

26 million *in situ* surface ocean CO₂ observations

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Abstract - The Surface Ocean CO₂ Atlas (SOCAT, www.socat.info) documents the increase in surface ocean CO₂ (carbon dioxide), a critical measure as the oceans are taking up one quarter of the global CO₂ emissions from human activity⁹. SOCAT version 2019 has 25.7 million quality-controlled surface ocean fCO₂ (fugacity of CO₂) observations from 1957 to 2019 for the global oceans and coastal seas. SOCAT enables quantification of the ocean carbon sink and ocean acidification, as well as evaluation of sensor data and ocean biogeochemical models. SOCAT represents a milestone in biogeochemical and climate research. SOCAT informs policy and high-profile climate negotiations. Maintenance and annual updates of the SOCAT product require sustained funding and community involvement.

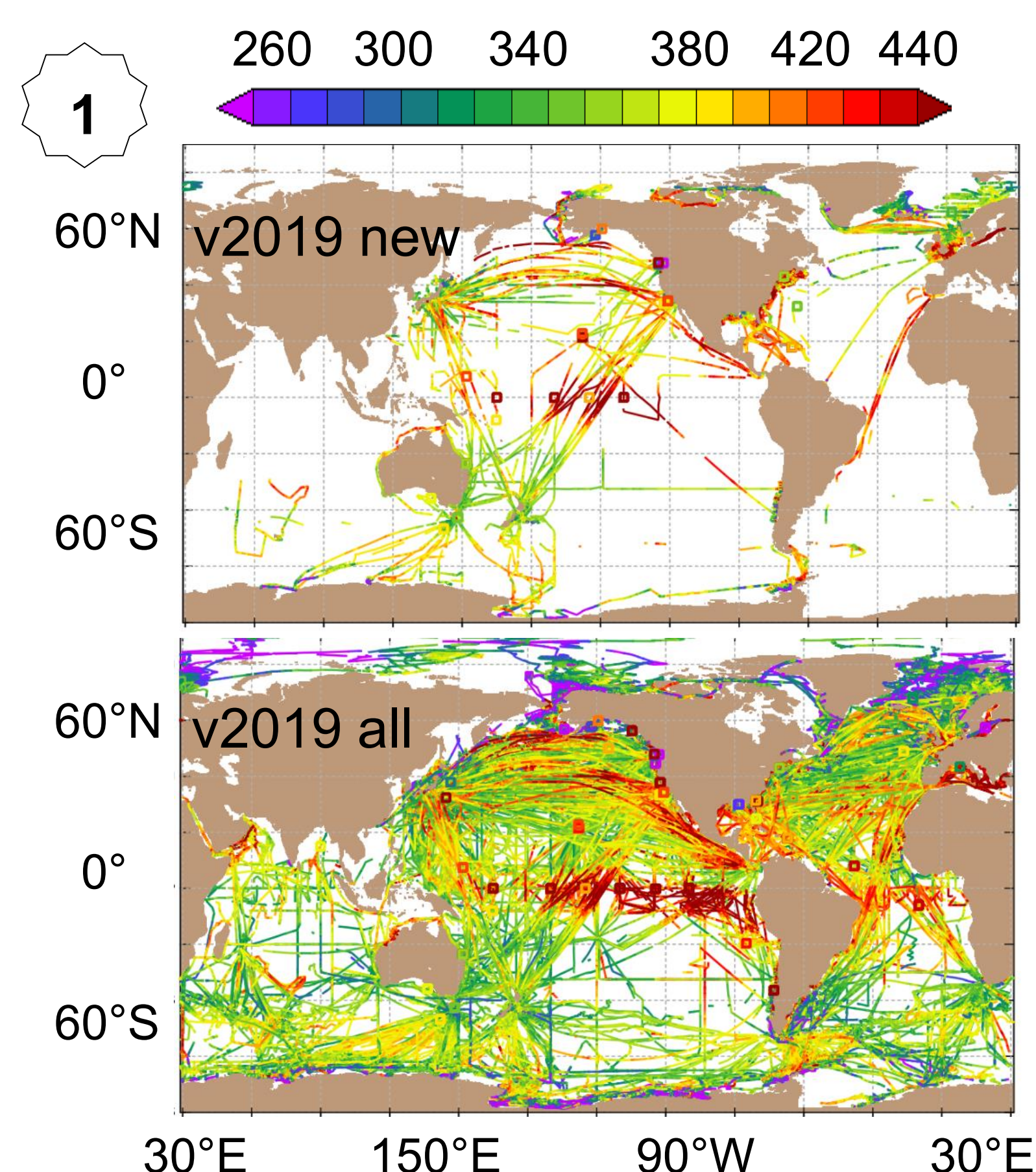


Fig. 1. a) Newly added and b) all *in situ* surface water fCO₂ observations (colour coded, μatm) in version 2019. Squares indicate moorings.

Fig. 2. Number of surface water fCO₂ values per year in SOCAT versions.

Fig. 3. Percentage of fCO₂ values with an estimated accuracy of < 2, 5 and 10 μatm and their data set flags for years in version 2019.

Fig. 4. Anthropogenic ocean carbon uptake in the 2018 Global Carbon Budget⁹ from SOCAT-based mapping^{b,h} (red), models (purple), model ensemble mean (black) and its uncertainty (shading). From^d.

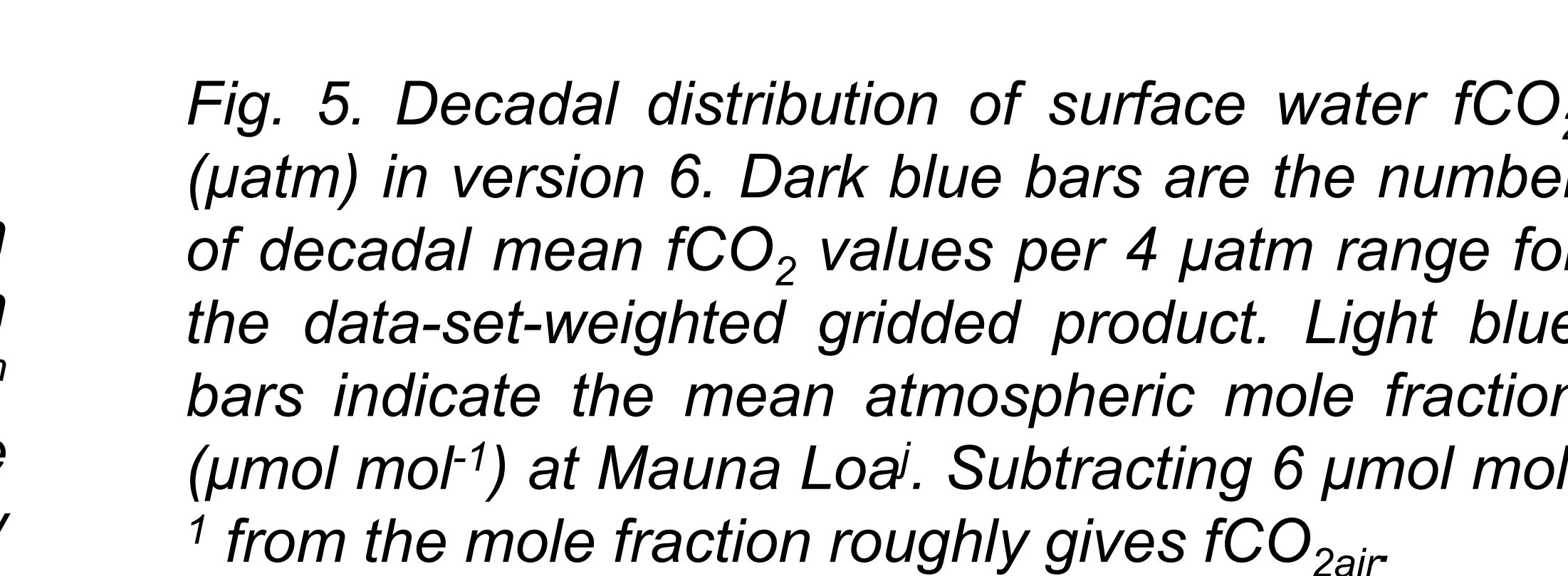
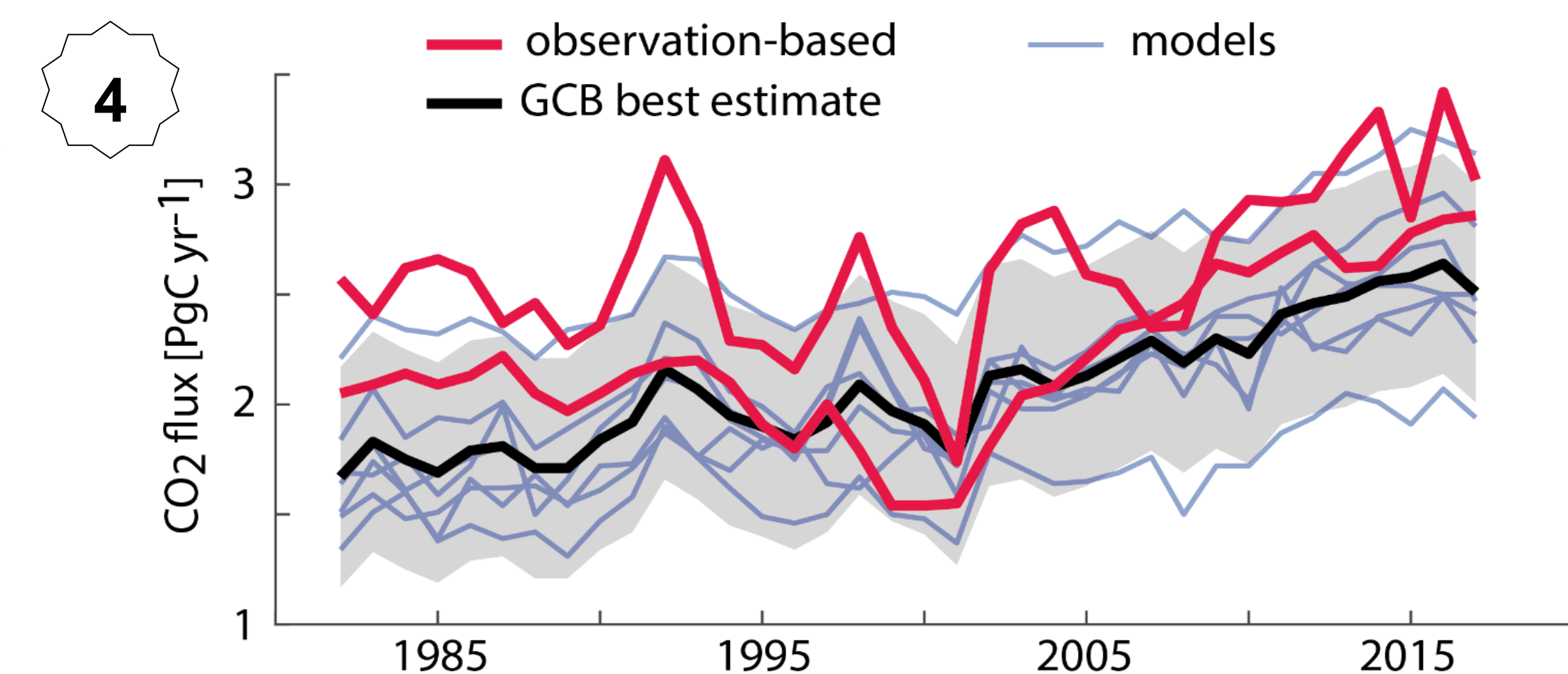
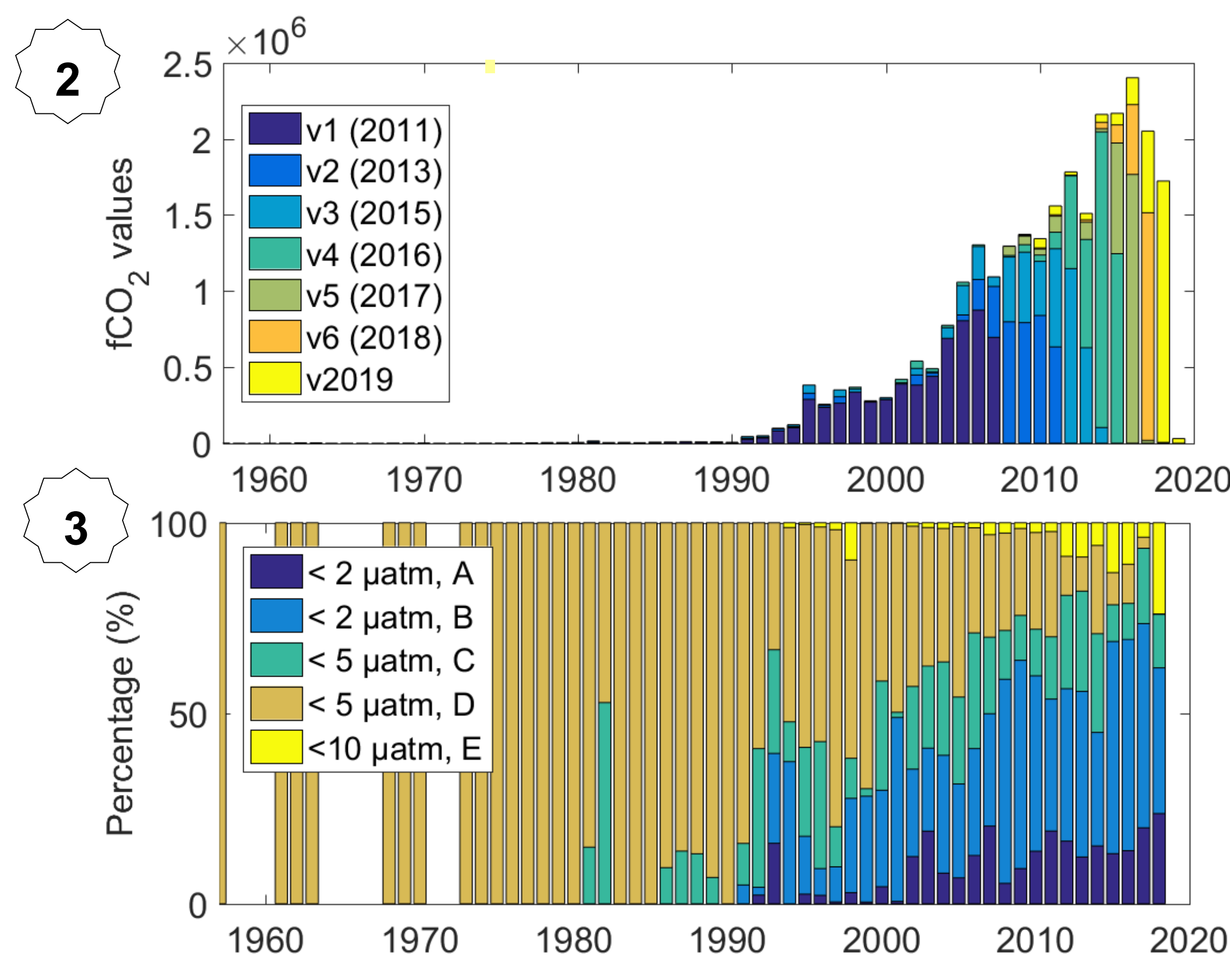
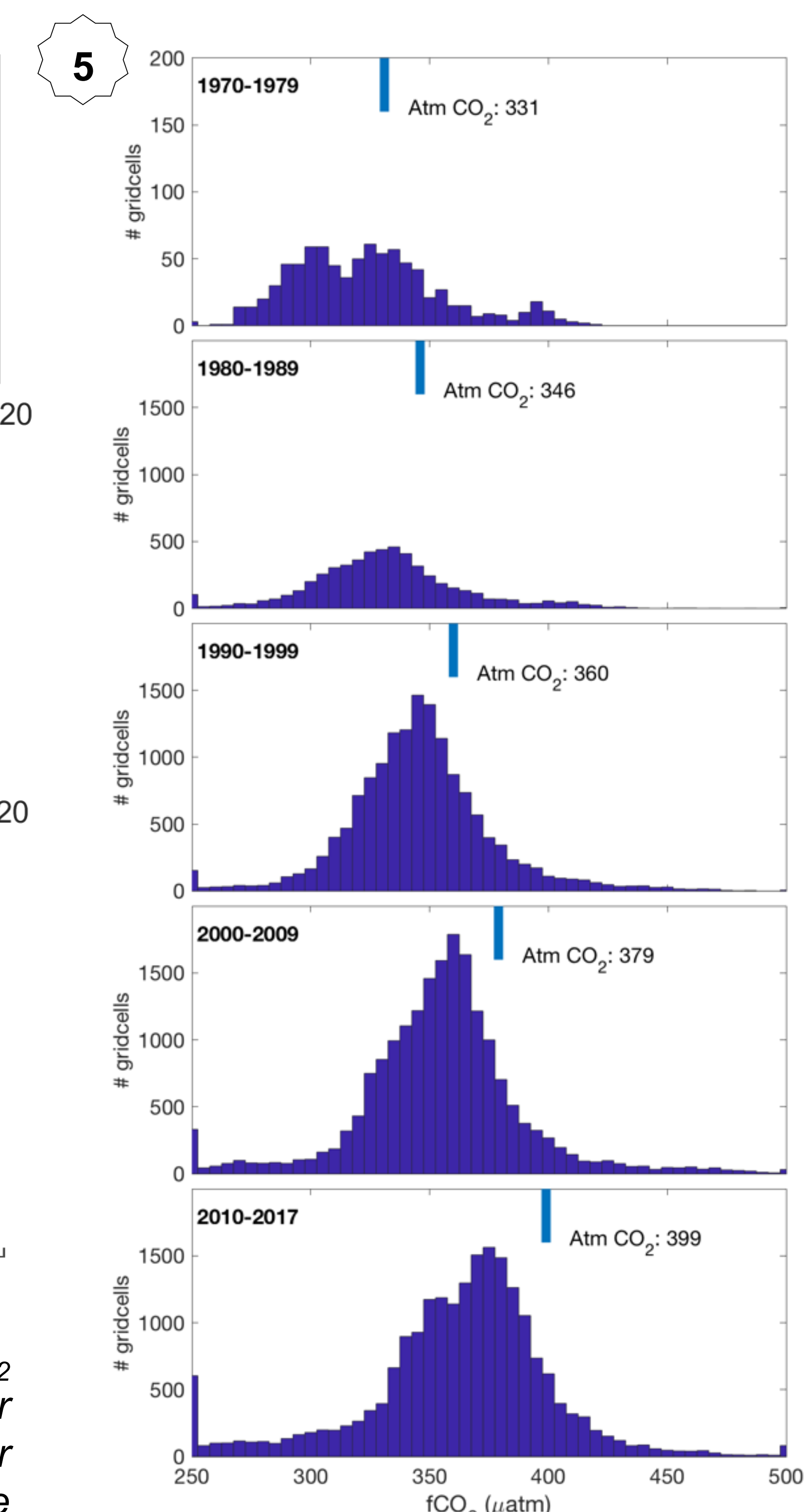


Fig. 5. Decadal distribution of surface water fCO₂ (μatm) in version 6. Dark blue bars are the number of decadal mean fCO₂ values per 4 μatm range for the data-set-weighted gridded product. Light blue bars indicate the mean atmospheric mole fraction (μmol mol⁻¹) at Mauna Loaⁱ. Subtracting 6 μmol mol⁻¹ from the mole fraction roughly gives fCO_{2air}.



Key features

- Community-based 'volunteer' submission and quality control
- Synthesis and gridded, quality controlled products of *in situ* surface ocean fCO₂ measurements from ships, moorings and other platforms for the global oceans and coastal seas:
 - v2019 : 25.7 million fCO₂, 1957-2019,
 - v6 (2018): 23.4 million fCO₂, 1957-2017,
 - v1 (2011): 6.3 million fCO₂, 1968-2007
 with an estimated accuracy of < 5 μatm.
- Plus 1.7 million values with an accuracy of 5 to 10 μatm
- Online viewers and data download (www.socat.info)
- No quality control (QC) for sea surface temperature and salinity
- New contributors welcome
- Data submission for v2020 by 15/01/2020, QC by 31/03/2020

Scientific findings, applications and impact

- Documents the increase in global surface ocean CO₂^{b,c}.
- Data gaps in space and time addressed through advanced interpolation schemes^{b,h,i}.
- Large year-to-year variation in the global ocean carbon sink^{h,i}.
- Models underestimate variation in ocean carbon sink^h.
- Quantification of the ocean carbon sink^{b,h,i}, ocean acidification^f and priors for the land carbon sink^h.
- Informs mapping products^{b,h,i}, the Surface Ocean pCO₂ Mapping Intercomparisonⁱ and the Global Carbon Budget (GCB)⁹, evaluation of sensor data (BGC Argo floats^k, gliders) and models^g, incl. CMIP^a.
- Cited by >260 peer-reviewed scientific articles and >80 reports.
- Annual public releases as a Voluntary Commitment to the 2017 UN Ocean Conference for SDG 14.3 (#OceanAction20464).

Fair Data Use: To generously acknowledge the contribution of SOCAT scientists by invitation to co-authorship, especially for 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-V2019:** 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; Landschützer et al., 2014^b, 2018^c; Landschützer and McKinley, 2019^d; Laruelle et al., 2018^e; Lauvset et al., 2015^f; Le Quéré et al., 2018^g; Rödenbeck et al., 2014^h, 2015ⁱ; Tans and Keeling, 2018^j. Williams et al., 2017^k. **Affiliations:** ¹UEA, UK (d.bakker@uea.ac.uk); ²NORCE, ³UIB and ⁴BCCR, Norway; ⁵NOAA-AOML, USA; ⁶NOAA-PMEL and ⁷JISAO, UW, USA; ⁸NIWA, New Zealand; ⁹NOAA-NCEI, USA; ¹⁰LOCEAN, France; ¹¹NIES, Japan; ¹²CIMAS, ¹³NOAA-ESRL and ¹⁴LDEO, USA; ¹⁵IOCCP, Poland; ¹⁶CSIRO and ¹⁷ACECRC, Australia.