Decadal Oscillations in Southern Ocean Air-Sea Exchange

Arising from Zonal Asymmetries in Atmospheric Circulation

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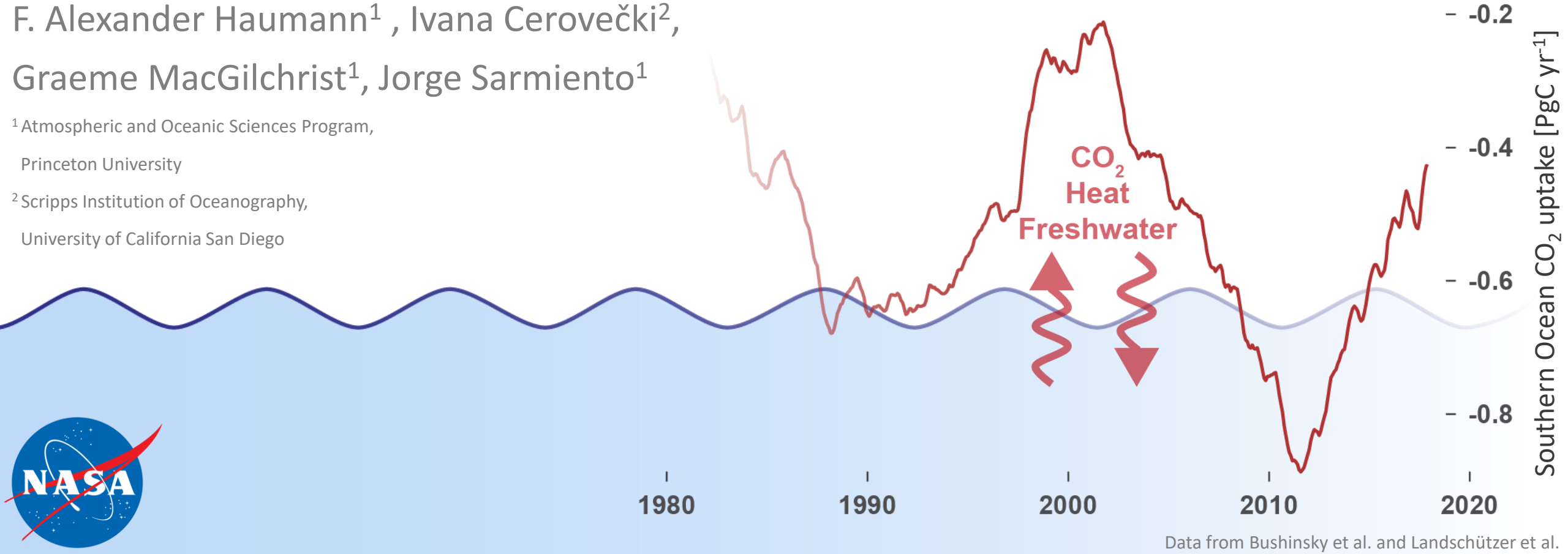
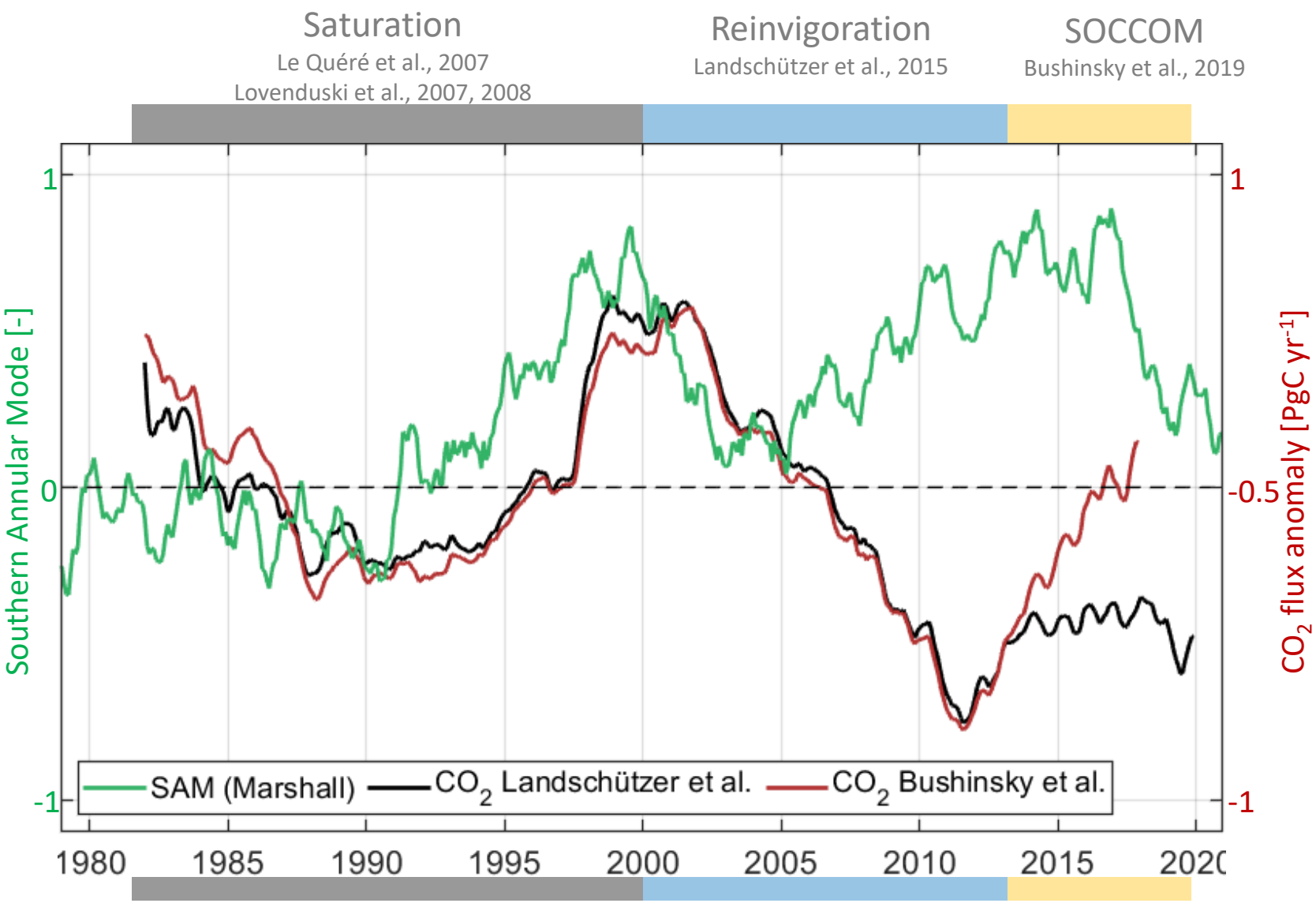


Data from Bushinsky et al. and Landschützer et al.

Possible drivers of Southern Ocean decadal variability

Southern Annular Mode and tropical teleconnections



Correlation coefficients:

	Landschützer et al., 2015	Bushinsky et al., 2019
SAM*:	-0.18	-0.12
SOI*:	-0.15	-0.26
PDO*:	0.16	0.32
IPO*:	0.10	0.16
AMO*:	-0.06	-0.10
ASL*:	-0.38	-0.55
ZW3*:	0.75	0.81

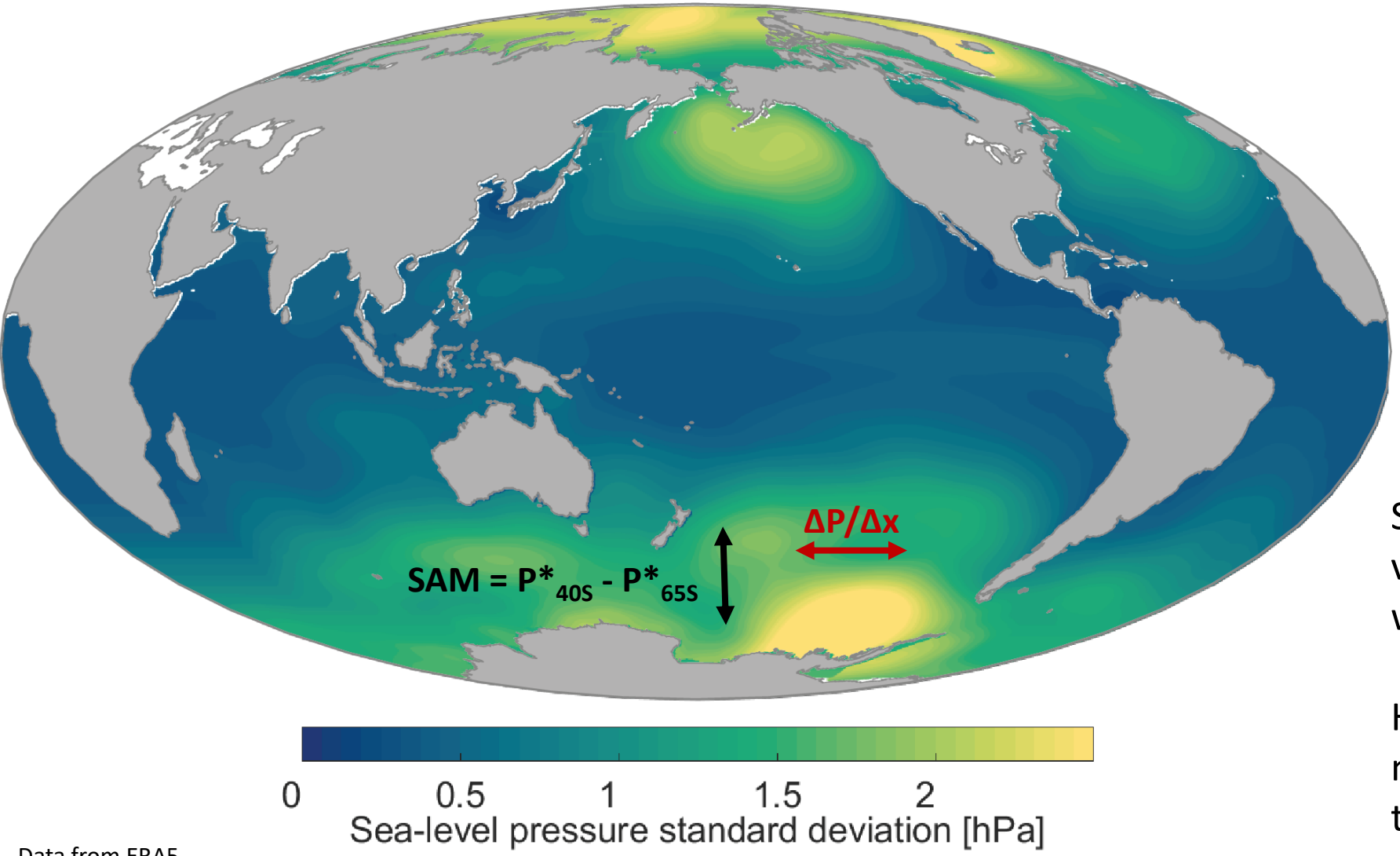
*filtered with a 5-year running mean

Zonal asymmetries in atmospheric circulation seem to induce decadal variations

See also Keppler and Landschützer (2019)

What other factors drive variability in air-sea exchange?

Strong zonal asymmetry in sea-level pressure variance



Data from ERA5

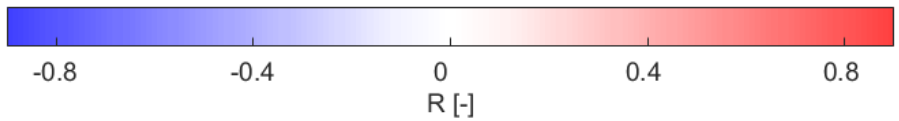
SAM captures the meridional variations in SLP and thus mostly westerly winds

However, **ΔP/Δx** determines the meridional exchange between the tropics and the high-latitudes

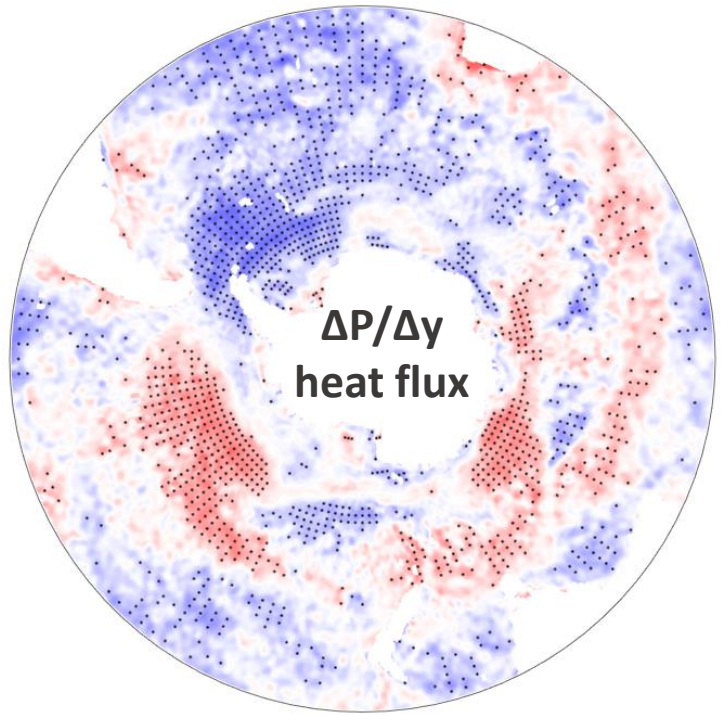
How does the influence of ΔP/Δx differ from ΔP/Δy?

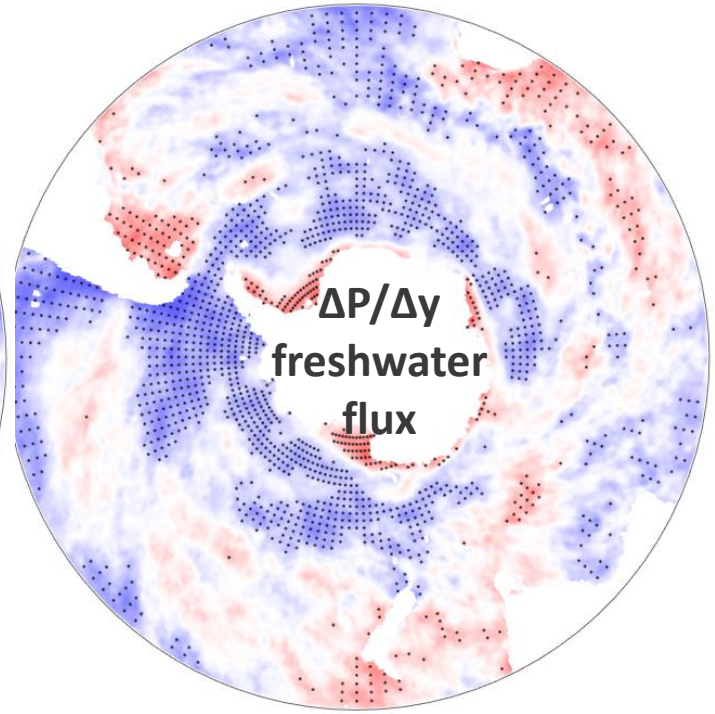
ΔP/Δy redistributes heat and freshwater

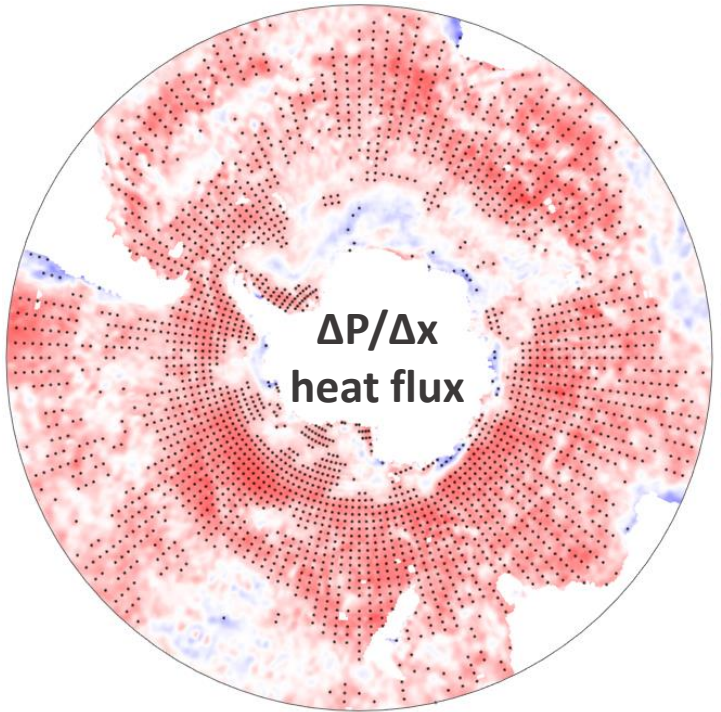
Stronger ΔP/Δx is associated with stronger advection of heat and moisture to the Southern Ocean

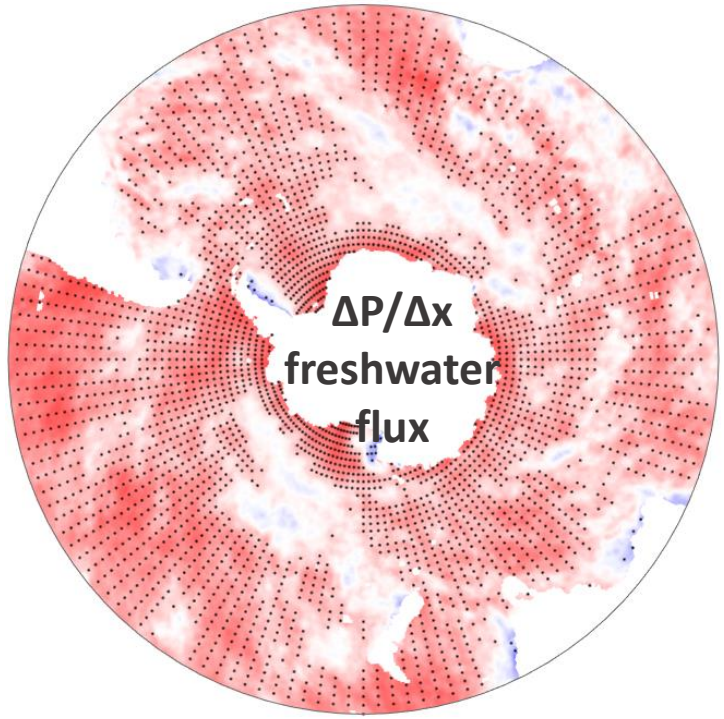


Data from ERA5



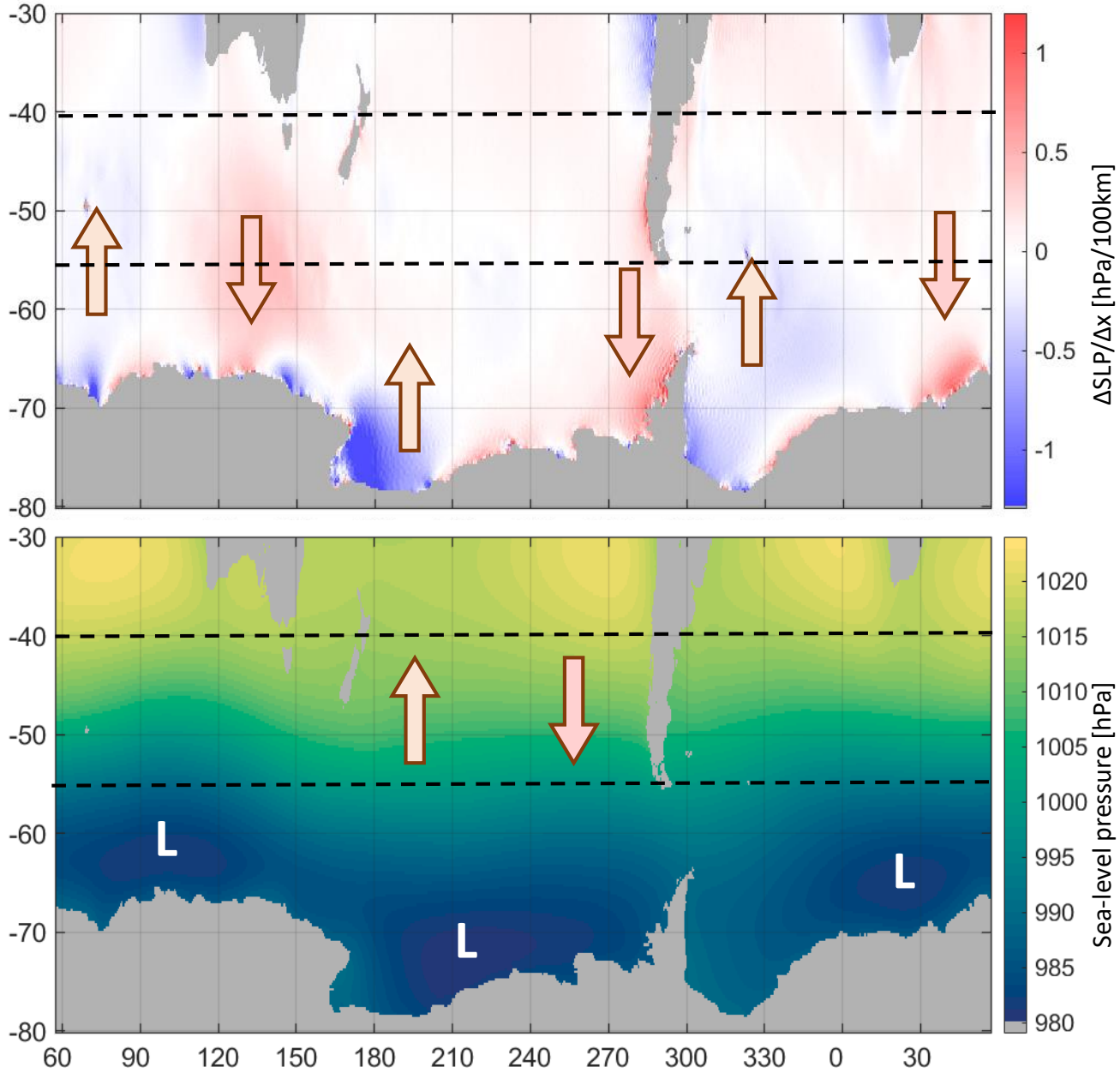






An index to capture meridional exchange of heat and moisture

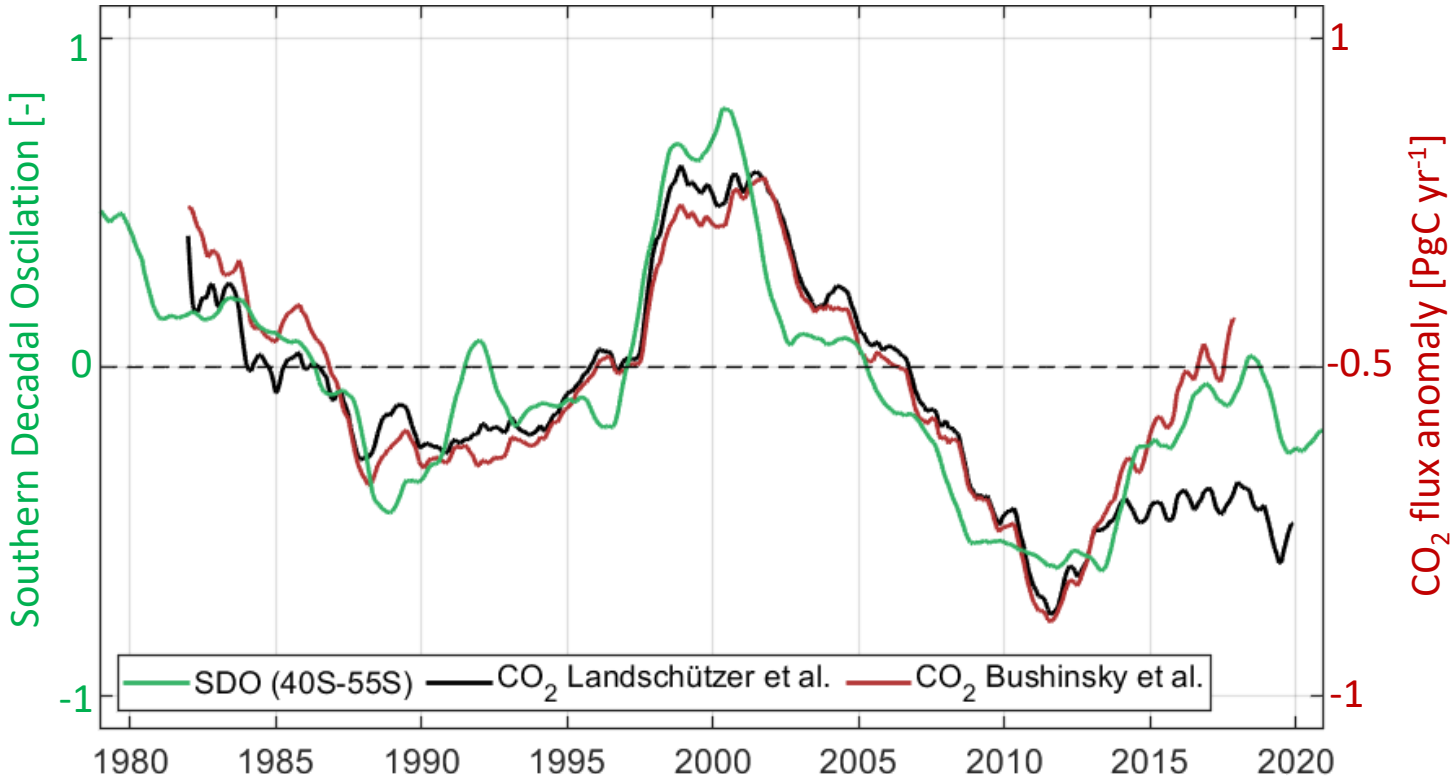
Southern Decadal Oscillation (SDO)

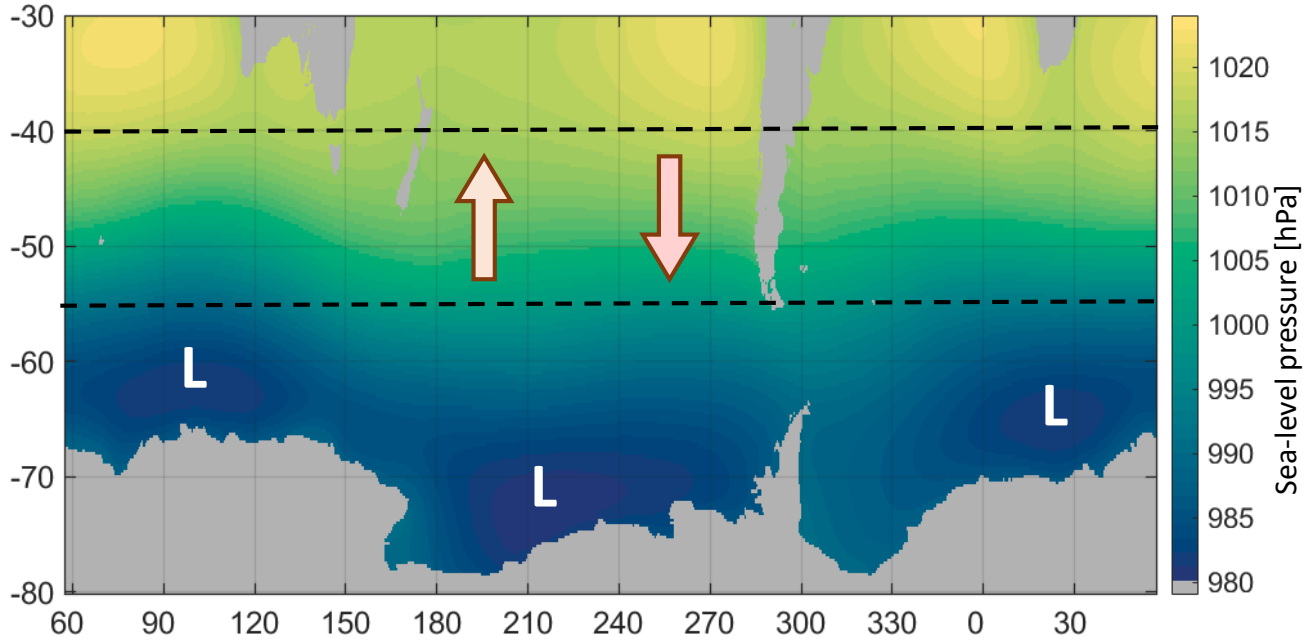


$$SDO = \frac{\sum_{i=1}^{n} A_i \left| \frac{\partial SLP_i^*}{\partial x_i} \right|}{\sigma \sum_{i=1}^{n} A_i}$$

*SLP**: 5-year running mean sea-level pressure anomalies Referenced to 1981-2010 (mean, std)

Relation between SDO and CO_2 flux





Correlation coefficients:

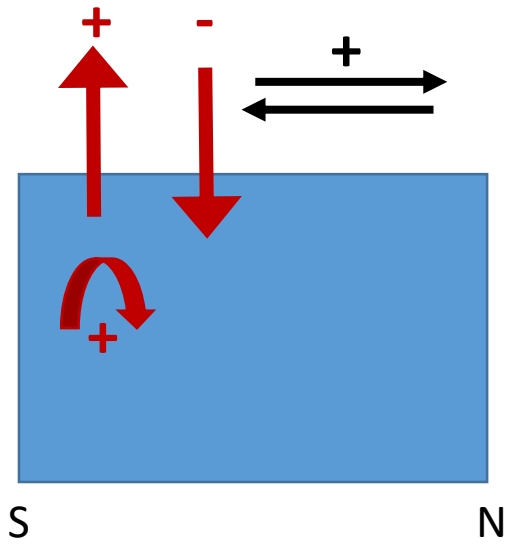
	Landschützer et al., 2015	Bushinsky et al., 2019
SDO (40S-55S):	**0.86**	**0.90**
SDO (55S-65S):	0.34	0.51
SDO (65S-80S):	0.27	0.23

Zonal asymmetries in sea-level pressure explain up to 81% of the variability in the CO_2 fluxes

SDO leads CO_2 flux by about 7 months corresponding to the air-sea equilibration time scale

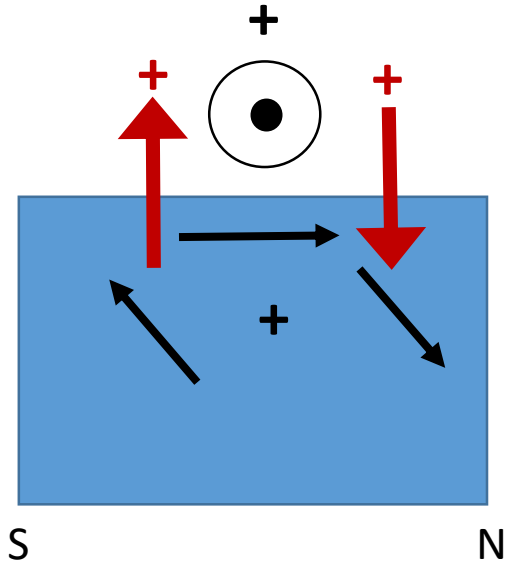
Hypothetical mechanistic understanding

Increased Zonal pressure gradient ΔP/Δx
→ meridional exchange
→ buoyancy-driven mixing
→ wind-driven mixing



Net Southern Ocean CO_2 uptake decreases

Increased Meridional pressure gradient ΔP/Δy
→ zonal exchange
→ Ekman transport
→ wind-driven mixing



Net Southern Ocean CO_2 uptake constant

- Increased zonal pressure gradients cause meridional exchange of heat and moisture, and thus buoyancy-driven water-mass transformation, entraining high pCO_2 waters into the surface ocean
- A higher surface ocean pCO_2 increases CO_2 release and reduces CO_2 uptake that drive surface ocean
- Results suggest that variations in Southern Ocean CO_2 fluxes on decadal time scales are mainly driven by buoyancy fluxes
- Increased meridional pressure gradients redistribute heat, moisture, and CO_2 circumpolar and through Ekman transport
- Both mechanisms affect wind-driven mixing and turbulent fluxes

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