Simulating MOC Water Mass Pathways and Variability in the South Atlantic

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MOC pathways in the South Atlantic

Previous observational and modeling efforts on the meridional overturning circulation (MOC) have been focused on the North Atlantic and the Southern Oceans, which are the main sites for deep-water formation. To understand the feedbacks between the North Atlantic and the Southern Oceans we need to improve our understanding of the pathways of the upper and lower limbs of the MOC in the South Atlantic (SA) Ocean, which are the most important links between them. The SA is not just a passive conduit for the transit of remotely formed water masses, but actively influences them through air–sea interactions, mixing, subduction, and advection.

The objective of this project is to improve our understanding of the pathways of the upper and lower limbs of the MOC in the SA. Our research is focused on the analysis of state-of-the-art high-resolution NOAA/GFDL coupled climate model and ocean-only simulations, non-eddying CMIP and IPCC AR5 models including the NOAA/GFDL coarse resolution models, process-oriented numerical experiments using a regional ocean models, and observations. This research presented in this poster was achieved in collaboration with Vincent Combes, Shenfu Dong, Bill Johns, Chris Meinen, and Jian Zhao.

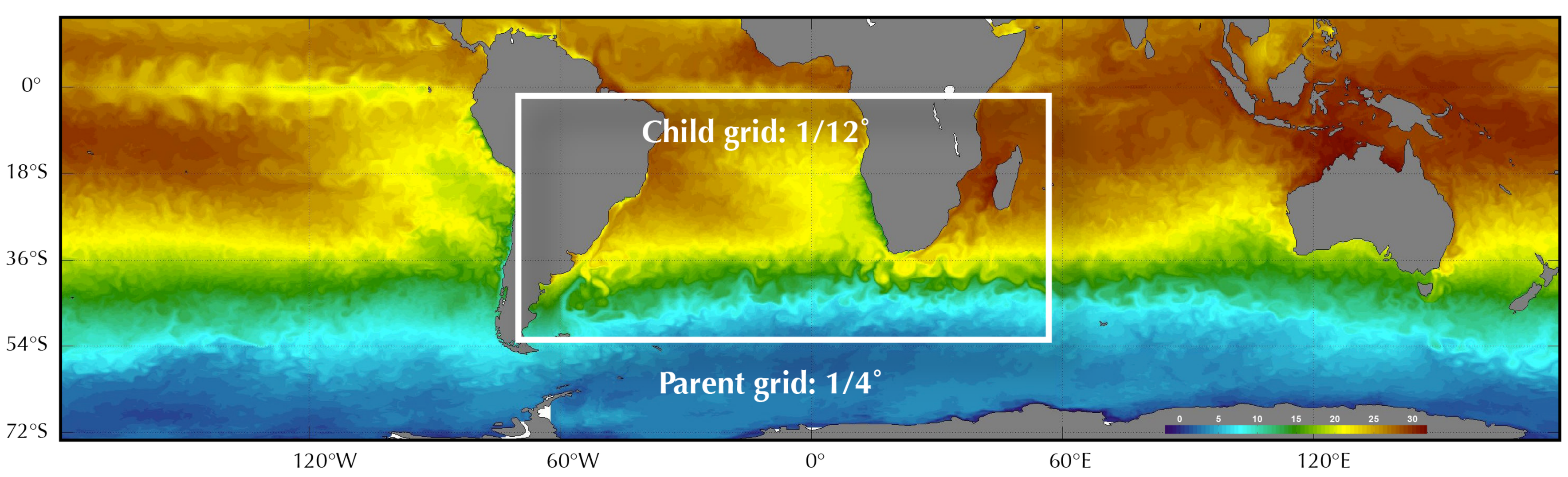


Figure 1: Snapshot of the sea surface temperature from the **ROMS benchmark simulation**. The "parent grid" encompasses all the southern hemisphere and extends to 15°N with horizontal resolution of ¼°. The "child grid" encompasses the SA and has a horizontal resolution of 1/12° in the SA. At the surface, the model is forced by the ERA-Interim data set from 1979 to 2012. At the northern open boundary of the parent grid (~15°N), we impose a modified radiation boundary condition with nudging to the SODA monthly mean climatology. Both models have 40 vertical levels with enhanced resolution at the surface (Combes and Matano, 2014; Matano et al., 2014).

ROMS Benchmark Simulation

Here we report on the development of a high-resolution nested model using the Regional Ocean Modeling System (**ROMS**, **Figure 1**) and present results from two preliminary numerical simulations using this model configuration: a benchmark simulation and a simulation where the Vitória-Trindade (VT) Ridge at 20°S has been removed.

The **benchmark simulation** was spun-up for 20 years and run in a diagnostic mode for another 20 years. This experiment will be used to investigate the sensitivity of the SA circulation (surface, intermediate and deep) to changes in the model configuration (e.g., bottom topography, wind stress forcing, mixing parameterization). Preliminary assessment of slightly modified version of this model shows good agreement with observations (Combes and Matano, 2014; Matano et al., 2014). To determine the pathways of the main water masses in the SA we released passive tracers at different density levels of the model. **Figure 2** shows a snapshot of a tracer distribution after 4 years of its release at the Agulhas Retroflection region, and the pathways of the Indian Ocean waters in the SA. Note, the persistence of the Agulhas eddies throughout the basin. Many of these eddies can be tracked until they impinge on the eastern boundary of South America and, on occasion, to the Brazil/Malvinas Confluence.

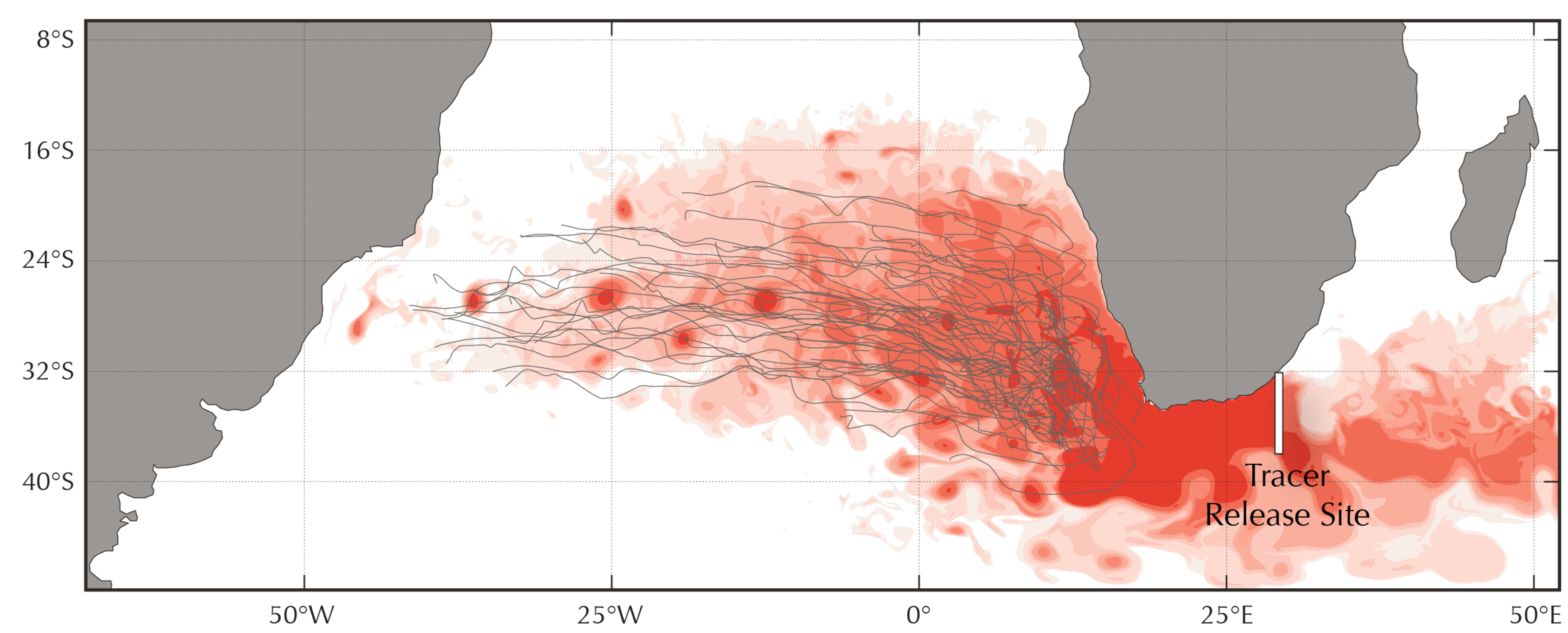


Figure 2: Snapshot of the surface distribution of a passive tracer released at the Agulhas Retroflection region in the **ROMS benchmark simulation**. The black contours mark the trajectories of Agulhas eddies computed from altimeter data by Schouten et al. (2000).

Vitória-Trindade Ridge Simulations

Figure 3 shows a snapshot of a passive tracer released in the northwestern corner of the child model and at NADW levels (1500-3000 m) in the **benchmark simulation**. There are offshore extrusions of NADW near 10°S, 20°S and 45°S. The most remarkable is the one observed near 20°S, which is the approximate location of the VT Ridge, because there is no clearly defined offshore mean flow in this location. The offshore detrainment of the deep waters in this location appears to be a largely eddy-driven process (van Sebille et al., 2012; **Garzoli poster TT1**). The question, therefore, is whether these eddies driving this outflow are produced locally (e.g., through interaction between the western boundary current and the VT Ridge) or are the deep-ocean expression of surface eddies.

We are presently running a suite of sensitivity experiments to test the sensitivity of the SA water mass pathways to local and remote forcing. In our first **sensitivity experiment**, which is underway, we **"removed" the VT Ridge** to test the sensitivity of the NADW pathways to the existence of this morphological feature. This experiment is still under development (spin-up not complete) but preliminary analysis shows a reduced offshore spreading pattern of NADW although a substantial portion of the NADW is still detrained in the offshore direction at this particular location.

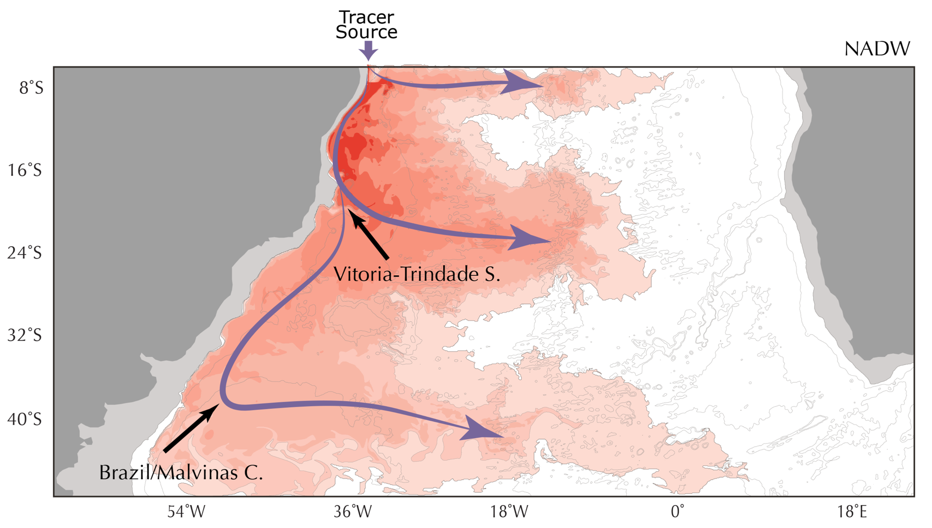
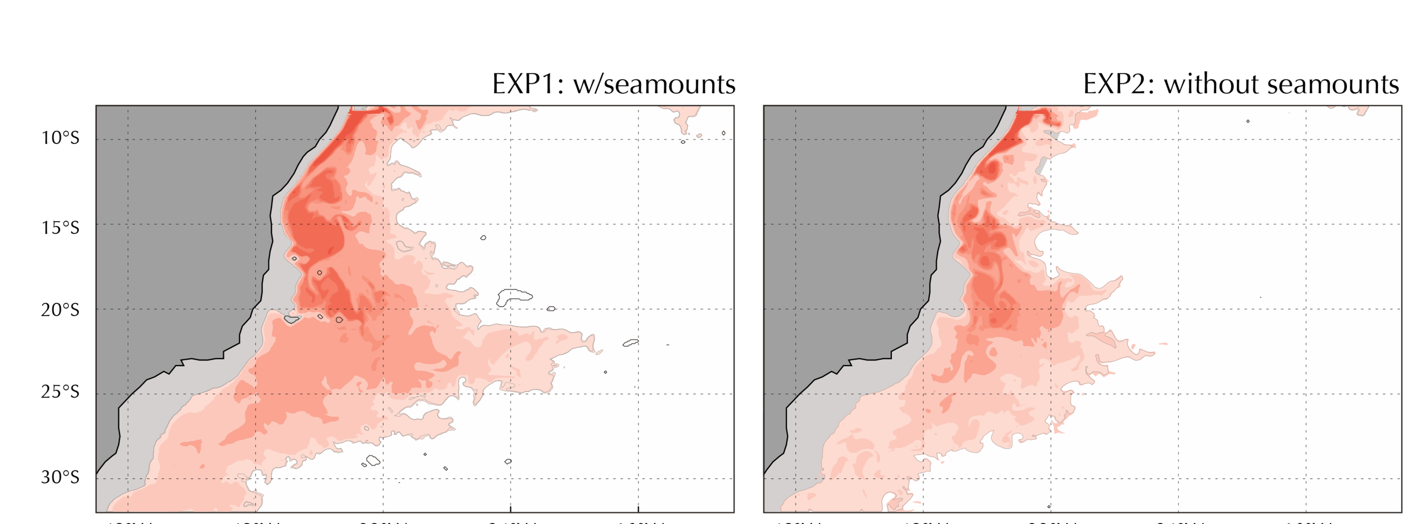


Figure 3: (top) Snapshot of the average tracer distribution at NADW depths after 20-years of the **ROMS benchmark simulation** spin-up. The tracer shows three tongues of NADW being entrained at regions of large mesoscale variability. (bottom) Same after 10-years of the (left) **benchmark** and (right) removed VT Ridge **sensitivity experiment** spin-up.



NOAA/GFDL Simulations

As a first step to understanding the variability of the MOC inherent to the **NOAA/GFDL numerical simulations**, we analyzed the sensitivity of the seasonal cycle of the volume transport by the MOC to wind forcing at the latitudes of the RAPID/MOCHA/WBTS array (26.5°N) and SAMBA array (34.5°S). The simulations include the high-resolution **CM2.5**, and its ocean-only counterpart **CM2.5 CORE**, and the IPCC AR4 simulation **CM2.1**. Years 21-30 from the simulations are compared with observations and a **two-layer idealized ocean model** (Zhao and Johns, 2014) forced with the observed and simulated winds. Although some of the simulations are able to reproduce observed total and geostrophic variability at 26.5°N, none are able to reproduce observed variability at 34.5°S (**Figure 4**).

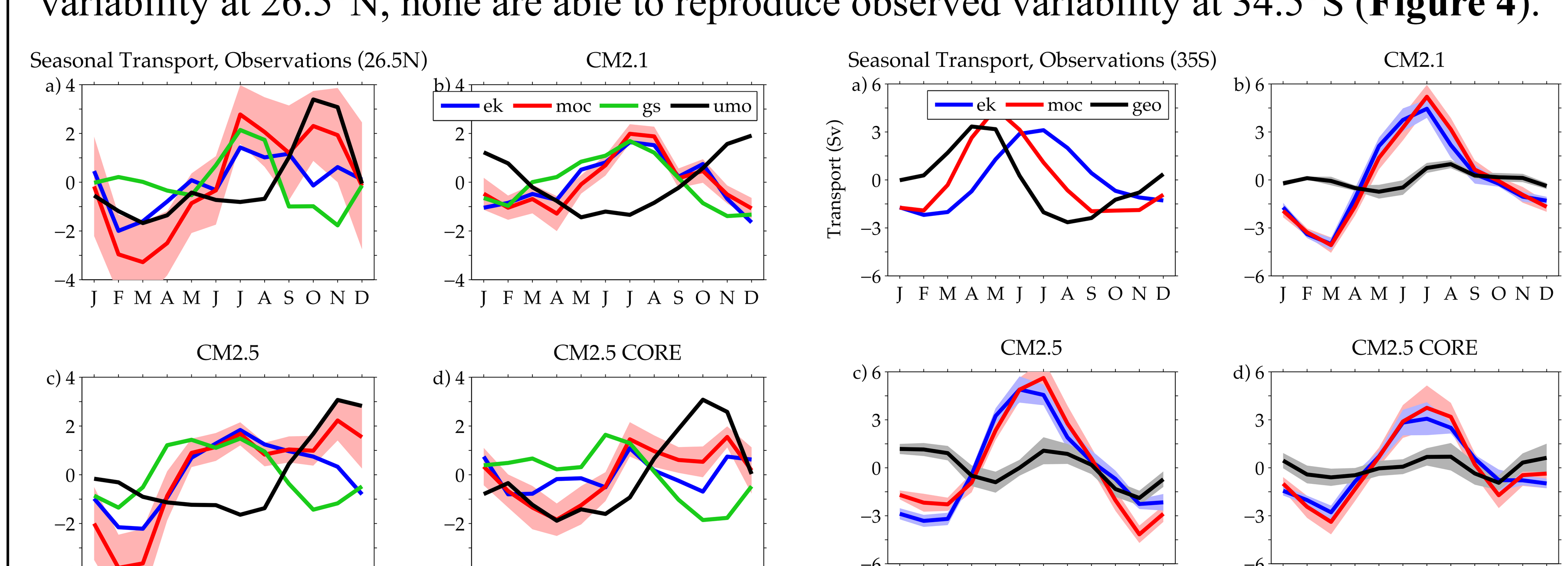
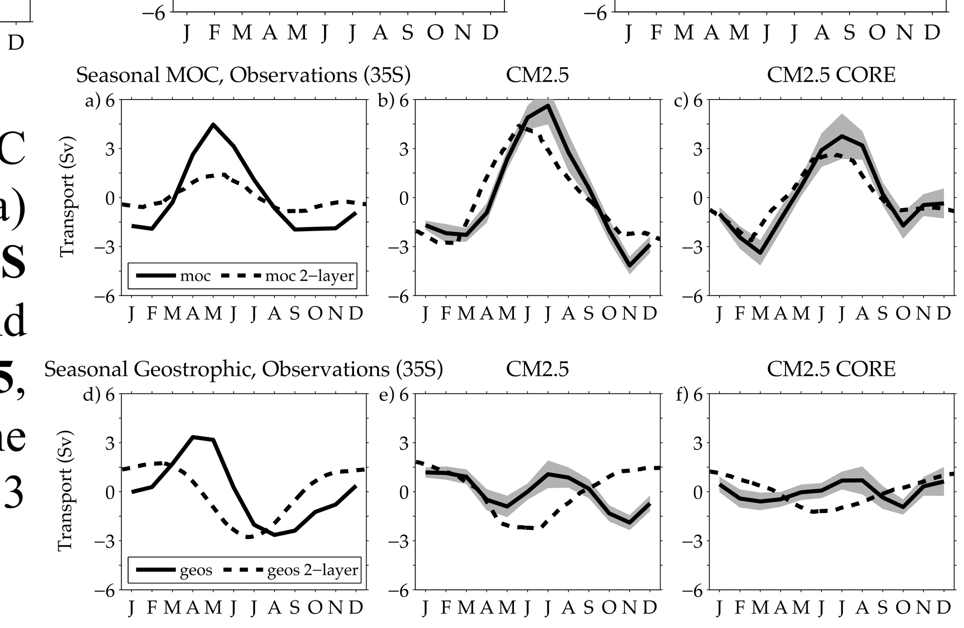


Figure 4: (top) Seasonal cycle of MOC transport along (left) 26.5°N for (a) 2004-2011 **RAPID/MOCHA/WBTS observations** (Smeed et al., 2014) and three simulations: (b) **CM2.1**, (c) **CM2.5**, and (d) **CM2.5 CORE**. (right) Same except along 34.5°S and for (a) 2004-2013 **Argo** observations (Dong et al., 2014).



(bottom) Seasonal cycle of total MOC transport along 34.5 a) **observations**, b) **CM2.5** and c) **CM2.5 CORE** simulations (solid lines), and the corresponding **2-layer idealized model** (dashed lines). Panels (d)-(f) geostrophic component. The 2-layer geostrophic and total MOC seasonal cycles are similar to those produced by the original simulations. However, the phasing of the 2-layer geostrophic seasonal cycles agree better with the observations.