they could potentially produce a standard, but not certify it. There has been no news from Korea or China on the matter.

The SSG noted that the effects of shortage in CRM supply are already seen in the latest GLODAP release. The consequences of inability to use CRMs on GO-SHIP cruises will also affect other observing platforms which rely on GO-SHIP data to validate their measurements, e.g. Biogeochemical Argo. The SSG discussed the need for a clear and urgent global action plan and coordination of efforts which IOCCP could be in position to lead.

The decision to coordinate such a global response to the challenge of providing a sustained supply of carbon reference materials reinforced the past **recommendation (already included in the IOCCP Action Plan) to:**

- **convene a virtual meeting to compile information around potential support for developing a bid for reference labs to routinely produce ocean carbon CRMs (among other aspects of integration between various ocean carbon observing approaches).**

Maribel volunteered to take charge of this coordination effort with support from the Office, and in consultation with IWG-OA, GOA-ON, ICOS-OTC and other partners.

It was noted that the community has a growing need, and potential capacity for, RMs for pH and pCO_2, and the SSG recommended keeping this broader aspect of CRMs for the full carbonate system in the upcoming discussion.

Thematic Mini-workshop: Augmenting Existing observing platforms with new and emerging biogeochemical Observing Technology

This thematic mini-workshop was organised and led by Veronique, Artur and Dariia with an objective to initiate a discussion around augmenting existing observing platforms, both those integrated as GOOS networks and otherwise, with new and emerging biogeochemical observing technology. In the recent past such discussions and efforts have largely focused on augmenting the existing capacity on repeat hydrography cruises (Bio GO-SHIP) while similar developments related to autonomous and other ship-based observations remained outside of IOCCP's scope of coordination support. This mini-workshop helped clarify where such support would be needed, and establish priorities for IOCCP SSG to initiate relevant actions.

Observations performed by the civil society (citizen science)
Veronique and Artur presented a selection of recent efforts where IOCCP SSG and Office engaged with different civil society groups performing ocean observations with interest to expand onto biogeochemistry and marine pollution. This was followed by a presentation from Martin Kramp, OceanOPS Officer, who has been leading efforts in GOOS to establish partnerships with various civil society groups and recently developed a proposal for a UN Decade Project "Odyssey" which aims to operationalize the contribution of citizens to integrated GOOS data streams. The subsequent discussion among the SSG and guests was moderated to focus on unique types of civil-society ocean-observers as described below.

The Ocean Race, formerly the Volvo Ocean Race, is a prestigious global sailing competition with a history of collaboration with GOOS. In the 2022 edition, as in the past, there are several sailors volunteering to deploy observing platforms but also carry out underway measurements of several EOVs, including Inorganic Carbon (surface pCO_2) and the emerging Marine Plastics Debris EOV (surface floating microplastics). In preparations for this year's edition, IOCCP was contacted with a specific request for guidance on how to best arrange for automatic measurements of dissolved oxygen concentration on selected yachts, in line with current best practices and using state-of-the-art technology. The SSG discussed the fact that IOCCP as GOOS Biogeochemistry Panel has the right mandate to provide such authoritative guidance and that promoting the adequate use of best practices for biogeochemical sampling and data processing is within our Terms of Reference.

Ponant Cruises is a French company organising pleasure cruises to the Arctic and the Antarctic, also with a history of collaborating with GOOS. The recently constructed ice-breaker Le Commandant Charcot has special facilities for performing scientific campaigns during its cruises. The company has large ambitions of providing a contribution to oceanographic research and starting in 2022 invites proposals for short and long-term scientific programmes to be performed using Ponant facilities and the Science Team.

Veronique leads one proposal aimed at supporting sustained marine biogeochemistry observations in the Arctic, fulfilling the needs outlined by several UN Decade Programmes: oxygen for GOOD, inorganic carbon for OARS, and marine plastics debris for IMDOS (which is likely to be proposed as a programme in the near future). The proposal was submitted by January 15th 2022, and has since then been recommended for implementation by Ponant.

Smaller scale engagements were also mentioned such as those initiated by the IOCCP Office with the SmartFin project, a non-profit initiative which is building sensors for the global surfing community; and with Ekkopol, a French NGO collecting low-cost marine plastic and other EOV measurements on a small coastal boat.

Martin Kramp mentioned his strong involvement with the Ocean Race Science Committee in the past, his interactions with Ponant Cruises, as well as with Plankton Planet. He highlighted the fact that the proposed Odyssey Project, managed out of OceanOPS, would provide a new framework for global coordination of sustained ocean observations by civil society groups, and recommended that IOCCP efforts in this domain be carried out in consultation with the OceanOPS Office. Martin also introduced the growing collaboration between OceanOPS and the shipping companies, starting from the Hamburg Süd and recently with Maersk. The shipping companies are required to participate in sustainability programs and in addition, are considering decarbonizing their fleets. These developments have made them more open for scientific collaborations, including with GOOS. Martin emphasised that engaging the private sector is another key priority for the UN Decade project Odyssey.

The SSG inquired about the prospects of carrying out widespread underway pCO_2 measurements on the Maersk fleet. Martin explained that drilling a whole in the hull of a ship is no longer an issue, and that while the Hamburg Süd in the past already offered 65 of their ships for such operations, there was a shortage of instruments available for deployment, as well as shortage of scientists able to carry out such a project. The group commented that tech companies would be able to increase sensor and instrument production if and when the market demand grows (e.g. a 300 vessel fleet from Maersk) and a new business model becomes possible. There was no suggestion for how to address the issues of shipping companies not willing to pay for person's time to operate the instrumentation.

Apart from instruments' and scientists' availability, there exist a number of issues related to adhering to best practices, standardising instruments (see discussion on SOCONET) and coordinated approach to contacting ships. The new Odyssey project hopes to provide such services at a global scale and across disciplines, building on the current capacity of OceanOPS to track what a given vessel was doing for the scientific community in the past.

In addition, Dariia mentioned that in Canada there is interest from shrimping vessels to conduct environmental measurements onboard, and that the scientific community is working on developing solutions for underway measurements with that fishing community.

In conclusion it was **recommended that IOCCP:**

- **Setup an ad-hoc task team to provide authoritative guidance on conducting oxygen and other biogeochemical measurements and management of data during and after the Ocean Race 2022.**

- **Develop a general process to respond to requests for authoritative guidance on standards and best practices associated with augmenting existing and new platforms with biogeochemical sensors and instruments.**
- **Collaborate with OceanOPS to contribute to the UN Decade Project Odyssey on engaging civil society groups in sustained marine biogeochemistry observations.**
- **Contribute to a proposal for biogeochemical measurements with Ponant Cruises as a partner of GOOD and OARS UN Decade programs, and as coordinators of the IMDOS project.**

Adding biogeochemistry to OceanSITES and other fixed-point arrays and best practices for GBC sensors on OOI's

Dariia introduced the current status of work related to augmenting OceanSITES and other fixed-point arrays with capacity for biogeochemistry observations, including progress on the report with recommendations for adding biogeochemical (and biological) observations to OceanSITES are part of the Terms of Reference of SCOR WG 154 (P-OBS) which has already produced a report relevant for repeat hydrography surveys of GO-SHIP.

Dariia used the examples of the OSNAP and RAPID arrays to illustrate the major challenge of quality control of the sensors, especially in deeper waters, which are being added onto the moorings. While lab-on-chip sensors are now being developed, e.g. at the National Oceanography Centre in the UK, adequate QC procedures are needed.

The issue of unknown quality of collected data has also motivated the effort to build a Community of Practice for the Ocean Observatories Initiatives (OOI; https://oceanobservatories.org/) Biogeochemistry Sensor datasets. The SSG referred to an ongoing conversation between marine biogeochemists and the weather community which could offer lessons learnt. It is known that biogeochemical sensors are significantly more complex than the ones used for meteorological or physical measurements which creates a variety of challenges including those related to size, battery usage, vulnerability to elements, costs and more. It was noted that a standardised package would help ensure high quality of data and operationalize the observing network, but on the other hand, could limit (at least initially) the number of data providers able to meet the requirements, especially among the research community. It was also noted that a systematic approach to innovation would have to be implemented to prevent standardisation from holding innovation back.

AniBOS

Clive McMahon (Univ. of Tasmania, Australia) joined the meeting to introduce the new emerging GOOS OCG network Animal Borne Ocean Sensors (ANIBOS; www.anibos.com) which provides freely available oceanographic measurements across the world's polar and tropical oceans collected through bio-logging, the deployment of sensors on marine animals. These data complement conventional approaches by providing both physical and ecological data in ocean regions directly at the scale and resolution at which animals move. AniBOS will integrate animal collected data within GOOS to improve our ability to observe and predict global climate processes and animal behaviour for societal benefit.

The AniBOS network is unique because it delivers across all three of GOOS' critical themes: climate, marine ecosystem health and operational services. The objectives and nature of the network was very comprehensively described in a recent paper shared as a background document for this mini-workshop.

Clive's presentation incited a lively discussion about the benefits and challenges behind conducting biogeochemistry observations by migrating animals which help sample some of the most remote and undersampled polar regions of the ocean. AniBOS currently only collects data on dissolved oxygen and chlorophyll-a. These sensors are quite new and relatively cheap. However, they require plenty of work around standardisation and quality control. That is a task of the special Data Committee of AniBOS. Currently, there is work underway on a best practices document planned to be submitted for publication in mid 2022 along with an ethics welfare document.

The SSG inquired about the recovery rate of deployed sensors, which turns out to be 60-70% on average, depending on remoteness of the area and availability of personnel on the ground. Clive clarified that adult mammals can keep the sensors running for around 280 days. For turtles this is 300-400 days, with enough battery life in the basic CTD for the entire period, though with very low recovery for turtles.

The group discussed cross-network analysis with co-located BGC Argo fluorometer measurements and GO-SHIP hydrographic lines for oxygen. It was noted that such analysis happened with Argo and ships, described in a publication by Fabien Roquet, but so far not for any biogeochemical measurements. Univ. Tasmania started to work on integration of AniBOS data with those from Biogeochemical Argo. Also, some data is already integrated into some regional ecosystem models, e.g. around the Kerguelen Plateau. There it was found that measurements made by seals have helped reduce phytoplankton biomass estimation error below 5% relative to those from ocean colour remote sensing.

The SSG also suggested looking at deploying pH sensors along with oxygen since the used pyro sensor operates on similar principles to that of the oxygen one.

When asked about new technology developments, Clive suggested that now is the time for the community to come upfront and communicate their needs and support development together with instrument makers. Not a biogeochemist himself, Clive referred to AniBOS Steering Committee member Christophe Guinet (CEBC, CNRS – La Rochelle Université, France) for more detailed information about the current and planned work in relation to biogeochemical sensors and data used by AniBOS.

Thematic Mini-Workshop: Regional Implementation with Focus on Southern Mediterranean Sea

This thematic mini-workshop was organised and led by Veronique, Sana, Kim and Artur with the goal of (i) agreeing on a general strategy of IOCCP to support regional implementation of marine biogeochemistry observing requirements, and (ii) planning a dedicated workshop for

2022 to help address the needs of the Southern Mediterranean observing community in particular.

The session started with comments from the Office on how IOCCP has been supporting regional implementation so far, and especially since 2016 when a dedicated SSG member was first appointed in such a role. The SSG and Office exchanged views on what was successfully achieved through strong support for the Latin American community, with a clear focus on increasing the readiness level of ocean acidification observations. On the other hand, we discussed the drawbacks of giving preferential access to IOCCP support for a community from one geographical region having a direct representative on IOCCP SSG.

The SSG and guests attending the session strongly recommended better identification and leveraging of the capacity of existing structures already offering support for ocean observing in a given region, for example the GOA-ON regional hubs, GOOS Regional Alliances or various observing networks and communities of practice. Such an approach would help ensure connection to regional needs in areas which don't have a direct representation on IOCCP SSG. In the case of Latin America, Patricia Miloslavich recommended in particular to establish collaboration with the MBON Pole-to-Pole network which considers biogeochemistry and other environmental monitoring in parallel to the biodiversity surveys (contact Enrique Montes, president of IABO and member of SCOR Exec Committee).

IOCCP has historically been well connected to the Australian and Pacific Islands communities although no specific IOCCP support was requested in the past. Kim presented how the Pacific Islands have successfully managed to raise their observing capacity and establish excellent coordination and mutual support to meet the specific requirements identified in that region noting that other regions could learn from the PI countries to use one coordinated and agreed and therefore strong regional message (e.g. at COP meetings) which helped to build a strong sense of community. IOCCP has also had strong ties to the East Asia community, the latter however strongly focused on the needs and capacities of the Japanese community. The addition of Chinese and Korean representatives on IOCCP over the past 2 years has significantly broadened our perspective on how to better engage with the East Asia community across a number of themes which IOCCP coordination and communication services provide support for.

Until 2021, the IOCCP had very limited connection with and impact on the African observing community. Appointing a new SSG member from Tunisia in 2021 provided a new opportunity to better picture the landscape of requirements and observing capacities in this region of the world. During this mini-workshop Sana gave a summary presentation providing a perspective on what the key scientific issues of the Northern African observing community are, as well as the current status and gaps in that region. Importantly, Sana commented on the existing collaborations with and support from other Mediterranean countries, in particular Spain and France.

General unfavourable economic situation in the N. African region was deepened by the COVID pandemic, which has a strong impact on science. The relative cost of equipment and consumables is much higher than in neighbouring regions, namely southern Europe. Therefore any initiatives that IOCCP might want to lead in the region need to involve partners

from both sides of the Mediterranean. Also, utilising the networking and capacity building efforts already accomplished by the GOA-ON Med Hub will be critical.

Some regional networking beyond the OA Med Hub takes place among key partners in Algeria, Morocco, Tunisia and Egypt but information exchange is very fragmented and limited. Also other potential partners in those countries and the Libyan community are yet to be connected. Therefore it is critical that the very first step in our attempt to build capacity will be to organise a workshop where all invited participants would share their status across a wide set of (perhaps partially pre-defined) aspects like: their scientific objectives, their personnel and technical capacities, their potential to expand those, their ambitions beyond current capacities etc.

Currently, we have fragmented knowledge of technical capacity in the region. For example Sana informed us that: a glider system operates off the coast of Morocco with some biogeochemical sensors installed; a FerryBox system is installed on two transects: Tunis-Genoa and Tunis-Marseille but currently a pCO_2 sensor is not part of this system. A systematic approach to assessing the actual technical capacity in the region is needed before the workshop.

Also scientific expertise and interest need to be assessed to identify potential gaps and steps to increase readiness level across marine biogeochemistry domain. Ocean acidification and blue carbon were named as most promising areas of expertise in the region. At the same time uncertainty was expressed regarding availability of champions in carbonate chemistry observations.

Based on the synthesised knowledge from such a workshop, IOCCP will be in a better position to offer coordination in organising, co-sponsoring and/or fundraising for activities specifically tailored to the regional needs, keeping in mind a wider perspective including data-sharing, contribution to existing activities, utilising available funding streams etc.

Finally, COP27 which will be held in November 2022 in Egypt was indicated as a possible arena for raising the awareness of the need for significant improvement of the technical and scientific capacity of the southern Med countries to observe marine biogeochemistry in a coherent, integrated and effective fashion.

Based on the lessons learnt over the past 5 years and in conclusion of the discussions in this session, the SSG made the following key recommendations:

- **Ensure that regional support activities are available and applicable to more than one geographical region, and relevant to more than one theme of IOCCP.**
- **Collaborate with and leverage existing regional structures and communities of practice to streamline technical capacity building and other activities, and thus maximise their impact.**
- **Organise a workshop to bring together all the local players with a specific effort on the Southern Mediterranean involving the OA Med Hub, Spanish and French labs which are already collaborating with N African labs. Minimum outcome: getting a network of people from these countries together.**

Summary of IOCCP-SSG-16 Action Items

IOCCP & the UN Ocean Decade

ACTION: Communicate with OASIS' to clarify their request for SOCONET to become an endorsed project under OASIS (as opposed to an OCG network), and respond to the request to organise a webinar around pCO_2 observations.
Responsible: Maciej/Richard, Dariia (webinar)
Timeline: asap

IOCCP's interaction with GOOS

ACTION: Organise a meeting with Co-Chairs of GOOS Panels to agree how to interact with the OBPS repository (e.g. regular liaison for each Panel) so that it is functional for us and the observing community.
Responsible: the Office
Timeline: mid 2022

ACTION: Establish a relationship with ETOOFS regarding use of biogeochemical data in forecasting models.
Responsible: Fei Chai
Timeline: mid 2022

ACTION: Suggest an agenda block during GOOS SC on economic valuation of what is needed to maintain and develop an integrated GOOS.
Responsible: Co-Chairs and Office
Timeline: early 2022

Online OA QC Tool

ACTION: IOCCP and IOC/OARS to form the management team for this project, starting with writing down ToRs for each. Using the approved scope of work and timeline proposed by Adrienne, assemble members of the science group implementing the product.
Responsible: Adrienne Sutton, the Office
Timeline: convene group in early 2022

Technical Capacity Building

ACTION: Announce the postponement of the IOCCP Sensors Course to 2023; discuss jointly with SOLAS the future of ocean carbon training.
Responsible: The Office
Timeline: early 2022

ACTION: Recap the agenda and scope of the IOCCP Sensors Summer Course, including through a discussion with SOLAS on the general future of ocean carbon training.
Responsible: Dariia Atamanchuk, The Office
Timeline: mid 2022

Time Series Mini Workshop

RECOMMENDATION: Support Nico Lange in efforts to incorporate other ship-based time series sites in the EuroSea task on developing a synthesis data product.

RECOMMENDATION: Support coordination between EuroSea and METS RCN to jointly reach an ultimate outcome which is to obtain GOOS recognition for a coordinated observing network on ship-based time series, either under OceanSITES or another.

RECOMMENDATION: Establishing a formalised community of practice that would meet regularly (every 2 years?) to share results and new techniques in OA trend analysis and modify these best practices accordingly. --> Potential future role for IOCCP and GOA-ON

ACTION: Update the Time-Series directory tables on
http://www.ioccp.org/index.php/time-series-efforts
Responsible: Keyhong Park, the Office
Timeline: early 2022

Engaging citizens and expanding biogeochemistry

ACTION: Coordinate submitting an application for a 5-year program on sustained ocean observing onboard Ponant cruises.
Responsible: Véronique Garçon, the Office
Timeline: January 2022

ACTION: Coordinate with UN Decade Odyssey about any proposals for citizen science and private sector relevant for marine biogeochemistry, e.g. supplying Maersk ships with underway pCO2 systems.
Responsible: the Office, Richard Sanders
Timeline: 2022

ACTION: Develop a process to respond to requests for authoritative guidance on standards and best practices associated with augmenting existing and new platforms with biogeochemical sensors and instruments.
Responsible: IOCCP Exec, Dariia Atamanchuk
Timeline: 2022

Data Synthesis Products

ACTION: Expand data synthesis efforts beyond the traditional ship-based observations and consider that requirement when drafting an open call for SSG member responsible for synthesis activities.
Responsible: Siv, IOCCP Office

ACTION: To support and organise a follow-up workshop on GO2DAT.
Responsible: Véronique Garçon, the Office
TImeline: when requested

Regional Implementation

ACTION: Organise a workshop to bring together all the local players with a specific effort on the Southern Mediterranean involving the OA Med Hub, Spanish and French labs which are already collaborating with N African labs. Minimum outcome: getting a network of people from these countries together.
Responsible: Sana Ben Ismail, Maribel García-Ibáñez, the Office

Timeline: ca. June-September 2022 (Maribel to confirm dates of a large Spanish-French cruise planned for that period to avoid conflict of dates)

Ocean Carbon Monitoring

ACTION: Coordinate a global response to the challenge of providing a sustained supply of carbon reference materials.
Responsible: Maribel Garcia-Ibanez
Timeline: 2022

ACTION: Establish an internationally-agreed strategy and implementation plan for surface ocean carbon monitoring, that can be used by governments for funding decisions that enable integration of individual pilot elements to achieve the required global system.
Responsible: Richard Sanders, the Office
Timeline: end of 2022

ACTION: Establish an International Mission Team to guide and oversee the implementation of the surface ocean carbon observing system
Responsible: Richard Sanders, the Office
Timeline: end of 2022

ACTION: Secure funding to support a full-time coordinator as part of the OceanOPS Centre, ideally located at IOCCP Office in Sopot, Poland.
Responsible: Richard Sanders, the Office
Timeline: 2023-2024

ACTION: Secure funding to support operational data management centres and the data synthesis activity SOCAT
Responsible: Richard Sanders, the Office
Timeline: 2023-2024

Appendix A: List of meeting participants

Table A1. 2021 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)**	remotely
Véronique Garçon (F)	CNRS-LEGOS	France	Oxygen **(Co-Chair)**	In person
Siv Lauvset (F)	NORCE	Norway	Synthesis activities	In person
Adrienne Sutton (F)	NOAA PMEL	USA	Time-Series Efforts: Global	remotely
Sana Ben Ismail (F)	INSTM	Tunisia	Regional Implementation	remotely
Keyhong Park (M)	KOPRI	South Korea	Time-Series Efforts: Regional	remotely
Maribel García-Ibáñez (F)	UEA / CSIC	UK / Spain	Interior Ocean Observations	In person
Dariia Atamanchuk (F)	Dalhousie Univ.	Canada	Instruments & Sensors	In person
Steve Jones (M)	NORCE	Norway	Data & Information Access Services	In person
Richard Sanders (M)	NORCE	Norway	Surface Ocean Observations	In person
Fei Chai (M)	SIO/Univ. Maine	China/USA	Observations - Modelling Interface	remotely
Emmanuel Boss (M)	Univ. Maine	USA	Particulate Matter	Not attending

Table A2. 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	In person
Artur Palacz (M)	IOCCP/IO PAN	Poland	Project Officer	In person
Belen Martin Miguez (F)	OOPC/WMO	Switzerland	GOOS Physics Panel Officer	remotely
Patricia Miloslavich (F)	SCOR	USA	SCOR Executive Director	remotely
Maria Hood (F)	Mercator International	France	G7 FSOI EU Office Coordinator	In person
Martin Kramp (M)	OceanOPS	France	OceanOPS Officer	remotely
Clive McMahon (M)	Univ. Tasmania	Australia	AniBOS co-Chair	remotely
Dorothee Bakker (F)	UEA	UK	SOCAT Global Group Leader	remotely
Jan Newton (F)	UW	USA	GOA-ON	remotely
Christina McGraw (F)	Univ Otago	New Zealand	SCOR WG MEDDLE	remotely
Nico Lange (M)	GEOMAR	Germany	EuroSea Time Series Data product	remotely

Appendix B: Agenda

XVIth Session of the
International Ocean Carbon Coordination Project
Scientific Steering Group

GOOS Biogeochemistry Panel of Experts

22-24 November 2021

HYBRID MEETING AGENDA

Daily Schedule:

7:30 - 11:00 **Morning Plenary Hybrid Session**

11:00 - 12:00 time for in-person attendees to answer emails and attend other urgent matters online (2nd coffee service will be served during this time)

12:00 - 13:15 **Midday Session** (page 5 of the agenda document for details) for in-person participants with remote attendance of Sana, Keyhong and Fei feasible and appreciated.

13:30 - 14:30 Lunch break

14:30 - 17:30 time for in-person participants to either work in the meeting room, rest in the Hotel or spend time visiting Sopot, Gdansk, Gdynia.

17:30 - 19:30 **Evening Plenary Hybrid Session**

Online meeting etiquette

- Make sure that you have GoToMeeting on your computer whether you attend in-person or virtually as everyone will be connected to the meeting. Each day the meeting will be open 15 minutes before the scheduled start time to allow for informal interaction.
- By default, keep your microphone muted unless you are speaking. Please try to use video during discussions, unless it presents a problem for bandwidth.
- If you have a question or comment, please unmute your microphone and wait to be called upon, or use the chat box in GoToMeeting to type “I have a question/comment” or just type your question in order to be read by the moderator.
- Please be succinct in both your questions and answers.
- At the end of each item, please expect to be called upon, in a roundtable, to ensure all have had the possibility of commenting.
- If unable to express your comment/question verbally, please type in as much as possible into the chat box for the record.
- The sessions will be recorded for the secretariat, only for the purpose of writing the report, and the recordings deleted afterwards.

MONDAY, 22 November 2021 *[All times in local time, CET, Sopot, Poland]*

07:15-07:30 Logging in and informal chat (Kim Chairs the session, D1S1)

07:30-07:40 **Opening and Welcome** *(Vero and Kim; Maciej – meeting etiquette, logistics)*

07:40-07:55 **Overview of major achievements and challenges since IOCCP-SSG-15** *(Maciej)*

07:55-09:05 **IOCCP and the Ocean Decade for Sustainable Development**

- **GOOD** (*Veronique*, 10mins + 5mins Q&A)
  - *GOOD Factsheet*
  - *GOOS Report card 2021*
- **OARS** (*Kim*, 10mins + 5mins Q&A)
  - *Potential topics*
  - *OARS webpage*
- **GOOS** Programmes (*Kim*, 10mins + 5mins Q&A)
  - *Potential topics*
  - *GOOS Ocean Decade Programmes*
- **OASIS** (*Adrienne*, 10mins + 5mins Q&A)
  - *Join the OASIS community at https://airseaobs.org/airsea-community*
  - *Submit requests for endorsement as a UN Decade Project linked to OASIS: www.surveymonkey.co.uk/r/OASISDecade*
  - Link(s) to background docs: slides
- Update on involvement in other Programmes from the SSG members (10 mins)

09:05-09:20 **IOCCP and the Integrated Marine Debris Observing System (IMDOS) (*Artur*, 10 + 5 mins)**
Background documents:

- Plan of Action for establishing global coordination of IMDOS (March 2021)
- "Global coordination of surface floating plastics - a key component of IMDOS" slides from a meeting between GOOS and the Ministry of Environment, Government of Japan (MOEJ), 18 Oct 2021

09:20-09:50 Health Break

09:50-11:00 **Overview of major activities and interests of new SSG members**

- *Dariia, Keyhong, Sana, Richard, Maribel, Steve* (10mins each)

17:15-17:30 Logging in and informal chat (Vero Chairs the session, D1S2)

17:30-19:15 **Thematic mini-workshop on: Ocean Acidification Data Quality Control Online Package (*leads: Adrienne, Kim*)**

- Review scope of work
- MEDDLE presentation by Christina McGraw: meddle-scor149.org
- Renewed commitment from IOCCP to be involved (as partner organization or management lead?)
- Potential sources of funding for: contracting communications and programming group and travel for promotion at conferences
- Link(s) to background docs: slides, OA Data QC Online Package: Scope of Work

19:15-19:30 **IOCCP Sensors Summer School 2022 (*leads: Maciej, Artur, Dariia*)**

- Will the in-person activity be possible in 2022 under current circumstances?
- Topics (to be further discussed during the midday session the following day):
  - can we run components as online interactive prep material???
  - is capacity building of other sorts in our mission?
  - see specific agenda item for more details
- Link to IOCCP Technical training Page

19:30 Close for the day

TUESDAY, 23 November 2021

07:15-07:30 Logging in and informal chat (Kim Chairs the session, D2S1)

07:30-07:40 Overview of major activities and interests of new SSG members

- *Adrienne* (10mins)

07:40-09:00 Thematic mini-workshop on: Time Series (*leads: Adrienne, Keyhong, Kim, Siv*)

- METS RCN (*Kim*),
  - background and information
- EuroSea activity and planned work (Nico)
- Connection to OceanSITES (Link(s) to background docs: slides) (Adrienne)
- Time Series trends - best practices (Background docs: Eos article, slides) (Adrienne)
- Thoughts on future activities (Siv)

In general, what can we help with?

09:00-09:30 Health Break

09:30-11:30 Thematic mini-workshop on: Data Synthesis Products (*leads: Maciej-intro, Siv, Vero*)

9:30-9:45 **SOCAT** (Dorothee Bakker, SOCAT Global Group Leader)

- Dorothee's presentation
- Budgetary needs today and into the future
- How can IOCCP help?

9:45-10:05 Discussion on SOCAT business plan

What are the needs for SOCAT carbon data? Isn't it necessary to discuss combining SOCAT and GLODAP data products to meet some of the needs? Is operationalizing SOCAT needed/necessary/disadvantageous in order to allow for more effective long-term high-level fundraising?

10:05-10:20 **GLODAP** (Siv)

- Siv's presentation
- GLODAPv2.2021 release poster
- GLODAP Manifesto (Nature Comms paper)

10:20-10:40 Discussion on GLODAP

What are the needs for GLODAP carbon data? Isn't it necessary to discuss combining SOCAT and GLODAP data products to meet some of the needs? Is operationalizing GLODAP needed/necessary/disadvantageous in order to allow for more effective long-term high-level fundraising?

10:40-11:00 **GO2DAT and synthesis product** (Véronique)

- GO2DAT poster at COP26
- What are the next steps and what that means for IOCCP

11:00-11:15 Other data synthesis products? (All participants)

11:15-11:30 Siv rotates off, we need discussion around IOCCP needs related to inviting new member (Kim analyses the matrix, all discuss the topic)
Link to IOCCP Skills-roles-responsibilities-matrix

17.15-17.30 Logging in and informal chat (Vero Chairs the session, D2S2)

17.30-19.30 Thematic mini-workshop on: Augmenting existing observing platforms with new and emerging biogeochemical observing technology (*leads: Véronique, Artur, Dariia*)

17:30-17:50 Introduction, Ocean Race, Ponant cruises (*Véronique*)
Surfers, Plankton Planet & Particulate Matter, Ekkopol and Plastics (*Artur*)

17:50-18:00 UN Decade Project "Odyssey" (*Martin Kramp, OceanOPS Officer*)

18:00-18:20 Discussion on Citizen Science (*All participants*)

18:20-18:30 AniBOS (*Clive McMahon, AniBOS co-Chair*)
Clive's presentation: slides
Background document: McMahon et al. (2021; FMARS)

18:30-19:00 Discussion on animal telemetry (*All participants*)

19:00-19:15 Adding biogeochemistry to OceanSITES and other fixed-point arrays and OOI Best practices on BGC sensors (*Dariia*)
Background document: SCOR WG 154 draft report

19:15 - 19:30 Discussion (*All participants*)

19.30 Close for the day

WEDNESDAY, 24 November 2021

07:15-07:30 Logging in and informal chat (Kim Chairs the session, D3S1)

07:30-11:00 Thematic mini-workshop on: Ocean Carbon Monitoring (*leads: Maciej-intro, Richard, Adrienne, Kim*)

- G7/FSOI Activity (*Maria Hood, G7 FSOI*)
  - Scoping Paper
  - What that means for IOCCP? What that means for the community?
- SOCONET (*Richard, Adrienne, Maciej*)
  - OceanObs'19 White Paper
  - We badly need to reactivate the network
- IOCR WG Report (Maciej)
  - What are the next steps and what that means for IOCCP?
  - Maciej's slides
- ICOS Intercomparison overview and preliminary results (Dariia)
- Carbon RM's (Kim)
  - Background information:
  - recording of OA Community Discussion Around CO2-in-Seawater Certified Reference Materials (CRMs)
  - link to Science news article

17.15-17.30 Logging in and informal chat (Vero Chairs the session, D3S2)

17.30-19.30 Thematic mini-workshop on: Regional IOCCP Implementation. Focus: Southern Mediterranean Sea (*leads: Sana, Kim, Vero, Artur*)

17.30-17.45 How does IOCCP support regional implementation of its ToRs?*(Maciej and Artur)*
- Lessons learnt from supporting regional ocean acidification observations

17.45-18.00 Discussion on Global topics (Ocean Acidification, Blue Carbon, Marine Litter) (**Vero ?**)

18.00- 18.20 Regional discussion: Focus on Southern Mediterranean (*Sana*)
- Scientific issues and actual status

18.20- 18.40 Regional discussion: Focus on East Asia (*Keyhong*)
- Scientific issues and actual status

18.40- 19.00 Regional discussion: Focus on Pacific Islands (*Kim*)
- Scientific issues and actual status

19.00- 19.30 **Decision on concrete action plan**

Hopeful outcomes: what elements would be most beneficial to S.Med community, who on SSG could be made responsible, plan for regional workshop.

19.30 ***Close for the day***

Midday Session Monday, 22 November 2021

(remote attendance of Sana, Keyhong and Fei feasible)

12:00-13:15 **Overview of our role(s), partners and opportunities in GOOS (leads: Maciej, Artur)**

- Structures of GOOS and beyond (15 mins including Q&A)
- FOO and EOVs (10 mins including Q&A)
- Skills Roles and Responsibilities Matrix in this context (brainstorming)

Midday Session Tuesday, 23 November 2021

(remote attendance of Sana, Keyhong and Fei feasible)

12:00-13:15 **Brainstorming around potential training and capacity building activities (*leads: Maciej, Artur*)**

- will the in-person activity be possible in 2022 under current circumstances?
- can we run components of such Course as online interactive preparation material for the in-person course in the future??? Example OTGA online course based on 2019 Training (*Artur*)
- venue (Sweden, Africa thru DOTCAN, others)
- potential for linking to other summer schools
- course curriculum - sensors are their applications, new research topics;
- linkage to Ocean Best Practices, other SOPs, OCB, SOLAS, GO2NE training
- Are there other options to build technical training tools for online use?
- is capacity building of other sorts in our mission?

Midday Session Wednesday, 24 November 2021

(remote attendance of Sana, Keyhong and Fei feasible)

12:00-13:15 **Focus on individual Actions items across the Action Plan (*leads: Maciej, Artur*)**

- Approving timeline and realistic responsibilities
- cross-Panel interactions for delivery of individual Action items
- developing Action items and Actions as needed
