Southern Ocean carbon processes and budgets: notes from SOCCOM3 Annual Meeting June 2025

Slides from Seth Bushinsky, Guillaume Liniger, Jade Sauve, Ken Johnson, Magdalena Carranza

Lynne Talley July 22, 2025 US CLIVAR Summit

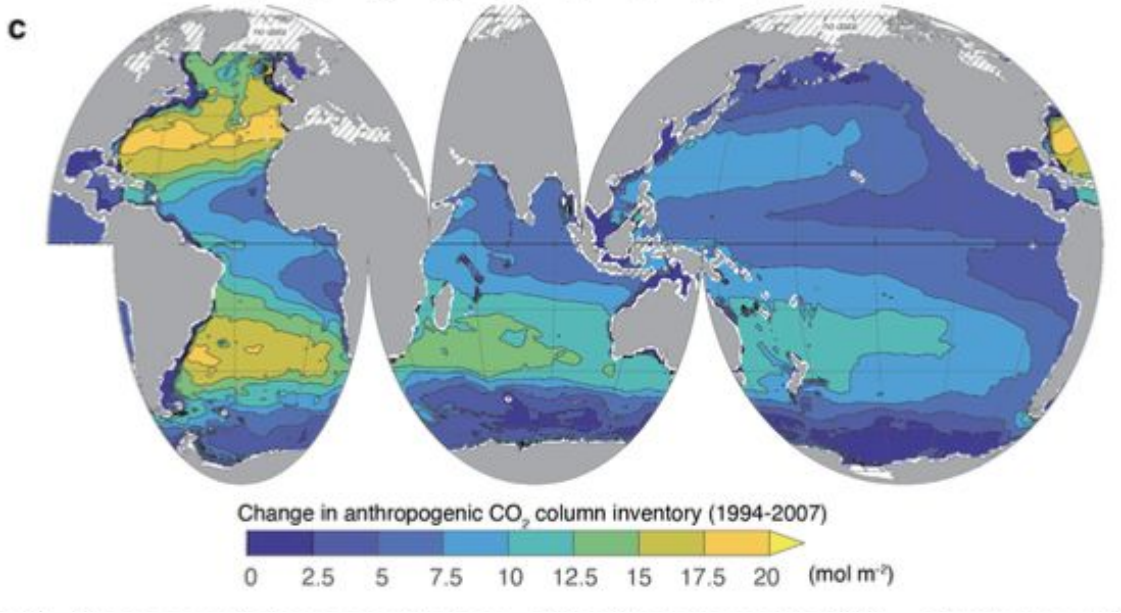
NSF OPP funded program 2014 - present

Biogeochemical Argo in Southern Ocean since 2014

SOCCOM BGC Argo sensors and derived carbon parameters

SOCCOM objective: Coupled climate model and climate prediction improvement through focus on Southern Ocean and carbon with

1. circumpolar and under-ice observations that resolve the annual cycle in all Southern Ocean regimes: BGC Argo
2. state estimation to combine models and observations
3. model metrics/experiments



Anthropogenic Carbon (full ocean depth)

Gruber et al. (Nature, 2023)

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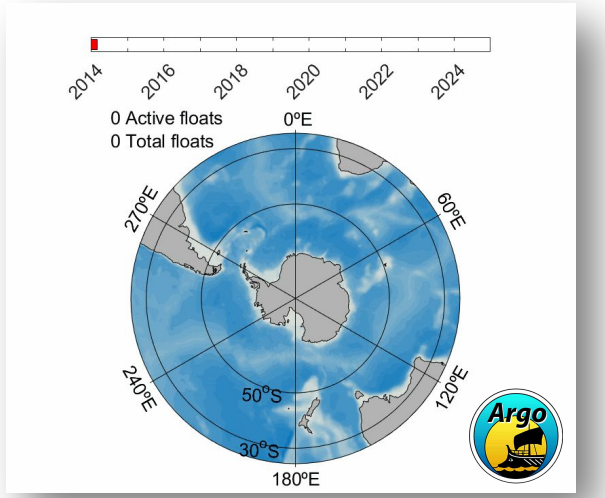

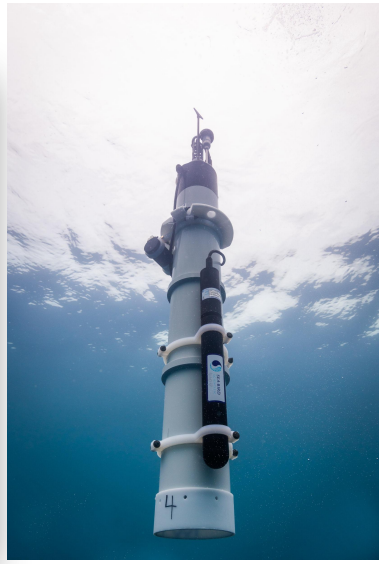

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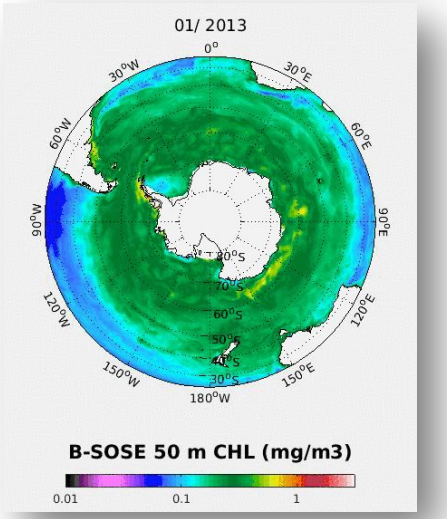
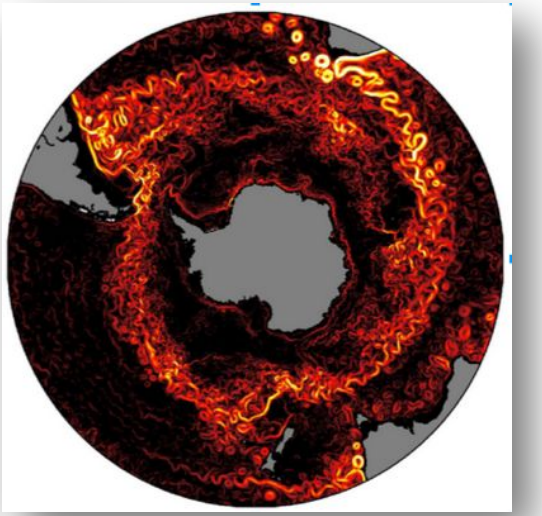
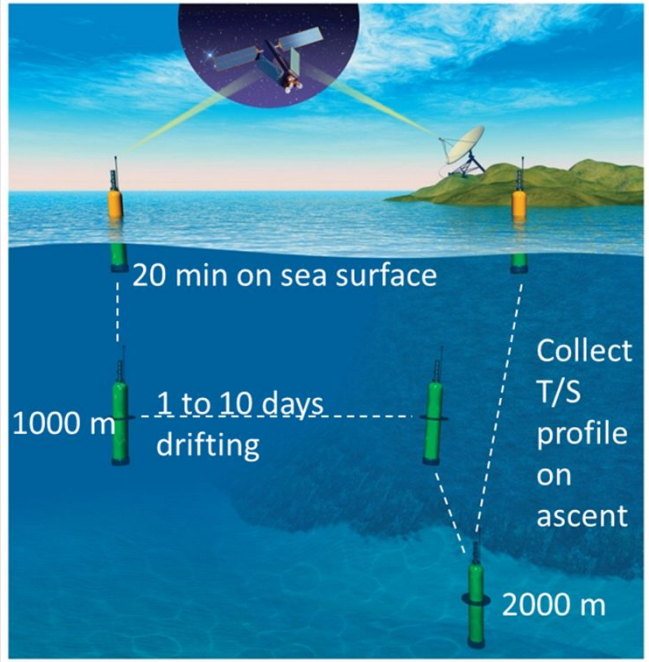




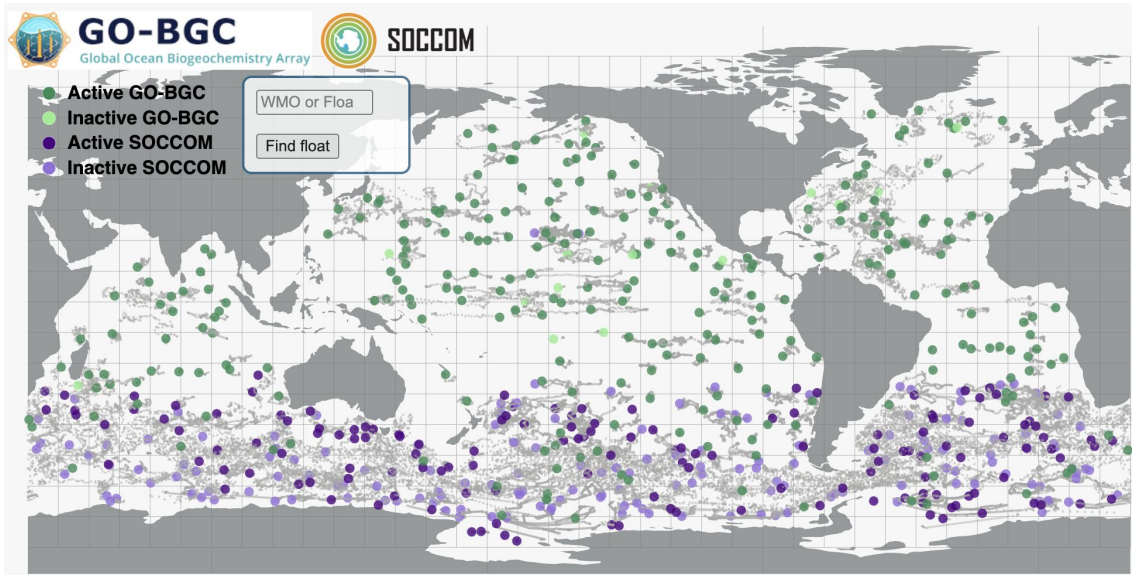
SOCCOM Argo profiling floats with BGC sensors



- **Oxygen, nitrate, pH, fluorescence, backscatter, (downwelling irradiance) + T/S/p**
- Enough batteries for ~200 to 250 cycles from ~2000 m to surface
- ~6 year life at 1 cycle/10 days
- All data available on the internet within 24 hours without restriction

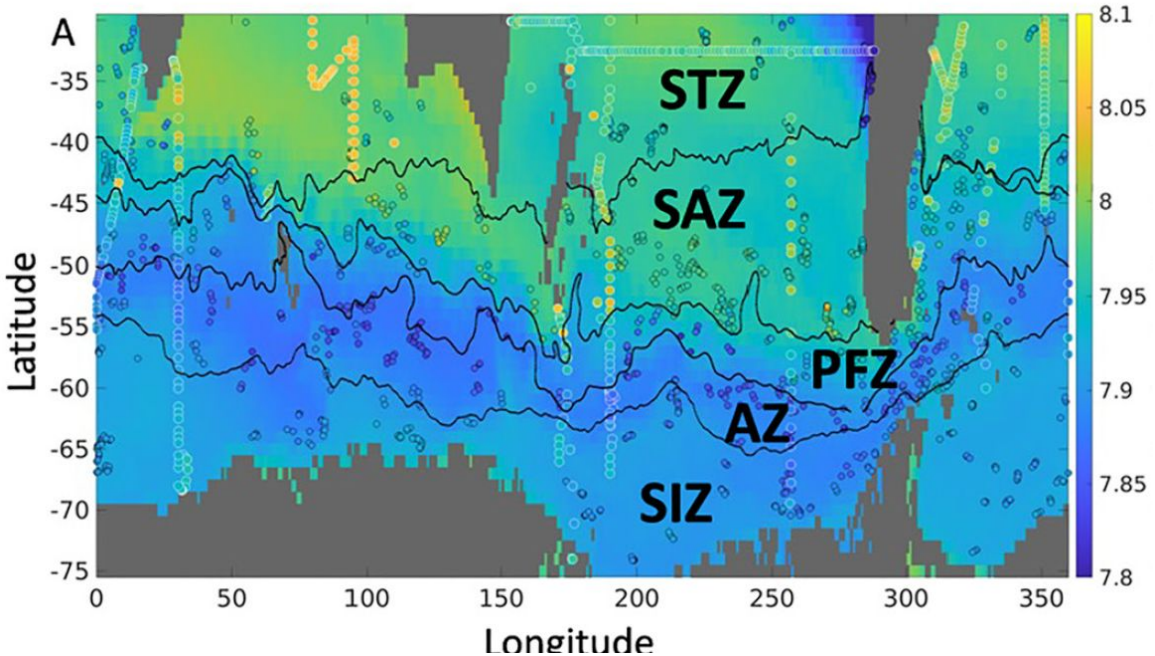
Derived parameters

- Chlorophyll
- POC
- Alkalinity
- DIC
- pCO2

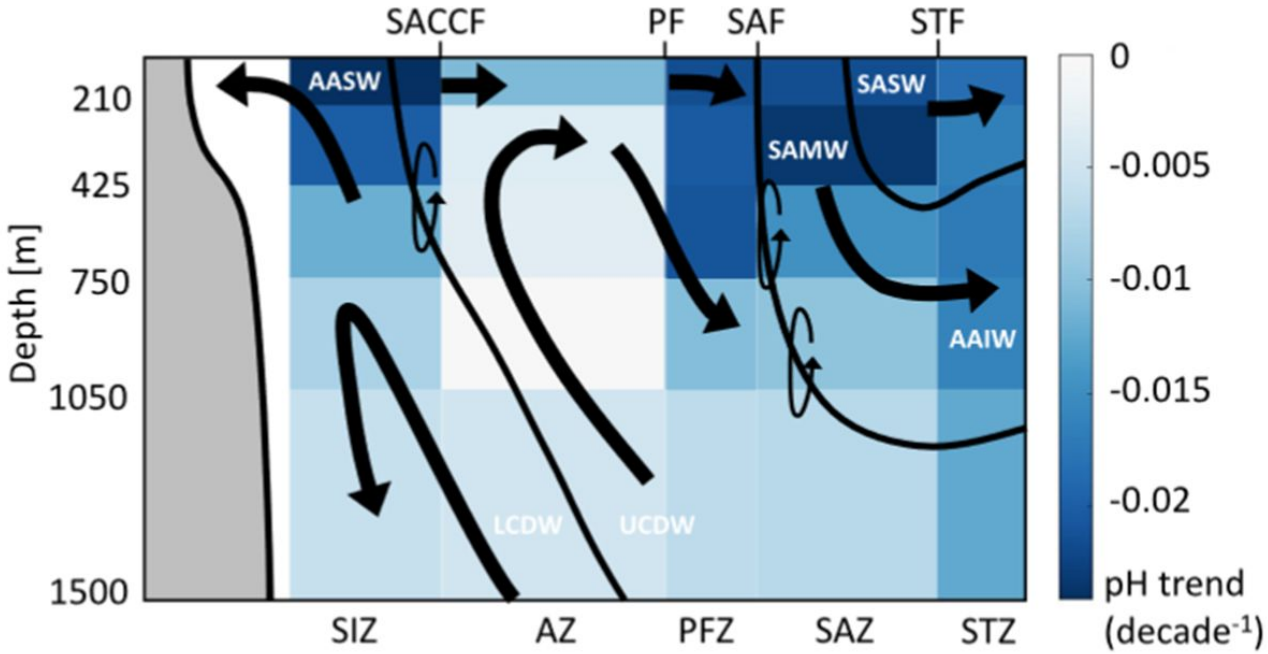


Southern Ocean acidification from SOCCOM floats
Mazloff et al. (JGR, 2023)

The summer mapped (float + ship) pH field



Rates of zonally-averaged pH change (pH/decade) in each zone with overturning circulation overlaid.

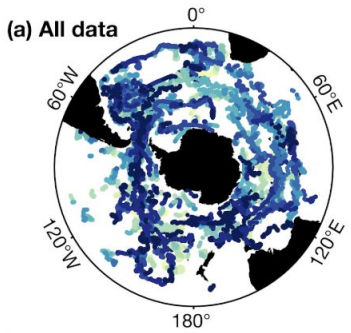


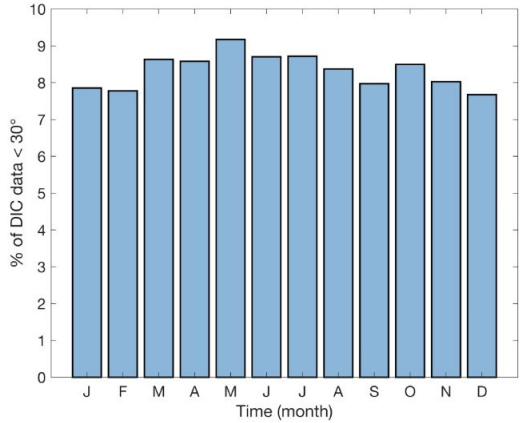
SOCCOM

DIC increases observed using 10 years of SOCCOM mapped float data, using Sharp's machine learning approach with gridded Argo T/S, attributed to anthropogenic sources

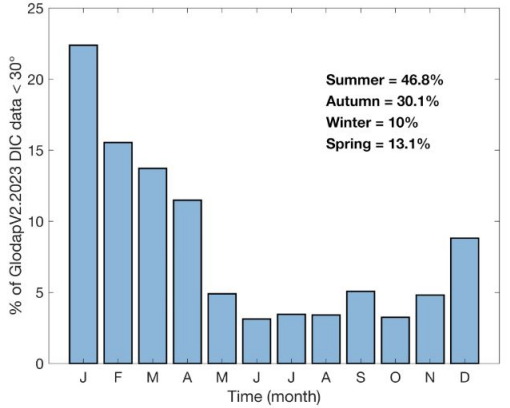
Liniger, Johnson, Sharp, et al. (in prep.)

Background and Motivation





Floats



Glodap

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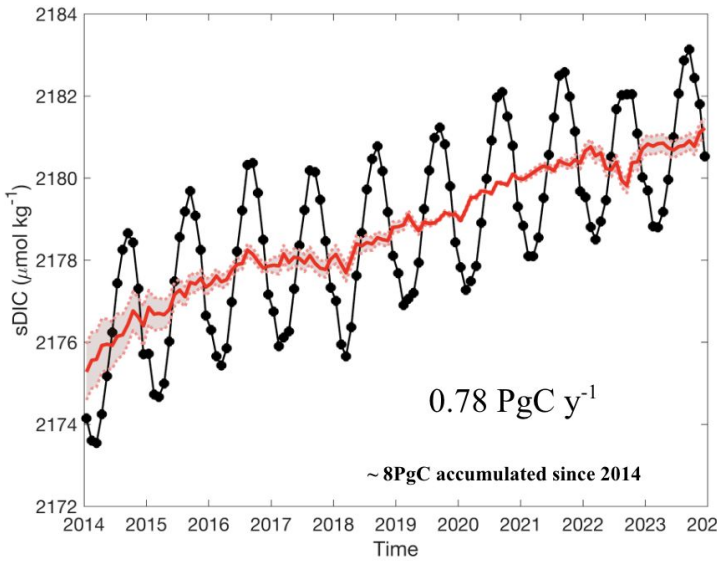

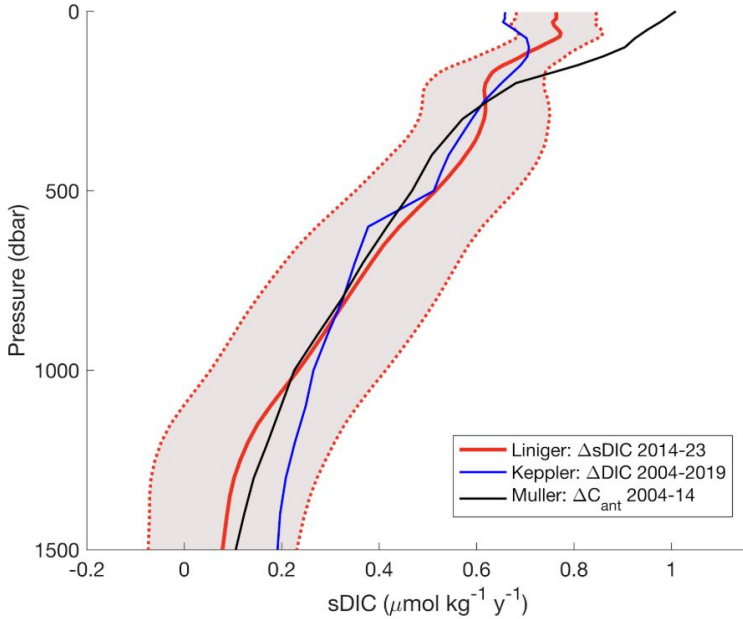

Monthly mapped DIC
Spatially-averaged

Compared with previous products

SOCCOM

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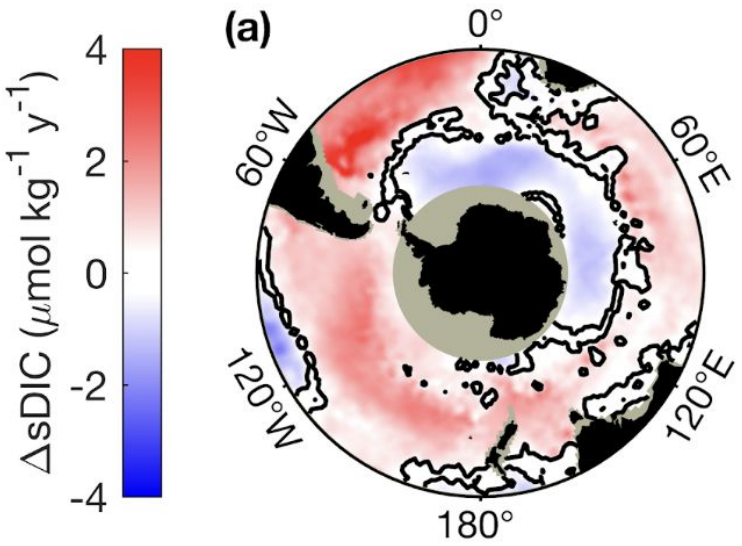
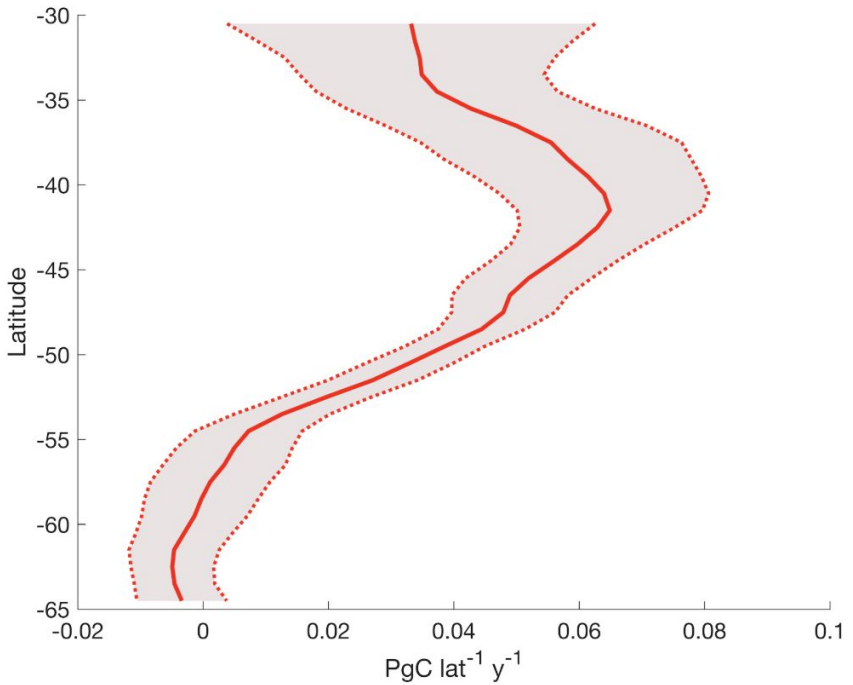
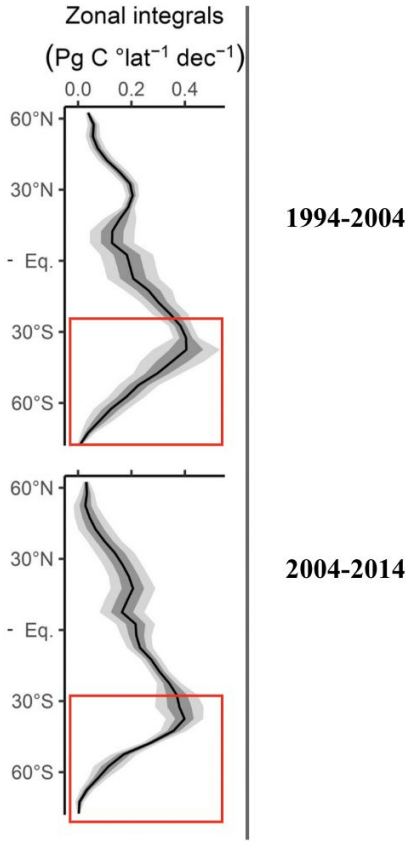


Spatial structure of trend

Results



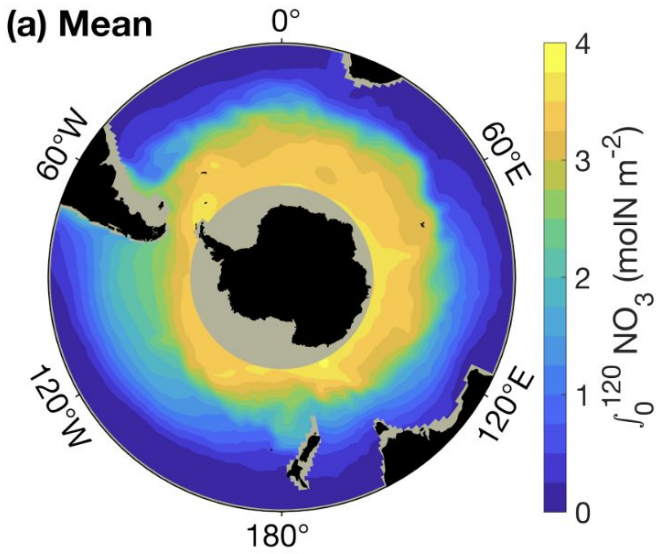


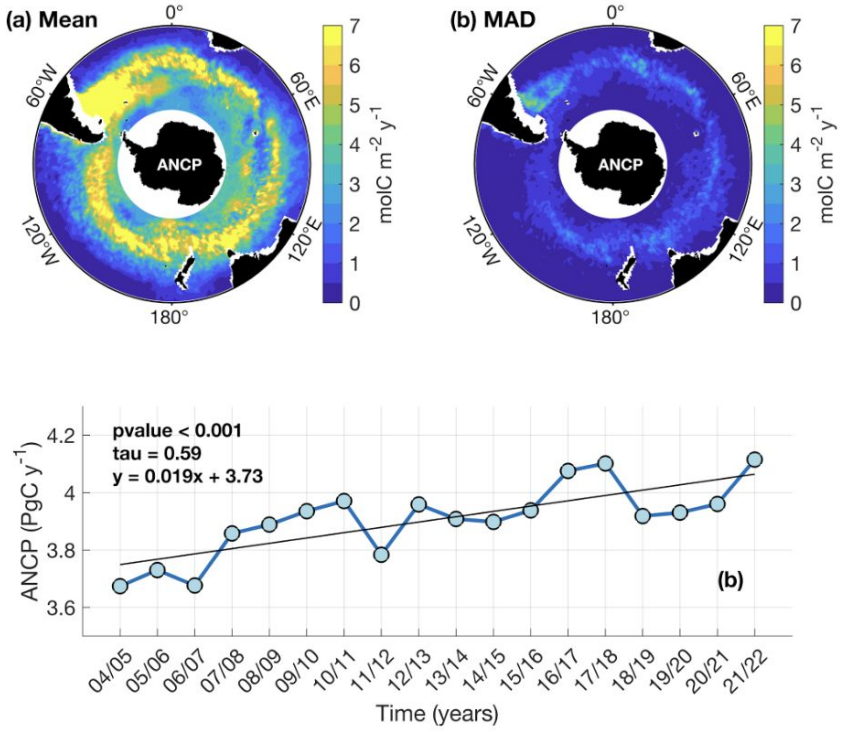
Muller et al. (2023)

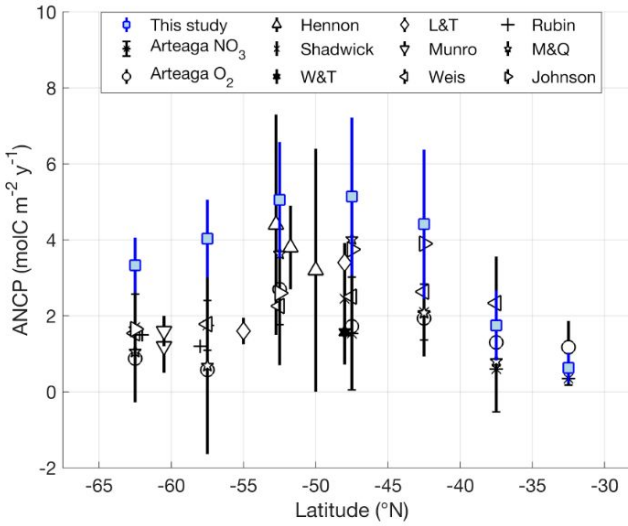
Southern Ocean (subtropical) is taking up large amount of carbon, centered at 40°S. Far south is losing carbon.

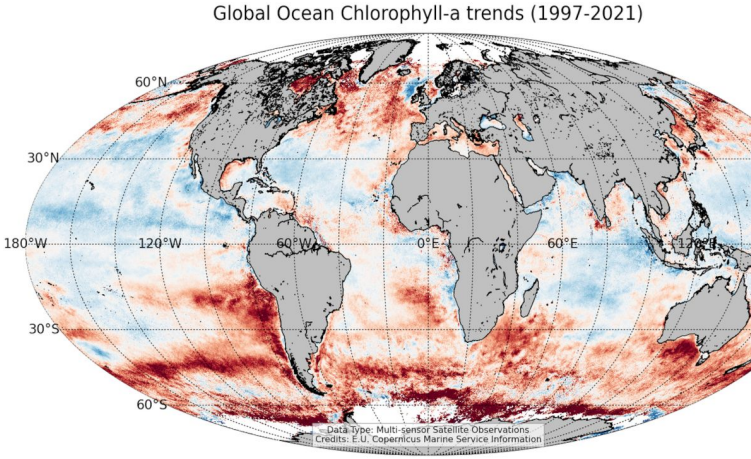
SOCCOM

ANCP increases based on BGC Argo nitrate observations and ML gridding
Liniger, Johnson, Sharp, et al. (submitted)









Nitrate gridding, like Sharp Oxygen

Compute ANCP from nitrate differences: increasing ANCP in time

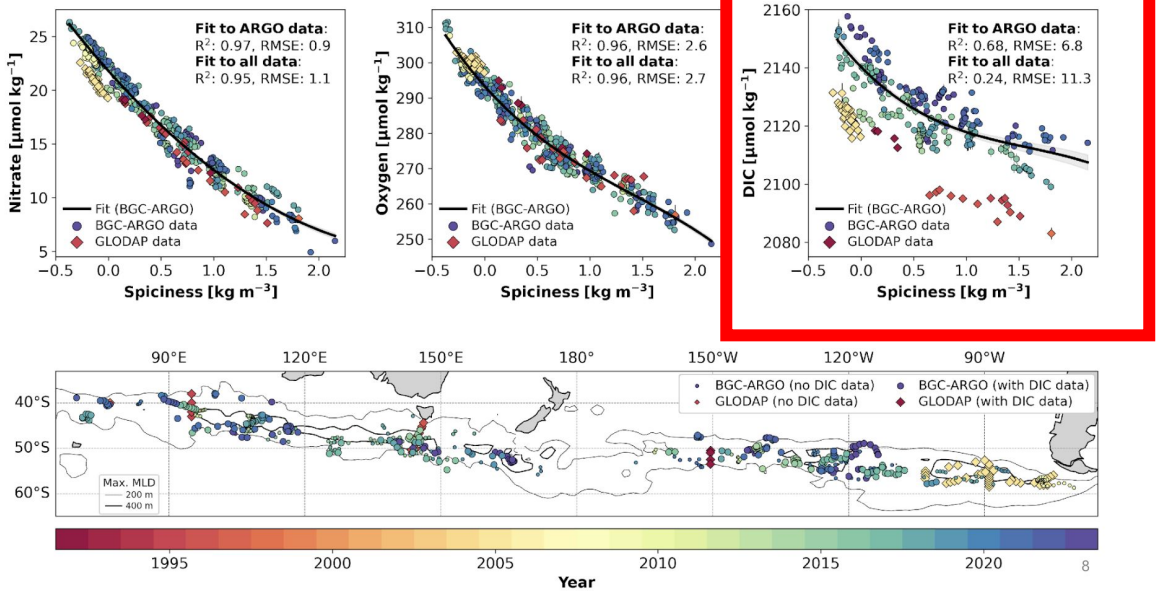
Consistent with greening observed from surface chlorophyll

SOCCOM

Anthropogenic carbon changes in Subantarctic Mode Water observed from SOCCOM floats vs. GLODAP (historical ship-based)

König, Bushinsky, Jutras & Cerovečki

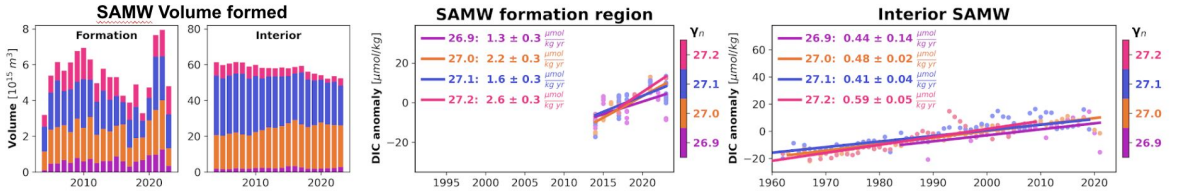
Biogeochemistry of SAMW formation region



DIC accumulation in SAMW formation regions vs. interior

Pacific Ocean

- DIC accumulation rates increase with density (more or less)
- Higher rates in formation region than interior
- Interior rates lower than in Indian, generally similar for different densities



Slope is carbon accumulation: ACO2

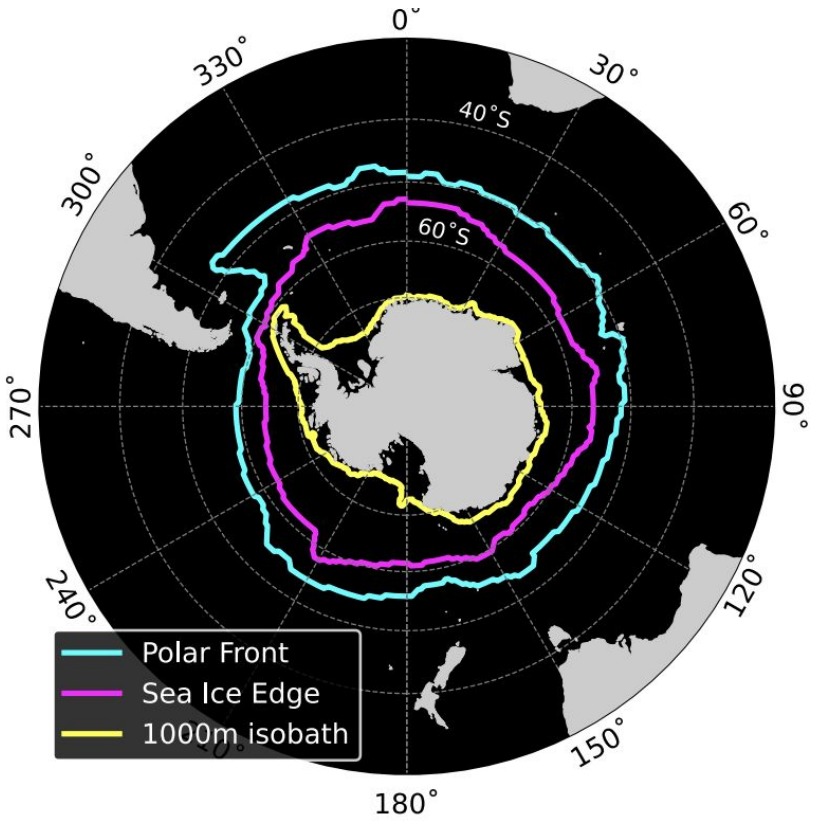
DIC change: analysis based on direct, ungridded observations

SOCCOM

Closed carbon budget for the mixed layer, model-observation comparisons: BGC floats, B-SOSE, and OMIP models

Sauve et al. (2023) & Sauve, Gray, Mazloff, Nissen, Lovenduski (in prep)

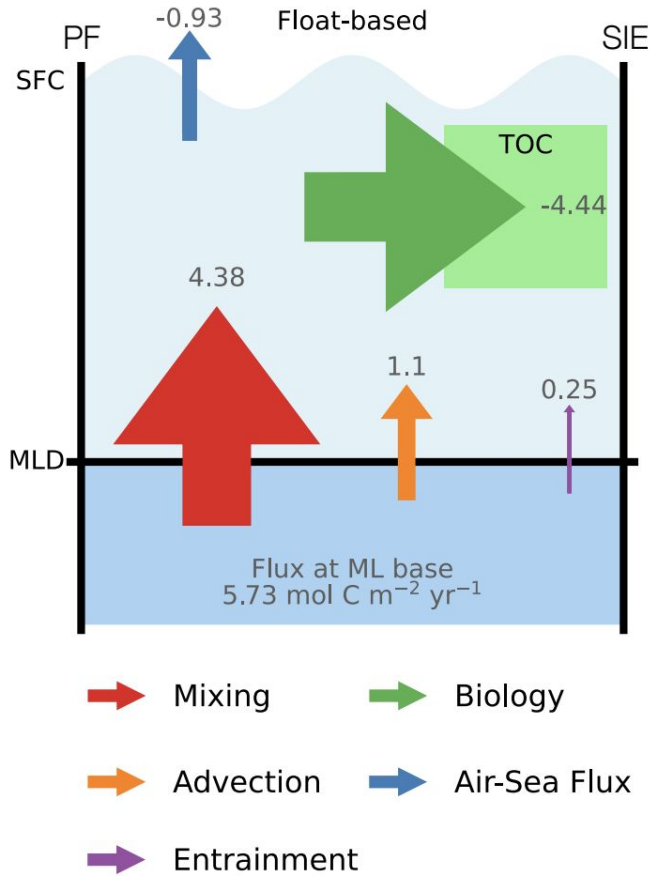
Focus on ‘Southern Zone’ where air-sea carbon flux is outgassing



Mixing with DIC-rich waters at the base of the mixed layer brings carbon into the mixed layer while net biological production consumes DIC.

In the float-based estimate, all fluxes at the mixed layer base add to supply DIC to the mixed layer.

Annually integrated DIC fluxes



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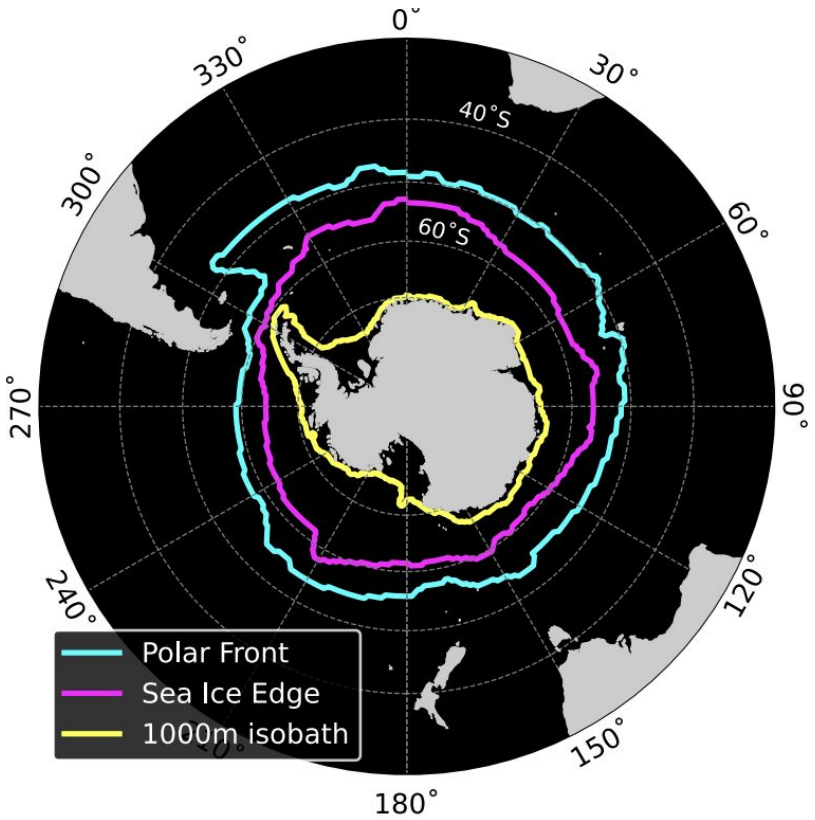
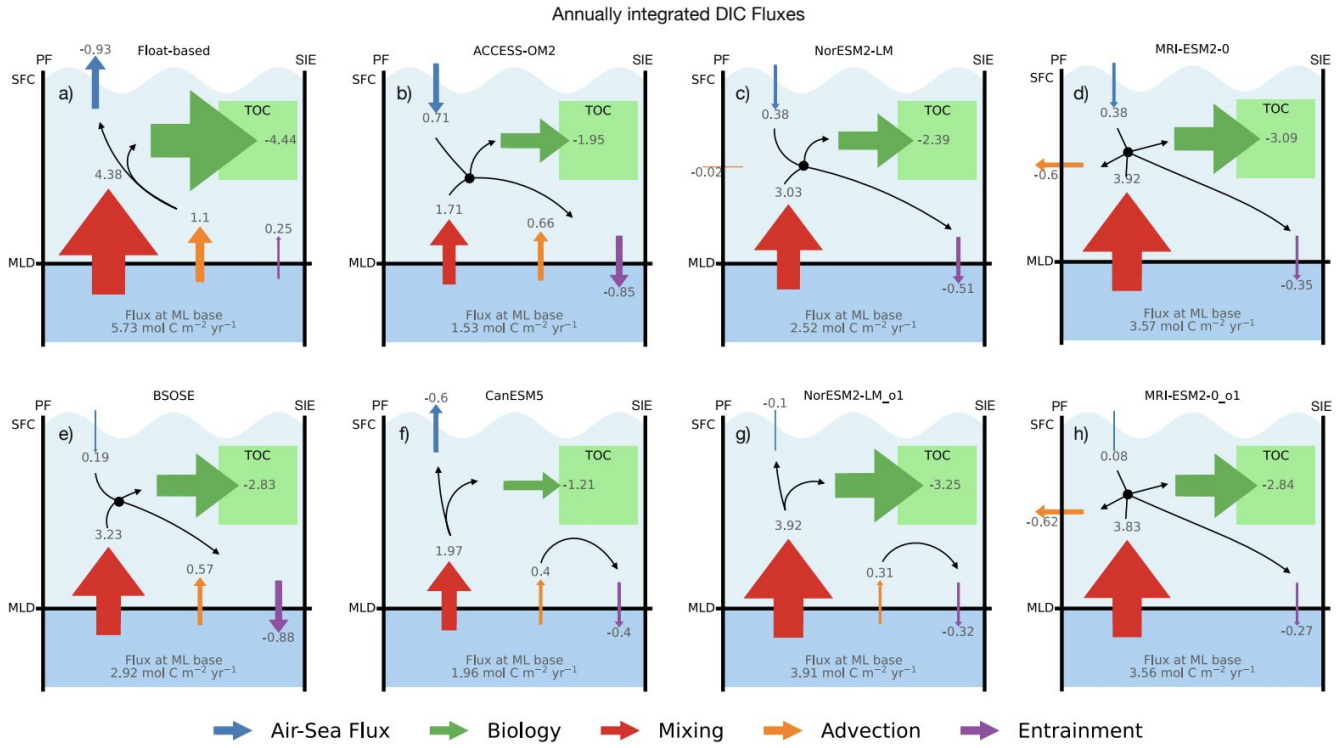


Floats

B-SOSE

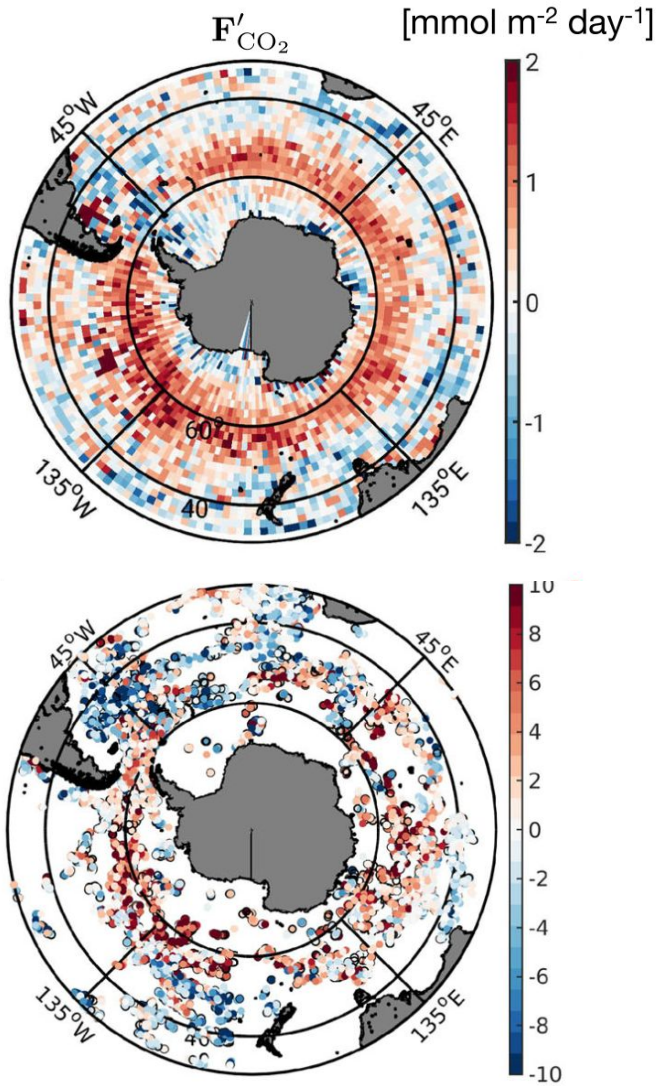


6 OMIP models

SOCCOM

Extratropical storms induce carbon outgassing over the Southern Ocean

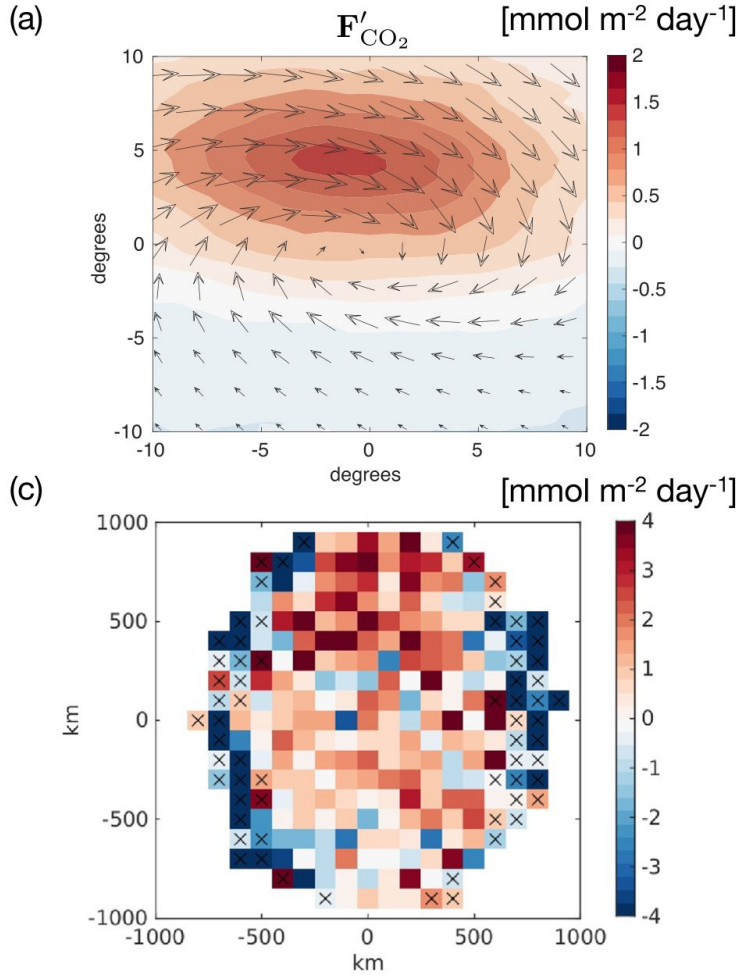
Magdalena Carranza et al. (npj 2024)



CES M

SOCCOM floats

Composite storm



SOCCOM

Global Carbon Project

RECCAP2

RESEARCH ARTICLE
10.1029/2023GB007848

The Southern Ocean Carbon Cycle 1985–2018: Mean, Seasonal Cycle, Trends, and Storage

Judith Hauck[1], Luke Gregor[2], Cara Nissen[1,3], Lavinia Patara[4], Mark Hague[2], Precious Mongwe[5], Seth Bushinsky[6], Scott C. Doney[7], Nicolas Gruber[2], Corinne Le Quéré[8], Manfredi Manizza[9], Matthew Mazloff[9], Pedro M. S. Monteiro[5,10], and Jens Terhaar[11,12,13]

Key Points:

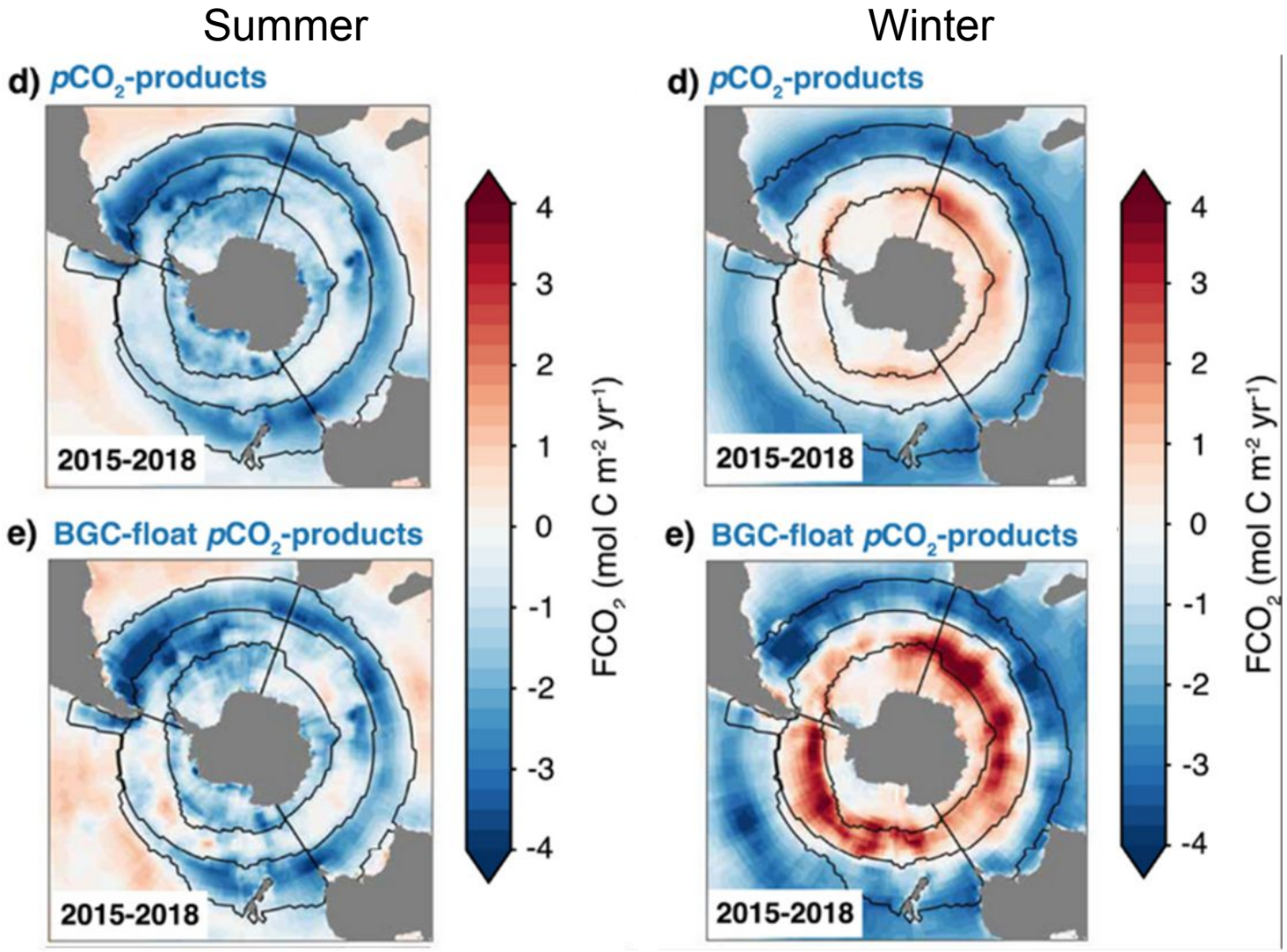
- Ocean models and machine learning estimates agree on the mean Southern Ocean CO_2 sink, but the trend since

Air-sea flux of CO_2 mapped now using very sparse shipboard observations.

BGC Argo floats provide seasonal, circumpolar fluxes.

Ships only

Ships and BGC floats



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