Series of Workshops on surface ocean $pCO_2$ observations, synthesis and data products

- Tentative agenda -

06. - 09. November (morning to lunch) 2023

Flanders Marine Institute (VLIZ), InnovOcean Campus, Oostende, Belgium

Surface ocean $pCO_2$/$fCO_2$ (partial pressure/fugacity of CO$_2$) data products and air-sea CO$_2$ fluxes determined from them have become an important input in the quantification of the ocean carbon sink strength in the Global Carbon Budget (GCB) as well as in determining variability and trends of ocean acidification. There are however several aspects of the $pCO_2$ products and the fluxes based on them that are less well known, e.g. their sensitivity to data quality and availability, method of interpolation/gap filling and the overall uncertainty in the air-sea CO$_2$ fluxes.

We encourage in-person attendance of the workshop, however there will be opportunity for online participation. Please, indicate your preference for in person or online attendance via this form.

More and updated information will be found here: https://www.icos-otc.org/node/217.

Organizers:

| Tobias Steinhoff, NORCE Norwegian Research Centre AS, Norway/GEOMAR, Germany |
| Thanos Gkritzalis, Flanders Marine Institute, Belgium |
| Dorothee Bakker, University of East Anglia, UK |
| Peter Landschützer, Flanders Marine Institute, Belgium |
| Shin-ichiro Nakaoka, NIES, Japan |
| Kevin O’Brien, NOAA Pacific Marine Environmental Laboratory, USA |
| Richard Sanders, NORCE Norwegian Research Centre AS, Norway |
| Adrienne Sutton, NOAA Pacific Marine Environmental Laboratory, USA |
| Kathy Tedesco, NOAA Global Ocean Monitoring and Observing Program, USA |
| Maciej Telszewski, IOCCP, Poland |
| Bronte Tilbrook, CSIRO, Australia |
| Rik Wanninkhof, NOAA Atlantic Oceanographic and Meteorological Laboratory, USA |

Associated programs and sponsors:

| Surface Ocean CO$_2$ Atlas (SOCAT) |
| Surface Ocean Reference CO$_2$ Observing Network (SOCONET) |
| Global Carbon Project (GCP) |
| International Ocean Carbon Coordination Project (IOCCP) |
| Ocean Thematic Centre (OTC) of the European infrastructure Integrated Carbon Observation System (ICOS) |
| National Oceanic and Atmospheric Administration’s Global Ocean Monitoring and Observing Program (NOAA GOMO) |
**DAY 1 – Monday 6 November 09:00 - 18:00 CET**

**Global Carbon Budget**

**Aims:**
- The aim of the first day is to identify and develop ways to implement time-varying (e.g. through changing pCO2 data availability) and regional uncertainty into the GCB pCO2-uncertainty
- Identify common needs and experimental designs between SOCAT, SOCONET and SOCOM communities

**09:00 – 12:30**

**Morning session: Uncertainty from sparse observations in pCO2-products**

**Chair: Peter Landschützer**

Currently, the GCB includes uncertainties for the GCB pCO2 products from literature derived sources (pCO2 uncertainty, gas transfer uncertainty, wind uncertainty, uncertainty in river adjustments and mapping uncertainty). These represent mean uncertainties (added to the annual flux as +/- uncertainty) and are not time varying. Recently, the pCO2-based estimates and ocean models diverged to a degree that the best estimates lie outside their combined uncertainty intervals. Could this be due to missing uncertainties/biases?

Model subsampling exercises e.g. reveal time-dependent and region-dependent errors in pCO2 products (Gloege et al 2021, Hauck et al 2023) that are linked to data sparsity. This open-input discussion session aims to gather the latest knowledge on possible subsampling experiments and the best implementation of time varying errors into the GCB uncertainty estimate.

The goal of the morning sessions is (a) to find ways to implement time varying errors into the pCO2 product uncertainty, (b) to discuss best practice experiments to do so, including needs from the model community and (c) to discuss ways to integrate time varying uncertainties into the current GCB uncertainty framework.

**12:30 – 14:30**

**Lunch break**

**14:30 – 17:30**

**Afternoon session: How can we make use of the pCO2 mapping infrastructure to quantify the added value of pCO2 measurements?**

**Chair: Peter Landschützer**

Recently, we see a worrying trend that many established pCO2 measurement lines disappear from the map. On the other hand, OSSE’s suggest that we need a strong integrated observing system in place to reconstruct the air-sea CO2 flux. It is thus unclear whether (a) fewer measurements in previously well observed regions will have an effect on the GCB best estimate (including uncertainty) and (b) how large this effect may be. Additionally, many ocean regions remain sparsely observed and it is not yet clear what impact a single cruise would add on the overall air-sea CO2 flux estimates from pCO2-products.

This discussion sessions aims to define experiments that can be done in collaboration between SOCOM (Surface Ocean CO2 Mapping) and SOCAT/SOCONET (Surface Ocean CO2 Atlas/ Surface Ocean CO2 Reference Network) to highlight the direct effect on the air-sea CO2 flux of (a) adding pCO2 lines in data sparse regions, (b) changing/reducing the number of observations in previously well observed ocean regions and (c) adding measurement biases of 2 µatm, 5 µatm and 10 µatm to the pCO2 measurements and test the difference in the reconstructions. In addition, the importance of predictor variables and possible improvements (including remote sensing) should be discussed.

**17:30 – 18:00**

**wrap up**
## DAY 2 – Tuesday 7 November 09:00 – 18:00 CET

### SOCONET

**Aims:**
- Identify governance structure and requirements for a Surface Ocean CO₂ Observing Network (SOCONET) of global reference measurements
- Identify path forward for developing an observing network design (building on day 1 outcomes)
- Establish connections/interaction with other networks through, for example, the GOOS Observation coordination group (OCG) and GOOS operations group (OPS)

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| 09:00 – 12:30 | **Morning session: Status of SOCONET**  
**Chair:** Rik Wanninkhof |

In the same year [WMO committed](#) to coordinating an international global greenhouse gas monitoring initiative, new surface ocean pCO₂ observations delivered to SOCAT have continued to [decline](#). This calls for increased coordination and support of the nascent **SOCONET** to ensure continued ocean reference measurements in support of global greenhouse gas monitoring and data-based ocean CO₂ flux products.

**What is SOCONET**

The following topics will be discussed during the morning session: Network justification, deliverables, implementation, connection to other networks, governance structure, challenges. The goal is to get affirmation of partners on overall execution of SOCONET and becoming a network of GOOS. Furthermore, we will discuss how we get from surface water CO₂ measurements to flux products: procedures, uncertainty, development of network design. We aim to get an improved understanding of impact of data quality and temporal/spatial sampling requirements.

### 12:30 – 14:30

Lunch break

### 14:30 – 17:30

**Afternoon session: Expectations of SOCONET for participants and stakeholders**  
**Chair:** Rik Wanninkhof

**What makes SOCONET a reference network**

Topics: Means of intercomparison, collaborative responsibility for checking/servicing equipment, regional and/or platform subgroups and their roles, requirement setting, best practices, resource requirements, whether to include atmospheric CO₂ measurements in SOCONET

Goal: Understanding the data quality of different instruments and the compromises between data quality vs. ease of operation vs. data gaps

### 17:30 – 18:00

Wrap up

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[Global Carbon Project](#) [SOCAT](#) [SOCONET](#) [ICOS](#) [NOAA](#)

Version: 12 July 2023
### DAY 3 – Wednesday 8 November 09:00 – 18:00 CET
(Thursday 9 November 09:00 – lunch: possible hands-on data submission training)

**SOCAT**

**Aims:**
- Identify SOCAT Needs and Ways forward
- Consider the SOCAT organisation
- Consider data submission and quality control
- Consider feedback from the user (GCB) and SOCONET/observational communities
- Discuss emerging issues
- Consult the SOCAT community

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| 09:00 – 12:30 | **Morning session:** Chair: Dorothee Bakker  
Our ability to quantify the uptake of carbon dioxide by the oceans is under threat, at a time when the importance of constraining the uptake is well recognized by efforts such as the WMO Global Greenhouse Gas Watch and the UN Global Stocktake. SOCAT-based estimates have shown that the oceans take up a quarter of the CO\textsubscript{2} emissions from human activity, thus helping to mitigate climate change and providing a way to balance the Earth’s carbon budget. The SOCAT (Surface Ocean CO\textsubscript{2} Atlas, www.socat.info) synthesis products and the fCO\textsubscript{2} measurements in them are key for quantification of ocean CO\textsubscript{2} uptake at a monthly timescale, providing vital observational information for climate policy. However, the open ocean data collection effort has dramatically declined since 2017. SOCAT itself is at immediate risk upon losing its European data management team, while facing persistent funding shortfalls. The need for accurate knowledge of ocean CO\textsubscript{2} uptake and its variation now and in the future makes sustained funding of accurate surface ocean CO\textsubscript{2} observations and their synthesis imperative.  
This morning’s session will highlight SOCAT achievements, status and needs, leading to discussion on ways forward, including on the organisation of SOCAT (SOCAT Terms of Reference) and a SOCAT Perspectives document and the SOCAT collaboration with the Global Carbon Budget. |
| 12:30 – 14:30 | **Lunch break** |
| 14:30 – 17:30 | **Afternoon session:** SOCAT Data submission, quality control and innovation  
Chair:  
SOCAT is a live community effort. Aims for this session are to share knowledge and to provide feedback within the SOCAT community and to the SOCAT global group. This afternoon we will take stock, discuss data submission, and carefully consider the SOCAT quality control criteria and the potential for SOCAT innovation. This discussion will take place against the need for an efficient SOCAT operation against a backdrop of bare-bone SOCAT resources for data management and data submission.  
We will use this afternoon’s session to discuss data submission to SOCAT, including the imminent automation of metadata submission, doi-s for SOCAT data submissions and how the automation feeds into SOCAT products available for Sustainable Development Goal 14.3.1. The second part of the discussion will consider revision of the SOCAT quality control cookbook and the desirability of assigning point by point uncertainty to fCO\textsubscript{2} values. Finally, the discussion will consider SOCAT innovation by machine to machine data exchange, new platforms and sensors, and priorities for inclusion of additional variables. |
<p>| 17:30 – 18:00 | <strong>wrap up</strong> |</p>
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<td>09:00 – 12:30</td>
<td><strong>Chair: Kevin O’Brien</strong>&lt;br&gt;The session will show the data submission system for the SOCAT database. After an introduction we will give hands-on training for SOCAT data submission and discuss possible issues with the procedure.</td>
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<td>12:30 – 14:30</td>
<td><strong>Lunch</strong></td>
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