Changes in the Southern Ocean CO_2 sink: A large-scale modeling perspective

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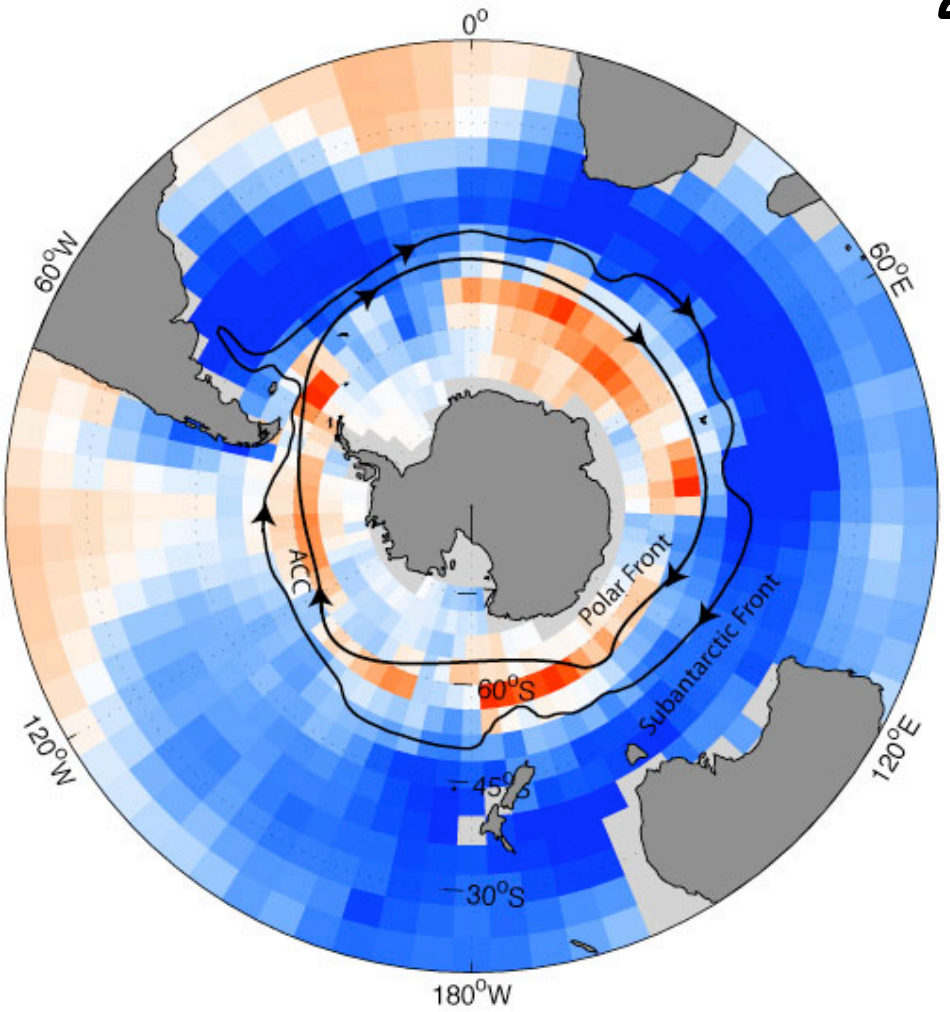
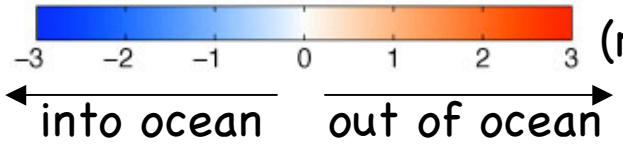
Part I:
Mean Southern Ocean CO_2 fluxes

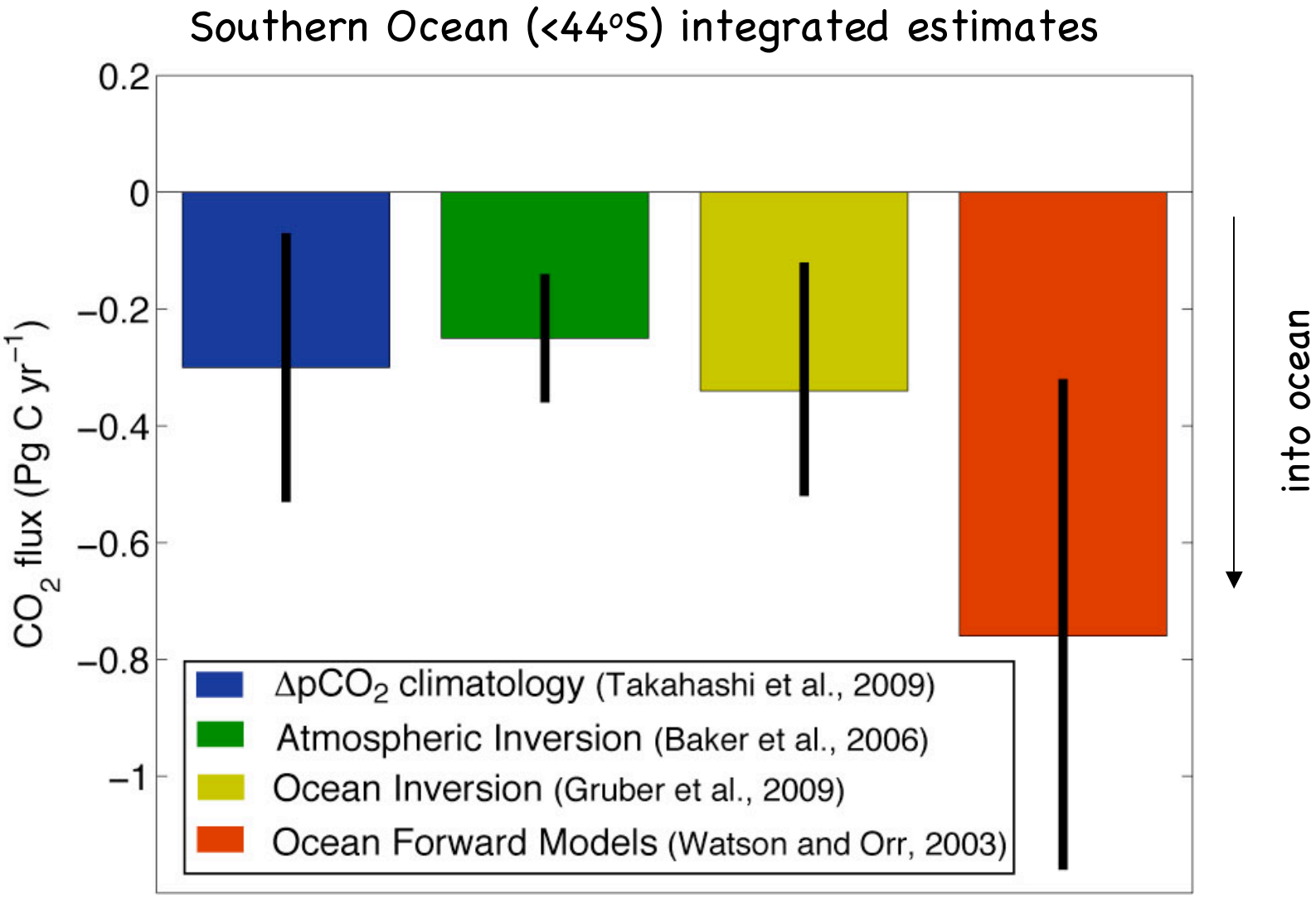
Observed Southern Ocean CO_2 fluxes





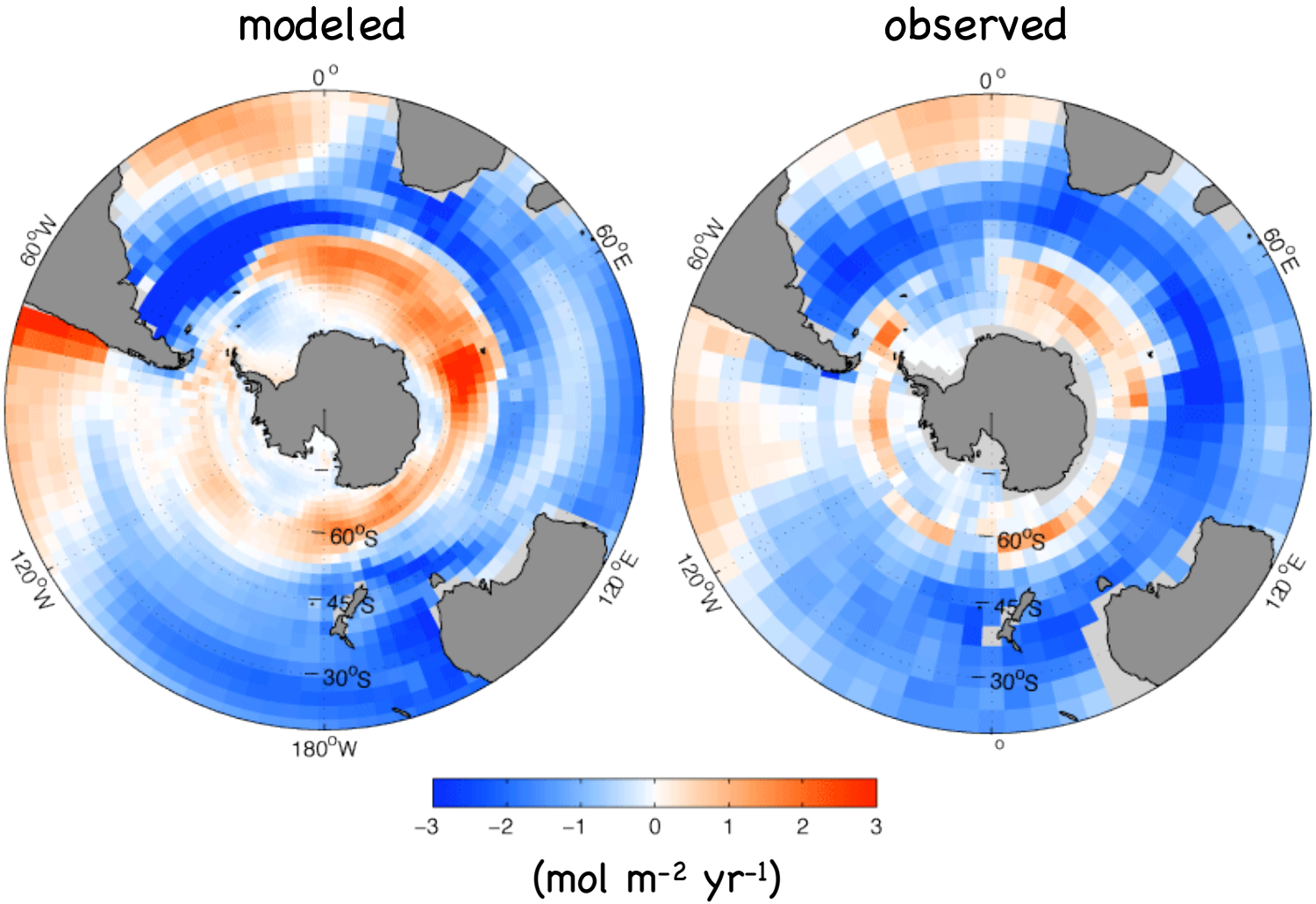
Takahashi et al. (2009)

Modeled Southern Ocean CO_2 fluxes



Gruber et al. (2009)

Regional differences in CO_2 fluxes

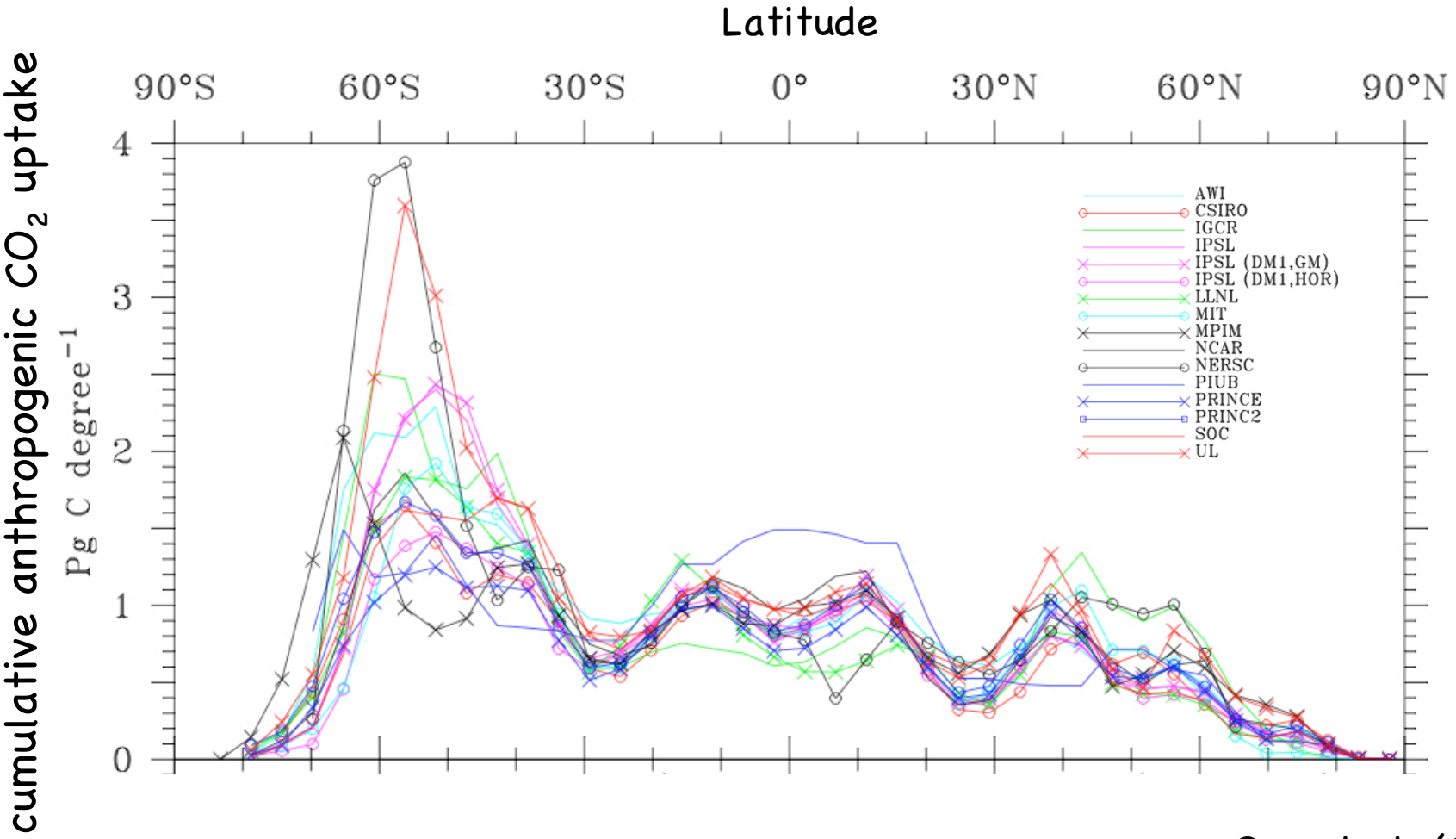


Lovenduski et al. (2007)

Takahashi et al. (2009)

Uncertainty in modeled CO_2 fluxes

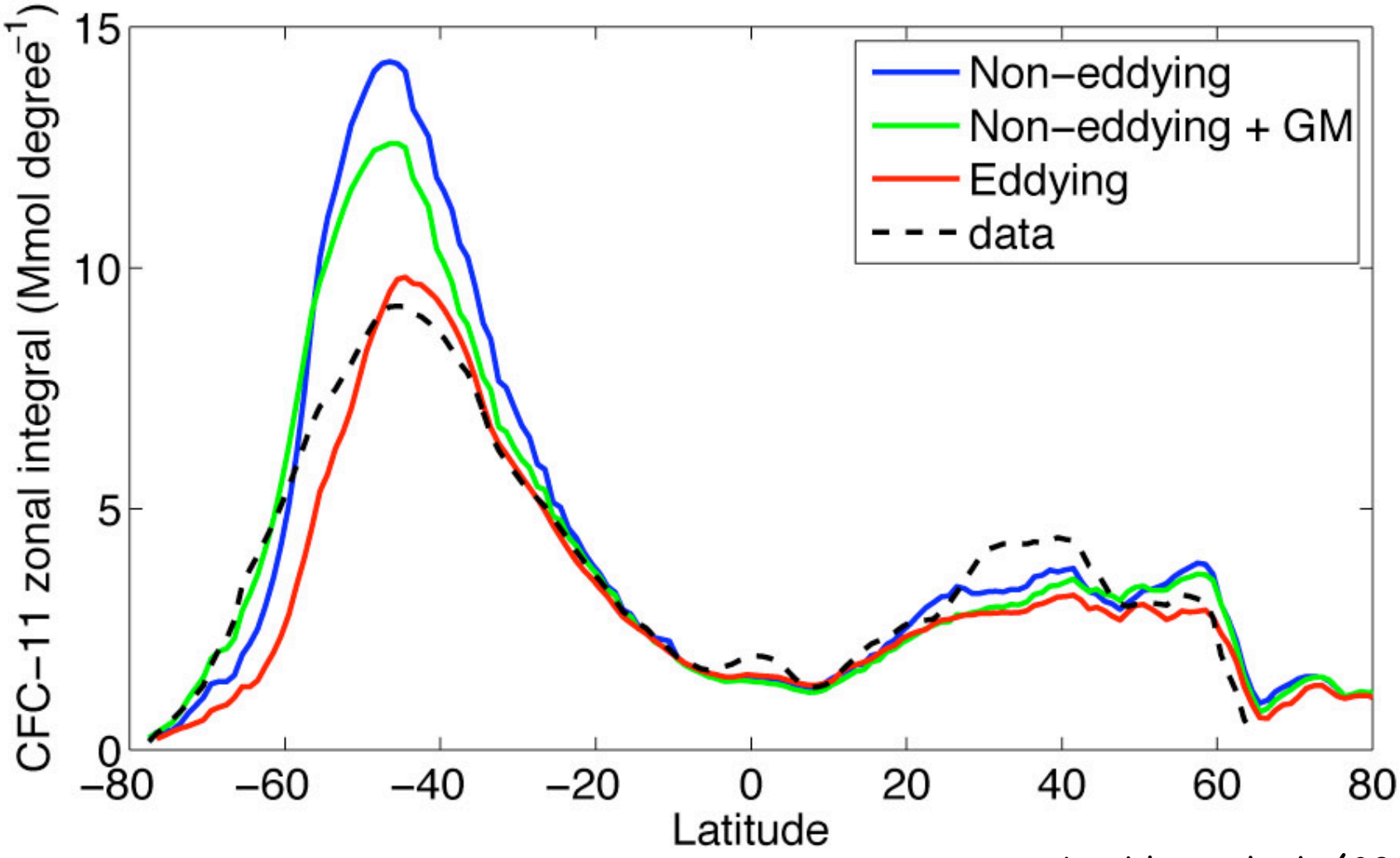
due to physical processes



Orr et al. (2002)

Representation of subgrid-scale processes

Implications for tracer inventories in the Southern Ocean



Lachkar et al. (2007)

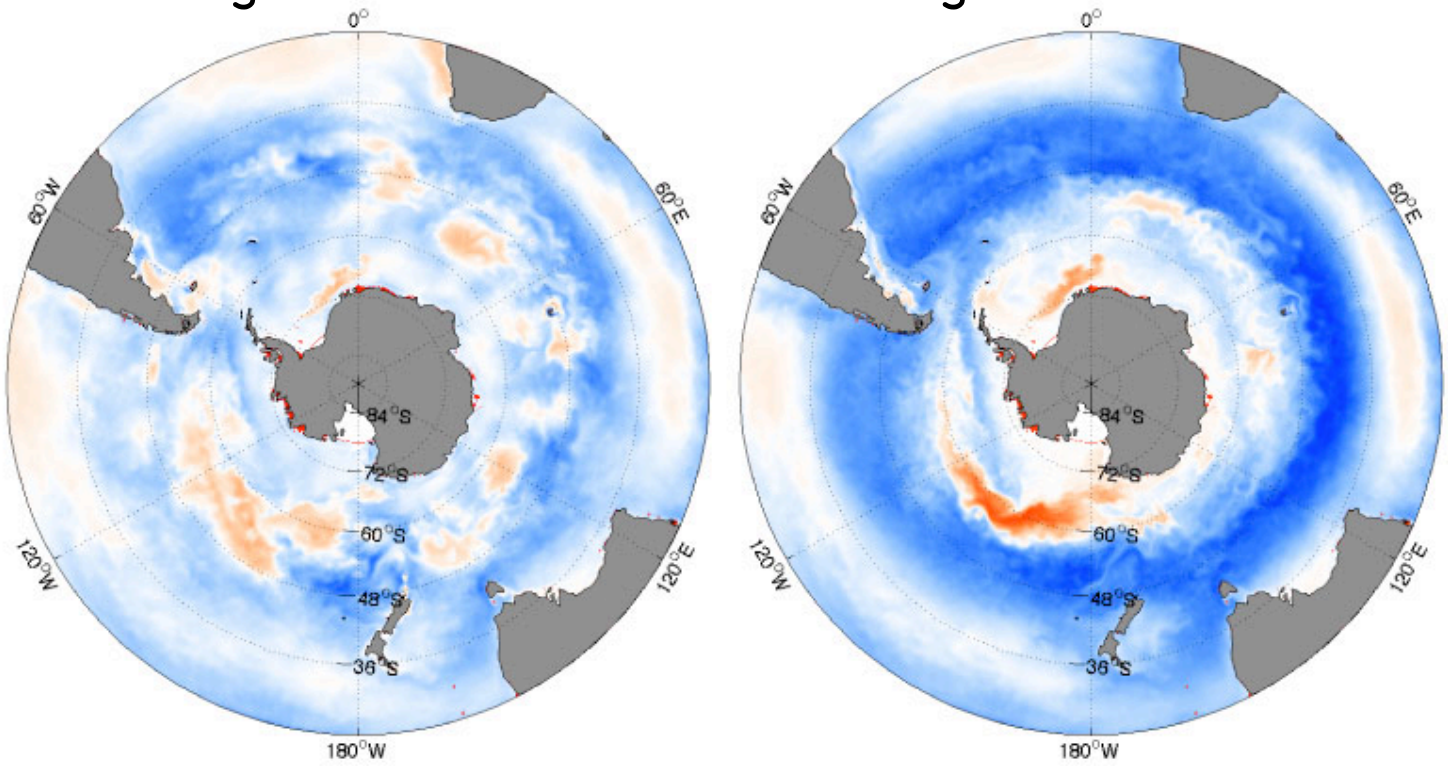
Uncertainty in modeled CO_2 fluxes

due to biogeochemical processes

Annual mean CO_2 Flux

MITgcm - OCMIP

MiTgcm - Dutkiewicz

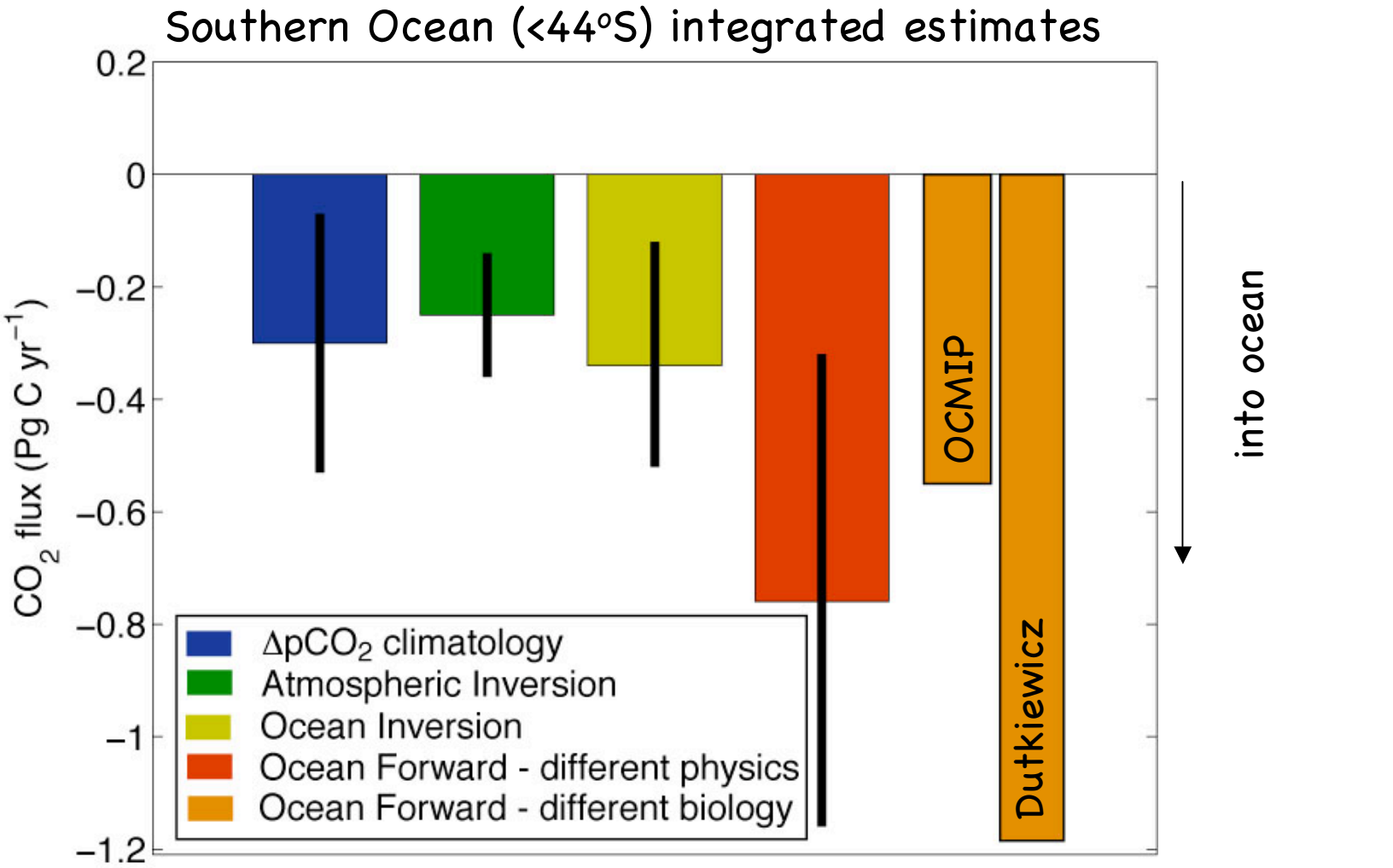


(mol m^{-2} yr^{-1})

T. Ito (unpublished)

Uncertainty in modeled CO_2 fluxes

due to biogeochemical processes

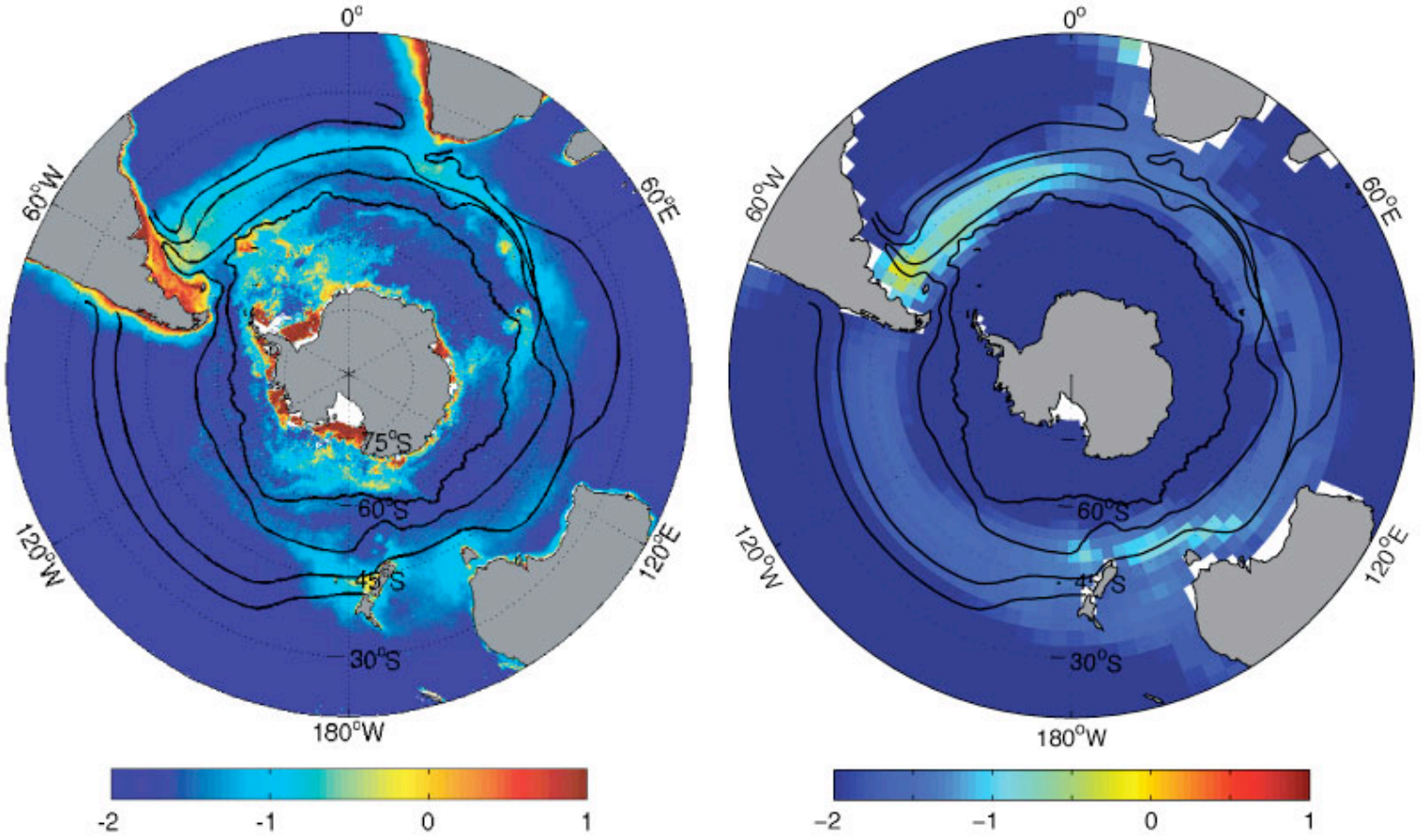


N. Lovenduski (unpublished)

Southern Ocean Chlorophyll

Observed

Modeled



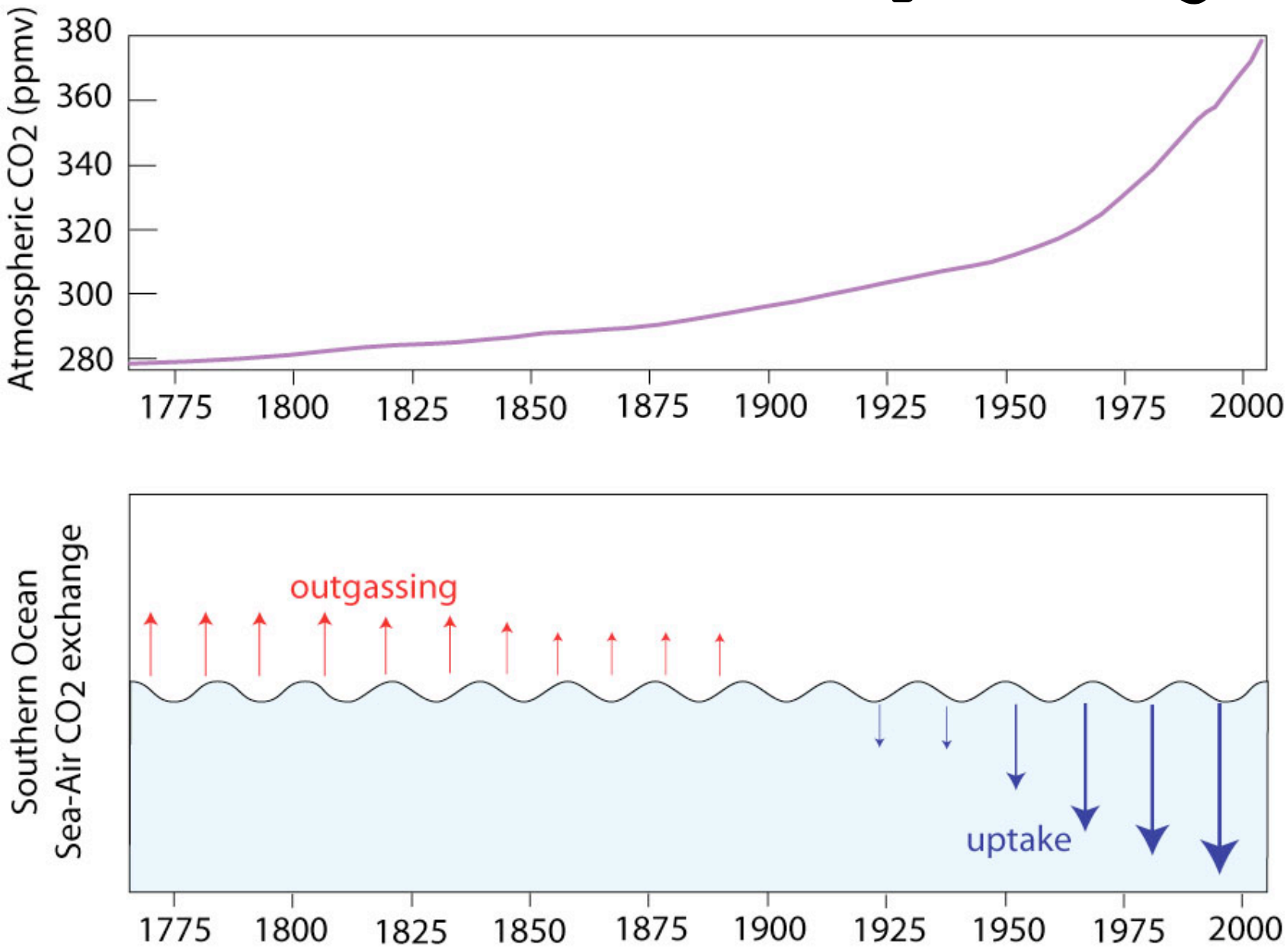
ln(mg m^{-3})

SeaWiFS

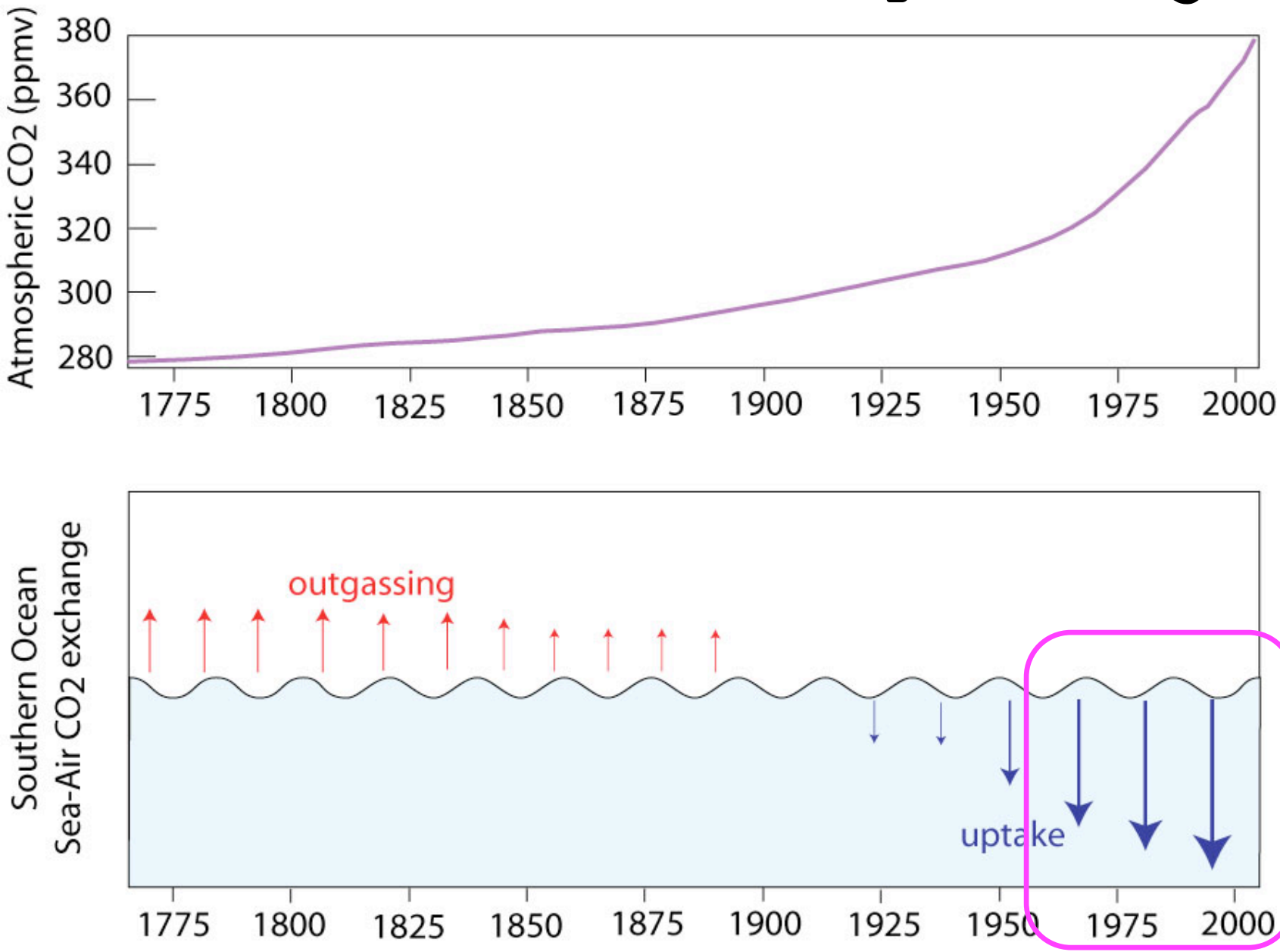
Lovenduski et al. (2007)

Part II:
Changes in Southern Ocean CO_2 fluxes

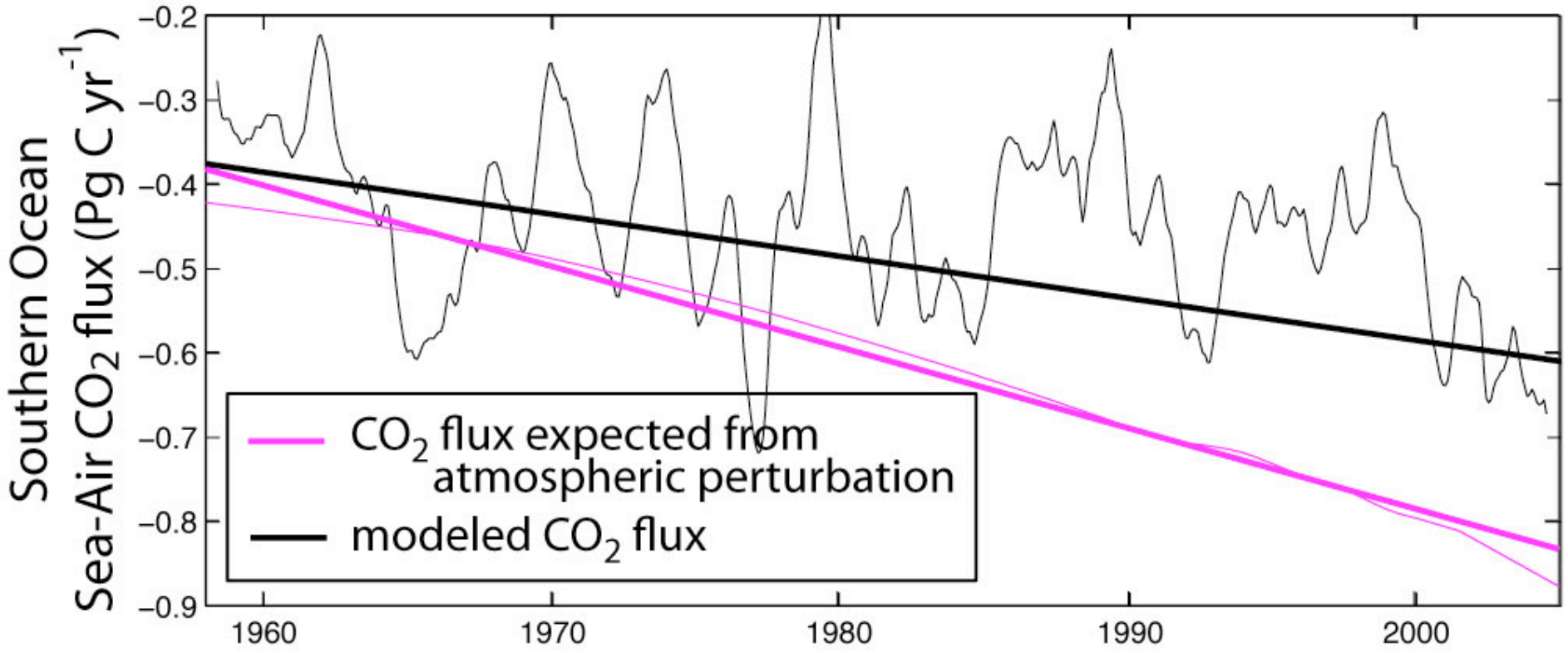
Historical evolution of CO_2 exchange



Historical evolution of CO_2 exchange

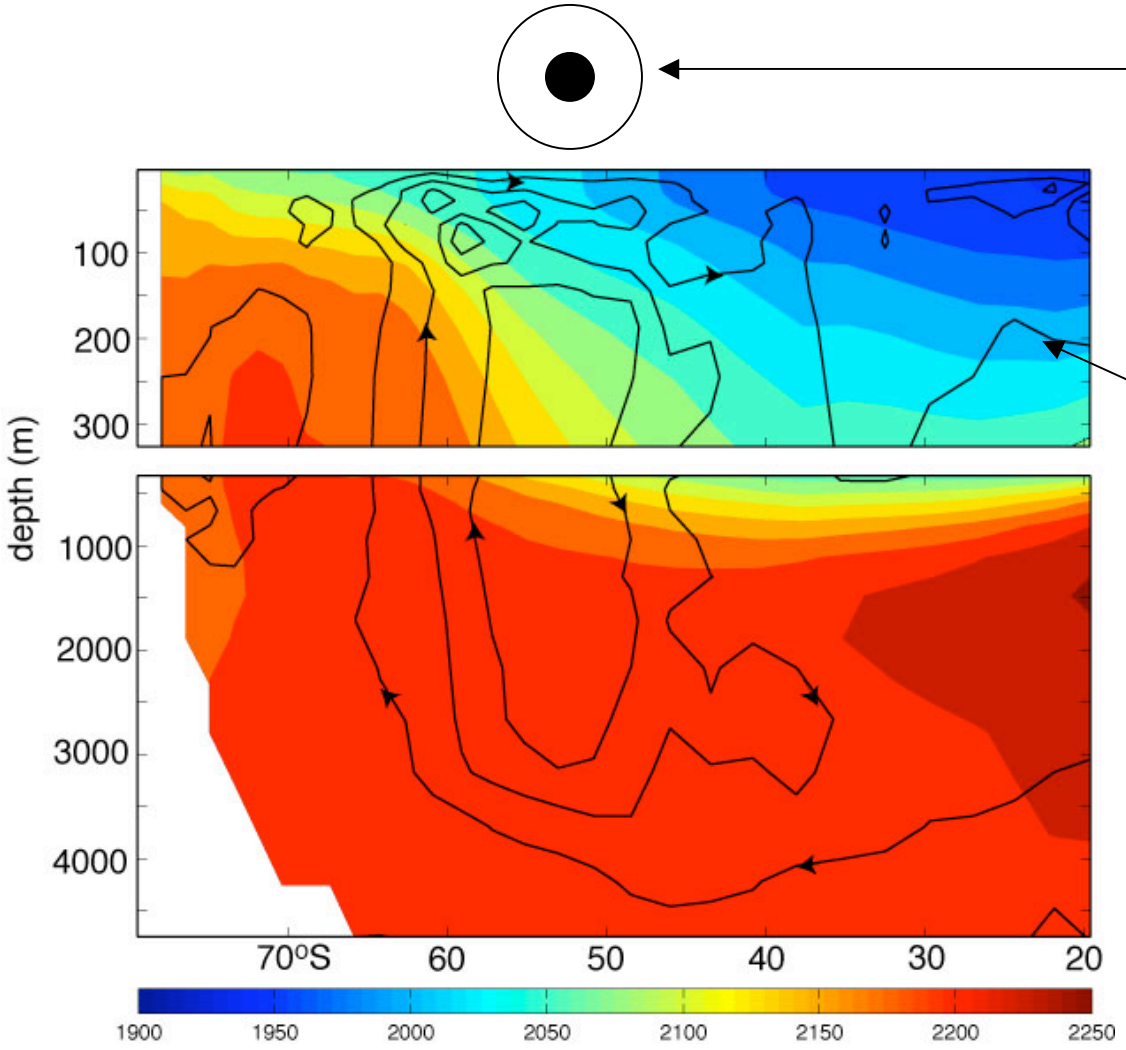


A recent change in the sink strength?



Lovenduski et al. (2008)

Underlying causes of change



trend in
wind stress

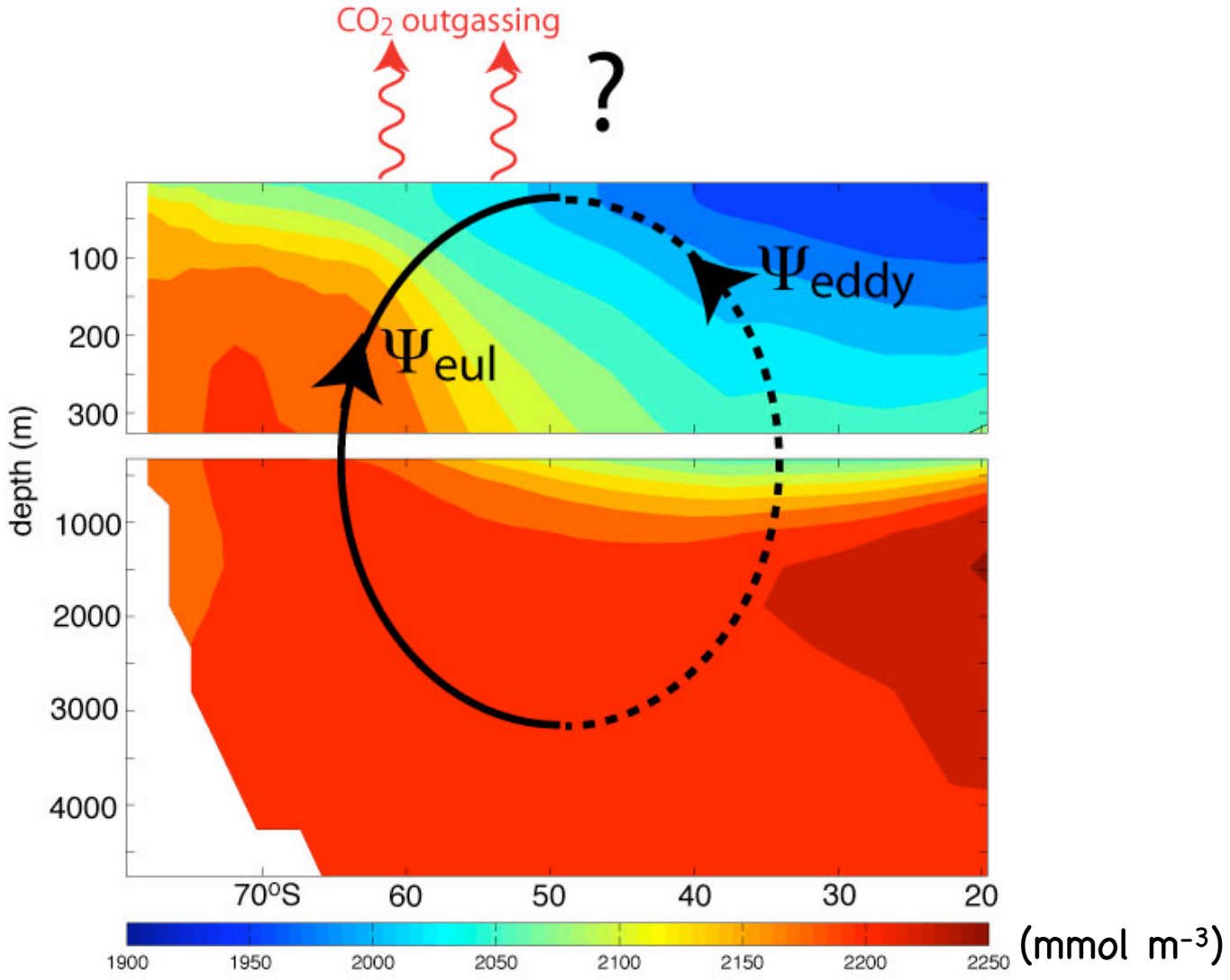
trend in
meridional overturning
(0.3 Sv yr^{-1} contours)

(mmol m^{-3})

zonal-mean dissolved inorganic carbon

Lovenduski et al. (2008)

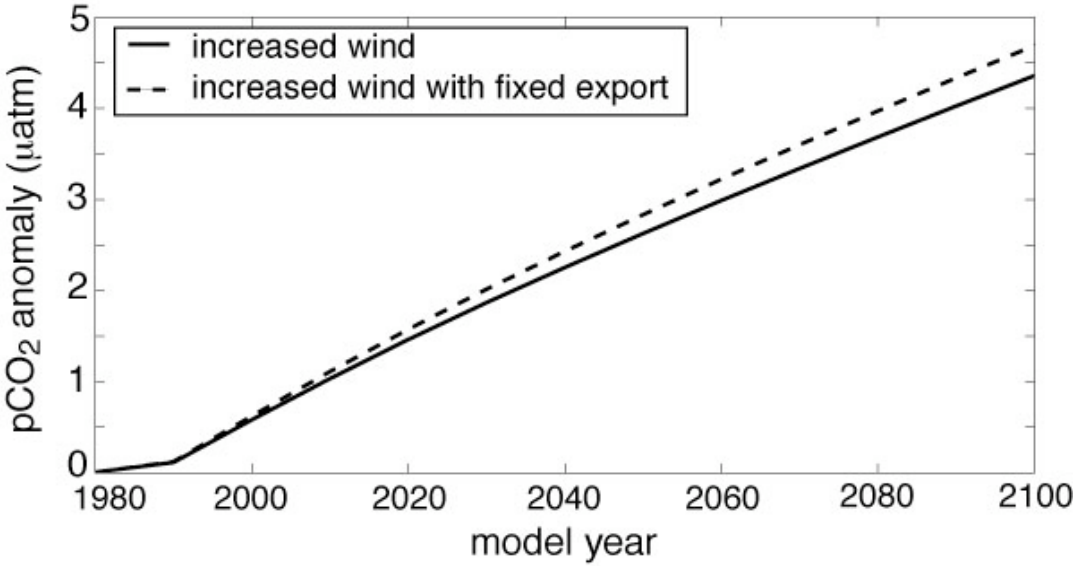
What about subgrid-scale processes?



zonal-mean dissolved inorganic carbon

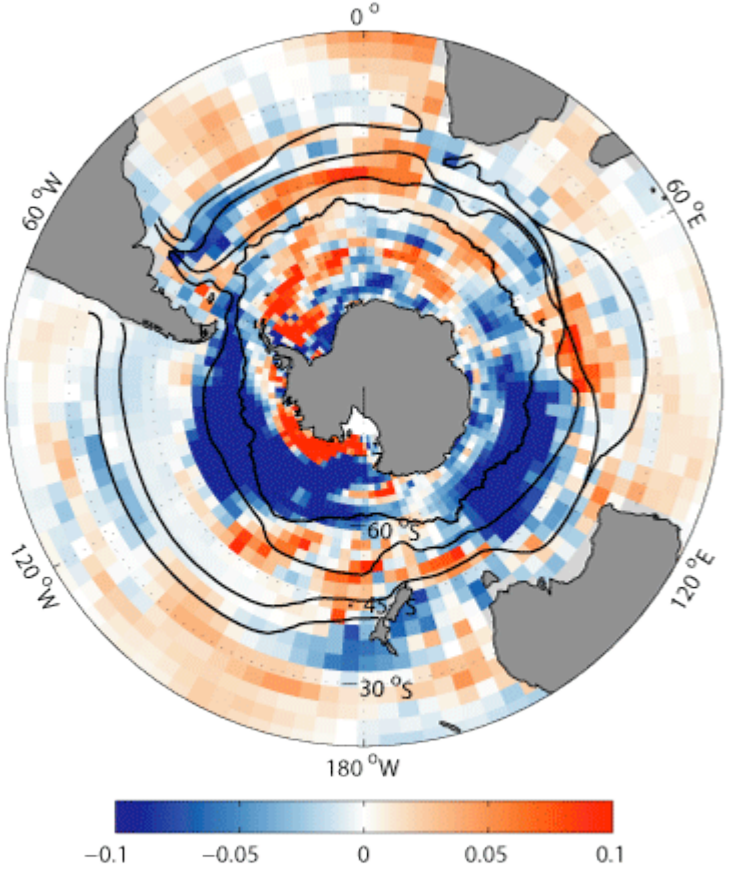
What role does biology play?

Surface ocean (<30°S) average pCO_2 anomaly with linearly increasing wind stress



Lovenduski and Ito (submitted)

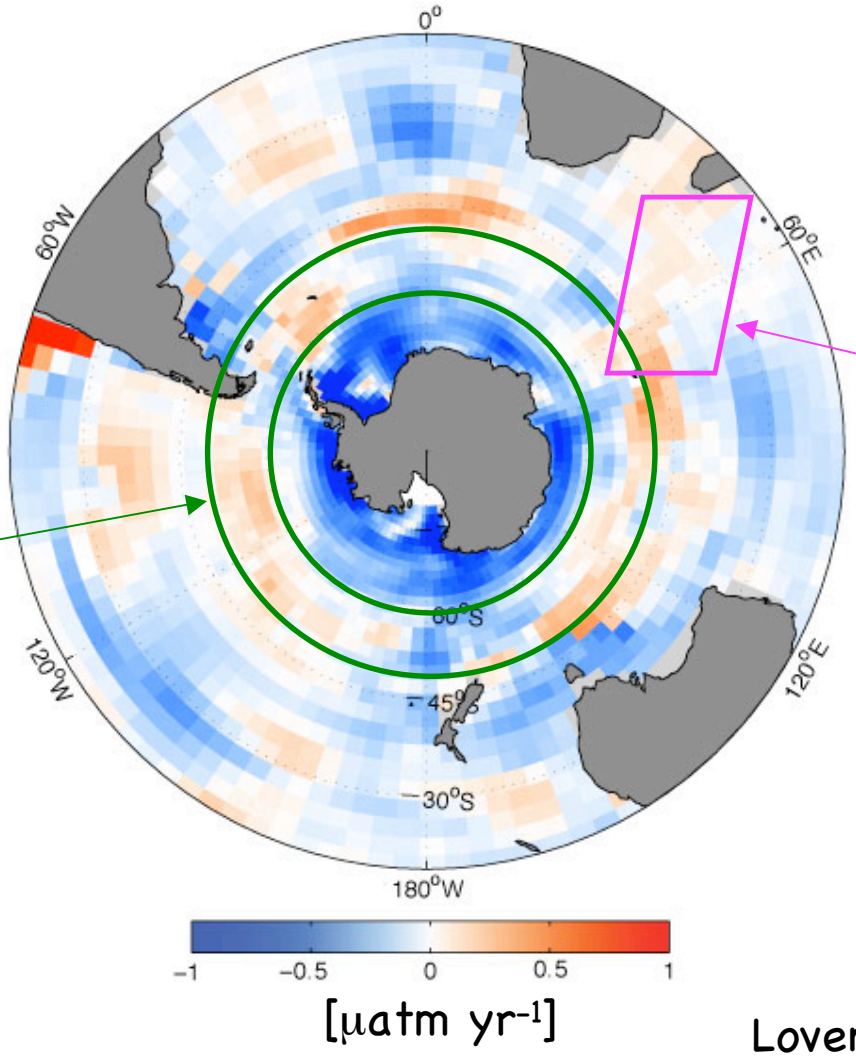
Southern Ocean chlorophyll anomalies during periods of increased wind stress



Lovenduski et al. (2007)

Are these trends observable?

modeled ΔpCO_2 trend
1979-2004



Takahashi et al. (2009):
observed trend
1986-2007
+0.5 μatm yr^{-1}

Metzl (2009):
observed trend
1991-2007
+0.4 μatm yr^{-1}

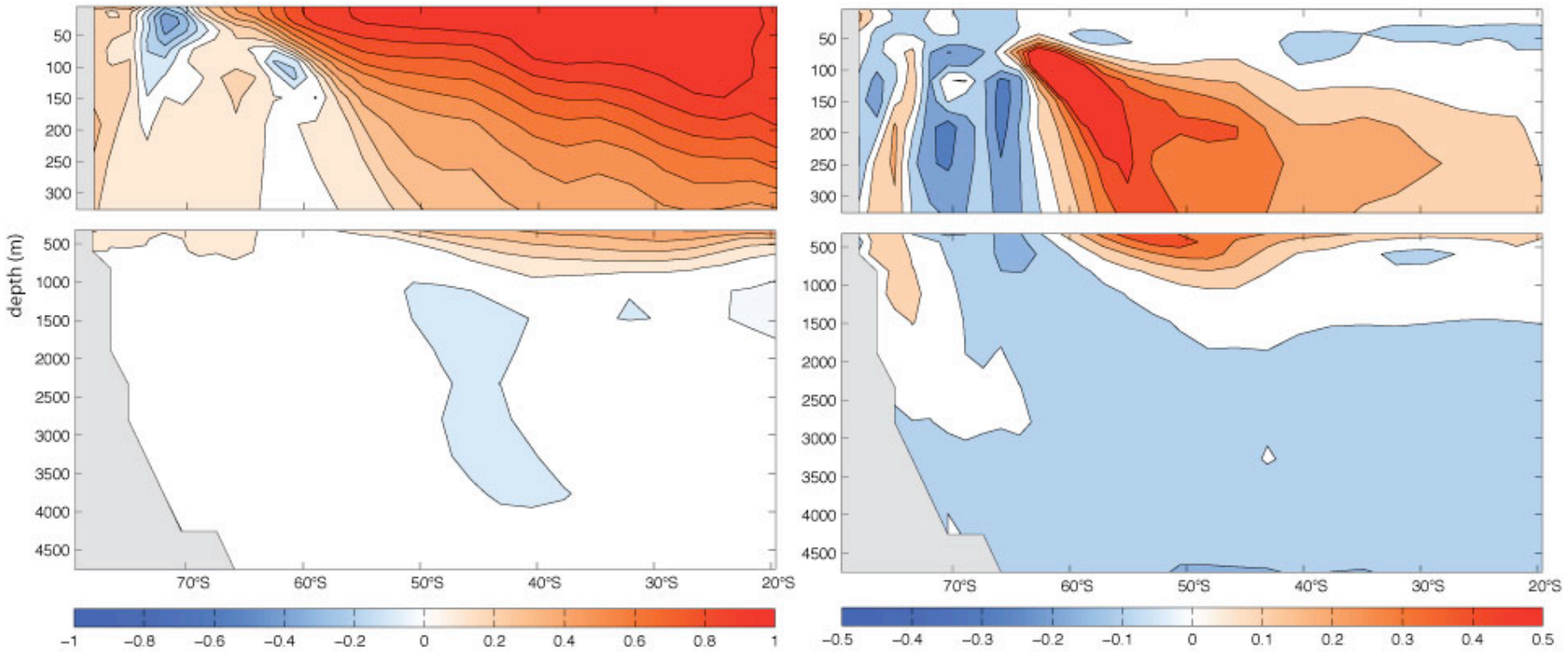
Lovenduski et al. (2008)

Are these trends observable?

modeled interior ocean trends

Dissolved Inorganic Carbon

Oxygen



(mmol m^{-3} yr^{-1})

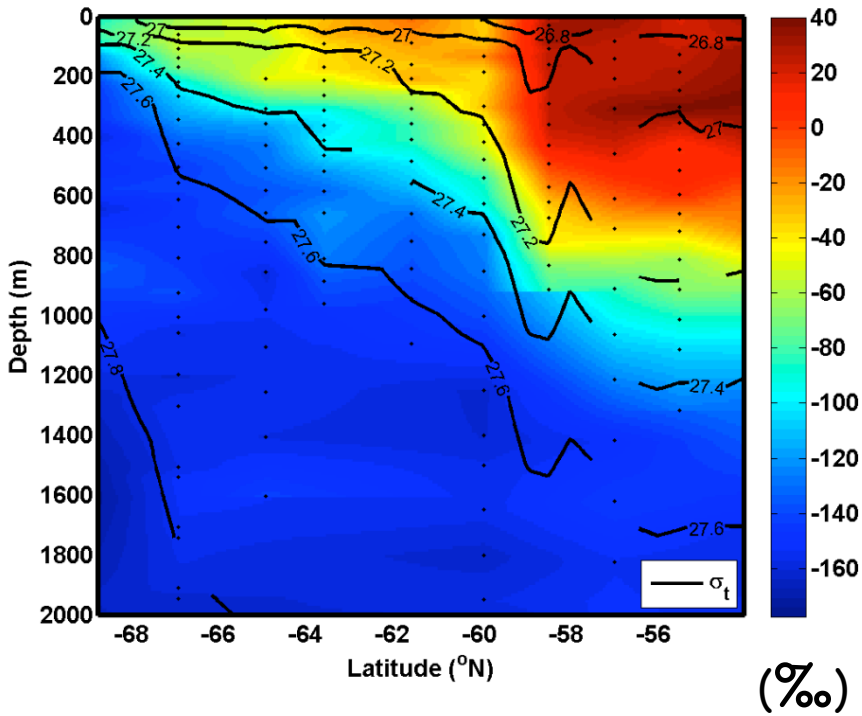
(mmol m^{-3} yr^{-1})

Lovenduski et al. (2008)

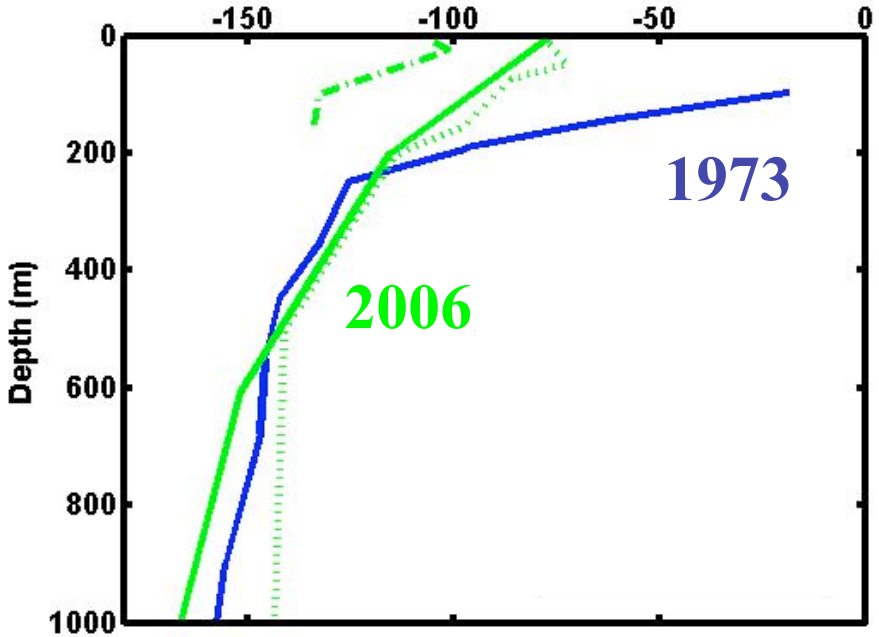
Are these trends observable?

observed $\Delta^{14}C$ in Drake Passage

mean $\Delta^{14}C$



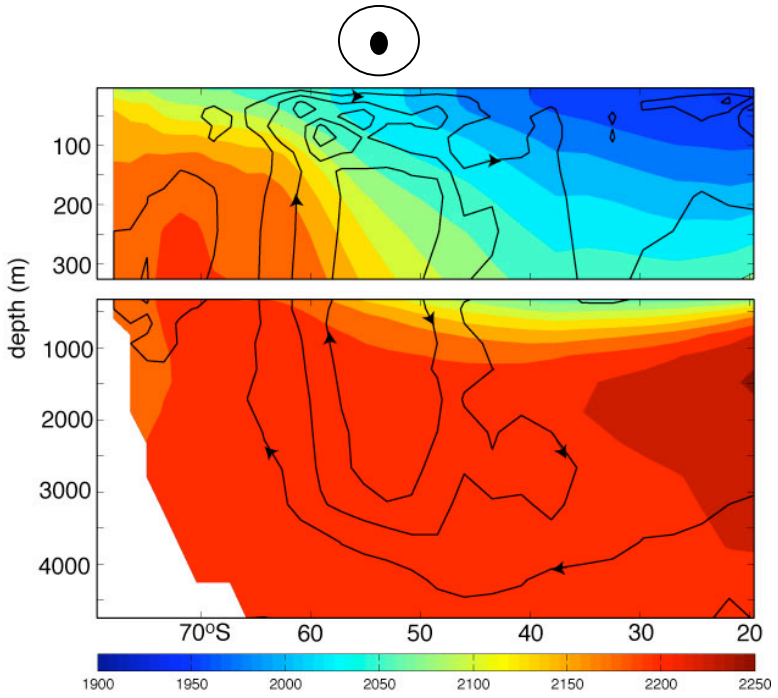
changes in $\Delta^{14}C$ (‰)



C. Sweeney (unpublished)

Summary

- Models and observations find that the Southern Ocean is a sink for atmospheric CO_2.
- The magnitude of the sink is model dependent and a function of physical and biogeochemical parameterizations.
- A number of model studies have shown that the Southern Ocean CO_2 sink has weakened over the past few decades as a result of stronger winds and overturning.
- There is some observational evidence to support the idea of a weakening CO_2 sink.



Unanswered Questions

1. How has the Southern Ocean carbon cycle behaved in the past?
2. What are the processes controlling Southern Ocean CO_2 fluxes today?
3. How will the Southern Ocean respond to future climate change, and how will this influence atmospheric CO_2?

Possible Solutions

Observational Efforts:

- Adequate sampling of Southern Ocean
- Determine processes controlling spatial and temporal distribution of carbon
- Early detection of changes in carbon and underlying processes

Modeling Efforts:

- Intercomparison of physical processes and model resolution
- Intercomparison of biogeochemical and ecological processes
- Prediction of changes in carbon and underlying processes