SOCAT version 2019: 26 million *in situ* surface ocean CO_2 observations

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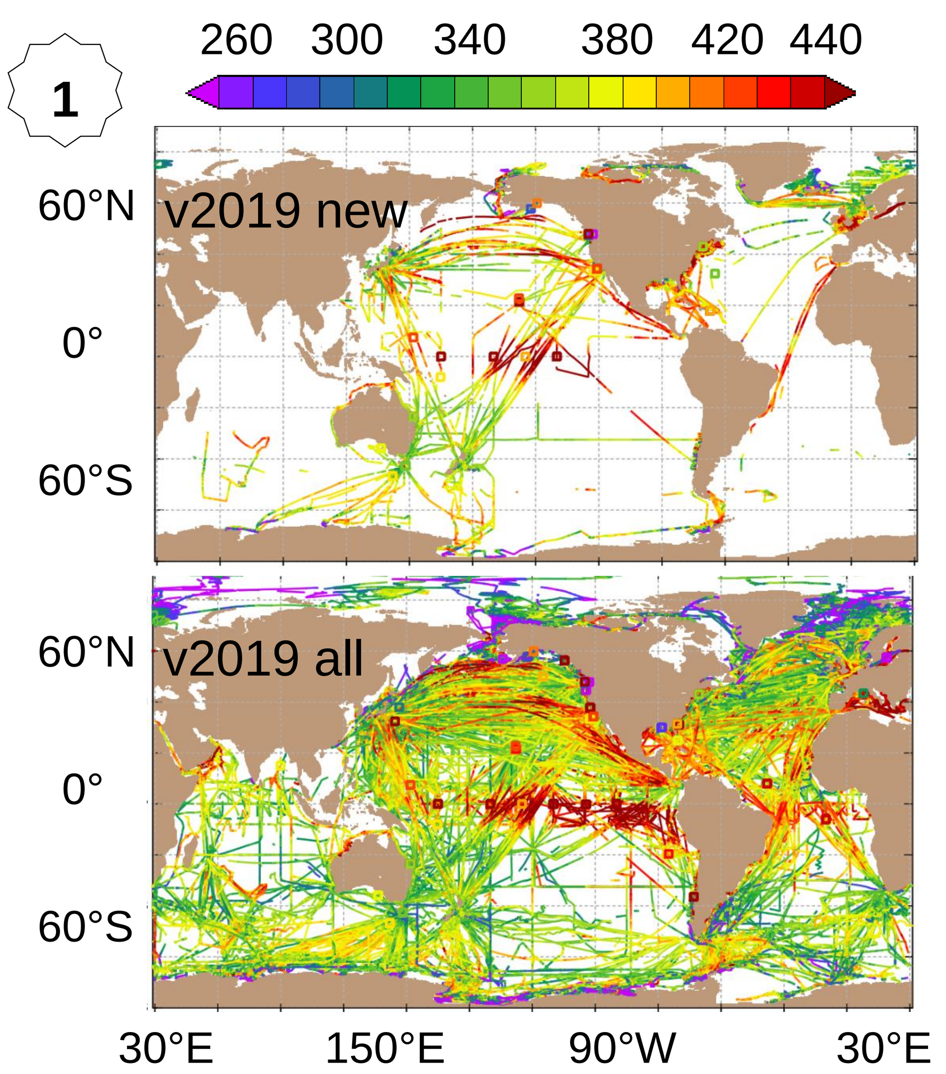
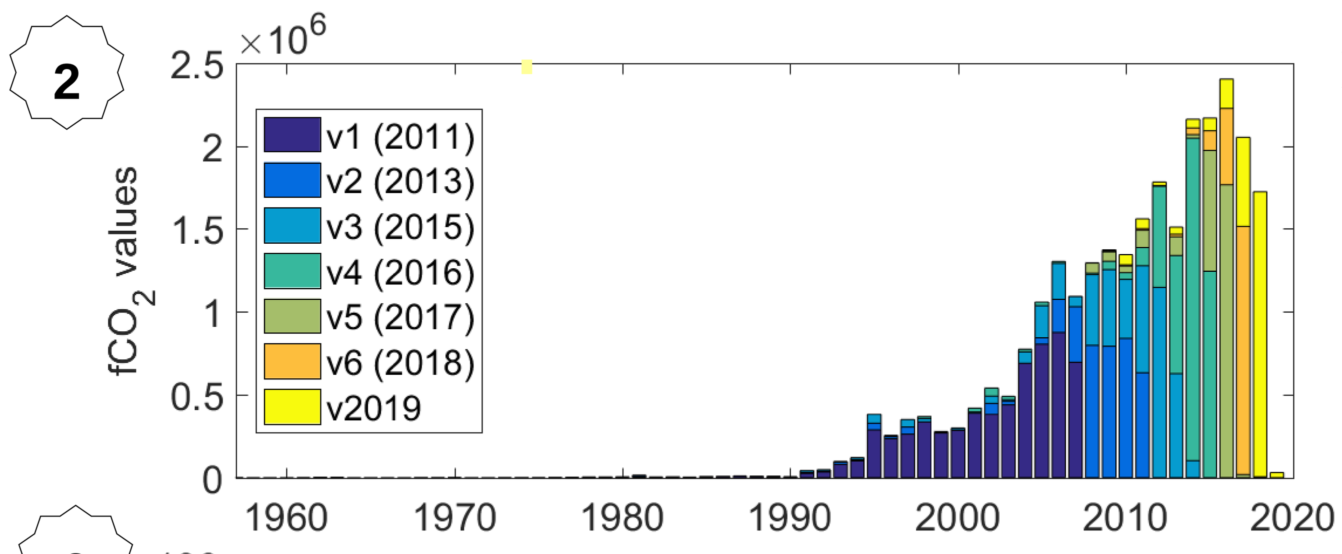
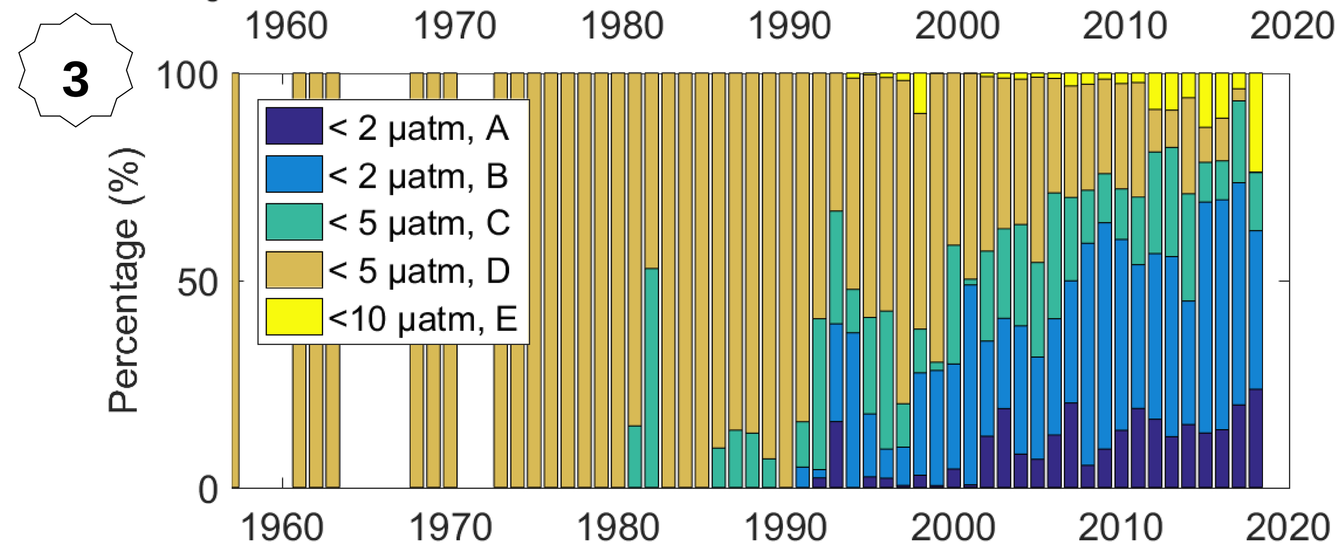
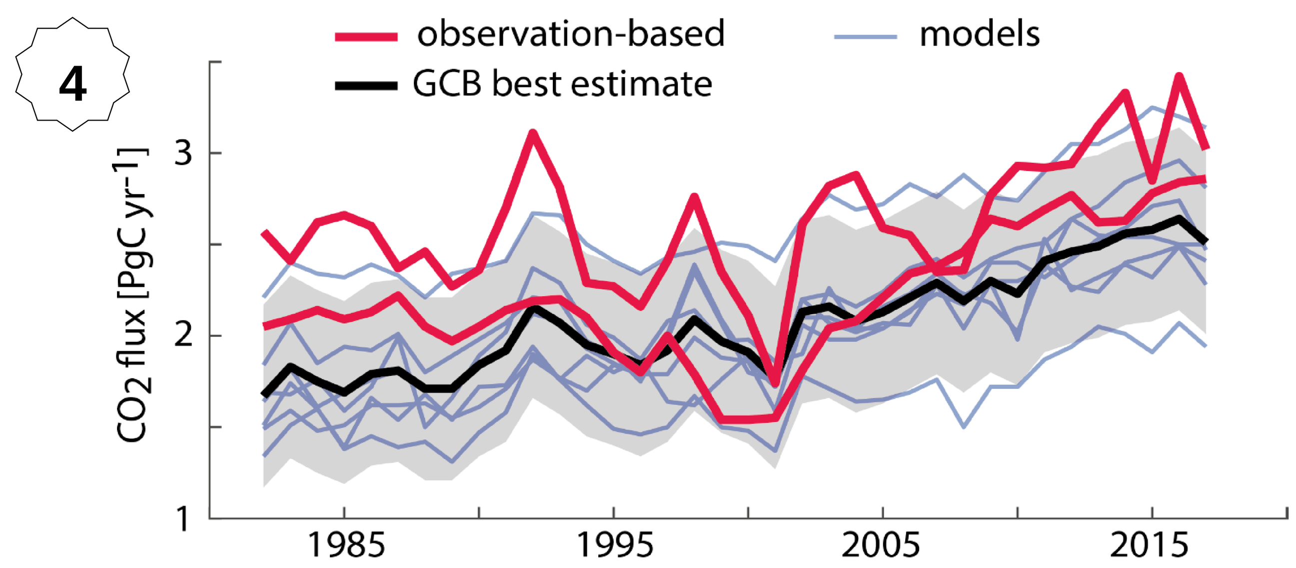
Abstract - The Surface Ocean CO_2 Atlas (SOCAT, **www.socat.info**) documents the increase in surface ocean CO_2 (carbon dioxide), a critical measure as the oceans are taking up one quarter of the global CO_2 emissions from human activity[g]. SOCAT version 2019 has 25.7 million quality-controlled surface ocean fCO_2 (fugacity of CO_2) 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.









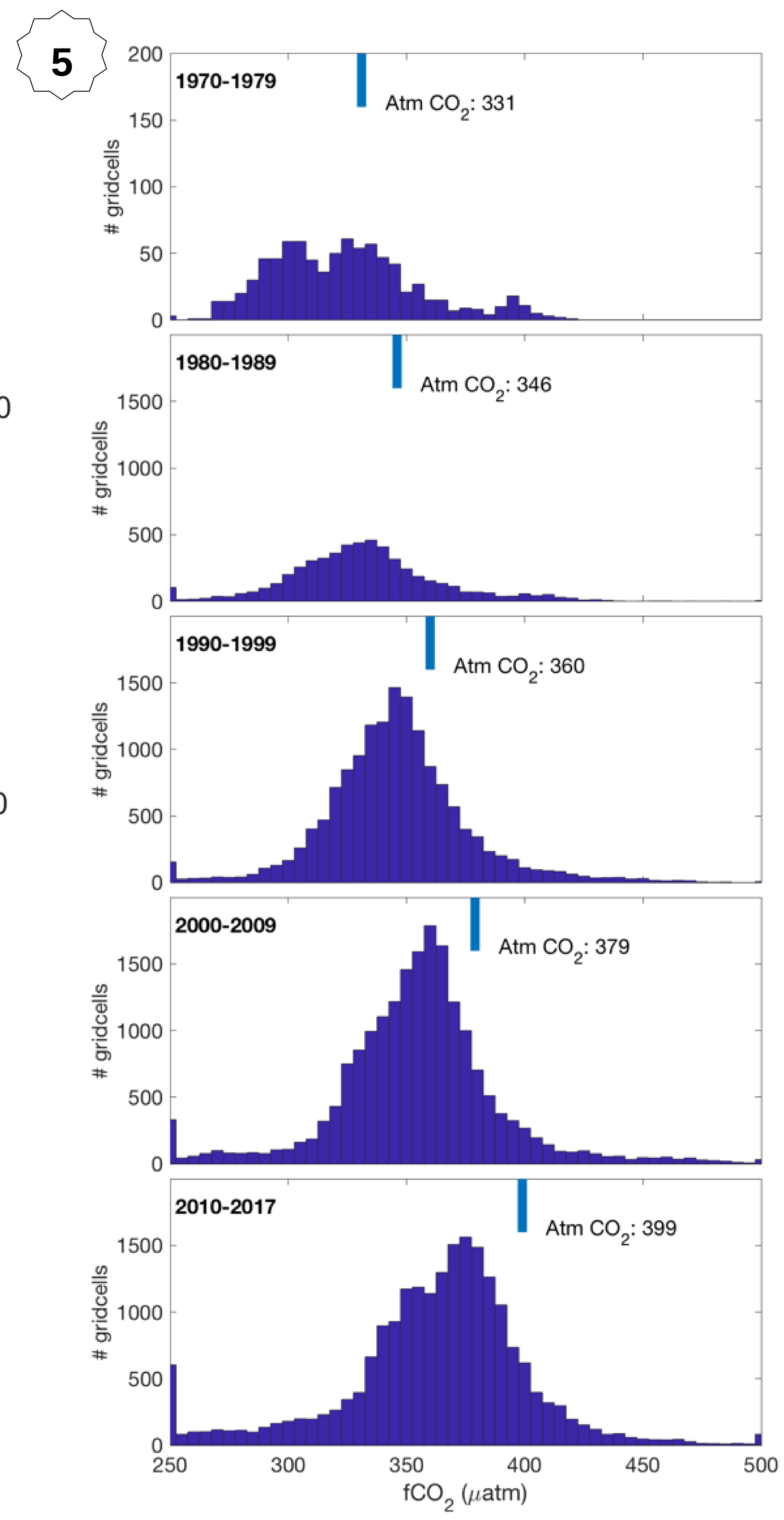


Fig. 1. a) Newly added and b) all in situ surface water fCO_2 observations (colour coded, µatm) in version 2019. Squares indicate moorings.

Fig. 2. Number of surface water fCO_2 values per year in SOCAT versions.

Fig. 3. Percentage of fCO_2 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 Budget[g] 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 fCO_2 (µatm) in version 6. Dark blue bars are the number of decadal mean fCO_2 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 Loa[j]. 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 fCO_2 measurements from ships, moorings and other platforms for the global oceans and coastal seas:
  v2019 : 25.7 million fCO_2, 1957-2019,
  v6 (2018): 23.4 million fCO_2, 1957-2017,
  v1 (2011): 6.3 million fCO_2, 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 CO_2[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 pCO_2 Mapping Intercomparison[i] and the Global Carbon Budget (GCP)[g], 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 for 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], 2015[i]; Tans and Keeling, 2018[j]. Williams et al., 2017[k]. **Affiliations:** [1]UEA, UK (**d.bakker@uea.ac.uk**); [2]NORCE, [3]UiB and [4]BCCR, Norway; [5]NOAA-AOML, USA; [6]NOAA-PMEL and [7]JISAO, UW, USA; [8]NIWA, New Zealand; [9]NOAA-NCEI, USA; [10]LOCEAN, France; [11]NIES, Japan; [12]CIMAS, [13]NOAA-ESRL and [14]LDEO, USA; [15]IOCCP, Poland, [16]CSIRO and [17]ACECRC, Australia.