Agulhas Leakage in eddy-resolving CCSM: a Lagrangian approach

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I. Introduction

The Agulhas system plays a critical role in the global thermohaline circulation through the control of Indo-Atlantic inter-basin water exchange (Gordon et al., 1992). The Agulhas leakage of feeds to the upper arm of the Atlantic meridional overturning circulation (AMOC) with warm and salty water. The leakage volume flux and its associated buoyancy flux may affect the stability of the AMOC, and hence the climate (Beal et al., 2011; Weijer et al., 1999).

Recent studies based on Ocean General Circulation Models indicate that Agulhas leakage may be increasing in response to anthropogenic climate change and therefore strengthen the AMOC (Biastoch & Böning, 2013), which is in contrast to the predicted weakening with anthropogenic warming. To estimate the relative role of the above mentioned mechanisms and reasonably predict future climate, a coupled model study is necessary. However, the current generation of coupled climate models do not resolve mesoscale dynamics, and fail to simulate the Agulhas return current and thereby overestimate the Agulhas leakage. Therefore, we employ the high-resolution Community Climate System Model (CCSM3.5) with a one-tenth degree ocean to perform this study. The first difficulty we must overcome is quantifying Agulhas leakage robustly. Here we attempt to tackle this problem using a Lagrangian tracking method.

II. Data and Methodology

Monthly output spanning 54 years of pre-industrial CCSM3.5 simulation, (Kirtman et al., 2012) is used. Unlike previous work based on coarse resolution CCSM4 (Weijer & van Sebille, 2014), the spatial resolution of this simulation for the atmospheric and ocean component is 0.5° and 0.1° respectively. For this study, we apply the

The Lagrangian method is chosen due to its advantage of including leakage of every forms, such as Agulhas Rings, eddies and filaments. With the aid of Connectivity Modeling System (CMS)(Paris et al., 2013), we release particles, each representing 0.1 Sv, every month along specific sections and follow their trajectories. We integrate these particles using 3-D local velocity field from CCSM3.5 for five years to obtain the trajectory of each float particle. The Agulhas leakage is computed by tracking when each float last crosses the GoodHope line (van Sebille et al., 2010). Figure 1 shows the trajectories of particles released along Agulhas Current Timeseries Experiment mooring array (ACT) in upper 1500m in the first model year.

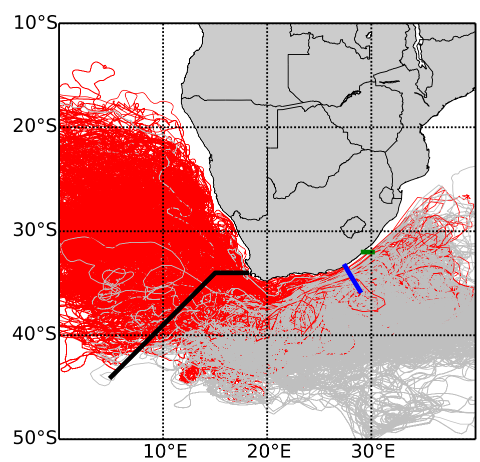

Figure 1. Trajectories of particles released along ACT line (blue), Particles that result in Agulhas leakage are colored red. GoodHope line is indicated in black and 32°S release section in green.

III. Results

We first compare the Agulhas leakage transport using different release sections, 32°S and ACT line (Figure 2). The former is chosen to compare to previous studies, and the later to the ACT mooring array. The ACT line release case is larger than the 32°S case with mean values of 26.7 Sv and 12.2 Sv respectively. While Weijer (2012) reporting 43 Sv of leakage in coarse resolution CCSM simulations, our values are closer to both observational and numerical estimates based on surface drifters and OGCMs experiments, ranging from 12 Sv to 17 Sv (Richardson, 2007; van Sebille et al., 2010).

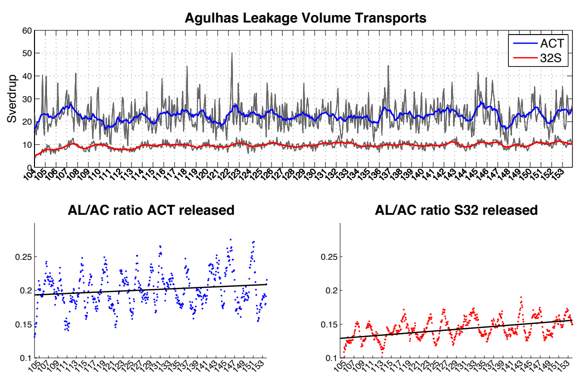

Figure 2. Agulhas leakage volume transports time series of different releasing sections ACT (blue) and 32°S (red), and their corresponding Leakage to mean transport ratios.

We also look into the fraction of Agulhas leakage to the Agulhas current transport to see if there is any upstream control. The ACT case has a 0.2 mean ratio while the 32°S case reports about 0.15.

In addition, for the same amount of released particles, less arrive in the GoodHope line due to the introduction of turbulence module. This module provides random kick to the particles to mimic turbulent diffusion. Without turbulence, all particles released at the same time and location will follow the same trajectory. For the 32°S case, the mean leakage transport decreases to 9.6 Sv, and for the ACT case, the mean leakage is about 22.6 Sv.

IV. Future work

Future works include the comparison of Lagrangian Agulhas leakage transport to Eulerian transport across the GoodHope line. We plan to apply the same strategy to high-resolution CCSM daily output to address the degradation of trajectories and leakage transport due to coarse temporal resolution.

V. References

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