Mechanisms Affecting the Life Cycle of Anticyclonic Eddies in the Caribbean Sea

a systematic analysis using a regional model

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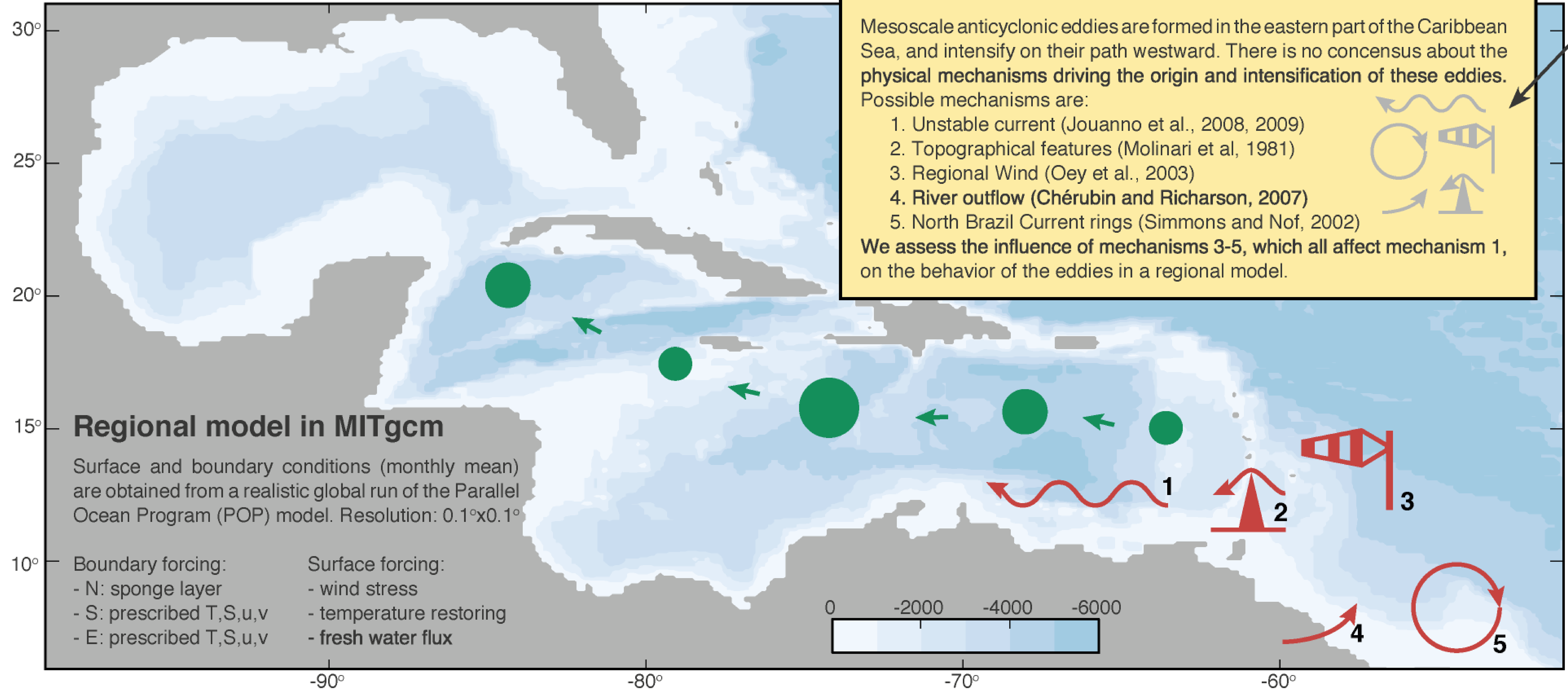
I. Introduction

Mesoscale anticyclonic eddies are formed in the eastern part of the Caribbean Sea, and intensify on their path westward. There is no concensus about the **physical mechanisms driving the origin and intensification of these eddies.** Possible mechanisms are:

1. Unstable current (Jouanno et al., 2008, 2009)
2. Topographical features (Molinari et al, 1981)
3. Regional Wind (Oey et al., 2003)
4. **River outflow (Chérubin and Richarson, 2007)**
5. North Brazil Current rings (Simmons and Nof, 2002)

We assess the influence of mechanisms 3-5, which all affect mechanism 1, on the behavior of the eddies in a regional model.



Regional model in MITgcm

Surface and boundary conditions (monthly mean) are obtained from a realistic global run of the Parallel Ocean Program (POP) model. Resolution: 0.1°x0.1°

Boundary forcing:
- N: sponge layer
- S: prescribed T,S,u,v
- E: prescribed T,S,u,v

Surface forcing:
- wind stress
- temperature restoring
- **fresh water flux**

II. Performance of the regional model

- **The mean flow is anticyclonic in the Caribbean Sea.** There is a smaller cyclonic gyre at 11°N (Fig. 1a).
- The typical life cycle of the anticyclones, including the **western intensification is found in the model (Fig. 1b).**
- Two distinct peaks are present in sea-level variance in the western Caribbean Sea (crosses in Fig. 1c).

Our findings are in line with observations of Johns et al. (2002), and modelling studies of Jouanno et al., (2008, 2009, 2013).

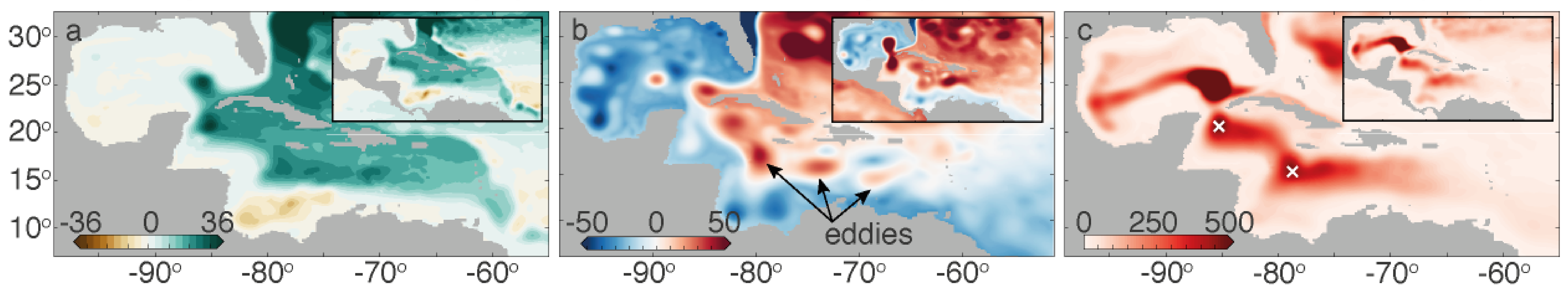


Figure 1: Model outcomes of the Barotropic stream function (a), Sea-surface height of the last month of the simulation **(b), and the sea-level variance is obtained monthly-mean fields from 20 years of the model simulation. Same calculations** are performed for the global POP model (inlays).

III. Characteristics of anticyclones in the regional model

- The anticyclones have two preferred pathways in the Caribbean Sea (Fig. 2a).
- **The western intensification of the anticyclones is visible in the amplification of the amplitude and swirl velocity** towards the western side of the basin (Fig 2a-b). These characteristics are in agreement with Richardson et al. (2005).
- The density difference with the environment increases towards the west (Fig 2c).
- The density of the eddies is approximately constant. The background density has a zonal gradient (Fig. 2d-e).
- This implies that the eddies have little interaction with their environment, and that the density difference is caused by the zonal gradient in the background density (Fig 2f).

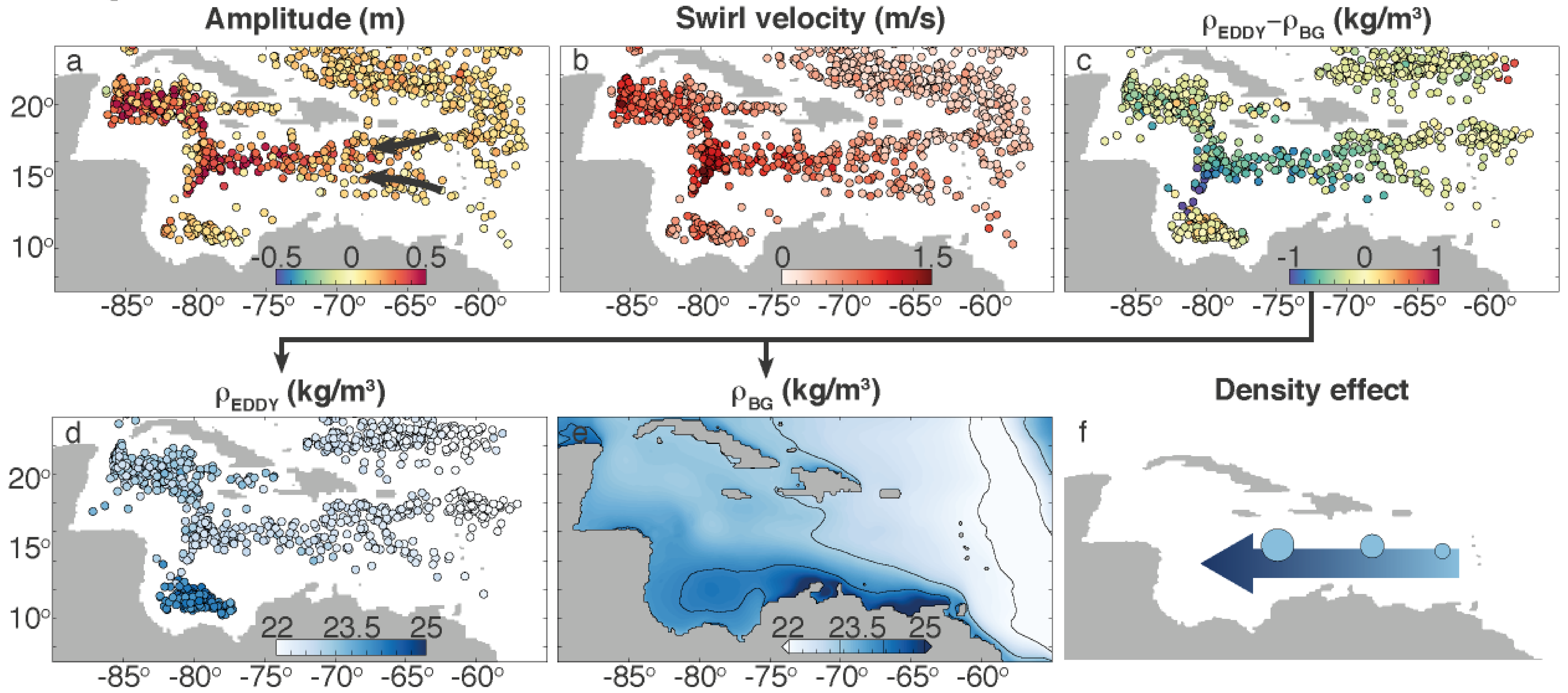


Figure 2: Different monthly-mean properties of the eddies. Density anomaly (ρ) is taken at the surface, and the seasonal cycle is removed. Locations of the eddies were obtained with the py-eddy-tracker (Mason et al., 2014). The background properties (BG) are 20-year averages.

IV. Sensitivity of the anticyclones to mechanisms 3-5

We performed four model simulations, where in each simulation one of the mechanisms 3-5 is excluded.

- Omitting wind forcing leads to a decrease in sea-surface variance within the Caribbean Sea (Fig. 3a).
- **Omitting the surface fresh water flux slightly alters the** sea-surface variance (Fig. 3b).
- The absence of North Brazil Current rings creates a northward shift of the sea-surface variance (Fig. 3c).

The largest change is observed when the wind forcing is omitted. Therefore, we will look in more detail to the wind-driven processes in the Caribbean Sea in a more realistic setting.

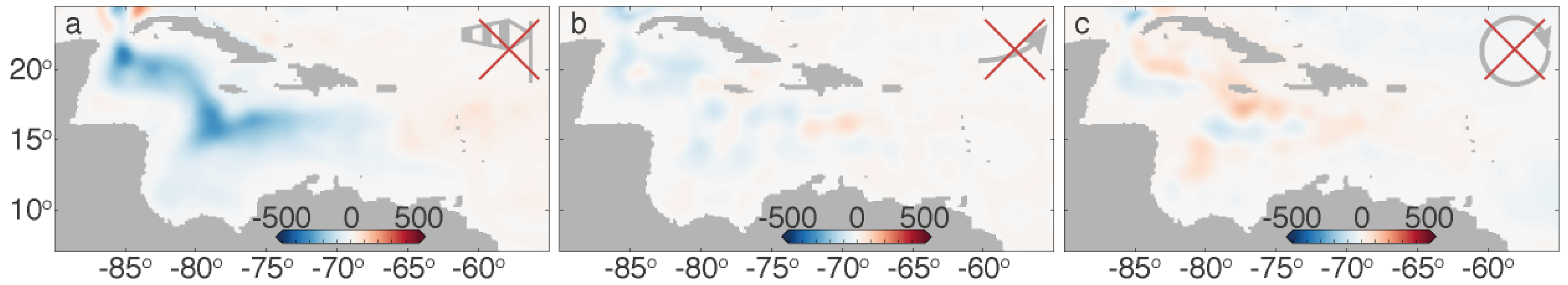
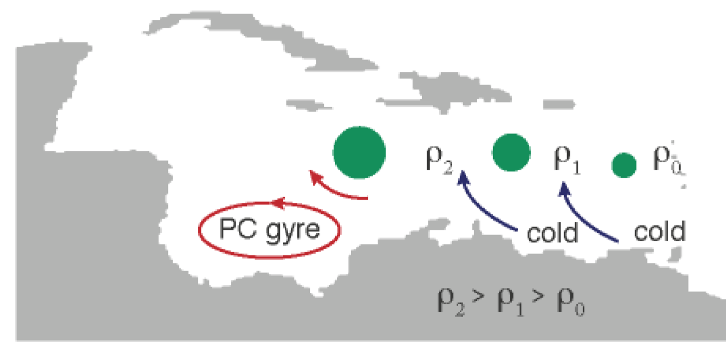


Figure 3: Difference in sea-level variance (cm²) of the sensitivity runs with the reference run (sensitivity - reference). The exclusion of the mechanism is indicated with the symbols. Obtained from 6 year model simulations.

V. Ekman upwelling and the Panama-Colombia gyre

The absence of two of the major wind-driven processes **in Figure 3a, might influence the life cycle of the eddies:**

1. Ekman upwelling along the South-American coast alters the background density (Fig. 2c).
2. Panama-Colombia gyre (PC gyre) accelerates **the mean flow, which might intensifies the eddies** (Fig. 2a-b).



The influence of the Ekman upwelling is investigated by adding a constant to the zonal wind stress:

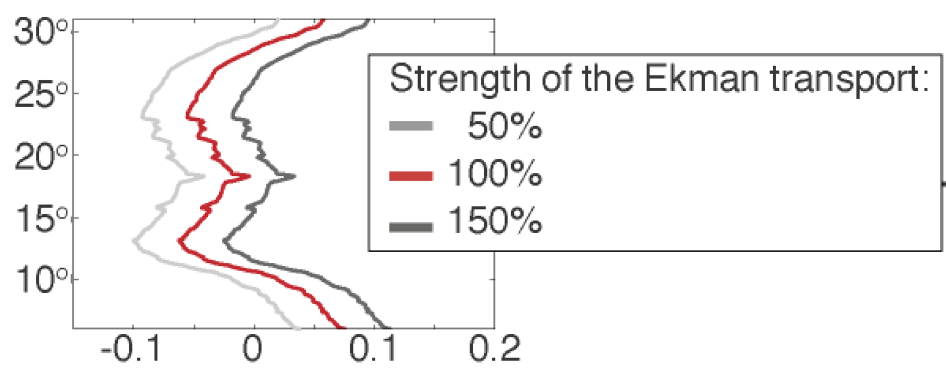


Figure 4: Zonally averaged wind stress (N m⁻²) to test the sensitivity of the eddies to changes in the Ekman transport.

First results show the following changes in the behavior of the anticyclones:

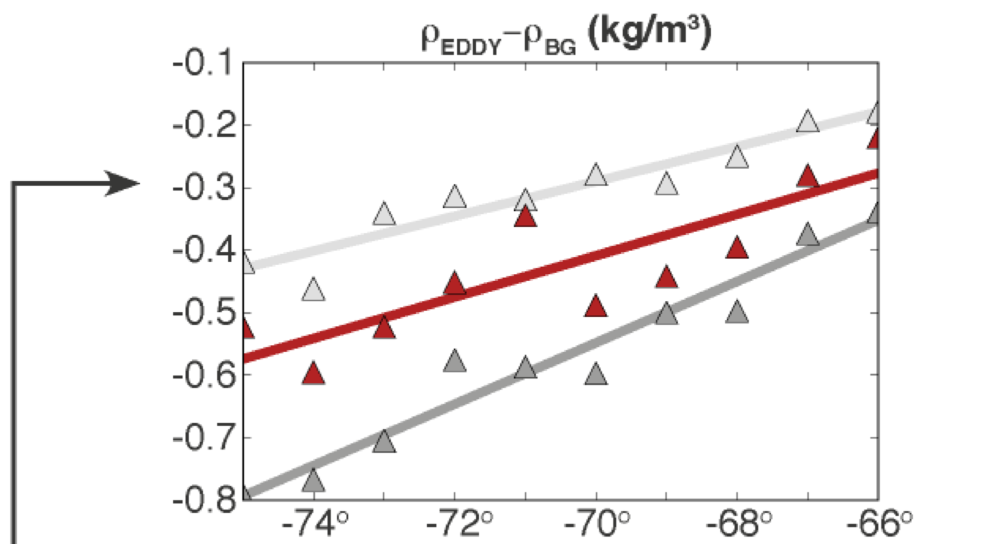


Figure 5: Surface density difference between the anticyclones averaged per degree between 12.5-16.5°N and 66-75°W for different strengths of Ekman transport (Fig 4). Solid lines indicate the trends through the points.

- The density difference between the eddies and the background density is larger (smaller) for stronger (weaker) Ekman transport (Fig. 5).

Next step is to further analyse the relation between **the density difference and the intensification of the** anticyclones. Other wind-driven phenomena, such as the Panama-Colombia gyre, will be analysed on how they affect the life cycle of the anticylones.

VI. Conclusions

We developed a regional model to identify and analyse mechanisms affecting the life cycle of the anticyclones. We concluded the following:

- The regional model captures the variability and transport within the Caribbean Sea.
- The amplitude, swirl velocity and the density difference between the eddies and their enviroment increases towards the western side of the basin.
- Omitting the wind forcing diminishes the variability.
- The strength of the wind-driven Ekman transport affects their density difference with the environment, which could affect the behavior of the eddies.

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