Tipping Points in the Southern Ocean Overturning (TIPSOO)

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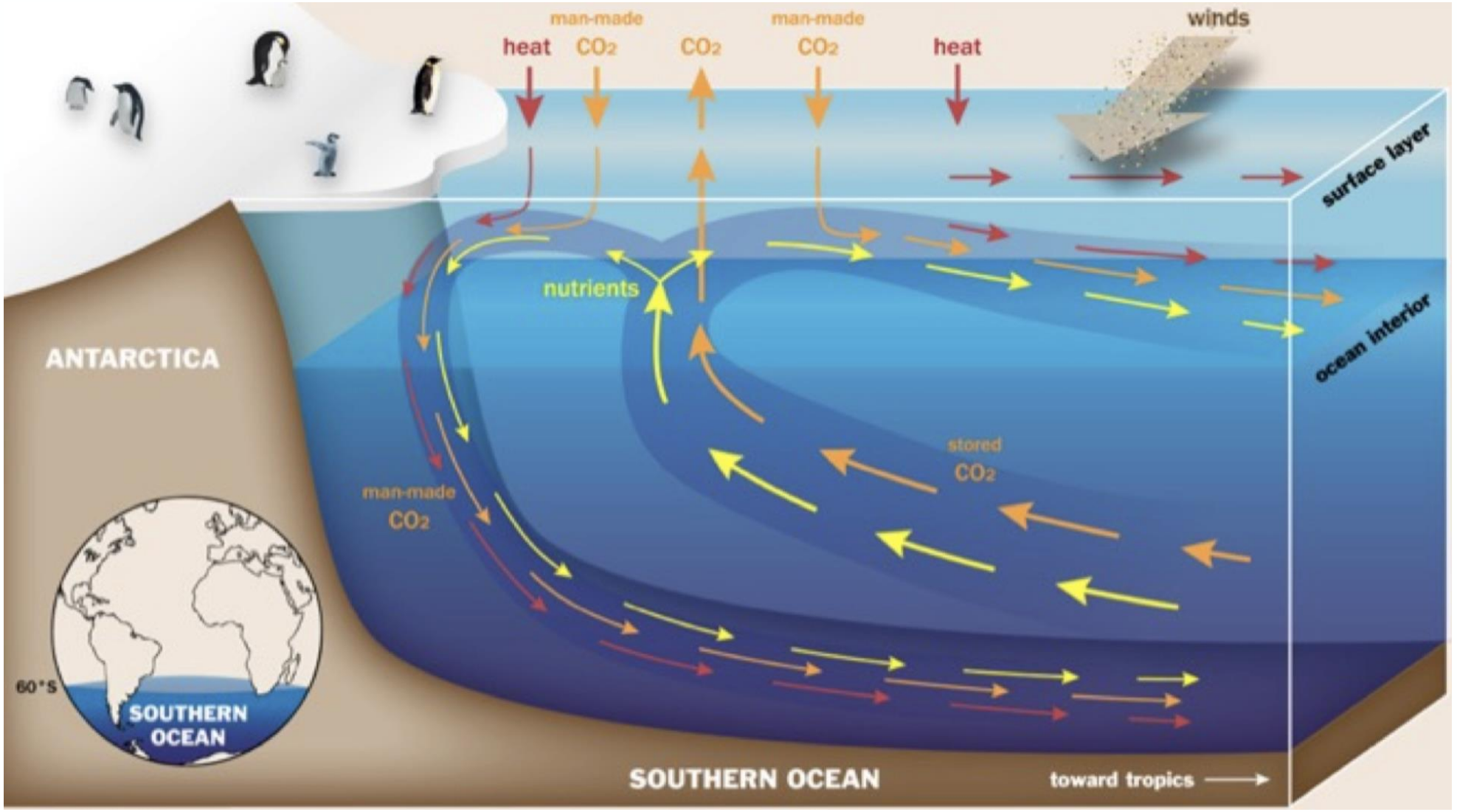
Project Objectives

- Tipping Points ESA call
- Test whether tipping points in the Southern Ocean Overturning Circulation can be detected from satellites
- 2025-2028
- Involved in EU Horizon project: SYNCHRONY (led by AWI)
- Involved Antarctica In-Sync (contributed to white papers)

Southern Ocean Overturning Circulation



75% of heat and 45% of anthropogenic carbon uptake by the ocean

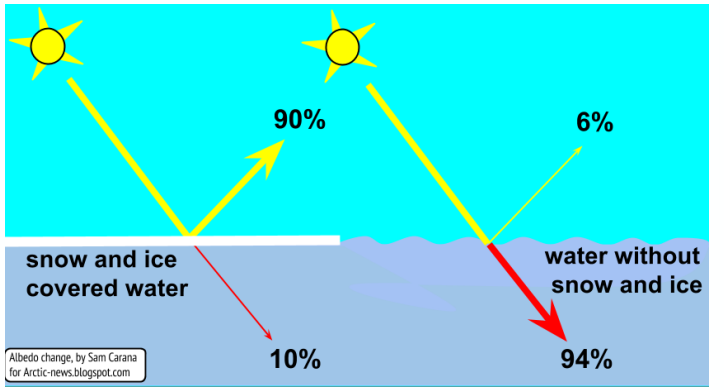
upper cell (2050-2100)

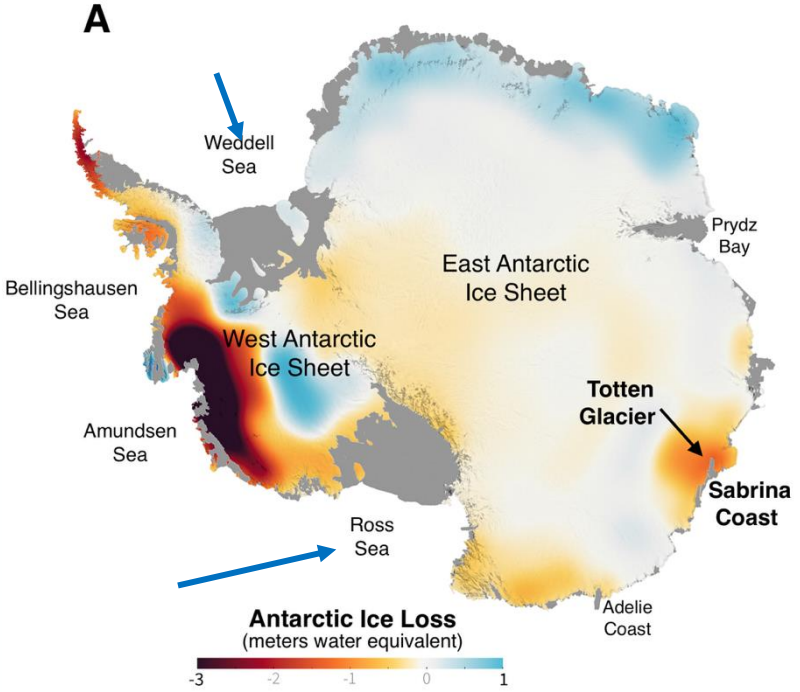
lower cell/ Antarctic Overturning (2100-2300)

Southern Ocean: Tipping system with cascading effects

Accelerate global warming: heat and carbon release + sea ice albedo

→ influence net zero requirements





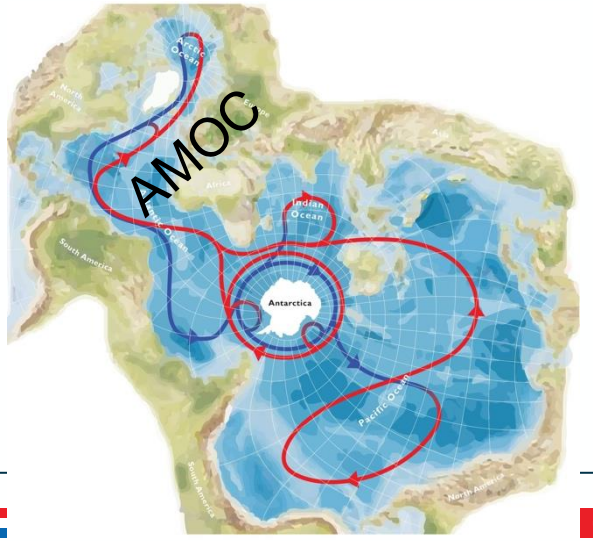
Accelerate sea level rise: Ross and Weddell shifts to a warm regime

→ meters of sea level rise stored in those basins

Abyssal circulation weakening

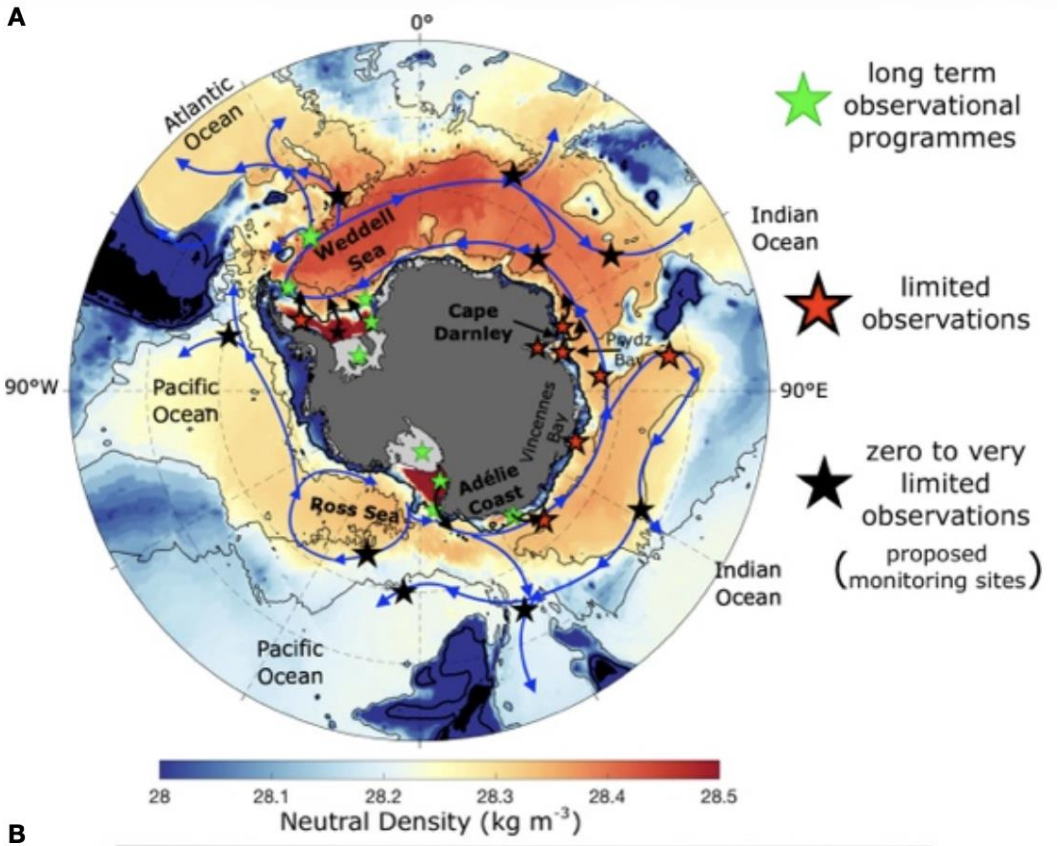
Impact on other tipping systems: AMOC

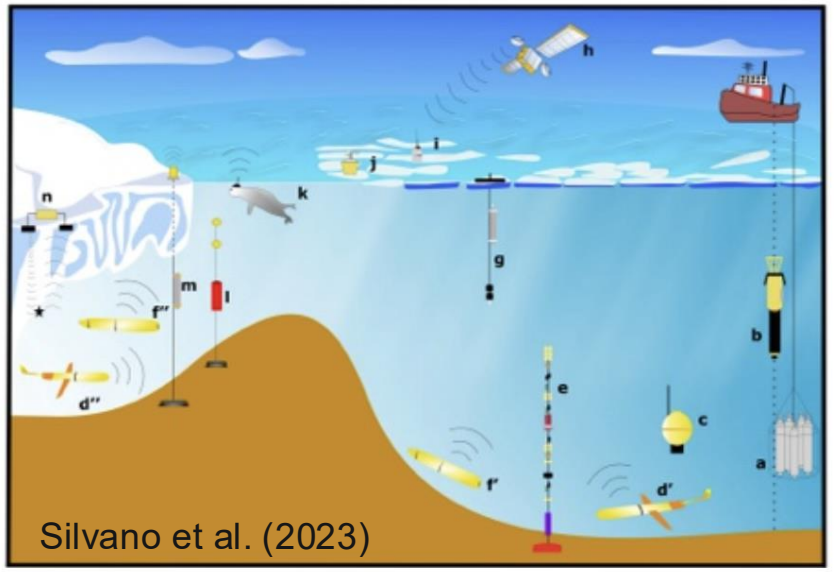
→ sustain/weaken AMOC (contrasting results)



How do we monitor this?

- Virtually impossible with only in situ observations
- Need for satellite observations
- Need for fingerprints
- And modelling (not only for future projections!)





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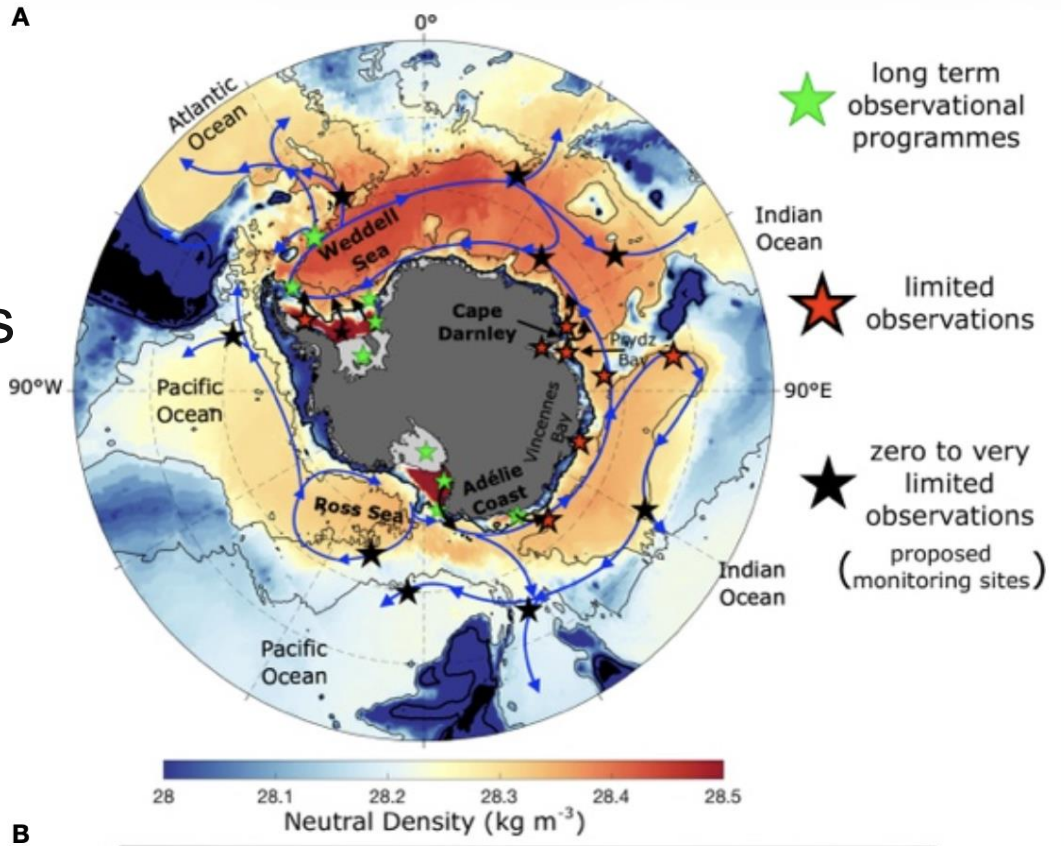
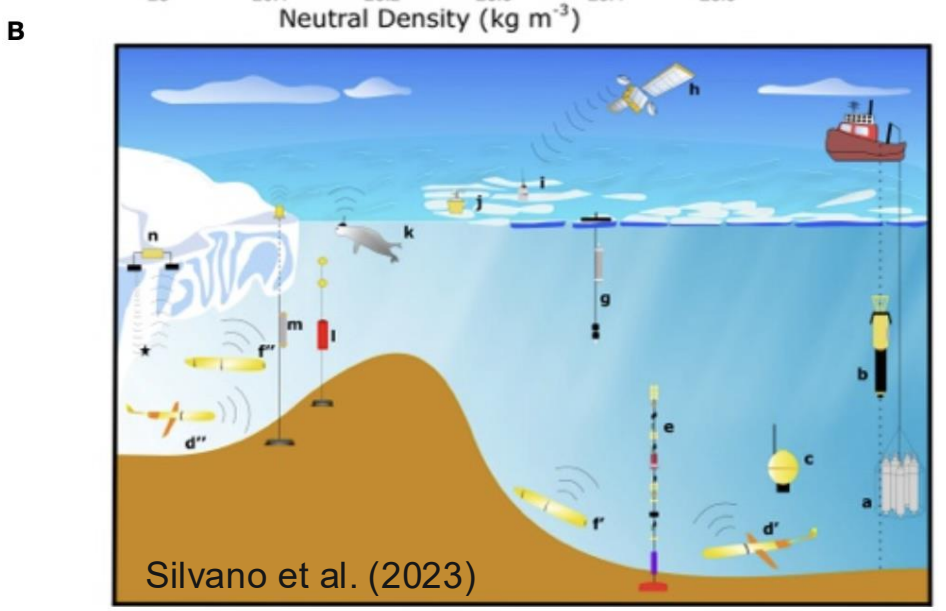
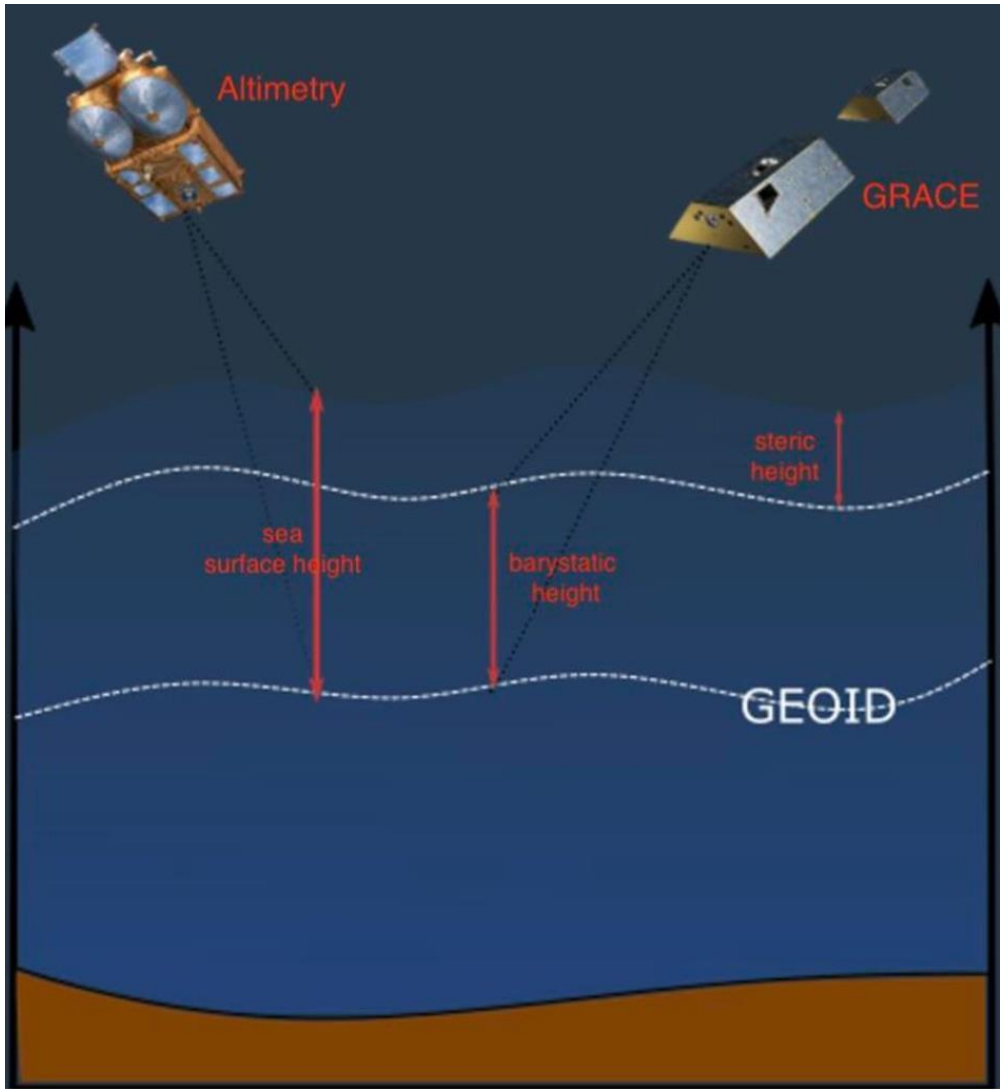
- Sea Surface Height (SSH)
- Steric Height
- Sea Surface Density





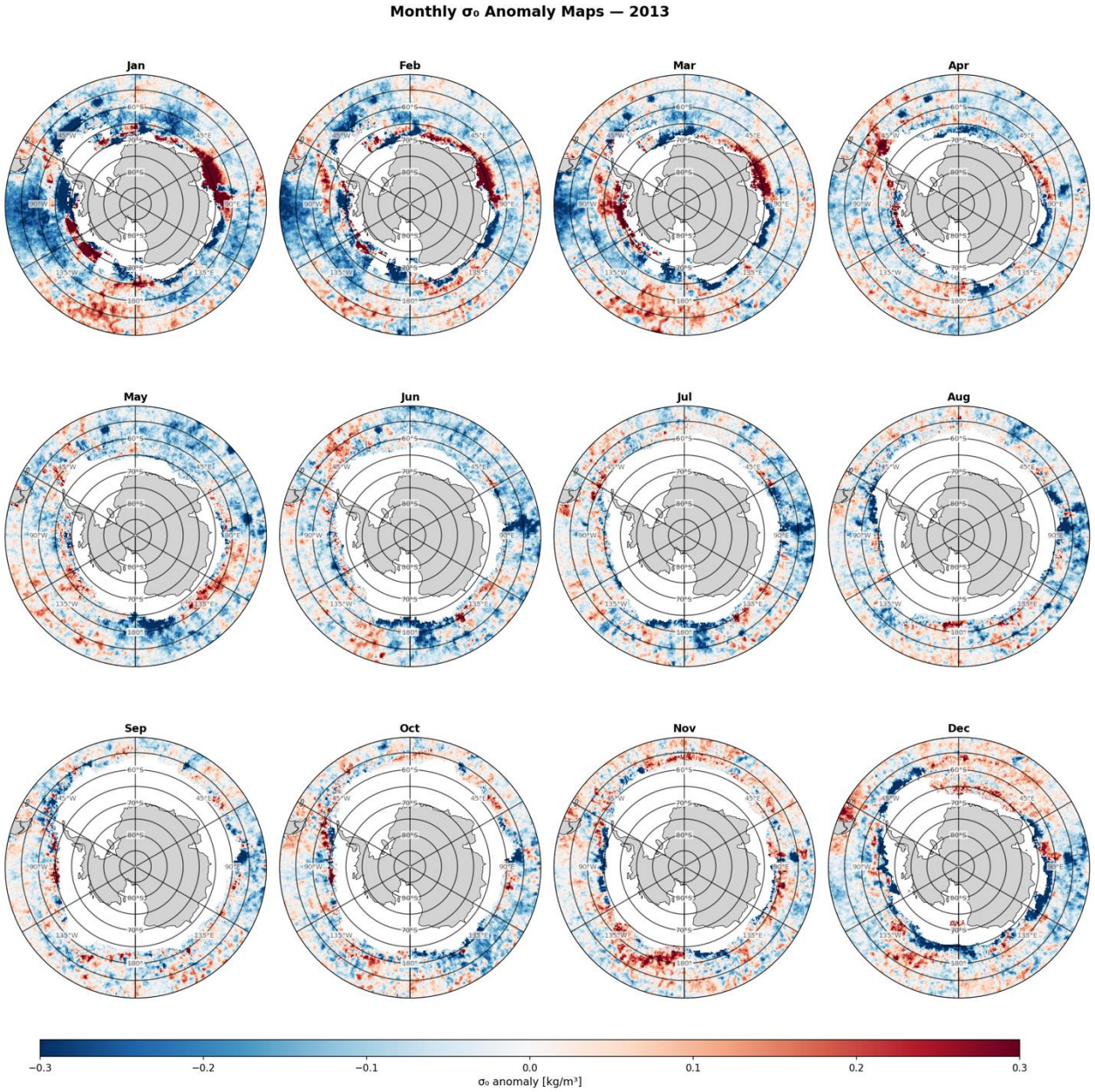
EO-based method for the Upper Cell: Steric Height

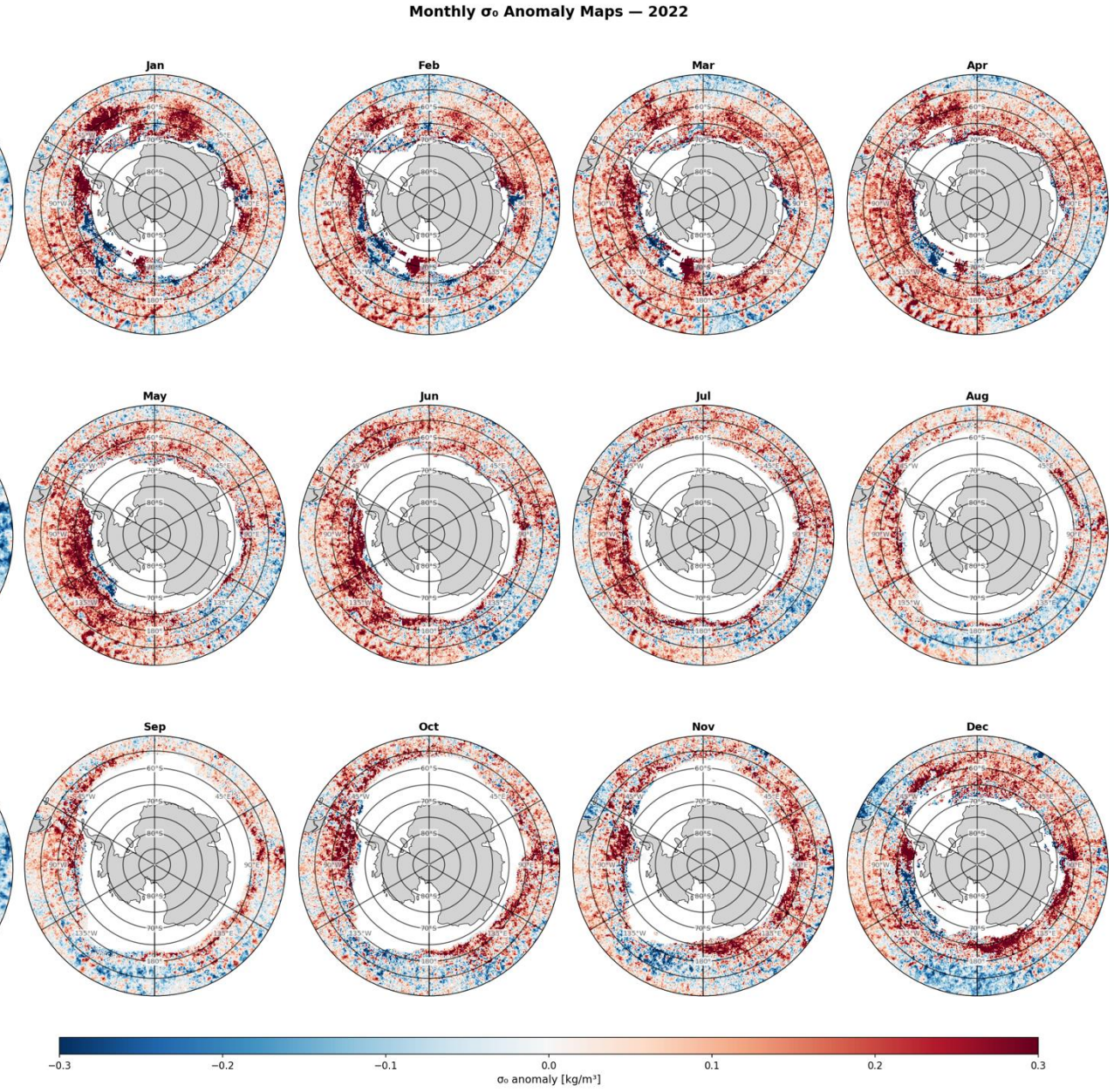


- Steric Height (SSH and ocean mass): density
- Density controls circulation and watermass transformation of the upper cell → **fingerprint 1**

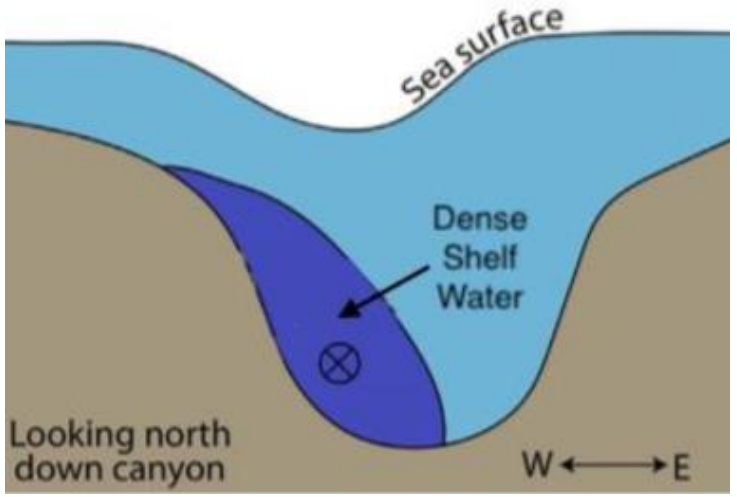
EO-based method for the Upper Cell: Sea Surface Density (SST + SSS)

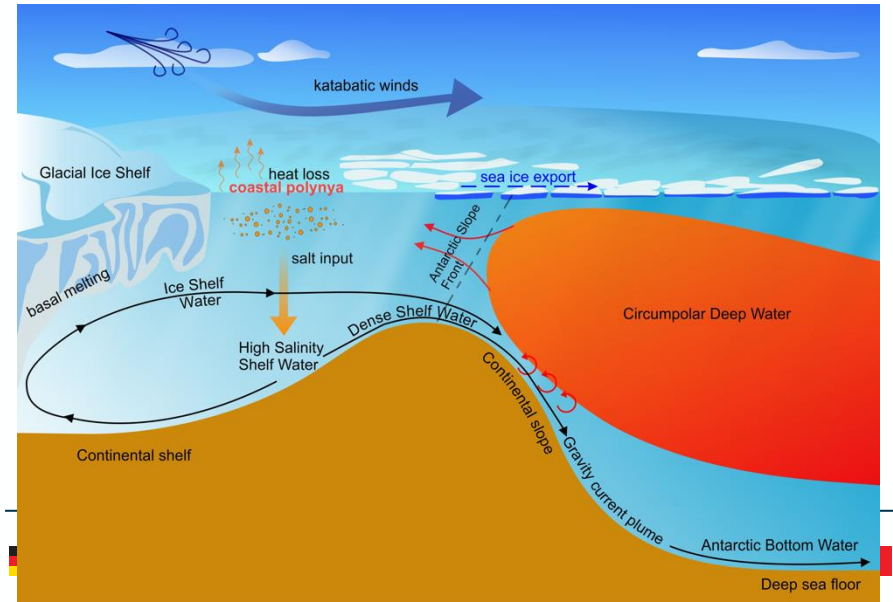
$\sigma_0 = \rho(SA, \Theta, p_{ref}=0) - 1000\ \mathrm{kg\ m^{-3}}$



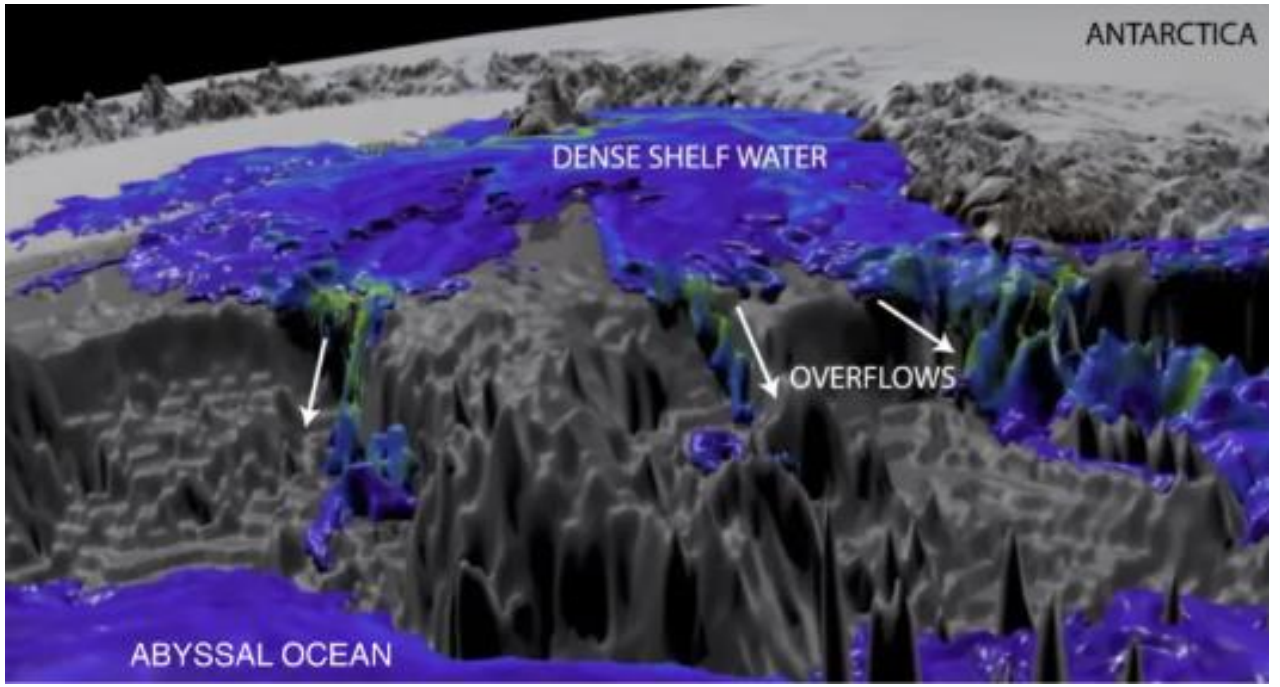


EO-based for the Lower Cell: Sea Surface Height (SSH)





Morrison et al. (2020)

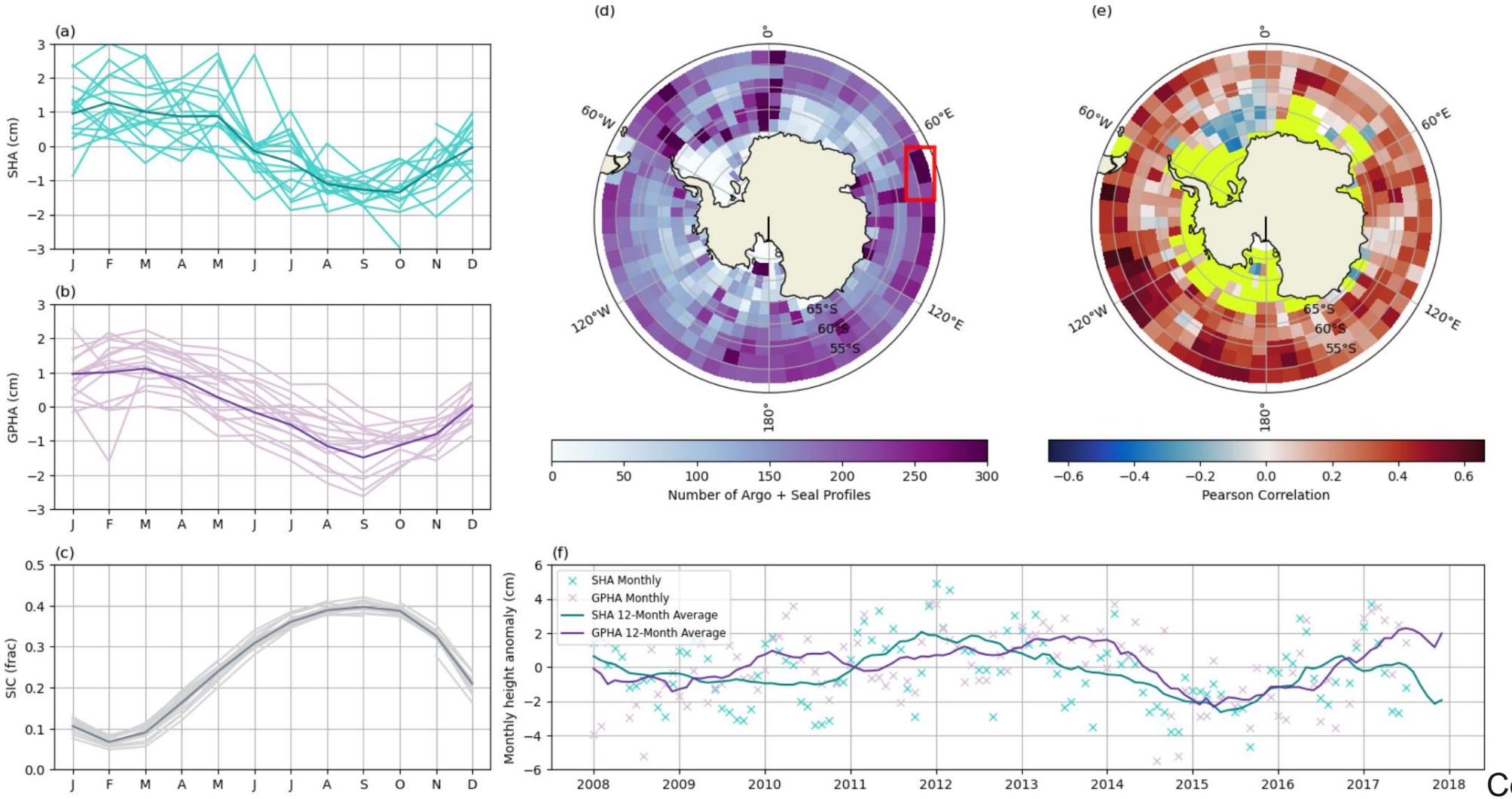


Silvano et al. (2023)

ECVs being used

- ECVs: Sea Level, SST, SSS (ocean mass from GRACE)
- Expect to capture fingerprint of circulation changes
- Sea level: under ice, relatively high res (km scale), temporal resolution of along-track allows 50-100 data per year (need for multiple satellites)
- SST and SSS good spatial and temporal coverage, contamination near sea ice (and cannot see under ice)
- GRACE: unique dataset, low spatial resolution (300 km)
- Improve spatial resolution of gravimetry and reduce leakage near continents
- Increase spatial resolution of SSS

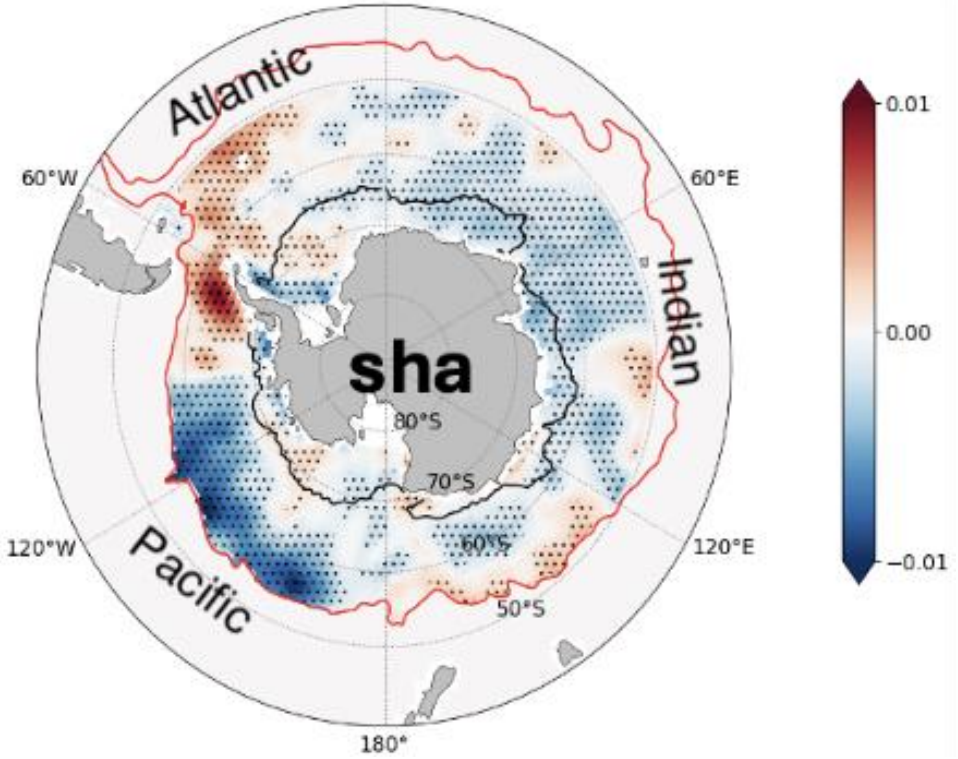
Steric Height comparison with in situ observations



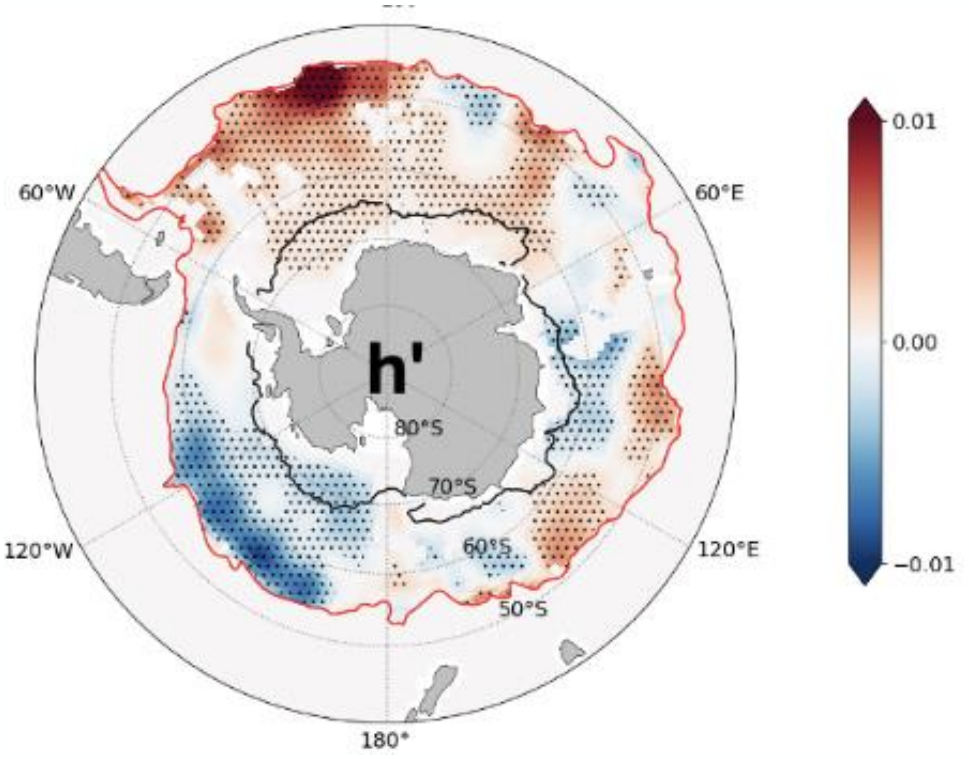
Cocks et al. (2025)

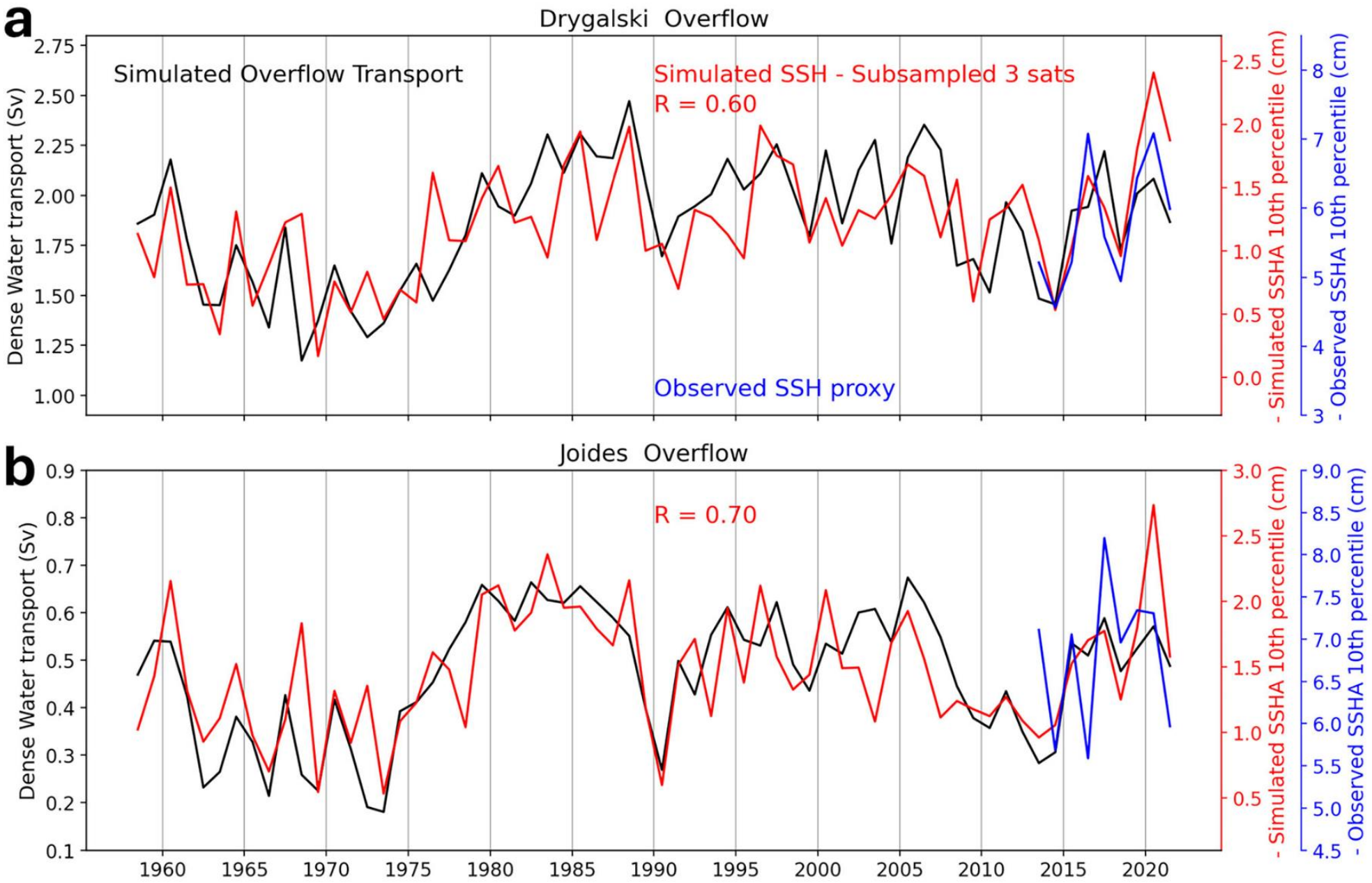
Trends

2004-2016
Satellites
(cm/decade)



2004-2016
Observations
(cm/decade)





Auger et al. (2025)

TIPSOO

- Testing whether these fingerprints can be used to detect changes in the Southern Ocean Overturning circulation

- Use models to simulate tipping points (e.g. collapse of the lower cell by imposing high freshwater fluxes)

- Quantify the surface signals of tipping points

- Assess whether these signals can be detected by satellites

https://os.copernicus.org/articles/21/1609/2025/

https://www.nature.com/articles/s43247-025-02210-7