

SOCAT version 2021 for quantification of ocean CO₂ uptake

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Abstract – The oceans are taking up a quarter of the global CO₂ (carbon dioxide) emissions from human activity^c. The Surface Ocean CO₂ Atlas (www.socat.info) documents the increase in surface ocean CO₂ for the global oceans and coastal seas. Quantification of the global ocean CO₂ uptake to better than 0.2 Pg C yr⁻¹ requires an accuracy of < 2 μ atm for *in situ* surface ocean *f*CO₂ (fugacity of CO₂) measurements^a. Quality-controlled, synthesis and gridded products in SOCAT version 2021 contain 30.6 million *in situ* surface ocean *f*CO₂ measurements with an estimated accuracy of < 5 μ atm. A further 2.1 million *f*CO₂ values with an accuracy of < 10 μ atm are also available. Data collection has continued during the pandemic, albeit at a reduced rate. SOCAT-based data products are used for quantification of ocean CO₂ uptake and ocean acidification and for evaluation of sensor data and climate models. The community-led SOCAT synthesis products are a key step in the value chain based on *in situ* inorganic carbon measurements of the oceans^d, which provides policy makers in climate negotiations with essential information on ocean CO₂ uptake. Some regional data collection is variable and at risk for lack of longterm funding. The global need for accurate knowledge of ocean CO₂ uptake and its (future) variation makes sustained funding for *in situ* surface ocean CO₂ observations imperative.

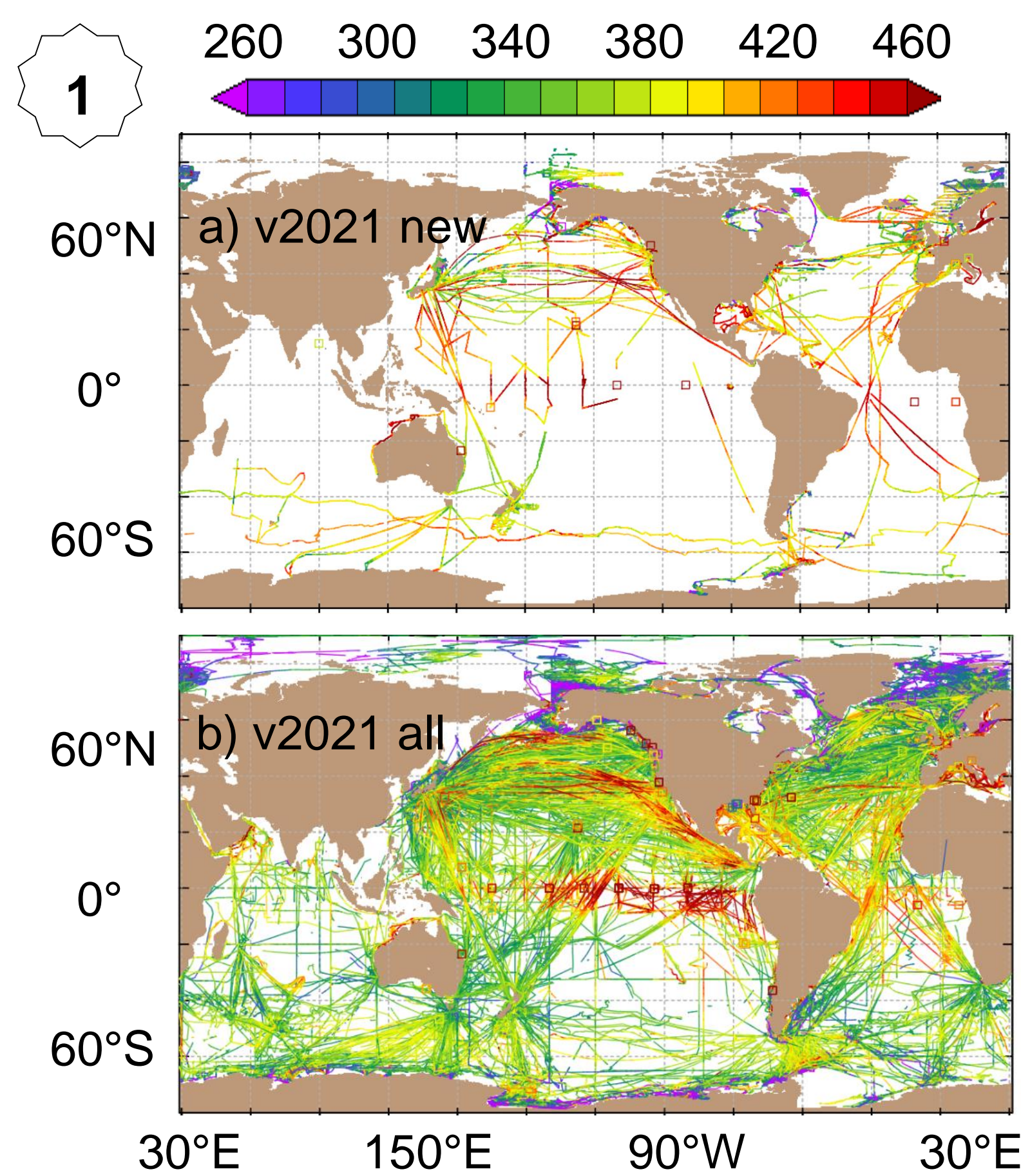


Fig. 1. a) Newly added and b) all *in situ* surface ocean *f*CO₂ values (colour coded, μ atm) with an accuracy of < 10 μ atm in version 2021. Squares indicate moorings.

Fig. 2. Number of surface ocean *f*CO₂ values with an accuracy of < 10 μ atm for years in SOCAT versions 1 to 2021.

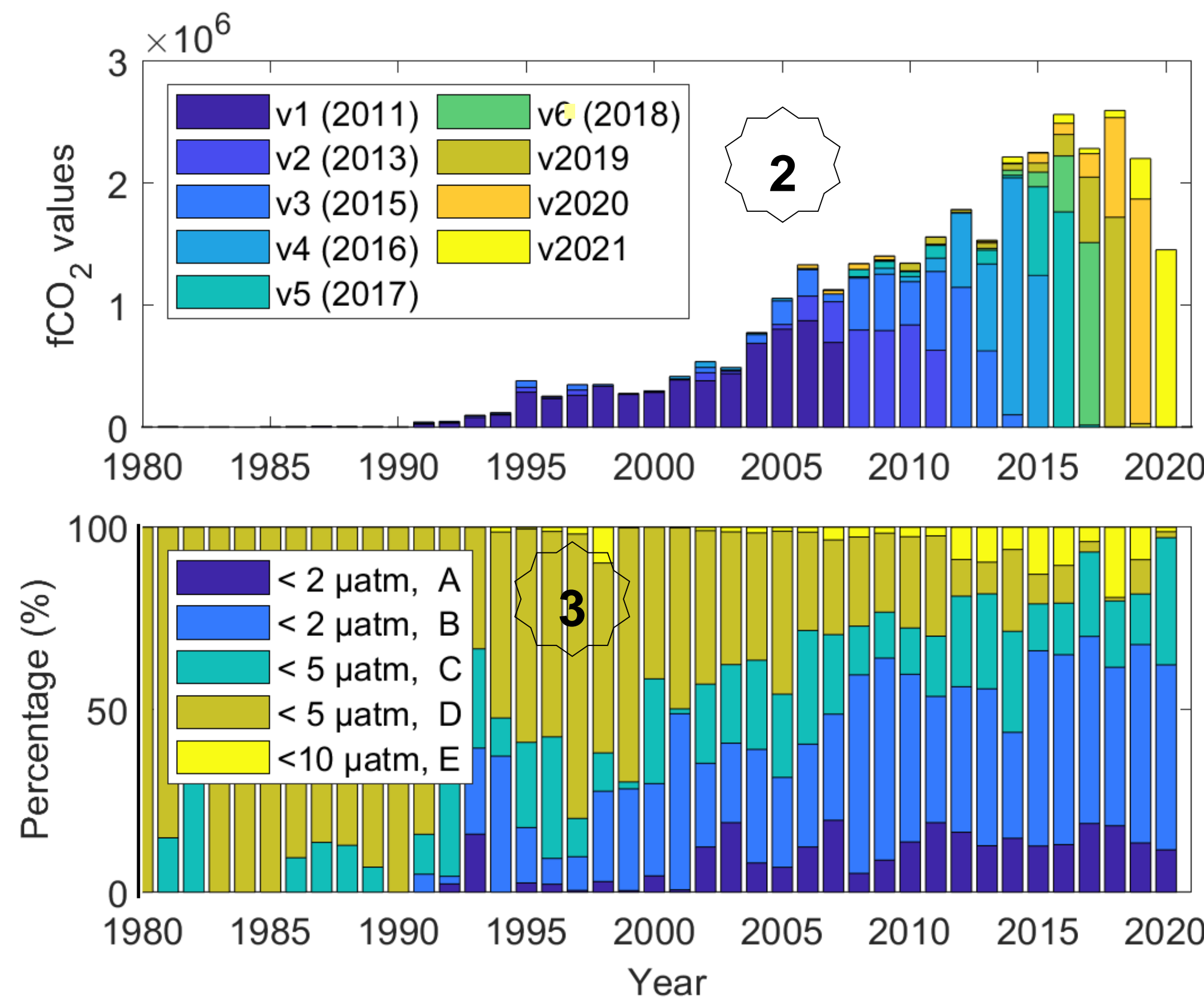
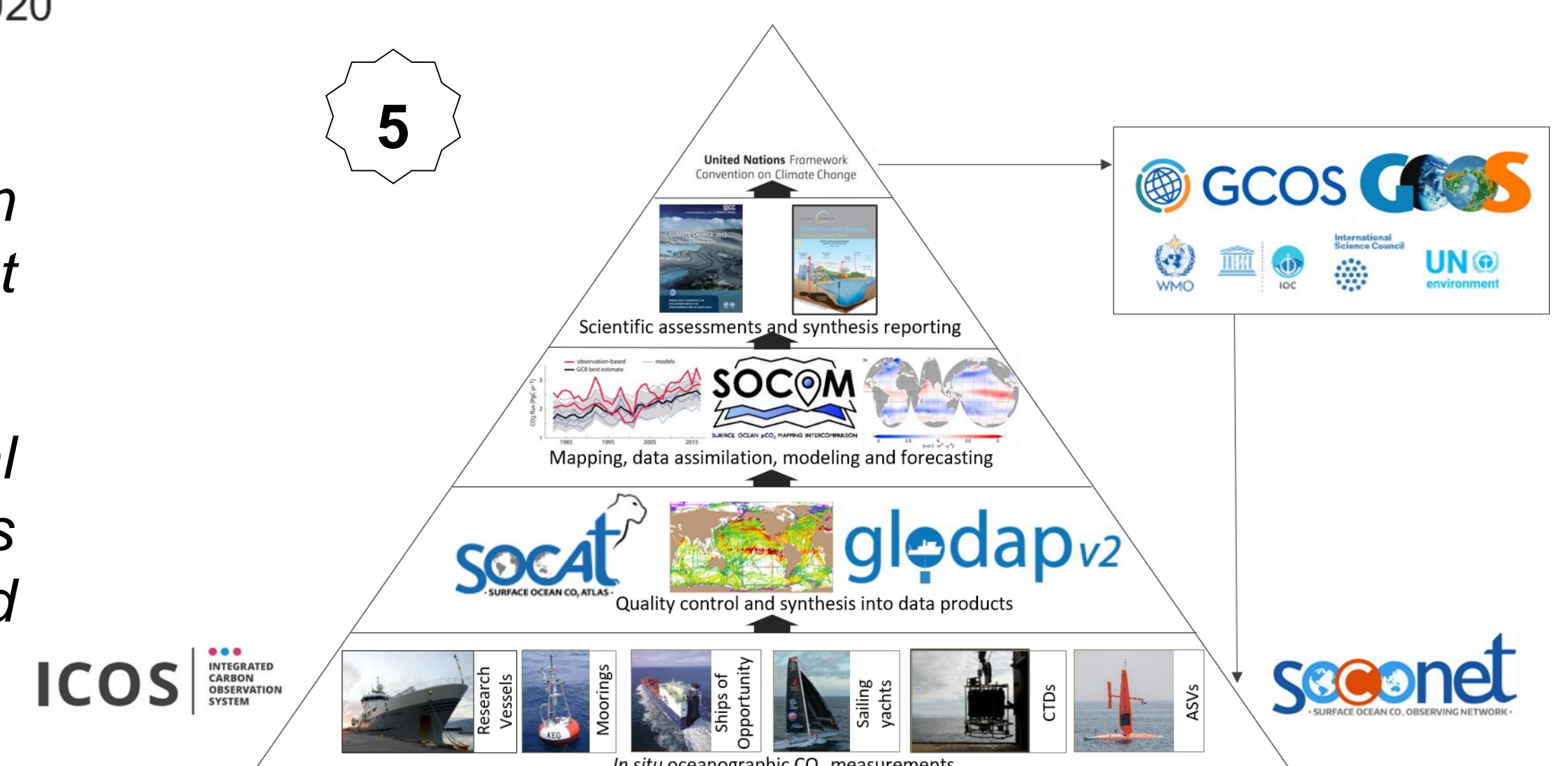
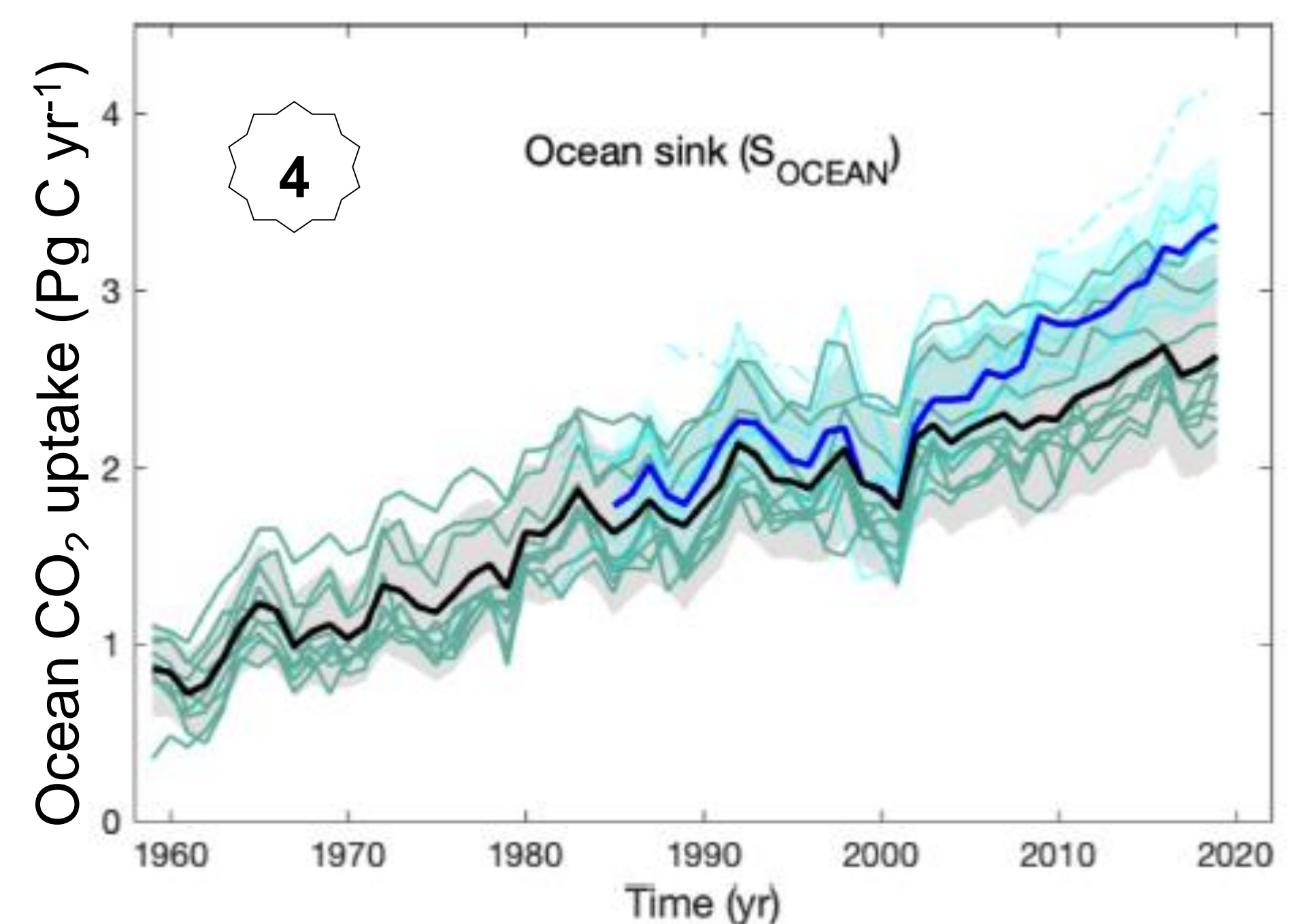


Fig. 3. Percentage of *f*CO₂ values with an accuracy of < 2, 5 and 10 μ atm and data set flags A to E for years in version 2021.

Fig. 4. Ocean CO₂ uptake in the 2020 Global Carbon Budget^c. Cyan and blue (mean) lines for SOCAT-based estimates. Blue-green and black (mean) lines for model results. From^c.

Fig. 5. The value chain based on *in situ* inorganic carbon measurements of the oceans. Modified from^d.



Key features

- Community-led, 'volunteer' data submission and quality control
- Quality-controlled, synthesis and gridded products of *in situ* surface ocean *f*CO₂ measurements on ships, moorings, autonomous and drifting surface platforms for the global oceans and coastal seas from 1957 to 2021
- 30.6 million *f*CO₂ values with an accuracy of < 5 μ atm in main synthesis and gridded products, plus 2.1 million *f*CO₂ values with an accuracy of < 10 μ atm separately available
- Accuracy of *f*CO₂ estimated during quality control
- Limited quality control for sea surface salinity
- Online viewers and data download (www.socat.info)
- Regional data collection at risk for lack of funding
- Data collection during the pandemic, albeit at a reduced rate
- Data submission and quality control for v2022 by 14/01/2022 and 31/03/2022

Scientific findings, applications and impact

- Documents the increase in global surface ocean CO₂^f
- Data gaps in time and space addressed through advanced interpolation schemes^{f,i,j}
- Year-to-year and decadal variation in global ocean CO₂ uptakeⁱ
- Models underestimate variation in ocean CO₂ uptakeⁱ
- Quantification of ocean CO₂ uptake^{c,f,g,i,j} and ocean acidification^{e,h}
- Informs the Global Carbon Budget^c
- Evaluation of sensor data (BGC Argo floats^k, gliders, moorings) and models, incl. CMIP^b
- Used in hundreds of peer-reviewed scientific articles and reports
- Annual public release contributes to UN Sustainable Development Goals (SDG) 13 and 14 (#OceanAction20464) and to the UN Decade of Ocean Science for Sustainable Development

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 v3-v2021:** 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:** Bender et al. 2002, LSCOP^a; Eyring et al., 2016^b; Friedlingstein et al., 2020^c; Guidi et al., 2020, doi:10.5281/zenodo.3755793^d; Jiang et al., 2019^e; Landschützer et al., 2014^f; Laruelle et al., 2018^g; Lauvset et al., 2015^h; Rödenbeck et al., 2014ⁱ, 2015^j; Williams et al., 2017^k. **Affiliations:** ¹UEA, UK (d.bakker@uea.ac.uk); ²NOAA-PMEL, USA; ³UiB & ⁴BCCR, Norway; ⁵Marine Institute, Ireland; ⁶VLIZ, Belgium; ⁷NOAA-NCEI, USA; ⁸NORCE, Norway; ⁹LOCEAN, France; ¹⁰CIRES, UoC & ¹¹NOAA-ESRL, USA; ¹²NIES, Japan; ¹³JISAO, UW, USA; ¹⁵NOAA-AOML & ¹⁶CIMAS, USA; ¹⁷RSMAS, USA; ¹⁸GEOMAR, Germany; ¹⁹CSIRO & ²⁰AAPP, Australia; ²¹SMHI, Sweden.