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Measuring the Atlantic Meridional Overturning Circulation at 26°N

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ABSTRACT

The Atlantic Meridional Overturning Circulation (AMOC) plays a key role in the global climate system through its redistribution of heat. Changes in the AMOC have been associated with large fluctuations in the earth's climate in the past and projections of AMOC decline in the future due to climate change motivate the continuous monitoring of the circulation. Since 2004, the RAPID monitoring array has been providing continuous estimates of the AMOC and associated heat transport at 26°N in the North Atlantic. We describe how these measurements are made including the sampling strategy, the accuracies of parameters measured and the calculation of the AMOC. The strength of the AMOC and meridional heat transport are estimated as 17.2 Sv and 1.25 PW respectively from April 2004 to October 2012. The accuracy of ten day (annual) transports is 1.5 Sv (0.9 Sv). Improvements to the estimation of the transport above the shallowest instruments and deepest transports (including Antarctic Bottom Water), and the use of the new equation of state for seawater have reduced the estimated strength of the AMOC by 0.6 Sv relative to previous publications. As new basinwide AMOC monitoring projects begin in the South Atlantic and sub-polar North Atlantic, we present this thorough review of the methods and measurements of the original AMOC monitoring array.

A review of measuring the AMOC

The world's oceans are a major part of the heat engine of the global climate system, moving heat, together with the atmosphere, from equatorial regions to the high latitudes. The South Atlantic is the exception in this picture of heat redistribution, transporting heat northwards (Bennett, 1978) across the equator as part of the Atlantic Meridional Overturning Circulation (AMOC). The heat released by the ocean over the North Atlantic contributes to the relatively mild climate of north western Europe (Seager et al., 2002) with the AMOC being responsible for the approximately 3 °C warmer temperatures on the northwestern European seaboard compared to similar maritime climates on the western seaboard of North America (Rhines et al., 2008).

Observation of the AMOC is quite challenging, requiring measurements that span a complete basin, so historically the observational record has been quite limited. There have been several reviews of AMOC observations focusing on aspects such as the history of observations (Warren and Wunsch, 1981; Mills, 2009), the representations, (Richardson, 2008) and the quantification (Longworth and Bryden, 2007) of the AMOC. Early estimates on the size of the deep circulation were based solely on property distributions. Sverdrup et al. (1942) estimated a 7 Sv (1 Sv = 10^6 m^3/s) flow of deep water out of the North Atlantic and across the equator that could be traced southward through the South Atlantic and around the Southern Ocean. Swallow and Worthington (1957) made short term float trajectory observations in the deep western boundary current off South Carolina that supported the value of 7 Sv for the deep circulation. This value was maintained by Worthington (1976) in his influential summary of North Atlantic circulation.

Modern estimates for the size of the overturning circulation began with analyses of coast-to-coast hydrographic sections in the early 1980s (Bryden and Hall, 1980; Hall and Bryden, 1982; Roemmich and Wunsch, 1985). They found an overturning circulation of about 18 Sv, contradicting the previous value of 7 Sv, and a northward heat transport of 1.2 PW (1 PW = 10^{15} W). Analysis of historical and modern hydrographic sections generally finds an Atlantic overturning circulation of the order of 18 Sv and its associated northward heat transport robustly positive.

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