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**Title:** The role of cyclonic eddies in the detachment and separation of Loop Current eddies.

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We sincerely thank the reviewers for their valuable comments and suggestions. Their detailed and constructive feedback has helped us significantly improve the manuscript.

All revisions made in response to the reviewers' comments are highlighted in the diff.pdf file. Line numbers referenced below correspond to those in diff.pdf.

## Response to Reviewer 1

### General comments

In this manuscript, the authors use satellite altimetry observations of the Loop Current (LC) and of ocean eddies to analyze the role of cyclonic eddies in the detachment and separation of LC Eddies. They find that temporary detachments are more frequent as they happen south of the Gulf, as opposed to final separations that are more frequent in the north. They also find that cyclonic eddies tend to be present to the east of the LC in temporary detachment cases, and on both sides of the LC in final separation cases. Finally, they find that the merging of these two cyclonic eddies leads to a large cyclonic eddy that can block the northward extension of the LC.

This is a very nice study, and I enjoyed reading the manuscript. It is generally well written and presents very interesting results that provide a very solid background for analyzing future LC detachment/separation cases. I think the manuscript would benefit from discussing some of its results in relation to previously published results that I believe are relevant to the present study. I also think some aspects need to be clarified. Please see the specific comments below for more details.

### Specific comments

Some of the results presented here nicely complement previously published results. For example, Le Henaff et al. (2014) found that cyclonic eddies along the Campeche Bank tend to be observed immediately after a detachment or separation of an LC Eddy, which suggested that, since such eddies are involved in the pinching off of LC Eddies (Zavala-Hidalgo et al., 2003), they could only do so after the LC Eddy reattaches to the retracted LC. This is consistent with the present study, which demonstrates that temporary detachments are dominant in the southern part of the basin, meaning that LC Eddies frequently re-attach to the LC there. Since the present study also demonstrates that such eddies along the Campeche Bank tend to be involved in the final separation of a LC Eddy, this suggests that there is a typical sequence starting with the initial, temporary detachment of an LC Eddy, under the influence of a cyclonic eddy on the eastern side of the LC (based on the present study), followed by the formation of a cyclonic eddy on the western side of the LC, which can later be involved in the final separation of the LC Eddy. Such a sequence is consistent with the modeling results from Yang et al. (2023), who found that, during a 2010 LC Eddy shedding sequence, a cyclonic eddy along the Campeche Bank forms only in simulations in which the pre-existing cyclonic eddy on the eastern side of the LC is sufficiently intense to lead to an LC Eddy detachment (and independently from the boundary conditions from the Caribbean Sea). Results from the present study thus suggest that such a teleconnection between the initial presence of a cyclonic eddy on the eastern side of the LC and the later formation of a cyclonic eddy along the Campeche Bank might be quite common. I think it would be nice that these ideas are discussed in the manuscript.

In this context, regarding the role of cyclonic Caribbean eddies discussed in the manuscript, which is also important as illustrated in the study, it is possible that the timing of such eddies matters: a cyclonic anomaly propagating from the Caribbean Sea to the southern Gulf at the time of the initial LC Eddy detachment might find favorable conditions for intensification or growth (allowing it to be detected by current observing platforms), whereas it might not intensify otherwise.

We agree with the reviewer. We have now included Yang et al. (2023b) in the paragraph about the cyclonic eddies that participate in the detachment of LCEs (lines 63-65):

“Yang et al. (2023b) suggest that cyclonic eddies west of the LC, which are instrumental in promoting the “pinching off” mechanism, correlate with the occurrence of strong and large cyclonic eddies east of the LC.”

Furthermore, we have incorporated the studies of Hénaff et al. (2014) and Yang et al. (2023b) in the discussion addressing the long-standing question on whether cyclonic eddies west of the LC that participate in the separation of LC eddies are locally generated or advected from the Caribbean (lines 289-297):

“From the analysis above, cyclonic eddies on the west side of LC potentially facilitate the final detachment of an LCE, and the question then arises as to their origin. Are they formed locally, or are they advected from the Caribbean Sea? This question has been the subject of several studies over the years. Candela et al. (2002); Athié et al. (2012), and Jouanno et al. (2016) show that several LCE separation events coincide with the propagation of Caribbean eddies into the GoM. In contrast, Yang et al. (2023b) use an ensemble of numerical simulations for the 2010 detachment of the LCE Franklin, in which different ensemble members are generated by perturbing empirical orthogonal function modes of the circulation, leading to variations in the amplitude and structure of cyclonic eddies east of the Loop Current. They find that the occurrence of strong and large cyclonic eddies east of the LC can promote the formation of a cyclonic eddy west of the LC, which significantly affects the timing and occurrence of the LCE detachments.”

We also added a paragraph in the discussion section about the possible origin of western cyclonic eddies that participate in separation events (lines 386-400):

“In this context, our results contribute to the ongoing discussion on the origin of cyclonic structures west of the LC during separation events. For separations south of  $26^{\circ}\text{N}$ , our observations show that cyclonic anomalies propagate from the Caribbean through the Yucatan Channel and contribute to the formation of western cyclonic structures and barrier eddies in the Gulf of Mexico. This interpretation is consistent with numerical studies showing that reducing Caribbean mesoscale variability leads to increased mean LC penetration into the GoM (Le Hénaff et al., 2012; Garcia-Jove et al., 2016). This behavior can be understood as a consequence of fewer Caribbean cyclonic anomalies reaching the Gulf, resulting in fewer barrier eddies and a Loop Current that spends more time in an extended state. From a complementary perspective, Yang et al. (2023b) use an EOF-based ensemble approach to mainly perturb the properties of cyclonic eddies east of the LC and suggest that strong and large eastern cyclones can induce the local formation of western cyclones. It is plausible that both mechanisms act together: eastern cyclones trigger the formation of western cyclones, while Caribbean cyclonic eddies reinforce them, enabling the “pinch-off” of LCEs and the formation of barrier eddies. However, it is also possible that EOF-based perturbations not only directly influence cyclonic eddies east of the LC but also indirectly alter the Caribbean circulation near the Yucatan Channel, potentially limiting the propagation of cyclonic anomalies from the Caribbean into the GoM. Taken together, these observations and sensitivity studies highlight remaining uncertainties regarding the relative roles of locally generated versus Caribbean-advected cyclonic eddies in LCE separation events. These questions could be addressed through process-oriented numerical experiments in which Caribbean eddies are explicitly included or excluded at the boundaries, allowing a direct assessment of their impact on western cyclones, barrier eddies, and Loop Current behavior. Such experiments would help assess the relative importance of locally generated cyclonic eddies to those coming from outside the GoM in the separation events.”

Regarding Figures 4, 5, 6, 7, and 8: the captions mention that these composites are for separation cases, but the manuscript mentions that these figures include both reattachment and separation events (l. 165). This needs to be clarified, as some analyses in the text would not be possible if these figures merge both types of events (l. 175-177, l. 205-206).

We agree with the reviewer, and have rewritten the sentence (lines 210-213):

“Specifically, cyclonic eddies west of the LC are associated with a westward shift of the LC away from the Campeche Bank (first fourth columns in separations south of  $26^{\circ}\text{N}$  in Figure 4; Zavala-Hidalgo et al., 2003; Sheinbaum et al., 2016), a configuration not observed during reattachment events (first fourth columns in Figure 5).”

In the initial analysis of Figures 1 and 2, point 3 (l. 133-134): I am not sure I fully understand the reasoning here. Can the authors better explain this result? Also, the equivalence between an 1800 km length and the distance to the Mississippi Fan is only mentioned in the summary and discussion, later in the manuscript.

We agree with the reviewer. We have added the LC length definition (lines 148-151). We have also rewritten the list of points to properly communicate that a) the detachment latitude largely determines if LCEs tend to reattach or separate; b) that a minimum LC length is required for eddy detachments; c) that the southern the detachment, the larger the LC eddies; and d) LC length does not control whether a detachment results in reattachment or separation (lines 153-171).

## Technical corrections

- l. 23: Shay et al. (2000) could also be cited here.

Done.

- l. 62: I suggest “tends to form” instead of “forms”. Otherwise, there would not be cases in which this does not happen, mentioned in the following sentence.

Done.

- l. 97: Tables in the Appendix are named A1, A2 etc., not S1, S2. Also, tables A3 and A4 do not seem to be used in the manuscript. If they are not, they should be removed.

We have changed the figures prefix. Tables A1–A3 are directly cited in the manuscript (lines 110-111) as providing detailed information for each detached eddy, including the date, region, and eddy name. Although Tables A3 and A4 are not used for analysis in the main text, we retain them because they offer useful reference information for readers to verify the data and explore individual cases, enhancing the transparency and reproducibility of the study.

- Figure 1 caption: There is no MF on the figure, and there are no continuous gray contours.

We have removed the MF acronym and properly defined the bathymetric contours: The contours refer to the 200 m (continuous) and 2500 m (dashed) depths.

- l. 167: In the appendix it is Figure A1, not S1.

Done.

- l. 178 and 180: I believe it is “south of 25oN” instead of “south of 25oN”.

Apologies for the confusion, here we are comparing separations south 25°N and separations between 25-26°N. The text has been rewritten for clarity (lines 214-215).

- l. 180: I believe it is Figure 4 instead of Figure 5.

Here, we are referring to the Figures 4 and 5. The figure numbers have now been corrected.

- l. 180 and 182: the locations of the cyclonic eddy with respect to the LC are hard to identify, since the shape of the LC changes. In Figure 6 the mean LC appears to be detached at -30 days, so it is hard to tell what North, East or West of the LC means, compared to Figure 5 for example.

We no specify the coordinates where Tortugas eddies are (lines 215-218):

“For separations south of 25°N, the eastern cyclonic eddy is located near the Dry Tortugas (between 22-26°N and 84-87°W; Figure 4a<sub>3-4</sub>,b<sub>3-4</sub>) and is often referred to as a Tortugas Eddy (Fratantoni et al., 1998).”

For cyclonic eddies northeast the LC (lines 223-225):

“Instead, the eastern cyclonic circulation develops northeast of the LC, between 26-28°N and 85-87°N (Figure 4c<sub>3-4</sub>).”

- l. 216-218: Based on Figure 10d (not Figure 10a-d), it seems that barrier eddies persist for more than 5 months (not 4) northwest of the LC after separations that occurred below 24 °N, and 4 months (not 3) after separations between 24 and 25 °N.

We agree with the reviewer. We have rewritten the text to include the proper persistence time periods (lines 278-283):

“Both mean and median persistence times indicate that barrier eddies last up to nearly 5 months northwest of the LC after separations that occurred below 24°N, about three months and a half after separations between 24 and 25°N, and one month after separations between 25 and 26°N (Figure 6a–d). Furthermore, the LC does not penetrate into the GoM four months (thin dashed line) after separation events below 24°N, three months (thin black line) after separations between 24 and 25°N, and one month (thick black line) after separation between 25 and 26°N (Figure 6a-c).”

- Figure 10 caption: There is no subplot e, so the text “The cumulative persistence of blocking cyclonic structures over the 29-year period is shown in e. The cumulative persistence is computed by multiplying the mean persistence of blocking cyclonic structures by the number of separations per region” should be removed. Also, what are the 3 types of LC contours visible on Figure 10a-c?

We agree with the reviewer. The reference to cumulative persistence corresponded to a subplot included in an earlier version of the manuscript and is no longer applicable. We have therefore removed the corresponding text from the Figure 10 caption. In addition, we have revised the caption to explicitly describe the three LC contours shown in Figure 10a–c, which represent the composite LC positions 1, 3, and 4 months after detachment events.

- l. 239: SLA, not SAL.

Done.

- Figure 11 caption, I suggest: “Hovmöller composites of SLA (first column) and the occurrence of cyclonic eddies from the AVISO Atlas (second column) during separations occurring below 24°N etc.”

Done.

- Figure 12 caption seems to have many mistakes. I suggest: “Hovmöller composites of SLA (first column) and the occurrence of cyclonic eddies from the AVISO Atlas (second column) during reattachments occurring below 24°N (first row), between 24-25°N (second row), and between 25-26°N (third row). Thick continuous-black contours etc.” There are only 3 rows, not 5.

We agree with the reviewer. The Figure 12 caption contained errors in the description of the number of rows. We have corrected the caption to accurately describe the three rows and their corresponding latitude ranges.

- Figure 13 caption: In the second column, it seems that SWOT data are blended with CMEMS data outside the SWOT swath, is that correct? If so, this should be mentioned.

We agree with the reviewer. The figure caption has been modified as follows (page 22):

“Examples of a comparison between SLA estimations between altimetric gridded maps from CMEMS (first column) and along-track observations from SWOT (second column). Both the first and second columns show CMEMS SLA fields and the spatial extent of the SWOT swath. In the second column, SWOT along-track measurements are additionally overlaid on the CMEMS fields within the swath. Each row refers to a different date. Continuous black contours show the 200-m depth contour, whereas dashed black contours show the 2500-m depth contour. The following describes the differences between the two products. First row: Cyclonic structure around 86°W, 19°N that is not visible in CMEMS but is visible in SWOT. Second row: Cyclonic structure around 84°W, 21°N that is not visible in CMEMS but is visible in SWOT. Third row: Cyclonic structure around 87°W, 19°N that is not visible in CMEMS but is visible in SWOT. Fourth row: Cyclonic structure around 83°W, 21°N with a weak signature in CMEMS but clearly visible in SWOT.”

- Figure 14: Based on the description of the thick black line and the thin black segmented line, I believe these lines should be the same on the 1st and 2nd rows. Can the authors explain?

Hovmöller composites using CANEK mooring array only consider separation events between July 2012 to October 2020, whereas Hovmöller composites using CMEMS data consider separation events between 1993 and 2021. This is the reason why thin and thick contours, representing the LC signature from altimetric observations, differ in the CANEK and CMEMS Hovmöller composites. This has been clarified in the figure caption:

“ADT contours in altimetric observation composites are computed from all separation events between 1993 and 2021 within the respective latitude ranges, whereas in the CANEK composites, the contours are computed from separation events between July 2012 and October 2020.”

- l. 279: I suggest starting a new paragraph after “from the LC.”

Done.

References:

- Le Hénaff, M., Kourafalou, V. H., Dussurget, R., and Lumpkin, R. (2014). Cyclonic activity in the eastern Gulf of Mexico: Characterization from along-track altimetry and in situ drifter trajectories. *Prog. Oceanography* 120, 120–138. doi: 10.1016/j.pocean.2013.08.002

- Yang, X, Le Hénaff, M., Mapes, B., and Iskandarani, M. (2023). Dynamical interactions between Loop Current and Loop Current Frontal Eddies in a HYCOM ensemble of the circulation in the Gulf of Mexico. *Front. Mar. Sci.* 10:1048780. doi: 10.3389/fmars.2023.1048780

- Shay, L.K., Goni, G.J. and Black, P.G. (2000). Effects of a warm oceanic feature on Hurricane Opal. *Monthly Weather Review*, 128(5), pp.1366-1383.

## Response to Reviewer 2

This is a very interesting paper that reveals patterns of meso-scale variability in the Gulf during Loop Current Eddy formation. Through composites of satellite SSH, the authors show that the "necking down" preceding Loop Current eddy separation is associated with two cyclonic features. On the eastern side, a meander along the periphery of the Loop Current grows through some combination of baroclinic instability triggered by vortex stretching due to Loop Current interaction with the Mississippi Fan. On the western side, a cyclonic eddy with origins in the Caribbean and/or Yucatan Channel. This pattern is clearly present for southern separations. In other words, while detachments occur with just the eastern cyclone, separations require a source of cyclonic vorticity along the eastern edge. This paper will have significant impact and represents an important step toward understanding and predicting Loop Current Eddy separations. I clicked the 'major revision' button but I think its closer to minor revision. well done.

### Major Comment

The discussion could be substantially strengthened. As it stands, the results lean toward kinematic rather than dynamic interpretation. I encourage you to place these results in a more dynamical context even if somewhat speculative or perhaps by interpreting your results in the context of previous work. I believe this work will serve as a launching point for future studies.

For example, modeling studies suggest barotropic instability is important for detachments. How do the cyclonic eddies interact with this process? Could either the western or eastern eddy strengthen the horizontal shear, thereby enabling barotropic instability? Additionally, are the western eddies truly "fundamental"? Is their role dynamical, or do they simply narrow the Loop Current width? Is there a relationship between the eddies? Is it appropriate to say that the eastern cyclone gets established and as soon as a cyclonic eddy propagates into the Gulf, separation occurs?

Is this worth exploring? The deep, nearly depth-independent cyclone in the channel just north of Yucatan (see Perez-Brunius et al. 2018, Fig. 4) may be key. Perhaps the western cyclones squeeze the Loop Current, reducing its width, while the eastern cyclones and the deep channel cyclone then accomplish the separation. I think that the large cyclonic feature may just be the surface expression of the depth-independent gyre (24.5N, 85.5W) rather than the merging of the western and eastern cyclone – but this is a hypothesis.

We agree with the reviewer that our initial discussion emphasized kinematic relationships more than dynamical interpretation. We have now expanded the discussion to better place our results within the context of previous dynamical studies (lines 409-414):

“Finally, our results about the role of cyclonic eddies in the detachment of LCEs also agree with the findings of Chérubin et al. (2006) and Yang et al. (2023a) regarding the occurrence of strong barotropic energy conversions during detachment events. The coexistence of strong LC and cyclonic eddy vorticity during the shedding process is consistent with enhanced horizontal shear, potentially favoring barotropic energy conversions. At the same time, observational analyses (Donohue et al., 2016b; Hamilton et al., 2016) suggest that baroclinic energy conversions associated with the formation of large-scale meanders may contribute to the development of cyclonic eddies that participate in detachment events.”

Regarding the importance of cyclonic eddies west of the LC, our composite analyses indicate that the formation of a barrier eddy, which isolates the freshly detached LCE from the Loop Current, requires cyclonic eddies on both the eastern and western sides of the LC. When a western cyclonic eddy is absent, no barrier eddy forms, and the LCE typically reattaches to the LC. Statistically, detachments are associated with the occurrence of barrier eddies, indicating that cyclonic eddies on both sides of the LC are essential for separation events. This is now mentioned in the summary and discussion section (lines 341-344).

We also agree that the deep, nearly depth-independent cyclone identified by Pérez-Brunius et al. (2018) may be dynamically important for Loop Current separation. However, the present study is based on a 29-year satellite altimetry record, which provides continuous and spatially consistent surface observations. While subsurface datasets such as RAFOS float measurements document the existence of the deep cyclone, their temporal coverage is limited and does not allow for a comparable long-term statistical analysis. For this reason, we focus on surface cyclonic eddies, for which we have sustained observations without significant gaps. We agree that the potential connection between the deep cyclone and the surface barrier eddy remains an important hypothesis that should be explored in future studies combining long-term subsurface observations and high-resolution modeling.

## Additional Comments

The paper could benefit from increasing the clarity by homing in on the key results. I appreciate the comprehensive nature of the work – it’s impressive yet perhaps not all needs to be in the main body of the paper. Some figures are quite small and may not be essential to the main narrative (see specific suggestions below). Given the comprehensive nature of this work, consider moving some material to the appendix to streamline the main text.

To be clear, the following are suggestions and I’ll leave it to the authors to decide whether they benefit the manuscript.

Kathy Donohue

### Abstract:

Line 8: ‘latter’ I don’t know what ‘latter’ refers to here. The preceding sentence is quite long and so latter is not clear.

We agree with the reviewer, and we have rewritten the ideas as follows (lines 4-10):

“Our observational analysis also shows that i) before a detachment can occur, the LC needs to extend far enough north in the Gulf to reach the Mississippi fan ( $\sim 27.5^\circ\text{N}$ ); and ii) the ratio of separations to reattachments depends on latitude, with detachments being more prone to reattach if they occur south of  $25^\circ\text{N}$  and to separate if they occur north of  $25^\circ\text{N}$ . In case iii), cyclonic eddies are consistently present during the detachment process, with one cyclonic eddy on the eastern side of the LC if the LCE is to reattach, and one on each side if the LCE is to separate. When cyclonic eddies occur on both sides of the LC, their co-occurrence in the LC bottleneck zone forms a large cyclonic structure.”

Line 12: This is an interesting comment that is not discussed (much) in the summary and discussion section.

We agree with the reviewer, and we have added a sentence about it in the summary and discussion section (lines 350-353):

“These statistical associations between cyclonic eddies and LCE detachments provide a framework to anticipate future separation events based on the evolving mesoscale circulation, and can guide targeted numerical simulations to explore, for example, the dynamical mechanisms by which barrier eddies limit LC penetration into the GoM.”

### Introduction

Line 42: why is cyclonic capitalized?

We thank the reviewer for noting this. We have corrected the capitalization of “cyclonic” throughout the manuscript to ensure consistency.

Line 50: Worth citing Oey?

Oey, L. Y., H. C. Lee & W. J. Schmitz (2003) — Effects of winds and Caribbean eddies on the frequency of Loop Current eddy shedding: A numerical model study, *Journal of Geophysical Research: Oceans*, 108(C10).

<https://doi.org/10.1029/2002JC001698>

Done.

Line 40: Barotropic/baroclinic energy conversions. Donohue did not even consider the barotropic eddy conversion so the studies are not at odds with one another. I don’t see how an observational study that shows the baroclinic conversion modeled by Hurlburt and Thomson, Oey and others is controversial. Meanders along the eastern side, deepen, these cyclonic features often have high Rossby numbers – they may be existing features that have propagated in from the west. The deepening is a baroclinic intensification process. All models show this.

We agree with the reviewer. This issue is addressed together with the following comment, as the two points are closely related.

Yang et al. (2023) show that during Loop Current Eddy detachment, the eddy kinetic energy increase is primarily fueled by barotropic instability, with barotropic energy conversions dominating the horizontal energy budget relative to buoyancy forcing during detachment. I would argue that the energy conversion in the MITGCM might be underestimated based on the low deep eddy kinetic energy relative to observations (see Morey’s paper).

We have rewritten the paragraph to clarify how numerical and observational studies on energy conversion in LCE shedding complement each other (lines 35-49):

“In addition to large-scale rotational and wave dynamics, several studies have linked LCE detachments to internal instabilities and energy conversion processes. Chérubin et al. (2006) used a numerical approach to indicate that LCE detachment results from a combination of baroclinic energy conversion in the deep GoM layers and barotropic

energy conversion in the upper layers. More recently, Yang et al. (2023a) reported that barotropic energy conversions play a dominant role in the energy balance during detachment events. However, Morey et al. (2020) compared observational estimates of deep eddy kinetic energy from Pérez-Brunius et al. (2018) with outputs from MITgcm (Massachusetts Institute of Technology general circulation model), ROMS (Regional Ocean Modeling System), and HYCOM (Hybrid Coordinate Ocean Model) and found that all three models substantially underestimate deep eddy kinetic energy, typically by more than a factor of two. This discrepancy highlights current limitations in numerical models in reproducing deep eddy variability and raises uncertainty regarding how barotropic and baroclinic energy conversions contribute to the deep eddy kinetic energy budget. From an observational perspective, using a mooring array spanning the Campeche Bank, Mississippi Fan, and West Florida Shelf, Donohue et al. (2016b) and Hamilton et al. (2016) provide direct evidence for the role of baroclinic processes in deeper waters. Their results also indicate that LCE detachments are associated with an increase in deep eddy kinetic energy due to the conversion of available potential energy, consistent with the development of large-scale meanders in the northern and eastern LC regions.”

Line 42: I would change the topic sentence to ‘Omnipresent in both the GOM and the Caribbean.’ Most of this paragraph is about Caribbean vorticity entering the Gulf. This is an opportunity to discuss both cyclonic and anticyclonic vorticity into the Gulf.

This paragraph is intended to synthesize existing hypotheses involving cyclonic eddies that interact with the Loop Current and have been proposed to influence LCE detachment. While cyclonic eddies are present in both the Caribbean and the Gulf of Mexico, the emphasis here is on their role within the Gulf, where LCE detachment occurs and where our analysis is focused. For this reason, we retain the wording “omnipresent in the GoM”. Regarding Caribbean anticyclones, their potential role in Loop Current evolution is beyond the scope of this work, as our composite analyses do not reveal a consistent association between anticyclonic features and LCE detachment, in contrast to the clear and recurrent role of cyclonic eddies.

Line 55: I don’t love ‘debate’. Reads more adversarial than necessary. Consider something like – reflecting the complex and not yet fully resolved role of Caribbean cyclonic eddies in the shedding process.” Or reflecting our incomplete understanding of Caribbean cyclonic eddies, perhaps due to the difficulty in both observing and modeling these features. (This last sentence would set the stage for your section about how the altimeter barely resolves these cyclones.)

We agree and have revised the wording.

Line 62: as mentioned before, I think this large cyclonic feature is really that deep cyclone sitting at 24.5N observed by the Rafos floats.

We agree that the deep, nearly depth-independent cyclone identified by Pérez-Brunius et al. (2018) could be dynamically important for Loop Current separation. However, this study relies on a 29-year satellite altimetry record that provides sustained surface observations, whereas subsurface datasets such as RAFOS floats have more limited temporal coverage. For this reason, we focus on surface cyclonic eddies, which can be analyzed consistently over the full record. The connection between the deep cyclone and the surface barrier eddy remains an important question that should be addressed with dedicated subsurface observations and high-resolution numerical simulations.

Figure 1 – nice figure! The caption needs a rewrite. Maybe just delete that first a) and write Figure 1. Detachment locations. Odd to put panel d in the lower left – you don’t label the other figures in this clockwise manner. Could you make the height of panel d smaller – I spent misguided time trying to align the latitudes in histogram plot with the maps.

We agree with the reviewer. We have rewritten the caption, and we fixed the order of the panel labels. I also understand the problem with trying to visually compare the vertical axes of maps and the histogram. To facilitate this connection, we added horizontal segmented lines to mark each histogram bin on the maps, as well as lines linking the latitude limits of the histogram bins to the corresponding regions in the maps.

Line 111: Detachments that lead to reattachments maybe say Detachments with subsequent reattachments. Lead sounded odd. Would one say detachments that lead to separations?

We agree with the reviewer. We have revised the text throughout the manuscript and replaced the wording “detachments that lead to reattachments/separations” with “detachments with subsequent reattachments/separations” for clarity and consistency.

Line 133: I read this over and over and I’m still not sure what the authors are communicating. Please consider a rewrite.

We agree that the original wording was unclear and have revised the section accordingly. We now provide a clearer definition of LC length (lines 148–151) and have rewritten the list of statements to improve clarity and readability

(lines 153-177).

**Figures 3, 4, 5, 6, 7, 8:**

-why this colorbar for the vorticity? Why not make negative vorticity red and positive vorticity blue. In that way, the anticyclonic features are red in the SSH anomaly plots and red in the vorticity plots.

We agree that using the same colors for anticyclonic and cyclonic features in both SSH anomaly and vorticity fields could appear visually intuitive. However, we preferred to retain the traditional vorticity/Rossby number color convention. In geostrophic balance, negative SSH anomalies are associated with cyclonic circulation and thus positive relative vorticity/Rossby number. Reversing the vorticity colormap to visually match the SSH anomalies would therefore imply an opposite sign relationship between SSH and vorticity, which could be misleading for readers interpreting the dynamics. For clarity, we now explicitly state the sign convention used for SSH anomalies and vorticity in the figure captions.

Are all the panels in 4-8 necessary. The text hardly talks about the Ro# or occurrence of cyclonic eddies. Could these be in the appendix or a supplement. In that way, you might be able to condense to 4-8 to 1 or 2 plots. I think that would really help the reader see the patterns at a glance.

We now present a single figure showing SLA time-evolution composites that includes all latitude ranges. The Rossby number composites and the spatial occurrence of cyclonic eddies during separation events have been moved to the Supporting Information.

The titles should be changed because they are consistent with the text. For example, ‘below’ should ‘south of’ and above should be ‘north of’ Perhaps you were trying to keep the titles short. Done.

Figure captions generally: Please take a careful look at the captions. We thank the reviewer for this comment. All figure captions have been carefully revised for clarity and consistency.

Lines 182-189: This is very confusing. Please try to rewrite.

We agree with the reviewer. The idea has been rewritten for clarity (lines 214-231):

“There is a difference in the separation processes that occur south of 24°N and between 25-26°N that we believe can be largely attributed to the position of the cyclonic eddies east and west of the LC. For separations south of 25°N, the eastern cyclonic eddy is located near the Dry Tortugas (between 22-26°N and 84-87°W; Figure 4a<sub>3-4</sub>, b<sub>3-4</sub>) and is often referred to as a Tortugas Eddy (Fratantoni et al., 1998). In these cases, the coexistence of a Tortugas Eddy east of the LC and a cyclonic eddy west of the LC promotes LCE separation through a classical pinch-off mechanism. In contrast, during separations occurring between 25-26°N, no Tortugas eddies are present east of the LC. Instead, the eastern cyclonic circulation develops northeast of the LC, between 26-28°N and 85-87°N (Figure 4c<sub>3-4</sub>). In these cases, the western cyclonic eddy appears to play a different role: its interaction with the LC shifts the current eastward toward the Florida Strait, partially obstructing the westward propagation of trailing cyclonic eddies. This obstruction favors the merging of frontal cyclonic eddies northeast of the LC, leading to the formation of a northeast cyclonic eddy that participates in the detachment process. The merging of frontal eddies northeast of the LC has been documented by several authors, including Zavala-Hidalgo et al. (2003), Le Hénaff et al. (2012), and Hiron et al. (2020).”

Line 189: Self-serving sure, but you say frontal eddy, I say meander and while there may be eddies merging I think it was clear from Donohue that substantial meander growth happens through baroclinic instability and that it’s the trough (cyclonic vorticity) that grows.

We agree that baroclinic instability and the growth of cyclonic troughs play a central role in Loop Current meander amplification, as demonstrated by Donohue et al. (2016a). In this study, however, we refer to cyclonic eddies traveling around the LC as frontal eddies instead of meanders because, as pointed out by Hénaff et al. (2014), they exhibit a Rankine-like structure with a solid-body rotating core. They can also constitute dynamically coherent structures (Hiron et al., 2022) and are objectively identified as mesoscale eddies in the AVISO mesoscale eddy trajectory atlas, based on the detection method of Chelton et al. (2011).

We therefore adopt the term frontal eddy to remain consistent with these observational and theoretical frameworks, while recognizing that baroclinic instability and meander growth are intrinsic to their development.

Figure 10 uses both term barrier and blocking eddy. Please clarify if they are different. How is barrier eddy defined in the analysis leading to Figure 10?

Apologies for the confusion, we have used blocking eddy in a previous manuscript version to refer to the barrier eddy. We defined barrier eddies in lines 250-254:

“In the days after a separation occurring south of 26°N (final detachment), all lagged composites at days 15 and 30

show the presence of large cyclonic features acting as barriers between the LC and LCEs (Figure 4a<sub>5-6</sub>, b<sub>5-6</sub>, c<sub>5-6</sub>). These large cyclonic features typically result from the merging of cyclonic eddies originating from both sides of the LC neck, and their presence appears to prevent the LC from reattaching to the detached eddies. These cyclonic structures (hereafter referred to as barrier eddies) have been documented in several observational studies.”

We also added the methods about the identification of barrier eddies in lines 274-278:

“To identify barrier structures more reliably, we adopt the -28 cm ADT contour method to detect cyclonic frontal eddies proposed by Hiron et al. (2020), but focusing on cyclonic features that appear after detachments, with a minimum diameter of 200 km, and a maximum distance of 85 km between the LC contour (17 cm ADT contour) and the perimeter of the cyclonic feature. It is important to note that this size constraint limits the analysis to larger structures, yet it facilitates a clear distinction between barrier structures and other frontal eddies.”

Figure 11: typo in caption for the bottom panels. It should be EMF, I think.

Done.

Figure 13: last sentence. ‘that is not visible in AVISO’. I’ll argue that the cyclone is visible – it is just weak and displaced relative to SWOT. This displacement is likely do to sampling of the ‘standard’ altimeters. These are nice figures!

We agree with the reviewer, we change “not visible in CMEMS” to “with a weak signature in CMEMS”.

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