Interannual variability of the Antarctic Circumpolar Current (ACC) around the western Drake Passage

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ABSTRACT

An empirical mode decomposition (EMD) was applied to 20-year (1992-2012) time series of Maps of Absolute Dynamic Topography (MADT) distributed by the AVISO. The Hilbert–Huang transform (HHT) uses the EMD method to decompose a complicated dataset into a finite number of components, the so-called intrinsic mode functions (IMFs). As a result, low frequency and higher relationships have been found in the vicinity of the Western Drake Passage. Lee (2005) has provided a hypothesis that vortex shedding in the eastern South America might trigger El Niño in the tropical Pacific. It could provide a mechanism to explain that there exists a mechanism to trigger both phenomena simultaneously.

INTRODUCTION

The opening of the Drake Passage established the strongest and longest current system in the world ocean, the Antarctic Circumpolar Current (ACC) extending around the globe with a length of roughly 24000 km. As the most important link between the ocean basins of the Atlantic, Pacific and Indian Oceans, the ACC serves as a conduit of all active and passive oceanic tracers which affect the Earth's climate (D. Olbers et al, 2004). Many researches have indicated the ACC is also an important component of the climate system (Gordon, 1986, Rintoul, 1991, Sloyan and Rintoul, 2001a, Sloyan and Rintoul, 2001b and Speich et al., 2001). Nevertheless, the remoteness of the Southern Ocean and its harsh environmental conditions means that this region is poorly sampled by hydrographic sections (Billany, W., et al, 2010).

In recently studies, the use of Maps of Absolute Dynamic Topography (MADT) has been used to locate fronts in the ACC (Sokolov and Rintoul, 2007, Swart et al., 2008, Sokolov and Rintoul, 2009a, Sokolov and Rintoul, 2009b, Billany, W., et al, 2010 and Swart et al., 2010). Thus, the application of MADT is extremely useful in a challenging location like the Southern Ocean.

The object of this paper is to examine the interannual variability of the ACC around the Western Drake Passage, an uncomplicated analysis via sea level anomaly data has been used. To examine whether teleconnections exist between the ACC and ENSO period, the correlation coefficients were calculated from the MADT and the MEI.

DATA AND METHODOLOGY

MADT

A 20-year (1992-2012) time series of Maps of Absolute Dynamic Topography (MADT) and absolute geostrophic velocity are distributed by AVISO was reanalyzed in this study (http:// www.aviso.oceanobs.com). The data is outlined on a Mercator grid of 1/3°x1/3°. In this case, MADT has been used to trace the ACC path positions between the Southeastern Pacific and the Drake Passage and to examine their associated variability. A map of the study region is shown in Fig. 1

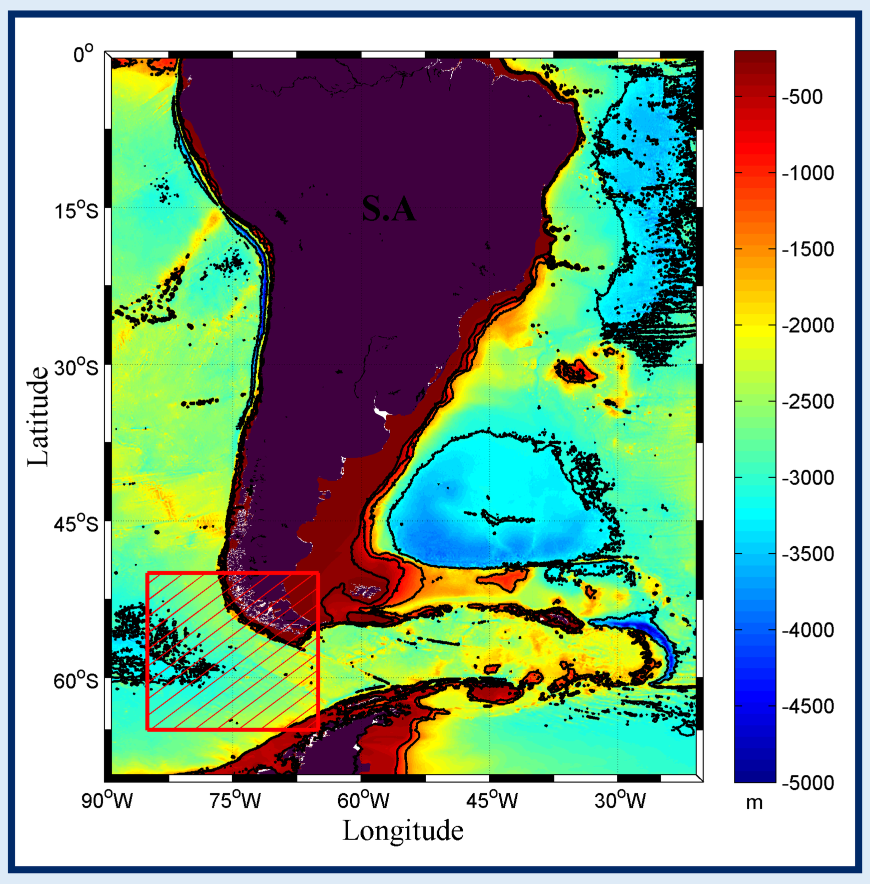

Figure 1. The research area was presented between latitude 50^0 to 65^0 S and longitude 85^0 to 65^0W

Multivariate ENSO Index

Areas with large positive values of the index depict the "El Niño" warm phase of the ENSO phenomenon. On the contrary, a areas with large negative values of the index depict the "La Niña" cold phase of the ENSO phenomenon (http://www.esrl.noaa.gov/psd/enso/mei/table.html).

HHT

The Hilbert-Huang transform (HHT) uses the empirical mode decomposition (EMD) method to decompose a complicated dataset into a finite number of components, the so-called intrinsic mode functions (IMFs). The EMD is adaptive, with each IMF giving an individual (orthogonal) frequency and amplitude(Huang et al., 1998).

ANALYSES METHODS AND RESULTS

Using low-pass filtered Method

To understand whether low frequency and higher relationships exist within the domain, the original data has been filtered via the "Low-pass" Filtered method with annual, biennial periods. The correlated maps have been used to examine the relationships between the research area and the Multivariate ENSO Index (MEI), as shown in Fig. 2(a)-(c). The results presented a positive correlation coefficient larger than 0.5 in the vicinity of the nearby Peru Current. On the contrary, negative correlation coefficients of approximately -0.4~-0.5 were shown in the vicinity of the Western Drake Passage. Three regions have been chosen to show a high relationship with MEI in the research area, as highlighted in Fig. 2(d).

Using HHT Method

As in the above regions, the empirical mode decomposition method has been performed to extract various IMFs. The 3rd IMF has been filtered with the annual period (Red line). A 12-month running mean has been applied to the climate indices which make the interannual variability easily discernible (black dashed line). The peak-to-peak comparison between the 3rd IMF and the 12-month running mean of the climate index have been shown to have close agreement. As a result, there was a positive relationship in Area 1. In contrast, negative relationships could be seen in Area 2 and Area 3, as shown in Fig. 3

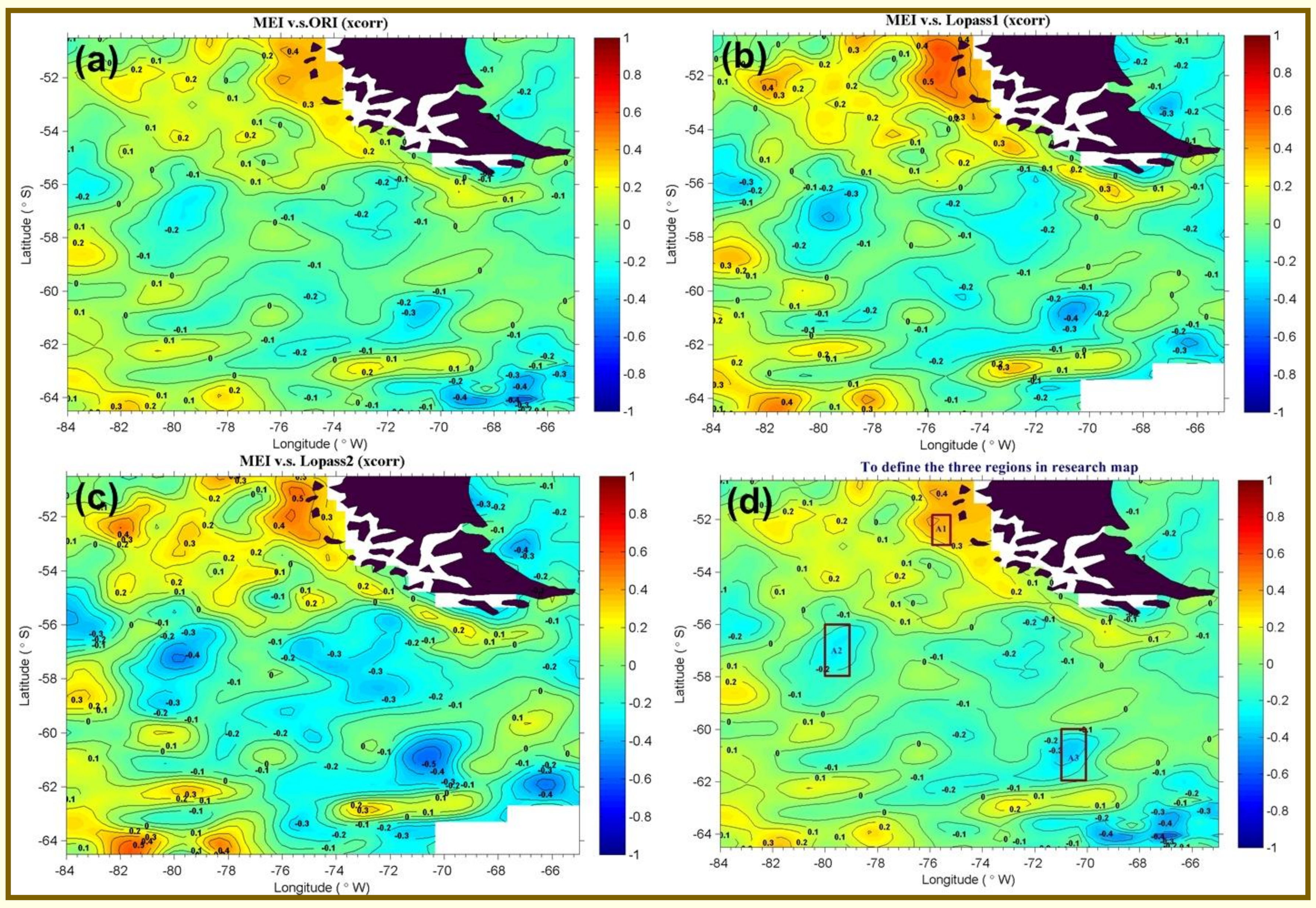

Figure 2(a)-(d). Correlations between the MEI and 20-year MADT data in the research area, during the period from October 1992 to February 2012. (a) Raw data (b) Low-pass filtered with annual period (c) Low-pass filtered with biennial period (d) Three areas with the highest relationship coefficients with MADT data. Area 1 (delimited by 76^0-75^0W, 52^0-53^0S), Area 2 (delimited by 80^0-79^0W, 56^0-58^0S), Area 3 (delimited by 71^0-70^0W, 60^0-62^0S)

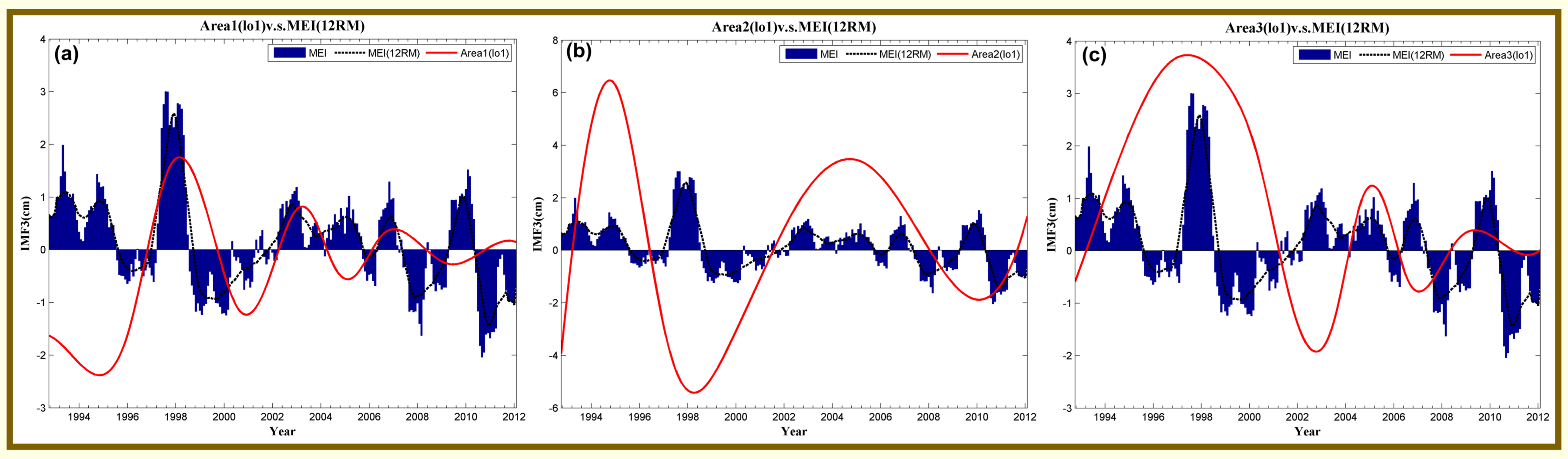

Figure 3. The comparison between the 3rd IMF and the 12-month running mean of MEI in the three high relationship regions. (a) in Area1 (b) in Area2 (c) in Area3.

CONCLUSIONS

The correlated maps show that low frequency and higher relationships exist within the domain. Positive relationships in the vicinity of the nearby Peru Current; on the contrary, negative relationships were shown in the vicinity of the Western Drake Passage. This result may suggest that there exists a mechanism to trigger both phenomena simultaneously. Lee (2005) has provided a hypothesis that if the South American Continent that interrupts the ACC can be treated as a structure in a flow, the vortexes developed behind the continent will then shed periodically. The flow through the Drake Passage between South America and the Antarctic will be greater resisted as vortexes are developing and will rush into the Atlantic Ocean as the vortex is shed away. The pattern is sketched as shown in Fig. 4, where the vortex is developing in stages 1 and 2 and shedding in stage 3, and in Fig. 5, where the ACC water is rushing further water into Atlantic Ocean. The periodic vortex shedding will then induce periodic variation of the Peru Current and the consequent El Niño. It could provide a mechanism to explain that there exists a mechanism to trigger both phenomena simultaneously.

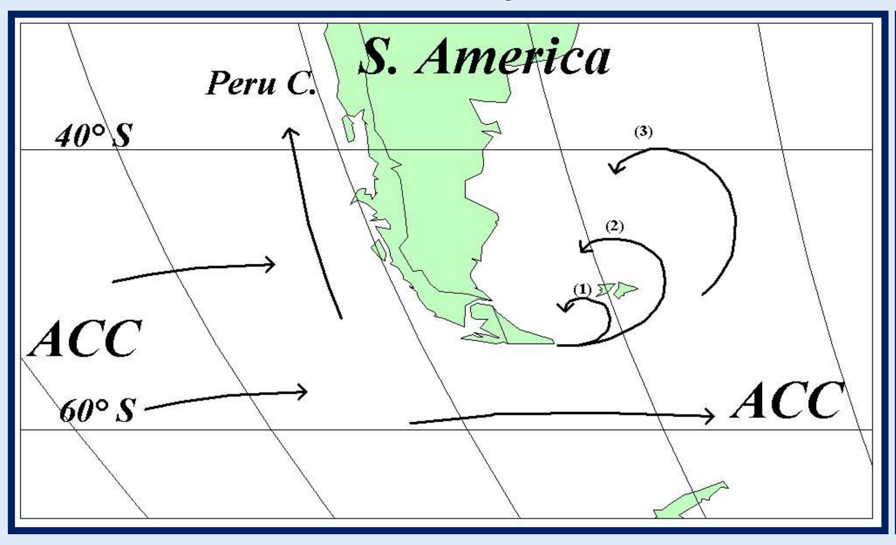

Figure 4. Three possible stages of vortex shedding behind the cape Horn

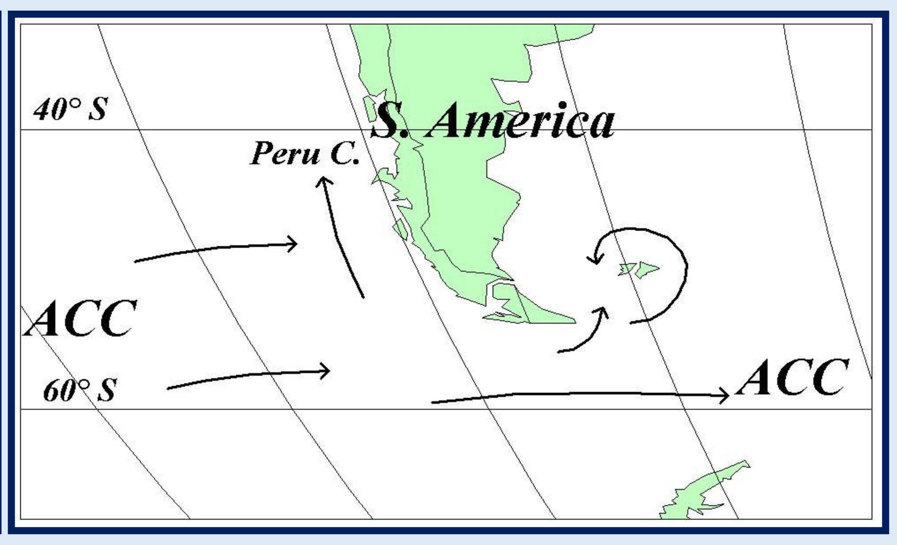

Figure 5. The possible increased intrusion of ACC water into Atlantic Ocean and resulting reduction of Peru Current

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