SOCAT version 2023 – An alarming decline in the ocean CO_2 observing capacity

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Abstract – Our ability to quantify the uptake of carbon dioxide (CO_2) 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[n] and the UN Global Stocktake. SOCAT-based estimates have shown that the oceans take up a quarter of the CO_2 emissions from human activity[c], thus helping to mitigate climate change and providing a way to balance the Earth's carbon budget. The latest update of the community-led Surface Ocean CO_2 Atlas (www.socat.info), version 2023, has delivered 35.6 million, quality-controlled, *in situ* surface ocean fCO_2 (fugacity of CO_2) measurements collected between 1957 and 2022 with an estimated accuracy of <5 µatm. The SOCAT synthesis products and the fCO_2 measurements in them are key for quantification of ocean CO_2 uptake at a monthly timescale, providing vital 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_2 uptake and its variation now and in the future makes sustained funding of accurate surface ocean CO_2 observations and their synthesis imperative.

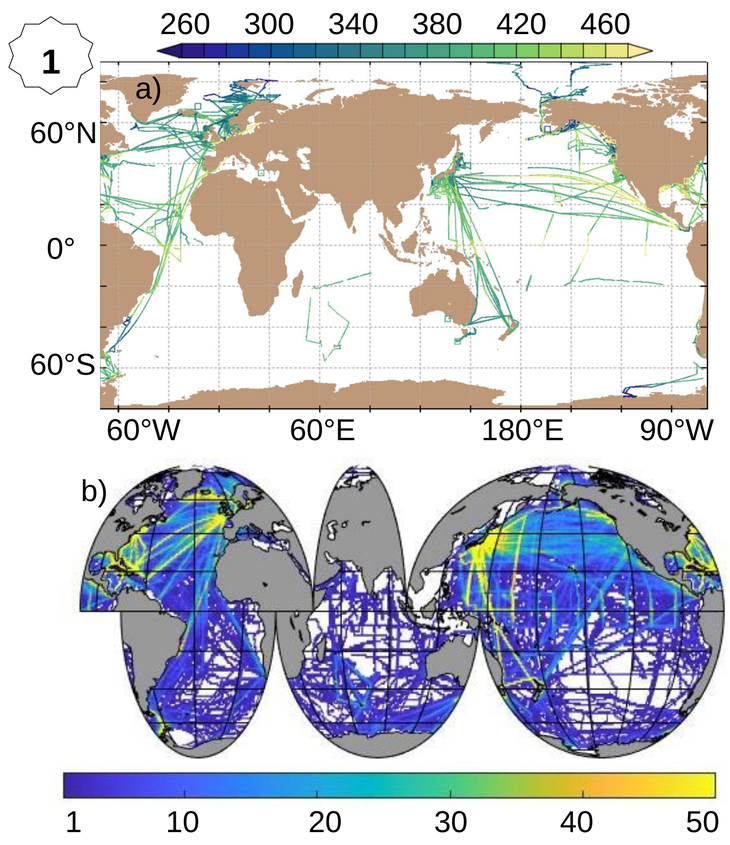

Fig. 1. *a) Newly available fCO_2 (colour coded, µatm) with an estimated accuracy of <10 µatm in v2023. Squares indicate moorings. b) The number of individual months with 1° x 1° gridded surface ocean fCO_2 values between 1970 and 2022.*

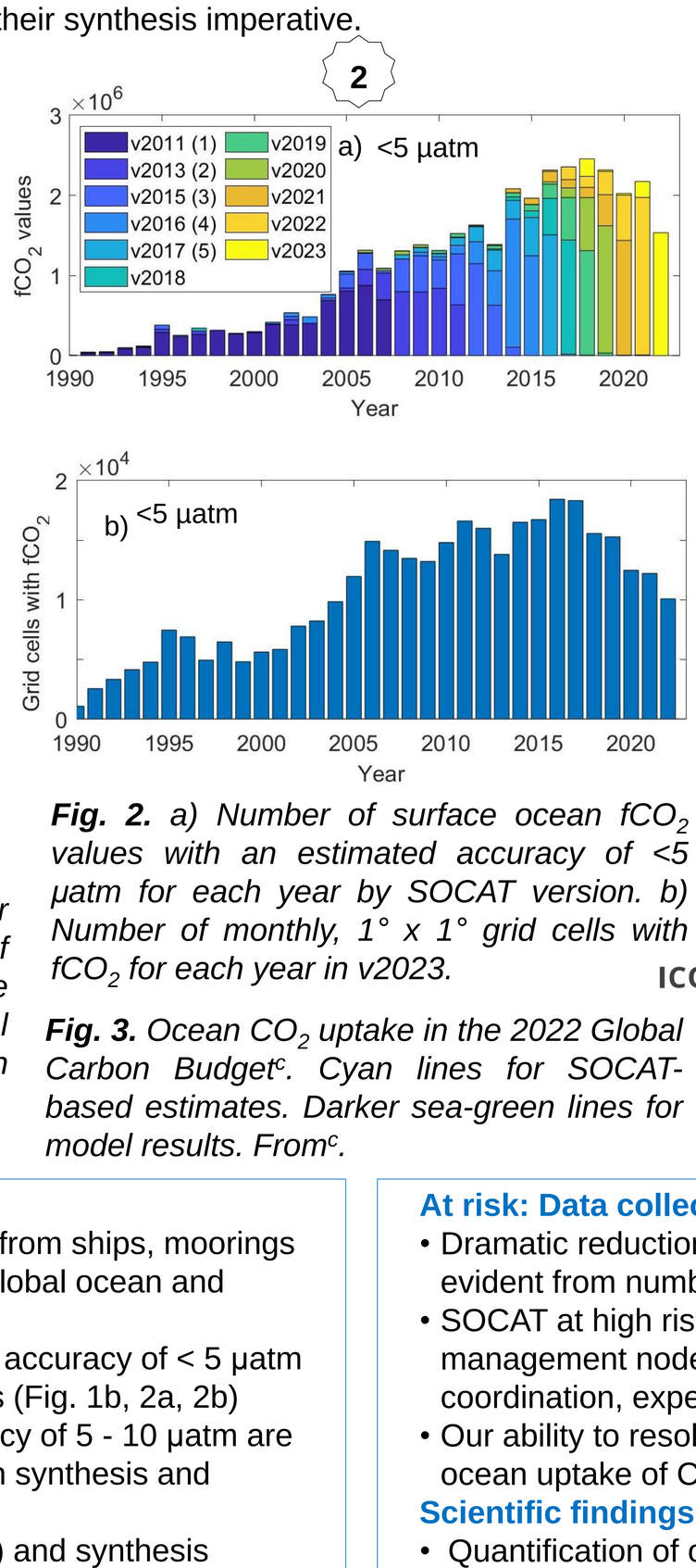

Fig. 2. *a) Number of surface ocean fCO_2 values with an estimated accuracy of <5 µatm for each year by SOCAT version. b) Number of monthly, 1° x 1° grid cells with fCO_2 for each year in v2023.*

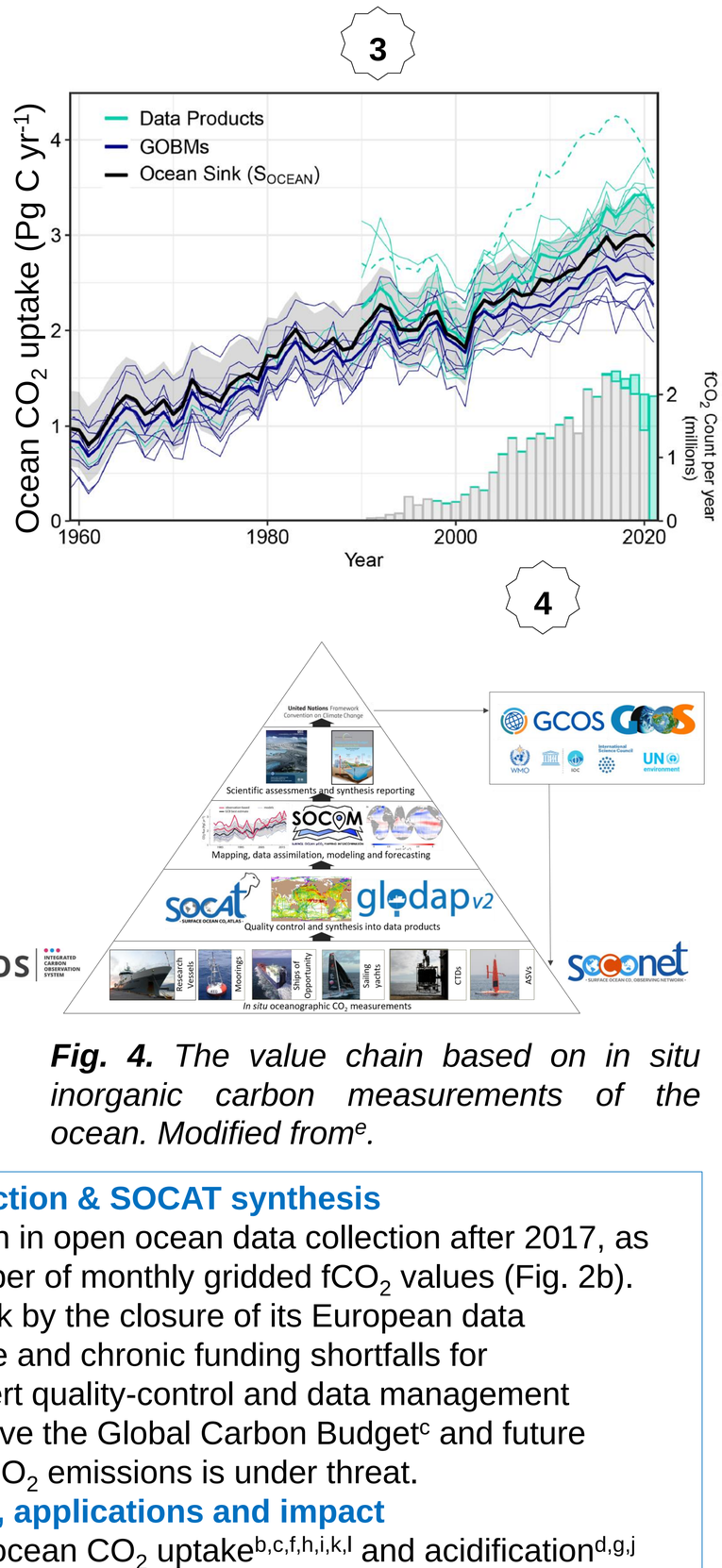

Fig. 3. *Ocean CO_2 uptake in the 2022 Global Carbon Budget[c]. Cyan lines for SOCAT-based estimates. Darker sea-green lines for model results. From[c].*

Fig. 4. *The value chain based on in situ inorganic carbon measurements of the ocean. Modified from[e].*

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 2022
- 35.6 million fCO_2 values with an estimated accuracy of < 5 µatm in the main synthesis and gridded products (Fig. 1b, 2a, 2b)
- 7.2 million fCO_2 values with a lower accuracy of 5 - 10 µatm are separately available but are not in the main synthesis and gridded products.
- Community-led, expert quality-control (QC) and synthesis
- Annual, public release
- Online viewers and data download (www.socat.info)

Outlook

- v2024 data submission by 15/01/2024, QC by 29/03/2024
- Automation of metadata upload
- Component of the Sustainable Development Goal (SDG) 14.3 federated data system

At risk: Data collection & SOCAT synthesis

- Dramatic reduction in open ocean data collection after 2017, as evident from number of monthly gridded fCO_2 values (Fig. 2b).
- SOCAT at high risk by the closure of its European data management node and chronic funding shortfalls for coordination, expert quality-control and data management
- Our ability to resolve the Global Carbon Budget[c] and future ocean uptake of CO_2 emissions is under threat.

Scientific findings, applications and impact

- Quantification of ocean CO_2 uptake[b,c,f,h,i,k,l] and acidification[d,g,j]
- Evaluation of climate models[a] and sensor data[m]
- Data gaps addressed through interpolation schemes[d,g,h,i,k,l]
- Ocean CO_2 uptake estimated from SOCAT-based products and models differs by ~0.8 Pg C yr^{-1} for the year 2021[c] (Fig. 3).
- Cited in hundreds of peer-reviewed scientific articles and reports
- Critical policy info from value chain[e] (Fig. 4)
- Key for WMO Global Greenhouse Gas Watch[n], UN Global Stocktake, Decade of Ocean Science and SDGs 13 and 14

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 v2023:** 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:** Eyring et al., 2016[a]; Fay et al., 2021[b]; Friedlingstein et al., 2022[c]; Gregor and Gruber, 2021[d]; Guidi et al., 2020[e]; Hauck et al., 2020[f]; Jiang et al., 2019[g]; Landschützer et al., 2014[h]; Laruelle et al., 2018[i]; Lauvset et al., 2015[j]; Rödenbeck et al., 2014[k], 2015[l]; Williams et al., 2017[m]; https://public.wmo.int/en/media/press-release/world-meteorological-congress-approves-global-greenhouse-gas-watch[n]. **Affiliations:** [1]UEA, UK (d.bakker@uea.ac.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]CIRES, UoC & [12]NOAA-GML, USA; [13]NIES, Japan, [14]CICOES, UW & [15]NOAA-AOML, USA; [16]IOW & [17]GEOMAR, Germany; [18]CSIRO & [19]AAPP. Australia.