Ocean Carbon Uptake in CMIP-5 Models

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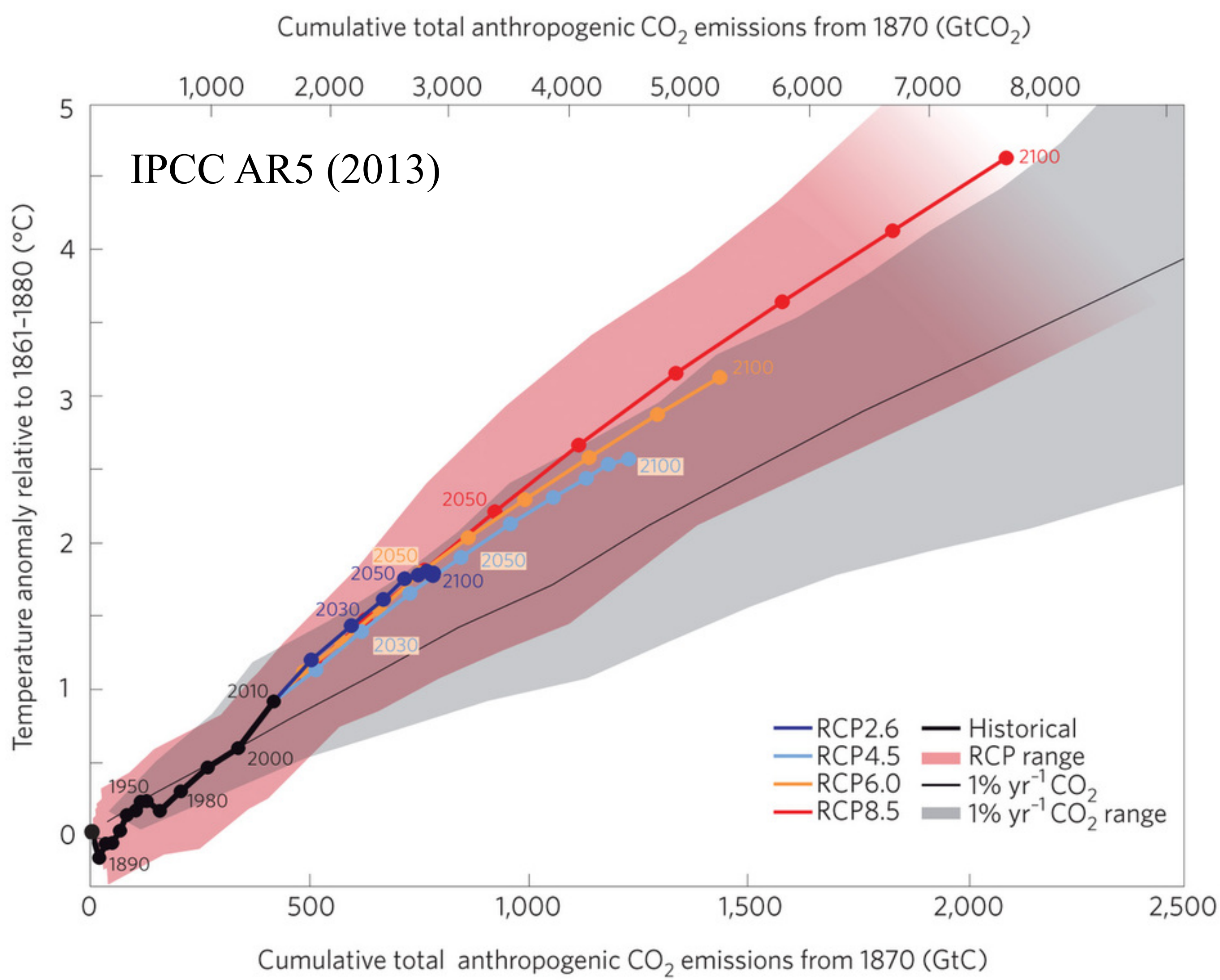
Objectives:

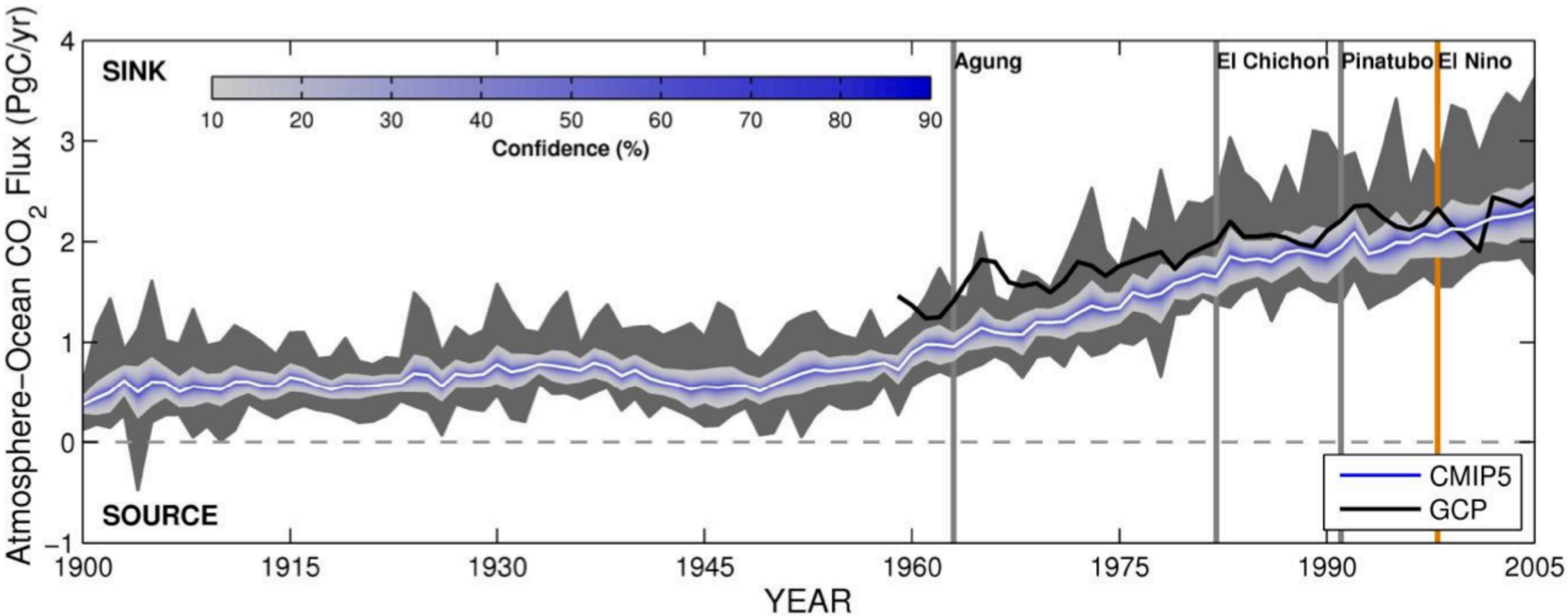
1. Foster and promote collaboration between members of the US CLIVAR and OCB communities and between modelers and theoreticians within each community.
2. Advance our understanding of the processes responsible for the oceanic carbon uptake and their representation in climate models.

Carbon Emission and Global Mean Temperature



Ocean carbon uptake

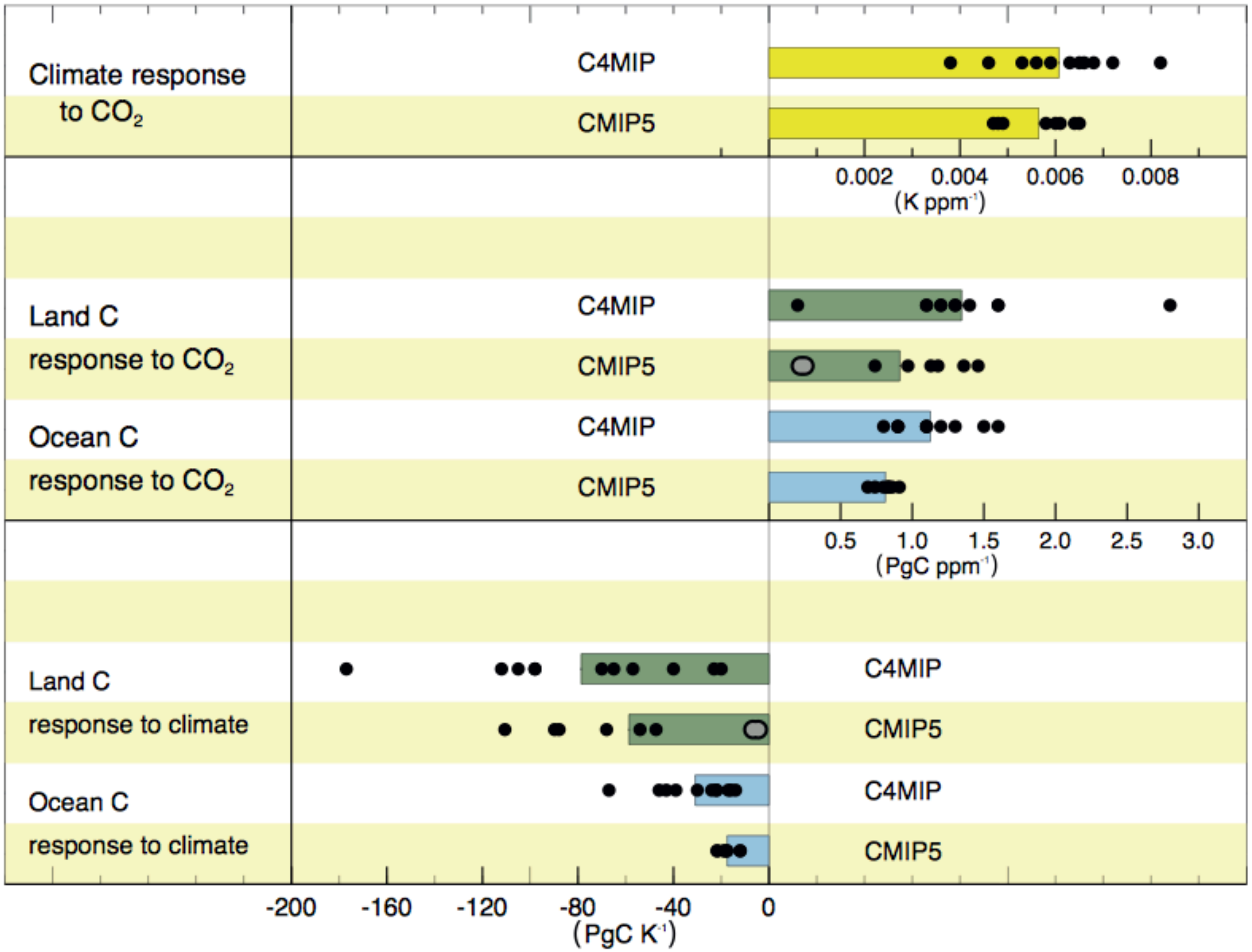
CMIP-5 historical CO_2 uptake ensemble



CMIP-5 ensemble mean oceanic CO_2 uptake (1.47±0.58 PgC: 1960-2005) underestimates observations (1.92±0.30 PgC, Le Quere 2009)

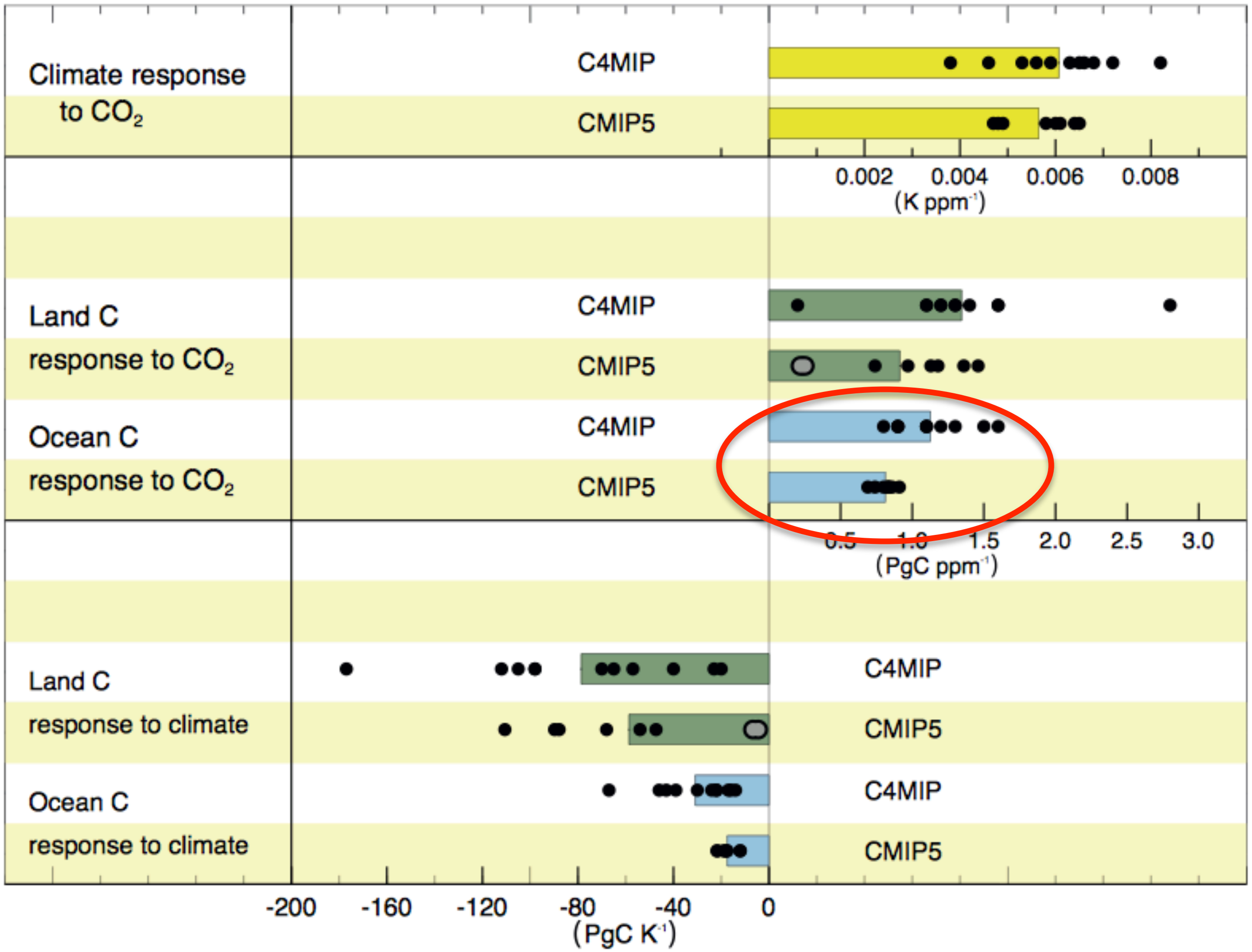
Carbon-Climate Feedback in C4MIP/CMIP-5

IPCC AR5 (2013)



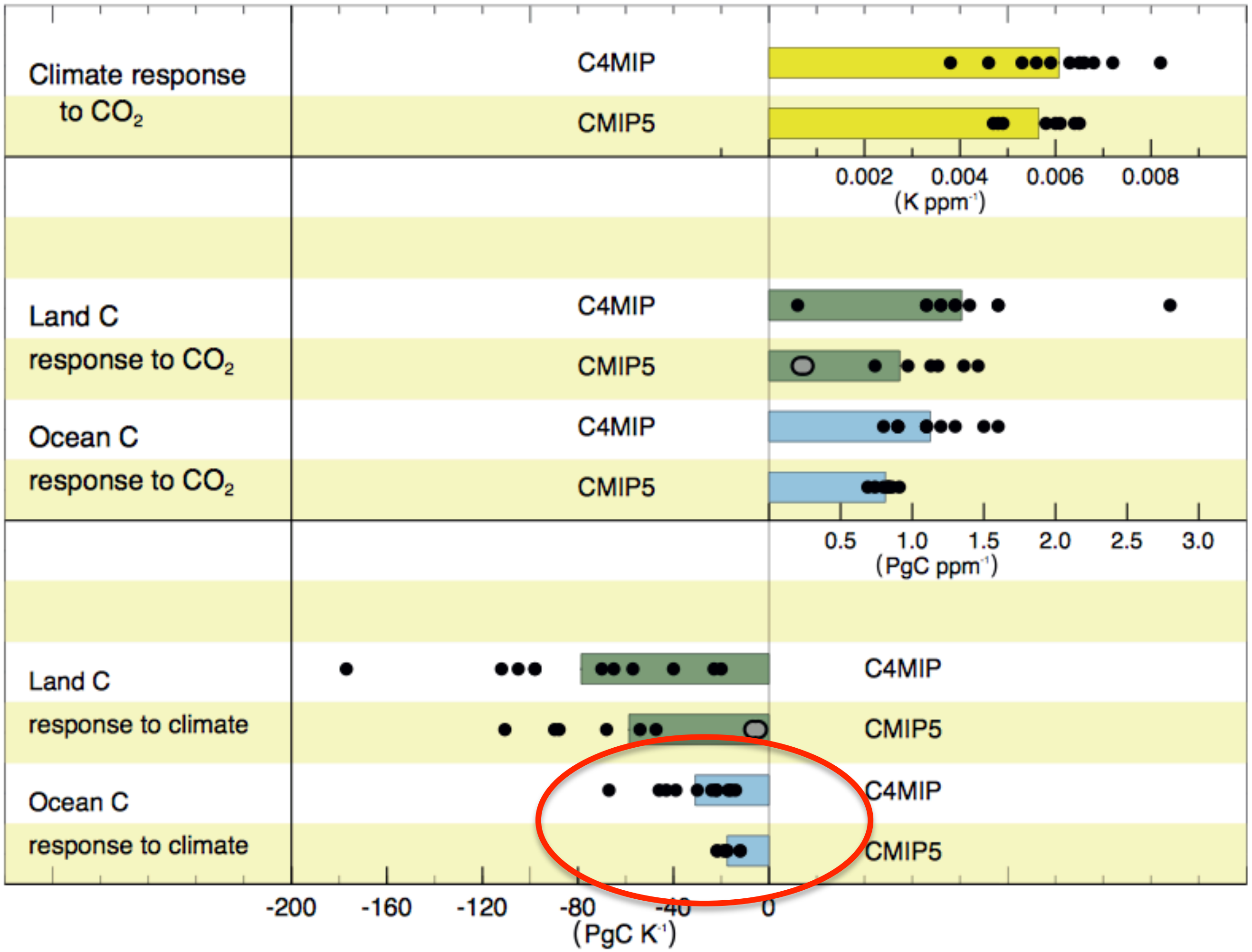
Carbon-Climate Feedback in C4MIP/CMIP-5

IPCC AR5 (2013)



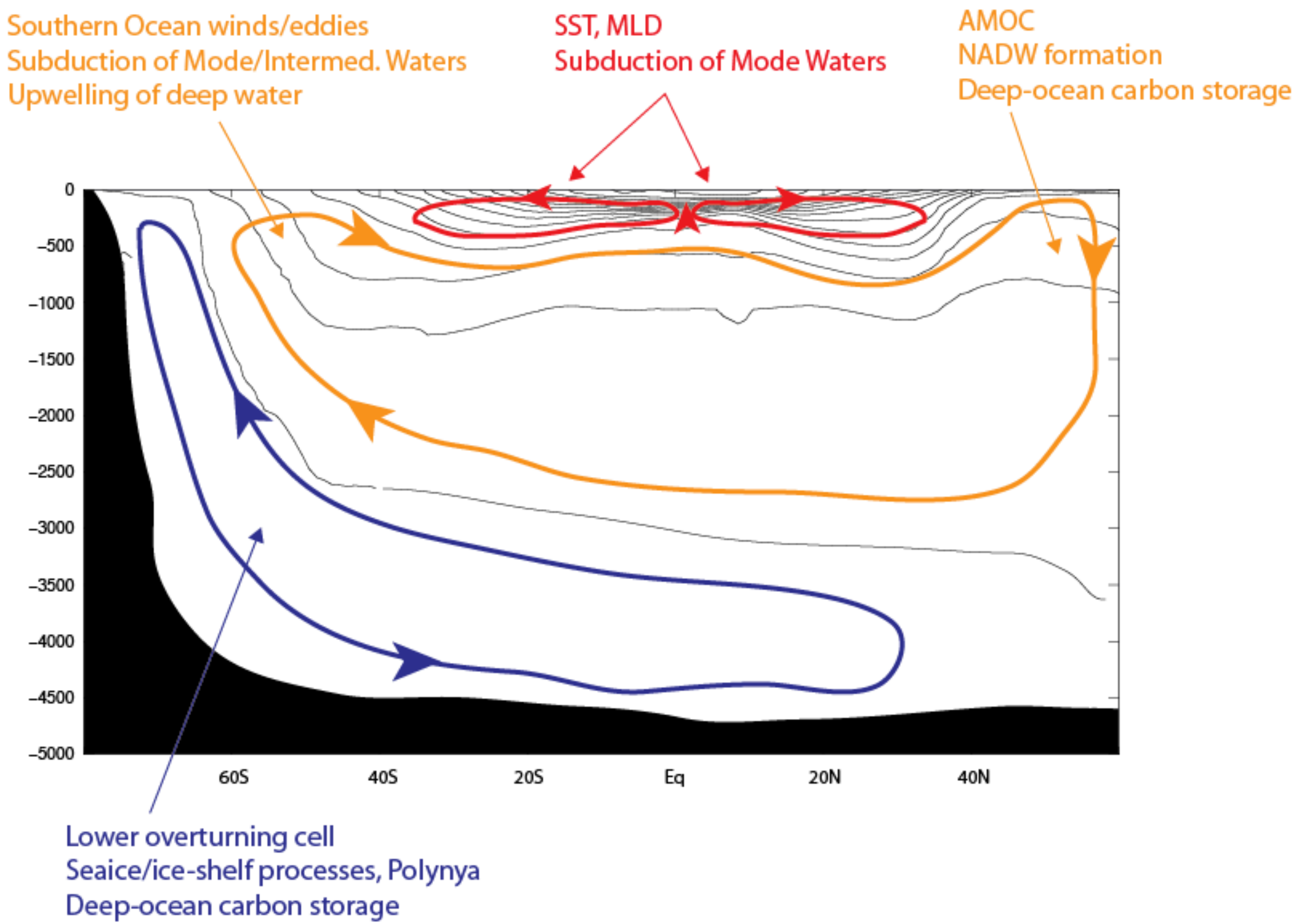
Carbon-Climate Feedback in C4MIP/CMIP-5

IPCC AR5 (2013)



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?

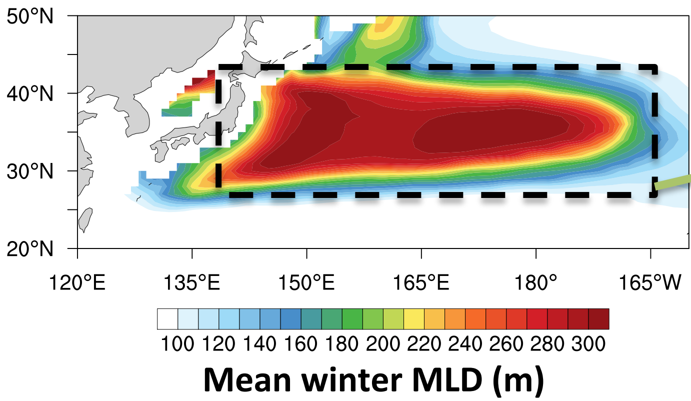
Key physical processes?



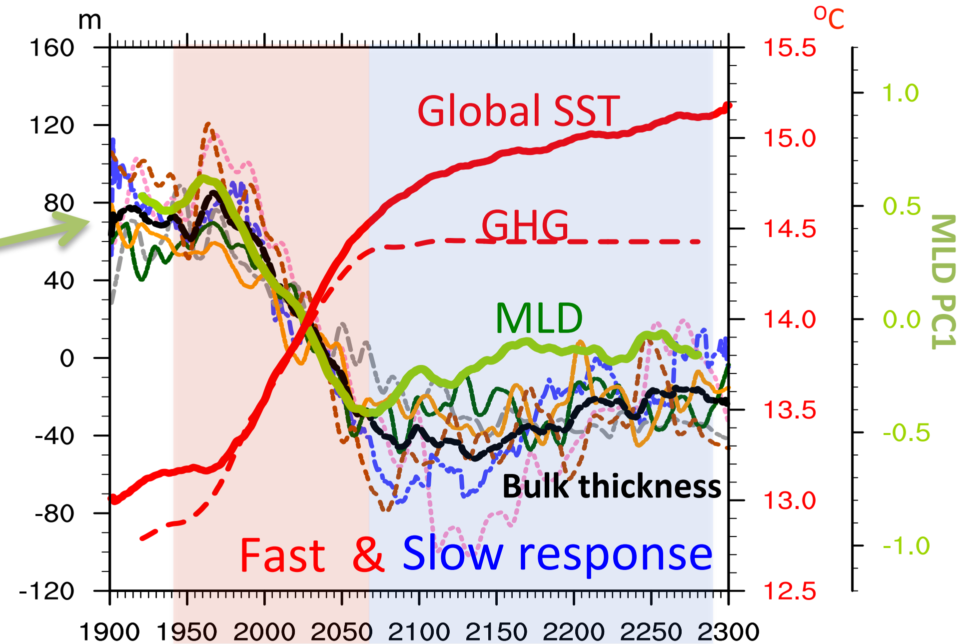
Fast and slow response of Ocean Mixed Layer and Mode Waters

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.

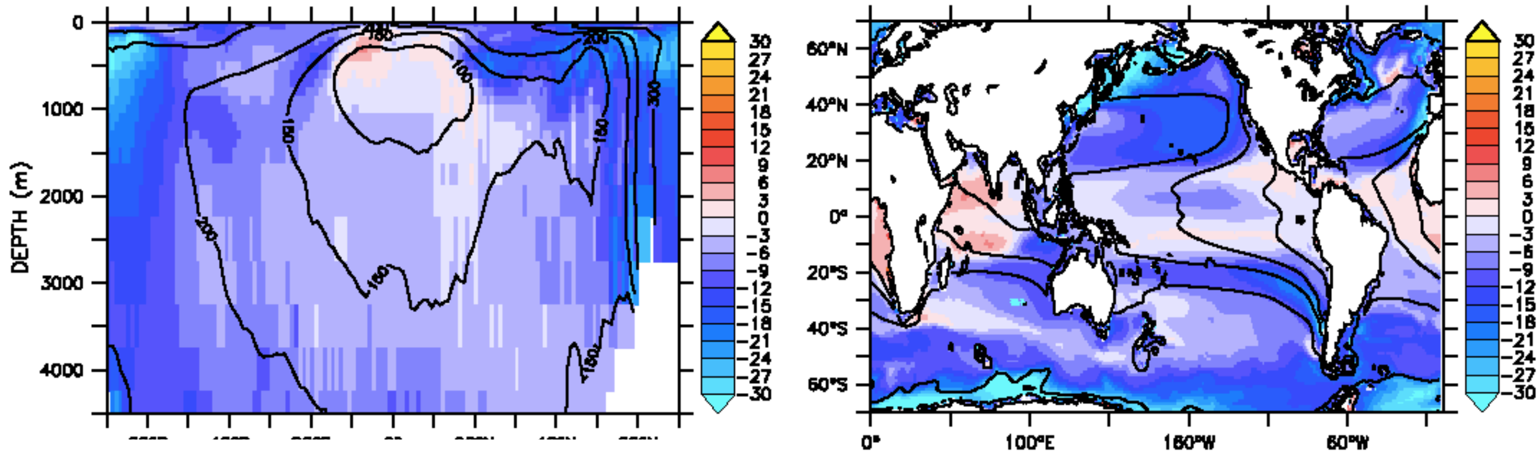


Response of ocean mixed layer and mode water consists of two distinct stages:

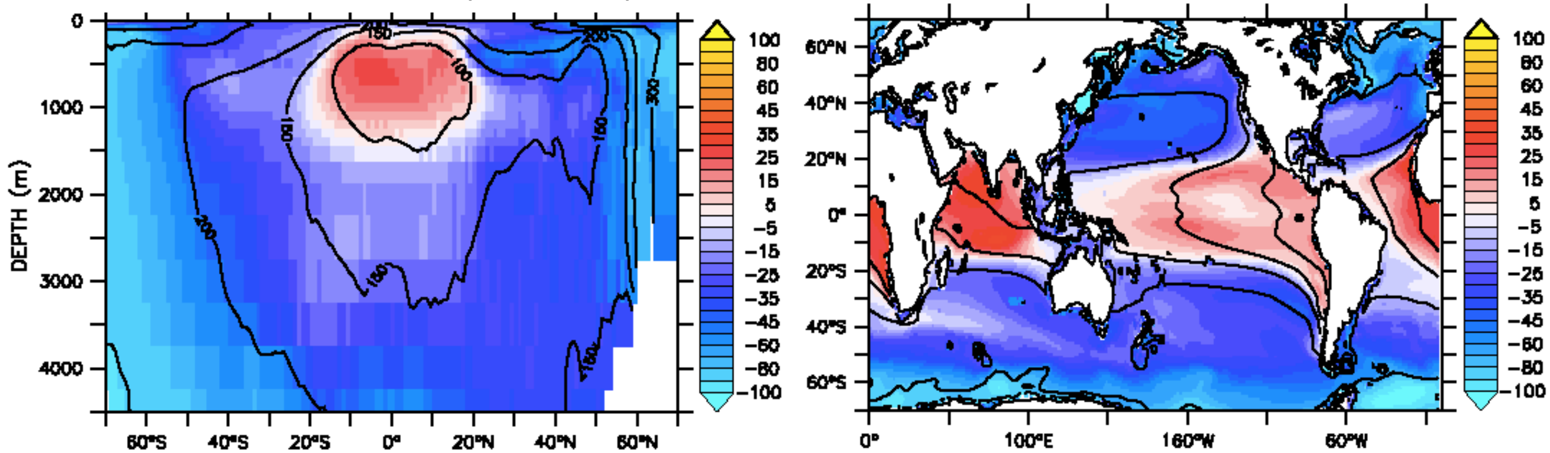
- Fast response with increasing radiative forcing: mixed layer depth (MLD) shoals and the mode water thickness shrinks rapidly as the surface warming strengthens the stratification.
- Slow response with radiative forcing leveling off after 2070: MLD and mode water change ceases despite a continual increase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

Extra-tropical de-oxygenation and tropical oxygenation (Deutsch et al.)

2100 – 1900 multi-model trend (RCP 8.5)

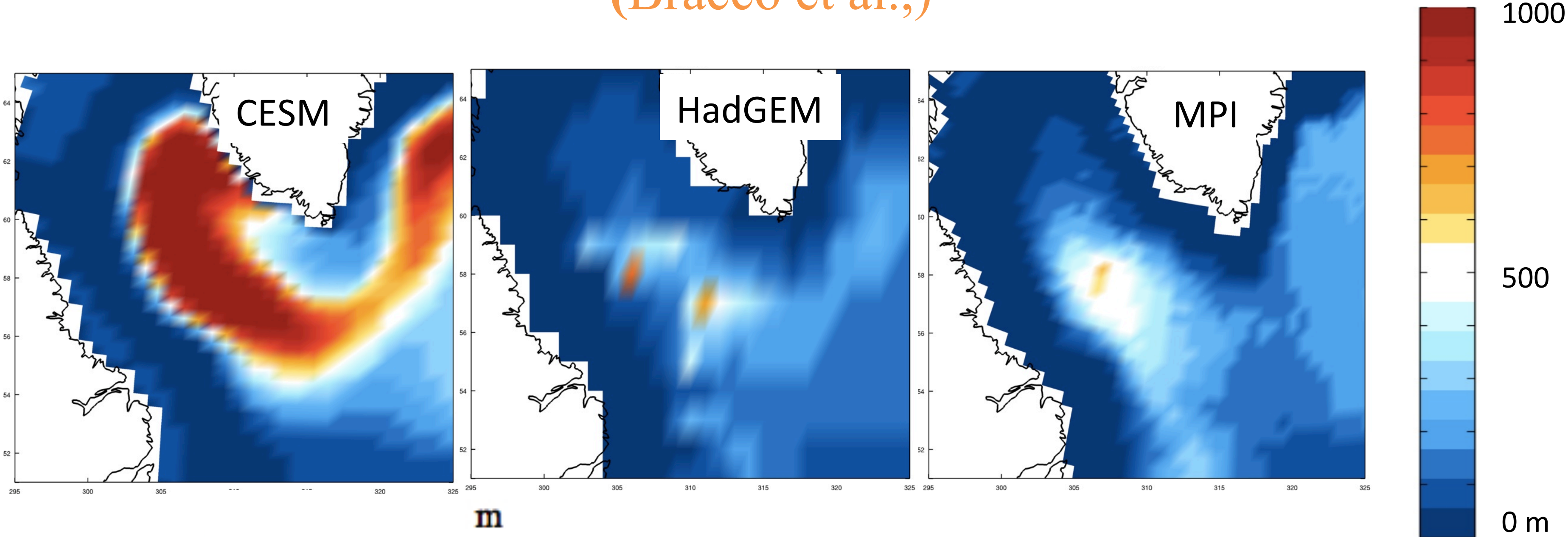


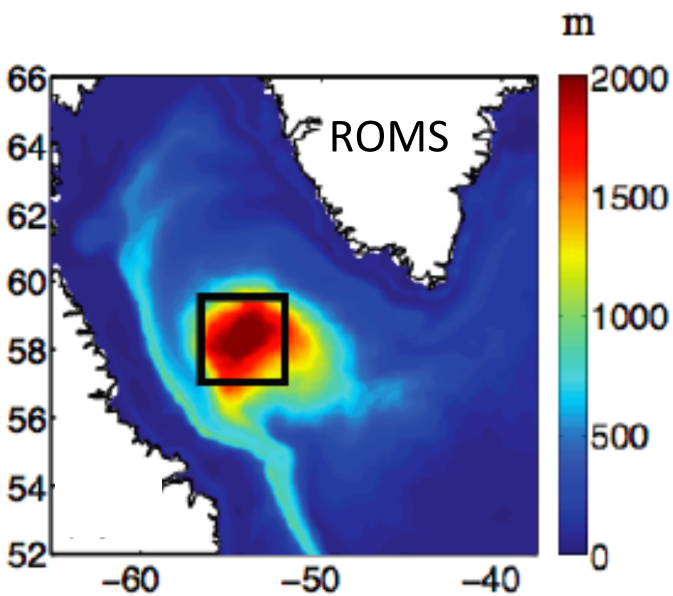
2300 – 1900 multi-model trend (RCP 8.5)



Most CMIP-5 models exhibit tropical – extratropical dipole in the oxygen trend

Labrador Sea convection in CMIP-5 models
(Bracco et al.,)

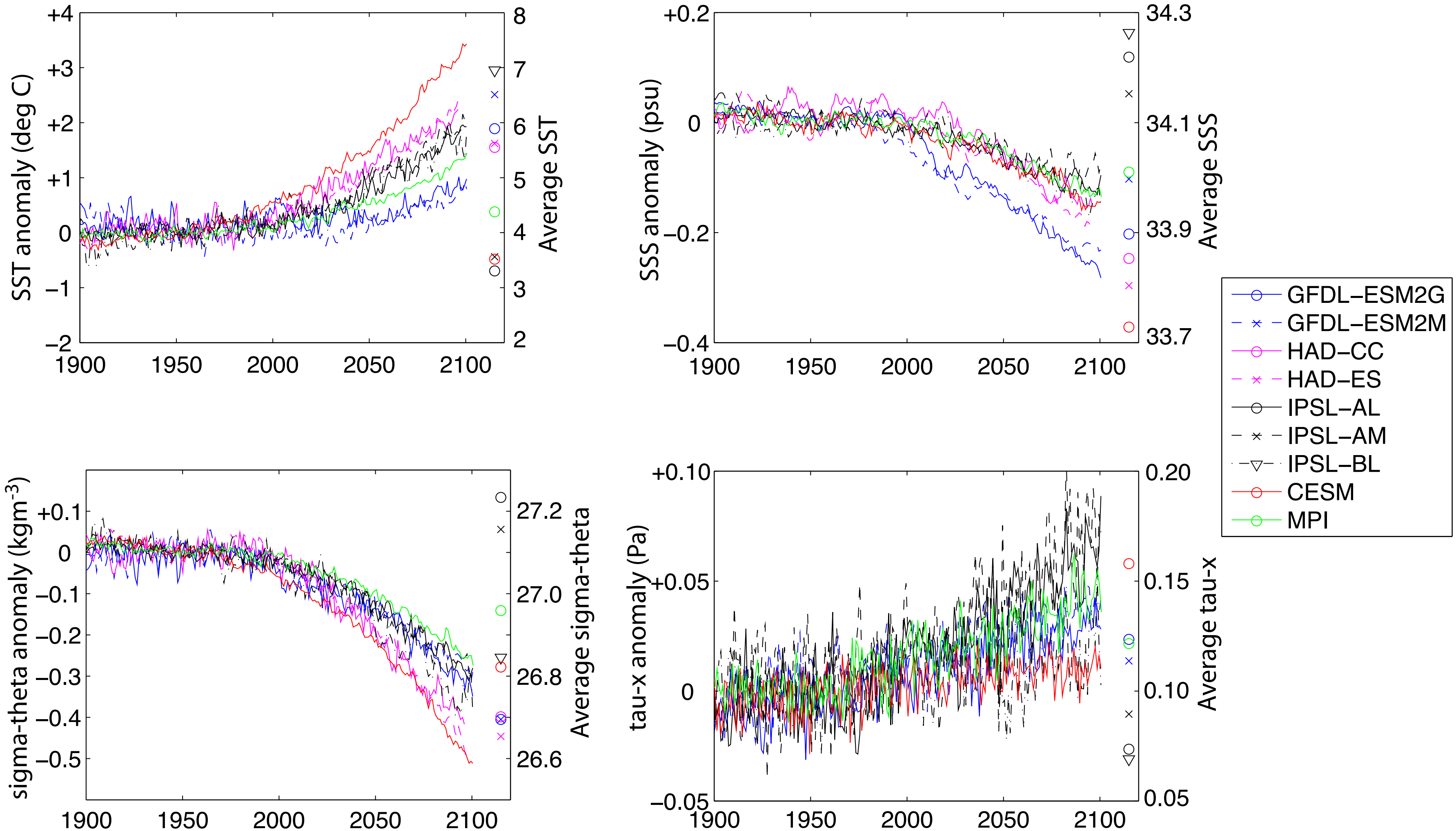




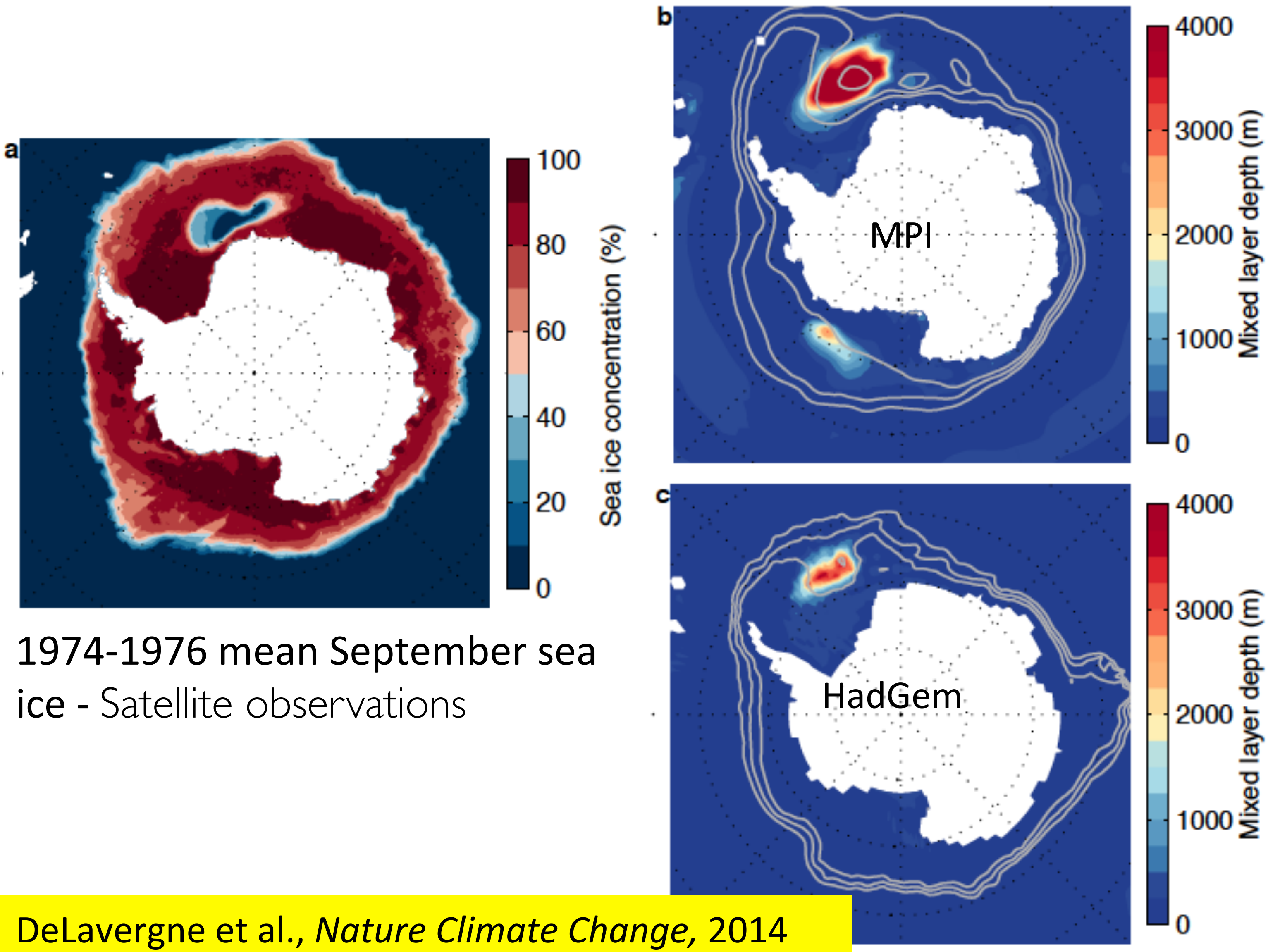
1960-2005, FMA averages

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.

Trends in the Southern Ocean wind and buoyancy forcing (45°S – 60°S)



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

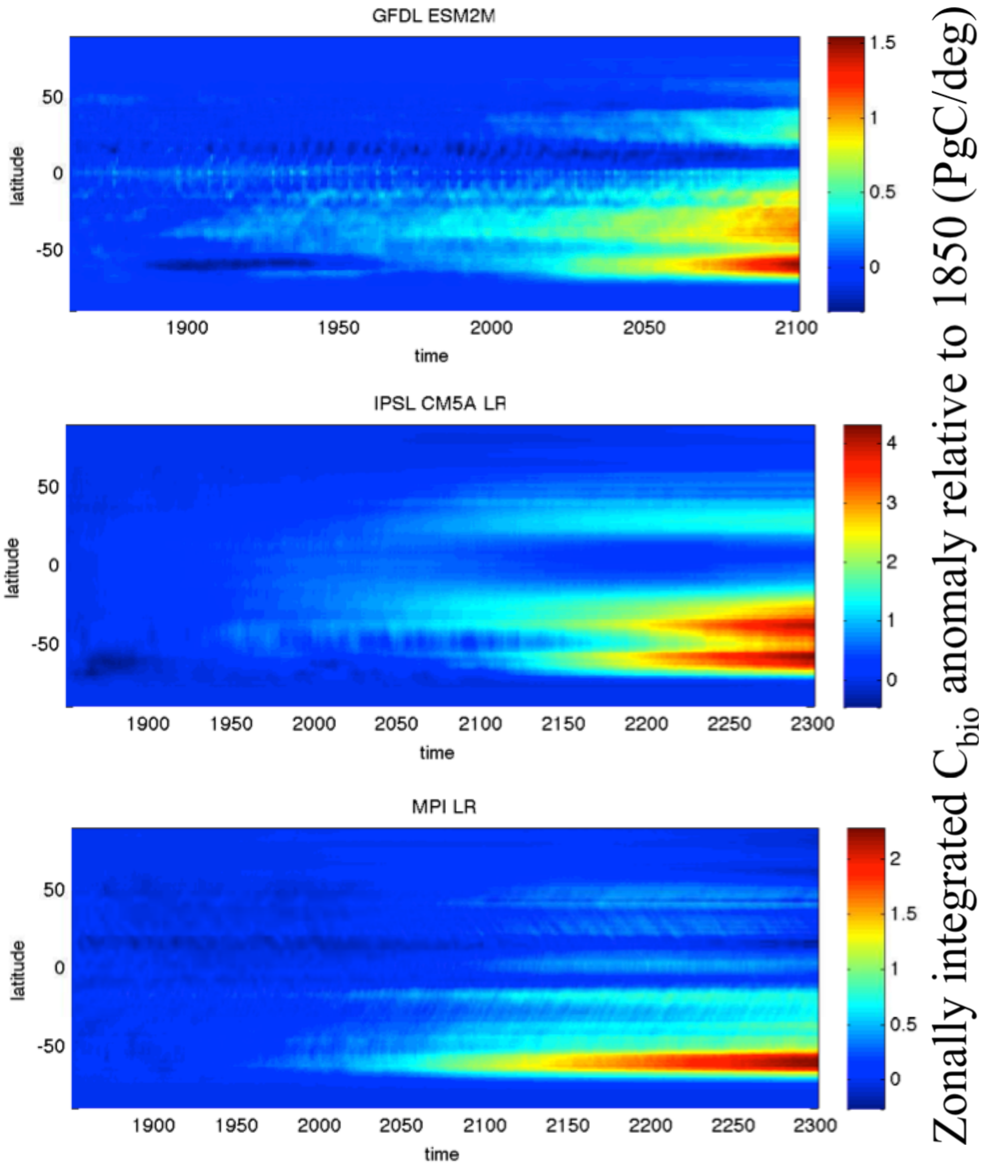


1974-1976 mean September sea ice - Satellite observations

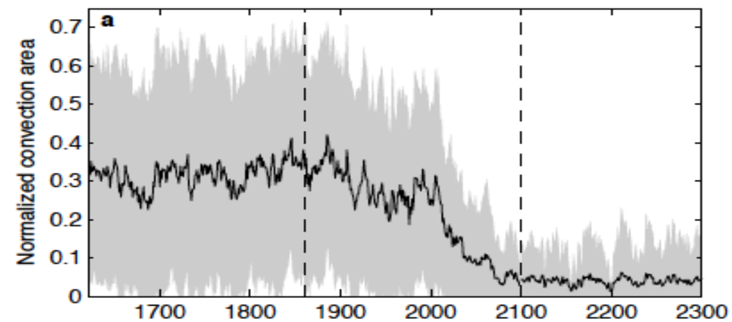
Mixed layer depth in two models with extended simulations, good AABW properties, and realistic-looking Weddell Polynya. Germany's MPI (top) and UK's HadGem (bottom).

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

Global 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).

Ocean Carbon Uptake in CMIP-5 Models

- CMIP-5 models have provided wealth of resources to advance our understanding of global carbon and biogeochemical cycling under changing climate

- Representations of key physical/biogeochemical still **vary widely** across the models

- There are also **robust features** in the CMIP-5 ensemble involving climate – biogeochemical feedback and its regional expression → opportunity for improved understanding