International Ocean Carbon Coordination Project

Progress Report for SCOR, July 2022

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EXECUTIVE SUMMARY

Scientific assessments urge the global community to achieve net-zero greenhouse gases (GHGs) emissions by 2050 in order to meet the Paris Agreement's goals, and to avoid potentially dangerous climate impacts. Net-zero is a critical long-term goal for nations aiming to balance uptake and release of GHGs contributing to global warming. The atmospheric CO_2 concentration depends on the uptake and storage of CO_2 in the ocean. Policies aiming for a net-zero transformation must therefore consider the ocean and its potentially changing baseline as an essential part of the calculation. Net-zero roadmaps need a vigorous re-thinking, given that the word 'ocean' was not considered in the original Paris Climate Agreement. Broad deployment of existing monitoring tools can generate assessments of natural sinks of the ocean, as well as the anthropogenically-forced trends. Also, new observational tools should take into consideration the ocean (e.g. sail drones, argos, gliders, etc.), as it may have significant potential in fulfilling an efficient and sustainable 'net-zero' future.

Over the past 20 years, the ocean carbon community with significant help from IOCCP, has been building the elements of the value chain we need to convert these societal needs for ocean carbon information, into the observing and forecasting system required to deliver it. Starting with observations through SOCONET, GO-SHIP, BiogeochemicalArgo and OceanSITES, through data synthesis products like SOCAT, GLODAP and GO2DAT, through collaboration with modelling community to deliver the oceanic part of the annual Global Carbon Budget. All these community-led elements have been operating for several years mostly on a volunteer basis, supported by short-term research funding, which makes them rather fragile, and hinders progress.

The IOCCP is now heavily involved in several activities aimed at transforming the existing, mostly research-funded pilot activities into an integrated operational global ocean carbon observing system. Our current focus includes contribution to policy and decision makers through close collaboration with G7-FSOI or providing input to interventions at the COP26 as well as leadership at the more technical level, working to increase the observing system's readiness level for becoming operational. This report highlights the most relevant activities we were involved in, in the past 12 months.

PROJECTS & MAJOR ACTIVITIES

Surface Ocean Carbon Monitoring Strategy

In the past 12 months, the IOCCP continues to work in partnership with the G7 Future of the Seas and Oceans Initiative and other ocean carbon-centric programmes to catalyse and facilitate the development of an internationally-agreed strategy for sustainable, operational monitoring of the surface ocean CO_2 globally,, and to build on existing observing programmes, data management structures, and coordination bodies to create a global surface monitoring CO_2 network capable of responding to the needs of global and regional policy drivers including the UNFCCC Global Stocktake 2023. Following the Strategy, we envisage proposing a concrete implementation plan that would enable interested nations, including G7 members, to coordinate investments in a sustained, fit-for-purpose surface CO_2 monitoring network as part of GOOS. This network would build on and enhance existing global activities, principally by expanding the pilot reference network of SOCONET, in partnership with GOA-ON and the SOCAT database project and evolve with relevant Decade programmes. Global coordination for the network would be provided by an enhanced IOCCP and GOA-ON secretariat, with strong links to the IOC-WMO OceanOPS Centre.

Most of the global observing networks that currently contribute to the global ocean observing system are platform-based, bringing together scientists and funding agencies around implementation of a single platform, such as Argo, where the coordination challenges and implementation strategies are relatively straightforward. Surface Ocean CO_2 observations come from a combination of trans-ocean shipping routes using automated instruments on commercial and private vessels, instruments on research ships, fixed moorings - in particular, observations in the equatorial Pacific and Atlantic and at a few other open ocean sites, and recently, from new designs of autonomous surface vehicles. Development of an implementation strategy will therefore require an integrated system-design approach using the Essential Ocean Variables across multiple platforms, combined with satellite data and modelling / data-assimilating models / AI techniques. The coverage of observations made over the last 30 years has varied substantially, but it has never been sufficient to define the flux of CO_2 into the global ocean to the required accuracy of 10% (e.g., GCOS Implementation Plan). However, recent studies indicate that, at its best (from about 2005 to 2015), the coverage in the North and Equatorial Atlantic and Pacific, when combined with satellite and Argo float measurements of wind, temperature, and salinity, was sufficient to define the flux in those regions to the required accuracy. Since that time, the density of coverage has decreased and is no longer adequate even in those regions.

In recent years, serious gaps have developed in surface CO_2 data coverage owing to funding cuts in some key underway pCO_2 programmes that had been operating for decades, highlighting the fragility of the network and the global volunteer efforts that have built it. These programmes, and the international ocean and climate science communities they serve, suffer from the lack of an internationally-agreed strategy that recognizes individual programmes as essential elements of a coordinated global network.

While defining the observation requirements for the core global surface CO_2 monitoring network would be the main objective of a IOCCP/G7 FSOI Task Team, we can already identify past and current essential contributions that constitute the building blocks of the global network. For example:

- NOAA in the US, JMA and JAMSTEC in Japan and CNRS in France provide essential and ongoing support for fixed stations and research vessel observations in the Equatorial Pacific and Atlantic, and the Western Pacific. Canada provides support for a key time series station in the North East Pacific. Automated instruments on research and supply vessels in the Antarctic operated by the US, UK, France, Germany, and Australia (among other nations) provide important observations in the Southern Ocean. Italy contributes crucial observatories in the

Adriatic and Mediterranean focussed on understanding marginal sea contributions to the global carbon cycle These ongoing efforts are essential and must be continued.

- In the period of 2005-2015, coverage in the northern and equatorial Atlantic and Pacific was adequate to define the net CO_2 sink in these regions to the required accuracy. At that time, there were about five trans-ocean shipping routes operated by commercial vessels in both the North Pacific and North Atlantic, as well as routes in the Caribbean. These were operated by various nations (US, Japan (NIES), France, UK, Germany, Norway, Spain). These complemented the coverage by NOAA, JMA, JAMSTEC, and CNRS time series stations, moorings and research vessel observations. Several of the trans-ocean routes have now ceased operation or become much more intermittent due to the short-term nature of their funding support, and these regions are no longer adequately covered. Automated instrumentation on trans-ocean commercial shipping routes is a cost-effective way of observing large regions. In ocean basins covered by regular shipping routes (North Pacific and North and South Atlantic, Indian) these need to be restored and maintained.
- In the South Pacific and the Southern Ocean, observations are far less numerous and have mostly been provided by research vessels. Historically, these regions have never been observed with sufficient density. Since 2014, the US Southern Ocean Carbon and Climate Observations and Modelling (SOCCOM) program launched a substantial number of biogeochemical (BGC) Argo floats in the Southern Ocean, and this approach, along with new G7-led international commitments to implementing approximately 70% of the global biogeochemical Argo array in the coming years, may provide adequate surface observations to provide the required coverage here and in other data-sparse areas. However, the BGC Argo floats measure pH, not dissolved CO_2 partial pressure, and there remain large uncertainties in estimating pCO_2 from a combination of these pH measurements and estimates of alkalinity measured by decadal repeat hydrographic surveys. Furthermore, calibration and interpretation of BGC Argo pH measurements can only be resolved through independent pH measurements (especially from deep pH observations where variability is low) and through surface CO_2 observations using research vessels and /or autonomous surface vehicles. Ongoing and increased pH reference observations and sustained direct surface pCO_2 observations from research vessels, autonomous vehicles, and moorings, coupled with continued development of the BGC Argo float observations, are required in these under-sampled regions.
- For a global network, resources to observe coastal areas and shelf seas are also required. The status of surface CO_2 and pH observations in coastal zones is varied with GOA-ON providing a coordination role. Major capacity building activities by GOA-ON and its regional hubs, with support from sponsoring agencies IOC-UNESCO and the Ocean Acidification International Coordination Centre of the IAEA, have helped to expand the network and have increased the number of ocean acidification measurements, partly provided by surface ocean measurements. For reasons of carbon accounting as well as protection of biodiversity and food security, nations with significant coastal seas will require a monitoring network in place to allow for the observation of carbon uptake and acidification in those waters. Additionally, monitoring the effects of restoration, blue carbon sinks, and other negative emission technologies (e.g., alkalinization) will require targeted ocean CO_2 monitoring. The proposed activity would catalyse a stronger coordination of coastal programmes at the regional level and globally.

During the initial phase of this activity we identified a large group of international partners and we initiated direct collaboration with experts from (inter alia) G7 national programmes, the IOCCP SSG Experts, SOCONET, SOCAT, GOA-ON, the EU Research Infrastructure Integrated Carbon Observing System (ICOS) Ocean Thematic Center, the EU Joint Programming Initiative Healthy and Productive Seas and Oceans (JPI Oceans) programme, the IOC Integrated Ocean Carbon Research (IOC-R) Working Group, the Global Carbon Project, OceanPredict, relevant UN Ocean Decade programmes (e.g., Observing Air-Sea Interactions Strategy (OASIS), CoastPredict, the Ocean Acidification Research for Sustainability (OARS) programme of GOA-ON and the IOC), and the World Meteorological Organization's Global Atmosphere Watch to develop this strategy and the community of practice and coordination structure to manage this global network. Currently the specific tasks include to:

- Develop an internationally-agreed observing strategy required to determine net ocean-atmosphere fluxes to an accuracy of 10% or better regionally and globally, and to monitor global ocean acidification, building on existing infrastructures and making best use of the combination of in situ observing platforms, satellite data, and models to fill gaps.
- Develop international agreements on the system components required to support the observing network, including data management and global coordination support.
- Develop a roadmap, phased-implementation plan, and budget requirements by the end of 2022 for a sustained surface ocean CO_2 monitoring system, with the goal of establishing a fully-functional system for the 2nd Global Stocktake of the UNFCCC in 2028, where all Parties under the Convention have committed to conserving and enhancing sinks and reservoirs of greenhouse gases, including oceans and coastal and marine ecosystems. Additionally, this Task Team should provide comprehensive information on ocean carbon system monitoring to assist interested nations, including G7 Members, in their reporting on the SDG ocean acidification target (14.3 SDG target and the indicator 14.3.1) and to assist interested countries with the goal of establishing global representative coverage of all open ocean areas.
- Work with international partners to reach agreements on coordinated contributions and investments to implement the full fit-for-purpose observing system, including coastal areas, regional seas, and regional hubs (e.g., GOA-ON) and coordination support, by 2028.

Developing the necessary strategy and roadmap by building on existing networks and infrastructure should be achieved by mid-2023. Discussions and consultations across the G7 members and other countries about the roadmap, and initial commitments to implement the system, could be carried out within the following 1-year period.

Phase 1: Strategy Development (mid-2022 to mid-2023)
Work with the IOCCP/G7 FSOI Task Team and partners to address tasks listed above through an international workshop (virtual or mixed) and through regular writing team meetings to draft and circulate for extensive international review a strategy for a global surface CO_2 monitoring network, including a phased implementation plan (roadmap) and budget requirements.

Phase 2: Establishment of the Global Network and Implementation agreements (mid-2023 to early-2024)
Using the Draft strategy and roadmap developed by the Task Team in Phase 1, host a stakeholders forum and global workshop for government agencies and ministries to address the last task; namely, identify existing national programmes that are elements of the global surface ocean CO_2 monitoring network, identify critical gaps in the observing system (including global coordination structures and data management activities), and reach agreements on priorities for coordinated investment to establish the global network.

Collaboration with WMO towards a coordinated Global Greenhouse Gas Monitoring Infrastructure

In order to monitor climate change and assist in mitigation efforts in support of the COP-21 Paris Agreement and COP-26 pledges, systematic observation of greenhouse gases and other factors affecting the carbon budget and integration of the output data into global models of the carbon cycle will be required. Currently, most of the overall greenhouse gas (GHG) monitoring efforts undertaken globally rely heavily on research capabilities and research funding, both in terms of observations and modelling, and sustained global monitoring on a routine daily or even weekly basis is therefore difficult to achieve. Given the increasing focus on the role of carbon as a driver of climate change and its central role in mitigation steps, it is timely to explore the need to transition into an international collaborative operational framework.

The World Meteorological Organization (WMO) has invited IOCCP to lead the ocean component of their newly initiated long-term activity aimed to:

1. Develop a potential way forward to consolidate integrated observational requirements for global GHG monitoring.
2. Review current and planned observational capabilities for GHG monitoring.
3. Review the current modelling and data assimilation applicable tools for GHG monitoring, including ocean and terrestrial components.
4. Provide recommendations to optimize the use of current and planned overall capabilities for GHG monitoring.
5. Define recommendations for WMO on the best course of action to support GHG and carbon monitoring.

During our initial discussions we agreed to take the following first steps:

- to engage with the modelling community to identify and consolidate key observational and scientific gaps that need to be advanced
- to improve global coordination of GHG and carbon monitoring across domains and within domains
- to implement the required sustained observational and modelling capabilities with long-term commitment

Results of our discussions were included in the presentation during the 75th WMO Executive Council in June 2022, where WMO Member States had first opportunity to react to this long-term initiative. Our next step will be a joint workshop in late 2022, where a wider community of data providers and data users will be able to voice their needs, concerns and expectations.

IOCCP's involvement in endorsed programmes of the UN Decade of Ocean Science for Sustainable Development Programmes

Ocean Acidification Research for Sustainability (OARS)

IOCCP's Veronique Garcon and Maciej Telszewski agreed to co-lead and contribute to, respectively, a working group on OARS Outcome 3, with the aim of co-designing and implementing observation strategies to ensure vulnerable areas are adequately monitored. The first 12 months of this outcome is focused on developing a strategy for co-designing OA observations locally and regionally.

OARS Outcome 3 will contribute to the the main Programme goals which are providing society with the observational and scientific evidence needed to sustainably identify, monitor, mitigate and adapt to ocean acidification, from local to global scales, by co-designing and implementing observational strategies in collaboration with data/information producers and end users by 2025.

In the first 6 months we applied the "Theory of Change" going upstream from the [Root causes-Problem-Consequences] to [Means-DesiredResult-Impact] to [Impacts-Benefits-Outputs-Outcomes-Activities-Engagement]. Based on this information, we developed the following summary:

Briefly, Outcome 3 will include two main pillars: i) clear identification of stakeholder networks and their engagement, and ii) the understanding of factors limiting the collection of data (e.g. access to instrumentation and appropriate maintenance in developing countries, availability of expertise) and implementation of solutions to these issues. These two pillars are the prerequisite foundation to create an enhanced OA observing network locally, regionally and eventually globally by increased observing capability and geographic distribution of monitoring.

The ultimate benefits and impacts will be: increased observation capabilities in place to derive an improved understanding of global climatic trends, e.g. ocean pH and oceanic carbon uptake. This information, necessary to the development of societally relevant predictions and projections, will also enable the assessment of proposed carbon removal strategies. It will establish a common and mutually agreed upon knowledge base to support international policy debate and science-based political vision by designing a forward-looking climate decarbonization policy. By co-designing with stakeholders, common goals will be agreed upon, possibly favoring access to funding. Specifically, the increased collection of good/usable data respecting the "Findable Accessible Interoperable Reproducible" (FAIR) principles and building of reliable databases with internationally agreed standard treatment (e.g., quality checks, quality flagging, adjustment procedures) will ease the comparison of results between international research groups to deliver globally consistent baseline information. Specific attention will be paid to proactively designing and implementing new observation strategies to ensure vulnerable areas are adequately monitored.

In the course of the next 6-18 months, we will focus on developing/strenthening partnerships required to deliver the outcomes mentioned above through producing these following key outputs:

- Advancement of sensor technology and coordination with other ocean and atmospheric observation systems
- Sustainable production and distribution system for Certified Reference Materials (CRMs) and secondary standards developed
- Wider, systematic access to community approved best practices and calibration protocols
- Stakeholder-oriented and consulted capacity developed
- Systematic co-location of biogeochemical and biological observations
- Observations/research based informational products useful for decision making, e.g. time series analysis tools and mechanisms visualizing the impacts of OA on marine life
- Baseline OA observing needs in areas of potential marine intervention for carbon removal and evidence-based guidance on the development and implementation of such projects.

Global Ocean Oxygen Decade (GOOD)

In October 2021, members of GOOD Programme met in Paris to finalize main outcomes and agree on key activities for the group to engage in over the next 6-18 months. IOCCP's Véronique Garçon and Maciej Telszewski are members of GOOD and their responsibility is to connect and shape IOCCP's activities focused on increasing the readiness level of the Oxygen EOV in terms of observations, data management and knowledge and information production, with priority actions agreed upon by the GOOD and GO2NE teams.

The outcomes agreed during the meeting are:

I. Increase knowledge about the causes, impacts and threats of deoxygenation, including ecological and socio-economic vulnerabilities and resilience, biogeochemistry-climate feedbacks, historical variations, natural baselines, and possible tipping points in the context of multiple stressors.
II. Increased capacity to measure, document, map, monitor and understand ocean deoxygenation, as well as develop measures aimed at its mitigation and, where mitigation is not possible, adaptation.
III. Indicators and related methodologies will be provided to agencies and industries to ensure safe operating spaces and extension of the concepts of planetary boundaries and planetary health to marine oxygen.
IV. Actionable strategies to mitigate and adapt to ocean deoxygenation on local to global scales.

Further, the group agreed on 8 main activities:

i. Deoxygenation and ocean life: identifying and understanding threats to improve mitigation and adaptation strategies. Key issues are (i) deoxygenation effects on life at the individual/species, population, community and ecosystem level; (ii) manifestation and consequences of sublethal effects; (iii) effects of natural oxygen variability on tolerances and thresholds for low oxygen conditions; (iv) interactions of deoxygenation with ocean warming, acidification and changes in food supply; (v) opportunities that may arise for mitigation and adaptation.
ii. Deoxygenation, water quality and the climate system: Understanding processes and feedbacks and developing actionable indicators. Key issues are (i) deoxygenation impacts on marine chemical budgets, including nutrients, pollutants, the production of greenhouse gases and toxic volatiles; (ii) effects on marine carbon sequestration via impacts on the respiration and burial of organic carbon; (iii) a comprehensive understanding of the underlying redox-sensitive processes and feedbacks; (iv) the development of robust and actionable indicators for safe-operating spaces, monitoring and risk management.
iii. Deoxygenation and ecosystem services: Assessing and valuing the impact of deoxygenation. Case studies and workshops are proposed to identify and quantify impacts of oxygen loss on ocean services that include provisioning (fisheries, aquaculture), regulating (climate), supporting (nutrient cycling, water quality, biodiversity, tourism opportunities), and cultural/spiritual elements.
iv. Deoxygenation and co-stressors: Understanding, monitoring and mitigating deoxygenation in a multiple stressors context. Key issues are (i) developing a sound understanding of how locally and globally forced multiple stressors affect physical, chemical, physiological and ecological mechanisms at multiple scales; (ii) designing and testing effective monitoring and accurate modeling schemes to (iii) evaluate the performance of mitigation and adaptation actions (in terms of possible responses, resilience, tipping points, risks); and (iv) to account for economic and social aspects to support management decisions.
v. Economic and societal consequences of deoxygenation. The activity will determine the potential loss in economic value due to deoxygenation, evaluating potential changes in gross revenue and direct and indirect operating costs using benefit-cost analysis methods, institutional and market analysis. Potential economic and social impacts of declining ocean oxygen will be estimated via the potential losses and gains in total revenues, profit, wages, number of jobs and impact throughout the wider economy for fisheries, aquaculture and associated sectors under different scenarios.
vi. Deoxygenation: Understanding causes, attributing changes and developing mitigation approaches. Key issues are (i) a quantitative understanding of drivers of oxygen changes; (ii) a reliable attribution of causes and impacts; (iii) the development of models capable of reproducing seasonal, interannual to decennial variations in marine oxygen; (iv) reconstruction of paleo-oxygen changes at decadal, centennial and longer time scales to understand the natural baseline and long-term causes; and (v) developing efficient mitigation approaches.
vii. Mapping and Modelling oxygen. Key issues are the full exploitation of (i) data from new robotic platforms like Argo floats and gliders equipped with oxygen sensors; (ii) high-performance computing infrastructures; and (iii) the Artificial Intelligence revolution to generate enhanced mapping and prediction of ocean oxygen on coastal, regional and global scales. A key outcome will be the Global Ocean Oxygen Atlas (GO2AT) aligned with the FAIR principles and Best Practices gathering oxygen data with a transparent and consistent quality flagging and offering oxygen gridded products, including a business plan focusing on economic values of the oxygen data platform products.
viii. Capacity building and ocean literacy. Key issues are (i) capacity building in communities that rely on ocean services affected by deoxygenation, including a number of developing nations, (ii) adopting World View Citizen consultations and (iii) establishing stakeholder co-design approaches.

IOCCP will collaborate with and within GOOD on outcomes II and III and activities iv, vii and viii.

Observing Together

Observing Together is a GOOS Sponsored Decade Programme. The Programme aims to transform ocean data access and availability by connecting ocean observers and the communities they serve, through enhanced support to both new and existing community-scale projects. Globally, many communities are unable to access ocean data in decision-ready formats and so cannot see the value of investment in ocean observations. The Programme leverages the Global Ocean Observing System's network of expertise to bring needed observations and forecasts to community users and into global data streams, making every observation count.

Observing Together currently works with 5 endorsed Projects:

- **Norway NTNU**: Sailing4Science - expanding the capacity for ocean observations and ocean citizen science awareness and stewardship
- **Mauritius Meteorological Services**: Enhancing the ocean observing system within The Republic of Mauritius
- **National Commission for Education, Sciences and Culture, Morocco**: Enhancement of hydrographic and oceanographic observations in support of marine scientific research
- **Indonesia Meteorological, Climatological and Geophysical Agency [BMKG]:** Fisherman Weather Field School Sekolah Lapang Cuaca Nelayan
- **ATLANTOS:** Connecting communities to Atlantic Ocean observing

IOCCP's Kim Currie served as co-Chairs from the inception of the Programme idea until June 2022 when she was replaced by Capitán de Corbeta Alvaro Santiago Scardilli (Argentina).

Recognizing shortage of Certified Reference Materials

IOCCP has been actively supporting the international observing community in addressing the global issue of shortage of production and delivery of seawater carbonate system Certified Reference Materials (CRMs) since it was first recognized at the height of the first wave of the COVID-19 pandemic. During the 16th Session of IOCCP SSG & GOOS Biogeochemistry Panel Meeting (IOCCP-SSG-16) it was noted that the effects of the shortage in CRM supply are already seen in the latest release of the data synthesis product GLODAP.v2021, and that 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, and decided to take the lead in coordinating such a global response to the challenge of providing a sustained supply of carbon RMs. IOCCP SSG member Maribel Garcia-Ibanez volunteered and was nominated to take charge of this coordination effort with support from the IOCCP Office, and in consultation with the US Interagency Working Group on Ocean Acidification (IWG-OA), the Global Ocean Acidification Observing Network (GOA-ON), the Integrated Carbon Observing System-Ocean Thematic Centre (ICOS-OTC) and other partners. It was also 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.

In direct follow-up from this decision, on 14-17 March 2022 IOCCP convened a virtual meeting to compile information around potential support for developing a bid for reference labs to routinely produce ocean carbon CRMs and to discuss a global action plan to address the above-mentioned issues. The meeting participants identified three most urgent actions which IOCCP immediately proceeded to pursue. They are briefly summarized below. You can find more information about the proceedings and summary of actions under the Meetings & Workshops section of this report.

Regular communication around seawater carbonate system RMs and standards

The need to maintain and strengthen regular communication around seawater carbonate system reference materials and standards through a dedicated mailing list and shared workspace was acknowledged. In response, the IOCCP Office established a dedicated communication platform and collaborative workspace in Slack (https://carbonate-system-crm.slack.com) with dedicated channels for main actions resulting from the workshop. Currently, the workspace has 29 members from Europe, North America, South America, Asia, Africa and Oceania.

International community position paper on the importance of and requirements for sustained global production and supply of seawater carbon standards

The group agreed to convene a writing team to draft and publish a position paper (or a community white paper) explaining the importance of and requirements for sustained global production and supply of seawater carbon standards. An initial outline of the paper was prepared by the IOCCP Office and the first meeting of the writing team is anticipated to be called for August/September 2022. Recognizing the critical role of national metrology labs in future production and certification of standards, the group has also submitted an abstract to present the issue and present ideas for solutions at the WMO Metrology for Climate Action Workshop to be held virtually in September 2022.

Standard Operating Protocol for production of secondary reference materials

The participants agreed to convene a writing team for the Standard Operating Protocol (SOP) to produce secondary reference materials and a unified SOP to produce secondary (in-house) standards. It is anticipated that dedicated resources will be required for the experts to produce such a document. The writing team will be formally assembled pending confirmation from at least two leaders who would drive the effort forward. A dedicated channel on the Slack workspace has been established with 13 members of the international community in contributing to the process.

Global data synthesis activities

Accomplishments, challenges and near-term actions related to global data synthesis products were discussed in detail during a thematic mini workshop organised during IOCCP-SSG-16. The main objective was to decide how the IOCCP should continue its support of the established data synthesis products (Surface Ocean CO_2 Atlas - SOCAT, and Global Ocean Data Analysis Project - GLODAP), and to what extent IOCCP should support the development of new and emerging data synthesis products.

Surface Ocean CO_2 Atlas (SOCAT)

With regard to SOCAT, the IOCCP SSG concluded 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. Further details and additional recommendations can be found from the report from the joint IOCCP-G7 FSOI first planning meeting which took place in conjunction with IOCCP-SSG-16.

In June, we were excited to announce the release of SOCAT version 2022 which has quality-controlled *in situ* surface ocean fCO_2 (fugacity of CO_2) measurements made on ships, moorings, autonomous and drifting surface platforms for the global ocean and coastal seas from 1957 to 2021. IOCCP acknowledges the tremendous effort of Dorothee Bakker (UEA, UK) as the leader of SOCAT Global Group, and all who have contributed to the timely, annual release of SOCATv2022.

The main SOCAT synthesis and gridded products contain 33.7 million fCO_2 values with an estimated accuracy of < 5 µatm. A further 6.4 million fCO_2 sensor data with an accuracy of 5 to 10 µatm are separately available. SOCAT is used for quantification of ocean CO_2 uptake and ocean acidification and for evaluation of climate models and sensor data. The SOCAT synthesis products are a crucial step in the value chain based on *in situ* inorganic carbon measurements of the ocean, which provides policy makers with vital information in climate negotiations. The need for accurate knowledge of global ocean CO_2 uptake and its variation makes sustained funding of *in situ* surface ocean CO_2 observations and their synthesis imperative.

Future evolution of SOCAT will focus on automation of metadata upload and integrating SOCAT as a component of a federated data system supporting the SDG Target 14.3 ('reduce ocean acidification') indicators. More information on SOCATv2022 can be obtained from the release poster.

Global Ocean Data Analysis Project (GLODAP)

The discussion on GLODAP 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 in the report from IOCCP-SSG-15.

GLODAPv2.2021, the release of which we announced in August 2021, is an update of the previous version, with 43 additional cruises, extension of time coverage until 2020, and the inclusion of DOIs for each individual cruise. GLODAPv2.2021 includes measurements from more than 1.3 million water samples from the global oceans collected on 989 cruises. The original data, their documentation and doi codes are available at the Ocean Carbon Data System of NOAA NCEI. This site also provides access to the merged data product, which is provided as a single global file and as four regional ones. An accompanying article was published in Earth System Science Data in December 2021.

Global Oxygen Data Atlas (GO2DAT)

The Global Oxygen Data Atlas (GO2DAT) has been supported by IOCCP from its inception and saw many important developments over the past year. Most importantly, the roadmap towards GO2DAT implementation was published in Frontiers in Marine Science. Eight current and recent IOCCP SSG members contributed to the work carried by 57 scientists from 45 institutions in 22 countries aimed at

fully harnessing the increasing volumes of oxygen data already delivered and in anticipation of much higher quantities of data from autonomous platforms in the open ocean and coastal areas.

The roadmap is very detailed in its timeline, partnerships, goals and envisaged outcomes and in coming months and years, IOCCP's engagement around the Oxygen EOV will, to large extent, focus on implementing the roadmap laid out in this paper. GO_2DAT is hoped to combine oxygen data from the coastal and open ocean measured by a variety of methods on a myriad of operating platforms. Community-agreed, fully documented and consistent quality control (QC) procedure and quality flagging (QF) system will be adopted to support the development of advanced biogeochemical models and data synthesis products, significantly improving our mapping, understanding and forecasting capabilities.

These comprehensive data synthesis products will support the development of climate and ocean health indicators allowing for knowledge-based decision-making processes aimed at sustaining a healthy, productive and resilient ocean as prioritized by international policies and initiatives (e.g., UN SDG 14, the EU MFSD, the UN Decade of Ocean Science for Sustainable Development) associated with the emerging blue economy, the conservation of marine resources and their associated ecosystem services and the development of management tools required by a diverse community of users (e.g., environmental agencies, aquaculture and fishing sectors).

The implementation of the proposed roadmap for GO_2DAT requires internationally coordinated engagement from the scientific community, data providers, data managers and end-users. Engagement around and implementation of GO_2DAT will be promoted by the UN Decade GOOD Programme. Finally, based on the lessons learnt from the SOCAT and GLODAP experience, GO2DAT sets out with estimating their budgetary requirements from the onset by considering them as part of GOOD resource assessment produced in late 2021.

Time-series Biogeochemistry Data Product (METS RCN)

IOCCP's Kim Currie sits on the Steering Committee of the EarthCube-funded METS Research Coordination Network (RCN), which brings together a cross-section of the ocean and data sciences communities for a sustained dialog to address long-standing METS challenges, most prominently the lack of consistent and FAIR data practices and approaches related to biogeochemical parameters on time series stations. METS RCN activities are focusing on consensus-building and aligning with FAIR implementation in related communities; broadening users and applications of METS data; and building capacity to ingest, analyze, and integrate METS data with other complementary data sets to accelerate scientific discovery.

During the past year the data working group has investigated the use of controlled vocabularies (e.g., BODC/NERC, CF), semantic approaches, and advised on minimum metadata package(s) for:

- Date, time, location, depth cruise
- Nutrients and Dissolved Oxygen,
- Carbon
- Biodiversity and Biomass

A Town Hall was held at the Ocean Sciences Meeting 2022, and a more widely accessible webinar was held in May 2022 to introduce the concept of a METS-RCN and to solicit feedback from the biogeochemistry community. IOCCP's focus on ship based and moored time series stations lead by Adrienne Sutton and Keyhong Park is strongly related to the US OCB-led METS RCN.

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 IOCCP 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.

Integrated Marine Debris Observing System (IMDOS)

Throughout 2021 IOCCP managed to further strengthen or initiate a number of close collaborations for the benefit of establishing global coordination of IMDOS and sustained observations of Marine Plastics Debris as a new EOV. Most notably, GOOS through IOCCP agreed on areas of joint work with the UNEP Global Partnership on Marine Litter (GPML), GEO Blue Planet through Mercator Ocean International (MOI), the Ministry of Environmental Government of Japan (MOEJ), JAMSTEC, and the International Ocean Colour Coordinating Group (IOCCG) Task Force on Remote Sensing of Marine Litter, among others. The rationale for developing IMDOS, its ambition, and requirements for project coordination support are described in an IMDOS flyer co-developed by IOCCP and MOI in advance of the 2022 UN Ocean Conference.

IOCCP on behalf of GOOS contributed as co-organizers of two the high level public events: 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, and the "Integrating Marine Litter Monitoring to Inform Action" Official Side Event to the 2022 UN Ocean Conference which introduced the international Interim Steering Committee and initial proposed Terms of Reference of IMDOS. Moreover, IOCCP co-organized important community workshops such as the Macroalgal Community Workshop to promote augmenting coastal biodiversity surveys with litter monitoring and the 2022 EOOS Technology Forum to enhance the dialogue between marine debris monitoring technology developers and scientific experts responsible for observation requirement setting. Details of these events can be obtained from the Meetings & Workshops section of this report.

Significant progress in establishing IMDOS coordination was achieved in follow-up of the Clean Ocean Laboratory Satellite event on IMDOS which among other things resulted in agreement to establish a joint project office for IMDOS by GOOS and GEO Blue Planet with IOCCP project officer Artur Palacz Mercator Ocean International's Audrey Hasson providing part-time coordination and communication services. This was immediately followed by formation of an international Interim Steering Committee of IMDOS represented by world-leading experts in the field of marine debris and broader ocean observations who currently include: Stefano Aliani (CNR ISMAR, Italy), Paolo Corradi (ESA, Netherlands), Francois Galgani (Ifremer, France), Georg Hanke (JRC, Italy), Kara Lavender Law (SEA, USA), Nikolai Maximenko (Uni Hawaii, USA), Toste Tanhua (GEOMAR, Germany), Alexander Turra (Uni São Paolo, Brazil).

Guided by the Interim Steering Committee, IOCCP co-developed the initial terms of reference for IMDOS which are to:

- promote the development of a global network of marine debris observations according to Regional Seas Programme Action Plans and integrated within GOOS in cooperation with existing ocean observing infrastructures, networks and communities of practice;
- define strategies and priorities for coordinated and harmonised marine debris observations based on most relevant monitoring methods, standards and practices;
- develop standard sampling protocols and best practices in marine litter data collection and support training activities for their implementation;
- promote integration of data management activities to provide free and open access to marine debris data and information products for stakeholders (e.g., via the GPML Digital Platform);
- support the development of remote sensing methods to detect marine debris by enhancing availability of required ground-truthing data;
- strengthen the interface between marine debris monitoring and modelling communities to support the development of a Digital Twin of the Ocean for Marine Litter Pollution;
- evaluate the readiness level and promote technological innovation to advance global observing approaches;
- create communication services for the marine debris monitoring community

Critical to the successful integration of IMDOS within GOOS is the process of setting observing and data management requirements through the new Marine Plastics Debris EOV. An initial version of the Specification Sheet was drafted based on expert and community consultations carried out since early 2020, and published as part of the EU H2020 EuroSea project deliverable report submitted by IOPAN in April 2022.

Near-term activities will focus on hiring a dedicated full-time project officer for IMDOS (application process closed in June 2022) to be hosted at the IOCCP headquarters at IOPAN; drafting an initial science and implementation plan for IMDOS, conducting broad community consultations on the draft Marine Plastics Debris EOV Specification Sheet; and better aligning the IMDOS initiative with existing programmes and projects under the UN Decade of Ocean Science for Sustainable Development where IMDOS can make transformative contributions to address several challenges presented by the Decade.

Setting requirements for EOVs and ECVs

GOOS Implementation Plan

In alignment with the 2020-2023 IOCCP Action Plan, IOCCP continued to provide input into GOOS Implementation Plan. IOCCP Co-Chairs and Office have attended regular meetings organized by GOOS Central Office and participated in discussions about setting priorities on GOOS actions, identifying resource needs for their near- and long-term realization, and specifying milestones and anticipated outcomes for actions led by IOCCP as well as those requiring our substantial contribution.

Examples of cross-GOOS actions led by IOCCP SSG and Office include the development of an Integrated Marine Debris Observing System (IMDOS), advancing biogeochemical and biological observations across global networks (co-led with GOOS BioEco) or implementation of the multidisciplinary initiative VOICE. Examples of cross-GOOS actions to which IOCCP provides significant contributions include the development of a global ocean indicator framework (led by GOOS Physics & Climate), evolution of the Ocean Observing Report Card (led by OceanOPS) and

development of the three GOOS Programmes endorsed under the UN Decade of the Ocean for Sustainable Development (led by GOOS Central Office).

Progress against GOOS IP actions is now being monitored through professional project management software Monday.com. This enables unprecedented capability to track activities across the wide range of GOOS structures, establish and maintain regular and transparent communication among the globally distributed GOOS Secretariat, and strengthen the legacy of individual actions and contributions towards the 2030 GOOS Strategic Objectives by maintaining an online archive of completed, ongoing and discarded actions. IOCCP Project Office interacts with GOOS Central Office and other GOOS structures through this platform to an increasing extent, although issues remain with latency of information flow among the distributed Secretariat of GOOS which traditionally has and continues to primarily rely on ad hoc email communication.

GOOS Task Team on EOVs

The assembly and work of the GOOS Task Team on EOVs stalled once more due to lack of input from various GOOS structures and significant delays in hiring a dedicated GOOS consultant to coordinate the work. By the end of 2021, GOOS Central Office took the decision not to hire a consultant, and instead, attempted once more to deliver what is needed through GOOS Panel Secretariat coordination. IOCCP Project Officer prepared a new template for updating EOV Specification Sheets consistently across the Panels of GOOS. With assistance of Wolf & Player hired by GOOS Central, a professional layout and icons for all GOOS EOVs were designed and distributed to GOOS Panels in early 2022. Updates to Biogeochemistry EOVs are in progress.

The outstanding task of publishing a paper on the EOV framework was taken up by the new OOPC Officer. An initial draft, updated from the previous versions in 2018 and 2020, was produced with input from IOCCP Office and GOOS BioEco Office with the anticipated final product available by end of 2022. It should be noted that the paper is meant to provide a foresight perspective on the evolution of the EOV framework which needs to be reconciled with the proposed development of an ocean indicator framework. To this end, close communication between the two Task Teams was initiated in early 2022. In parallel, IOCCP and other GOOS Panels are working on publishing guidelines on reviewing requests for new EOVs, what it means to be an emerging EOV, and other pragmatic aspects of curating EOVs across the multidisciplinary space of ocean observations.

In line with efforts to reconcile global and regional requirement setting frameworks, IOCCP Project Officer attended remotely the 2022 Arctic Observing Summit on 30 March - 1 April to present the EOV framework and participate in discussions about the adequacy of proposed Shared Arctic Variables considered by the Sustaining Arctic Observing Networks (SAON) as one of the means towards connected, collaborative, and comprehensive long-term pan-Arctic Observing System that serves societal needs.

Global Climate Observing System Implementation Plan 2022

In October 2021 IOCCP proposed actions for the new 2022 GCOS Implementation Plan relevant to biogeochemical observations and data management to support the climate observing system. In several instances, IOCCP consulted experts or organizations outside of IOCCP to ensure optimal representation across the full spectrum of marine biogeochemistry observations. In particular, input from the International Ocean Colour Coordination Group (IOCCG) was sought in the context of next 5 year priorities for Ocean Colour EOV/ECV observations. Several proposed actions required coordination across IOCCP and GOOS BioEco Panel, for instance, with regard to augmenting biogeochemical and biological observations on existing observing platforms such as ship-based hydrographic cruises or moored fixed point observatories - following recommendations from SCOR Working Group 154.

Frequent and iterative consultations between IOCCP and OOPC led to several key such actions being accepted in the draft 2022 GCOS IP which was subsequently released for public review in spring 2022.

The last round of expert review is expected to take place soon, with the final version of the document presented at COP-27 in November 2022.

Task Team on Ocean Indicators Framework

In the very complex landscape of international coordination and management of issues related to ocean-climate interaction, ocean health and a wider context of ocean-based ecosystem services, there is a strong need for the definition of relevant "ocean indicators". GOOS Panel for Physics (OOPC) has taken a lead to develop and implement a GOOS-wide action on this subject. As the international landscape is moving very fast, Karina von Schuckamn and Sabrina Speich initiated a cross-GOOS Panel Task Team to work with relevant external (to GOOS) experts and address this issue on a variety of scale and with a variety of stakeholders in mind. IOCCP's Veronique Garcon and Maciej Telszewski are involved in this work from its inception and a wider group of IOCCP SSG Experts are being asked to contribute to specific aspects of the framework being developed.

An ocean indicator can be defined as '*A simple easy to understand tool to describe, measure and monitor a complex Ocean phenomenon. The Ocean indicator may change globally to locally, at different time scales, and can be utilized for Ocean literacy, and to build a sustainable Ocean observing system for holistic scientific assessment and stewardship*' (von Schuckmann et al., 2020). Indicators are necessary for regular reporting on the state of the ocean, its variability and change. Indicators can also be used to identify knowledge gaps and observing system gaps that limit our capacity to respond to society's needs for ocean information, and thus serve as useful guides to prioritize investments in the observing system. While playing this multi-faceted scientific and technical role, indicators are also key communications tools for the general public, enhancing ocean literacy and the engagement of citizens in the global effort to develop 'The Ocean We Need for the Future We Want' the leitmotif of the UN Decade of Ocean Science for Sustainable Development (Ryabinin et al., 2019).

The OceanObs'19 conference held in September 2019 brought together 2400 scientists from 60 nations and produced 140 Community White Papers outlining the state of the ocean observing system and priorities for the next decade. The OceanObs'19 Conference Statement specifically highlighted the need for indicators. *'Indicators based on ocean observations help nations meet national goals and targets of the United Nations 2030 Agenda on Sustainable Development, the Paris Climate Agreement, the Sendai Framework for Disaster Risk Reduction, the Convention on Biological Diversity, and the Small Island Developing States Accelerated Modalities of Action Pathway. Ocean observations are fundamental to increase the scientific and information content of indicators, contribute to the United Nations Decade of Ocean Science for Sustainable Development (2021–2030) and are coordinated by Global Ocean Observing System (GOOS) and Group on Earth Observations (GEO).'*

The World Meteorological Organization uses Global Climate Indicators to produce an annual State of the Global Climate report (WMO, 2017). Five out of seven indicators of the WMO Global Climate Indicator Framework are ocean-related indicators, but with the exception of ocean acidification, they are limited to physical aspects only, and do not address biogeochemical changes, extreme variability, or marine biology and biodiversity. The Global Ocean Observing System uses Essential Ocean Variables, ocean Essential Climate Variables, and ocean Essential Biodiversity Variables to define monitoring requirements, and the GOOS 2030 Strategy calls for these to be streamlined into sets of indicators. The UN Sustainable Development Goal 14 to Conserve and Sustainably Use the Oceans, Seas, and Marine Resources for Sustainable Development has indicators to help nations track their individual and collective progress towards ocean protection and sustainable management. The UN Trans-boundary Waters Assessment Programme has developed indicators for Large Marine Ecosystems that address both natural and human dimensions. The International Council for the Exploration of the Seas has a Working Group on Social Indicators for developing integrated

ecosystem assessments. The EU Copernicus Marine Service uses Ocean Monitoring Indicators to produce an annual Ocean State Report, which provides a comprehensive and state-of-the-art assessment of the state of the global ocean and European regional seas. These examples represent a subset of the relevant international efforts working on this issue, and there are also numerous regional and national ocean indicators in use that target a variety of local and regional needs.

In addition, there are several developments at the international level that demonstrate the various facets of use for an indicator concept. There are established and evolving holistic frequent assessments provided by the international and multidisciplinary science community that provide a specific topical focus such as the global carbon budget (Friedlingstein et al., 2019), the global sea level budget (WCRP, 2018) and the Earth heat inventory (von Schuckmann et al., 2020). These topic-specific community efforts not only provide quantification on the current evolution of environmental change, but they also provide an in-depth assessment of the related uncertainties, the observing system status, limitations and needed future evolution. Moreover, these frameworks have established a scientific platform to provide and coordinate specific expertise, which can lead to unique advancements in both climate science and observing system recommendations. A critical example is the Special Report on Ocean and Cryosphere (SROCC) as part of the IPCC 6th assessment cycle.

However, there is currently no internationally-agreed comprehensive set of ocean indicators to characterize physical, biogeochemical, or ecosystem processes, nor a common framework with agreed methodologies that would unite these individual efforts to create the common understanding and baselines required to monitor changes in the ocean in a transparent and authoritative way.

- The Indicators Task Team has initially focused on specific aspects for the development of the indicator framework such as:
- to develop a list of characteristics and criteria for ocean indicators
- to provide topical classifications for the indicator framework
- to provide a targeted set of indicators and their definitions for each topical multidisciplinary classification from global to regional scale
- to synthesize and promote the initiative through a high-level publication
- to interlink already existing activities within different structures and frameworks and drawing particularly on EOVs and ECVs (e.g. OOPC, OceanObs Living Action Plan, GCOS GCIs, WMO, UNFCCC, GEO Blue Planet, SDGs, etc.), and to extend activities to include underrepresented topics (e.g. marine biology, deep sea, etc.)
- to promote their adoption (e.g. OceanObs Living Action Plan, GEO Blue Planet), and their use for regular reporting processes such as planned under the UN Decade of Ocean Science for Sustainable Development
- to provide a long-term perspective and guidance on the evolving developments of an indicator framework (e.g. methodologies, best practices, involvement of services, etc.)

An international and multidisciplinary Task Team of 15 ocean experts in the core team was established, with further contributions to be solicited should such need arise during the framework development phase. Currently the Task Team is focused on developing a perspective paper. The overall goal of the paper is to provide a perspective raising the need for and the benefit from the establishment of an international framework of ocean indicators. This paper is aiming at providing a fundamental baseline from the scientific community on guiding a future establishment of an international ocean indicator framework – potentially developed as part of the UN Ocean Decade for Sustainable Development. The objective is to share a final draft of this perspective paper in Q3 2022 in time for COP27.

Technical capacity development, standards and best practices

Ocean Acidification Data QC Online Package

During IOCCP-SSG-16 a special session was organized to review the current status of work regarding the Ocean Acidification Data QC Online Package - a joint endeavour by IOCCP and GOA-ON the vision for which was described in the past report. IOCCP and UNESCO-IOC discussed how to share responsibility for management and coordination according to agreed terms of reference. IOC offered to provide limited financial support, including Katherina Schoo's time for coordination work.

The proposed scope of the product, presented by IOCCP SSG member Adrienne Sutton, was deemed appropriate. Fundraising for the end product development is associated with the UN Ocean Decade Programme OARS and its resource assessment from August 2021. Moreover, the potential role of the Ocean Teacher Global Academy (OTGA) as a platform to host the OA Data QC Tool was discussed.

The group consulted Christina McGraw (Uni Otago, New Zealand) extensively about a recent development of an online interactive tool MEDDLE, done by SCOR WG 149 "Changing Ocean Biological System", to learn lessons about the entire development process, from characterizing the intended audience and outlining the scope and timeframe of work, to production and ongoing dissemination and promotion, including allocation of resources. Formation of the respective task team was postponed until the second half of 2022.

3rd Sensors training course: new dates, long-term sponsorship of ICOS

Due to COVID-19 travel restrictions, the IOCCP SSG approved the recommendation of the IOCCP Executive to further postpone the next edition of the IOCCP Training Course on A Suite of Biogeochemical Sensors until June 2023. The venue has already been confirmed for the new dates. This time we decided that we will run the Course regardless of travel restrictions in some parts of the Planet. Huge interest in participating in the 3rd edition of this training course expressed by the global ocean observing system and the marine biogeochemistry community persuaded us that we have a service to provide even if not all members of the community will be able to benefit directly.

Despite the postponement, ICOS OTC extended its offer to co-sponsor the next edition of the sensors training course. More importantly, it was confirmed that IOCCP and ICOS OTC had reached an agreement on a long-term co-sponsorship of this unique technical capacity building initiative for the marine biogeochemistry community.

EU H2020 ECOTIP Summer School

As part of the H2020 ECOTIP project which provides partial support for IOCCP Project Officer, there was a summer school organized in June 2022 at the Husö Biological Station on the Åland Islands, Finland. During an intense two weeks, twelve early-career ocean professionals from various European institutes received scientific lectures and practical training focusing on the rapid environmental, ecological and social changes happening in the Arctic – and how to communicate them - from world-class experts. The students also earned course credits, built their professional networks and showcased their research. Apart from contributing to the summer school agenda development, IOCCP Project Officer gave a lecture on the Essential Ocean Variable Framework and the value of ocean observations.

Expanding biogeochemical and biological observations through collaboration with civil society and industrial partners (Artur)

During the 16th Session of IOCCP SSG a thematic mini-workshop was organised 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 established priorities for IOCCP SSG to initiate relevant actions which were followed up upon in the following months.

Observations performed by the civil society (citizen science)
Members of IOCCP SSG and IOCCP Office have in the past engaged with different civil society groups performing ocean observations with interest to expand onto biogeochemistry and marine pollution. However, these efforts were very opportunistic, not part of any strategy and not well coordinated. With the onset of the UN Decade of Ocean Science for Sustainable Development, OceanOPS has recently kicked-off a new project called "Odyssey" to operationalize the contribution of citizens to integrated GOOS data streams. During IOCCP-SSG-16 and during the Odyssey Kick-Off event IOCCP discussed with OceanOPS how to most efficiently contribute to this new project and how to prioritize engagement in most relevant and potentially most impactful initiatives.

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.

IOCCP Co-Chair Veronique Garcon led a successful proposal to support 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 (currently not endorsed under the Decade). First data was acquired during several cruise legs in the Arctic in May 2022. Currently, discussions are underway regarding optimal flow of these and future data acquired by Ponant, with consultations including IOCCP SSG, OceanOPS, GO2NE and Ponant Science.

Other opportunities for engaging the private sector in marine biogeochemistry observations include but are not limited to carrying out widespread underway pCO_2 measurements on the Maersk fleet, working with Canadian shrimping vessels to conduct environmental measurements onboard, or carrying out coastal biogeochemical and physical measurements by surfing communities in collaboration with the SmartFin project.

Over the first part of 2022 IOCCP has been strengthening communication with OceanOPS in line with the IOCCP SSG recommendation to develop a general process to respond to requests for authoritative guidance on standards and best practices as well as data management associated with augmenting existing and new platforms with biogeochemical sensors and instruments, and to contribute to the UN Decade Project Odyssey on engaging civil society groups in sustained marine biogeochemistry observations.

Adding biogeochemistry to OceanSITES and other fixed-point arrays

IOCCP, led by Dariia Atamanchuk and Emmanuel Boss, is increasingly promoting coordinated actions to augment existing ship-based surveys and fixed-point mooring arrays with biogeochemical sensors in line with the recommendations for adding biogeochemical (and biological) observations to GO-SHIP and OceanSITES as produced by SCOR WG 154 (P-OBS). Key challenge to address is that of ensuring quality control of the biogeochemical sensors deployed, especially on moorings placed in deeper waters. 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 with which IOCCP will continue to liaise.

AniBOS

During IOCCP-SSG-16 IOCCP also inaugurated its interaction with the 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.

IOCCP SSG discussed with AniBOS leadership 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. IOCCP will engage with 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.

MEETINGS & WORKSHOPS

Between July 2021 and June 2022 IOCCP SSG members and secretariat organized several meetings and workshops, almost all virtual, and attended a large number of virtual and a few in-person events. In this report we highlight only a selection of meetings and workshops with the most significant impact on our ability to deliver against IOCCP Terms of Reference.

International Ocean Carbon Discussion, 14 September 2021, online

Organized by GOOS including IOCCP, and the Ocean Frontier Institute, and supported by the G7 FSOI Coordination Centre this scientific / technical workshop gathered around 30 senior PI's actively pursuing the critical role of fully understanding the ocean carbon cycle in context of recent societal requirements expressed in high level statements by intergovernmental and international organizations.

Scientific assessments urge the global community to achieve net-zero GHGs emissions by 2050 in order to meet the Paris Agreement's goals, and to avoid potentially dangerous climate impacts (IPCC, 2021). Net-zero is a critical long-term goal for nations aiming to balance uptake and release of greenhouse gases (GHGs) contributing to global warming. Significant cuts in GHG emissions will be needed over the next 5 to 10 years to keep global warming to no more than 1.5 °C and safeguard a livable climate. For example, to achieve no or limited overshoot of 1.5°C, global net anthropogenic CO_2 emissions should have declined by about 45% from 2010 levels by 2030, reaching net zero around 2050 (IPCC, 2019). To keep net zero target achievable by around or after 2050, very low and low GHG emissions and CO_2 emissions should be implemented (IPCC, 2021). Net-zero targets can be achieved through a combination of balancing human emissions and the removal of GHGs via Nature-Based Solutions (NBSs). These include direct air capture, biomass electric power with carbon capture and storage, and various storage technologies and long-term strategies.

The atmospheric CO_2 concentration depends on the uptake and storage of CO_2 in the ocean (Watson et al., 2015). Policies aiming for a net-zero transformation must therefore consider the ocean and its potentially changing baseline as an essential part of the calculation. Net-zero roadmaps need a vigorous re-thinking, given that the word 'ocean' was not considered in the original Paris Climate Agreement. Broad deployment of existing monitoring tools can generate assessments of natural sinks of the ocean, as well as the anthropogenically-forced trends. Also, new observational tools should take into consideration the ocean (e.g. sail drones, argos, gliders, etc.), as it may have significant potential in fulfilling an efficient and sustainable 'net-zero' future.

During the workshop the importance of establishing a network of ocean carbon observatories providing the necessary data to quantify and understand the changing ocean carbon sink was demonstrated and discussed. A North Atlantic Ocean Carbon Observatory (**NACO**) **as a global exemplar** providing a baseline scientific monitoring system that can constrain the spatio-temporal and long-term trends and variability of the North Atlantic Ocean carbon uptake, was suggested. Such an observatory requires not only detailed and robust ocean observations, but excellent (near-) real-time data management and information delivery to policy makers. It must also deliver robust data adequate for modeling future carbon absorption patterns and to help bridge the knowledge gap between science and stakeholders. This will help to shape national, regional and international strategies towards a net-zero carbon emission future. Design and implementation of NACO will facilitate the development of an internationally agreed observing strategy that is capable of responding to the needs of global and regional policy requirements.

IOCCP will continue to respond to requests from G7-FSOI, NACO and other involved organizations and will provide its services to further the notion of the integrated sustainable global ocean carbon observing system.

GOA-ON Ocean Acidification Week, 13-17 September 2021, online

Our prime involvement in the OA Week 2021 was focused around the ongoing global efforts to address the current shortage of supplies and vulnerability of the long-term provision of carbonate system RMs. A recording of a dedicated 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 is available from GOA-ON website. IOCCP was responsible for collecting

global and European perspectives on the problem and potential solutions. 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 the status of CRMs and updates on resilience building globally and regionally in the US, Europe and for developing and less resourced laboratories.

IOCCP's role as coordinator of activities initiated around this topic globally continued well beyond this initial community forum and are discussed in the CRM section of this report.

ECOTIP 2nd Annual Meeting, Copenhagen, Denmark, September 2021

In September 2021 IOCCP Project Officer took part in the 2nd Annual Meeting of the EU H2020 ECOTIP project where he is co-leading one of the work packages responsible for data management, dissemination and exploitation activities. After the project kick-off and all subsequent meetings had taken place virtually, it was the first time that the ECOTIP consortium gathered in-person to meet and discuss progress on the project, and next steps at the Copenhagen Zoo in Copenhagen, Denmark..

The meeting provided an opportunity to better specify plans and timelines for performing two tasks that are highly relevant to increasing the readiness level of marine biogeochemistry observations specifically in the Arctic region. First, several consortium members discussed providing recommendations for optimized monitoring strategies in the Arctic based on the project outcomes and pilot demonstration of innovative sampling techniques relevant for better understanding of carbon sequestration among other phenomena. Second, initial discussions took place about organizing a workshop towards specifying ocean carbon and biodiversity modelling requirements for sustained observations of selected EOVs, primarily Particulate Matter, Phytoplankton and Zooplankton EOVs. Last but not least, IOCCP helped facilitate a technical workshop on standard metadata and data formats and FAIR data management applicable to the ECOTIP project results. In particular, the consortium received training on adopting a common Darwin Core metadata standard and sharing all metadata through a dedicated GeoNetwork facility established on IO PAN servers.

16th Session of the IOCCP SSG & GOOS Biogeochemistry Panel, 22-25 November 2021, Sopot, Poland and online

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.

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. The last day of the meeting was organised jointly with G7 Future of Seas and Oceans Initiative (FSOI) as a first Planning Meeting of the Surface Ocean CO_2 Monitoring Strategy.

Complete meeting agenda, list of participants and summary of actions can be found in the meeting report available from the IOCCP website.

Towards a Coordinated European Observing System for Marine Macroalgae workshop, 23-25 November 2022, online

As part of the EuroSea Project and as part of the strengthened interaction between IOCCP and GOOS BioEco Panel, IOCCP Project Officer co-organized a EuroSea Workshop 'Towards a Coordinated European Observing System for Marine Macroalgae' which place on 23-25 November 2021 (online). The event discussed priorities for sustained and coordinated observations needed to preserve macroalgae and their associated biodiversity, and to ensure those ecosystems will continue to deliver key ecosystem functions and services in a changing ocean. IOCCP's main role was to promote augmenting coastal biodiversity surveys with marine litter monitoring and joint satellite detection algorithm developments for the two communities - an important element of the emerging Integrated Marine Debris Observing System. To this end, IOCCP engaged experts from the EU Marine Strategy Framework Directive Technical Group on Marine Litter, the IOCCG Task Force on Remote Sensing of Marine Litter and Debris and Tartu University in Estonia to provide an overview of the rationale and discuss perspectives for co-designing surveys plans for the Macroalgal Canopy Cover EOV and the Marine Plastics Debris EOV.

Observing methods for seafloor plastics are the same as for macroalgae (i.e., visual scuba diving and ROVs). There are minimal requirements for seafloor macroplastics (>2.5 cm) to be included in the Standard Operating Procedures. These requirements would be a rectangular area/line transect for counting litter items and litter items reported in density of litter items per category per m2/km2. There is a harmonized list of litter categories for standardized monitoring currently available, advanced development of marine litter ontology to support indicator frameworks (e.g., MSFD and SDG), and EMODnet and OBIS are ready to ingest marine plastics data (visual survey data products are in planning stages only). However, some challenges do exist, such the difficulty in integrating programs (e.g., plastics monitoring with marine mammal surveys) when litter is as small as 2.5 cm, many macroalgal sites do not show macrolitter accumulating and thus not all areas might require regular observations and it is not possible to integrate sampling requirements for eDNA with microplastics as very large water volume is required for eDNA. A key recommendation moving forward from this workshop is to develop a pilot project that combines visual surveys with macrolitter monitoring. Initial exchange with Nova Mieszkowska on MarCLIM was facilitated through this workshop.

Satellite Activity of the UN Ocean Decade Clean Ocean Laboratory on IMDOS, 17-19 November 2021, online

Virtual event titled 'One Integrated Marine Debris Observing System for a Clean Ocean' was organized by 14 organizations, including IOCCP, and hosted by GEO Blue Planet and Mercator Ocean International – as an official satellite activity of the UN Ocean Decade Laboratory on 'A Clean Ocean'. IOCCP co-organized this event in line with its task to develop capacity and coordination for sustained global ocean observations of Marine Plastics Debris as a new EOV.

Attended by 197 participants from 46 countries, the event consisted of a series of three live online sessions in English and French. 26 excellent speakers and panellists from 18 different countries world-wide came together to share their knowledge and discuss the growing threat and multidimensional problem of marine debris to marine ecosystems, ocean and coastal users. The event discussed the

current state of marine debris observations and ways forward for implementing an Integrated Marine Debris Observing System (IMDOS). Recent advancements in observational techniques and technologies were presented, and cooperation bringing together multidisciplinary approaches from diverse stakeholders was discussed. The event also included a virtual poster hall featuring 50 posters, including seven video presentations on transdisciplinary approaches, monitoring technologies and modelling, networks and digital ecosystem contributing to global marine debris observation. For more information (presentations, agenda, resources, replays of all sessions), click here.

Marine Plastic Litter Data Sharing Project International Expert Workshops, 29 November 2021 & 4 March 2022, online

In line with the objectives to establish global coordination of sustained ocean observations of marine debris, IOCCP continues to develop a strong collaboration with the Ministry of Environment, Government of Japan (MOEJ) which, acting on behalf of G20 countries, has commissioned a development of a global data hub for microplastics, and in the long-term, other fractions of marine litter. Upon invitation from MOEJ, IOCCP on behalf of GOOS, engaged in further expert consultations on the MOEJ Plastics Data Hub to maximize the potential of this initiative in the context of IMDOS, and to guide the MOEJ effort towards sustainability and future integration in the global data management systems of GOOS.

A series of two workshops on "Marine Plastic Litter Monitoring Data Sharing Project" were organized by MOEJ as online events on 29 November 2021, and on 4 March 2022. IOCCP was invited to provide expert advice on a number of topics included in the workshop agendas, including those related to optimizing the structure and functionality of the database, data quality control and curation, data policy, coordination of future sampling surveys, and synergies with other international initiatives.

2022 International Ocean Data Conference, 14-16 February 2022, Sopot, Poland and online

At the International Ocean Data Conference 2022 took place in Sopot, Poland, between 14-16 February 2022 in Poland, 200 online and 60 on-site attendees agreed on the need to establish a global ocean digital ecosystem to share and disseminate data and information that will contribute to the objectives of the UN Ocean Decade and beyond. The Conference highlighted the importance of increased efforts in standardization, best practices, interoperability, and networking to achieve this goal. IOCCP Project Officer participated remotely in the Conference which provided important information on global data management strategies being developed at IODE relevant to the ongoing development of the Marine Biogeochemistry Global Data Assembly Centre as well as to the development of data streams which will provide a foundation for IMDOS as a backbone system behind UNEP GPML Digital Platform.

Production of seawater reference materials workshop, 19-22 March 2022, online

The COVID-19 pandemic highlighted the fragility of the production system of primary reference materials (CRMs) for the seawater carbonate system being dependent on one unique lab (Dickson's lab, Scripps Institution of Oceanology, USA). Many laboratories are producing secondary (in-house) standards to overcome the problem with no coordination and accordinging to their own methodology. In continuation of past public debates on how to address the shortage of CRM production and supply, IOCCP convened a four-day long virtual workshop on 19-22 March 2022 which was attended by 25 invited experts representing key institutes and initiatives from all continents engaged in or interested in contributing to addressing the problem on regional to global scale. The meeting was organized by IOCCP SSG member Maribel Garcia-Ibanez with assistance from the IOCCP Office.

The main goal of this series of meetings was to coordinate and foster collaboration between the different groups capable of producing CRMs and/or RMs for seawater carbonate system parameters. The first meeting held on 14 March was devoted to hearing status updates from different groups on sustaining existing/developing new production facilities, potential size and reach of distribution, funding situation. The second meeting on 15 March focused on discussions on the modality of production to be envisioned choosing between several production centres that also certify vs several production centres but only one certification centre. Production of secondary standards and developing best practices for this process was discussed during the third meeting on 16 March, while the last day tackled the need to find a sustained funding solution for the selected production model as well as the need to maintain and strengthen future communications around this issue. Below is a summary of key recommendations and actions stemming from this meeting.

Given the current impossibility to reproduce Dickson's lab elsewhere, in the near future, the production scheme is envisioned to consist of one lab producing CRMs (most probably the National Institute of Standards and Technology (NIST), USA) and regional hubs producing secondary reference materials (ultimately dependent on the values of the primary reference materials - CRMs). It was highlighted that regional production of secondary RMs would reduce costs since most of them come from shipping. The use of those secondary RMs would need to be recognized within the community. For that to happen, the production and use of the secondary RMs need to be robust. Therefore, the group agreed on the need for SOPs for producing secondary reference materials and secondary standards for the seawater carbonate system, and to encourage regional hubs to produce the secondary RMs, and smaller labs to use secondary (in-house) standards. Different requirements were highlighted to create such a network of regional hubs: cross-calibration exercises between regional hubs of secondary RMs and the CRM production centre to assess the quality of the RMs; sustainable distribution through time; profound knowledge of quantifying uncertainties; careful assessment of costs; etc.

Through the Ocean Foundation (ToF), an SOP for producing secondary (in-house) standards is also being produced. Andrew Dickson has also submitted an NSF proposal to write an SOP for secondary (in-house) standards. However, the above-mentioned SOPs don't include the measurement procedure (including uncertainty analysis) nor the checks for stability and homogeneity. The latter would be needed to adapt such SOP for producing and certifying secondary reference materials. The SOP for secondary RMs should contain a protocol for their preparation and certification, including how to quantify uncertainties. The starting point of the SOP for secondary standards and secondary RMs could be a rejected paper by Dickson on the production of CRMs (shared with the group).

During the workshop, it was noted that there was potential interest from several funding bodies to provide the resources to address the challenge of lack of sustained production and supply of seawater carbonate system reference materials. The group agreed that to communicate efficiently with the funding organisations worldwide, we need to clearly describe the importance of the seawater carbonate system reference materials for the scientific community, and what the international community sees as the way forward to ensure a sustained and global production and supply of such reference materials.

A two-page document was recommended with approximately half devoted to describing the scientific importance of reference materials for high-quality ocean measurements and the other half to the proposed global solutions along with an approximate budget estimate. In particular, the document would outline the need for developing regional hubs capable of producing and distributing secondary reference materials with a known uncertainty estimate, at an affordable price. The need for central certification and global intercomparison of regional hubs would be emphasised.

The group recommended that IOCCP and the UN Decade Programme OARS take the lead in drafting the document using the support of the IOCCP, GOA-ON, and NOAA OAP Secretariats. Members of the research community would provide feedback and edit the paper before its publication and further dissemination.

The group agreed that there was a need for regular and transparent communication among the international community to coordinate recommended actions identified during this workshop, and

around any other efforts and initiatives addressing global seawater carbonate system reference material and standards. Currently, there is little communication between dedicated meetings typically taking place every couple of months. There is also no central place to access minutes, reports, references, or informal discussions related to the topic.

In response, a dedicated communication platform and collaborative workspace were set up in Slack (https://carbonate-system-crm.slack.com) with dedicated channels for two main actions resulting from the workshop: (i) #position-paper for the group working on the position paper, and (ii) #secondary-ref-mat-sop for groups working on best practices and standard operating protocols for secondary reference materials and secondary standards. New members can be added to the workspace by any existing member or requested from IOCCP Project Officer as the workspace administrator.

2022 EOOS Technology Forum

From 22 to 24 March 2022, the second edition of the EOOS Technology Forum took place as a virtual workshop, organised by EuroGOOS with the support from EuroSea and Minke and endorsed as an activity of the UN Decade for Ocean Science and Sustainable Development 2021-2030. IOCCP was represented on the Organizing Committee of the workshop, provided guidance on structuring the workshop so that it enhances the dialogue between marine debris monitoring technology developers and scientific experts responsible for observation requirement setting in the context of the new Marine Plastics Debris EOV, and reported out on the recommendations from one of the sessions on data infrastructures.

The workshop brought together over 120 participants representing instrument manufacturers, technicians, technologists, and scientists across the public and private sectors from across the globe. Participants discussed what technologies will be needed to achieve two goals of the UN Decade for Ocean Science and Sustainable Development 2021-2030: “A clean ocean where sources of pollution are identified and removed” and “A healthy and resilient ocean where marine ecosystems are mapped and protected”.

This three-day workshop included high-level presentations, panel discussions, and Show and Tell sessions on technological innovations. A wide range of recommendations came out of the discussions spanning the ocean observing and data value chain. It was recognized that sensor miniaturization, lower cost, new sources of power, and higher automation of marine technologies is allowing scientists to collect more and more data. The advances in cloud computing, big data processes, machine learning, and artificial intelligence have been reducing the need for human intervention. Innovations in cyber-infrastructure and communications, such as underwater Internet of Things, allow for more data storage and machine-to-machine interactions. The use of new sustainable materials for the production of technologies has increased and improved the ocean observing capacities. With the raise of opportunities and capabilities, the forum called for more partnerships and cross-disciplinary engagement between the public and private sectors.

11th Session of the GOOS Steering Committee, 25-28 April 2022, online

As members of the GOOS Executive and GOOS Steering Committee, IOCCP Co-Chairs and Office represented GOOS Biogeochemistry Panel at the 11th Session of GOOS Steering Committee (GOOS-SC-11) Part 1 which was held as an online event on 25-28 April 2022. The meeting was run twice each of the first three days to accommodate participation from all time zones, with a single session organized on the final day. In advance of the meeting, IOCCP provided a pre-recorded presentation on the past year’s achievements as GOOS Biogeochemistry Panel. In addition, we highlighted several issues which

we recommended should be discussed at the plenary during the actual meeting, in particular related to a common GOOS strategy on data management and information products.

IOCCP also reported on progress related to establishing global coordination of marine debris observing system and developments related to producing the first version of the Marine Plastics Debris EOV Specification Sheet.

EuroSea 3rd Annual Meeting and General Assembly, 9-13 May 2022, Cadiz, Spain

The 3rd EuroSea Annual Meeting took place from 9 to 13 May 2022 at the University of Cádiz, Spain. This hybrid event was hosted by the EuroSea partner Consejo Superior de Investigaciones Científicas (CSIC) and co-hosted by the University of Cádiz representing and coordinating the European University of the Seas.

The goal of the event was to share project progress, strengthen internal project collaboration and communication, exchange ideas, and engage in a face-to-face dialogue with local stakeholders as well as young scientists. It was the first time since the EuroSea kick-off meeting in November 2019 that all consortium members got the chance to meet in person. The meeting was attended by 92 participants in Cádiz and 35 participants who joined virtually. IOCCP Project Officer attended the meeting in person to take part in work package 1 discussions, present the current achievements related to IMDOS, and contribute to many workshop discussions related to ocean integration, sustainability of ocean observations, or the development of an ocean indicator framework.

The EuroSea General Assembly took place during the Annual Meeting. It included reports from the EuroSea committees on Gender and Diversity, Innovation and Stakeholders, and the International Scientific and Technical Advisory Board. The week concluded with a discussion on the next steps towards an improved ocean observing integration, a strong ocean governance, and the development of the European Ocean Observing System framework.

Observing Co-Design Workshop, 7-9 June 2022, online

The Ocean Observing Co-Design Programme hosted the first online Ocean Decade Co-Design Workshop on June 7, 8 and 9 2022. This workshop kick-started the development of Exemplar projects that will pilot and refine transformative co-design processes and best practices.

The Workshop plenary provided insights into lessons learnt from co-design across GOOS and other sectors. During breakout working sessions, teams started shaping the outline of co-design 'exemplar' projects. The use areas that the first six exemplar projects will focus on are noted below in the context of their societal benefits:

- Improving Carbon Data
- Advancing Cyclone Forecasting
- Sustaining development and conservation of living marine resources
- Improving Storm Surge Predictions
- Monitoring Marine Heatwaves Impacts on Biodiversity and Economies
- Observing Key Current Systems

IOCCP's Richard Sanders co-leads the "Carbon Exemplar" and several SSG members and representatives of a wider community joined discussions during this workshop. A more coherent and potentially consequential report from this workshop will be available later this year. The general consensus was reached around the notion that the carbon exemplar should support national policy makers and those assessing the global carbon budget. Currently there are a large number of initiatives underway aimed at addressing various elements of the ocean's carbon uptake value chain at different scales. These include actions focused on the surface, North Atlantic and European waters. This Exemplar will seek to extend the scope of these actions to cover the whole Globe, and the ultimate aim of enabling a whole ocean carbon observing network to come into being within the framework of the UN Decade that allows ocean uptake to enter the Global Stocktake alongside atmospheric accumulation and fossil fuel emissions as core elements of the global carbon cycle that are monitored and reported on.

"Integrating Marine Litter Monitoring to Inform Action" Official Side Event to the 2022 UN Ocean Conference

On 29 June in Cascais, Portugal, as part of the 2022 UN Ocean Conference, IOCCP on behalf of GOOS co-organized the UN Ocean Conference Official Side Event on "Integrating Marine Litter Monitoring to Inform Action" which provided a critical milestone in advocating the necessity of a global sustained Integrated Marine Debris Observing System (IMDOS) and gradually building the global IMDOS community. The full-day event, co-hosted by the AirCentre, GEO Blue Planet, GOOS and UNEP Global Partnership on Marine Litter (GPML) along with a number of partnering organizations, encouraged the cooperation among members of scientific institutions and international programs, governmental and intergovernmental representatives, and other policy makers and mitigation actors present among more than 80 participants from 23 countries around the world. It is worth noting that all sessions were moderated by Early Career Ocean Professionals (ECOPs) from the OceanBRIDGES initiative - a network programme endorsed by the UN Decade of Ocean Science for Sustainable Development.

The event introduced the international Interim Steering Committee and the initial Terms of Reference for IMDOS which is being established as a joint project of GOOS and GEO Blue Planet in close collaboration with UNEP GPML During a series of presentations, panels and roundtable discussions across several sessions, participants expressed overwhelming support for continued development of IMDOS, the vision for which was first presented at the OceanObs'19 Conference through a Community White Paper by Maximenko et al. (2019).

Recommendations from discussions and ideas for new collaborations will help determine priority activities within IMDOS to ensure integration into the existing global ocean observing system and provision of critical data and information to meet the requirements for addressing knowledge gaps and enabling risk-based assessments and science-based decision making. Strengthening existing and following up on the newly initiated interactions from this event will be critical to the successful development of IMDOS which relies on the ability to coordinate across a very broad landscape of organizations and initiatives involved in marine plastics debris observations providing scientific knowledge to address the marine litter pollution problem.

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