Atlantic Meridional Overturning Circulation: Towards a decade-long time series of observations at RAPID-MOCHA 26^{o}N

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MOTIVATION & RESULTS

The Meridional Overturning Circulation (MOC) transports heat northward in the North Atlantic, contributing to northwestern Europe's mild climate. Will the MOC slow down? How will we know?

RAPID-WATCH together with RAPID-MOC and MOCHA will create a decade-long time series of the Atlantic MOC (AMOC) at 26°N, showing variability in the strength and structure of the MOC.

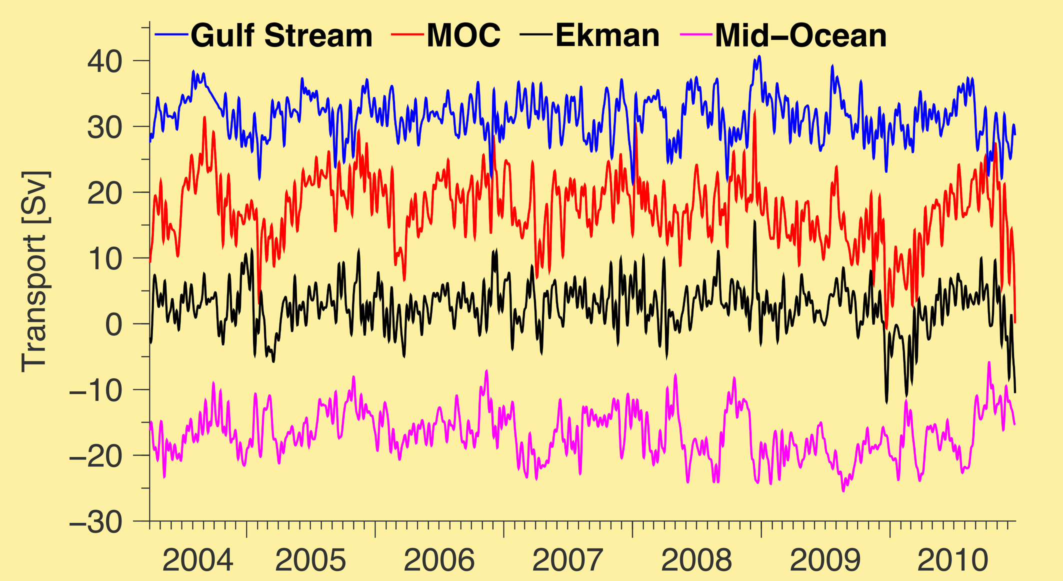


Figure (above right): 10-day low pass filtered transport timeseries. The MOC is in red. Note the apparent seasonal cycle from the first 4 years and the dramatic reduction in the MOC in 2009-10. Some of these changes are due to changes in the wind-driven Ekman transport, but also to deep ocean variability.

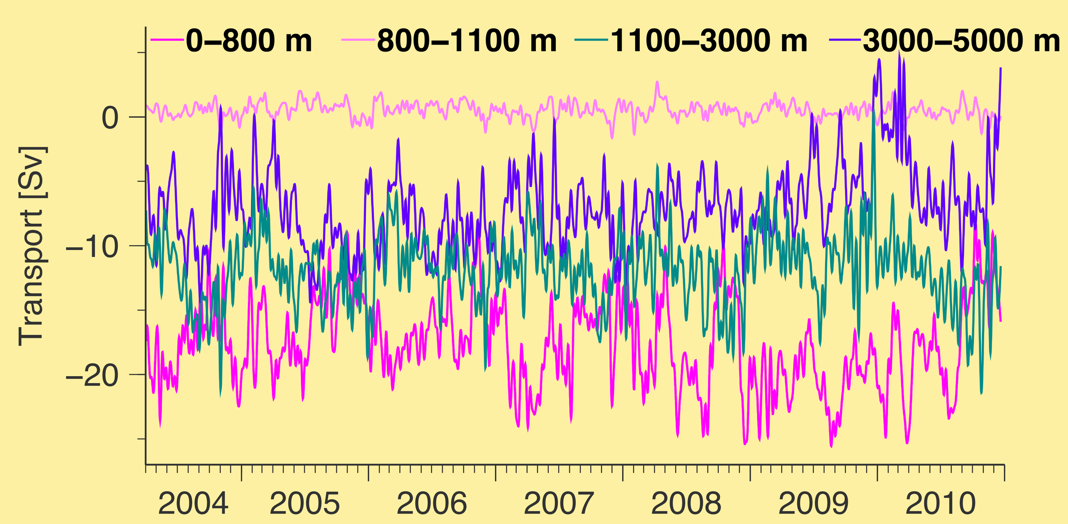
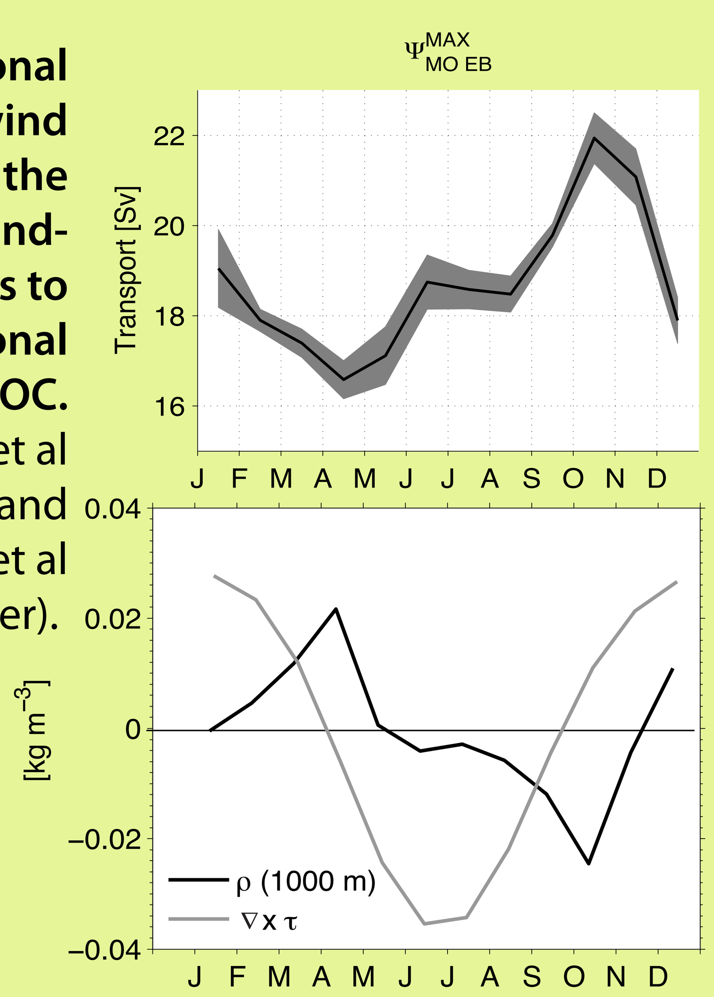


Figure (below right): Layer transports for mid-ocean variability. During the dramatic changes in the MOC in 2009-10, there was a reduction in the southward transport of lower NADW (positive anomaly of the dark blue curve).

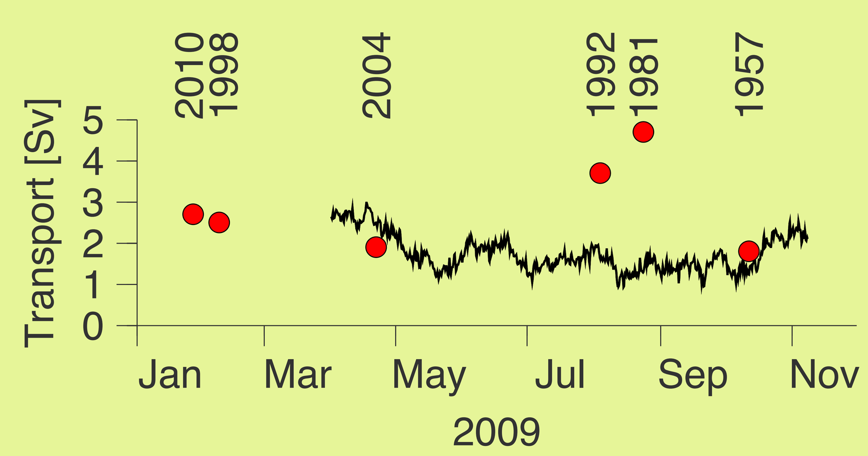
RESULTS FROM THE FIRST FOUR YEARS

The first four years of the MOC at 26°N showed a reasonably regular seasonal cycle, as well as large fluctuations on a range of timescales. **What are the sources of this variability?**

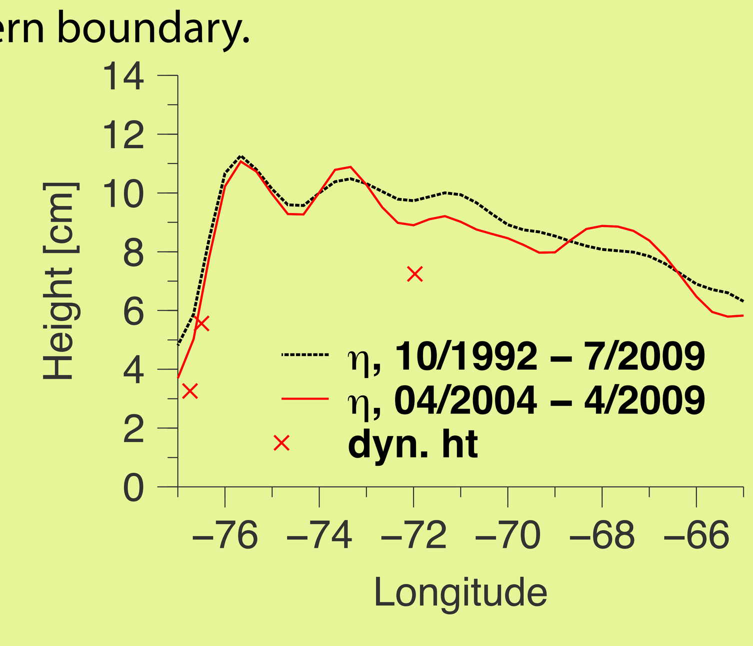
1. The seasonal cycle of wind stress curl on the Eastern Boundary contributes to the seasonal cycle of the MOC. Kanzow et al (2010, upper) and Chidichimo et al (2009, lower).

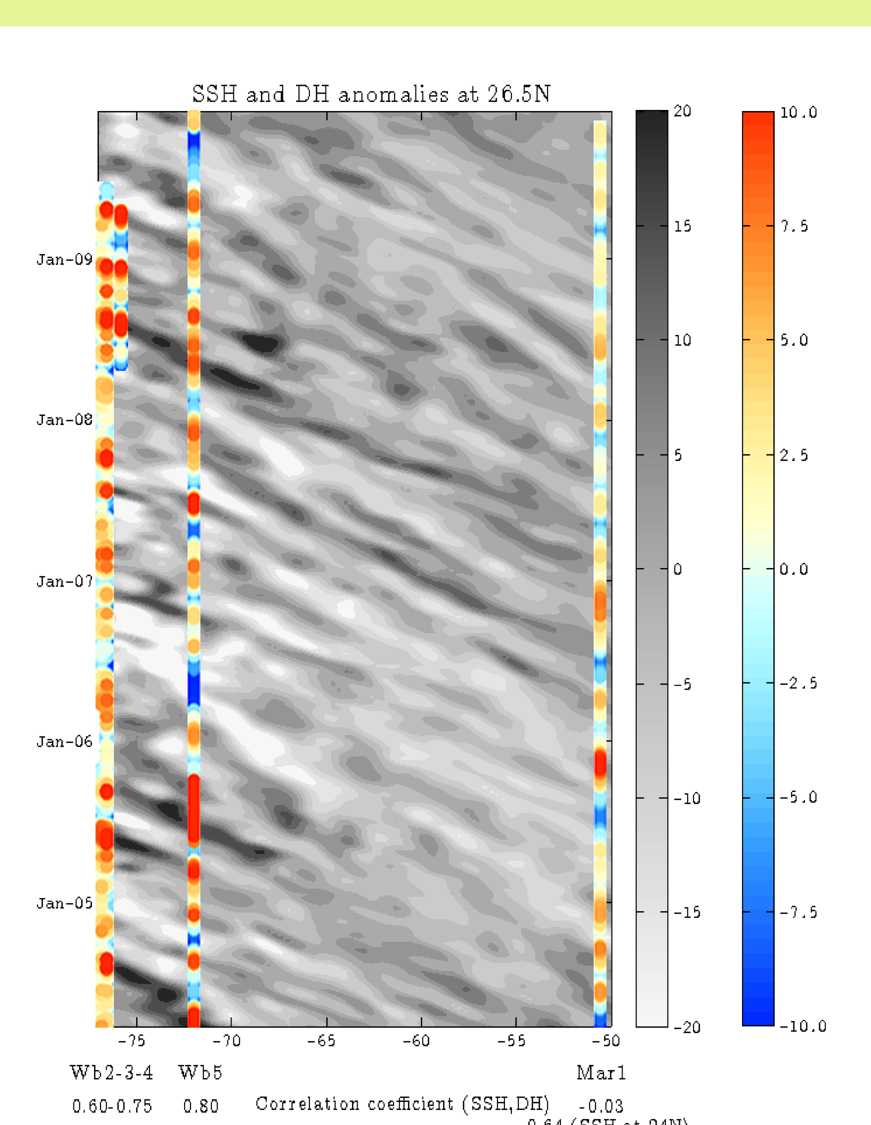


2. Antarctic Bottom Water transport at 26°N is variable, Frajka-Williams et al, 2011, below. Transport in even the deepest layers are variable, with a range of 1-3 Sv in 6 months, a large fraction of the variability estimated from hydrography.



3. Eddy variability is reduced as one approaches the western boundary, Bryden et al, (2009), Kanzow et al (2009, below). Thus, MOC variability is not dominated by eddies and observations must be quite close to the western boundary.

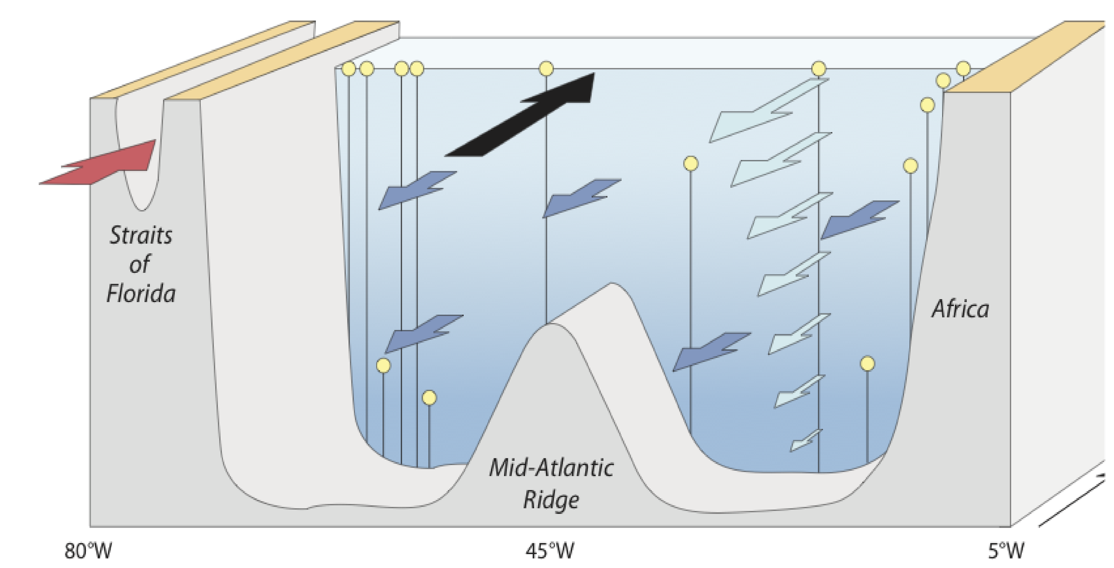




4. Residual eddy variability impacts the MOC. Clement et al (in prep, left). Szuts et al (in prep). Westward propagating anomalies in SSHA decrease in amplitude as they reach the boundary, but the residual variability is correlated with the mid-ocean transport.

METHOD

The main 3 components of the MOC transport at 26°N are (1) internal mid-ocean ocean variability, (2) Florida Straits from cable measurements, (3) Ekman from surface winds.



Internal mid-ocean variability is measured by current meter moorings at the west and the geostrophic transport between density at the west and east.

$$T_{moc} = T_{gs}+T_{ek}+T_{umo}$$

where Tmoc is the vertical integral of mid-ocean transport down to the deepest northward velocity (~1km) on each day.

DRAMATIC INTERANNUAL VARIABILIITY OF THE MOC SINCE 2009

The MOC in 2009 was anomalously weak compared to previous observations. In Dec 2009, the MOC reversed direction. This resulted from a strong Ekman transport anomaly, due to a southward shift of the winds, as well as a weaker Gulf Stream transport. However, changes are also visible in the deep flow (see left).
The MOC is responding to atmopheric forcing and driving changes through heat flux anomalies.

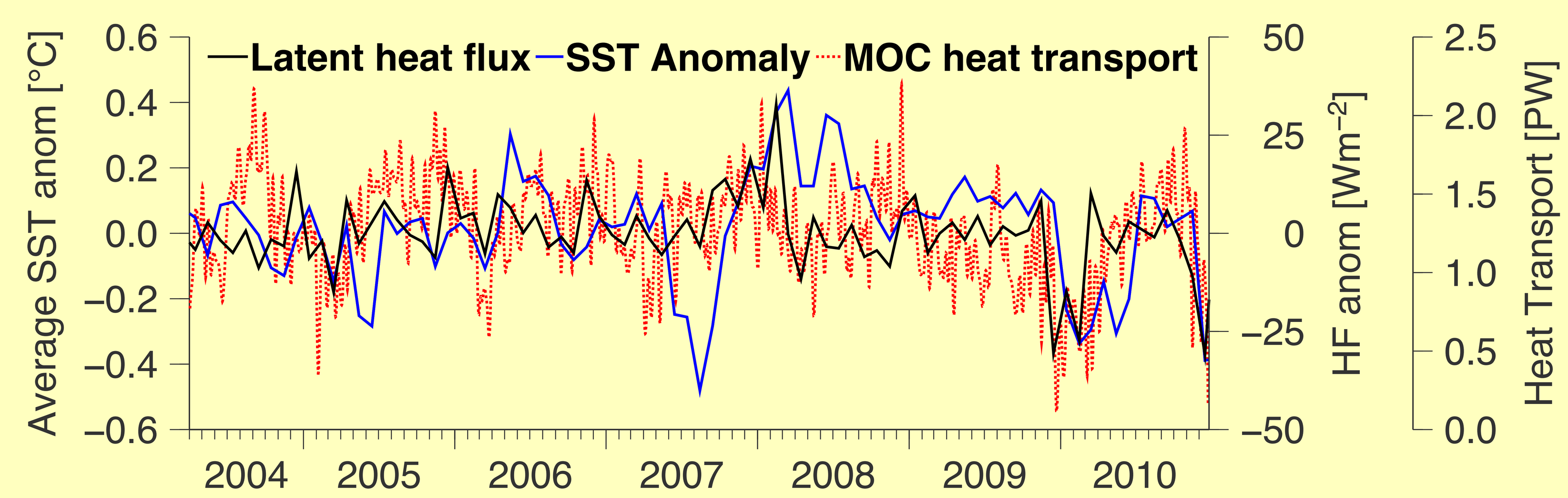
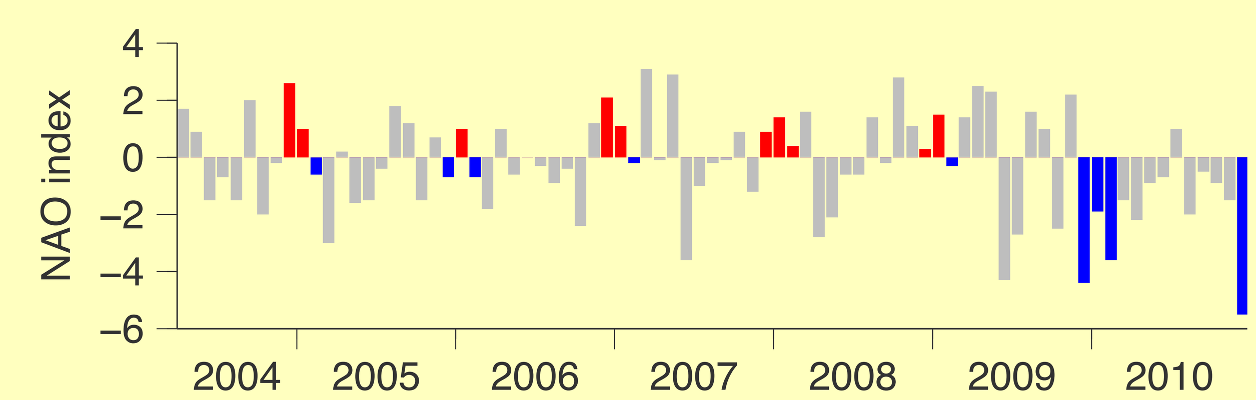
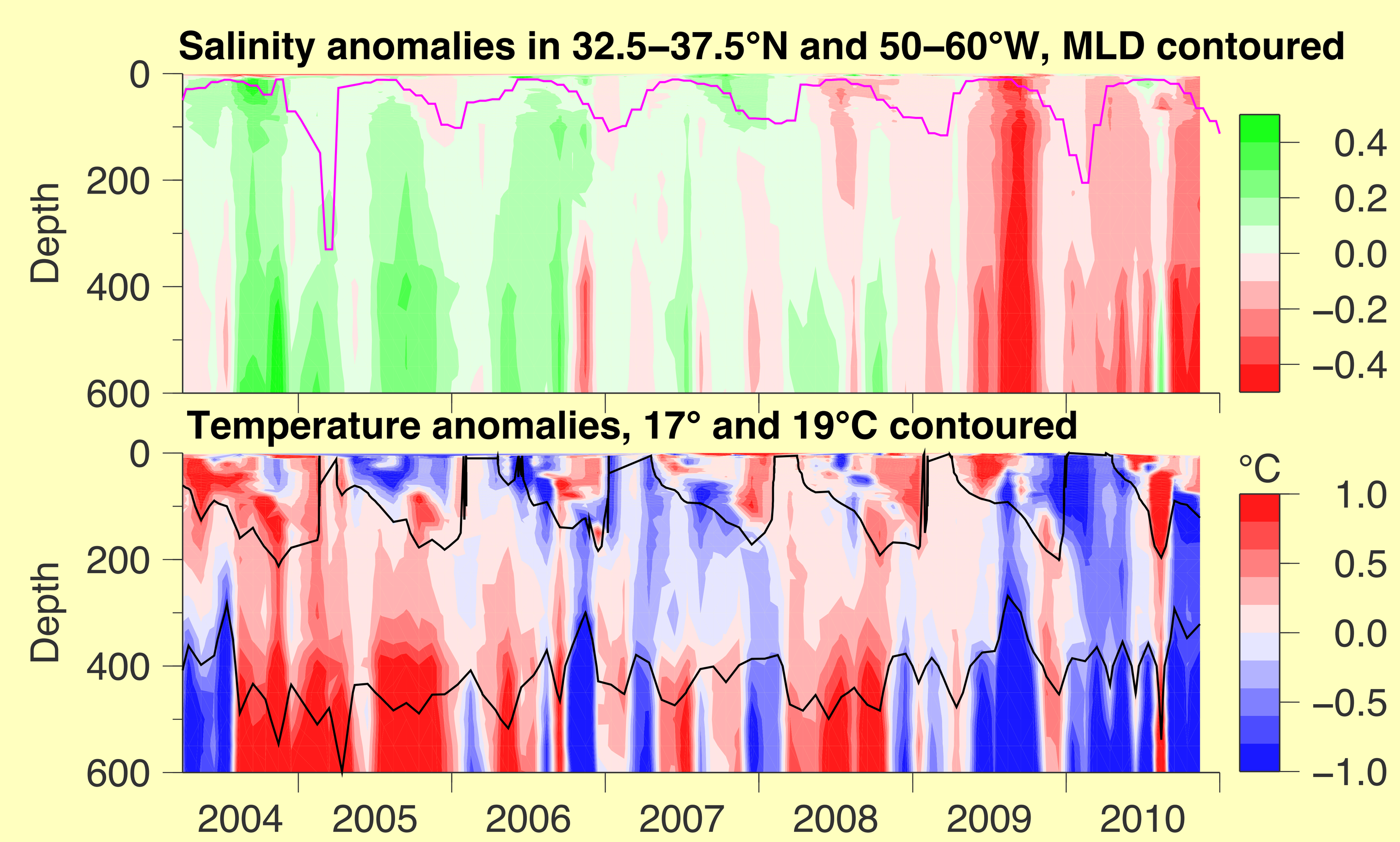


Figure (above) shows the northward heat transport by the MOC (red, see Johns et al, 2011 and poster **TH69B**), monthly surface heat flux anomaly (black, NCEP, 25-45°N), and monthly SST anomaly (blue, AMSRE, 25-45°N). The anomalous ocean heat transport was nearly 1 PW less than usual, and was present both in winter 2009-10 and again at the end of 2010.



The winter North Atlantic Oscillation index in winter 2009 was strongly negative, and again in winter 2010 (**left**). Winter months are highlighted in color.



Heat content in the subtropical North Atlantic was lower following the weak MOC event. This is due both to anomalous heat transport by the MOC and anomalous surface heat fluxes. **Figures (left)** show the salinity and temperature anomalies in the region of 18°C modewater formation from Argo floats. In the 2009-10 formation period, waters were colder (and fresher) than usual, resulting in a persistent heat content anomaly.

Both the anomalous MOC and anomalous air-sea fluxes contribute to changes in heat content. These changes then feedback on the atmosphere. What is the relative importance of MOC changes on the coupled system?

RECENT PUBLICATIONS FROM RAPID OBSERVATIONS:

Bryden, H. L., A. Mujahid, et al, 2009: Adjustment of the basin-scale circulation at 26°N to variations in Gulf Stream.... Ocean Science, 6, 871-908.
Chidichimo, M. P., T. Kanzow, et al, 2010: The contribution of eastern-boundary density variations to the AMOC... Ocean Science, 6 .
Clement, L., Frajka-Williams, E., Szutz, Z., et al, in prep.
Frajka-Williams, E., Cunningham, S. A., et al, Variability of Antarctic Bottom Water at 26°N, Journal of Geophysical Research, in press.
Johns, W. E., L. M. Beal, et al, 2010: Continuous, array-based estimates of Atlantic Ocean heat transport at 26.5°N. Journal of Climate, 2011.
Kanzow, T., H. Johnson, et al, 2009: Basin-wide integrated volume transports in an eddy-filled ocean. J. Phys. Oceanog., 39, 3091–3110.
Kanzow, T., S. A. Cunningham, et al, 2009: Seasonal variability of the Atlantic meridional overturning circulation at 26.5°N. J. Clim., 2010.
Rayner, D., J. J.-M. Hirschi, et al, 2011: Monitoring the Atlantic Meridional Overturning Circulation. Deep Sea Research II.

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Data are available from the project website: http://www.noc.soton.ac.uk/rapidmoc/