SOCAT version 2024: Ocean CO_2 observing effort down to levels of a decade ago

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Abstract – The ocean takes up a quarter of annual carbon dioxide (CO_2) emissions from human activity[d], thus helping to mitigate climate change. Since 2017 there has been a reduction in surface ocean CO_2 observations that is impacting our ability to quantify the ocean's role as a major sink for CO_2 emissions[a]. Version 2024 of the community-led Surface Ocean CO_2 Atlas (SOCAT; www.socat.info) shows data collection has declined to levels similar to those a decade ago with poor data coverage south of 20°N (Figs. 1a, 2a). Here the number of monthly, 1° latitude by 1° longitude gridded fCO_2 values is used as a measure for the open ocean CO_2 observing effort, as it is not affected by changes in the reporting frequency (e.g. from every minute to every second) nor by changes in the coastal ocean data collection effort. SOCAT version 2024 contains 38.6 million, quality-controlled, in-situ surface ocean fCO_2 (fugacity of CO_2) measurements collected between 1957 and 2023 with an estimated accuracy of better than 5 µatm. SOCAT fCO_2 measurements are key for quantification of ocean CO_2 uptake at regional and monthly scales, providing vital information for climate policy. However, in addition to the decline in observations, the integration, quality control and accessibility of data products by SOCAT is at risk from persistent funding shortfalls, with SOCAT now relying on a single regional hub. At a time where the importance of constraining ocean CO_2 uptake is well recognized by the WMO Global Greenhouse Gas Watch[n] and the UNFCCC Global Stocktake, there is an urgent need for sustained and expanded funding of accurate surface ocean CO_2 observations and their synthesis.

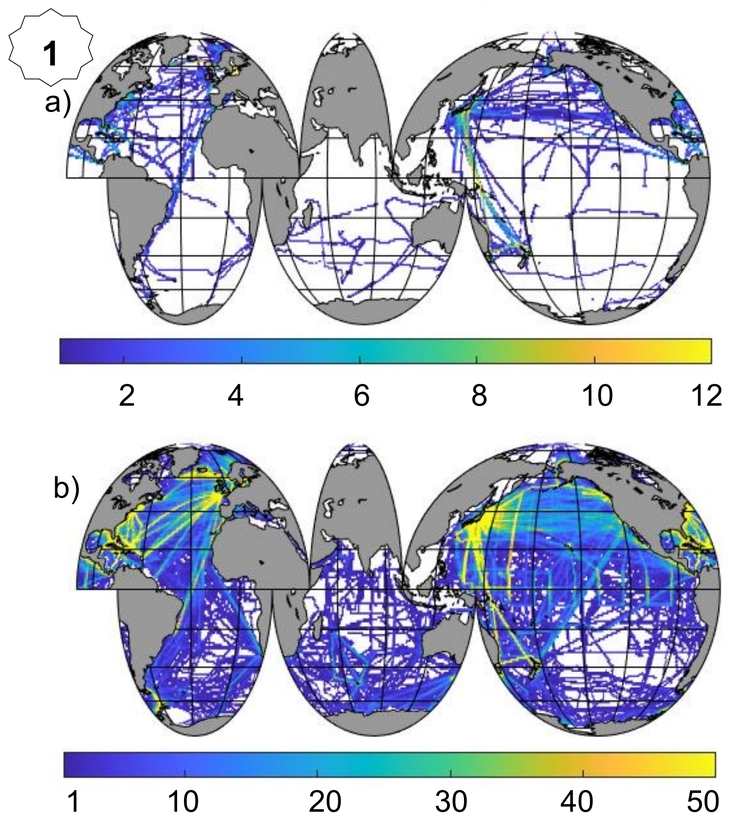

Fig. 1. *a) The number of year months with 1° x 1° gridded surface ocean fCO_2 in 2022 and 2023 in v2024. b) The number of individual months with 1° x 1° gridded surface ocean fCO_2 between 1970 and 2023.*

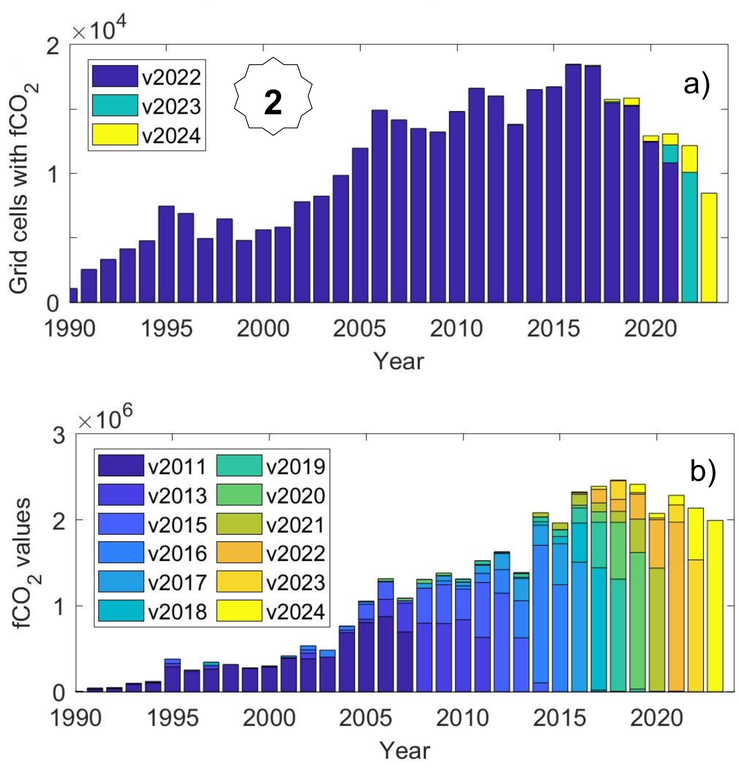

Fig. 2. *a) Number of monthly, 1° x 1° grid cells with fCO_2 for each year in v2022 to v2024, a measure for the open ocean CO_2 observing effort. b) Number of surface ocean fCO_2 values with an estimated accuracy of <5 µatm for each year by SOCAT version.*

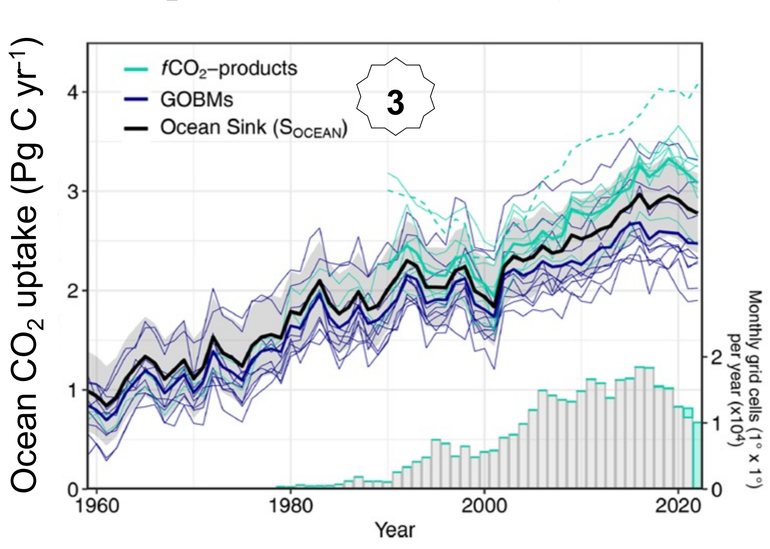

Fig. 3. *Ocean CO_2 uptake in the Global Carbon Budget 2023[d]. Turquoise lines for SOCAT-based estimates. Purple lines for model results. From[d].*

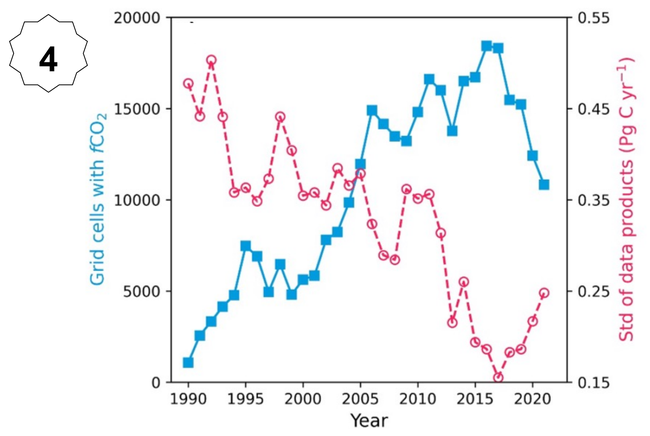

Fig. 4. *The number of monthly, 1° x 1° grid cells with fCO_2 per year in SOCATv2022 and the standard deviation in ocean CO_2 uptake from 7 SOCAT-based data products in the Global Carbon Budget 2022. From[a].*

Key features

- *In situ* surface ocean fCO_2 measurements from ships, moorings and autonomous surface vehicles for the global ocean and coastal seas from 1957 to 2023
- 38.6 million fCO_2 values with an estimated accuracy of < 5 µatm in the main synthesis and gridded products (Fig. 1, 2)
- 8.1 million fCO_2 values with an accuracy of 5 - 10 µatm, mainly from membrane-based sensors, are separately available.
- Community-led, expert quality-control (QC) and synthesis
- Annual, public release
- Online viewers and data download (www.socat.info)

Outlook

- v2025 data submission by 15/01/2025, QC by 21/03/2025
- QC cookbook revision, incl. for membrane-based sensors
- Automation of metadata upload & part of federated data system for Sustainable Development Goal (SDG) 14.3

Ocean CO_2 observing capacity at risk

- Decline in the ocean CO_2 observing effort to levels similar to a decade ago with poor data coverage south of 20°N (Figs. 1, 2a)
- Resultant reduction in the accuracy of SOCAT-based estimates of ocean CO_2 uptake in the Global Carbon Budget[a] (Fig. 4)
- SOCAT at risk by reliance on one regional hub and chronic funding shortfalls

Scientific findings, applications and impact

- Quantification of ocean CO_2 uptake[c,d,g,l,j,l] and acidification[e,h,k]
- Evaluation of climate models[b] and sensor data[m]
- Data gaps addressed through interpolation schemes[e,h,i,j,l]
- Difference of ~0.6 Pg C yr^{-1} in ocean CO_2 uptake estimated from SOCAT-based products and models for the year 2022[d] (Fig. 3)
- Cited in hundreds of peer-reviewed scientific articles and reports
- Value chain[f] critical for climate policy, WMO Global Greenhouse Gas Watch[n], UNFCCC Global Stocktake, SDGs 13 and 14 and Decade of Ocean Science

Data Use: To generously acknowledge the contribution of SOCAT scientists by invitation to co-authorship, especially for key data providers in regional studies, and/or reference to relevant scientific articles. **Acknowledgements:** We thank the numerous contributors, funding agencies, IOCCP, SOLAS and IMBER. **Documentation v2024:** Bakker et al. (2016) ESSD 8: 383-413; **v2:** Bakker et al. (2014) ESSD 6:69-90; **v1:** Pfeil et al. (2013) ESSD 5:125-143; Sabine et al. (2013) ESSD 5:145-153. **References:** Dong et al., 2024[a], https://creativecommons.org/licenses/by/4.0/; Eyring et al., 2016[b]; Fay et al., 2021[c]; Friedlingstein et al., 2023[d]; Gregor and Gruber, 2021[e]; Guidi et al., 2020[f]; Hauck et al., 2020[g]; Jiang et al., 2019[h]; Landschützer et al., 2014[i]; Laruelle et al., 2018[j]; Lauvset et al., 2015[k]; Rödenbeck et al., 2015[l]; Williams et al., 2017[m]; https://wmo.int/activities/global-greenhouse-gas-watch-g3w[n]. **Affiliations:** [1]UEA, UK; [2]NOAA-PMEL, USA; [3]BIOS, Bermuda; [4]Arizona State University, USA; [5]UiB & [6]BCCR, Norway; [7]VLIZ, Belgium; [8]NOAA-NCEI, USA; [9]NORCE, Norway; [10]LOCEAN/IPSL, France; [11]NIES, Japan, [12]CICOES, UW & [13]NOAA-AOML, USA; [14]GEOMAR, Germany; [15]CSIRO & [16]AAPP, Australia.