The Southern Ocean surprise: how rare data recalibrated the global ocean carbon sink

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Motivation

Observation-based products estimate global air–sea CO_2 fluxes by extrapolating sparse fCO_2 measurements. Each year, product creators update their products using the newly released SOCAT fCO_2 database, essentially extending their analysis for another year. These products get contributed to the Global Carbon Budget report.

Our 2024 updated LDEO products deviated from the previous year's reconstruction; the new estimate showed a significantly lower ocean carbon uptake. Here we assess the sensitivity of reconstructed surface ocean fCO_2 to newly added observations in SOCATv2024. We compare reconstructions based on SOCATv2023 and SOCATv2024 and further evaluate impacts using a CMIP6 Earth system model testbed.

Model Testbed confirms higher accuracy with additional data

Simulations using a CMIP6 model ensemble testbed (not shown) conclude that the increased sampling in the Southern Ocean in the SOCATv2024 database leads to a more reliable ocean sink estimate if data are unbiased.

Read the paper now at GRL! Fay et al. 2025

SOCATv2024 reduces the ocean sink

Using SOCATv2024, both LDEO products predict a substantial reduction in the ocean carbon sink as compared to previous estimate using SOCATv2023. The impact is a decline of 0.26 PgC yr^{-1} in the 2018-2022 global ocean carbon sink (Figure 1).

Southern Ocean is the epicenter of change

The global shift in uptake is almost entirely driven by new data from this region. Specifically, a few additional cruises in the Atlantic sector of the Southern Ocean results in higher fCO_2 reconstructions, leading to lower fluxes (Figure 2).

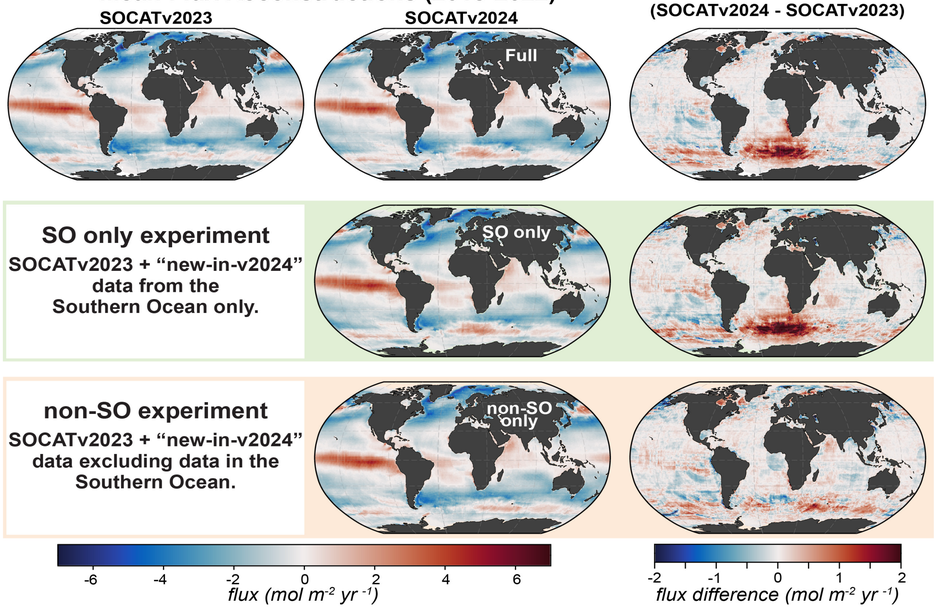

Figure 2. Reconstructions of mean flux (2018-2022) using different subsets of input data. Right hand column shows difference between SOCATv2023 and various SOCATv2024 reconstructions (Full, SO only and non-SO only).

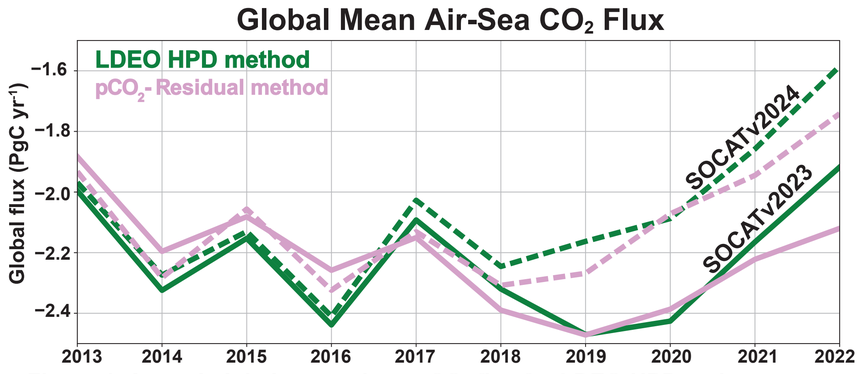

Figure 1. Annual global mean air-sea CO_2 flux for LDEO-HPD and pCO_2-Residual methods using SOCATv2023 (solid) and SOCATv2024 (dashed)

A few observations = a huge impact

About 2500 new observations in the data-sparse Southern Ocean caused a significant revision of the global sink estimate (Figure 3).

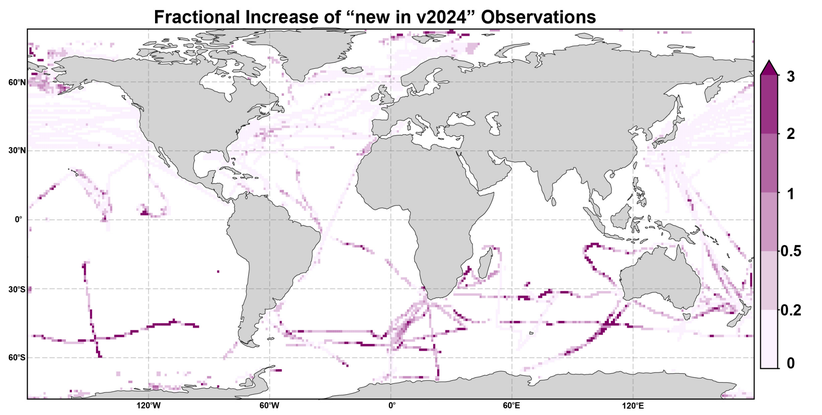

Figure 3. Spatial distribution of the fractional increase of "new-in-v2024" fCO_2 data. Fractional increase is calculated for each 1° × 1° grid cell as the number of "new-in-v2024" observations divided by the number of observations in SOCATv2023. If no data is available in SOCATv2023 (i.e., a denominator of 0), we divide by 0.001 so as to obtain a fractional increase value in that location.

TAKE-HOME MESSAGE

Global ocean carbon sink estimates are highly sensitive to a small number of observations in poorly sampled regions. In the Southern Ocean, rare but unbiased measurements can substantially shift global CO_2 uptake estimates and improve reconstruction fidelity.