Southward NADW transport and property changes at 16′N

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The MOVE project

The MOVE (Meridional Overturning Variability Experiment) observational setup consists of two endpoint moorings measuring density at the edges of an approximately rectangular section along 26°N in the tropical Atlantic, between Guadeloupe and the Mid-Atlantic ridge (NAR), used to calculate the geostrophic flow of North Atlantic Deep Water (NADW) through the section. Current meters are used to measure the flow over the Western boundary and bottom pressure records have been deployed alongside the MOVE 1 and MOVE 3 moorings at the boundaries in most years.

The moorings have been deployed in consecutive 1- or 2-year deployments since 2000, providing a 17-year time series of bottom-referenced NADW transport.

Western boundary water mass changes

The 17-year time series of bottom-referenced NADW shows distinct patterns of variability in several of the main NADW water masses.

Bottom pressure Variability

A key goal for the MOVE array going forward is to investigate the changes in velocity at the reference level, or, equivalently, the barostrophic component of the flow, to validate decadal trends in the bottom-referenced transport estimates. The MOVE mooring maintains a site on the Atlantic basin, an estimate of the barostrophic flow through mass conservation constraints as used in the RAPID array (McCaffrey et al., 2015) is not possible. To ascertain whether changes in the bottom-referenced transport estimates (see top right panel) correspond to real variability, the change in the reference level velocity needs to be resolved, which can be achieved by measuring pressure changes at both endpoints.

Although bottom pressure is measured in situ at the MOVE sites, the strong instrument drift that pressure recorders suffer from makes them unsuitable for measuring decadal trends in the reference level velocity. At the same time, the coarse sampling of the GLADAR mission, which measures ocean mass as gravity anomalies, together with the ocean-based measurements.

Numerical simulations

To put observations at MOVE into a broader context, we use output from a 60-year run of a high-resolution numerical model (Serra et al., 2010). Transport measured with a MOVE-like setup at 26°N for the entire 60-year model run compares well with the overturning on long time-scales, suggesting that our method can be used to monitor decadal to multi-decadal AMOC variability.

The best-estimate model NADW transport with observational results is found when integrating over a narrow region close to the Western boundary between 800-4400m, owing to differences in basin geometry in the model. The transport calculated over this region shows decadal trends consistent with observations. A large part of the decrease in LSW core thickness reveals large scale patterns correlated with transports at the MOVE latitude, aligned along the SW-NW direction, which is characteristic of planetary Rossby waves.

NADW transport through the MOVE section

The geostrophic transport between the MOVE3 and MOVE1 moorings is calculated from the thermal and salinity fields using the linearized form of the geostrophic balance. Integration, the velocity shear up to the depth of the free surface is calculated. The position of the depth of the free surface is calculated. The bottom-moored current meter at each site is used to obtain the velocity profile at each time step, which is then integrated between 1200 and 4900m to calculate the transport perpendicular to the meridional section. The depth of the free surface is fixed at 500m for all models. The reference level is chosen because it represents the approximate depth of the zero momentum level, where the NADW and isopycnal flows become the dominant pathways. The reference level variability is expected at those depths on long time scales (Senda et al., 2017). Two distinct modes are visible in the mean velocity profile, associated with the two main water masses of the MOVE: Labrador Sea Water (LSW) and Denmark Strait Overflow Water (DSOW). The current 17-year time series exhibits decadal variability, indicated by the dashed lines in the figure. Velocity profiles show a strengthening of both the LSW and the DSOW core in recent years relative to the beginning of the record.

Figure 3: NADW transport through the MOVE section.

Main points

- Bottom-referenced NADW transport at MOVE shows decadal variability, with multi-year periods of increasing and decreasing flow through the section.
- Properties of the main water masses making up NADW are changing over time, generally moving towards lower salinity and higher temperature.
- LSW salinity drops strongly between 2000 and 2002 due to the arrival of 1987-94 LSW, and decreases more gradually thereafter. The LSW salinity drop is evident in observations at MOVE.
- Resolving the reference level velocity is a crucial step towards validating transport estimates at MOVE, but a robust method to measure it remains elusive; bottom pressure data show only a weak trend on long time scales, but there may be sporadic trends in the GRAPE data used.
- MOVE transport variability differs from that at the other prominent mooring array measuring NADW flow: RAPID. Bottom pressure data validate the transport, but influence on long time scales; differences in trends persist despite the use of a similar reference level (data from a 60 year model run are shown).
- Model data show that the observed variability well matches the observations at MOVE. However, the model data suggests that the Rossby waves are responsible for the multi-decadal transport variability, which is consistent with the observations.

Figure 4: Comparison of NADW transport at MOVE and model data from a 60 year model run.