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Key Points:

- Robust relationship between: density, local WSC, and AMOC
- Density fluctuations drive the UMO transport at seasonal/interannual time scales

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Seasonal to interannual variability in density around the Canary Islands and their influence on the Atlantic meridional overturning circulation at 26°N

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Abstract The meridional interior flow obtained from the RAPID array is determined by horizontal density fluctuations at the eastern and western boundary of 26°N. The physical causes of these density variations are responsible for fluctuations in the Atlantic Meridional Overturning Circulation (AMOC) and through it, the meridional heat transport of the Atlantic. In this modeling study, a high-resolution ocean model is used to investigate the source and origin of the AMOC variability associated with the density fluctuations at the eastern boundary. The AMOC in the model is in good agreement with the RAPID observations and appears to adequately represent the smaller scale features of variability around the Canary Islands. In this paper, we identify a robust relationship between the density structure south of the Canary Islands, the local wind stress curl (WSC) around these islands and the AMOC using an empirical orthogonal functions analysis, wavelet transform, and wavelet coherence. We find that the deep density fluctuations at the eastern boundary of 26°N arise from the pumping effect of the spatial pattern of WSC south of the islands. These deep density fluctuations drive the AMOC both on seasonal and interannual time scales, through their influence on the basinwide tilt of the thermocline. At seasonal time scales, the density fluctuations south of the islands are driven by the WSC and directly influence the AMOC. At interannual time scales, a significant coherence is found between the density fluctuation and the southward Upper Mid-Ocean (UMO) transport although the origin of these density fluctuations is not explained by the direct pumping caused by the WSC.

1. Introduction

The ocean and atmosphere redistribute heat around the Earth. At 26°N, the Atlantic Meridional Overturning Circulation (AMOC) accounts for most of the total northward ocean heat transport in the Atlantic ($\sim$1.33 $\pm$ 0.40 PW) [*Johns et al.*, 2011], more than 30% of the total heat transport from the tropics to the poles [*Ganachaud and Wunsch*, 2000; *Hall and Bryden*, 1982; *Trenberth and Solomon*, 1994]. Changes in the AMOC and associated heat transport could have severe consequences for Europe's climate [*Vellinga and Wood*, 2002].

The AMOC transport varies on all time scales. In the short term, while modeling studies have shown reasonable representation of the AMOC, the variability tends to be underestimated either on seasonal or interannual time scales [*Matei et al.*, 2012; *McCarthy et al.*, 2012; *Roberts et al.*, 2013]. Long-term climate change projections of the AMOC strength show a wide range of possible behaviors, perhaps due to imperfect representation of AMOC driving mechanisms [*Bigg et al.*, 2003; *Stouffer et al.*, 2005; *Zickefeld et al.*, 2007] and a lack of data records to quantify long-term variability [*Kanzow et al.*, 2010]. On millennial time scales, *Ganopolski and Rahmstorf* [2001] suggested that the variability could be associated with unstable ice sheets in the past. On multidecadal time scales, the AMOC heat transport variability is linked with the North Atlantic Oscillation (NAO), which is responsible for the atmospheric heat flux variability [*Delworth and Greatbatch*, 2000; *Eden and Willebrand*, 2001]. On interannual and shorter time scales, the AMOC variations are caused by both fluctuations in the density field and in the wind stress [*Hirschi and Marotzke*, 2007; *Chidichimo et al.*, 2010; *Kanzow et al.*, 2010]. On very short (subdaily) time scales, the AMOC may undergo large oscillations due to near-inertial gravity waves [*Blaker et al.*, 2012]. In order to identify fluctuations on decadal or longer time scales, we must first understand the short term variability of the AMOC.

The RAPID-WATCH/MOCHA array (hereafter referred to as the RAPID array) has been monitoring the AMOC at 26°N since 2004, where the AMOC is computed as the sum of the Florida Straits transport (FST),