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Vertical-mode decomposition as a dynamic description of the Atlantic meridional overturning circulation

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The RAPID array monitors the vertical density structure across the North Atlantic at 26.5°N in order to calculate the basin or interior component of the meridional overturning circulation (MOC). By decomposing density fluctuations onto vertical modal structures whose dynamics are well understood, we gain a framework for interpreting fluctuations in the overturning circulation. In addition, this method separates the barotropic and baroclinic components and allows a ready comparison of satellite altimetry with the first baroclinic mode. We consider three data sets: moored density or geopotential anomalies (GPA) from the RAPID temperature and salinity moorings, bottom pressure (BP) measured at the base of the RAPID moorings, and sea surface height (SSH) from satellite altimetry. As a result of our hydrographic data coming from moored CTDs, a new decomposition technique was developed that extracts low-frequency (periods longer than 2 days) modal amplitudes directly from density anomalies. The barotropic mode that results is combined with BP. GPA from the original RAPID processing is called “standard," while that which is synthesized using the modal decomposition is called “reconstructed".

The modal decomposition recovers almost all of the variance in the vertical ($r^2 > 0.9$) with slightly less effectiveness right at the western boundary ($r^2 = 0.8$). Away from the boundaries, the reconstructed GPA and its gradient agrees closely with the standard GPA and with SSH, and almost all of the variance is contained in the first baroclinic mode. In contrast, at the boundaries the signals are much weaker overall and a significant amount of the variance is contained outside of the first baroclinic mode. Despite the fact that the first baroclinic mode extracts the near boundary transport signal most correlated with SSH, the reconstructed GPA does a poor job of recovering total transport fluctuations adjacent to the boundaries. An additional difference at the western boundary is the presence of energetic fluctuations with periods of 2–20 days. Given that the interior component of the MOC is calculated from boundary-to-boundary density gradients, our results suggest that the theoretical assumptions behind modal dynamics do not apply to the interior MOC, and that understanding boundary effects is critical to understanding the measured MOC signal.