

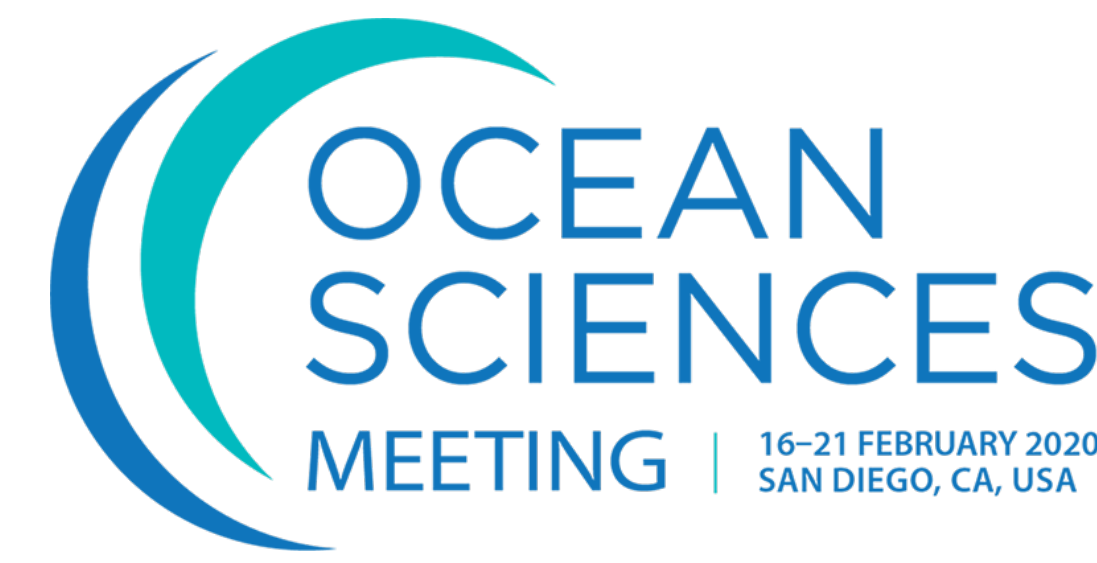
PL14B-2624: Deep Western Boundary Current variability at 26.5°N and its connection with local abyssal recirculation

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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, therefore its structure and variability have been the subject of numerous studies. Although the DWBC has been monitored since the late 80's at 26.5°N, a comprehensive understanding of the link between the mesoscale activity in the region and the DWBC meridional transport variability is still lacking.

Goals

Describe the DWBC transport based on the longest continuous velocity measurements available at 26.5°N, and understand its connection with the eddies within the Abaco Gyre (Figure 1, upper panel)

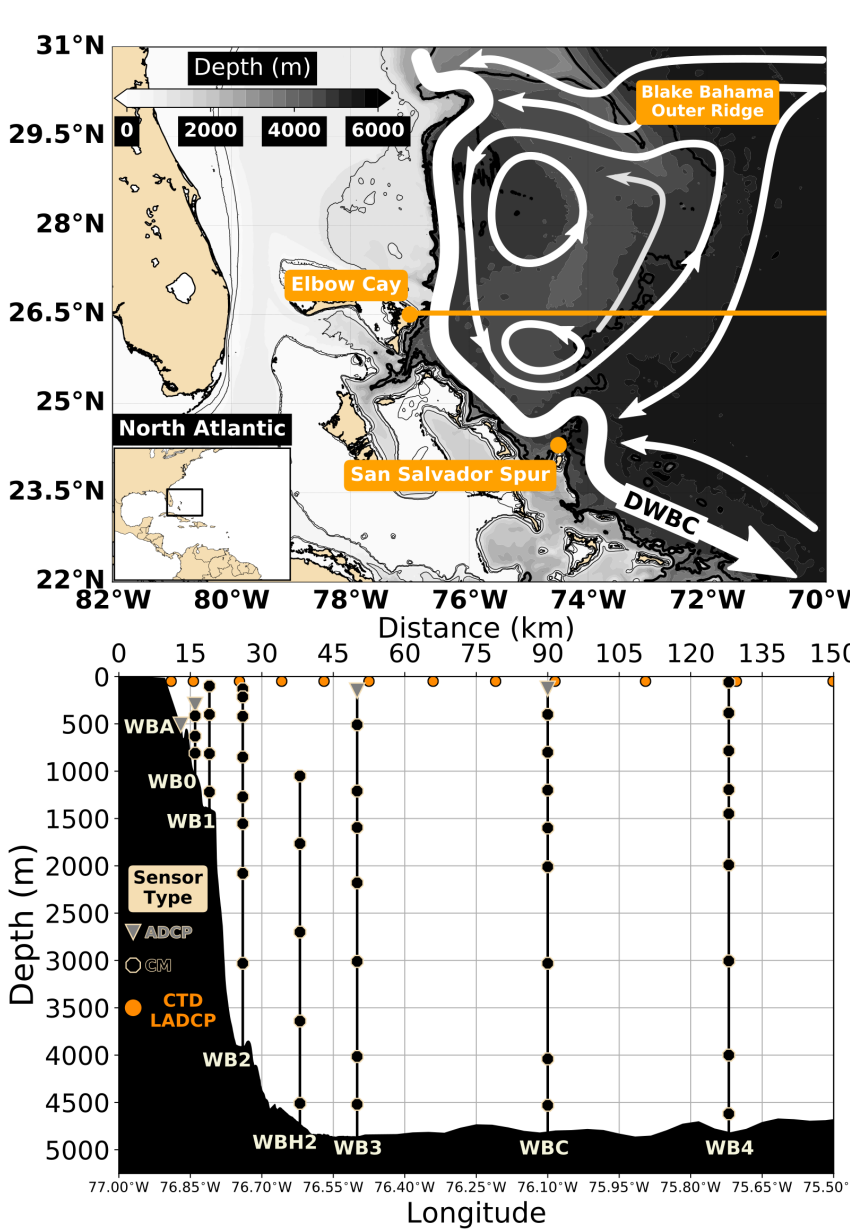


Figure 1: Mean Abaco Gyre circulation (i.e., depths > 1000 m) schematic based on Johns et al. (1997) and Biló & Johns (2019) (upper panel). The orange line indicates the 26.5°N parallel off Elbow Cay, Abaco, Bahamas. Schematic of the most recent MOCHA western mooring array instrumentation (lower panel). The acronym CM stands for Current Meters. Moorings WBH2, WBC, and WB4 were deployed after 2008.

Data and model

Observations off the Abaco Island, Bahamas at 26.5°N

■ **Lowered-ADCP (LADCP) profiles** obtained during 23 oceanographic cruises between 2001-2018. The cruises were conducted as part of the NOAA AOML's Western Boundary Time Series (WBTS) program;

■ **Moored current meter records** between 2004-2018 obtained under the U.S. Meridional Overturning Circulation and Heat Flux Array (MOCHA) and U.K. RAPID programs.

Ocean model For the Ocean Simulator (OFES)

■ **OFES eddy-resolving hindcast simulation** performed by JAMSTEC (Sasaki et al., 2008). The velocity outputs used in the present study have horizontal resolution of $0.1^\circ \times 0.1^\circ$, 54 vertical z-levels, and snapshots every 3 days between 1980-2013.

Approach

■ **DWBC transport** over a fixed area: 1000-5000 m depth and 75.5-77°W;

■ **Low-pass filtering in time**: Butterworth digital filter with different frequency cutoffs;

■ **Relative vorticity** ($\zeta = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$): Analysis of the spatial patterns and propagation of ζ temporal anomalies;

■ **Eddy-driven circulation hypothesis** (e.g., Rhines & Holland, 1979): $\vec{u} \cdot \nabla \vec{q} = -\nabla \cdot (\vec{u}'\vec{q}')$ (Turbulent Sverdrup balance), where $q = -\frac{(f+\zeta)}{\rho} \frac{\partial \sigma}{\partial z}$ is the Ertel's potential vorticity. Biló & Johns (2019) show that the DWBC recirculation gyres south of 30°N (e.g., Abaco Gyre) are characterized by mean streamlines crossing $\vec{q}$ isolines.

3. Sources of DWBC variability

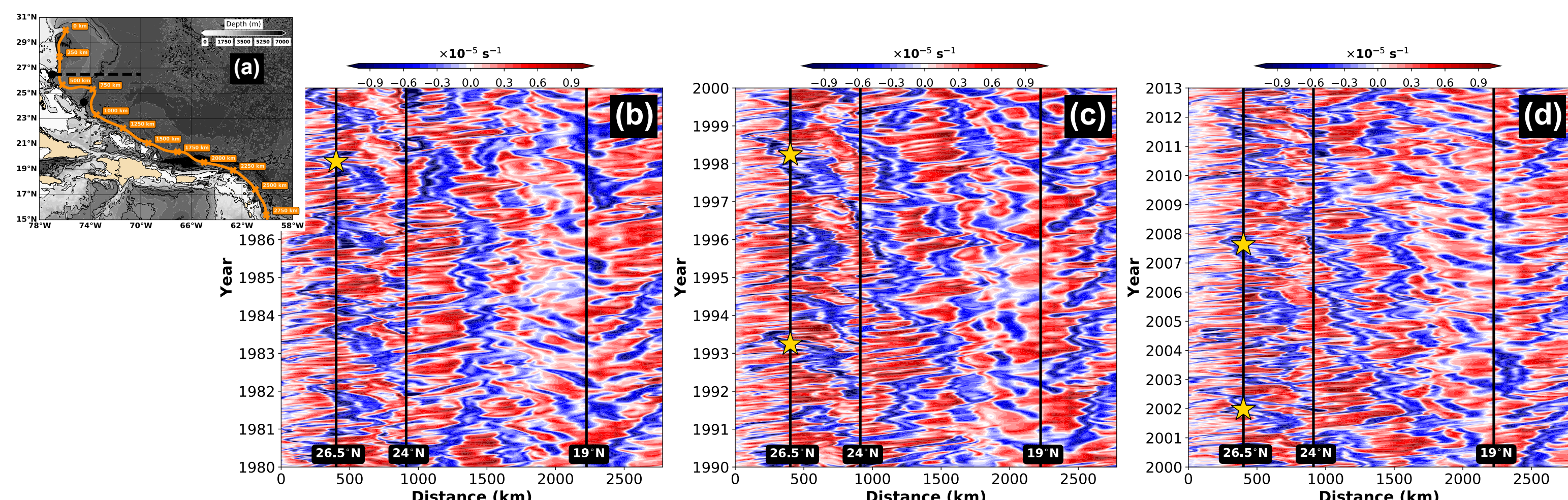


Figure 4: Hovmöller diagrams of the OFES 40-day low-pass filtered relative vorticity anomalies along the modeled DWBC mean path (orange line in panel a) | i.e., streamline along the DWBC velocity core at ~ 2000 m depth. In panel (a), the black dots indicate the locations of Elbow Cay, Abaco, Bahamas ($\sim 26.5^\circ\text{N}$) and San Salvador Spur ($\sim 24^\circ\text{N}$) while the dashed line shows the 26.5°N transect. The yellow stars represent the dates of the five of the strongest DWBC meridional positive transport anomalies at 26.5°N shown in Figure 3. To the north of 20°N , two types of oscillations can be seen: (1) Fast southward-propagating eddies/meanders (phase speed ~ 6 cm s^{-1}); and (2) Slow northward-propagating anticyclones (phase speed ~ 1 cm s^{-1}).

Summary and conclusions

Observed DWBC variability at 26.5°N

- DWBC transport variance between 2008-2017 is dominated by two “kinds” of perturbations (Figure 2):
 - ① Periods of 250-280 days that seem to occur regularly throughout the time-series;
 - ② Energetic oscillations with periods larger than 400 days that occur sporadically (i.e., every 5-6 years). Positive phase can last up to 6-9 months.

Variability in OFES

- DWBC transport time series indicate energy concentration in the same frequency bands as the observations (e.g., ~ 100 -360 days). Additionally, the strongest positive anomalies last several months and have significant amount of energy in time-scales longer than 400 days (Figure 3).
- Variability at 26.5°N is mainly due to eddies propagating along the western boundary (Figure 4).
- High spatial correlation between $\vec{u} \cdot \nabla \vec{q}$ and $-\nabla \cdot (\vec{u}'\vec{q}')$ suggests the turbulent Sverdrup balance holds and eddies are responsible for forcing the deep recirculation (Figure 5).

Velocity signature of northward-propagating anticyclonic eddies

- Northward-propagating anticyclonic eddies present a particular velocity signature that have been observed in the current-meter moorings (Figure 6).

1. Observed DWBC variability at 26°N

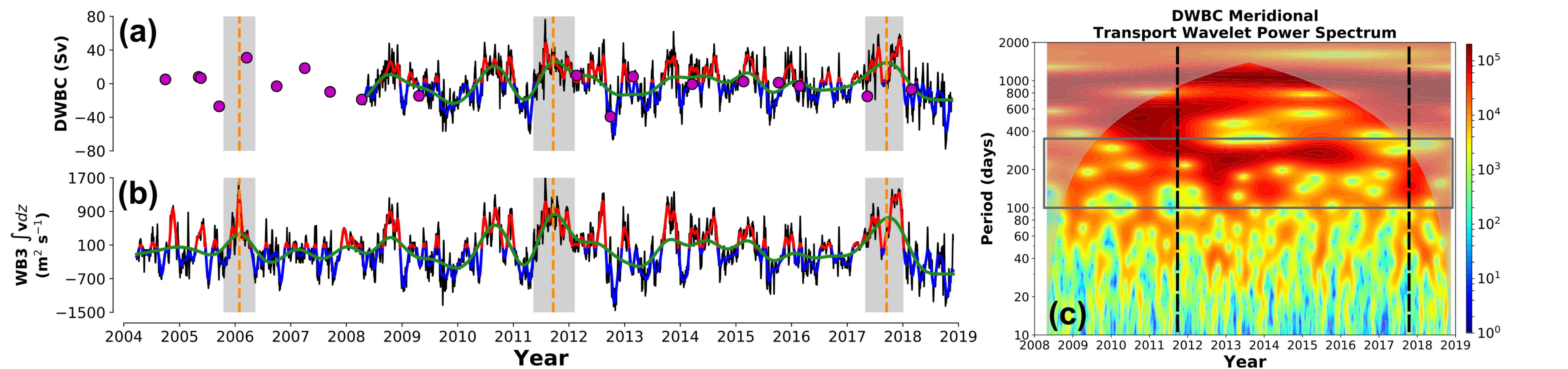


Figure 2: Current meter-based (a) DWBC meridional transport anomalies, and (b) vertically integrated meridional velocity component anomalies at the WB3 site (26.5°N , 76.5°W). Black curves show values every 12-hr, the red/blue curves are the 40-day low-pass filtered time series (positive and negative anomalies indicated in red and blue respectively), and the green curves show the 300-day low-passed time series. The magenta circles are the LADCP-based DWBC meridional transport estimates. The shaded light gray areas and the vertical dashed orange lines highlight times when large anticyclonic eddies impacted the DWBC (Oct./20/2005 - May/10/2006, May/16/2011 - Feb./05/2012, and May/02/2017 - Jan./01/01). Panel c depicts the wavelet power spectrum of the total DWBC meridional transport time series between 2008-2018 (i.e., black curve in panel a). The dashed black lines correspond to the dashed orange lines in panel a. Finally, the shaded area and gray box in panel c are the wavelet cone of influence and periods between 100-360 days respectively. Both LADCP and current-meter based average transports are approximately ~ 30 Sv.

2. Assessment of the DWBC variability in OFES

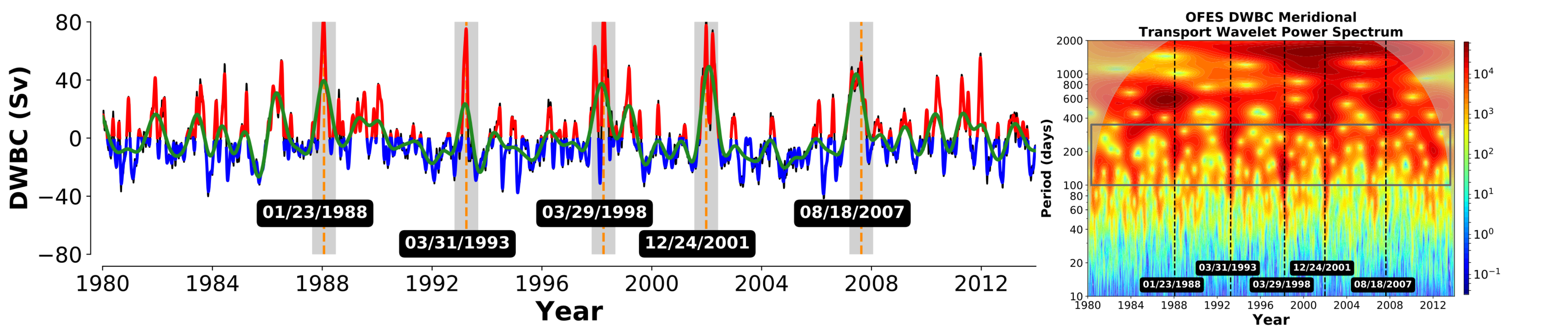


Figure 3: OFES simulated DWBC meridional transport anomalies (left panel). Black curves show values every 12-hr, the red/blue curves are the 40-day low-pass filtered time series (positive and negative anomalies indicated in red and blue respectively), and the green curves show the 300-day low-passed time series. The shaded light gray areas and the vertical dashed orange lines represent five of the strongest positive anomalous events centered around the displayed dates. Right panel depicts the wavelet power spectrum of the total DWBC meridional transport, where the dashed black lines correspond to the dashed orange lines in the left panel, gray box show periods between 100-360 days, and shaded area is the wavelet cone of influence. Similarly to the observations, the average DWBC transport in OFES is approximately ~ 30 Sv and the strongest positive anomalies (peaks of ~ 80 Sv) can last up to 6-9 months.

4. Eddy-forced recirculation

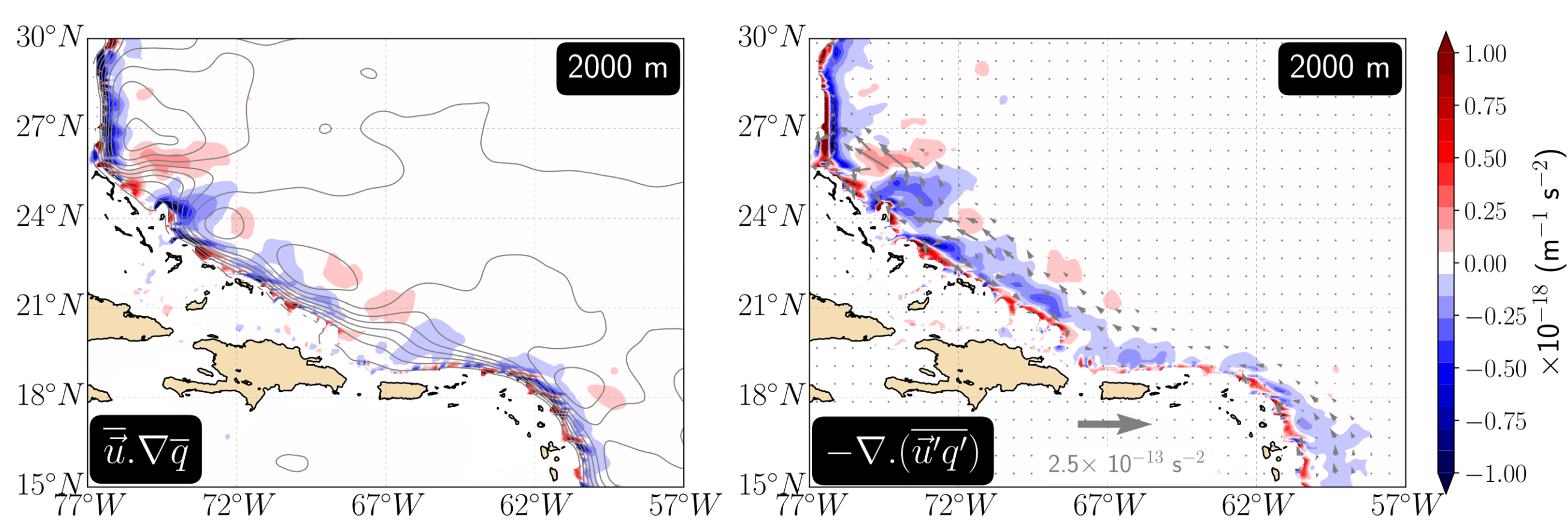


Figure 5: OFES mean potential vorticity advection $\vec{u} \cdot \nabla \vec{q}$ (left panel) and convergence of the mean eddy-potential vorticity fluxes $-\nabla \cdot (\vec{u}'\vec{q}')$ (right panel) at 2000 m depth. The continuous gray lines represent the mean streamfunction with interval of 1.5×10^{-3} $\text{m}^2 \text{s}^{-1}$. The gray vectors are the mean eddy-potential vorticity fluxes $\vec{u}'\vec{q}'$. The spatial correlation between the turbulent Sverdrup balance terms is ~ 0.85 . Additionally, the patterns of $-\nabla \cdot (\vec{u}'\vec{q}')$ are produced primarily by fluctuations on time scales associated with DWBC southward-propagating eddies/meanders.

5. Northward-propagating anticyclonic eddies

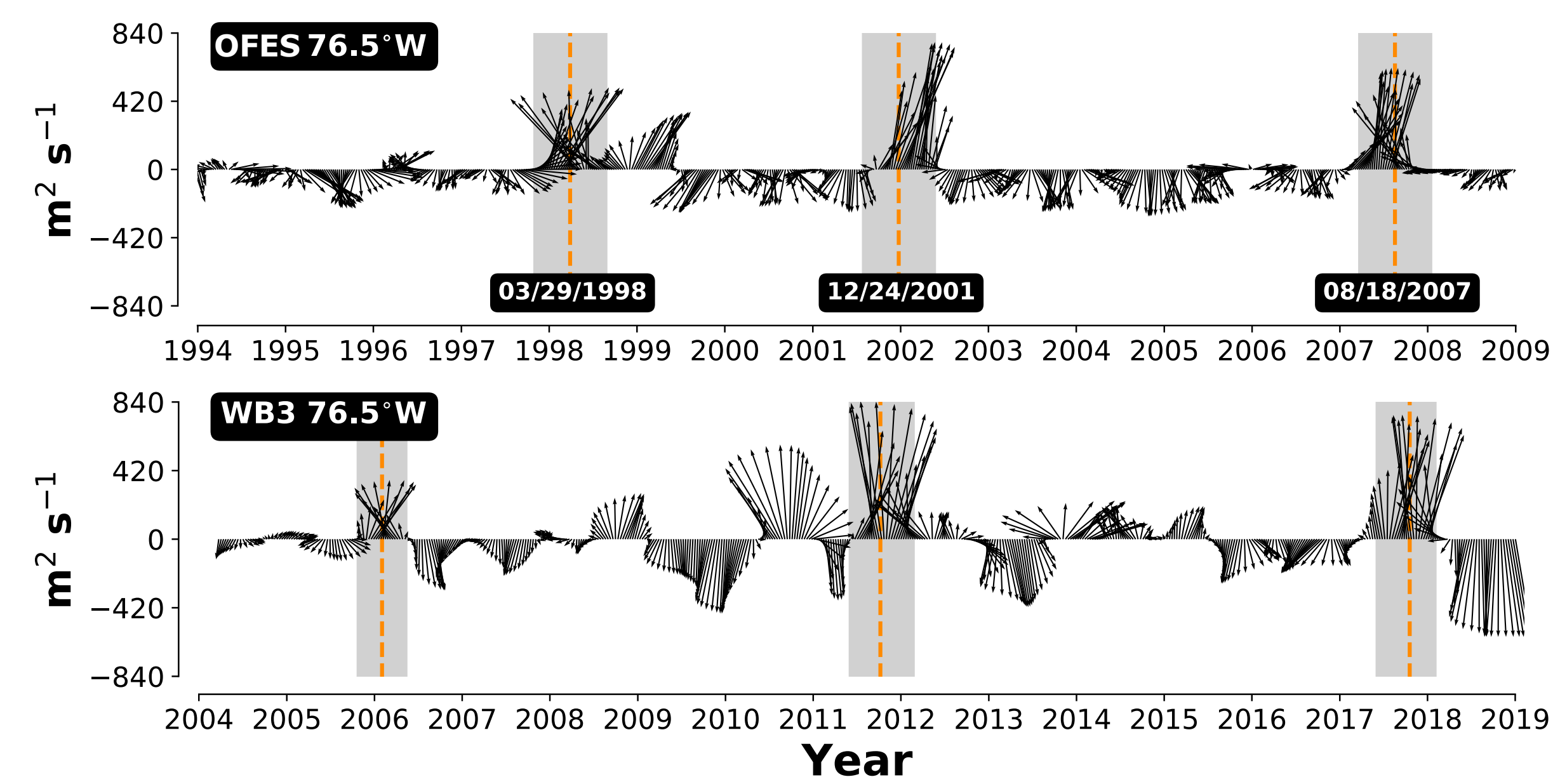


Figure 6: Time series of the OFES modeled (upper panel) and current meter observed (lower panel) 300-day low-pass filtered velocity vectors anomalies vertically integrated over the 1000-5000 m layer at the RAPID-MOC/MOCHA WB3 mooring site (i.e., 26.5°N , 76.5°W). The shaded light gray areas and the vertical dashed orange lines indicate DWBC transport anomalous events identified in Figures 2 and 3. The highlighted vector counter-clockwise rotation is a typical velocity evolution at a fixed point in space at the western lobe of anticyclonic eddies propagating northward.

References

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Acknowledgments

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