Velocity Structure and Transport of the Meandering vs. Non-Meandering Agulhas Current

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ABSTRACT

1. Introduction

The Agulhas Current (AC) is the largest western boundary current in the southern hemisphere with average transport of 70 Sv and current speeds greater than 2 m s^{-1}. Approximately 4-5 times a year, solitary meanders disturb the path of the otherwise stable current (de Ruijter et al, 1999). Solitary meanders significantly correlate with Agulhas Ring shedding events (van Leeuwen et al, 2000), which, themselves, constitute an important link in the global thermohaline circulation transporting warm salty Indian Ocean Water into the South Atlantic (Gordon, 1985). Observational studies of these climatically important features include: satellite studies that are limited to the surface (eg Rouault and Penven, 2012); and float and current meter studies that are relatively sparse (Lutjeharms et al, 2001). Here, we present full-depth, in-situ, hydrographic observations of a solitary meander in the AC, as well as across the non-meandering AC at the same latitude. Using these data, we describe how meanders affect the velocity structure and transport of the AC, as well as the implications of sampling bias on meander hydrographic data.

2. Method

In April 2010 and then again in November 2011, separate lines of hydrographic data were collected along the Agulhas Current Time Series Experiment (ACT) mooring line located at nominally 34°S in the Indian Ocean. This hydrographic data consisted of full depth velocity profiles captured by lowered acoustic Doppler current profilers (LADCP), along with CTD (conductivity temperature depth) data. SST (sea surface temperature) satellite imagery confirms a solitary meander 100-km in diameter was propagating across the ACT mooring line at 15 km day^{-1} in April 2010. In November 2011, the AC was found directly against the continental slope (Figure 1). Data from April 2010 will be referred to as the meander line, while that of November 2011 is the non-meander line.

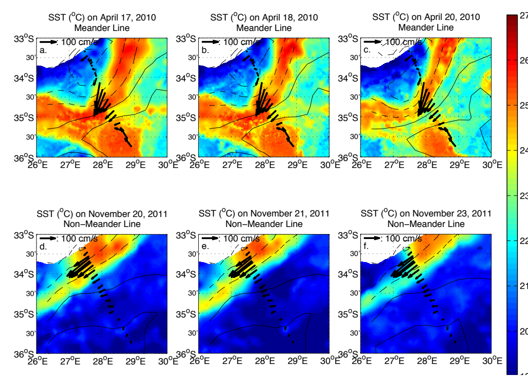

Figure 1: SST images from GHRSST corresponding to the timing of the meander (top row) and non-meander lines (bottom row). LADCP velocity vectors averaged over the top 200m are overlaid.

3. Results

The propagating meander pushes the core of the AC 123-km offshore, compared to 34-km for the non-meandering AC. As the current meanders, its width broadens almost 40-km from 88-km to 125-km (defined by the distance between the 0.5 m s^{-1} isotachs). Additionally, the Current's maximum velocity weakens from 208 to 136 cm s^{-1}. The weakening and broadening of the Current compensate for each other, such that the transport of the Current, in a streamwise sense, changes negligibly during meandering (120 ± 1.1 Sv for meander, and 125 ± 0.5 Sv for non-meander). At the same time, the meander induces an inshore counter current with a transport three times that of the northeastward velocity of the non-meandering current domain. This causes the overall Eulerian transport across the ACT line to fluctuate almost 20 Sv (101 ± 1.4 Sv for meander and 119 ± 0.9 Sv for non-meander).

Sampling bias in the meander line creates geostrophic and LADCP velocities that differ, while the non-meander line is strongly geostrophic (Figure 2). Johns et al, 1989 noted that the fractional error in geostrophic velocity due to a current's offshore progression is equal to the ratio between the current's lateral velocity to the ship speed offshore. Together with instrument error, this relationship explains almost all of this difference. We believe, therefore, that the difference in geostrophic and LADCP velocities in the meander line is not a real signal (e.g. surface Ekman flow, gradient wind balance), but rather an artifact due to sampling bias.

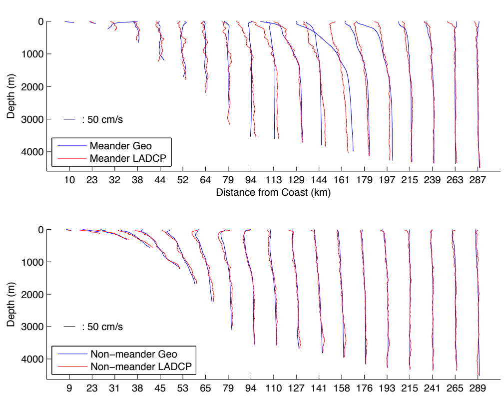

Figure 2: Geostrophic (blue) and LADCP (red) velocity profiles for the meander (top) and non-meander lines (bottom).

4. Remaining Questions and Future Work

Another facet of this study involves analyzing water mass changes induced by meandering. Future work will mostly focus on expanding this subject using both hydrographic data and a high-resolution model nested within the AC region (INALT01). In particular, we will analyze diapycnal and cross-frontal mixing of water masses induced by meandering.

5. References

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