Viewing ICOS in a global context: from coordinated ocean observations, through high quality data products to global ocean carbon fields and fluxes.

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Over the past two decades systematic automated surface water CO_2 observations are used to map CO_2 levels in the mixed layer over time for robust estimates of air-sea CO_2 fluxes and uptake of CO_2 by the ocean. They contribute two key pieces of information needed to assess the global carbon cycle and impact of fossil fuel release. The first is the fraction of CO_2 released by fossil fuel that is sequestered by the ocean; the second is the trends of surface water CO_2 increase. The fraction of CO_2 absorbed by the ocean is critical for quantifying the ocean's role in modulating the growth of atmospheric CO_2 and the resulting climate change. Trends allow determination of ocean acidification and the oceanic processes that affect, and are affected by, increasing CO_2 levels in the ocean. The observations from the Surface Ocean CO_2 Observing Network (SOCONET) and it's partners address the socio-economic needs of carbon accounting and tracking of the state of ocean ecosystems in support of the UN sustained development goals: *SDGs 13 Climate Action* and *SDG 14 Life Below Water* (www.un.org/sustainabledevelopment/sustainable-development-goals/).

These observations have generated numerous key publications ranging in topics from aquatic chemistry, and process level understanding, to global constraints on the carbon cycle. A tremendous advance took place when data from dozens of research groups were collated and distributed as part of the Surface Ocean Carbon Atlas (SOCAT, https://www.socat.info/), a volunteer community effort initiated by the International Ocean Carbon Coordination Project (IOCCP, http://www.ioccp.org/index.php). SOCAT is a synthesis activity for extensively quality-controlled, surface ocean CO_2 observations by the international marine carbon research community (>100 contributors). SOCAT data is publicly available, discoverable and citable. Since 2011, when SOCAT version 1 was released, the measurements feed directly into the annual Global Carbon Budget updates (Le Quéré et al., 2018), national climate and ecosystems reports (e.g. USGCRP, 2017), and authoritative assessment of the IPCC that are used to set national and international policies (IPCC(AR6), 2018) and the Paris accord (unfccc.int/paris_agreement/).

Currently there are over 23 million data points in SOCAT (version 6), however observations from ships or fixed sensors can only cover a tiny fraction of the spatio-temporal pCO_2 field of the global surface ocean. To obtain continuous air-sea CO_2 flux fields over larger areas or the entire ocean, interpolation methods are needed to estimate values in all the periods and areas not directly observed. This goal was recently achieved via the Surface Ocean pCO_2 Mapping Intercomparison (SOCOM, http://www.bgc-jena.mpg.de/SOCOM/). This community effort benefited from SOCAT data and 14 different mapping methods and investigated similarities and differences in their estimates of regional and global air-sea CO_2

fluxes on a variety of timescales. Resulting analyses led to significant improvements of mapping methods and several high-level publications dealing with global air-sea CO_2 flux and it's reginal and global trends.

In this presentation we will provide an overview of lessons learned from two decades of observations (SOCONET) and a decade of continuous data synthesis effort (SOCAT). We will also share some insights on the use of this data aimed at better quantification of the global carbon cycle (Global Carbon Budget, SOCOM). Scientists involved in ICOS OTC played critical, often leading, role in all these global efforts and this will be highlighted throughout the talk.