Variability in the Atlantic Meridional Overturning Circulation and Heat Transport Detected Remotely from Argo Floats

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Introduction

Available data for ocean temperature, salinity, and current at the present time do not have sufficient resolution to describe the variability in Atlantic Meridional Overturning Circulation (AMOC). To fill the gap, we are working on near real-time 3D synoptic temperature, salinity, and velocity (STSV) datasets from remotely sensed Argo profiling and trajectory data together with the Global Temperature-Salinity Profile Program (GTSPP), Navy's MOODS, and the OSCAR data using the optimal spectral decomposition (OSD) method. With establishment of the STSV dataset, the AMOC variability can be effectively detected and predicted.

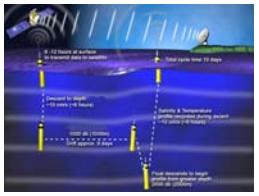

Fig1. Argo is a robotic system that watches the oceans (http://www-argo.ucsd.edu/Frpicturees.html).

Argo Trajectory Data

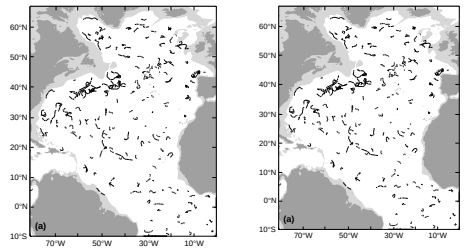

Fig. 2. Argo observation coverage of the North Atlantic in October-November, 04: (a) subsurface trajectories of floats parked at 1000 m and 1500 m, and (b) all float positions where temperature profiles were measured.

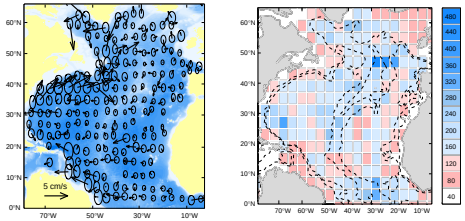

Fig 3. (a) Mean circulations at 1000 m depth from April 2004 to March 2005, estimated from the original Argo float trajectories using the bin method (with error ellipses), and (b) data distribution.

OSD

OSD is a recently-developed algorithm to process noisy and sparse ocean observational data (remotely sensed or in-situ measured) (Chu et al., 2003 a, b). It has three components: (1) determination of the basis functions, (2) optimal mode truncation, and (3) determination of the Fourier coefficients through solving a set of ill-posed algebraic equations. Determination of basis functions is to solve the eigen-value problem. The basis functions are only dependent on the geometry of the ocean basin, not dependent on the oceanic variables. This is to say, no matter which variable (temperature, salinity, or velocity) is concerned, the basis functions are the same, and can be pre-determined before the data analysis. For data without error, the more the modes, the more the accuracy of the processed field. For data with error, this rule of the thumb is no longer true. Inclusion of high-order modes leads to increasing error. The Vapnik variational principal is used to determine the optimal mode truncation. After the mode truncation, optimal field estimation is to solve a set of a linear algebraic equation of the Fourier coefficients.

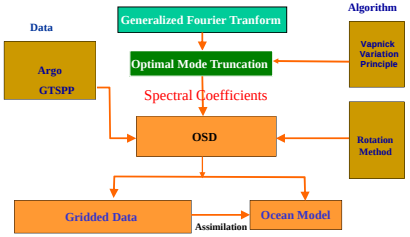

Fig 4. Schematic of OSD System.

$$c(\mathbf{x},t) = D_0(t) + \sum_{i=1}^{I} D_i(t)\Xi_i(\mathbf{x})$$

$$\mathbf{U}(\mathbf{x},t) = C(t)\nabla\Psi_0(\mathbf{x}) + \sum_{n=1}^{N} A_n(t)\nabla\times\left[\mathbf{k}\Psi_n(\mathbf{x})\right] + \sum_{m=1}^{M} B_m(t)\nabla\cdot\Phi_m(\mathbf{x})$$

Mid-Depth Circulation and Temperature

The reconstructed circulation (April 2004 – March 2005) is characterized by three major cyclonic gyres: tropical (south of 20ºN), subtropical (20ºN to about 50ºN), and subpolar gyre (North of 50ºN). Figs. 5 and 6 shows a sequence of bi-monthly snapshots for velocity and temperature. The tropical gyre is an elongated cyclonic gyre with velocities in a core of less than 2 cm/s. However, a spatial pattern corresponding to a cyclonic flow approximately around the center of Guinea dome (12ºN, 22ºW) is clearly seen in Fig. 5b. That agrees, for example, with Elmoussaoui et al. [2005] who observed the quasi-permanent cyclonic flow of the Guinea dome at the same depth and deeper. Warm water is located in mid-latitudes from 8ºC near western boundary at 25ºN-31ºN to higher than 10ºC in the eastern boundary at 30ºN-50ºN. The warm water was sandwiched by cool water in the low and high latitudes. The temperature is cooler than 4ºC north of the warm zone.

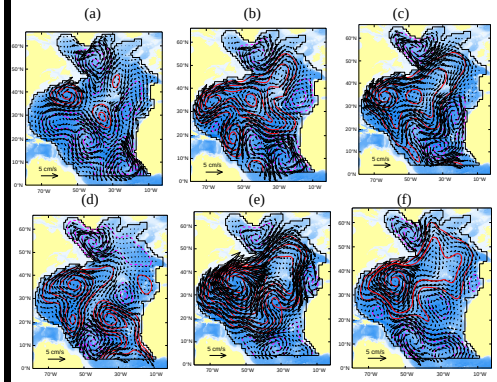

Fig. 5. Bi-monthly evolution of circulation at 1000 m depth for (a) April 2004, (b) June 2004, (c) August 2004, (d) October 2004, (e) December 2004, and (f) February 2005.

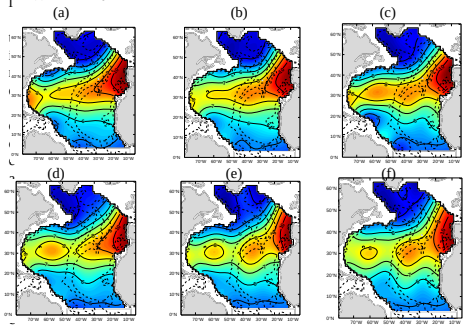

Fig. 6. Bi-monthly evolution of temperature at 1000 m depth for (a) April 2004, (b) June 2004, (c) August 2004, (d) October 2004, (e) December 2004, and (f) February 2005.

Mid-Depth Heat Transport

From the reconstructed monthly velocity and temperature fields, we compute the horizontal heat flux at 1000 m depth,

$$H_\tau = -u\partial T/\partial x - v\partial T/\partial y$$

with positive (negative) values for warm (cold) advection. Temporal and spatial variability of the horizontal heat flux (Fig. 7) shows evident Rossby wave propagation, which consists with the existing modeling results.

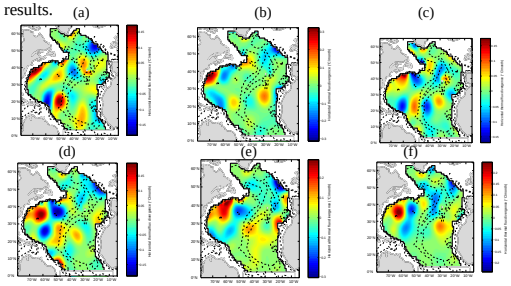

Fig. 7. Temperature) of the Pacific Ocean for June 2006 calculated from GTSPP-Argo data using the OSD method: (a) surface, and (b) 30 m depth.

Summary

Establishment of near-real time 3D synoptic temperature, salinity, and velocity (STSV) datasets using the OSD method from GTSPP-Argo, Navy's MOODS, and OSCAR with higher resolutions and better coverage than any products available, temporal (seasonal and inter-annual) and spatial (various scales) variability of AMOC can be identified through quantifying the derived variables such as the Atlantic meridional overturning circulation (AMOC), heat storage, meridional heat transport, etc..

References

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