Ocean Carbon Uptake in CMIP-5 Models

Working Group members:
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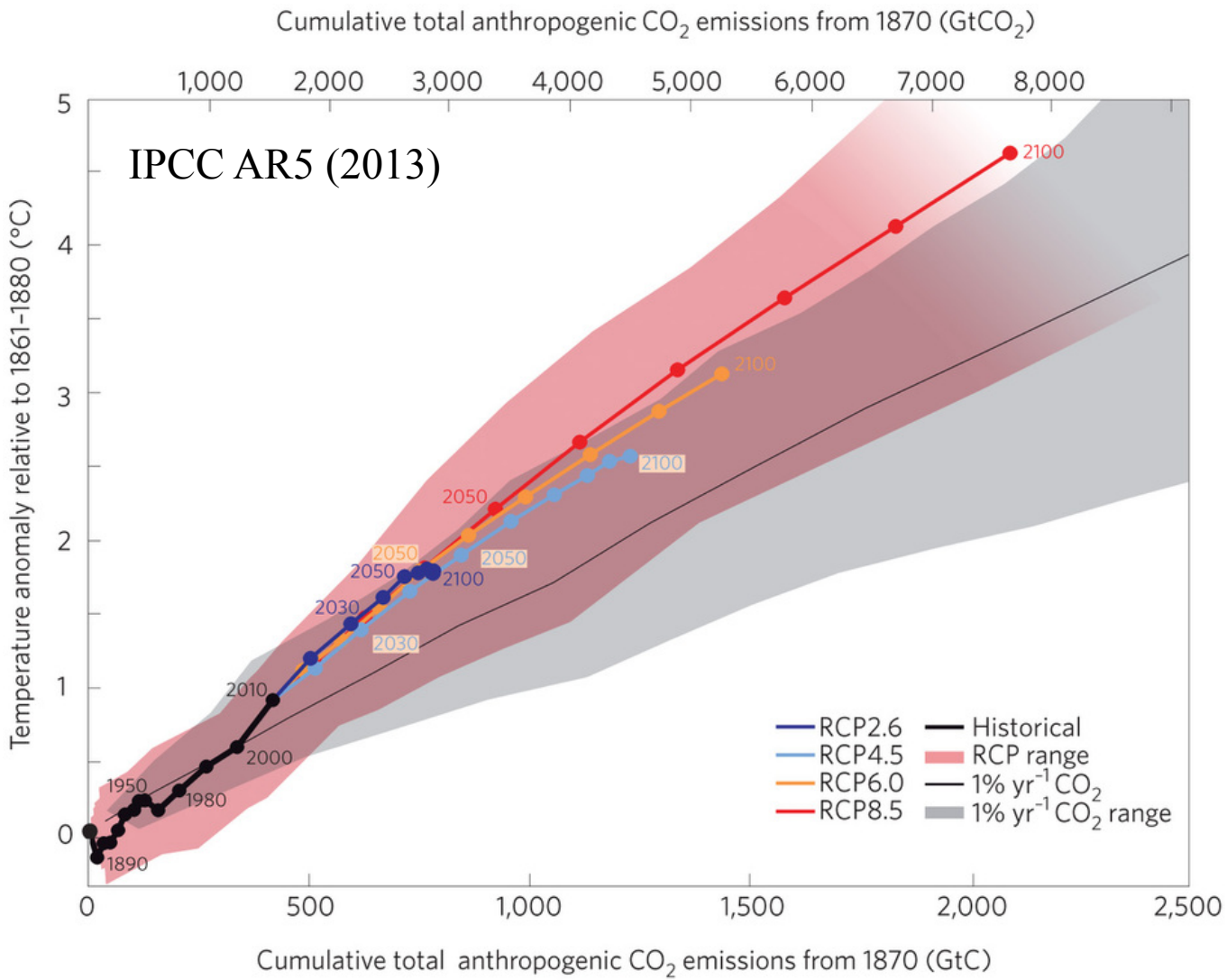
Objectives:

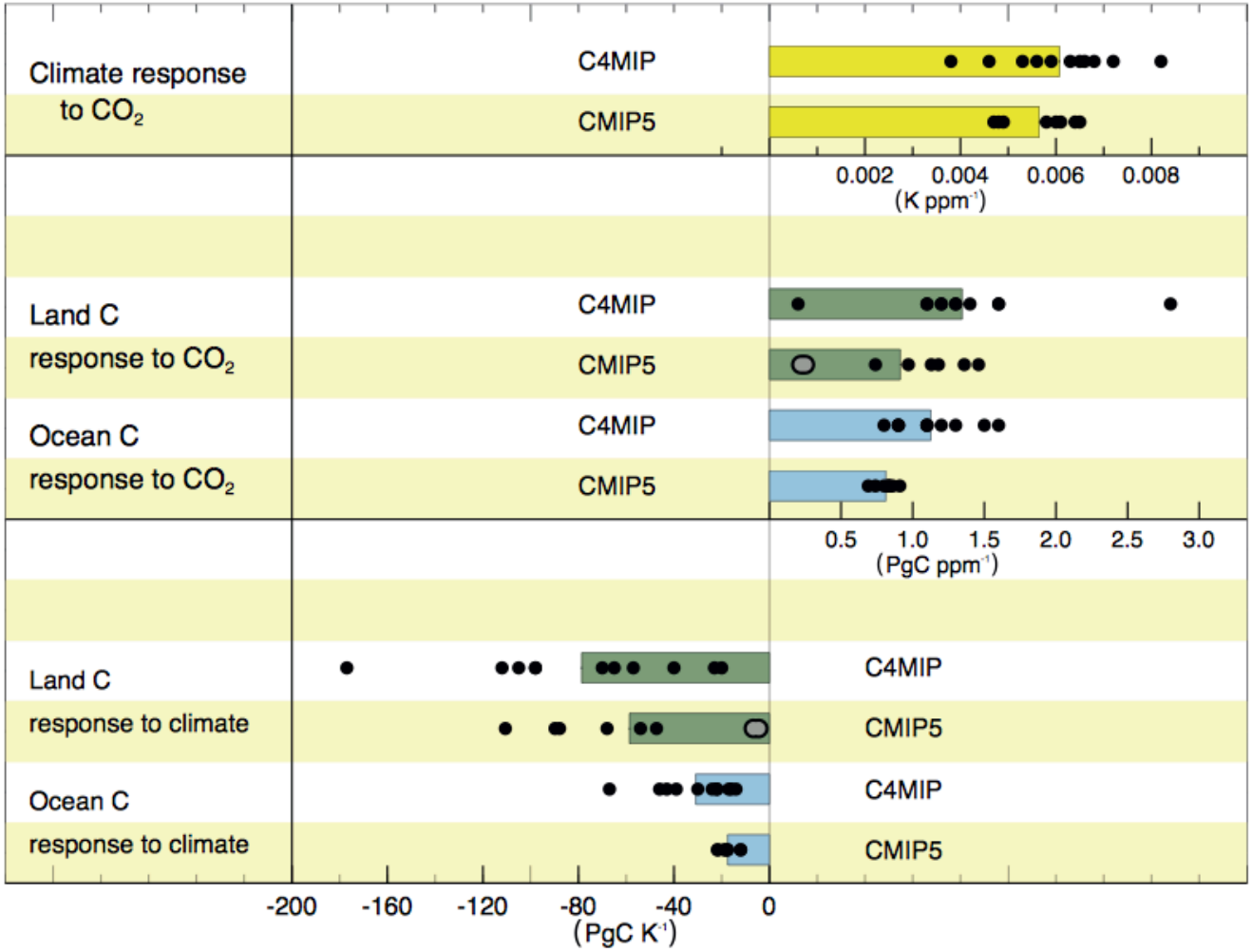
1. Foster and promote collaboration between members of the US CLIVAR and OCB communities and between modelers and theoreticians within each community.
2. Advance our understanding of the processes responsible for the oceanic carbon uptake and their representation in climate models.

Carbon Emission and Global Mean Temperature



Carbon-Climate Feedback in C4MIP/CMIP-5

IPCC AR5 (2013)



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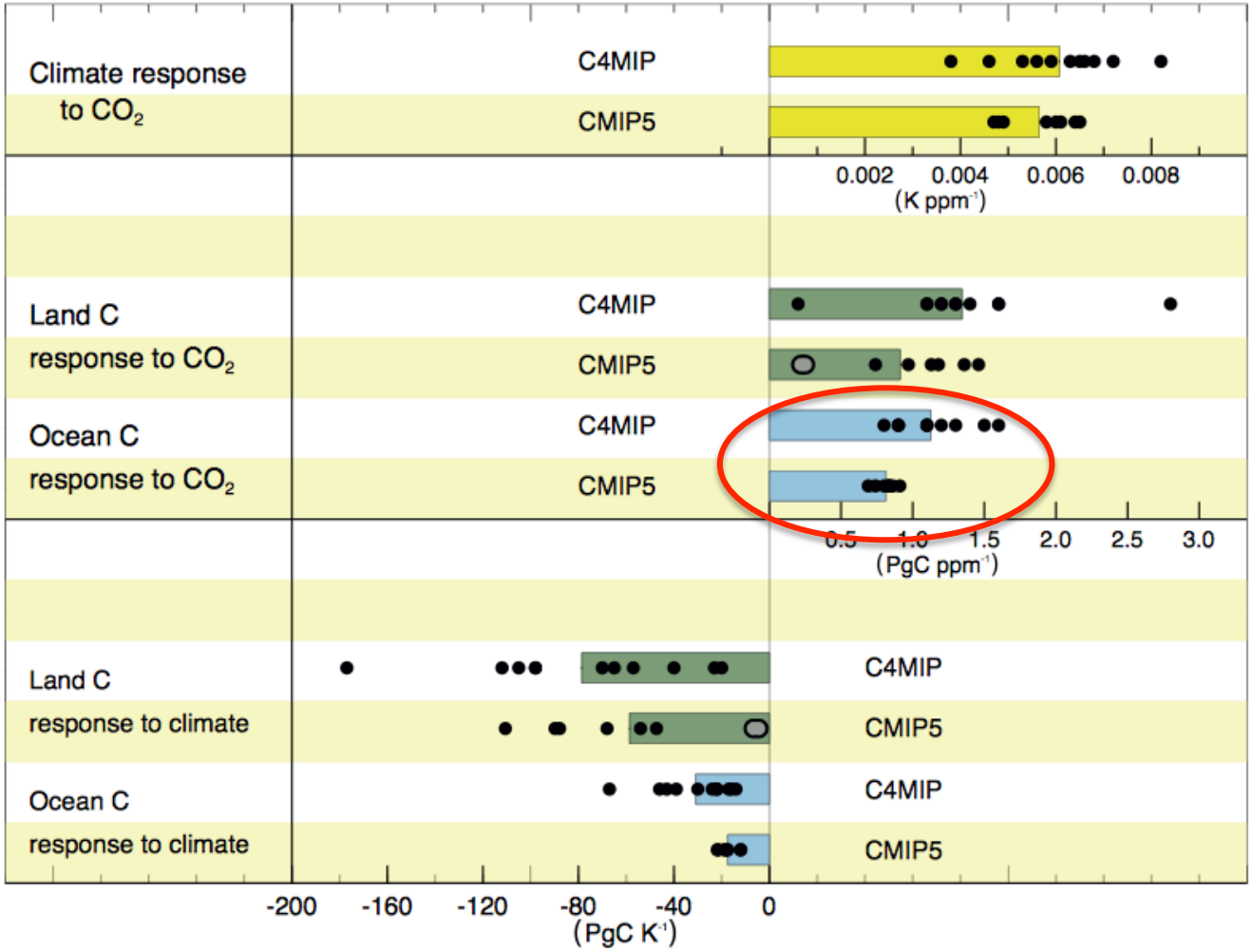

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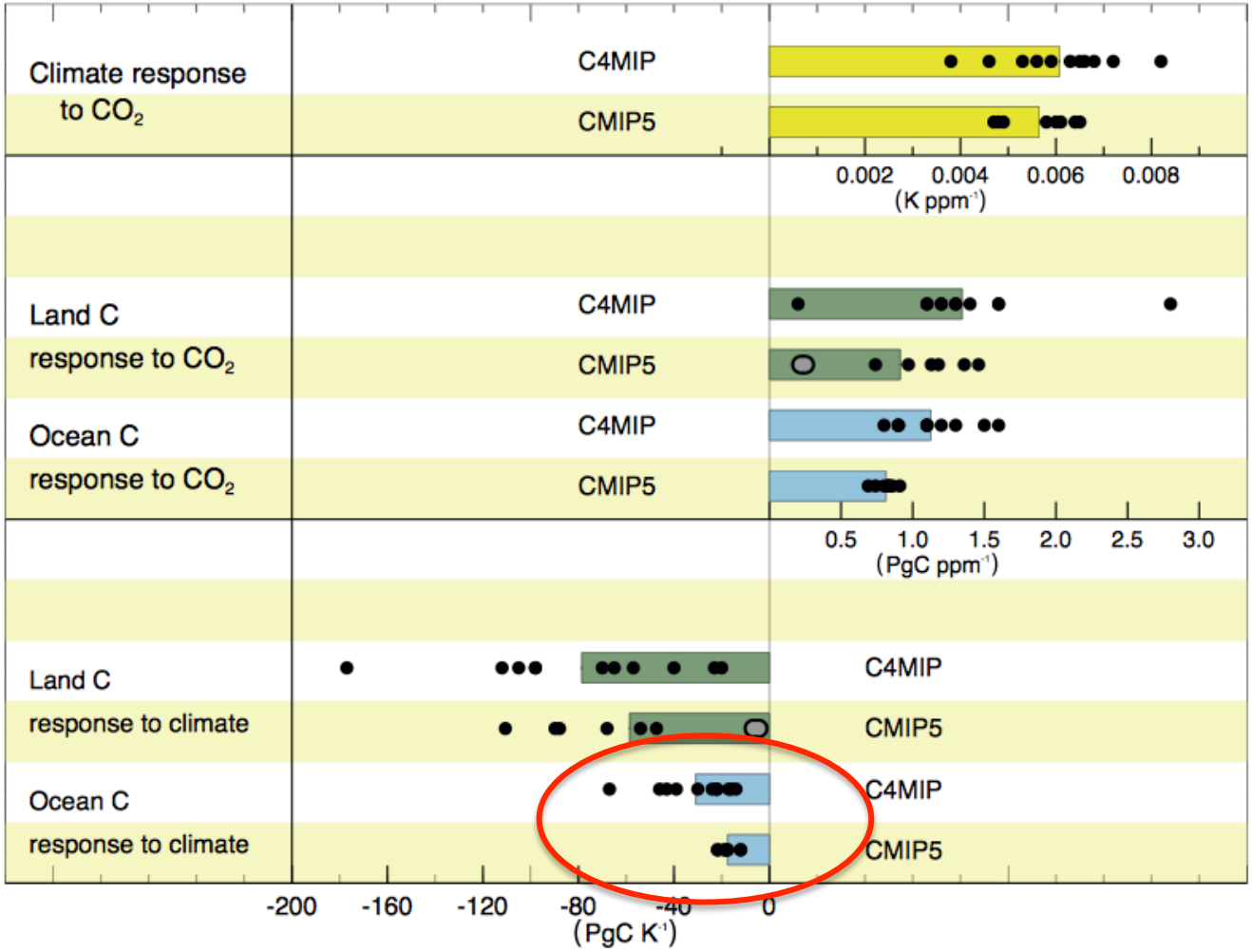
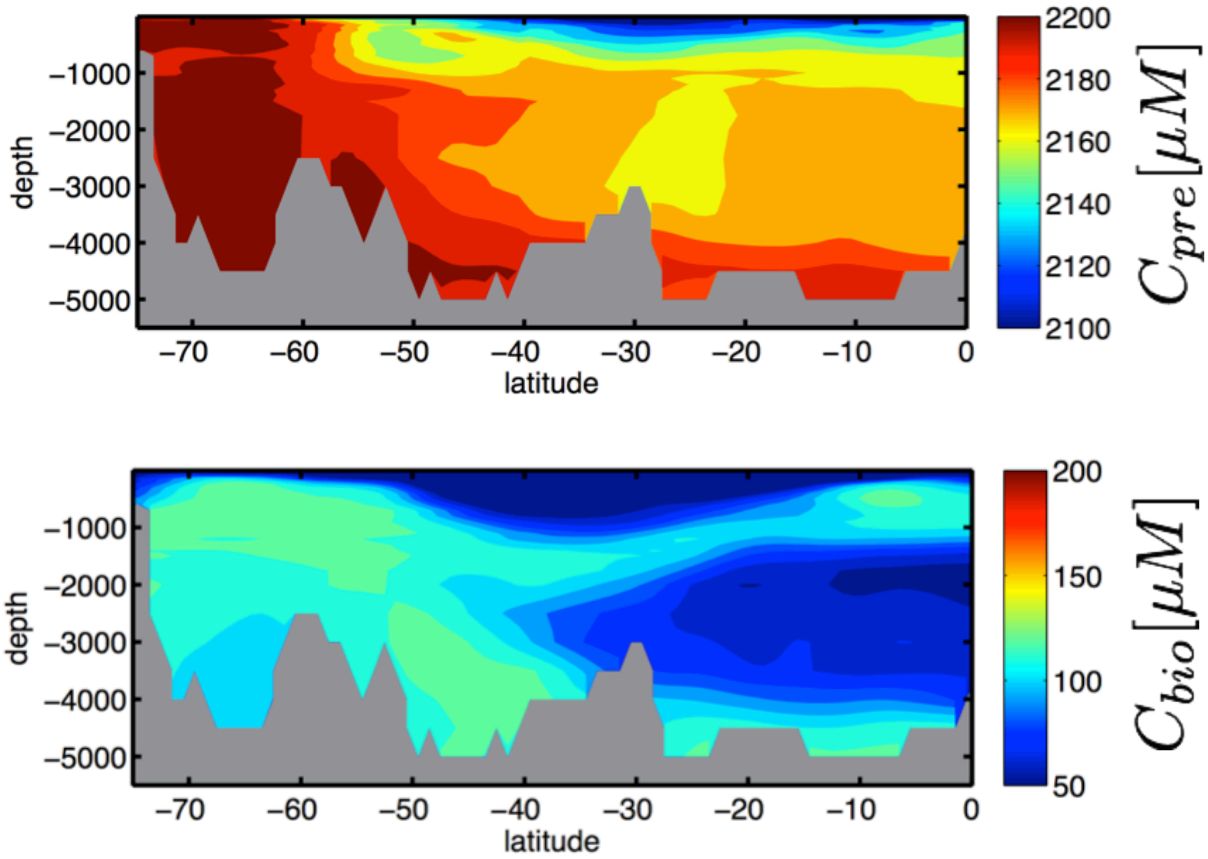


Metrics for climate-carbon feedback appear to be converging for the ocean carbon uptake. But how well are we representing the processes responsible for the ocean carbon uptake?

Ocean carbon pump and storage

The simplest, two-member decomposition $C = C_{pre} + C_{bio}$



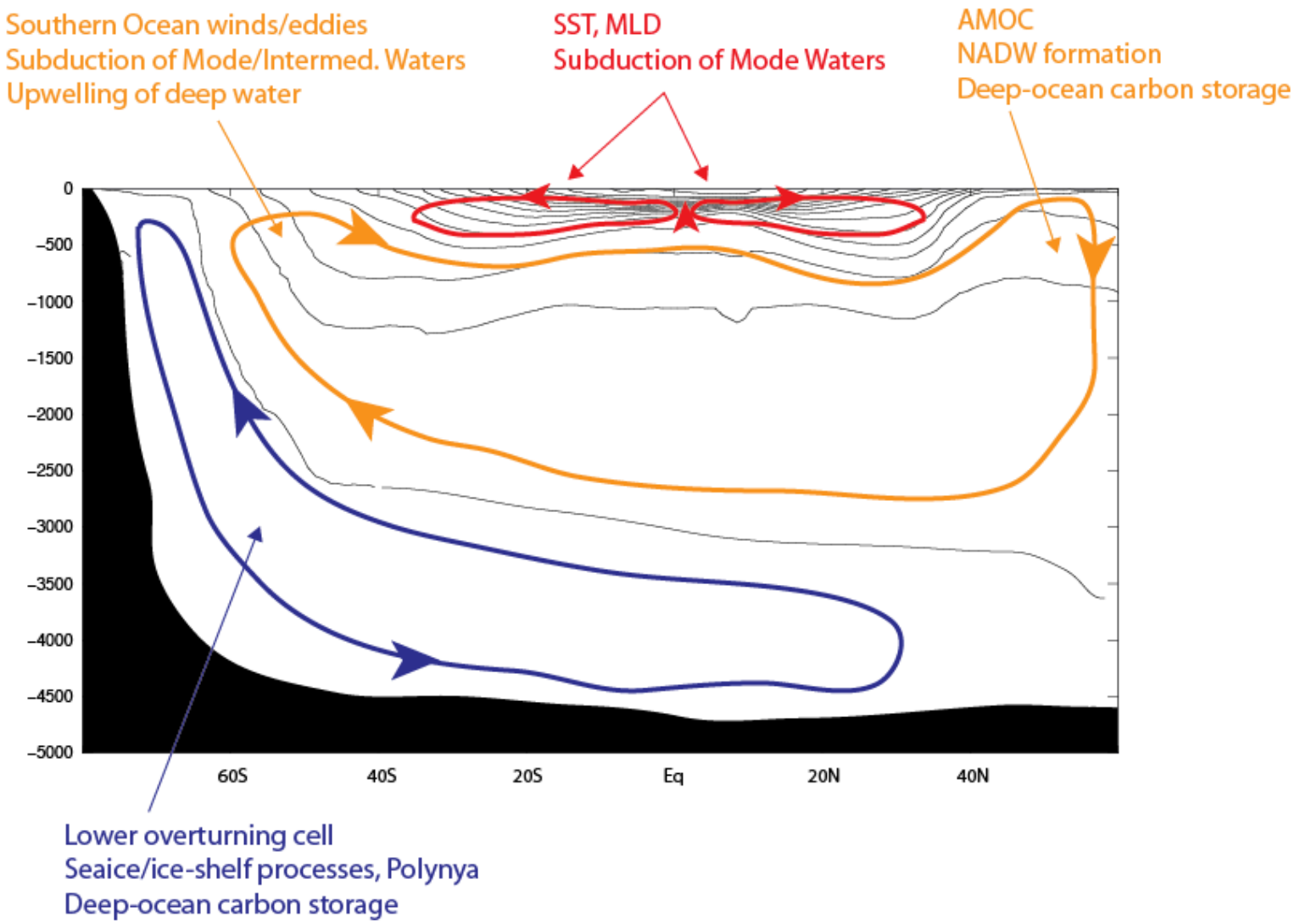
Preformed C is transported from the isopycnal outcrop

Cbio is generated by the dissolution of organic and carbonate particles

Atlantic 30°W GLODAP (Key et al., 2004)

Ocean carbon pump and storage

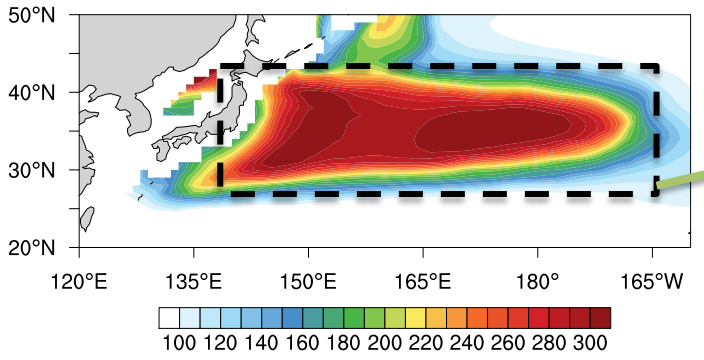
Key physical processes?



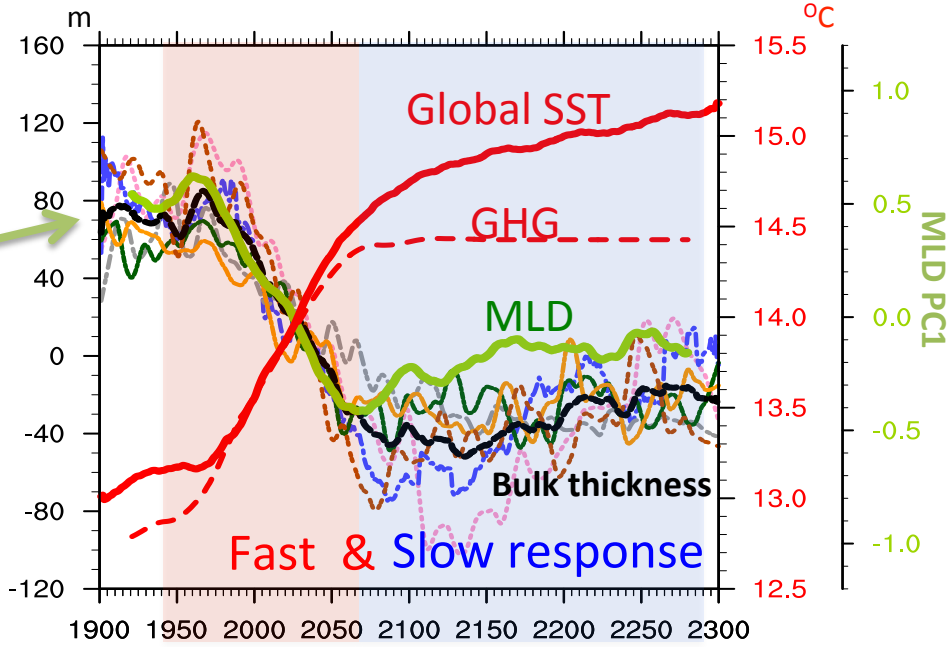
Fast and slow response of Ocean Mixed Layer and Mode Waters

Xu, L., S.-P. Xie et al. (2013, JOUC)

Extended RCP 4.5 runs by six CMIP5 models



In the Kuroshio Extension, deep mixed layer develops in winter, from which mode water subducts into the thermocline.

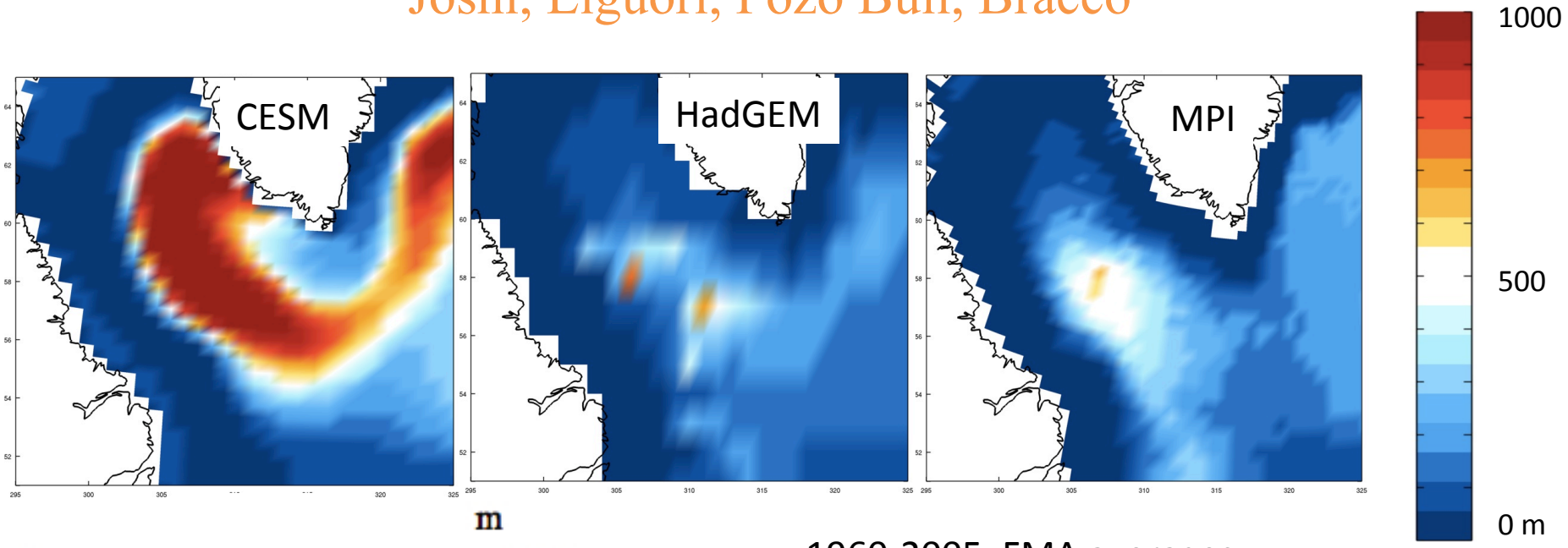


Response of ocean mixed layer and mode water consists of two distinct stages:

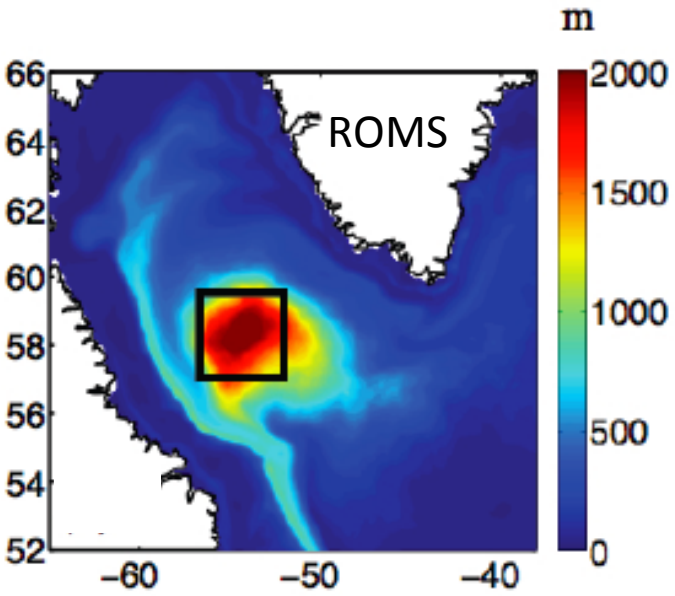
- Fast response with increasing radiative forcing: mixed layer depth (MLD) shoals and the mode water thickness shrinks rapidly as the surface warming strengthens the stratification.
- Slow response with radiative forcing leveling off after 2070: MLD and mode water change ceases despite a continual increase in global mean temperature. The ocean mixed layer is heated from beneath.

Labrador Sea convection in CMIP-5 models

Joshi, Liguori, Pozo Buil, Bracco

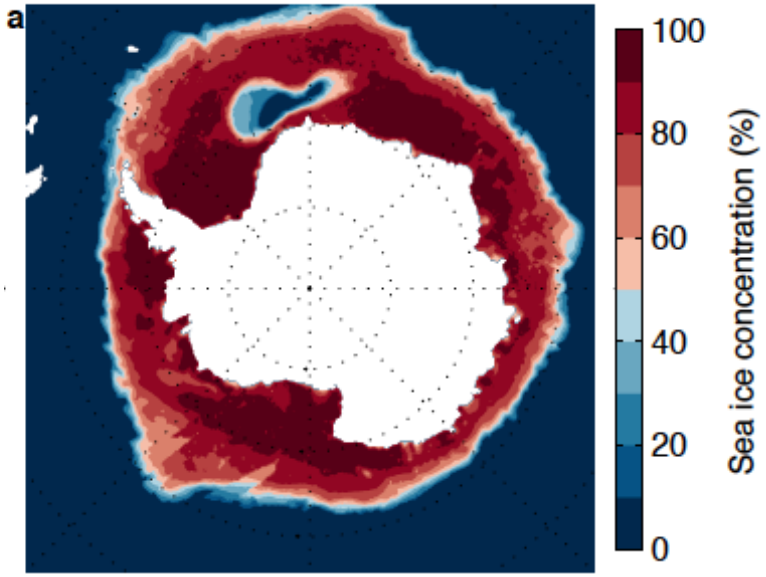


1960-2005, FMA averages

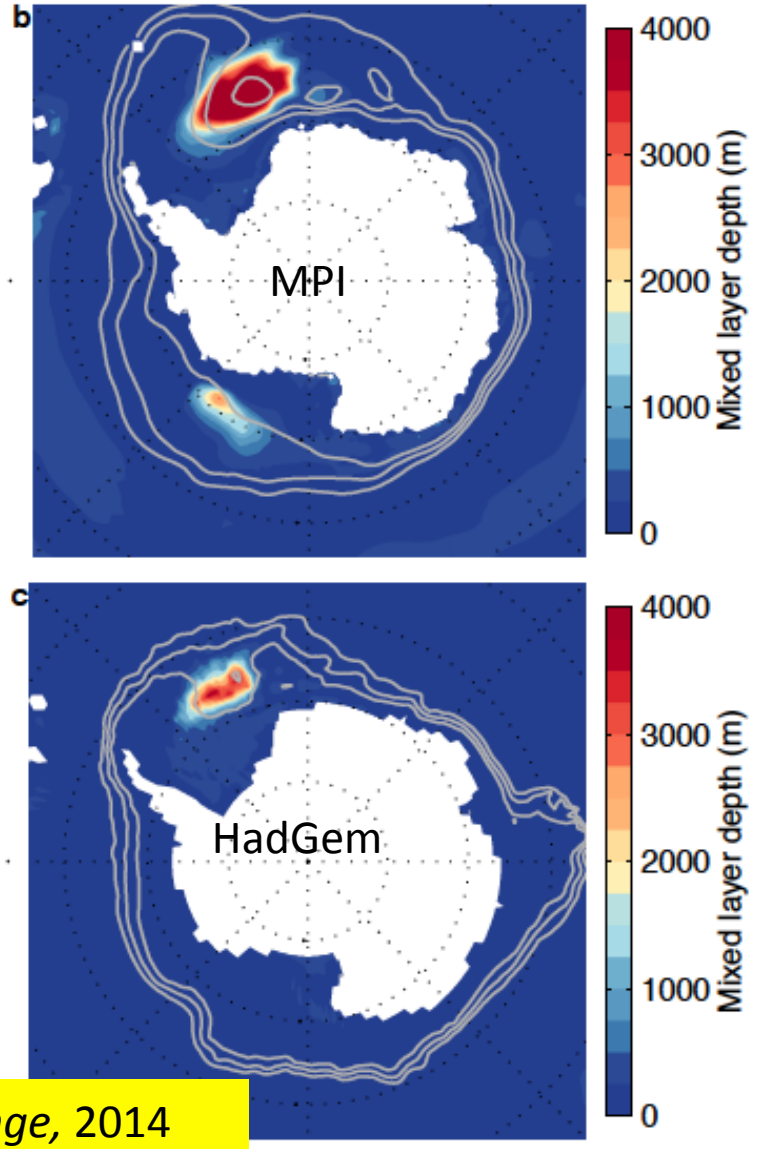


Mixed-layer depth in current climate in 3 CMIP5 models and in ROMS forced by NCEP fluxes.
The black box in the ROMS run indicates preferred location for deep convection, in observations. Model biases have profound implications for boundary current system structure and transport of LSW into the North Atlantic.

Southern Ocean Deep ocean convection—famously observed during the Weddell Polynya—is simulated by a majority of CMIP5 models under preindustrial conditions



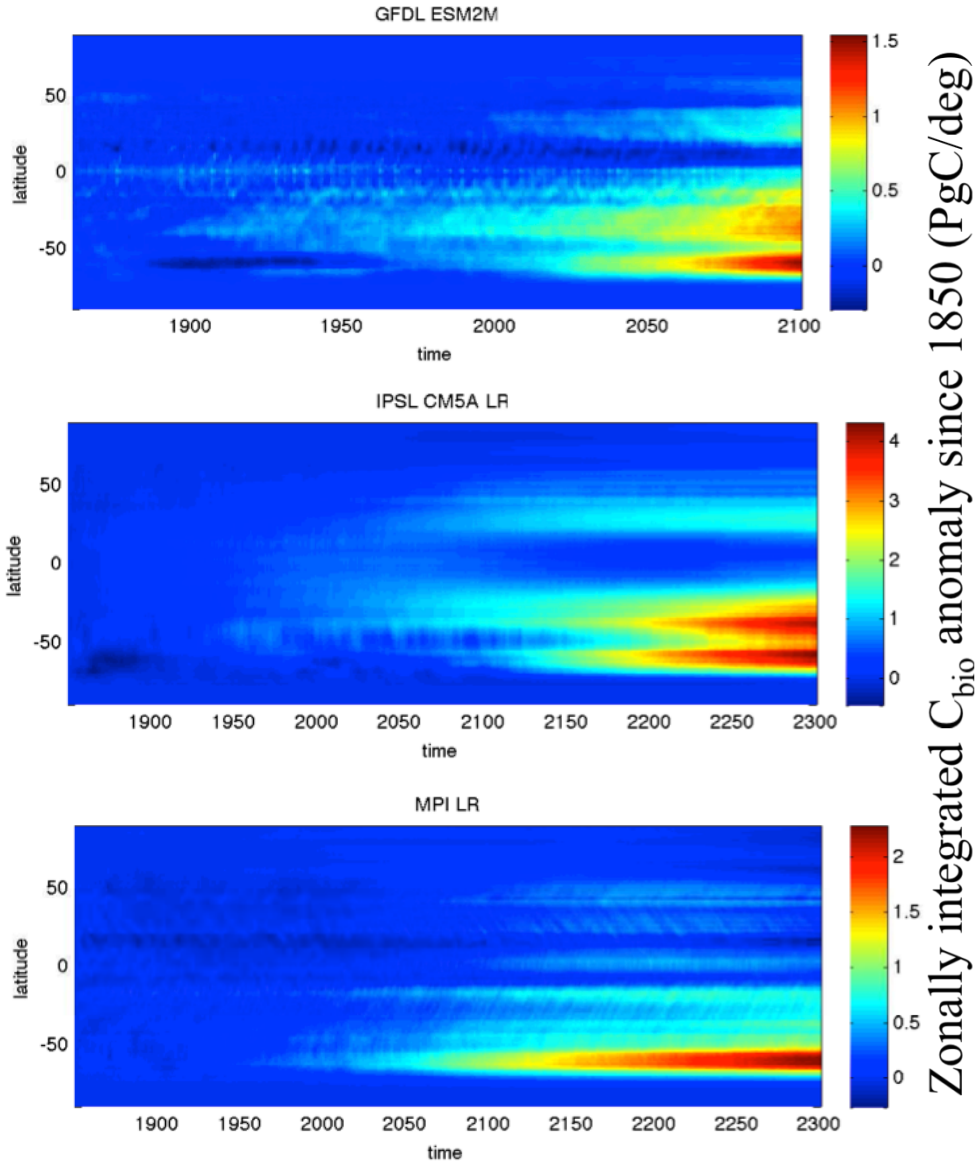
1974-1976 mean September sea ice - Satellite observations



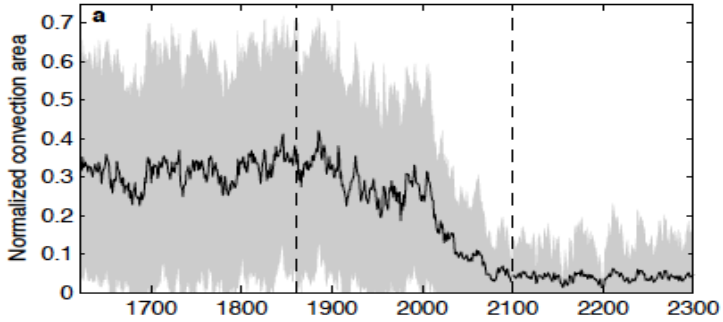
Mixed layer depth in two models with extended simulations, good AABW properties, and realistic-looking Weddell Polynya. Germany's MPI (top) and UK's HadGem (bottom).

DeLavergne et al., *Nature Climate Change,* 2014

Accumulation of C_{bio} in CMIP-5 models

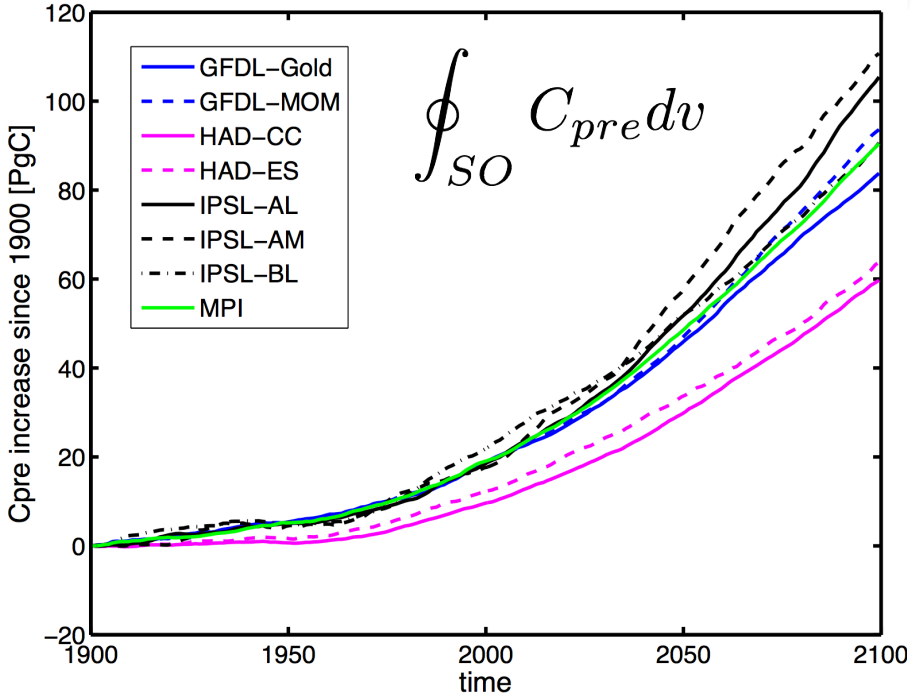


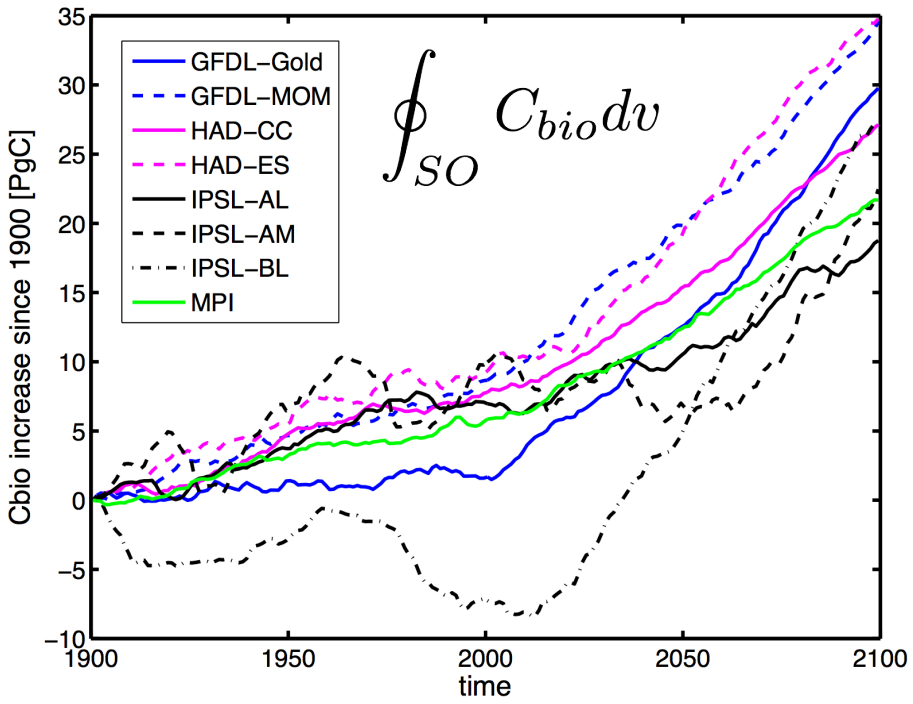
In the warming simulation (historic + RCP 8.5), the Cbio accumulates more strongly in the Southern Hemisphere.



Weakening of the Southern Ocean convection is a robust feature of the CMIP-5 models (DeLavergne et al. 2014).

CMIP-5 carbon storage (40°S-80°S)





- $+\Delta C_{pre}$, O(100 PgC) by 2100
- Primarily anthropogenic C uptake in the mode/ intermediate water

- $+\Delta C_{bio}$, O(30 PgC) by 2100
- Associating O_2 decline
- Weakening of the lower cell MOC under warming climate

Ocean Carbon Uptake in CMIP-5 Models

- Models show multiple timescales in the upper ocean response (MLD, Mode Water volume)
- Representations of key physical/biogeochemical processes vary widely, especially at high latitudes
- Globally integrating ocean C uptake may have masked these differences potentially due to the intrinsic compensations among different C reservoirs

- NCAR ASP summer colloquium 2013 “Carbon-Climate Connections in the Earth System Models” (Thomas et al., 2013, EOS)