

PL24A-1784: On the mean Deep Western Boundary Current recirculation in the North Atlantic subtropics: structure and forcing mechanisms

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Introduction

The Deep Western Boundary Current (DWBC) is the primary component of the lower limb ($z > 1000$ m) of the Atlantic Meridional Overturning Circulation. In the subtropical North Atlantic (15°-30°N), part of the flow recirculates in the ocean interior decreasing the net meridional transport along its path.

Motivation: The complex mean DWBC recirculation patterns revealed by localized observations and recent eddy-resolving simulations are still poorly understood.

Goals

Describe and understand the structure and formation dynamics of the DWBC recirculation in the subtropical North Atlantic.

Data set and Model

CNES-CLS13 Mean Dynamic Topography (MDT)

- Global 0.25°x0.25° resolution surface MDT for the period 1993-2012 (Rio et al., 2014).

RG-ARGO Temperature (T) and Salinity (S) climatology

- Global 0.5°x0.5° resolution T and S climatology for the period 2004-2015 at 58 pressure levels spanning 0-2000 dbar (Roemmich & Gilson, 2009).

Quasi-synoptic cruises

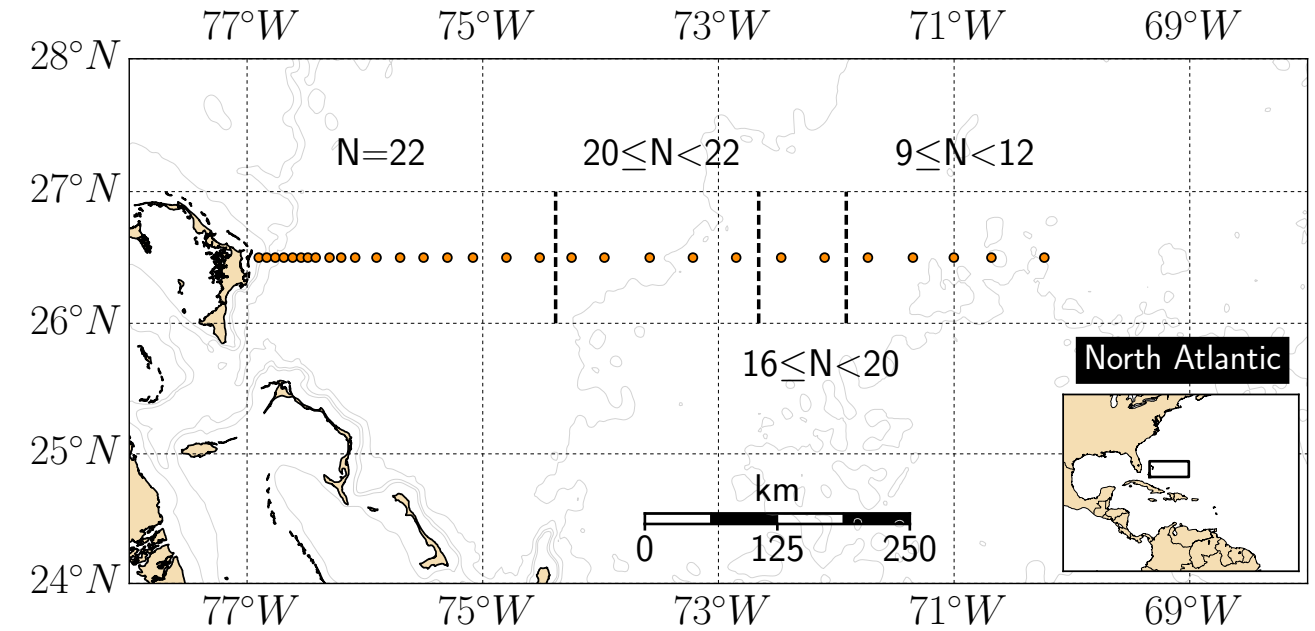


Figure 1: Positions (orange circles) of the CTD-LADCP profiles in the MOCHA repeat transect off the Abaco Island, Bahamas. Due to weather conditions, unexpected problems, and ship-time limitations not all the 22 cruises covered the entire area. The dashed lines delimit the approximate regions covered by different numbers (N) of cruises. The light grey lines represent the 1000, 2000, 4000, 5000 and 5500 m isobaths.

CTD, lowered-ADCP (LADCP), and shipboard-ADCP (SADCP) profiles obtained during 22 quasi-synoptic cruises between 2001-2017 off the Abaco Island, Bahamas at 26.5°N. The profiles were obtained on a repeated transect shown in Figure 1. Cruises were conducted as part of the collaboration between the University of Miami and NOAA's Atlantic Oceanographic and Meteorological laboratory under the U.S. the Meridional Overturning Circulation and Heat Flux Array (MOCHA) and NOAA Western Boundary Time Series (WBTS) programs.

Ocean model For the Ocean Simulator (OFES)

- Outputs (velocity, T and S) from a hindcast simulation climatologically (WOA) initialized and forced by NCEP-NCAR reanalysis surfaces fluxes with horizontal resolution of 0.1°x0.1°, 54 vertical z-levels, and snapshots every 3 days between 1980-2013 (Sasaki et al., 2008).

Approach

Mean subtropical North Atlantic circulation at 1000-2000 m

- ARGO Absolute Dynamic Topography: MDT Referenced Dynamic Method;
- OFES Streamfunction (Ψ):

$$u = -\frac{\partial \Psi}{\partial y} \text{ and } v = \frac{\partial \Psi}{\partial x};$$

- Ertel's potential vorticity (q):

$$q = -\frac{(f+\zeta)\partial\sigma}{\rho\partial z}.$$

Mean DWBC and its recirculation at 26.5°N

- Top-bottom velocity: v_{ladcp} , $v_{geos.}$, and v_{ofes} comparison;
- CTD absolute geostrophic velocity: SADCP Referenced Dynamic Method;
- North Atlantic Deep Water transport (T_{nadw}):

$$T_{nadw}(x) = \int_0^x \int_0^{1000} v dz dx.$$

Evaluation of forcing mechanisms in OFES

- Eddy-driven deep circulation (e.g., Rhines & Holland, 1979):

$$\bar{u} \cdot \nabla \bar{q} = -\nabla \cdot (\bar{u}'q') + D$$

where overbars and primes stand for time average and deviation from the mean respectively

Mean subtropical North Atlantic circulation at 1000-2000 m

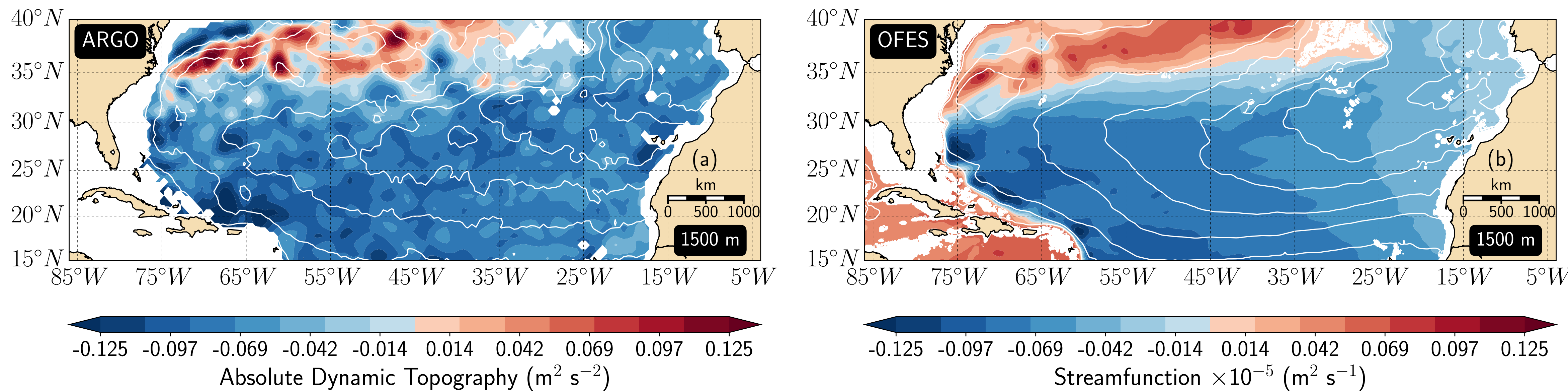


Figure 2: (a) Mean absolute dynamic topography derived from RG-ARGO climatology and CNES-CLS13 MDT at 1500 m depth; (b) Mean streamfunction mapped from OFES velocity outputs at 1500 m depth. The white lines represent Ertel's potential vorticity from ARGO and OFES respectively, and its interval is $4 \times 10^{-12} \text{ (m}^{-1} \text{ s}^{-1})$. Local minimum (i.e., deep blue shadings) indicate cyclonic circulation.

Mean DWBC and its recirculation at 26.5°N

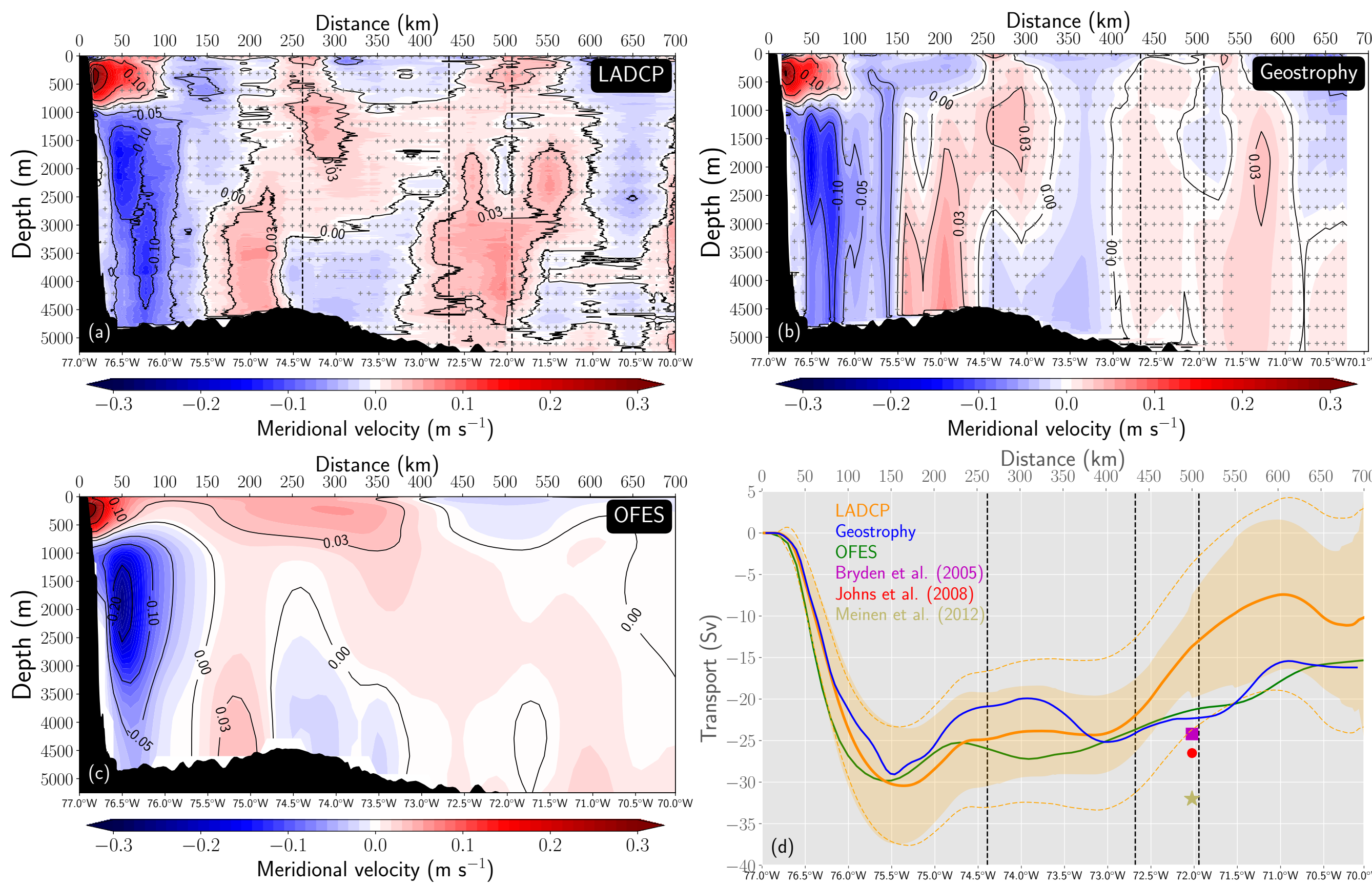


Figure 3: Mean meridional velocity transect at 26.5°N: (a) LADCP-observed velocity; (b) Absolute geostrophic velocity; (c) OFES modeled velocity. The isotachs correspond to -0.2, -0.1, -0.05, 0.0, 0.03, 0.1, 0.2 and 0.3 m s^{-1} . The gray "+" signs indicate the areas where the mean velocity is not statistically different from zero in the 95% confidence interval. Panel (d) depicts the meridional volume transports accumulated eastward from 77°W below 1000 m. The orange dashed lines and shaded area indicate two different estimates of the 95% confidence interval of the LADCP cumulative transport. The black dashed lines limit the approximate regions covered by different number of cruises shown in Figure 1.

Summary and Conclusions

Mean subtropical North Atlantic circulation at 1000-2000 m

- DWBC recirculation (15°-30°N): multiple cyclonic cells along the western boundary embedded in a larger scale recirculation;
- Cells are characterized by the presence of flow crossing mean potential vorticity gradients.

Mean DWBC and its recirculation at 26.5°N

- Complex vertical structure and clear distinction between the recirculation of the upper (depth ≈ 1000 -3000 m) and lower (depth ≈ 3000 -5000 m) North Atlantic Deep Water flows;
- Net recirculation of ≈ 17 Sv within 500 km offshore of the western boundary (75.5°-72°W).

Evaluation of forcing mechanisms in OFES

- Analysis of the potential vorticity budget terms suggests that eddies force the DWBC recirculation cells at 1000-4000 m.
- Vertical changes in the $\bar{u}'q'$ are due primarily to changes in the eddy-thickness fluxes (not shown); the eddy-relative vorticity fluxes remain vertically coherent.

Next step ...

- Understand the eddies characteristics and its relation to the eddy-fluxes convergence patterns shown in Figure 4.

Evaluation of forcing mechanisms in OFES

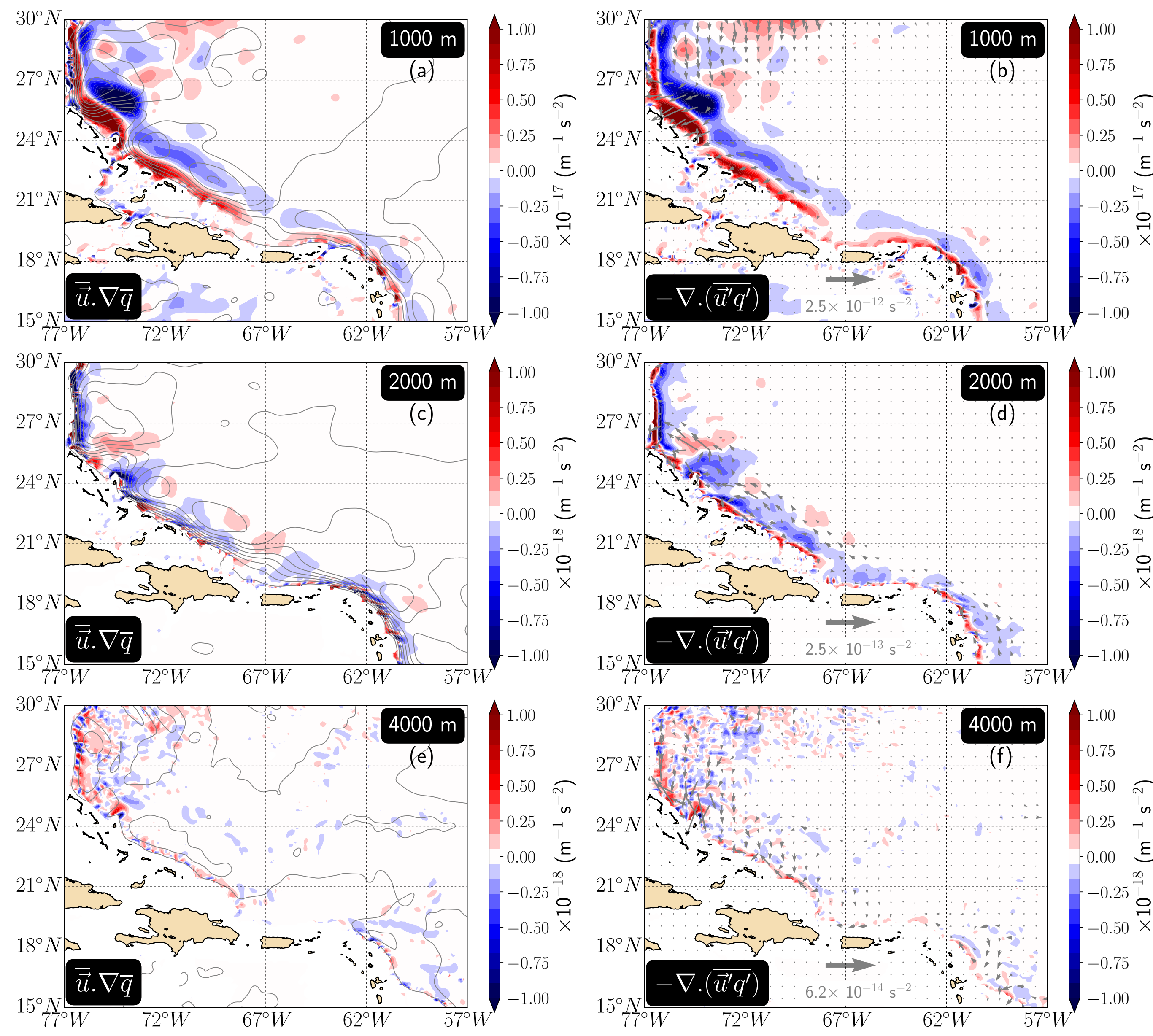


Figure 4: Mean potential vorticity advection $\bar{u} \cdot \nabla \bar{q}$ (left panels) and convergence of the mean eddy-potential vorticity fluxes $-\nabla \cdot (\bar{u}'q')$ (right panels) at 1000 m (a-b), 2000 m (c-d), and 4000 m (e-f). The continuous gray lines represent the mean streamfunction with interval of $1.5 \times 10^{-3} \text{ m}^2 \text{ s}^{-1}$. The gray vectors are the mean eddy-potential vorticity fluxes $\bar{u}'q'$. The spatial correlation coefficient between $\bar{u} \cdot \nabla \bar{q}$ and $-\nabla \cdot (\bar{u}'q')$ is approximately 0.9 over the recirculation cells domain (i. e., offshore distance from the western boundary ≈ 100 -1000 km) at depths 1000-3000 m. Below 3000 m, the coherent positive (at the boundary) and negative bands (offshore) of these terms break into a patched pattern and its correlation (≈ 0.7 at 4000 m) decreases progressively towards the ocean bottom. In contrast, the $\bar{u}'q'$ vectors present significant vertical changes below 1000 m.

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Acknowledgments

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