The AMOC and the seasonal cycle of the Canary Current

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ABSTRACT

Due to the important role of the eastern Atlantic in the Atlantic Meridional Overturning Circulation (AMOC), in this study we describe the seasonal cycle of the Canary Current system using hydrographic data from two cruises carried out in a box around the Canary Islands, the region where the eastern component of the RAPID array is placed. CTD, VMADCP and LADCP data were combined with inverse modelling in order to determine absolute geostrophic transports in the Canary Islands region in fall and spring. During spring, the overall transport of Canary Current (CC) and the transport in the Lanzarote Passage (LP) were southward. In the Lanzarote Passage (LP), between the Canary Islands and Africa, the transported was 0.6±0.20 Sv southward, while the Canary Current transported 1.0±0.40 Sv in the oceanic waters of the Canary Islands Archipelago. During fall, in the LP the transport was 2.8±0.4Sv northward, while the CC transported 2.9±0.60 Sv southward in the oceanic waters of the Canary Islands Archipelago. The amplitude of the seasonal cycle of the geostrophic transport obtained was quite similar to the seasonal cycle of the Eastern Atlantic contribution to the AMOC, as measured by the RAPID array. To understand the relationship between the seasonal cycle found in the CC and in the LP, and the amplitude of the seasonal cycle of the AMOC transport associated with Rossby waves, a sensitivity study of the Rossby wave model is included.

INTRODUCTION

The Atlantic meridional overturning circulation (AMOC) is recognized as an important component of the climate system, contributing to the relatively mild climate of northwest Europe. Due to its importance, the strength of the AMOC is continually monitored along 26ºN with several moorings located east of the Bahamas, in the Middle Atlantic Ridge and south of the Canary islands, known as the RAPID array. The measurements of the RAPID array show a 6 Sv seasonal cycle for the AMOC, and recent studies [1,2] have pointed out the dynamics of the eastern Atlantic as the main driver for this seasonal cycle, specifically, Rossby waves excited south of the Canary Islands [1].

MATERIAL AND METHODS

Two cruises were conducted in fall 2013 and spring 2014, with 53 (fall 2013) and 51 (spring 2014) hydrographic stations (Fig. 1). The station separation was about 30 km in the oceanic waters and 5-10 km for the coastal and shelf stations. A SeaBird 911+ CTD probe was used together with a 300/150khz Lowered Acoustic Doppler Current Profiler (LADCP). The mass transport was estimated in 13 neutral density layers, the thermocline waters correspond to the first two layers, the NACW are located on the next two layers, the intermediate water masses on the next three and the deep and bottom water masses in the denser layers.

Mass transports were initially estimated using geostrophic velocities obtained with a level of no-motion located at γ^n=27.975 kg m^{-3} (roughly 1950 m) for the oceanic waters, in the interface between the North Atlantic Central Waters (NACW) and the Mediterranean Waters (MW). For the stations in shallower waters the level of no-motion was at γ^n=27.380 kg m^{-3} (roughly 750 m), in the interface between the MW and the Antarctic Intermediate Waters (AAIW). The initial geostrophic velocities were corrected using the LADCP velocities. To reduce the large mass transports imbalances an inverse model [3] was applied to the volume enclosed by the hydrographic stations, and the African coast in the case of the fall survey.

RESULTS AND DISCUSSION

Hydrographic data, a long-term mooring and satellite altimetry-based sea level data show that the Canary Current, in the oceanic waters west of Lanzarote, has a seasonal cycle with amplitude of 1.9 Sv for the NACW and thermocline waters. Between Lanzarote and the African coast, in the Lanzarote Passage, there is a seasonal cycle of 3.4 Sv for the NACW and thermocline waters, that reach 4.0 Sv if the intermediate waters are included (Fig. 1).

This seasonality in the Canary Island region can be attributed to different mechanisms for the surface layer: the recirculation cell found in the eastern part of the Canary Basin and south of Cape Ghir; a cell that might be consequence of the termohaline anomaly created by the giant upwelling filament of Cape Ghir, which usually develops during the late summer; the upwelling current, that shows a seasonal variability due to the seasonal change of the wind-driven upwelling in the Lanzarote Passage.

In contrast, the reverse in the flow of the intermediate waters in the Lanzarote Passage, can be attribute to water column stretching forced by the seasonal cycle of the winds in the eastern subtropical Atlantic [2,4].

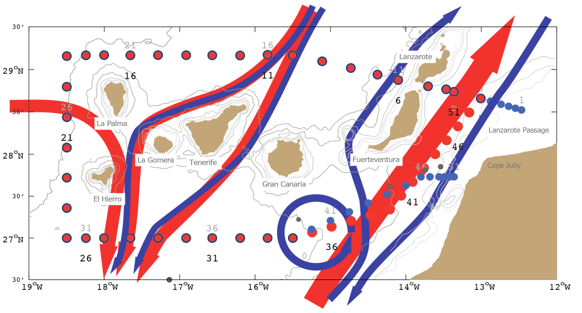

Figure 1. Map of the study area, showing the main topographic and geographical features referred in the text. The 200 m, 500 m, 1000 m and 2000 m isobaths are indicated with gray lines. The blue circles are the stations sampled in the spring 2014 cruise, while the red circles are the hydrographic stations that were sampled in the fall 2013 cruise. The thick red (fall 2013) and blue (spring 2014) lines correspond to the sketch of the thermocline and NACW transports. The grey circles denote the eastern Atlantic moorings of the Rapid array.

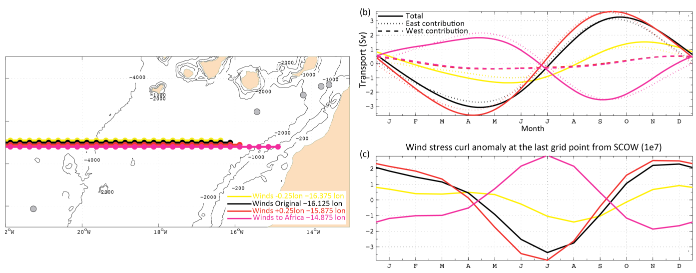

Figure 2. (a) Geographical extension of the SCOW wind stress curl anomaly used. The black line denotes the same winds used by [1]; the yellow line indicates the same winds used by [1] but without the last data point (0.25º in longiude further west); the red line indicates the same winds used but with one more data point (0.25º in longitude further east);the magenta line denotes all the available SCOW data points at 26.5ºN, to the African coast, this is 5 more data points that in [1]. The grey circles indicate the positions of the eastern Atlantic componente of the Rapid moorings. (b) Anomaly of basin-wide mid-ocean geostrophic transport for the first two baroclinic modes of a forced Rossby wave model as in [1], using the SCOW seasonal wind stress curl anomaly climatology. The thick lines show the total geostrophic transport, and the contributions from the variability the eastern boundary (western boundary) correspond to the dotted (dashed) lines. The color codes for the forced winds are the same as in (a). (c) wind stress curl anomaly seasonal cycle at the last data point at 26.5ºN. The color codes for the forced winds are the same as in (a).

Since [1] attributed the decrease in the southward flow in the eastern Atlantic to wind-forced Rossby waves, we carried out a sensitive study to test if the geographical extension of the SCOW wind stress curl (WSC) anomaly used in the wind-forced Rossby wave model has any impact in the magnitude of the seasonal cycle of the anomaly of basin-wide mid-ocean geostrophic transport (Fig. 2). The simulations show a high sensitivity to the SCOW WSC, with a reverse in the sign of the amplitude of the seasonal cycle if one grid point (25 km) was added, or substracted. The phase speed of the Rossby waves did not have any impact in the results when SCOW WSC was used. The uplift (depress) of the density surfaces in the spring (fall) cannot explain the seasonal variability found in the Canary Islands region. The high sensitivity of the wind-forced Rossby wave model to the geographical extension of the SCOW winds is due to the inconsistency between the geostrophic approach, used to estimate the basin-wide transport, and the high spatial resolution of the SCOW winds, smaller than the characteristic Rossby radius of deformation in the area. A smoothed version of the SCOW WSC or the NCEP winds, do not show this high sensitivity of the wind-forced Rossby wave mode to the geographic extension of the WSC.

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REFERENCES

1 - Kanzow, T. et al. (2010), Seasonal Variability of the Atlantic Meridional Overturning Circulation at 26.5°N, J. Climate, 23(21), 5678–5698, doi:10.1175/2010JCLI3389.1. Machín, F., and J. L. Pelegrí (2009), Northward Penetration of Antarctic Intermediate Water off Northwest Africa, J. Phys. Ocean., 39(3), 512–535, doi:10.1175/2008JPO3825.1.

2 - Perez-Hernandez, M. D., G. D. McCarthy, P. Vélez-Belchí, D. A. Smeed, E. Fraile-Nuez, and A. Hernández-Guerra (2015), The Canary Basin contribution to the seasonal cycle of the Atlantic Meridional Overturning Circulation at 26°N, J. Geophys. Res, 120(11), 7237–7252, doi:10.1002/2015JC010969.

3 - Hernández-Guerra, A., E. Fraile-Nuez, F. López-Laatzen, A. Martínez, G. Parrilla, and P. Vélez-Belchí (2005), Canary Current and North Equatorial Current from an inverse box model, J. Geophys. Res., 110(C12), doi:10.1029/2005JC003032.

4 - Machín, F., and J. L. Pelegrí (2009), Northward Penetration of Antarctic Intermediate Water off Northwest Africa, J. Phys. Ocean, 39(3), 512–535, doi:10.1175/2008JPO3825.1.