Circulation and Cross-Shelf Exchanges in the Northern shelf of the Southwest Atlantic

Vincent Combes and Ricardo P. Matano
College of Earth, Ocean & Atmos. Sciences, Oregon State University, Corvallis, Oregon, USA

OSU OregonState University
College of Earth, Ocean, and Atmospheric Sciences

1. Introduction

The studied region is the continental shelf bordered by the poleward Brazil Current to the east. The transport across the shelf break is perceptible from maps of satellite temperature, salinity, chlorophyll concentration, and from altimetry-derived geostrophic currents. Here we present the result of a high-resolution ocean model experiment which aims to describe the 3D structure of the shelf/open-ocean exchanges. The use of passive tracers and the release of floats allow to quantify the onshelf and offshelf transports. Of particular interests are (i) the transport across the shelf break in the subsurface layer found to be as important as the transport within the surface layer and (ii) the contribution to the advection of nutrient-rich shelf waters to the open-ocean by small-scale eddies generated where the shelfbreak changes orientation. The variability of the cross-shelf transport is also assessed here.

2. Model Configuration and Performance: Control Run

The model uses a 1/36° grid of the shelf nested into a 1/12° grid (*Fig. 1*). The simulation was run for the period 1992-2015 using ERA_Interim surface forcing and include tides and river discharges.
Figure 1 and other comparisons with altimetry (EFOs) show the relatively good performance of the model results.

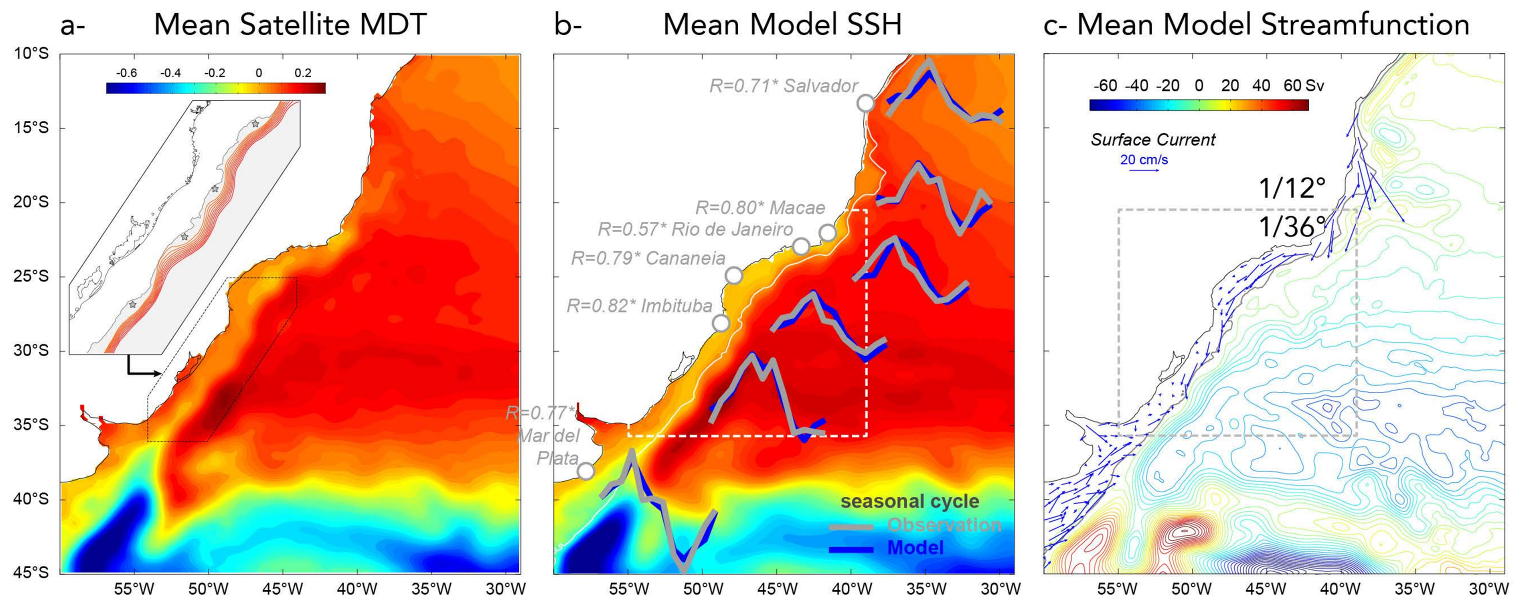

Figure 1: Mean State. (a) satellite and (b) mean SSH. The seasonal cycle is compared between the in-situ observation (grey) and model SSH (blue) at six coastal locations. (c) Model mean streamfunction and surface shelf velocities. Grey contour corresponds to the 200m isobath (shelfbreak).

3.1. Transport across the shelfbreak: Mean

Between 21°S and 25.2°S we find ~1.2Sv of onshelf transport mostly restricted to the layer below 50m while between 35°S and 25.2°S there is ~1.6Sv of offshelf transport with stronger outflow in the upper layer (Fig. 2)

The cross-shelf velocities of a high-resolution simulation show that the time mean cross-shelf exchanges are strongly modulated by the bottom topography (Fig. 2c).

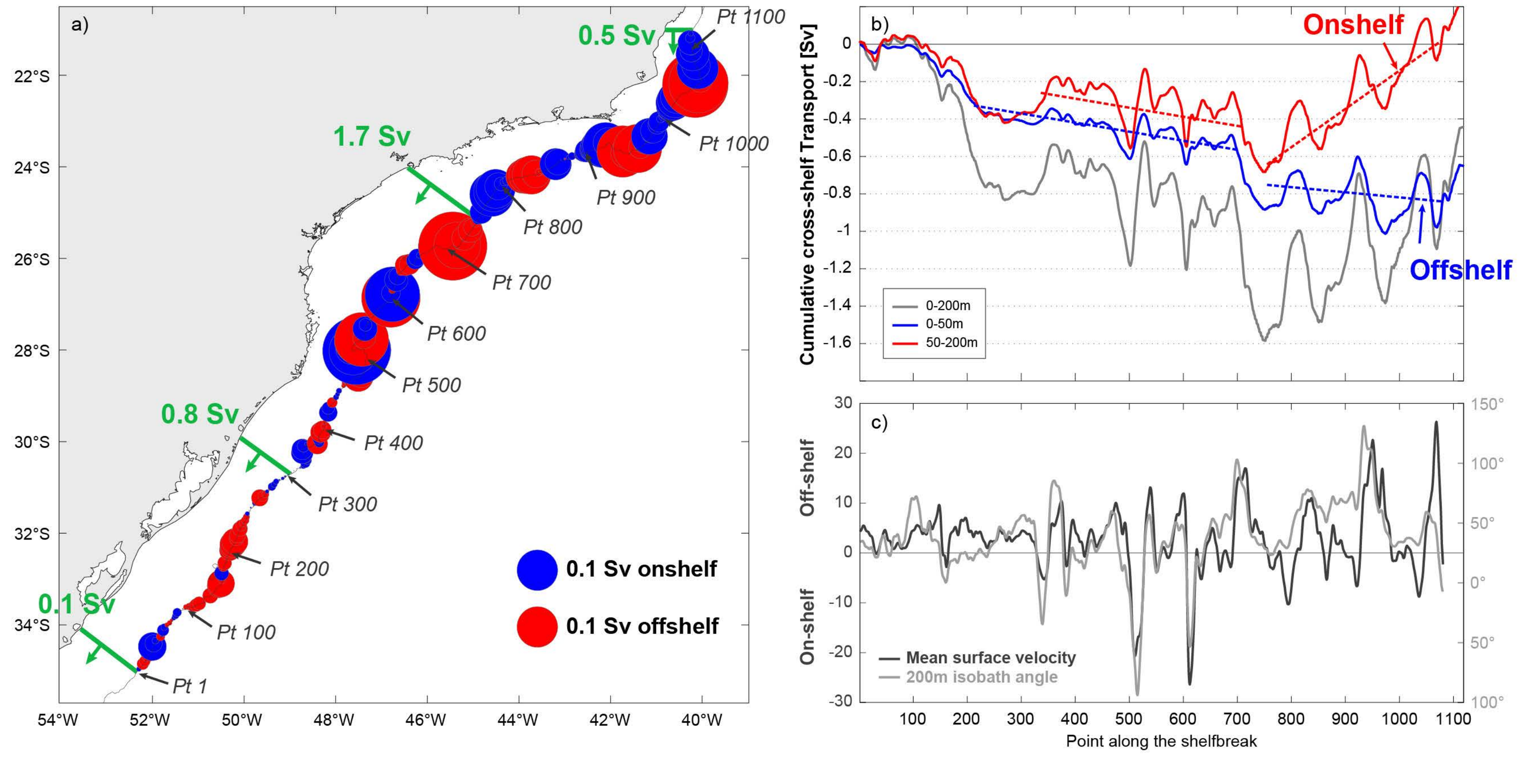

Figure 2: Cross-shelf transport. (a) Transport across the shelfbreak. (b) Cumulative transport across the shelfbreak (in Sv). Positive (negative) cross-shelf transport value indicates an onshelf (offshelf) transport. (c) compares the mean surface velocity across the shelf break (cm/s) and angle of the 200m isobath shelfbreak

3.2. Transport across the shelfbreak: Bottom boundary layer

- Tracer BC_sub is released consistently within the Brazil Current below 200m (Fig. 3). This Tracer is first adected onshelf through the bottom boundary layer before it gets upwelled at the coast.
- Using Lagrangian floats, we estimate at up to 0.15Sv the transport of deep Brazil water into the shelf (Fig. 4a).
- An analysis from a combination of passive tracers (not shown) and floats (Fig 4.c) also reveals the limited connectivity between the shelves north and south of Cabo Frio.

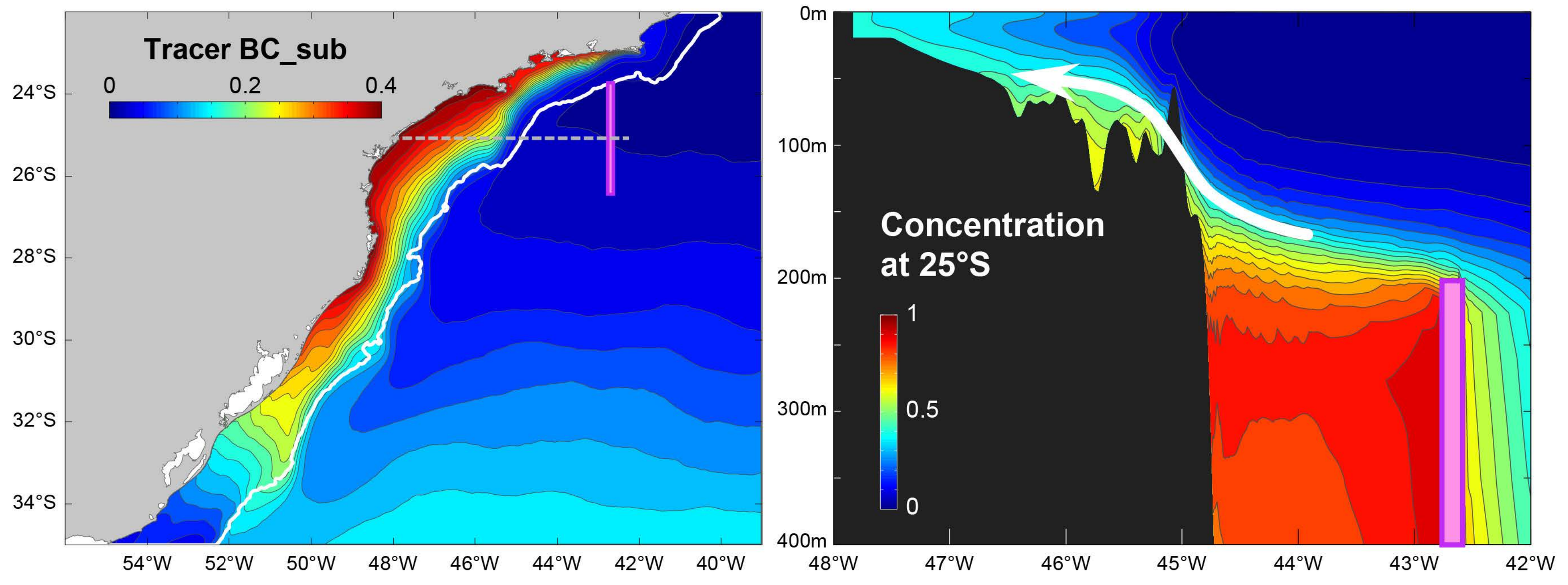

Figure 3: Passive Tracer. Mean surface concentration of passive Tracer and concentration at 25°S. Pink boxes indicate the locations where the tracer is released

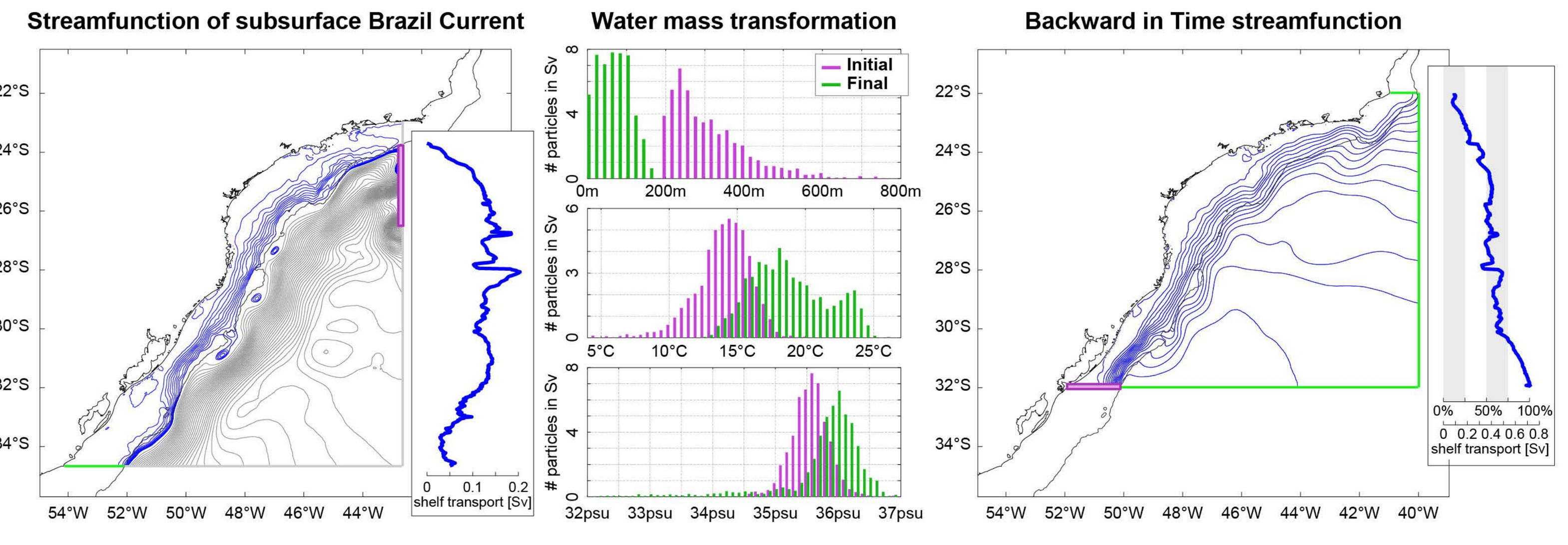

Figure 4: Forward/Background streamfunctions. (a) Lagrangian streamfunction for the water originated from the Brazil Current (purple transect) below 200m. Blue contour interval is 0.01Sv. Gray contour interval is 0.1Sv. The inset figure indicates the transport of this water over the shelf. (b) water mass transformation. (c) Lagrangian streamfunction for the water found over the shelf at 32°S (purple). Blue contour interval is 0.05Sv. The inset figure indicates the shelf transport.

3.3. Transport across the shelfbreak: Variability

- The local wind stress is highly correlated with the surface offshelf transport variability over the southern region and highly correlated with the subsurface onshelf transport variability over the northern region (Fig. 5)

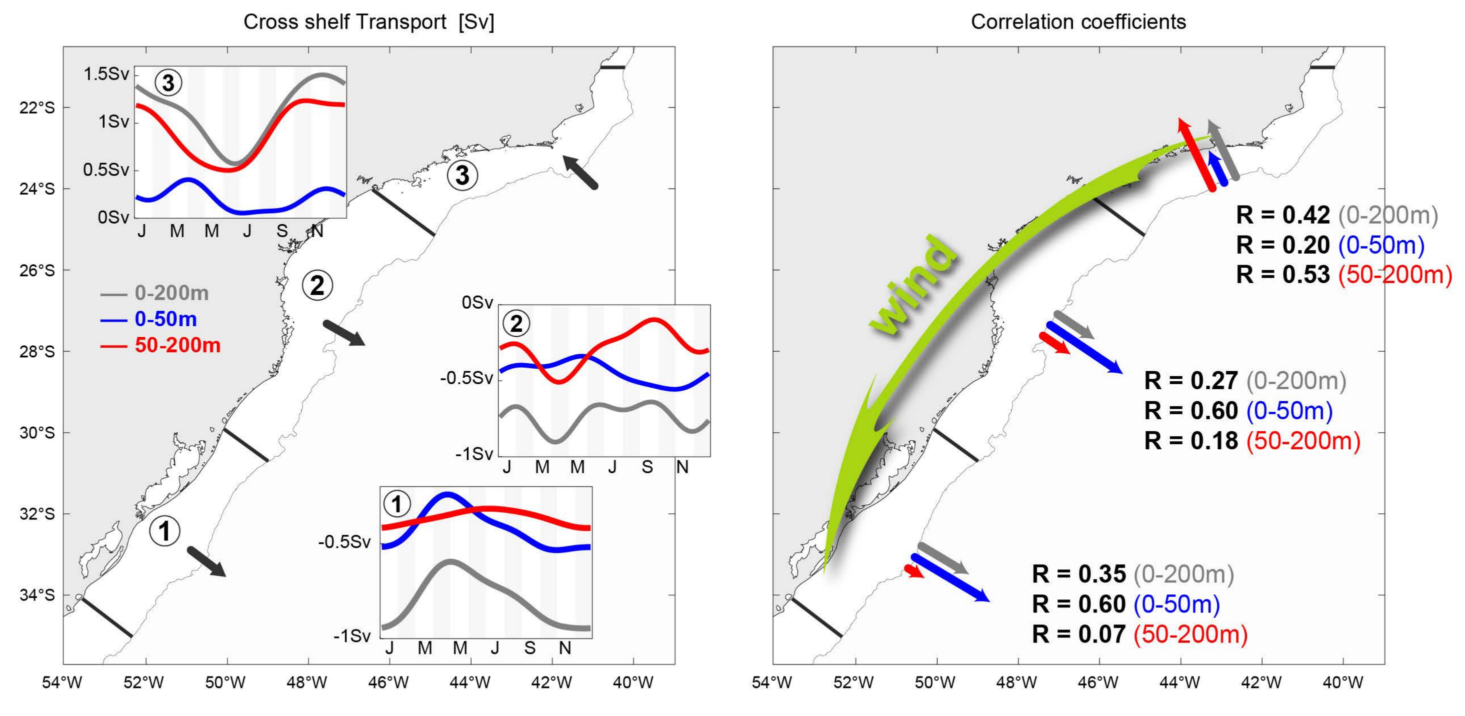

Figure 5: Seasonal/Interannual Transport. (left) seasonal variation of the transport across the shelfbreak. (right) Correlation coefficients between the interannual transport variability across the shelf break and the EOF1 of the shelf wind stress interannual variability (southward alongshore wind stress).

4. Stochastic variability

- Experiment Exp_Seas was run under seasonal forcing only. This means that the regions of interannual variability in Exp_Seas are regions of ocean internal variability (Fig. 6).
- We estimate that 0.2-0.4Sv of the shelf transport variability comes from ocean internal variability (~100% in the northern shelf (Fig. 7).

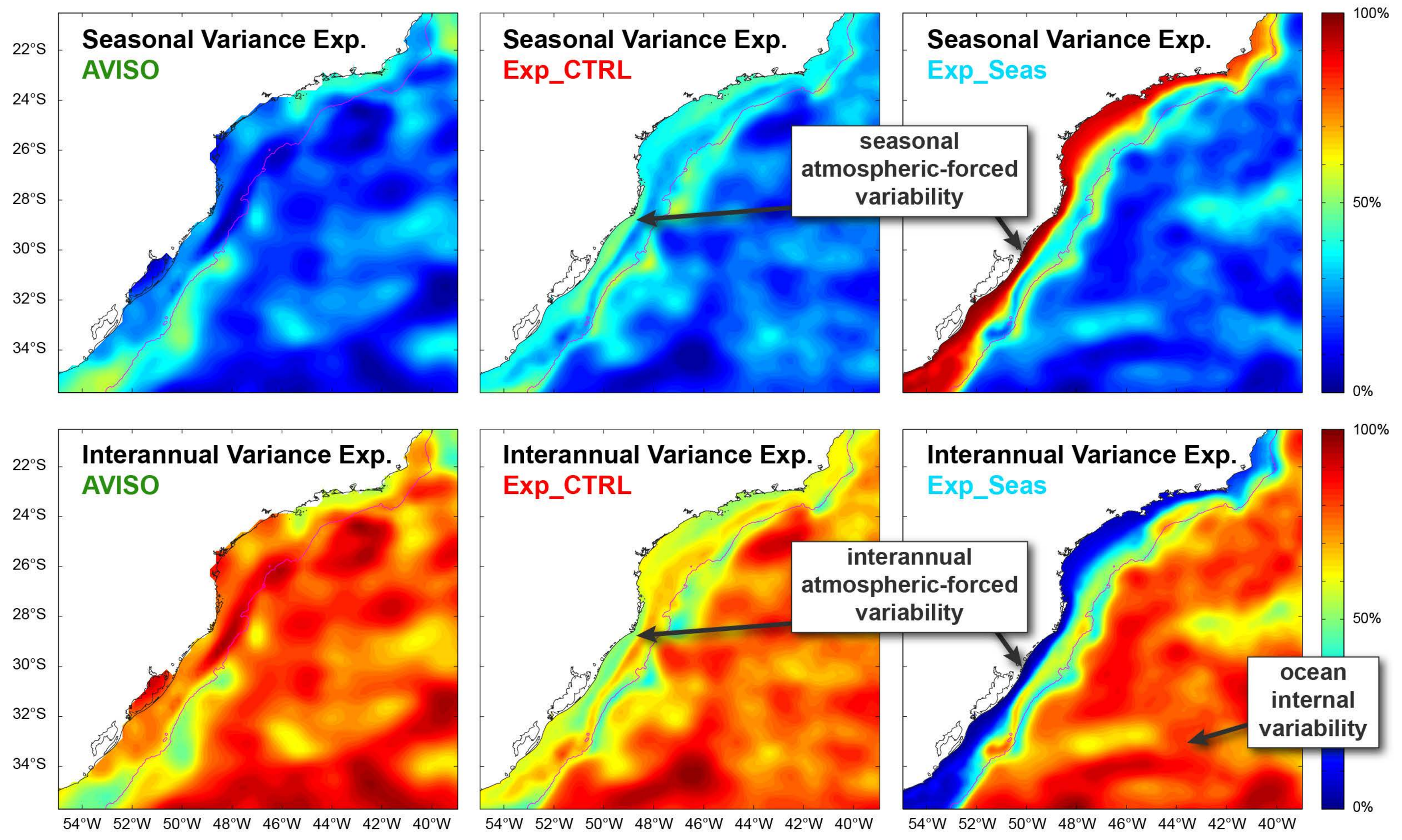

Figure 6: SSH variability. Variance explained by the SSH seasonal (top) and interannual (bottom) variability from AVISO, Exp_CTRL and Exp_Seas.

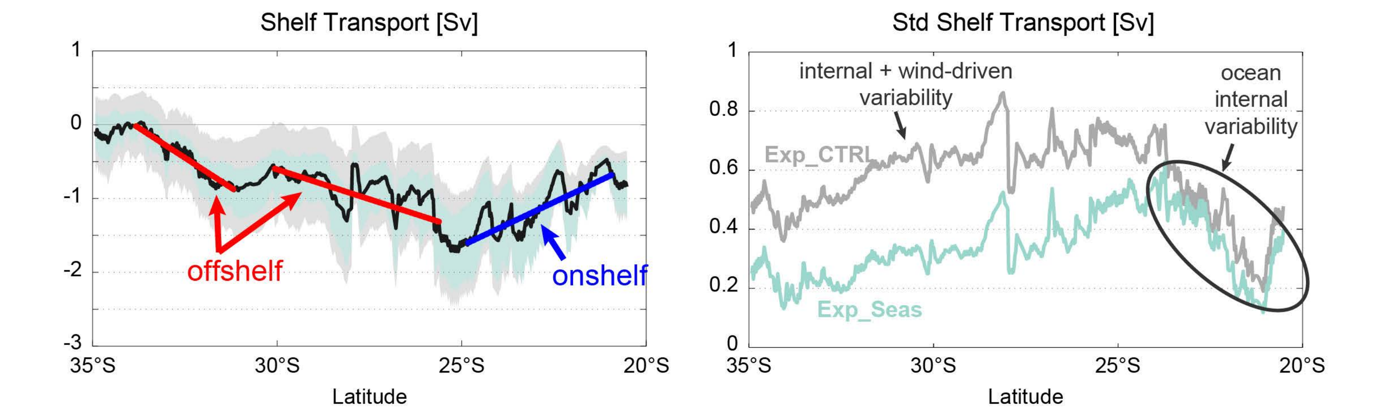

Figure 7: Shelf transport variability. Shelf transport (left) and standard deviation of the interannual variability for the Exp_Ctrl and Exp_Seas.

5. Eddy Dynamics

- Snapshots of the model experiment illustrate the role of small and mesoscale eddies in the exchange of water between the shelf and the open-ocean (Fig. 8).

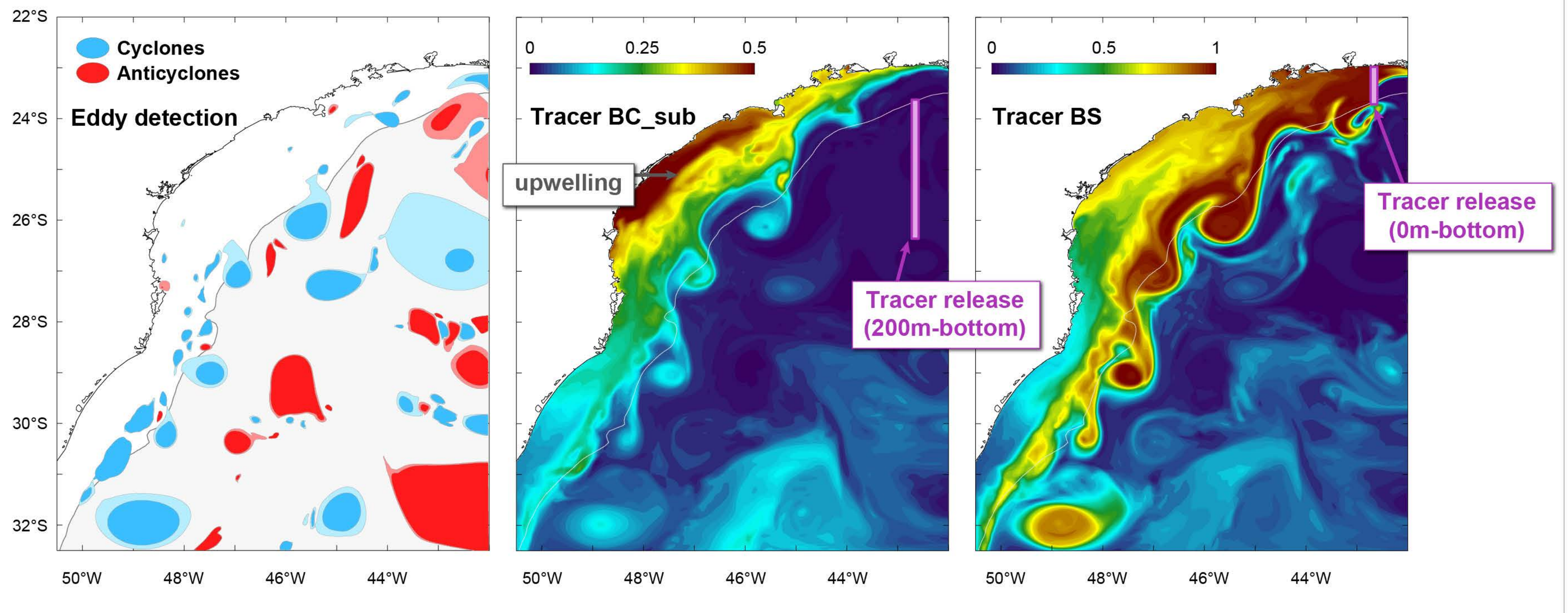

Figure 8: Snapshot for June 29th 1994. Eddy detection and surface Tracer concentration

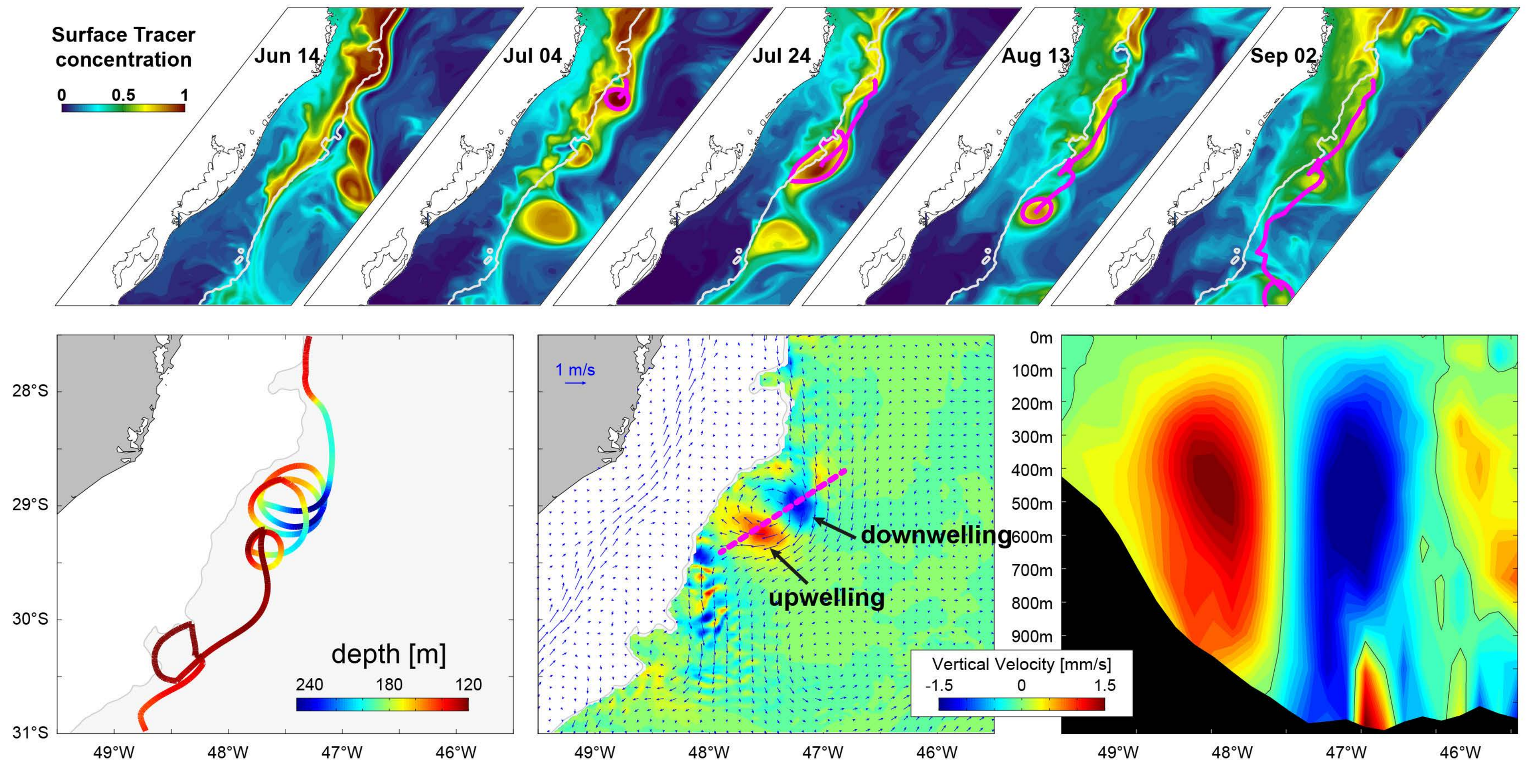

Figure 9: Evolution of the surface shelf Tracer (top). Bottom panel shows a depth-colored trajectory, model vertical velocity at 200m (colors), surface velocity (blue arrows), and vertical velocity across the magenta line.

- In addition of being an important process in the horizontal cross-shelf exchanges, these eddies also play an important role in the local vertical mixing (Fig. 9).
- The particle on Fig. 9 undergoes 5 vertical oscillations (~90m/day), which corresponds to 5 rotations around the eddy
- Downwellings always occur on the northeast part of the eddy while the upwellings are always located on the southeast part of the eddy, consistent with the spatial pattern of the model vertical velocity at 200m and is coherent with the map of the model current divergence.
- The vertical velocity dipole is caused by the presence of the Brazil Current and extends over the entire water column with maximum values at 400-500m depth (~1.8 mm/s or 155m/day)
- Cyclones are found more than 15% of the time downstream of where the shelfbreak changes orientation (Fig.10)
- Drifters data also seems to suggest that the curvature of the shelfbreak trigger cyclonic flows (Fig. 10).
- The horizontal and vertical exchanges produced by these eddy are highly relevant to local primary production as they export nutrient and iron rich waters offshelf (Fig. 10)

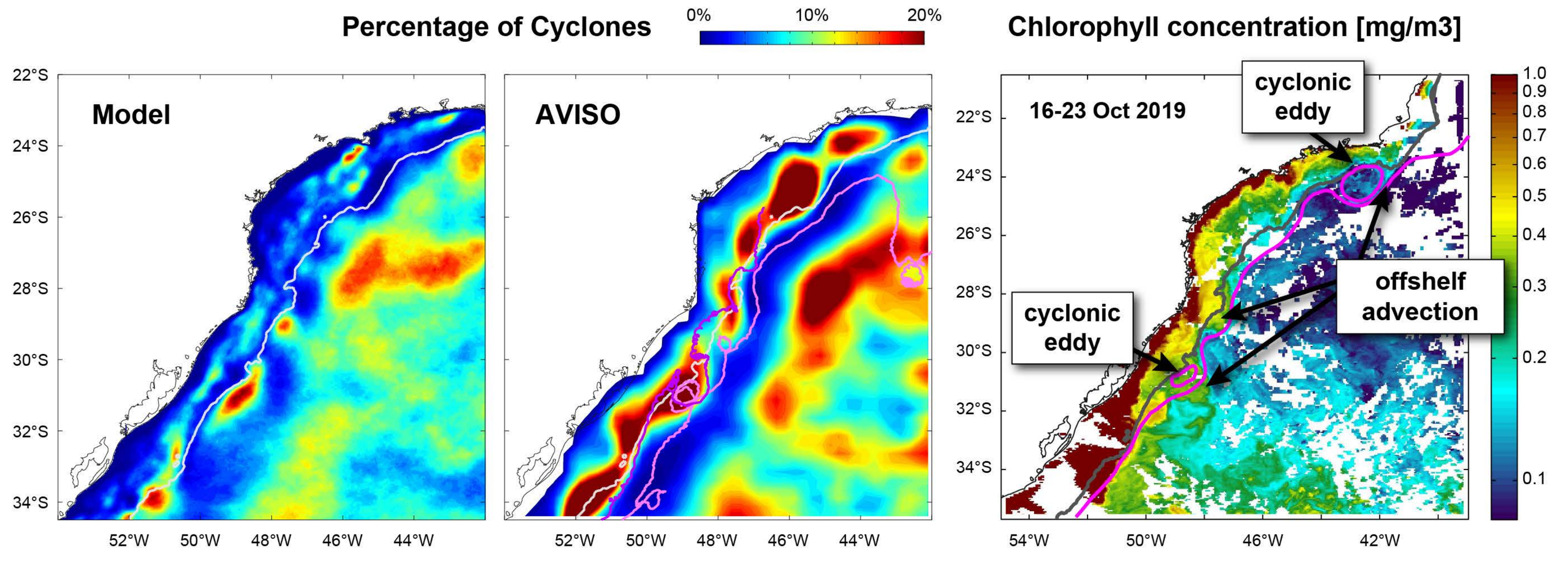

Figure 10: Satellite. % of Cyclones derived from model and altimetry. The magenta trajectories indicate the trajectories of two Argo floats. MODIS-Aqua chlorophyll concentration for 16-23 October 2019. The magenta contours correspond to the 59cm and 65cm contours of AVISO ADT.