1st Planning Meeting of the Surface Ocean CO_2 Monitoring Strategy

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

25 November 2021

Biogeochemistry Panel

1. WELCOME AND INTRODUCTION

Maria Hood, Maciej Telszewski, and Richard Sanders welcomed the participants to this first planning session for the Global Surface Ocean CO_2 Monitoring Strategy. A participants list is given in **Annex 1**.

This hybrid (virtual and in-person) meeting was co-located with the XVI[th] Session of the IOCCP SSG meeting at the IOCCP headquarters, Institute of Oceanology of the Polish Academy of Sciences in Sopot, Poland. It was developed to reach initial agreements on:

- the objectives, goals, and structure for a global surface ocean CO_2 observing network
- the strategy writing team membership
- the workshop planning team membership
- plans and dates for moving the strategy forward.

The meeting agenda is given in **Annex 2**.

Background references for the meeting include:

G7 FSOI Scoping Paper: A Surface Ocean CO_2 Monitoring Network: Facilitating the development of an internationally-agreed observing strategy and coordination structure for GOOS.

SOCONET paper for OceanObs19: https://www.frontiersin.org/articles/10.3389/fmars.2019.00400/full and updated details at: https://www.aoml.noaa.gov/ocd/gcc/SOCONET/

Bakker et al., 2016. *A multi-decade record of high-quality fCO_2 data in version 3 of the Surface Ocean CO_2 Atlas (SOCAT).* Earth Syst. Sci. Data, 8, 383–413, 2016 www.earth-syst-sci-data.net/8/383/2016/ doi:10.5194/essd-8-383-2016.

Siv Lauvset, Kim Currie, Nicolas Metzl, Shin-ichiro Nakaoka, Dorothee Bakker, Kevin Sullivan, Adrienne Sutton, Kevin O'Brien, Are Olsen, 2018. *SOCAT Quality Control Cookbook -For SOCAT version 7.*

Guidi, L., Fernandez Guerra, A., Canchaya, C., Curry, E., Foglini, F., Irisson, J.-O., Malde, K., Marshall, C. T., Obst, M., Ribeiro, R. P., Tjiputra, J., Bakker, D. C. E. (2020) *Big Data in Marine Science*. Alexander, B., Heymans, J. J., Muñiz Piniella, A., Kellett, P., Coopman, J. [Eds.] Future Science Brief 6 of the European Marine Board, Ostend, Belgium. ISSN: 2593-5232. ISBN: 9789492043931. DOI: 10.5281/zenodo.3755793

PIs using SOCAT-based, SOCONET observations to produce global map - latest paper is in open review until the end of the year: Rodenbeck et al., BGD - Data-based estimates of interannual sea–air CO2 flux variations 1957–2020 and their relation to environmental drivers (copernicus.org)

Denvil-Sommer, A., Gehlen, M., and Vrac, M. (2021) Observation system simulation experiments in the Atlantic Ocean for enhanced surface ocean pCO_2 reconstructions, Ocean Sci., 17, 1011–1030, 2021 https://doi.org/10.5194/os-17-1011-2021

2. OVERVIEW OF G7 / GOOS ACTIVITY

Maria provided an overview of the G7 FSOI Surface Ocean CO_2 Monitoring Strategy. She briefly reviewed the G7 FSOI work plan that was adopted in June 2021 to provide context for this activity, pointing out that it is *'scientific and technical support to the GOOS biogeochemistry panel*' and not an independent G7 activity.

The idea for this activity came from discussions with several G7 national focal points who indicated that they were willing to fund surface ocean CO_2 observing programmes but that they currently have no way of knowing if a particular proposal contributes to the establishment of a global observing network. Working with the IOCCP and other experts from G7 countries, a Scoping Paper was submitted to the G7 FSOI working group to propose a 2-year activity to develop an internationally-agreed strategy and implementation plan for a surface ocean CO_2 monitoring network. That activity was approved in June 2021. The Scoping Document was provided as a reference document for this meeting.

Maria pointed out that this activity would be a time-bound, delivery-focused effort to develop the strategy and implementation plan for a sustained surface ocean CO_2 monitoring system, as well as to seek funds required for the international mission team, data management and synthesis activities, coordination, and management of this integrated global network. She noted that this strategy will focus only on surface CO_2 required to "*determine net ocean-atmosphere fluxes to an accuracy of 10% or better regionally and globally on an annual scale"* (e.g., GCOS observing system requirements). The strategy will not focus on the full ocean carbon cycle nor repeat the background science and justification of the needs for a surface CO_2 network, but will instead refer to the work already carried out recently by the community (e.g., the IOC-R report).

Maria referred to this activity as 'low hanging fruit' since many of the fundamental building blocks of the system already exist, including 1) internationally-agreed requirements (e.g., GOOS inorganic carbon EOVs, GCOS ECVs, SOCONET requirements) 2) observing networks including the pilot reference observing network for climate-quality observations (SOCONET) and 3) two data centres (NOAA PMEL in the US, and University of Bergen in Norway) and a pseudo-operational data synthesis activity SOCAT, coordinated from the University of East Anglia, UK.

The goals for this activity at the end of the 2-year period are:

- an internationally-agreed strategy and implementation plan that can be used by governments for funding decisions that enable integration of individual pilot elements to achieve the required global system,
- an International Mission Team to guide and oversee the implementation of the surface ocean CO_2 observing system,
- funding to support a full-time coordinator as part of the OceanOPS Centre (located at IOCCP), and

- funding to support operational data management centres and the data synthesis activity SOCAT

Maria concluded by reminding the participants of the recent announcement of the US to COP 26 to establish a globally operational Surface Ocean CO_2 Reference Network: "*The network will integrate established and proposed national and regional surface ocean carbon dioxide (CO_2) research and monitoring efforts into a global framework, enabling countries to track changes in global ocean uptake of CO_2 over time. Through international engagement, NOAA will facilitate the development of the global network and produce high-value products, such as observation-based annual updates of ocean carbon uptake and changes in ocean acidification, that are critical for decision making about ocean-based mitigation options and marine ecosystem health.*"

The participants asked for more information about the difference between an International Mission Team and a Scientific Steering Team. Maria responded that the Scientific Steering Team is made up of experts who can cover one or more thematic aspects of the strategy and implementation plan and who guide the development of the system, including data and synthesis aspects. Maria informed the participants that this activity is an IOCCP activity where the G7 is providing support (staff, funds) to move it forward. As such, the IOCCP members with particular interest in this area are leading the Scientific Steering Team and have identified other outside experts to provide sufficient coverage of topics. For the IOCCP, this activity is led by IOCCP member Richard Sanders and Maria is providing G7 staff and funding support.

An International Mission Team is typically made up of one expert per country who can act as a national focal point to aid coordination and communication between the programme and experts / observing programmes in the country. As the strategy and implementation plans develop, this Mission Team concept will need to be examined since a surface ocean CO_2 programme will involve multiple platforms / observing programmes and one single representative may not be able to provide sufficient detail about their country's full range of programmes across all platforms.

3. DEFINING THE FUNDAMENTALS OF THE STRATEGY

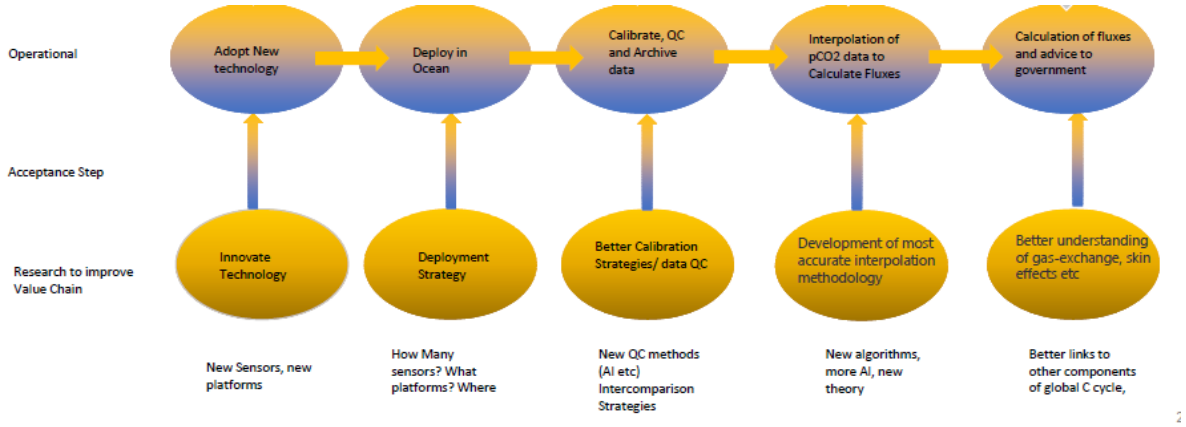
Note: because of the hybrid nature of the meeting over multiple time zones, a linear discussion that included all participants was not possible. The report of the meeting below presents a summary of discussions grouped by subject rather than a linear progression of the discussions.

Strategy Scope

Participants noted that, unlike existing GOOS networks, the in situ observing network for surface ocean CO_2 is based on a multi-platform approach (e.g., principally underway lines and time series stations but with critical information provided by GO-SHIP and Argo). Coordination of in situ observations, data management, syntheses and product development from multiple platforms having different implementation plans, steering groups, and funding streams is significantly more complex.

Participants agreed that the strategy should cover the full 'value chain' that includes elements running from research and technology development through to informing global policies and advising governments. Participants further agreed that research is needed at every step to

improve and evolve the operational system, illustrated by the diagram developed by Richard (below). Rik noted that we are aiming to develop a *system*, not only an observing network, noting that the value of our products has increased dramatically in the last few years and that we need a coordinated international effort to improve how we obtain data that make these products. Richard described the ambition for the value chain and the ICOS station certification process as a way of ensuring that observations included as part of the programme meet the required standards. Participants agreed that this kind of approach is needed for the high-quality reference network but that the programme should also be inclusive of lesser quality data that will be needed to achieve global coverage.



The Global Carbon Project, which regularly informs and reports to the IPCC and UNFCCC, was identified as one of the primary users for these data and data products, and two members of the GCP are included on the strategy development team (Judith Hauck and Dorothee Bakker). Judith pointed out that a sustained global monitoring system with high volumes of data are needed for the carbon models to evolve. She noted that ocean regimes are changing at the same time, making this a moving target, and explained that while the current ocean sink is dominated by atmospheric CO_2 concentrations, we have no idea how the ocean sink will change following peak emissions. Preparing for net-zero carbon emissions and global actions to reduce atmospheric CO_2 will require understanding what the natural sinks are doing and sufficient understanding of the processes controlling uptake to predict future changes.

Participants discussed the surface ocean CO2 data quality-vs-quantity issue and agreed that, in principle, generating surface CO_2 maps for fluxes requires high-quality data (± 2 µatm), but it was noted that data with higher uncertainties are better than no data at all. Thus, data with a quantified accuracy in the order of ± 5 µatm will provide highly useful information (especially in regions with little or no data), but the observing system overall must strive to achieve the best possible quality. Maria informed the group of the discussions led by the Canadian government to explore opportunities to develop an observing network pilot project in the North Atlantic (the North Atlantic Carbon Observatory, NACO) that would aim to observe the full ocean carbon cycle and said that she would report back to the group after the international workshop on 15 December 2021. Rik also stressed the need to work more closely with the Global Ocean Acidification Observing Network (GOA-ON) to obtain much-needed coastal data and to co-design the observing networks to obtain mutually-beneficial data. Participants agreed that it will be important to engage other users (data users as well as information / data product users) throughout the strategy development and as a regular part of the value chain feedback.

Decision 1: The strategy and implementation plan should cover the full value chain from research and innovation to informing global policies / policymakers. Research and innovation are essential to each step of the operational chain and scientific guidance is required across the full value chain to develop an integrated system. A system of validation / accreditation is needed to transfer R&D innovations to operational implementation.

Decision 2: The strategy and implementation plan should stay focused on developing a surface ocean CO_2 system but should link to other ocean carbon activities (e.g., NACO, GOA-ON, Decade programmes, IOC-R follow-up, etc.) early in the strategy and implementation plan writing phases to ensure that this strategy serves other groups' needs and that it integrates with other plans, particularly when considering data management issues and development of standards / best practices agreements.

Observing Requirements and Existing Capability

Maria opened this discussion noting the requirements in the GCOS strategy cited in the G7 FSOI Scoping Document: ***To determine net ocean-atmosphere fluxes to an accuracy of 10% or better regionally and globally on an annual scale***. She asked if this was still the best target or if this needed to be revised.

Decision 3. Participants agreed that the above GCOS requirements were still an appropriate (and achievable) target for responding to societal policy drivers of the UNFCCC Global Stocktake and Net Zero carbon emissions ambitions.

Maciej reminded participants of Andy Watson's discussion section in the G7 FSOI Scoping Paper showing that the in-situ coverage for pCO_2 was sufficient to meet required goals in the North Atlantic and North Pacific during the decade 2005-2015. He also reminded participants of the paper by Denvil-Sommer et al. (2021) and stated that the in situ observing network must make use of neural network analyses and model-based CO_2 distributions to fill gaps in global coverage. Judith cautioned that it is not possible to extrapolate algorithms developed for the North Atlantic to the full globe with any confidence and that the strategy should first focus on what we need and where. She noted that she and Christian Rodenbeck have made an attempt at this already using SOCAT and BGC Argo data locations.

Participants discussed the monitoring strategy that would be required to provide the data coverage and quality required to respond to these global drivers. Andy pointed out that we know from experience that we need something like a minimum of 3-4 lines crossing each ocean basin and something similar in the Southern Ocean. Participants discussed the importance of including time series and interpolation methodologies as a way of providing a more rigorous constraint on the coverage needed to calculate annual fluxes with an uncertainty of ± 10%. All agreed that while these exercises were necessary to guide the strategy, it is also important to set a goal for the network based on existing knowledge and experience to begin implementation, pointing to the Argo design of 3000 floats as an informed "round number".

In his presentation, Rik described SOCONET as a volunteer group of established operators who agree to submit data to SOCAT and work together to advocate for the development of a unified network of high-quality reference stations. Rik and Adrienne emphasized that while SOCONET can provide an important contribution to this global surface ocean CO_2 strategy,

the SOCONET network should remain focused on providing high-quality, standardized reference measurements (e.g., ± 2 µatm) required to estimate annual flux to ± 10%. They also stressed that the full system would need to include other data for geographical coverage as well as ancillary / supporting / emerging contributions.

Dorothee and Siv pointed out that 75% of the data in SOCAT having quality labels of 'A' and 'B' (e.g., ± 2 µatm) are provided by SOCONET stations (e.g., US providers). Siv also pointed out that much of the 'C' quality data (± 5 µatm) could probably be upgraded to meet SOCONET quality relatively easily, pointing out that with current technology, ± 2 µatm is not difficult to achieve. She also noted that the idea of data flags and quality are catching on and that most users now only use 'A' and B' quality data for their work, with the exception of large-scale modeling studies that need as much data as possible.

It was noted that data from moorings are obtained and treated differently than for underway systems, and that the best mooring data from NOAA (currently included as part of SOCONET) only get a label of 'C' largely due to different standardization procedures that have not been incorporated in best practice documents. Rik suggested that the NOAA moorings could meet the ± 2 µatm target with some changes to protocols, verifications, and calibration gases and that it was important to keep them in the SOCONET programme to work with them to encourage them to improve their systems.

Participants questioned how to define or apply a SOCONET label to systems that don't meet accuracy requirements but could meet them with relatively minor (or well-known) upgrades, where the limitation to upgrading is funding or that the instrument is part of another programme with lower accuracy requirements. Some exceptions will need to be made for important coastal CO_2 measurements where variability is higher and label A and B accuracy data will be more difficult to achieve. Participants agreed that this would be something to examine after the initial mapping of existing systems that could contribute to the global surface system.

Decision 4. Participants agreed that establishing SOCONET as the reference network for the global strategy and promoting this 'branding' of quality to which other operators should aspire could lead to a rapid increase in quality measurements from existing infrastructure. It was also agreed that operators generating 'C' flag data (accuracy of ± 5 µatm) should be included in the strategy but in a separate category, and that a system of regular review should be established to provide advice on how to upgrade those platforms to SOCONET quality where possible (with exceptions being established as necessary for coastal platforms). Participants further agreed that the Best Practice for *f*CO_2 Measurements need to be updated.

Defining Programs that Contribute to the Strategy

Given time limitations, participants focused on major technology or coordination challenges facing the global system and how to evolve existing measurements systems and technology for the future. Participants agreed that once the strategy and measurement criteria have been fully defined, an inventory of systems that contribute to the strategy must be carried out.

Participants stressed that a major gap that would be relatively easy to fill is installing underway CO_2 on research vessels. Akihiko presented an overview of Japan's underway systems on GO-SHIP vessels, particularly the *RV Mirai*, to measure CO_2 underway in the Arctic. He also noted that Tsuneo Ono of the National Institute for Fisheries Science in Japan collects extensive CO_2 data in the coastal ocean.

Participants agreed that coastal CO_2 measurements will also be essential for understanding global fluxes but noted with frustration the requirement to turn off underway systems when entering EEZs of some countries. All agreed that this was a serious issue that must be addressed in the global strategy and that establishing coastal monitoring stations rather than relying on ships may be a strategy to explore. Maria referred to the recent GOOS report on Ocean Observations in Areas under National Jurisdiction (OONJ) and noted that dealing with these intergovernmental issues should be one of the principal benefits of becoming a network of GOOS.

Decision 5. Participants agreed that underway systems should be installed on repeat hydrography ships (particularly for GO-SHIP lines) and that the community needed to work more closely with GOOS on issues of data collection in EEZs. Participants further agreed that coastal CO_2 observations may be more easily attained from national platforms rather than transiting ships.

The participants discussed issues of standardizing and harmonizing systems and noted that a smaller number of CO_2 systems with a standardized set of equipment and operations would be easier and cheaper to deploy and to maintain than the current situation with custom-built systems that require a specific PI to operate and maintain. The participants noted that such a standardized system could:

- reduce costs through large-scale production and availability of replacement parts,
- increase performance, make it easier and faster to install systems on more ships, and allow for wider participation in the network,
- improve and streamline data management, data sharing, and QA/QC,
- remove the strain of funding technical support for individual custom-built systems, and
- allow the global network to establish regional hubs where CO_2 systems on ships could get serviced routinely regardless of 'whose' system it is.

It was agreed that these issues of automation, standardization, traceability, and making a clearer separation between support for infrastructure and support for research and data product development are the fundamentals of the network that this community should work towards in this strategy.

Andy raised the issue of central support for the regional hubs and national coordinators/ technical personnel required to support and maintain this kind of observing network. He suggested that ICOS might be able to perform this service in collaboration with EU countries and that NOAA could most likely coordinate this function for the US, but for other regions and other countries where ocean carbon monitoring is not directly supported through government agencies, this will remain a problem that the strategy should address.

Decision 6. Participants agreed that the community should work towards a global network with a smaller number of standardized systems to increase performance / reliability / technical support, reduce costs, and extend the network to data-sparse regions. Participants further agreed that the establishment of regional hubs will also need to be considered in the strategy.

Participants discussed needs for links with other groups to provide ancillary and supporting measurements as well as infrastructure, including the Ship Observations Team, GO-SHIP, BGC Argo, and OceanSITES as well as operators of platforms such as gliders or Uncrewed

Surface Vessels (USVs). Rik suggested that the international coordination mechanism for this should be affiliated with the GOOS Observations Coordination Group. Participants agreed but emphasized the importance of keeping the coordination focused on a global network for surface CO_2 rather than dividing the coordination across existing platforms of OCG.

Decision 7. Participants agreed to contact the GOOS OCG to determine how best to coordinate the global surface CO_2 monitoring system with other global networks.

Participants also discussed the possibility for this network to obtain and/or provide infrastructure in partnership with other groups such as GOA-ON for ocean acidification (pH, total alkalinity, DIC) and air-side CO_2 measurements of the marine boundary layer over the open ocean from research ships. All agreed that the CO_2 and ocean acidification networks are tightly coupled and that the ambition of the strategy should be to provide infrastructure support to as many groups as possible without compromising the strategy for the CO_2. It was also recognized that the GOA-ON network will be an important provider of CO_2 data in the coastal zone. The participants agreed that a 2-step process could be followed to 1) get the CO_2 system up and running and 2) build on this infrastructure for (inter alia) ocean acidification and MBL CO_2, with the understanding that augmenting the basic network with these additional systems (particularly the MBL work) will be much more expensive and require a different set of technical expertise. Judith noted that for models to evolve, we will need a system that monitors a full range of carbon and biogeochemical parameters in a sustained way as ocean regimes change and respond to climate drivers.

Decision 8. Participants agreed to work closely with the GOA-ON network to ensure that the CO_2 monitoring strategy can also support ocean acidification monitoring where possible and vice versa, and to consult with ocean carbon research programmes to understand how the surface CO_2 network might provide support for and align with broader ocean carbon observation and research activities. Participants also agreed to maintain communication with the WMO's Global Atmosphere Watch community as part of the discussion / exploration of including underway CO_2 systems on research vessels.

Data Management and Synthesis

Siv, Dorothee, and Steve described the strong collaboration between the Bjerknes Climate Data Centre's CO_2 activities (Norway) and the NOAA PMEL CO_2 data group (USA), which provide complementary and coordinated services to the ocean CO_2 community. All agreed that they should be maintained as the core of the global system and that we will need to develop a global group of data managers and scientists as part of the strategy to identify needs and opportunities for additional data hubs.

Participants discussed whether this data service needed to be formalized with a governance structure or whether it could be done on a more collaborative basis, noting that sustained funding may require more formal structures. Steve described the difficulties with estimating costs for an activity that has been carried out in pilot mode and on a volunteer basis but noted the fragility of the 'global' system that relies on the good will of a very small number of volunteers. Dorothee, Siv, and Steve estimated collectively that they spend the equivalent of 3 months per year each on these volunteer activities. Dorothee noted that there is a real struggle to innovate (e.g., automation of metadata uploads) because of lack of funding, which ultimately makes the work harder and take longer.

Dorothee provided an overview of the Surface Ocean CO_2 Atlas. She pointed out that SOCAT is based on a volunteer effort initiated in 2007 that has pulled together 28 million quality-controlled surface water CO_2 observations spanning 50 years (2020 version). The SOCAT data products serves as the global basis for evaluating monthly fields of air-sea CO_2 flux. Delivery of an annual product requires data providers to submit data by mid-January, followed by work of 8 regional groups to carry out secondary quality for a final product release in mid-June.

Participants also noted that not all groups have the capacity to turn around their most recent data in enough time to make it into that year's SOCAT release and Global Carbon Budget, and that increased support for data management and sharing at the group or PI level will be needed to support the global strategy.

Dorothee informed participants that SOCAT has been operating largely unfunded for the past 5 years, supported mostly through volunteer efforts. Activities to support the SOCAT synthesis include data submission and quality control by scientists worldwide, coordination, data management and innovation. Data management is tasked with data retrieval, support for data upload, the Live Access Server, archiving and data products, provision of Matlab code for data products, web site maintenance, and programming efforts related to automation and innovation. She estimated that SOCAT data management, coordination, and quality control require between 26-40 person-months / year. The total cost to operate SOCAT is estimated to be 300-500k Euros / year, accounting for costs associated with data management, coordination, quality control and innovation required to automate procedures to make SOCAT data F.A.I.R. and interoperable with other ocean carbon synthesis products (e.g. UN SDG 14.3.1).

Dorothee informed the group that the surface CO_2 strategy group will need to decide what data SOCAT will include and raised the issue of how to manage atmospheric CO_2 data from ships and BGC Argo estimated CO_2 values within the surface ocean CO_2 system. She pointed out that SOCAT insists on calibration and does not accept all data, and currently does not accept calculated CO_2 values (e.g., from BGC Argo profiling floats.) Participants agreed that it would be preferable for calculated surface CO_2 values from BGC Argo to be kept in the BGC Argo database with the full profile. Siv noted that SOCAT also does not include (or duplicate) surface data from GLODAP since users can go to each network to obtain the data they need.

Discussing the data challenges from a multi-platform programme, Dorothee and Siv mentioned the notion of a federated system of data systems to cope with multi-platform data that will be needed for this programme and described the ERDDAP system that allows data providers to submit their data once to one data centre and be found in an interoperable system.

Dorothee further described some services that SOCAT provides for the community that are not the standard services carried out for a data synthesis activity. For example, when data providers submit their data to SOCAT, SOCAT ensures that the data are archived. She also highlighted problems and tensions with how DOIs are assigned, noting that national ocean data centres (NODCs) want to have data submitted directly to them for DOI assignment because this improves their performance metrics. However, the concern is that each NODC will treat CO_2 data differently and experience has shown that delays can be considerable, making it more difficult and time consuming to pull together the SOCAT synthesis. The process used at present by the SOCAT data management task team is to continue to encourage data submissions directly to SOCAT but then the Bergen data centre contacts the relevant NODCs to get a DOI number for the data sets directly from them. When this is not possible, a DOI number is

obtained from Pangaea (a data archive and publisher for earth and environmental sciences, member of the WDS)

Siv posed the question of how the GDACs operate for Argo, where Argo data are sent to Argo GDACs rather than NODCs for data processing, serving netCDF files, and archival. Participants agreed that it would be valuable to consult the Argo GDACS to understand how they deal with these issues.

Participants agreed that this is an issue that needs considerable consultation to develop the strategy. To create the data products that the community wants in a timely and coherent way, SOCAT has by-passed the standard data management services. While this has avoided some problems, it has created others, including the impression that SOCAT can do everything. The issue of who attributes the DOIs will be an important part of the strategy.

Decision 9. Participants agreed that the strategy must highlight both the needs and ambitions for data management and data synthesis, both in terms of operational costs and support for personnel but also for necessary innovations required to streamline and automate workflow to transition towards a sustained, operational system. Participants also agreed that the issue of assigning DOIs should be explored, beginning by consulting the existing operational system such as Argo GDACS and DOI attributions.

Data Product Development and Links to Users

Participants noted that data product development is an essential part of value chain that sits between SOCAT and users like the GCP but questioned whether that level of data product development should be included as part of the 'operational' network or whether independent groups could take that on.

Judith noted that this volunteer effort for using the SOCAT data for global analyses has worked well so far and that there are many people willing to do this. She noted that the Surface Ocean CO_2 Mapping Intercomparison (SOCOM) project run by Christian Rodenbeck should be included in these discussions. Peter noted that there is a need for a more coordinated and sustained activity to develop, intercompare, and evaluate mapping methods, perhaps as part of SOCOM but with support from the community.

Andy noted that the GCP and others are moving towards data-based estimates but cautioned that these estimates may not be as independent as you might expect because they use the same techniques and the same data products. Richard noted that Copernicus Marine Service is producing operational surface CO_2 estimates, but participants questioned how that one product was chosen as 'the' operational product of Copernicus. Maria informed the group that the Copernicus Marine Service products are chosen through competitive calls, and that the global ocean surface carbon product is produced by Marion Gehlen's group at LSCE / IPSL (France) following on from R&D activities that were carried out as part of the EU Horizon 2020 AtlantOS project. Participants agreed that we should encourage multiple independent groups to work with SOCAT to produce flux maps. Judith pointed out that we need to differentiate between development of new methods and regularly producing an operational subset of data products that can be used to evaluate new methods and innovations in modeling. Siv noted that the community is far from being able to operationalize these products in a meaningful way and that there is significant work to be done on methods and neural networks by the research community. Artur stated that it will be also important to engage Copernicus Climate Service

since CO_2 is on their roadmap for ECV product development in the Climate Data Store. Andy suggested that we should aim for quality operational products by the end of the UN Ocean Decade when the neural network mapping estimates will have evolved to be able to use all the information and knowledge that we have, which is not currently the case.

Given the large discrepancies between model and data-based estimates and the numerous groups active in this area, participants agreed to develop a session at the strategy workshop to map activities in this area and to have a more coherent picture of the downstream users and their needs. Richard pointed out that we need to foster diversity, research, and innovation as part of the strategy and all agreed that these issues need to be more fully addressed as an important part of the value chain and co-design process. Participants further agreed that it would be useful to increase support for the SOCOM modeling / data synthesis effort to carry out regular analyses and intercomparisons using SOCAT data, which would also provide feedback to the observing network on in situ requirements as well as improve the operational data products. Participants suggested names and groups to contact for these discussions in addition to Judith and Peter already on the team.

Decision 10. Participants agreed to develop a session at the strategy workshop to map activities in this area and to have a more coherent picture of the downstream users and their needs, and to discuss with modeling / data synthesis groups the potential to carry out regular intercomparisons using SOCAT data, which would provide feedback to the observing network on in situ requirements as well as improve the operational data products.

Best Practices, Standards, and Intercomparisons

Participants discussed the need to establish, update, and/or officially endorse best practices and standards to create an interoperable global network from multiple platforms that measure CO_2 and ancillary support data. For data handling, Siv noted that there is a SOCAT QC 'cookbook' and training videos online. Participants discussed the continuing need for regular intercomparison exercises between underway systems while recognizing the goal of transitioning towards a global network with a smaller number of high-quality standardized systems (see discussions above re Decision 6).

Participants questioned how to make best use of all available data that will come from voluntary contributions such as citizen science platforms or 'sailing for science' programmes where quality may not be sufficiently known or reported. Dorothee and Siv noted that SOCAT can be set up to distinguish between contributors that are 'sustained' parts of the system versus opportunistic data contributions by selecting data by platform to exclude the data you may not want.

Decision 11. Participants agreed that best practices need to be updated as a key action of the global strategy.

4. MOVING FORWARD

Participants agreed to use the information generated at this meeting and the G7 FSOI Scoping Document to begin outlining the strategy. A Strategy Writing Team will be formalized via IOCCP and a subset of this Team will lead the planning of an international workshop to inform the strategy and reach international consensus on the way forward with implementation.

Participants discussed the timeline for a workshop and tentatively agreed to the goal of publishing the strategy (or launching an open review / comment period on the strategy) in time for the UN Ocean Conference in Lisbon, June 2022. This would mean hosting a workshop no later than March 2022. Maria informed the group that the G7 FSOI could provide support for this workshop, which would likely be a hybrid event.

Participants agreed that the Strategy Writing Team and workshop planning group should be established in early January and begin holding regular meetings to begin advertising the workshop and contacting speakers in early February for a mid to late March workshop.

Decision 12. A Strategy Writing Team will be formalized via IOCCP and a subset of this Team will lead the planning of an international workshop, beginning in January 2022 with the goal of hosting a workshop in March and publishing the first draft strategy for open community review in time for the UN Ocean Conference in Lisbon in June.

ANNEX 1. PARTICIPANT LIST

Daria Atamanchuk – IOCCP SSG Expert, Ocean Frontier Institute, Dalhousie, Canada.

Dorothee Bakker – SOCAT Director, GCP member, School of Environmental Sciences, Uni East Anglia, UK.

Kim Currie – IOCCP SSG co-Chair, NIWA / UoO Research Centre for Oceanography, New Zealand

Maribel García-Ibáñez – IOCCP SSG Expert, Institut de Ciències del Mar, Barcelona, Spain.

Veronique Garcon – IOCCP SSG co-Chair, LEGOS, France

Judith Hauck – GCP member, Deputy Head, Marine Biogeosciences at Alfred-Wegener Institute, Helmholtz Centre for Polar and Marine Research, Germany.

Maria Hood – Director, EU Office of the G7 FSOI, Mercator Ocean International, Toulouse, France

Steve Jones – IOCCP SSG Expert, Data Manager, Bjerknes Centre for Climate Research, Uni Bergen, Norway

Peter Landschutzer – SOCOM member, Dept of the Ocean in the Earth System, Max Planck Institute for Meteorology, Germany.

Siv Lauvset – IOCCP SSG Expert, Senior Researcher, NORCE, Norway

Akihiko Murata – Principal Researcher (Senior) , Physical and Chemical Oceanography Research Group, JAMSTEC Global Ocean Observation Research Centre, Japan.

Artur Palacz – IOCCP Project Officer, Institute of Oceanology, Polish Academy of Sciences, Sopot, Poland

Richard Sanders – IOCCP SSG Expert, Director, Integrated Carbon Observing System Ocean Thematic Centre, Bergen, Norway

Adrienne Sutton – IOCCP SSG Expert, SOCONET co-chair, NOAA PMEL, USA

Maciej Telszewski – IOCCP Director, Institute of Oceanology, Polish Academy of Sciences, Sopot, Poland

Andrew Watson – Head, Oceans and Atmospheres Research Group, University of Exeter, UK.

Rik Wanninkhof – SOCONET co-Chair, NOAA AOML, USA

ANNEX 2. AGENDA

1st Planning Meeting of the Surface Ocean CO_2 Monitoring Strategy

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

25 November 2021

Biogeochemistry Panel

HYBRID MEETING AGENDA

1st Session (all times are CET):

09h00-10h30	1. Overview of G7 / GOOS activity (15 minutes + 5 minutes q/a) - background, objectives, status, timeline (Maria, Richard) *Note: Overview of SOCONET scheduled for afternoon session / Rik and Adrienne.* 2. Discussions (approx. 20 minutes each) • **Strategy scope** - *aspirations of an ideal system versus practicality of a basic observing network and data centre capable of meeting basic requirements as rapidly as possible.* • **Observing requirements** - *GCOS? GCP? Operational Forecasters? Who are stakeholders and what are the needs? What is the minimum 'target' for the initial network?* • **Defining programs that contribute to the strategy and gaps** – What are the criteria for determining which existing programs are contributions to the strategy and how do we assess the gaps? How do we fill the gaps? What is the role of networks like BGC Argo and GO-SHIP? Gliders?
Break (30 min)	
11h00 – 12h30	3. Overview of SOCAT (20 minutes) – scope, activities, existing staff, existing operating funds, challenges (Dorothee) 4. Discussion (approx. 20 minutes each) • Needs and existing structures for data management (how to build on SOCAT) • Needs for standards / best practices / CRMs / intercomparisons – what? who?

	• Links to other stakeholders (e.g., GCP) – what do they need / what from for observations-based estimates and models?

2nd Session (all times are CET)

15h00-16h30	5. Overview of SOCONET (20 minutes) - scope, activities, existing staff / operating funds, challenges (Rik / Adrienne) 6. Discussions (approx. 20 minutes each) • Can we build on SOCONET (obs) and SOCAT (data synthesis) to establish the global monitoring network? What needs to be added / expanded? What would the consequence be for each program (positive, negative)? • What would an organizational structure look like? What are staff and operational costs of the combination of SOCONET, SOCAT, and a coordinator of the SOCM network? Where? Who?
Break (30 min)	
17h00-18h30	**Moving Forward** **Timeline** – options? G7 FSOI members agreed for delivery of strategy and implementation plan after 2 years. Can we move faster? (Take advantage of US statement at COP and momentum, etc.) Phased approach – release strategy in mid-2022, implementation plan in early 2023? **Strategy Writing Team** – Who? *Get the fundamentals on paper; outline what input and discussions are needed with the community; plan workshop.* **Workshop Planning Team** – Who? *Workshop objectives, format, speakers, participants, when, where. Also think about initial International Mission Team (1 rep per country, experts actually running surface pCO2 programmes who have a good overview of all surface pCO2 work going on in their country / region.)* **Summary and Next Steps** Note: will need to finalize these after meeting to have input of all participants: • Agreement on the fundamentals (objectives, goals, structure) • Agreements on who is on/ should be asked to join the writing team • Agreements on who is on/ should be asked to join the workshop planning team • Target date for final meeting report and suggestions for next meeting.