Processes Affecting Anthropogenic Carbon in the Southern Ocean

I. Frenger1 (ifrenger@princeton.edu), G. de Souza1, C. Dufour1, J. Sarmiento1, S.Griffies2

1Program in Atmospheric and Oceanic Sciences, Princeton University, Princeton, NJ, USA ;
2NOAA/Geophysical Fluid Dynamics Laboratory, Princeton, NJ, USA

Motivation

Mesoscale ocean eddies (vortices of scales of approximately 100 km) are ubiquitous features in the Southern Ocean. They are dynamically important in that they partially compensate the wind-driven circulation. The net effect of eddies on the ocean circulation and the response to climate change are unclear as those features are difficult to observe (e.g. [1]).

Given the importance of eddies, it is anticipated that they affect Southern Ocean water masses and carbon storage [2]. The focus here is on Antarctic Intermediate Water (IW), a water mass which is thought to be critical for the sequestration of anthropogenic carbon.

Do eddies thin IW [2] and do they affect IW ventilation?

How do eddies affect IW anthropogenic carbon storage?

Is this effect represented in a coarse resolution model parameterizing eddies?

Method

Water mass boundaries:

Water mass characteristics are anticipated to be different in different model simulations, depending for instance on the model resolution. To account for this, water mass boundaries are determined “objectively” by an algorithm avoiding absolute threshold values of for instance temperature and salinity (inspired by [6]).

Based on a climatological section along 30°S, the algorithm finds density values (ρθ) separating water masses the following way:

• IW: based on inflection points bracketing the IW salinity minimum.

• MW: highest density at the base of the winter mixed layer.

• SW: on top of IW, BW: as in [6], CDW: in between IW and BW.

Resolution Dependence of Intermediate Water Volume

Resolution Dependence of Intermediate Water Carbon Storage

Results & Outlook

Preliminary conclusions:

1 Eddies thin and freshen IW, and increase ventilation (Fig. 1,2).

2 GM parameterization (and diffusion) tends to overcompensate except for the climate change response (Fig. 2,3).

3 Eddies attenuate IW volume and associated carbon inventory decrease in a changing climate (Fig. 3).

Next steps (science):

Why do eddies lead to a better representation of IW?

How is the change of carbon storage in IW related to fluxes (uptake from the air and export across 30°S)?

Do eddies lead to a different distribution of carbon in water masses? Does this affect the longer term storage?

Data

• Three GFDL climate model simulations varying only in the horizontal resolution of the ocean [3,4]: (1) Non-eddying with a GM eddy parameterization and lateral diffusion (1°: CM-1deg), (2) modest-eddying (0.25°: CM2.5) and (3) actively eddying (0.1°, CM2.6).

• Two scenarios: a preindustrial atmospheric CO2 concentration (ctrl), and an idealized climate change scenario (sens, prescribed 1%/yr CO2 increase); biogeochemical component: minBILNG [5].

• 200 years of simulation time, the climate change scenario branches off at year 120; climatological averages over the years 161 to 180 are used here; “observations” refers to the initial state of CM-1deg.