Ocean physics and biogeochemistry

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and

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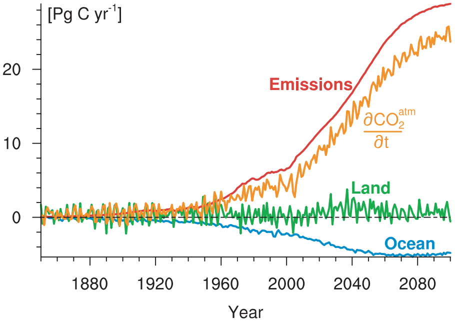
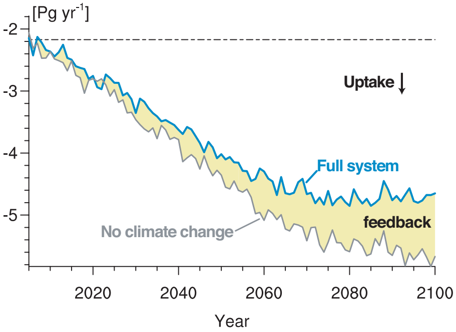
Breckenridge, CO
19 June 2012

RCP8.5 21st century

Surface CO_2 fluxes

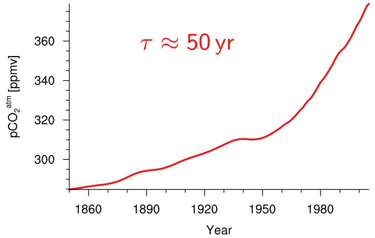


Ocean CO_2 uptake

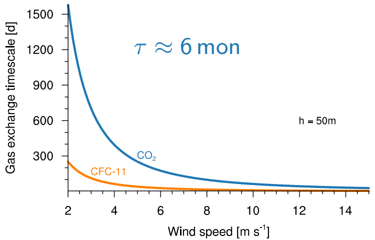


Ocean uptake: circulation is rate limiting

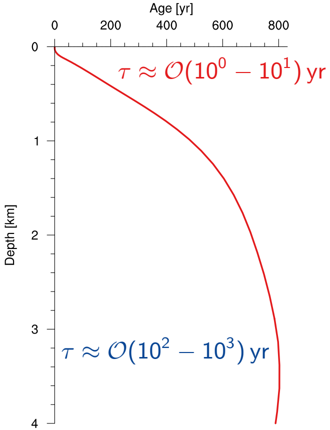
Anthropogenic pCO_2^{atm} perturbation



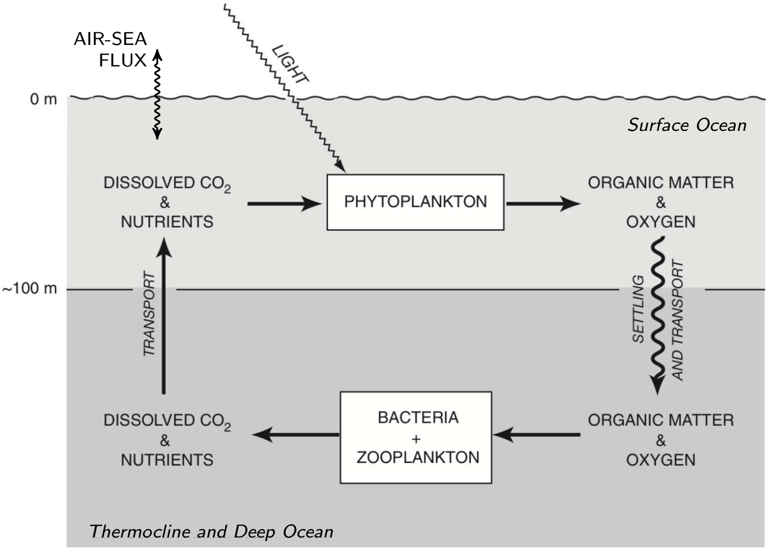
Gas exchange timescale ($\tau = \frac{h}{k}$)



Ventilation age



Biological pump

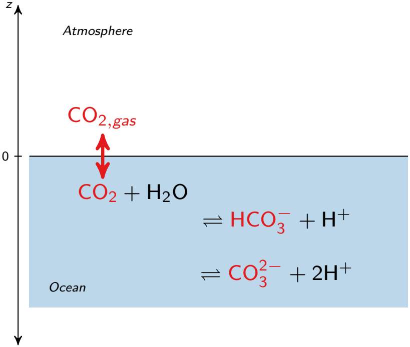


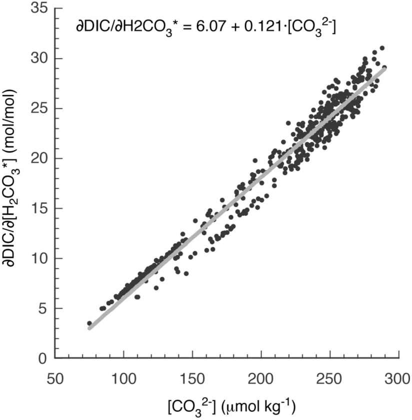
Sarmiento & Gruber 2006

Nonlinear carbon chemisty

Carbon in seawater

$$CO_{2,gas} + H_2O + CO_3^{2-} \rightleftharpoons 2HCO_3^-$$



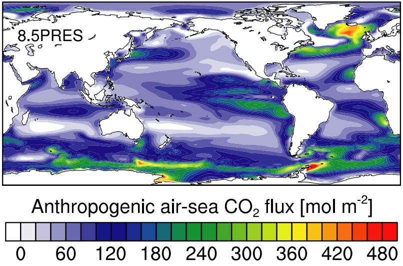


Sarmiento & Gruber 2006

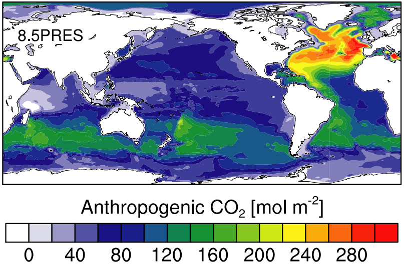
$$
\begin{aligned}
DIC &= \text{Dissolved inorganic carbon} \\
&= [CO_2] + [HCO_3^-] + [CO_3^{2-}]
\end{aligned}
$$

21st century ocean sink

Time-integrated flux anomaly



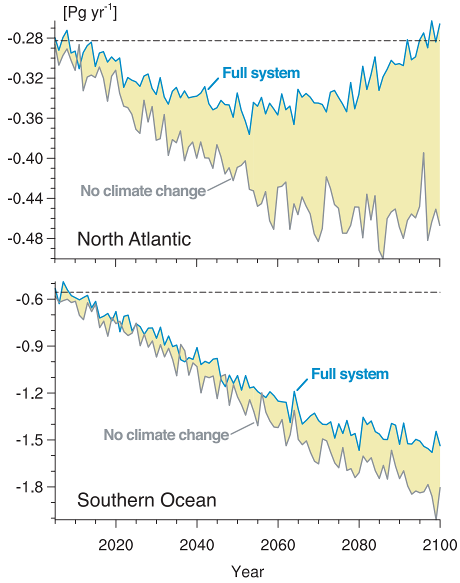
Storage (2100)



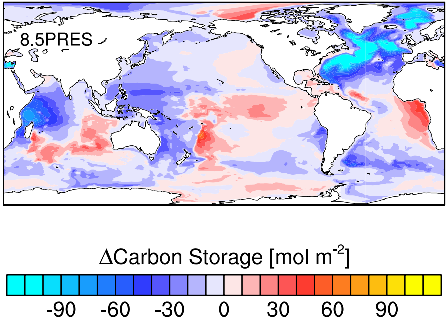
- Intense uptake in North Atlantic and Southern Ocean;
- Reduced outgassing in Equatorial Pacific.

Climate response in 21st century ocean sink

RCP8.5 sea-air CO_2 flux

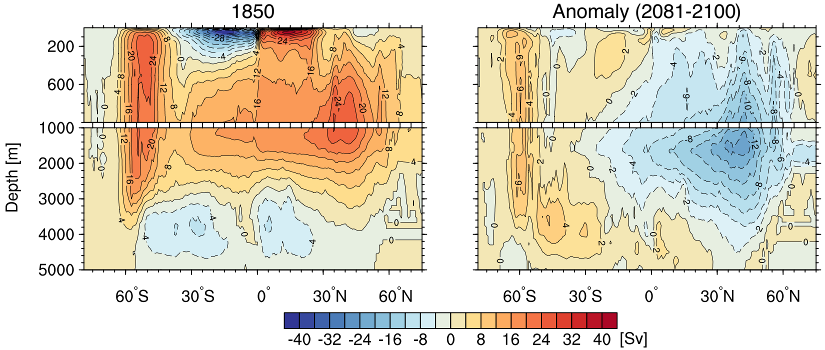


Climate-induced DIC anomaly



Ventilation rates

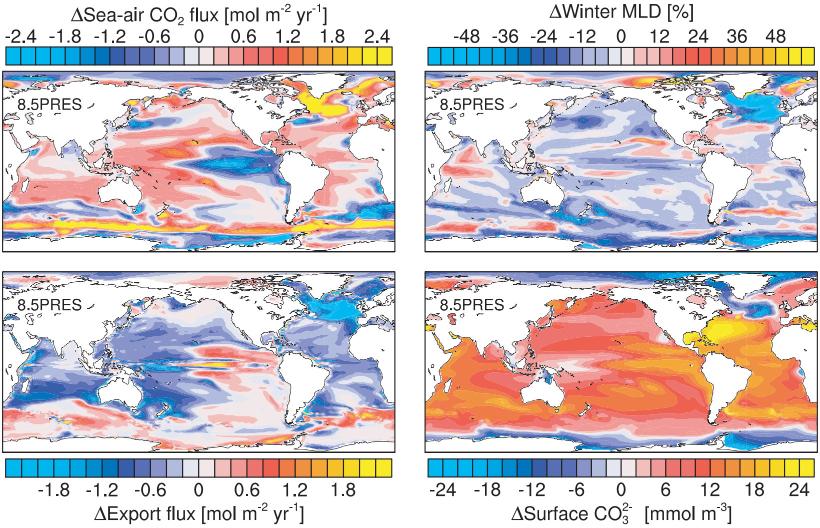
Meridional overturning circulation



- Poleward shift and slight intensification of Deacon Cell;
- Shoaling and reduction in North Atlantic overturning;
- AABW production reduced.

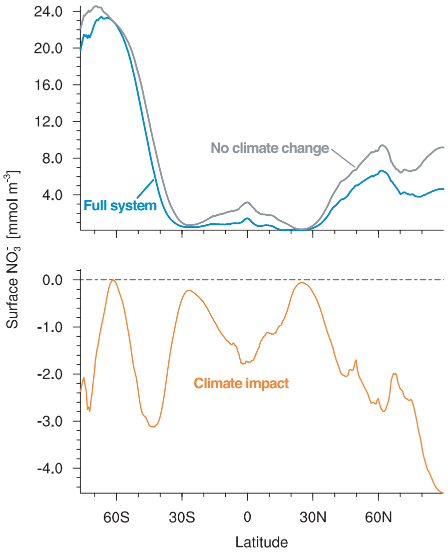
Mechanisms forcing climate response

Climate impact (full system minus constant climate integration)



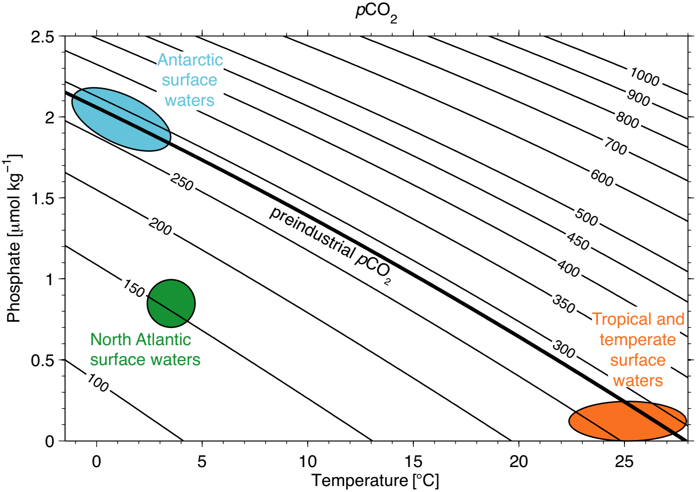
Reductions in surface nutrient

Zonal-mean surface nitrate



21st century ocean sink

Source waters



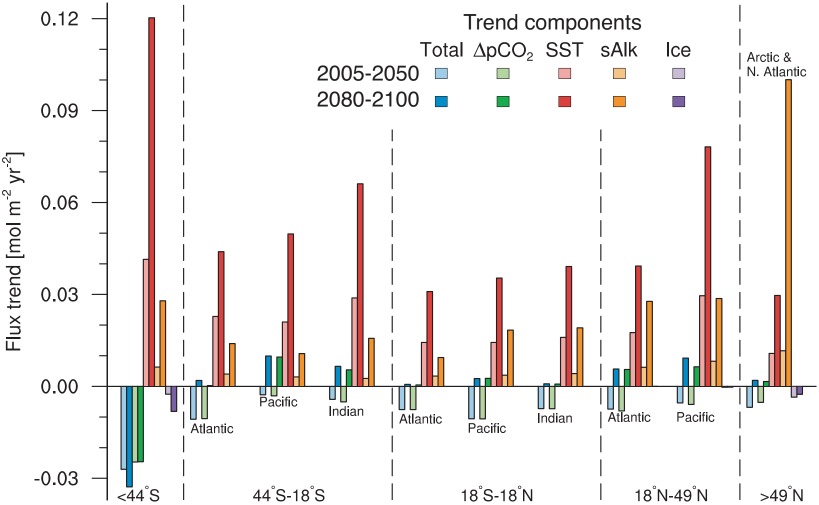
Sarmiento & Gruber [2006]

Summary

- Processes controlling ventilation rates are a fundamental contraint on nutrient cycles and transient tracer uptake.
- Ocean carbon sink stabilizes in the late 21st century under RCP8.5 due to chemistry feedbacks; climate feedbacks cause further reductions in sink strength.
- Differing circulation dynamics and biological response force different carbon cycle responses in the Southern Ocean and North Atlantic during the 21st century.

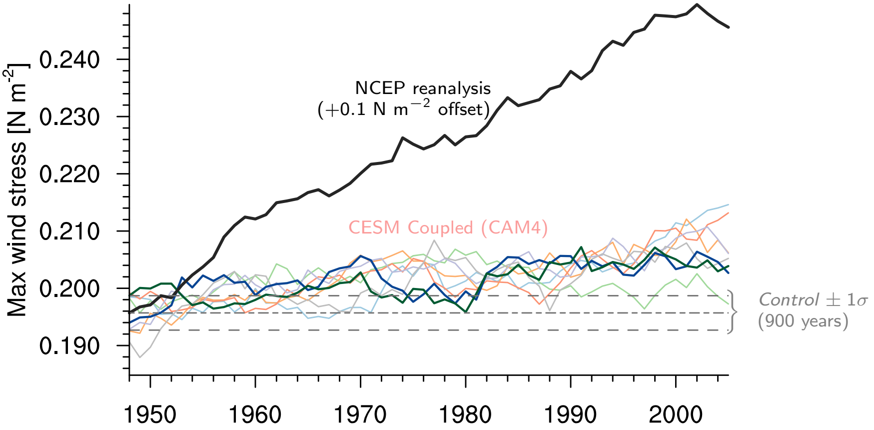
21st century ocean sink

Mechanisms forcing flux trends



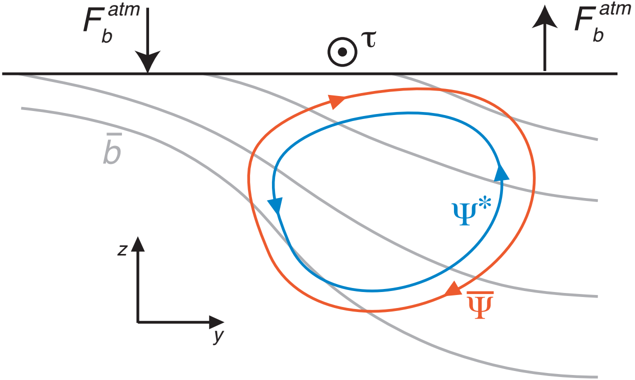
Trends in coupled model Southern Hemisphere windstress

Maximum zonal-mean zonal wind



11-year running mean

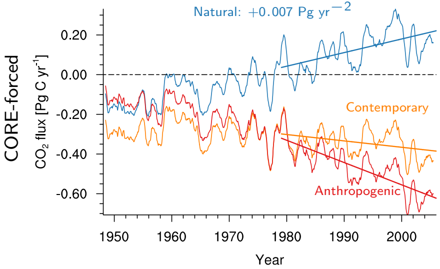
Residual mean theory

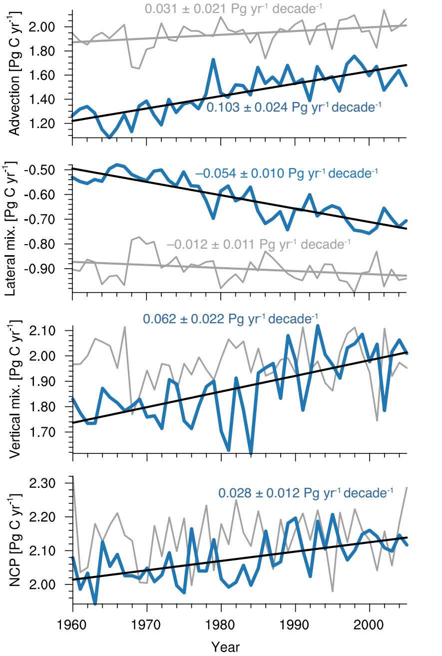


Marshall and Radko, JPO, 2003

Southern Ocean CO_2 fluxes

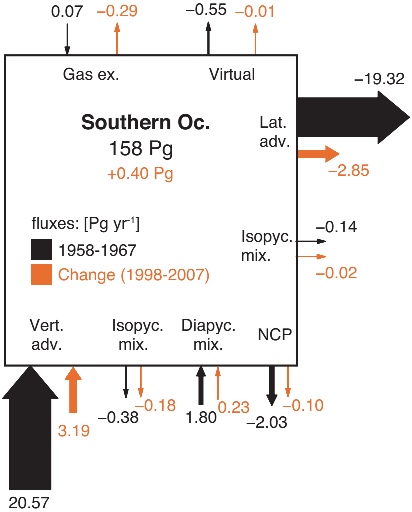
Spatially-integrated fluxes (south of 45°S)





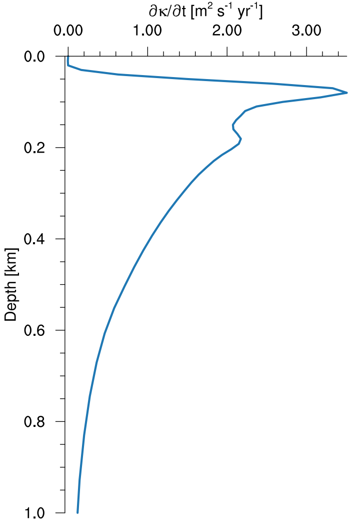
Variable eddy-induced advection coefficient

Upper ocean DIC budget ($z > -100$ m)

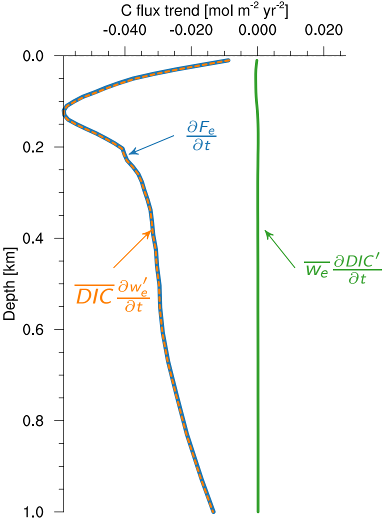


Variable eddy-induced advection coefficient

Trend in κ



Trend in eddy-induced DIC flux



Lovenduski et al., submitted to GRL