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Interactive comment on "Multicore structures and the splitting and merging of eddies in global oceans from satellite altimeter data" *by* Wei Cui et al.

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Reply to Referee comment 2

For a better reading experience, you can see the Supplement.

Thank you for your affirmation to our work and your valuable comments, it is very helpful for revising and improving our paper. We have studied comments carefully and have made correction which we hope meet with approval. The main corrections in the paper and the responds to the reviewer's comments are as following:

1 Only few eddy detection and tracking algorithm are able to identify merging or splitting

events. In order to describe the state of the art, the authors should refer to them explicitly in the introduction, especially in the fourth paragraph.

These references have been added and marked green in the third paragraph and the fourth paragraph.

2 Page 9 , line 273 'Although a cyclonic eddy could theoretically merge directly with an anticyclonic eddy, the mixing process is too complex and the observation of such an event too difficult for the current research.' When opposite sign vortices get close to each other they tend to form a dipolar structure which propagate at a constant speed. As far as I own no numerical simulations, laboratory experiments or remote sensing observation has shown that a cyclone and an anticyclonic could merge together! This statement should be suppressed or precise references, showing such event, should be provided here.

The sentence has been revised as "...a cyclonic eddy could theoretically interact directly with an anticyclonic eddy...", and the references have been provided. Amores et al. (2017) found that eddies in the global ocean would be surrounded by eddies of opposite polarity. Chang & Park (2015) investigated the temporal variation of the flow structure and consequent mixing process of a cyclonic mesoscale eddy as it collided with an anticyclonic eddy by analyzing the Hybrid Coordinate Ocean Model simulation for the Gulf Stream region. L'Hégaret et al. (2014) studied a collision of Mediterranean Water dipoles in the Gulf of Cadiz and found that the merger of two dipoles resulted in an anticyclone (a meddy) which drifted southeastward, coupled with the eastern cyclone.

Amores, A., Monserrat, S., Melnichenko, O., & Maximenko, N.: On the shape of sea level anomaly signal on periphery of mesoscale ocean eddies. Geophysical Research Letters, 44(13), 6926-6932, 2017. Chang, Y. S., & Park, Y. G.: Variation of flow properties during a collision event of two mesoscale eddies in the Gulf Stream region from numerical simulation. Ocean Science Journal, 50(3), 567-579, 2015. L'Hégaret, P.,

Carton, X., Ambar, I., Ménesguen, C., Hua, B. L., Chérubin, L., ... & Serra, N.: Evidence of Mediterranean water dipole collision in the Gulf of Cadiz. Journal of Geophysical Research: Oceans, 119(8), 5337-5359, 2014.

3 Flow chart figure 2. It seems that a third arrow indicating the possbility of single eddy (>6days) with a transient double core structure should be present at the end of the flowchart between the splitting and the merging events. Such case should correspond to the column 5 of the table 1, if I'm not mistaken.

It has been modified according to the comment.

4 Page 16 line 421: the authors do not provides here the number of (single-core) eddies with lifetimes > 6 days (numbers are given only for >30 days or >100 days) in order to compare with the number of multicore structures (> 6 days) mentioned just before.

Single-core eddies with lifetimes > 6 days are too short relative to the mesoscale phenomenon and do not represent a true oceanic eddy in the ocean. In another paper (The identification and census statistics of multicore eddies based on sea surface height data in global oceans, in press Acta Oceanologica Sinica), we compared the characteristics of multicore eddies and single-core eddies with lifetime > 30 days in global ocean. Only multicore structures that existed for more than 6 days within a 10-day window were considered real multicore eddy. Based on the multicore eddies, the eddy interaction is then studied by the matching of multicore eddies with single-core eddies. Because multicore eddies are an intermediate structure in the eddy evolution or interaction and their lifetime are expected to be shorter than single-core eddies, such an identification of multicore eddies with lifetimes > 6 days is adopted. If there is no single-core eddy with lifetime > 6 days before and after a multicore eddies, the multicore eddies will be considered as a transient eddy-like signatures.

5 Page 17 lines 428-440 : the recent paper of Garreau et al. 2018 (https://doi.org10.1029/2017JC013667) which depict the consecutive splitting and merging of the same anticyclone with its parent eddy could also be mentioned here.

The reference of Garreau et al. (2018) has been added and marked green in Section 4.

6 Page 19, lines 485-500: the authors mention that merging and splitting events are not correlated to eddy-rich regions. It is indeed interesting to highlights specific areas where the ratio (eddy-eddy events)/(total nb of eddies) is higher than the statistical mean. However, the mentioned areas (Antarctic Circumpolar Current, the Gulf Stream and its extension, Kuroshio Extension, Agulhas Return Current, and Brazil–Malvinas Confluence Zone) seems to me 'eddy-rich regions'. A more quantitative analysis could be done here to provide such statistical ratio or the correlation between the eddy lifetimes and the splitting-merging events as suggested by the authors.

Here, we compared splitting and merging events with frequency distribution of global eddies (Fig. 5 in Chelton et al. 2011) and found "Eddy splitting and merging events do not always occur most frequently in eddy-rich regions". Despite eddies are often generated and are high-amplitude in the Antarctic Circumpolar Current (ACC) and Western Boundary Currents (WBCs), the lifetime of eddies there is generally short and does not propagate too long. Therefore, the eddy frequency in ACC and WBCs may not be as obvious as eddies with long lifetime in the mid-latitude. So we came to this conclusion. Qualitative analysis shows that this phenomenon is easy to understand. The large-amplitude and high-strength eddies are more easily detached due to the instability of the flow in ACC and WBCs. Due to the significant interaction of eddy-current or eddy-topography, the instability of strong eddies is often caused, so the interaction events of eddy-eddy often occur. On the other hand, it is because of these interactions in ACC and WBCs that the lifetime of eddies here is shorter (although eddies with higher amplitude here) comparing with mid-latitude regions. Eddies in the mid-latitudes tend to have long lifetimes due to the ocean currents and eddy structures are stable with less (not zero) variation. As a result, census statistics for the numbers of eddy with long lifetime (Fig. 5 in Chelton et al. 2011) show the reduced number of eddies in ACC and WBCs and comparatively large numbers of eddies occurred in bands of mid-latitude regions of 20°–35° north and south. Hybrid tracking considering single-core and multicore eddies for full-lifetime evolution is highly complex given that some eddies might merge or split multiple times. Nevertheless, the description of full-lifetime eddy evolution needs to be addressed, and a comparison with the lifetime of traditional single-core eddy evolution without considering eddy-eddy interaction will be carried out in future study. And we are also ready to consider the relationship between eddy properties (e.g., eddy amplitude or eddy intensity) and the eddy-eddy interaction, which will be the focus of future research. This article focuses on abundant multicore structures and the eddy-eddy interaction (splitting and merging) in global oceans

We tried our best to improve the manuscript and made many changes in the manuscript. The other important changes are marked in green in revised paper. We did not list all changes which not influence the content and framework of the paper, especially for the changes of grammar and written expression. We appreciate for Editors/Reviewers' warm work earnestly, and hope that the correction will meet with approval.

Sincerely, Authors

Please also note the supplement to this comment:
https://www.ocean-sci-discuss.net/os-2018-96/os-2018-96-AC2-supplement.pdf

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