SOCAT version 2025: Open ocean CO_2 data submissions stabilise

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Abstract – The annual mean growth rate of atmospheric carbon dioxide (CO_2) was 3.77 ppm (µmol mol^{-1}) in 2024[h], a record high increase, highlighting the urgent need for quantification of the ocean carbon sink. Since 2011, the community-led Surface Ocean CO_2 Atlas (SOCAT; www.socat.info) offers an annual public update of global *in situ* oceanic *f*CO_2 (fugacity of CO_2) measurements. Version 2025 adds 451 new data sets and updates 44 data sets from ships, yachts, uncrewed surface vehicles (USVs), moorings and drifting platforms (Fig. 1a, 2a, 2b). Version 2025 contains 41.4 million, quality-controlled, *in situ* surface ocean *f*CO_2 measurements with an estimated uncertainty of better than 5 µatm collected between 1957 and 2024, which constitute the main SOCAT synthesis and gridded products (Fig. 1b, 2a, 2b). In addition, 8.2 million *f*CO_2 values with an uncertainty of 5-10 µatm, mainly from membrane-based sensors, are made separately available (Fig. 1a, 2c). Open ocean CO_2 data submissions have stabilised, as shown by the number of monthly, 1° by 1° gridded, surface ocean *f*CO_2 values in 2020 to 2023 (Fig 2a). Documentation of data sets has improved over time (reduction in D flags) (Fig 2c). SOCAT is key for quantification of ocean CO_2 uptake and ocean acidification, providing vital information for climate policy. As the importance of constraining ocean CO_2 uptake is well recognized by the WMO Global Greenhouse Gas Watch (G3W) and the UNFCCC Global Stocktake, there is an urgent need for sustained funding of accurate surface ocean CO_2 measurements and their synthesis. The SOCAT synthesis effort remains at risk by reliance on a single hub and funding shortfalls.

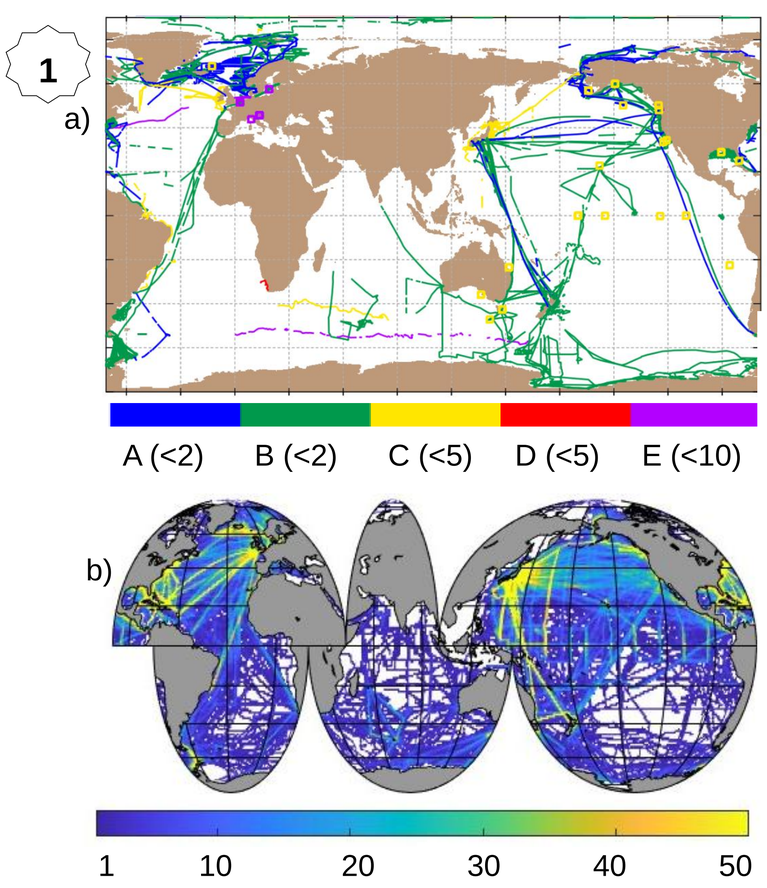
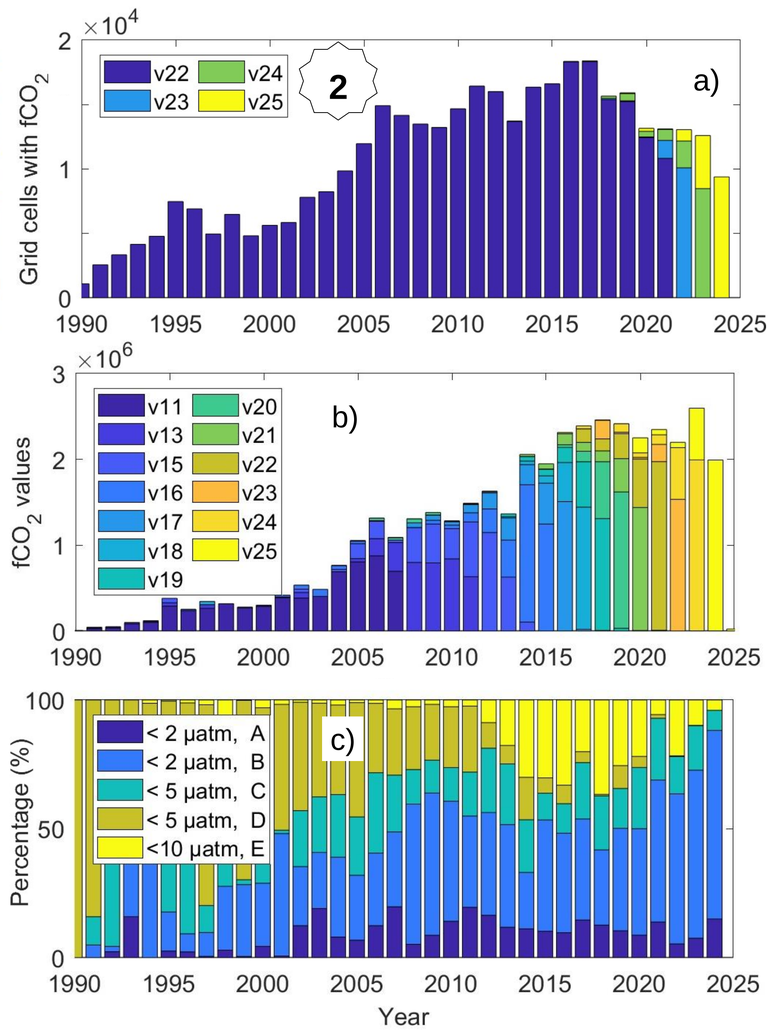


Fig. 1. *a) Newly available fCO_2 in v2025, colour coded by data set QC flag with the uncertainty in µatm in brackets. Squares indicate moorings. b) Number of individual months with 1° x 1° gridded fCO_2 from 1970 to 2024.*



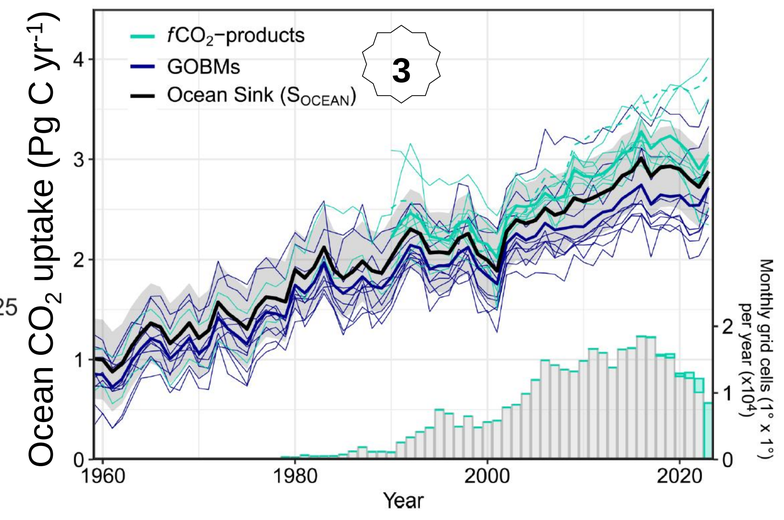


Fig. 2. *a) Number of monthly, 1° x 1° grid cells with fCO_2 by year from v2022. b) Number of fCO_2 values with an uncertainty of <5 µatm by year by SOCAT version. c) Percentage of fCO_2 with an uncertainty of <2, 5 and 10 µatm by year.*

Fig. 3. *Ocean CO_2 uptake in the Global Carbon Budget 2024[c]. Turquoise lines for SOCAT-based estimates. Purple lines for model results.*

Key features of SOCAT v2025 (www.socat.info)

- A community-led synthesis with secondary quality-control (QC), an annual, public release, online viewers and data download
- *In situ* surface ocean *f*CO_2 measurements from ships, yachts, moorings, drifters and USVs for the global ocean and coastal seas from 1957 to 2024
- 41.4 million *f*CO_2 values with an estimated uncertainty of < 5 µatm in the main synthesis and gridded products (Fig. 1b, 2a-b)
- 8.2 million *f*CO_2 values with an uncertainty of 5-10 µatm, mainly from membrane-based sensors, separately available (Fig. 1a, 2c)
- QC cookbook revised for v2025[f]: 1) Complete metadata for all new data, 2) Flag E for all new membrane-based sensor data
- Open ocean CO_2 data submissions have stabilised (Fig. 2a), as shown by monthly, 1° by 1° gridded surface ocean *f*CO_2 values.
- Improved data documentation over time (fewer D flags) (Fig. 2c)
- 19 data sets (collected in 2010-2022), included in previous SOCAT versions, suspended from v2025 for $\Delta T_{Teq\text{-}SST}$ issues.

SOCAT outlook

- SOCAT at risk by reliance on a single hub and funding shortfalls.
- V2026: data submission by 15/01/2026 & QC by 20/03/2026
- QC hackathon on 03/02/2026
- Automation of metadata upload & part of federated data system for Sustainable Development Goal (SDG) 14.3

Scientific applications, findings and impact

- Quantification of ocean CO_2 uptake[c,j] and acidification[d,g,i]
- Evaluation of earth system models[a] and sensor data[k]
- SOCAT-based ocean CO_2 sink estimates sensitive to available data in data-sparse regions[b].
- Difference of ~0.4 Pg C yr^{-1} in ocean CO_2 uptake estimates from SOCAT-based products and models for the year 2023[c] (Fig. 3)
- Cited in hundreds of peer-reviewed scientific articles and reports
- Value chain[f] critical for climate policy, WMO G3W[l], UNFCCC Global Stocktake, SDGs 13 and 14, 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 and SOLAS. **Data product:** Bakker et al. (2025) SOCATv2025, NCEI Accession 0304549, https://doi.org/10.25921/648f-fv35; **Method:** Bakker et al. (2016) ESSD 8: 383-413; **Gridding:** Sabine et al. (2013) ESSD 5:145-153. **References:** Eyring et al., 2016[a]; Fay et al., 2025[b]; Friedlingstein et al., 2025[c]; Gregor and Gruber, 2021[d]; Gkritzalis et al., 2024[e]; Guidi et al., 2020[f]; Jiang et al., 2019[g]; Lan et al. (2025), https://doi.org/10.15138/9N0H-ZH07[h]; Lauvset et al., 2015[i]; Rödenbeck et al., 2015[j]; Williams et al., 2017[k]; https://wmo.int/activities/global-greenhouse-gas-watch-g3w[l]. **Affiliations:** [1]UEA, UK; [2]NOAA-PMEL, USA; [3]NIES, Japan; [4]NOAA-AOML, USA; [5]CIMAS, USA; [6]Arizona State University, USA; [7]BIOS, Bermuda; [8]VLIZ, Belgium; [9]NOAA-NCEI, USA; [10]NORCE, Norway; [11]BCCR, Norway; [12]Hereon, Germany; [13]LOCEAN/IPSL, France; [14]CIRES, USA; [15]NOAA-GML, USA; [16]CICOES, USA; [17]UiB, Norway;[18]GEOMAR, Germany.

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