Processes Affecting Anthropogenic Carbon in the Southern Ocean

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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 (σ_2) 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.

Evaluation of Model Simulations and Water Mass Detection Algorithm

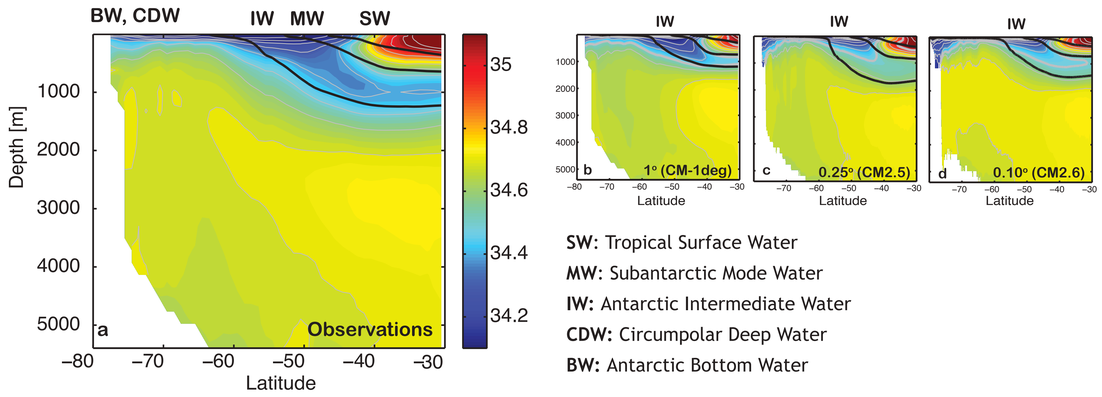
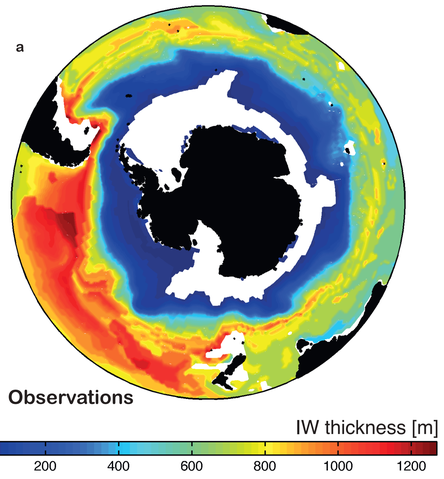


Figure 1: **Zonally averaged salinity**; a: observations; b, c, d: model simulations; black contours denote water mass boundaries.

Resolution Dependence of Intermediate Water Volume



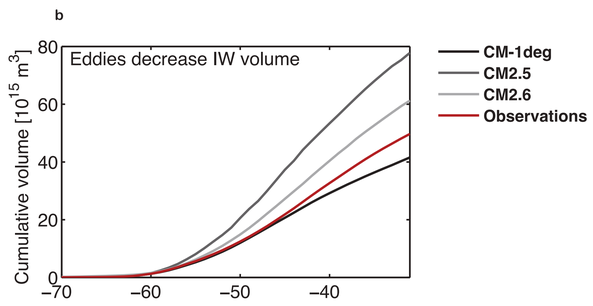


Figure 2: **Thickness of IW**; a: observed, and b: cumulative volume (integrated meridionally starting from 70°S) for observations (red) and models.

Resolution Dependence of Intermediate Water Carbon Storage

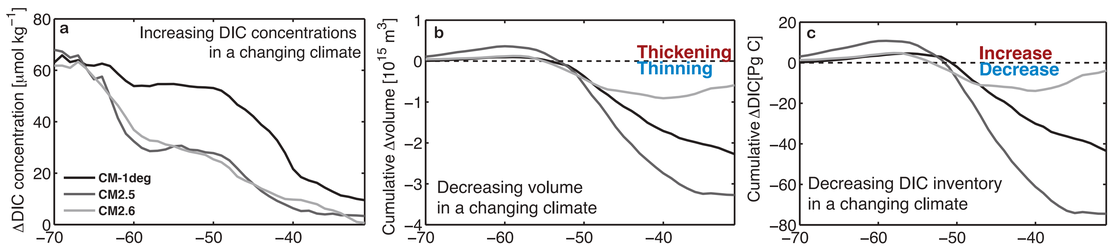


Figure 3: **Differences of IW between preindustrial and climate change simulations (*sens* minus *ctrl*)**; a: Dissolved inorganic carbon concentration (DIC), b: cumulative volume (integrated meridionally starting from 70°S, as in Figure 3), and c: cumulative DIC storage.

Results & Outlook

Preliminary conclusions:

- **Eddies thin and freshen IW, and increase ventilation (Fig. 1,2).**
- **GM parameterization (and diffusion) tends to overcompensate except for the climate change response (Fig. 2,3).**
- **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 CO_2 concentration (*ctrl*), and an idealized **climate change** scenario (*sens*, prescribed 1%/yr CO_2 increase); biogeochemical component: miniBLING [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 inital state of CM-1deg.

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