OFES Models and the MOC: A comparison of model-produced and observed MOC characteristics in the North Atlantic Ocean

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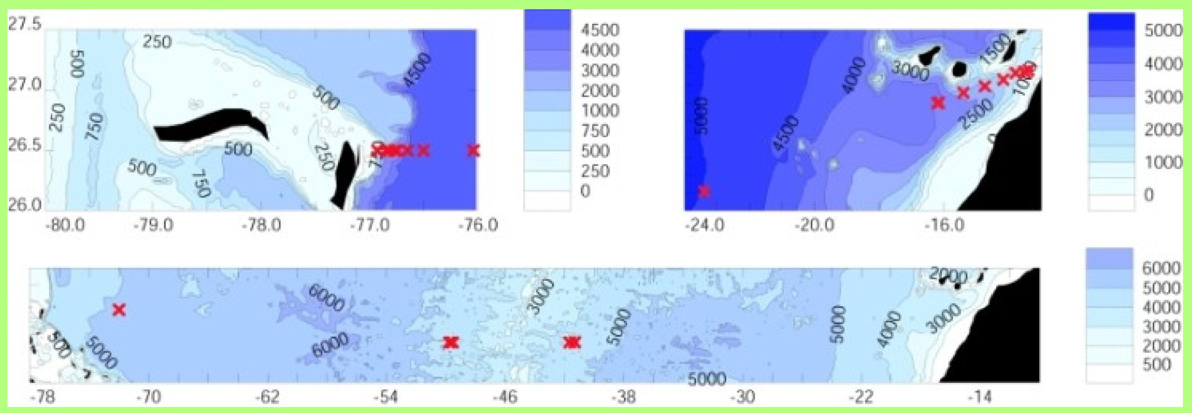
Abstract

The North Atlantic Meridional Overturning Circulation (MOC) has been cited as an important factor in the moderation of global climate. This poster presents an analysis of observed AMOC variability at 26.5°N on weekly to interannual time scales compared to variability characteristics produced from high-resolution, eddy-resolving OGCMs. The focus of the analysis is on the relative contributions of ocean mesoscale eddies and synoptic atmospheric forcing to the overall AMOC variability. Observations used in this study were collected within the framework of the joint U.K.-U.S. Rapid Climate Change (RAPID)-Meridional Overturning Circulation & Heat Flux Array (MOCHA) Program. The RAPID-MOCHA array has now been in place for nearly 6 years, of which 4 years of data (2004-2007) are analyzed in this study. The models were produced by the OGCM for the Earth Simulator (OFES), operated by the Japan Agency for Marine-Earth Science & Technology (JAMSTEC). Two identically configured models runs are analyzed, each having high-resolution (0.1°) horizontal grid spacing and 54 vertical levels. One model is forced by NCEP/NCAR-derived monthly climatology (OFES-CLIM), the other is forced by NCEP/NCAR reanalysis daily winds and fluxes (OFES-NCEP).

The RAPID-MOCHA Array

Figure 1: RAPID-MOCHA Mooring Locations

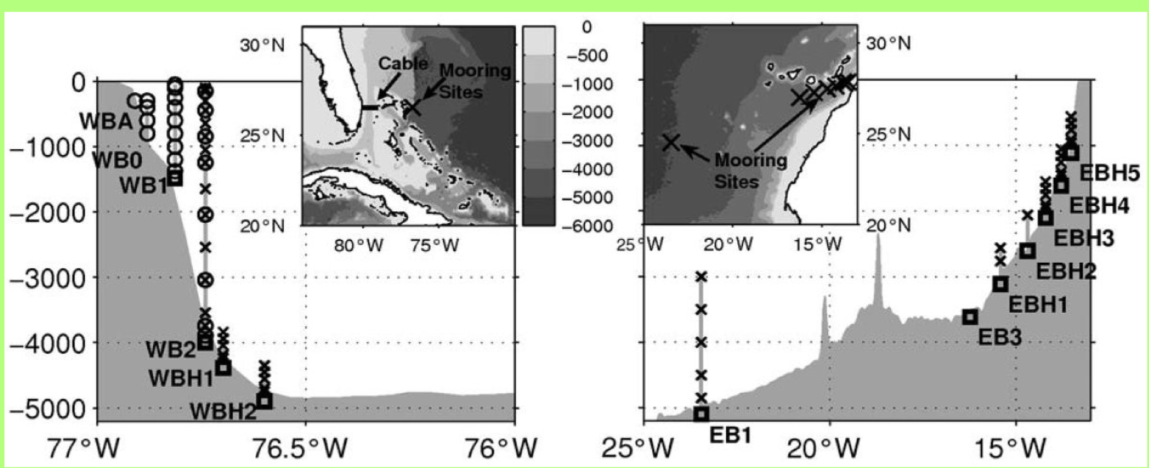
24 Moorings have been deployed across the North Atlantic basin at 26.5N since April 2004. One group of moorings is concentrated in the western Atlantic basin capture the Western Boundary Current variability, and another group of moorings are concentrated along the eastern side of the Atlantic basin. One mooring is also located on each side of the Mid-Atlantic Ridge.



(from http://www.noc.soton.ac.uk/rapidmoc/)

Figure 2: RAPID-MOCHA Mooring Diagrams

Instrumentation distributed throughout the full depth of the water column on the RAPID-MOCHA mooring array allows for description of the vertical structure of the overturning circulation. The Florida Current (FC) is measured via voltage induced in a cable across the Straits of Florida, and Ekman transport is calculated from winds measured by satellite scatterometry. In this diagram, squares represent bottom pressure sensors, crosses represent density measurements, and circles represent direct current measurements (western boundary only).



(from Kanzow et al., 2007)

Acknowledgments

We thank all members of the RAPID-MOCHA team from University of Miami, University of Southampton, and NOAA for their work collecting and processing the data. We are indebted to JAMSTEC for providing access to the OFES model output. Thanks to the University of Miami for funding provided by the UM Fellowship.

The Models

This study uses two identically configured OFES simulations produced by JAMSTEC. OFES is based on the Modular Ocean Model (MOM3) developed by the Geophysical Fluid Dynamics Laboratory (GFDL) of the National Oceanic and Atmospheric Administration (NOAA). They are run at a horizontal resolution of 1/10th degree have 54 layers. Vertical layer thicknesses vary from 5 meters at the surface to 330 meters at depth.

Model Name	Forcing	Dataset Length	Sampling
OFES-CLIM	NCEP-NCAR monthly mean climatology	8 years	1-day averages
OFES-NCEP	NCEP-NCAR daily means from 1950-2003	27 years	3-day snapshots

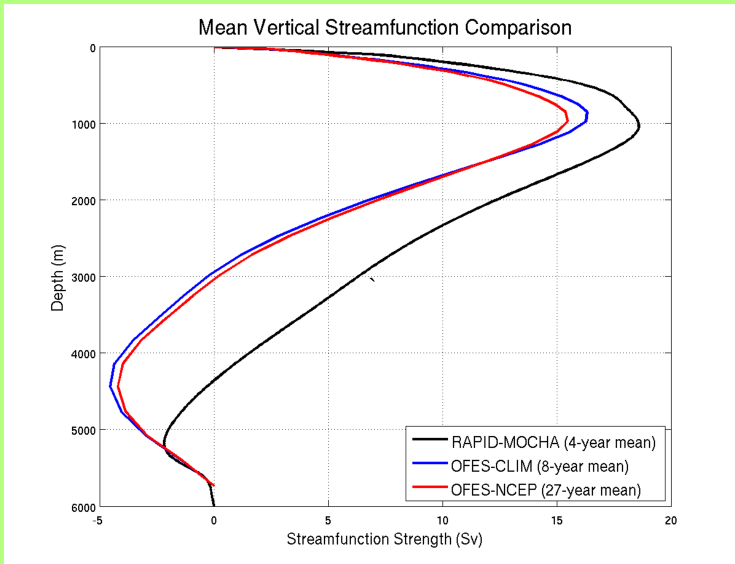


Figure 3: MOC Mean Vertical Structure at 26.5N

The meridional extent of numerical model output spans between 15N and 40N, but observations are limited to a single line of latitude at 26.5N. The maximum value of both model-produced Vertical streamfunctions and the RAPID-MOCHA stream-function occurs around 1000 meters. The models tend to underestimate the strength of the upper ocean cell of the MOC (the northward flow of upper ocean water balanced by southward flow of NADW) by 2-3 Sv, and have shallower overall cells. The modeled lower ocean overturning cells (northward AABW balanced by lower NADW) are stronger than RAPID-MOCHA observations.

MOC Variability

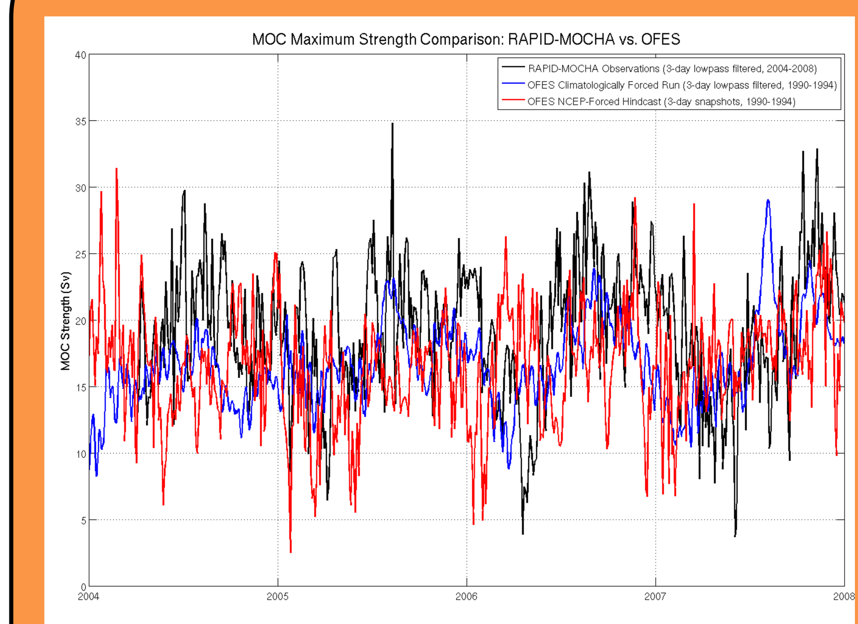


Figure 4: MOC Strength at 26.5N

An annual cycle can be seen in the observations, superimposed on variability at higher-frequencies. The OFES-CLIM and OFES-NCEP models exhibit slightly lower mean MOC strengths than the RAPID-MOCHA observations (see table below). The OFES-CLIM model shows an annual cycle similar to observations (annual cycle in OFES-NCEP is less apparent). Spectral comparison of the models shows that the OFES-CLIM model has less energy at higher frequencies, but tracks the OFES-NCEP model well at lower frequencies.

Source	Mean	STD	Max	Min
RAPID-MOCHA	18.5 Sv	4.9 Sv	35.2 Sv	-6.0 Sv
OFES-CLIM	16.2 Sv	2.8 Sv	29.1 Sv	-12.9 Sv
OFES-NCEP	15.2 Sv	3.9 Sv	31.4 Sv	-21.8 Sv

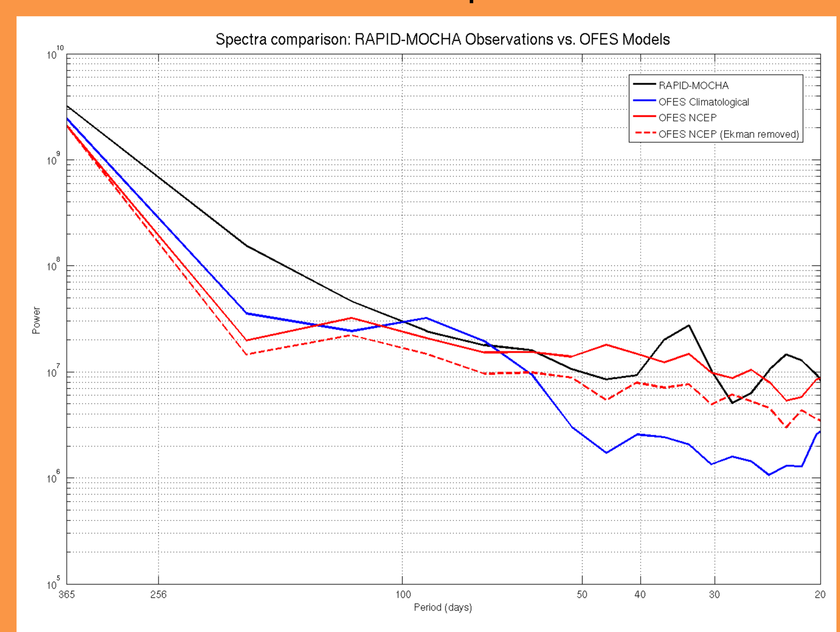


Figure 5: Spectral Analysis of MOC Strength at 26.5N

MOC Vertical Structure

1-year long hovmoller diagrams of Φ(z,t) show that the OFES models have a consistently thinner upper ocean overturning cell than observations (from the surface to ~3000m, whereas the observed upper ocean cell extends to 4500m). As a result, the lower ocean overturning cell in the OFES models occurs over a larger range of depths, from ~3000m to the sea floor (instead of 4500m to the sea floor). The variability of the lower cell in the models can not be directly compared with observations because RAPID-MOCHA assumes a climatological flow of Antarctic Bottom Water (AABW).

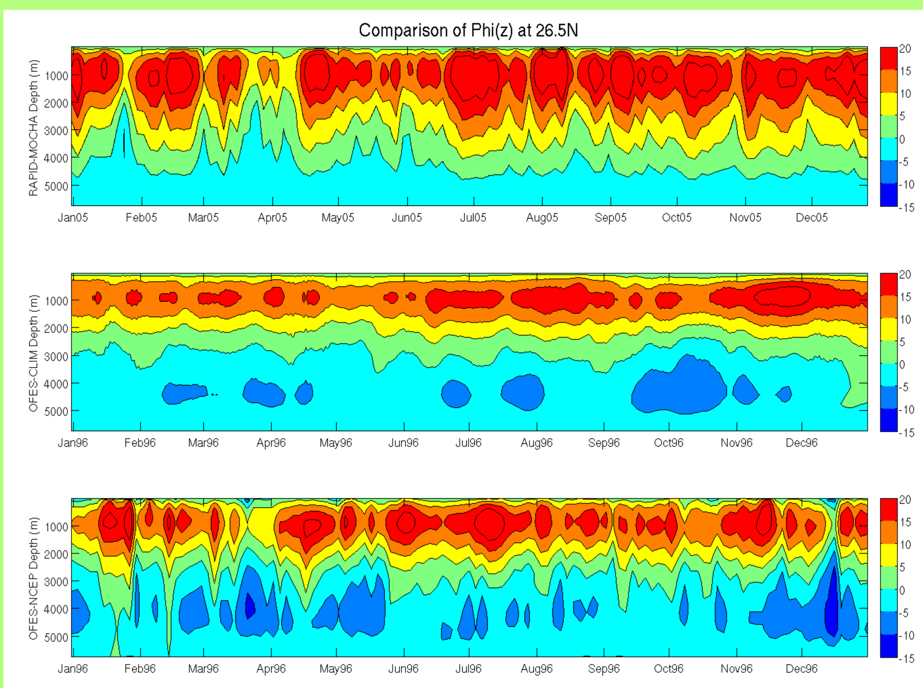


Figure 6: MOC Vertical Structure at 26.5N

Bandpassed MOC Variance

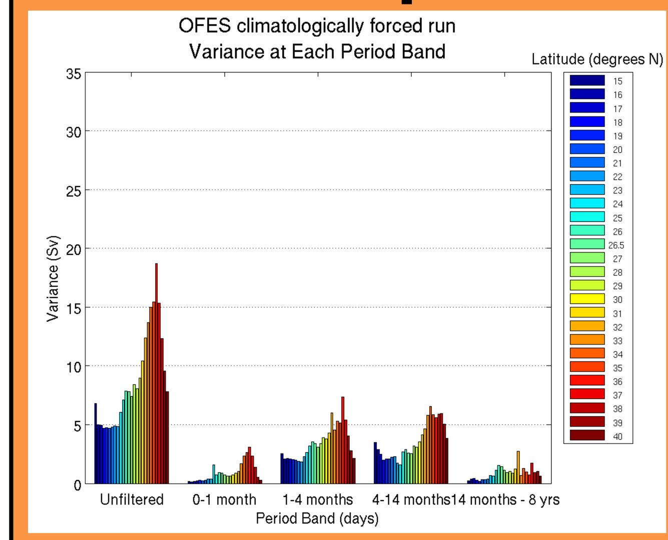


Figure 7: Band-filtered Variance in OFES-CLIM

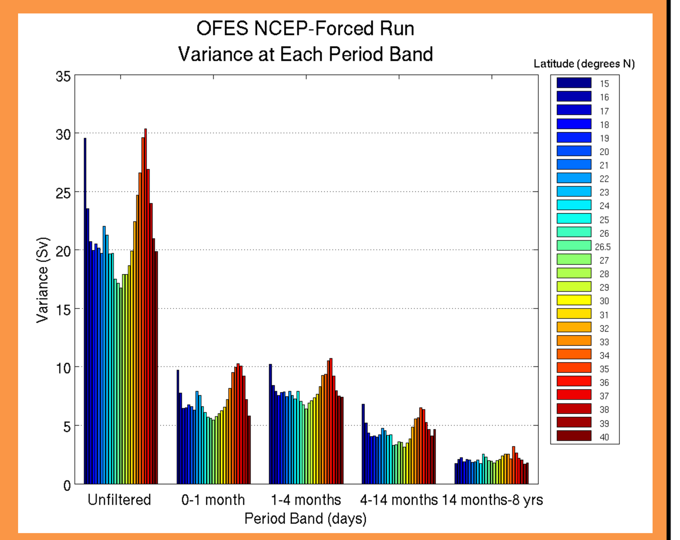


Figure 8: Band-filtered Variance in OFES-NCEP

OFES-CLIM variance is less than OFES-NCEP variance at all period bands, except perhaps for the 4-14 month period band.

Removing the direct influence of Ekman forcing on the MOC variability in OFES-NCEP (lower right panel) significantly reduces the variance at all periods, but variance in the 1-4 month period band remains higher than in OFES-CLIM.

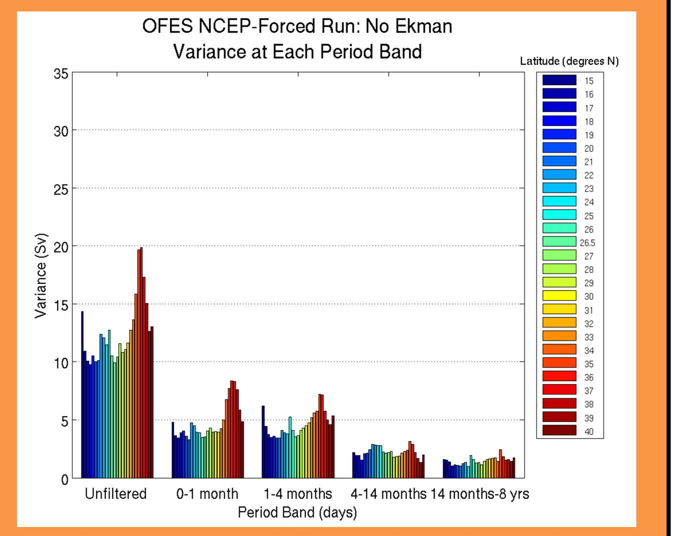


Figure 9: Band-filtered Variance in OFES-NCEP (Ekman removed)

Meridional Coherence

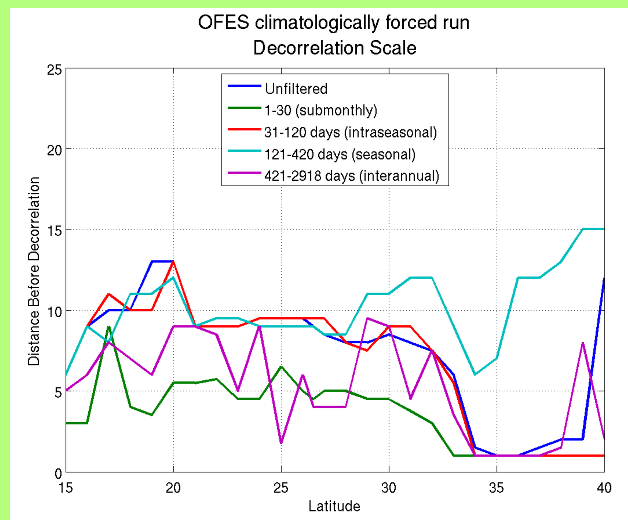


Figure 10: Band-filtered Variance in OFES-NCEP (Ekman removed)

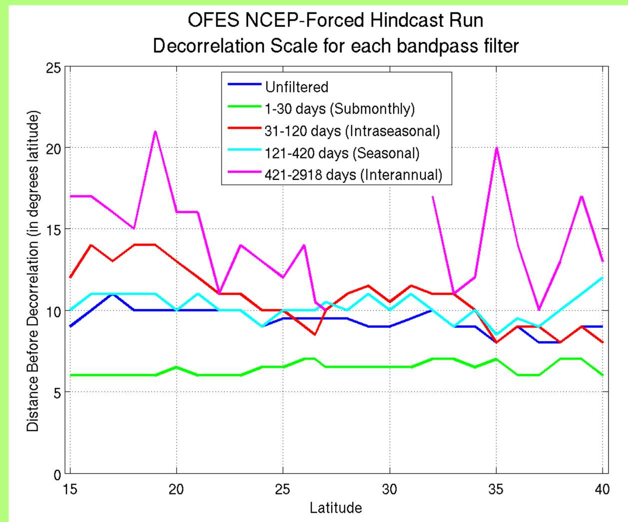


Figure 11: Band-filtered Variance in OFES-NCEP (Ekman removed)

The decorrelation scales calculated for both models are similar (approx. 8-10 deg. through the subtropics). Important differences between the models include:

1. North of ~33N, correlation in the OFES-CLIM and OFES-NCEP (*no* Ekman) models break down over a much shorter distance than in the OFES-NCEP model (*with* Ekman).

2. The decorrelation distance is much longer in the OFES-NCEP model for the inter-annual period band, with or without Ekman.

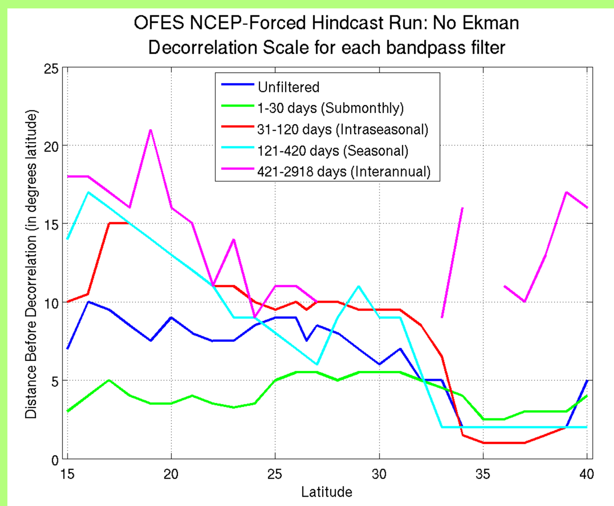


Figure 12: Band-filtered Variance in OFES-NCEP (Ekman removed)

Conclusions

1. Both the climatologically and synoptically forced models track the observed MOC strength at 26.5N well. A robust annual cycle appears to be present in observations and the OFES-CLIM model.

2. Spectral analysis of the MOC timeseries at 26.5N indicates that the influence of the atmosphere (Ekman transport) on the MOC's energy is important at timescales shorter than intraseasonal. Beyond intraseasonal timescales, the effect of Ekman transport is weak.

3. For periods shorter than annual, the extent of meridional coherence of the MOC is greatly reduced when the effect of Ekman transport is excluded. This suggests that the scale of the MOC variability is set by the meridional scale of Ekman forcing, i.e. the meridional scale of atmospheric forcing.