“Seasonal and ENSO-related ocean variability in the Panama Bight” by Rafael R. Torres, Estefanía Giraldo, Cristian Muñoz, Ana Caicedo, Ismael Hernández-Carrasco & Alejandro Orfila.

We would like to thank the reviewer for their helpful and constructive comments to improve our paper. We have tried to respond to all of the comments and we hope that the paper has improved so as to now be acceptable for publication.

Referee #2:
The main goal of this study is to evaluate the ENSO effects on the interannual variability of the mean seasonal circulation patterns in the Panama Bight and Eastern Tropical Pacific region. For this purpose, different products were used to assess the hydrographic dynamics and physical variables in the region, such as, mean sea level, sea surface temperature, surface salinity and geostrophic currents. My overall appreciation is that this is a welcome addition to the literature of studies which evaluates the impact of climatic events on the physical dynamics, which have a direct impact on the biological and carbon cycles in the ocean. In my opinion, the data presented in the manuscript is highly valuable and the manuscript itself is mostly clearly presented and overall well-written, however, the methodology and discussion sections should be improved. Additionally, in general, the figures show the information in a clear manner, however, sometimes they are difficult to follow in connection with the main hypothesis of the manuscript. Please find below my explicit suggestions.

Comments, questions or suggestions:

Methods:

- Line 134: “Anomalies are computed by subtracting the 1993-2019 spatial mean using all data in the ETP (66.0 cm, 26.6 °C and 33.8 gr kg-1).” Does this indicate that only one average value was taken for the entire study area?. Why didn't the authors use spatial anomalies, i.e., considering pixel by pixel?. I ask this since not all of the Panama Bight region has the same conditions and it is a highly diverse region in physical terms.

All responses refer to lines and figures from the first version of the paper.

Lines 128-132 describes the methodology to compute ADT, SST and SSS monthly means under the three ENSO-related conditions used to assess spatial anomalies in the two main seasons (Figures 2, 3, 4 and Aux 2). Lines 133-138 describe the methodology to compute regionally averaged time series, showing anomalies for the 12 months of the year under the three ENOS-related conditions (Figures 5 and Aux 3). In both cases, monthly anomalies (under the three ENSO-related conditions), are obtained subtracting the multiannual monthly mean, a unique value computed regionally in the 1993-2019 period (e.g. 66.0 cm, 26.6 °C and 33.8 gr kg^{-1} for the ETP). We followed this methodology in order to show, in the first case, spatial differences or gradients at seasonal and interannual (ENSO) time-scales. This is important in the case of ADT, as geostrophic currents result from these gradients. In the second case, this method allowed us to show the monthly variations of ocean properties (ADT, speed, SST, SSS) in a defined region (ETP and Panama Bight), as well as the interannual variations (related to ENSO) which affect the seasonality and the mean (interannual shifts). Therefore, we consider that computing this method is suitable to show the seasonal circulation in the Panama Bight, and how this seasonality, as well as other ocean properties, are affected by ENSO, which are the main goals in the paper.

- Line 160: Why do the authors use El Niño 3 index here, if they had previously used the El Niño 1+2 index?. This is confusing to me. I believe it is important to discuss or clarify why the authors use two different types of ONI indices, mainly in relation to their use in the different subsequent analyses. Also, if the authors found similar ocurrence values with both indices (lines 117-123), why not use only one index?.

Lines 112-114, explains that Niño 1+2 is used as an indication of ENSO's local effect in the Panama Bight, as the SST region used for this index, partially covers the Cold Tongue, which affects the bight's air-ocean dynamics.

The El Niño-3 region is used for two purposes; first, it allows us to assess if results from the analysis stand with an ENSO index that indicates SST variations in the central equatorial Pacific. We think this is important, because we show that both indices have the same order in the frequency of occurrence (normal, La Niña, El Niño), but the percentages of occurrence are different (Lines 117-123). Furthermore, a comparison between panel f in Figures 5 and Aux 3 shows large differences in the months of occurrence of the ENOS conditions when Niño 1+2 and Niño 3 are used respectively (Lines 285-286).Second, as mentioned in Lines 159-162, the El Niño 3 is used to correlate SOM residual time series with ENOS. In this case, we use Niño 3 because SOM analysis is performed using all data from the ETP. Consequently, the six temporal SOM patterns and their corresponding time series (Figure 6) represent the variability of the entire ETP.

We believe that the El Niño 3 index is more appropriate than the El Niño 1+2 to assess ENSO-related variability, when the area of study is the entire ETP, because of the SST areas used to compute these indices. In the former, the area is 5°N-5°S; 150°W-90°W, while in the latter the area is 0°-10°S; 90°W-80°W. In summary, , El Niño 3 SST region covers twice the region covered by El Niño 1+2 in the ETP defined in our study being the former better to assess the relationship between the residual SOM time series with the ENOS. For completeness, it is appropriate to report also if the findings stand when the Niño 1+2 region is used as an additional result.

Results and discussion:

- It seems interesting to me that in section 3.1 the authors could discuss the reasons for the differences between SOM and MDT circulation in the Panama Bight, since this is the area of interest for this study. Ideally, a discussion is important in terms of validation of the SOM methodology.

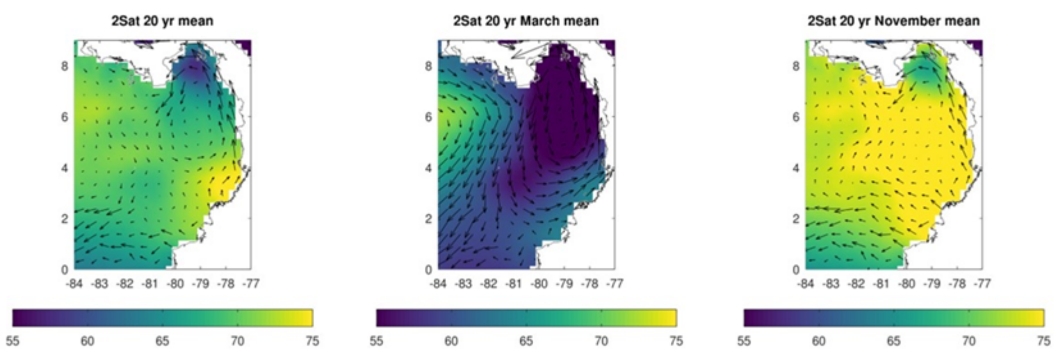
Thank you for the comment. Based on a comment from Referee #1, we realized that the SOM mean circulation we used in the first version of the paper could be confusing. This is because the essential point in the applicability of SOM is the topological character of the mapping: similar patterns are mapped in the nearby locations on the map performing a topology that preserve mapping from the multi-dimensional input space onto map units so that relative distances between data points are preserved. Therefore, in the new version of the paper we remove all references to the SOM mean circulation. Please see the answer to your next comment, where we indicate the SOM, MDT and ADT differences between the first and the new version of the paper.

- Again in section 3.2 the authors express differences by using ADT, MDT and SOM but do not discuss these differences in terms of methodology and/or which should be the most accurate methodology to be used. This discussion is also important, for example, to explain why the authors report differences related to ENSO events only considering the values obtained with the ADT product (Figure 5).

Thank you for the comment, as it opens an important opportunity to indicate main differences between the first version of the paper and the new one . Reviewer #1 asked us to verify the differences in the circulation patterns that we found in the Panana Bight between MDT and ADT. The reviewer also gave us some suggestions for the assessment. One recommendation was to compare the ADT mean circulation in the Bight with the MDT using the same period (1993-2012). Another recommendation was to verify an ADT product based on two satellites during the entire time series (“2-Sat”), instead of using the ADT product using all available satellites (“All-Sat”) , which was the one we used in the original paper.

Following this recommendation we computed the annual mean circulation in the Panama Bight using the ADT “2-sat” product (https://data.marine.copernicus.eu/product/SEALEVEL_GLO_PHY_CLIMATE_L4_MY_008_057/description) for the 1993-2012 period (Figure R3). Besides, we calculated the 20-year mean circulation for March and November, the same months used in the paper to assess seasonality.

Figure R3. “2-Sat” ADT in centimeters (colorbar) and geostrophic currents.



We found, as expected, a very consistent comparison between the mean ADT and MDT circulation patterns, the latter shown in the paper’s Figure A1-b. . Besides, in March and November (different seasons), the circulation patterns are also consistent with the MDT, particularly in the Panama Gulf and the Colombia Coastal Current.

Consequently, in this regard, the new version of the paper include the following changes:

- All ADT assessments are done with the “2-Sat” product, as it is dedicated to the monitoring of the sea level long-term evolution for climate applications.

- MDT figure (previously in the supplementary material) has been moved to the main text as figure 2.

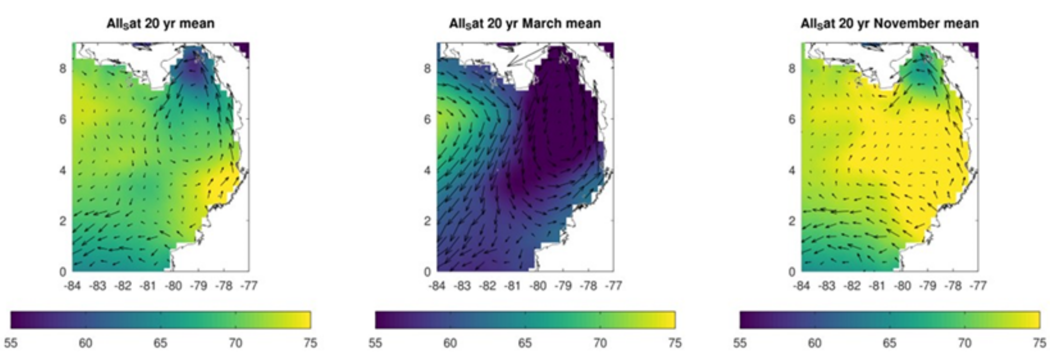
- Figure of the mean SOM circulation has been removed.

- SOM analysis is performed with the “2-Sat” product for consistency.

- The manuscript has been accordingly being modified to account with the new results. Note that now, the MDT and ADT circulation patterns coincide in the ETP, including the Panama Bight, which was the main problem in the former version of the paper.

After we posted Referee’s #1 response, we continue investigating the reasons of the ADT circulation differences between the two available products (“2-Sat” and “All-Sat”). Thus, we downloaded the latest version of the “All-Sat” product (https://data.marine.copernicus.eu/product/SEALEVEL_GLO_PHY_L4_MY_008_047/description), and computed the Panama Bight circulation pattern for the 1993-2012 period, as we did with the “2-Sat” product (Figure R4). Note that results are very similar in the two ADT products, what give us confidence that the inconsistency in the Panama Bight circulation, shown in the first version of the paper, is resolved in the new version.

Figure R4. “All-Sat” ADT in centimeters (colorbar) and geostrophic currents.



- Lines 275-276: What are the authors' criteria for limiting sea level ranges?

ADT ranges of 35 cm were defined based on the ADT anomalies variations observed in the normal ENSO conditions in Figure 2 (b and e) and Figure 3 (b and f).

One of the findings of the paper is that positive/negative ENSO conditions shift upward/downward the regional mean ADT without changing the circulation patterns. As geostrophic currents respond to ADT gradients and not to the mean level, we decided to highlight the ADT gradients by maintaining the 35 cm range in these two figures. However, in order to account for the ENSO-related shifts in mean ADT, the color scale is also shifted +10/-5 cm for the positive/negative ENSO conditions, when compared to normal conditions. Thus, the reader can see that ADT gradients (circulation) do not change much due to ENSO, regardless of the regional mean shifts produced by this climatic pattern. This was explained in Lines 215-216 & 230-231 in the s' legend, as well as in Lines 272-275 in the Results section 3.3 (circulation variations related to ENSO). In the new version of the Manuscript , we complemented briefly the description of the sea level ranges, given in section 3.3.

- Lines 284-288 and 307-309: I recommend reviewing "VARIATION IN THE SURFACE CURRENTS IN THE PANAMA BIGHT DURING EL NIÑO AND LA NIÑA EVENTS FROM 1993 TO 2007 by Corredor-Acosta et al., 2011" where differences in the velocity of different geostrophic currents and cyclonic/anticyclonic circulation patterns were observed in relation to different ENSO events and neutral years. Perhaps the authors did not find differences because they took a regional average value to calculate the anomalies?

Thank you for mentioning this paper, which we missed in our bibliographic review. Corredor et al. (2011) reports statistical differences in the NECC, SEC intensity and in two other circulation systems, denominated Coastal Current and Anticyclonic eddy, shown in their Figure 1b (mean currents for September 1995 under La Niña conditions). These last two circulation patterns are not seen neither in the MDT nor in the ADT March and November averaged currents shown in our study (Figure 3), regardless of the ENSO-related condition. Besides, we could not find references to these circulation patterns in the bibliographic review.

Corredor et al. methodology is very different to the one that we follow in our study. They use the Oceanic Niño Index, which uses SST in the 3.4 region. Their results are limited to September to November, using four years representative of moderate El Niño, three years for moderate La Niña, and four neutral years, all in the 1993-2007 period. They use total currents, estimated as the sum of the Ekman currents and surface geostrophic currents. The latter are computed from the geostrophic relation using ADT, which has a limitation close to the Equator due to the small Coriolis effect. For this reason, they excluded the band between 0-1°N. The statistical analysis is performed for four sub-regions described in their Table 1, three of them south of 5°N.

On the contrary, we focus on the Panama Bight, and include the ETP to give context to our findings. We claim that seasonal circulation differences are stronger than ENOS related variations, giving evidence of the physical process based on SST and SSS variations, strongly related to air-sea interaction local processes (Panama and Choco wind surface jets). Besides, in the abstract we indicate that "ENSO … climatic variability does not modify the <u>seasonal circulation patterns</u> in the Panama Bight". This finding is supported in three ways: (i) the comparison in the spatial and temporal (both seasonal and interannual) circulation patterns shown for the ETP (Figure 2) and Panama Bight (Figure 3); (ii) , in the ETP and Panama Bight seasonality shown with regional averages (Figure Aux 3 and Figure 5 respectively) and (iii) the SOM analysis (Section 3.5).

Furthermore, our results are consistent with findings from Chaigneau et al. (2006), a study that we missed in the first version of our paper which has been included . In the updated Ms, , a similar seasonal circulation is shown based on 25 years of satellite-tracked drifters' trajectories in the Panama Bight.

For completeness, we included the Corredor et al. (2011) work , at the end of Section 3.3. We indicate that statistical differences in the currents might exist in some areas. For this reason, we report small differences in the ENSO-related circulation patterns in both, the ETP and Panama Bight.

Summary and final remarks:

I suggest that this section be limited to the main results obtained according to the main hypothesis proposed in the manuscript.

Thank you for the suggestion. Indeed, in the updated version of the paper, the first paragraph of this section is changed to present the results of the main problem addressed with the paper in a more clear way. Consequently, we explain the observed seasonal circulation patterns in the Panama Bight, which includes a permanent Colombia Coastal Current and westward flow in the Panama Gulf, regardless of other strong seasonal circulation differences.

We prefer to present a "Summary and final remarks" section, instead of a "Conclusions" section because, in our point of view, many readers after revising the abstract, will check this last section, in order to review the most relevant results of the work .

Minor suggestions:

- Please review some citations in the manuscript where compound surnames should be hyphenated, e.g., Rueda-Bayona; Rodríguez-Rubio; Devis-Morales.

Corrected

- Line 87: "….we also assess SST and Sea Surface Salinity (SSS) variability in the region in seasonal and interannual timescales." Please change "in seasonal" by "at seasonal".

Corrected

- Lines 152-153: Please specify what means "sufficient resolution and statistical accuracy"

This refers to the compromise between accuracy of the results and resolution of the structures obtained. In general, a large number of neurons produce a large number of small but compact clusters (records assigned to each cluster are quite similar). Small maps produce less but more generalized clusters. A "right number of clusters' ' doesn't exist, especially in real world datasets. It all depends on the detail which one wants to examine the specific dataset.

- Line 344: I suggest specify the most relevant references rather than only "section 2".

Corrected, we included two references (Poveda and Mesa, 2000; Hastenrath and Lamb, 2004).

References

Chaigneau, A., Abarca del Rio, R., and Colas, F.: Lagrangian study of the Panama Bight and surrounding regions, Journal of Geophysical Research: Oceans, 111, https://doi.org/10.1029/2006JC003530, 2006.

Corredor, A., Acosta, A., Gaspar, P., and Calmettes, B.: Variation in the surface currents in the Panama Bight during El NIño and La Niña Events from 1993 to 2007, Boletín de Investigaciones Marinas y Costeras, 40, https://doi.org/10.25268/bimc.invemar.2011.40.0.127, 2011.

Hastenrath, S. and Lamb, P. J.: Climate dynamics of atmosphere and ocean in the equatorial zone: a synthesis, International Journal of Climatology, 24, 1601–1612, https://doi.org/10.1002/joc.1086, 2004.

Poveda, G. and Mesa, O. J.: On the existence of Lloró (the rainiest locality on Earth): Enhanced ocean-land-atmosphere interaction by a low-level jet, Geophysical Research Letters, 27, 1675–1678, https://doi.org/10.1029/1999GL006091, 2000.