Observed amplification of the seasonal CO_2 cycle at the Southern Ocean Time Series

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The IMOS Southern Ocean Time Series (SOTS) makes autonomous, multi-trophic observations of air-sea CO_2 exchange, biological production, and carbon export in the Subantarctic Southern Ocean. The data shown here were collected with the Southern Ocean Flux Station (SOFS) mooring between 2011 and 2021.

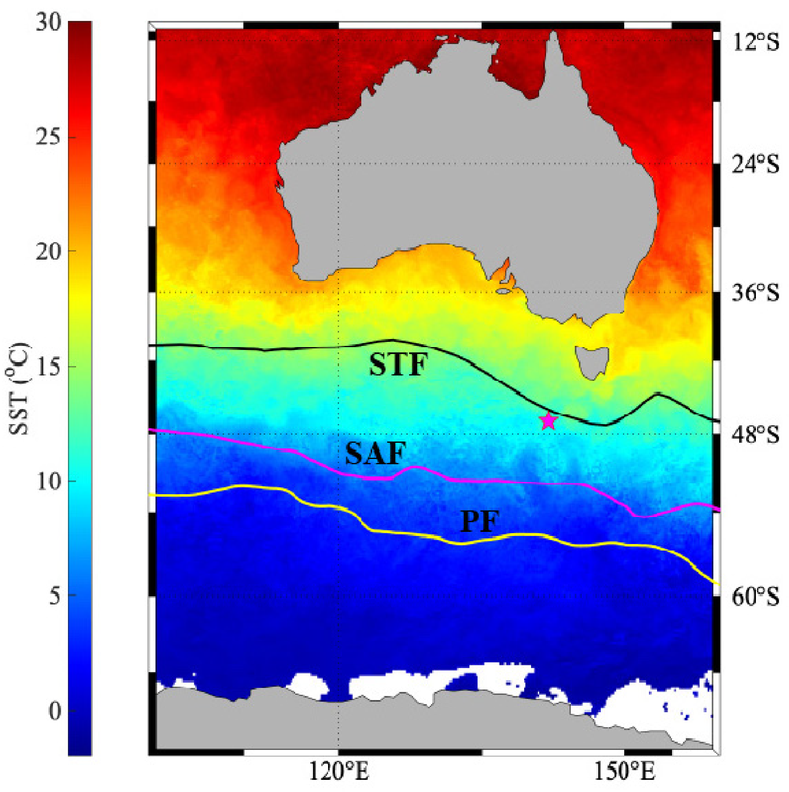

Figure 1. The IMOS SOTS site is located in the Subantarctic Zone, between the Subtropical (STF) and Subantarctic (SAF) fronts.

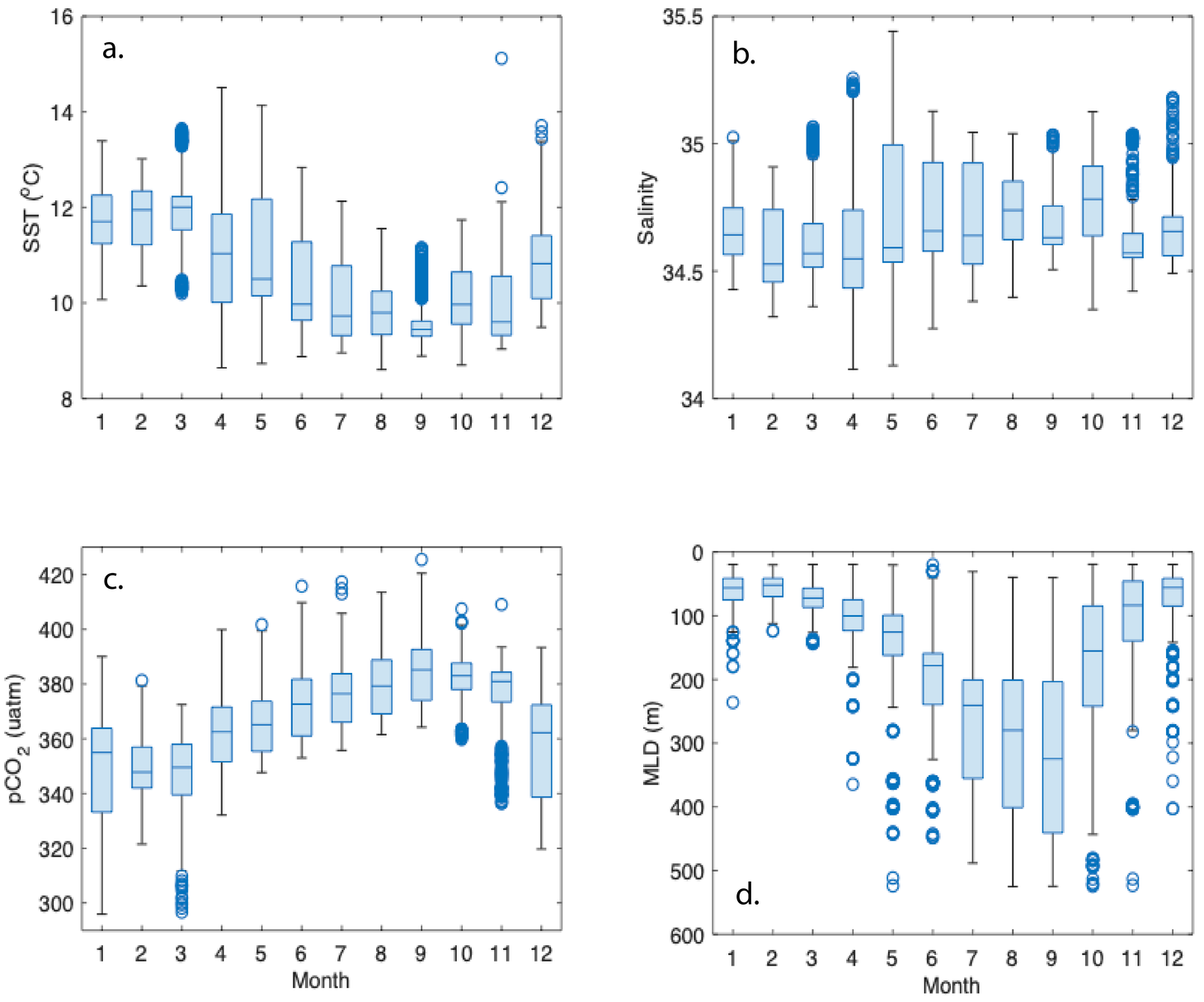

Figure 2. A decade of observations at SOTS has yeilded a robust understanding of seasonality. (a) sea surface temperature (SST) indicates a weak seasonality, with mean summer SST of 12°C, and mean winter SST of ~10°C. (b) sea surface salinity is stable throughout the year; variability is likely driven by frontal movements and mesoscale features. (c) the CO_2 partial pressure (pCO_2) seasonality is controled by both physical (warming, freshening, gas exchange) and biological (photosynthesis) processes; biological production reduces pCO_2 in spring/summer, return to atmospheric equilibrium in autumn and winter is facilitated by deep mixing. (d) mixed layer depth (MLD) is computed from an array for temperature sensors; deep mixing (~400-500m) is associated with the formation of Subantarctic Mode water, which contributes to the uptake and storage of anthropogenic CO_2.

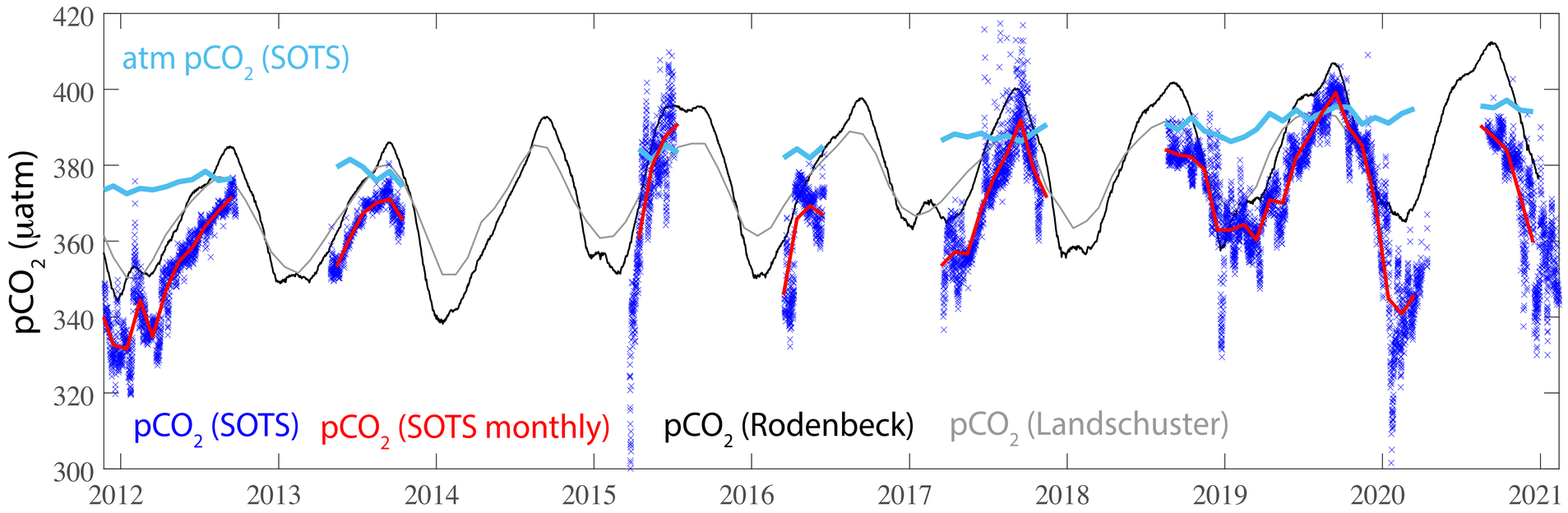

Figure 3. Surface ocean pCO_2 in the Subantarctic is increasing faster than the atmosphere; oceanic forcing dominates decadal change. Observations collected between 2011 and 2021 (3-hourly data in dark blue, monthly averages in red) reveal seasonal ranges from roughly 300 µatm at the height of the productive season (occuring between late December and mid-January) to more than 400µatm in winter. Brief periods of winter outgassing have been observed, but do not occur in all years. The change in mean winter (JJA) pCO_2 at SOTS indicates a trend of 3.1 µatm/yr, which is larger than the change in atmospheric CO_2 (2.3 µatm/ year; monthly averages in pale blue). The SOTS data also reveal an amplification of the seasonal cycle, seen in particular via comparison to two global time series products (black solid and gray dashed line) at the site. While gaps in the data make assessment of trends difficult, there are indications of shoaling summer and deepening winter mixed layers, as well as increases in net primary production, consistent with the enhanced seasonality in pCO_2.

References: Landschützer, P., et al Biogeosciences, 2022; Rödenbeck, C., et al. Ocean Sci., 9, 2013.

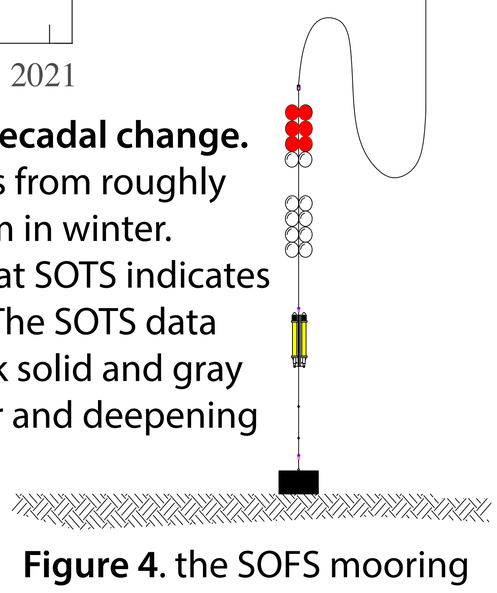

Figure 4. the SOFS mooring

IMOS Integrated Marine Observing System

Australian Government Bureau of Meteorology

CSIRO

AAPP Australian Antarctic Program Partnership

PMEL

SOOS Southern Ocean Observing System