LOW-FREQUENCY AMOC VARIABILITY: AN ASSESSMENT BASED ON AN OCEAN DATA ASSIMILATION SYSTEM

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The Atlantic meridional overturning circulation (AMOC) plays a critical role in establishing the global climate at various spatial and time scales. Changes in the AMOC can directly result in variations in deep ocean heat content, meridional transports of freshwater and heat, and inter-ocean exchanges of mass, heat, and freshwater. Because of the rarity of historical observations and the difficulty in directly observing the AMOC, ocean analyses based on models and data become important in understanding and monitoring the AMOC changes that are associated with changes in ocean temperature, and salinity.

The AMOC is estimated using NCEP operational Global Ocean Data Assimilation System (GODAS), which assimilates observed temperature and synthetic salinity profiles down to 750m. The averaged (1982-2004) AMOC is approximately16 Sv near 37ºN and at 1000 meter depth (Fig.1a), consistent with other observed analyses and model simulations.

An EOF analysis indicates that the AMOC variation in GODAS exhibits a broad spatial structure extending from 55ºN and 500m to 20ºN and 2500m (Fig. 1b). The location of maximum AMOC variation is located near 45ºN and 1500m, which is different from the location of the maximum AMOC (37ºN and 1000m). The AMOC variation is in an opposite phase between 20ºN and 38ºN above 1000m.

The EOF principle component (Figure 1c) shows that the AMOC in GODAS increased from 1980 to 1994 and decreased from 1994 to 2008, which is consistent with the maximum AMOC at 40ºN (Fig. 1c) in GODAS and observations at 26ºN [1] and suggests a low –frequency (LF) variability of approximately 30 yr.

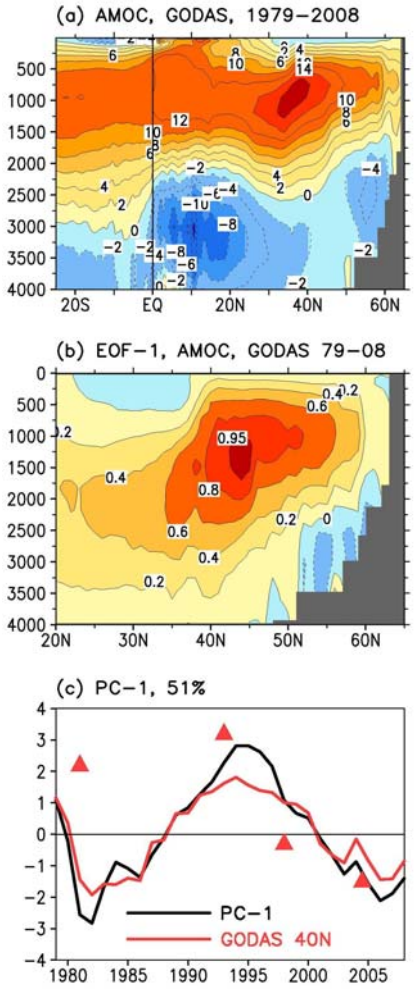

Figure 1. (a) Mean (1979-2008) AMOC in GODAS. (b) First EOF of detrended AMOC in GODAS. The first EOF represents 51% total AMOC variance. (c) First PC of AMOC in GODAS, along with de-trended maximum (0-2000 m) AMOC anomaly in GODAS at 40ºN and observed AMOC anomaly [1] (▲) near 25ºN. The AMOC anomalies are relative to a mean AMOC of 16.3 Sv. A 3-yr running mean is applied in (c).

The changes in AMOC are largely density-driven in GODAS, which can essentially be attributed to changes in temperature that, in turn, is associated with changes in surface heat flux in the North Atlantic. Certain features of the temperature and salinity fields in the GODAS are analyzed and compared with observations from World Ocean Database 2005 (WOD05).

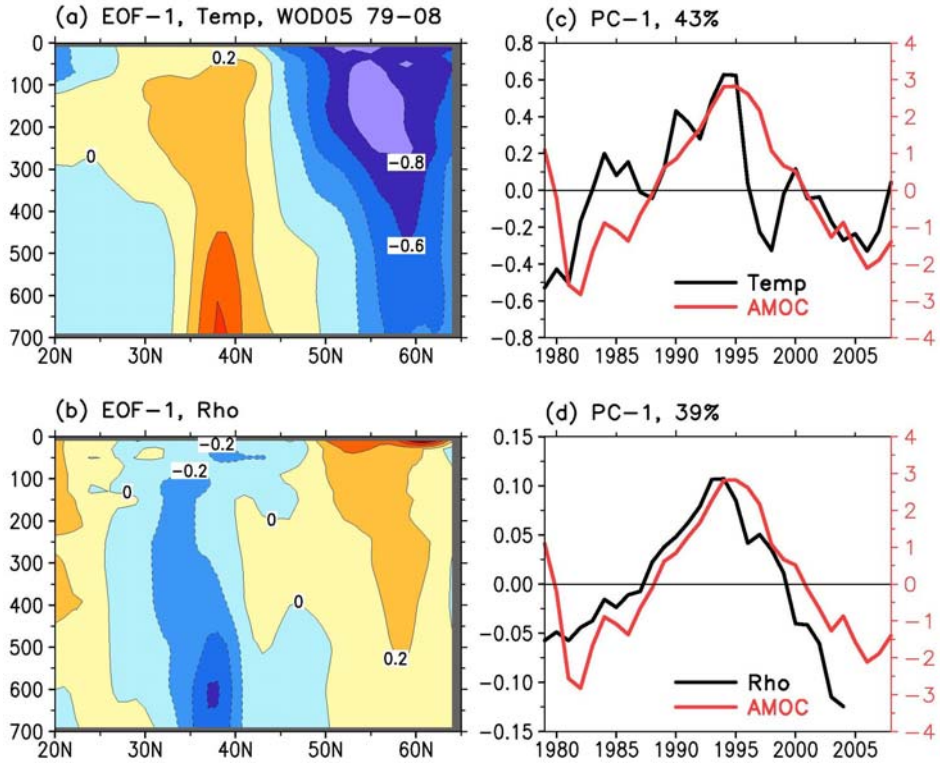

Figure 2. First EOF of detrended and basin-averaged (a) temperature and (b) density in the Atlantic in WOD05. First PC of (c) temperature and (d) density along with AMOC in the Atlantic. The units are ºC in (c) and kg m^{-3} in (d). The variance explained by the first EOF is approximately 43% and 39% for temperature and density.

EOFs and PCs of salinity, temperature, and density between 20ºN and 65ºN from the surface to 700 m in WOD05 are analyzed separately to understand causality in LF variability of the AMOC. The first EOF and PC (Figs. 2a and 2c) show that, zonally averaged temperature exhibits an anomalous cooling north of 45ºN and an anomalous warming between 25ºN and 45ºN from 1979 to 1995, and an opposite tendency after 1995. This LF variability of temperature represents 43% of total variance, and dominantly contributes to the LF variability of density (Figs. 2b and 2d). The contribution of salinity to the density variability is weak (not shown). The EOF1 of density represents 39% of total variance.

The coherence of temperature and density features with aspects of the AMOC suggests that they can serve as fingerprints of the AMOC.

The PC1 of GODAS AMOC is significantly correlated with PC1 of WOD05 density (0.78) and temperature (0.60, after 3-yr running mean in PC1's of WOD05 temperature).

GODAS successfully simulated the temperature and density features observed in WOD05. Correlation coefficients of EOF1 and PC1 of temperature and density between WOD05 (Fig. 2) and GODAS are up to 0.8.This suggests the LF AMOC variability can be documented based on an ocean analysis system such as GODAS.

Reference

1. Bryden, H.L., et al. (2005), Slowing of the Atlantic meridional overturning circulation at 25N, *Nature*, **438**, doi:10.1038/nature04385.