Responses to reviewer 2#'s comments point by point

MS No.: essd-2025-683

Title: A Global Eddy Splitting and Merging Trajectory Dataset Based on Satellite Altimetry Utilizing Eddygroup, Eddytree and Eddygraph

Author(s): Fenglin Tian et al.

Dear Reviewer,

We highly appreciate the detailed and valuable comments of the referee on our manuscript entitled "A Global Eddy Splitting and Merging Trajectory Dataset Based on Satellite Altimetry Utilizing Eddygroup, Eddytree and Eddygraph (ID: essd-2025-683)". These comments are all valuable and helpful for revising and improving our paper, as well as providing important guidance for our research. In the past few days, we have referred to the comments and improved the paper.

As follows, we would like to clarify some of the points raised by the Reviewer. The original comments begin with "**Comment**" and are quoted in italicized font, the responses begin with "**Response**" in normal font, the original sentences and phrases are in blue letters, the revised sentences and phrases are in red letters, and the line number in the revised manuscript is highlighted in yellow. We appreciate the Reviewer's warm work and taking the time to review the manuscript, and we hope that the corrections will meet with approval.

Yours Sincerely,

Fenglin Tian, Xiangwen Kong, Yingying Zhao, Ge Chen

2026-3-13

Comment:

This data paper presents a nice framework for global eddy identification and tracking by enhancing the efficiency of the detection algorithm and incorporating a particle-drift approach for trajectory tracking. The authors provide a 31-year dataset (1993-2023) containing daily global eddy identification results and related parameters, together with annually compiled trajectories of eddy splitting and merging events. This dataset responds to the current demand for long-term, systematically organized records of eddy evolution and has high value for research on ocean transport processes and climate variability. Furthermore, the manuscript innovatively extracts representative splitting and merging cases from the tracking dataset and applies a normalization approach to investigate morphological changes of eddies and eddygroups during these interaction processes.

While the study demonstrates technical effort in dataset construction and attempts to summarize the statistical characteristics of eddy evolution, several aspects of the manuscript could be improved. Although the morphological analysis of eddies is meaningful, important methodological details remain insufficiently transparent; despite being described as a global dataset, the results seem to lack representation of high-latitude Arctic regions, raising questions about the effective spatial coverage of the dataset; the current analysis focuses primarily on morphological aspects of splitting and merging events, while further exploration of these processes could enhance the scientific depth of the study. In addition, the manuscript would benefit from improvements in language clarity and organization.

With clearer methodological description, more comprehensive spatial coverage, and strengthened analysis of eddy interaction processes, the dataset has the potential to make a valuable contribution to ESSD and the broader community studying oceanic eddies.

Response：

Thank you for the thorough review of our work and the helpful feedback provided. We are glad that the reviewer recognizes the value of the dataset created in this study for identifying and tracking global mesoscale eddies, along with its potential significance for research on ocean transport processes and climate variability. We also sincerely appreciate the reviewer's valuable suggestions regarding the dataset construction methodology, the spatial coverage, and the analysis of eddy splitting and merging processes. Following the reviewer's comments, all corresponding revisions have been addressed point by point below and incorporated into the revised manuscript.

Major Comments:

Comment:

1. Inadequate Algorithm Description and Lack of Code to Reproduce the Dataset

The manuscript describes the algorithms used for eddy identification, as well as for tracking eddy splitting and merging. However, the implementation details provided are still insufficient, which limits the reproducibility of the dataset. The authors are therefore encouraged to:

(1) Publicly release or share the relevant source code;

(2) Provide a more thorough explanation of the eddy tracking process, specifically how segments are linked into branches and then structured into eddygraphs, as currently this is only depicted through schematic diagrams.

Without clearer methodological documentation, the reproducibility and long-term usability of the dataset could be limited.

(1)Response： Thank you for your valuable suggestion. We fully understand the reviewer's concerns about the availability of the source code and the reproducibility of the dataset. However, due to institutional intellectual property restrictions, we are currently unable to make the source code for the eddy splitting and merging identification and tracking algorithm publicly available. Additionally, the algorithm is still being refined through ongoing internal optimization. We intend to continue this work in the future and plan to release updated versions of the dataset to support further research on the evolution of mesoscale eddies.

(2)Response： Thank you for your valuable suggestion. We recognize that the original manuscript did not provide enough detail about the eddy tracking process, especially concerning how segments are linked into branches and then organized into eddygraphs. Following the reviewer's suggestion, we have added a more detailed explanation in the corresponding section of the revised manuscript. The updated text is as follows:

- Original sentence:

"These segments are then linked sequentially under the constraint that the surviving target on day *I* corresponds to the identical target on day *i+1*."

- Revised sentence:

"Since each segment records the survival relationship of an eddy between two consecutive days, the surviving target identified in the segment on day *i* can be used to link the live segments from day *i* to day *i+1*. Following the same rule, the live segments between day *i+1* and day *i+2* are then connected, and this procedure continues sequentially, linking live segments from consecutive days into a continuous trajectory until no corresponding live segment can be found on the following day." (Please see Line 293-297)

- Added sentence:

"For example, if a branch terminates with a merging event, there must exist other branches that merge into the same target eddy at the same time. Conversely, if a branch terminates with a splitting event, multiple new eddies are generated on the next day, which are then used to establish connections with the corresponding branches on that day." (Please see Line 308-311)

Comment:

2. Insufficient Detail in the Methodological Normalization Process

The manuscript presents a complete workflow for eddy identification, tracking, and morphological normalization. However, the explanation of the normalization procedure lacks sufficient technical detail to enable replication of the results. In particular, the normalization strategy for eddygroups is not clearly explained. In multi-eddy systems, it remains unclear how the relative spatial configuration among individual eddies and the eddygroup is preserved during the normalization process, and whether the transformation might introduce geometric distortions.

The authors are therefore encouraged to:

(1) Provide a more detailed description of the normalization algorithm and clearly explain how eddygroup structures are handled;

(2) Consider providing code or pseudocode.

(1)Response： We appreciate your thorough review of the normalization method and your insightful suggestions. In the original manuscript, the normalization approach for eddygroups was not described in sufficient detail, and the procedure for maintaining the relative spatial relationships between eddies and eddygroups during normalization process was not clearly explained. Following the reviewer's suggestion, we have supplemented the relevant methodological description in the revised manuscript, offering a more comprehensive explanation of the normalization process. The revised text is as follows:

- Original sentence:

"The angle θ required to rotate this line to the horizontal is recorded, and a corresponding rotation is applied to both the eddy boundaries and the ADT background field, yielding Fig. 18b."

- Revised sentence:

"To eliminate the influence of orientation differences of dipole eddy structures across different events, the rotation angle θ required to align the line connecting the centroids with the horizontal direction was calculated and recorded for each event at every time point. The corresponding eddy boundaries and ADT background fields were then rotated by this angle, producing the configuration shown in Fig. 18b." (Please see Line 451-454)

- Added sentence:

"Based on the previously described dipole eddies normalization procedure, the corresponding parent eddygroups were also normalized. First, the midpoint of the line connecting the centroids of the two eddies was chosen as the origin to establish the normalized coordinate system. Using the same origin as the dipole normalization avoids introducing relative displacement errors and preserves the spatial relationship between the parent eddygroup and the dipole structure throughout the normalization procedure. Next, the boundary of the parent eddygroup was then rotated by the same angle θ derived from the corresponding dipole event to ensure consistent orientation. Subsequently, the scaling parameter $S(n)$ associated with the same event was applied to scale-normalize the boundary of the parent eddygroup, yielding normalized eddygroups for each event and each time point." (Please see Line 460-467)

- Added sentence:

"After orientation alignment, scale normalization was applied to the single-eddy structures that appear after merging and before splitting. Specifically, the scaling parameter *S(n)*, derived from the dipole structure at the nearest time step within the same event, was used to adjust the single-eddy boundary and its corresponding background field. Since the size of the eddies involved in the same merging or splitting event typically remains relatively stable over a short period, adopting the scaling parameter determined during the dipole stage helps maintain scale consistency in the normalized results before and after the event, thereby facilitating meaningful comparisons of morphological characteristics across different stages." (Please see Line 472-478)

(2)Response： Thank you for pointing out this issue. In response, we have expanded and clarified the relevant methodological descriptions related to the normalization process in the revised manuscript to make them more complete and transparent. Specifically, we have provided detailed explanations of the normalization procedures for the dipole eddy structure, parent eddygroup, single-eddy structure, and the associated background field normalization. The code implementation follows the same procedures as those described in the manuscript.

In addition, the typical eddy splitting and merging events presented in the manuscript have been included in the dataset, enabling readers to reproduce the corresponding normalization results. With these revisions and clarifications, we believe that the current methodological description sufficiently reflects the algorithmic workflow; therefore, pseudocode has not been provided separately.

Comment:

3. Lack of Sensitivity Analysis for Key Identification Parameters

The identification framework relies on several threshold-based criteria (e.g., $20 \leq I \leq 4000$, shape error $\leq 55\%$, amplitude ≥ 1 cm, and a 5×5 window for seed point detection). These parameters may produce region-dependent effects under different dynamical *regimes (e.g., high vs. low latitudes, strong vs. weak current systems). However, the manuscript does not include a sensitivity analysis of these parameter choices.*

Specifically:

(1) The potential differences in detection results across different ocean regions under the same parameter settings, as well as the influence of alternative parameter values on eddy counts, spatial distribution, and splitting–merging statistics, are not investigated;

(2) The relationship between the amplitude threshold and the spatial resolution of the dataset is not discussed.

Without such analysis, the robustness and general applicability of the dataset remain insufficiently demonstrated.

(1)Response： We appreciate your suggestion regarding the identification parameters. Compared with other identification approaches, SLA-based eddy detection methods are better suited for large-scale and global applications. Previous researches have applied identification parameters including eddy amplitude, area, and shape error to identify eddies on a global scale and obtained stable results. Subsequently, (Tian et al., 2019) further confirmed the applicability and reliability of this SLA-based approach for global eddy identification using all-satellite SLA data.

In this study, we follow the identification framework and parameter settings adopted in the aforementioned studies, focusing primarily on creating a global eddy dataset. Therefore, we did not perform a detailed sensitivity analysis of how parameter settings might affect identification outcomes in different ocean regions.

Reference:

Tian, F., Wu, D., Yuan, L., and Chen, G.: Impacts of the efficiencies of identification and tracking algorithms on the statistical properties of global mesoscale eddies using merged altimeter data, International Journal of Remote Sensing, 41, 2835-2860, https://doi.org/10.1080/01431161.2019.1694724, 2019.

(2)Response： Thank you for raising this issue. In the original manuscript, the identification parameters were not described in sufficient detail, and the relationship between the pixel-number constraint and the spatial resolution was not clearly explained. Following your suggestion, we have supplemented the description of these parameters and added the following text in the revised manuscript.

"The number of pixels *I* is used to constrain the area of mesoscale eddies. Referring to the parameter values adopted in previous studies, *I* between 20 and 4000 in this study; this number increases as the grid resolution becomes finer. The shape error is introduced to constrain the morphological characteristics of eddies and is defined as the ratio of the total area difference between the closed contour and its fitted circle to the area of that circle. Thus, a smaller shape error indicates that the eddy's shape is closer to an ideal circle. In addition, the constraint on eddy amplitude is related to the contour generation interval chosen for this study, which is set as 0.5 cm; therefore, the eddy amplitude is required to exceed at least two contour intervals. The size of the seed point detection window is also related to the spatial resolution of the data: higher spatial resolution leads to a denser data grid and a larger number of pixels within the seed point detection window." (Please see Line 226-234)

Comment:

4. Global Scope of the Dataset and Limited Representation of the Arctic Region

The dataset is described as a global ocean product; however, the figures presented in the manuscript show very limited or absent eddy detection in the high-latitude Arctic Ocean. Given the increasing importance of Arctic dynamics in the context of rapid sea-ice retreat and its role in the global climate system, mesoscale eddy activity in this region is of growing scientific interest. It remains unclear:

(1) Whether the current methodology is capable of reliably identifying and tracking eddies in the Arctic Ocean;

(2) Whether future versions of the dataset are planned to include the Arctic region.

At present, there appears to be a discrepancy between the dataset's stated global scope and its effective spatial coverage. This limitation should be clarified more transparently in the manuscript.

(1)Response： Thank you for raising this important question about the spatial coverage of the "global" dataset and for highlighting the scientific importance of mesoscale eddies in the Arctic Ocean.

Currently, most ocean products derived from satellite altimetry, such as the CMEMS ADT dataset used in this study, are provided on a regular latitude–longitude grid. In high-latitude regions, the convergence of meridians and the presence of sea ice can affect the spatial distribution and quality of satellite altimetry data. As a result, the continuity and reliability of sea surface height data in the Arctic Ocean are relatively limited. Under these conditions, when using the method outlined in this study to identify eddies in the Arctic region, the identification results might be less reliable.

In principle, the identification and tracking framework used in this study can also be applied to Arctic eddy detection, provided that reliable and continuous sea surface height data are available.

(2)Response： Regarding the future development of the dataset, we appreciate the reviewer's forward-looking suggestion. As the quality of satellite observations in polar areas continues to improve, if high-quality sea surface height and flow field data for the Arctic Ocean become available in the future, upcoming versions of the dataset will aim to expand coverage to the Arctic region, thereby providing more comprehensive support for global mesoscale eddy studies.

Comment:

5. Limited Exploration of Dynamical and Kinematic Aspects

The analysis primarily focuses mainly on the morphological characteristics of eddies and eddygroups. While these results are useful for understanding structural evolution during eddy interactions, the dataset appears to contain additional daily dynamical parameters (e.g., amplitude, mean velocity, radius, and position) that could support further analysis. The manuscript would benefit from exploring the dynamical and kinematic aspects of splitting and merging processes. For example:

(1) Examining changes in kinetic energy or intensity before and after splitting or merging events;

(2) Investigating whether trajectory deflections, angular momentum variation, or pre-splitting rotations occur during these processes;

(3) Exploring the relationships among morphological, dynamical, and kinematic characteristics.

Such analyses could further enhance the scientific value of the dataset and its application to studies of eddy evolution.

Response:

Thank you for this insightful suggestion. We fully agree with the reviewer that further dynamical and kinematic analyses of eddy splitting and merging processes would provide valuable insights. As the reviewer noted, several parameters, including eddy amplitude, mean velocity, radius, and position, have already been calculated and recorded during the eddy identification stage. These parameters serve as a crucial foundation for further study of the dynamical and kinematic aspects of eddy interactions. However, considering the scope and length of the manuscript, as well as the nature of this data-focused paper, a systematic dynamical and kinematic analysis of eddy splitting and merging processes is not included here. We plan to address these analyses in future research using this dataset. Accordingly, the relevant statements in the future work section of the manuscript have been revised.

- Added sentence:

"Additionally, the research primarily concentrates on the morphological characteristics of the eddy splitting and merging processes involving two eddies, while whose involving three or more eddies remain to be further explored. And their dynamical and kinematic mechanisms still need further investigation." (Please see Line 618-620)

(1)Response: Thank you for this suggestion. Analyzing changes in eddy kinetic energy or intensity before and after splitting or merging events would certainly enhance our understanding of energy changes during eddy interactions. The dataset already contains relevant dynamical parameters, offering a solid foundation for these analyses. We plan to conduct these investigations in future research using this dataset.

(2)Response: Thank you for this valuable suggestion. Investigating whether eddies exhibit trajectory deflection, angular momentum variation, or possible rotation features before splitting events is crucial for comprehending the kinematic mechanisms behind eddy interactions. These aspects will be further explored in future studies based on this dataset.

(3)Response： We appreciate this important suggestion. The connection among morphological features, dynamical and kinematic properties is truly a crucial factor in comprehending the mechanisms of eddy evolution. Future studies will further investigate these relationships based on the dataset introduced in this work.

Minor Comments:

The manuscript still contains several issues related to grammar, wording clarity, redundancy, and terminology consistency. Some sentences are overly long or contain ambiguous expressions. The authors are encouraged to carefully proofread the manuscript and improve language clarity.

Response:

Thank you for the reviewer's suggestion. Following the reviewer's comments, we have revised the manuscript accordingly, focusing especially on correcting language issues identified in the manuscript, including grammatical corrections, reduction of redundant expressions, and clarification of ambiguous terminology.

Comment 1:

Line 11:

"… that encloses a seed point (a local extremum) …"

"(a local extremum)" should be "(local extremum)". The definition is somewhat wordy.

Response: Thank you for pointing out the grammatical redundancy. We have removed the preposition "a" in the revised manuscript. (Please see Line 11)

Comment2:

Line 46:

"… the SLA-based method is not constrained by threshold parameters …"

This is potentially misleading: SLA-based methods typically still use thresholds (amplitude, radius, contour step).

Suggested revision: "…is less dependent on certain threshold parameters…"

Response: Thank you for pointing out that the statement was overly absolute. SLA-based method does indeed involve certain identification parameters. We have revised the sentence in the manuscript to: "… the SLA-based method is less dependent on certain threshold parameters." (Please see Line 53-54)

Comment 3:

Line 47:

"… the most widely eddy identification method at present."

Suggested revision: "...the most widely used eddy identification method at present."

Response: Thank you for pointing out this wording issue. We have revised the sentence to "… the most widely used eddy identification method at present." in the revised manuscript. (Please see Line 55)

Comment 4:

Line 51:

"… essential for understanding of interactions between eddies."

Suggested revision: "...essential for understanding interactions between eddies." (or "…for understanding eddy–eddy interactions.")

Response: Thank you for pointing out this wording issue. We have revised the sentence to "… essential for understanding interactions between eddies" in the revised manuscript. (Please see Line 59)

Comment 5:

Line 53:

"… do not introduce new kind of vertical structures…"

Should be: "...do not introduce new kinds of vertical structures…"

Response: Thank you for your suggestion. We have removed the unnecessary preposition, and the sentence now reads: "… do not introduce new kinds of vertical structures…" in the revised manuscript. (Please see Line 61)

Comment 6:

Line 95:

"… makes the following contributions:(1) We …"

Missing space after colon.

Response: Thank you for pointing this out. The formatting issue has been corrected in the revised manuscript. (Please see Line 103)

Comment 7:

Line 98:

“… leading to the creation of splitting and merging tracking algorithm …”

Missing article. Should be: “… leading to the creation of a splitting and merging tracking algorithm …”

Response: Thank you for pointing out this grammatical issue. We have added the missing article and revised the sentence to “… leading to the creation of a splitting and merging tracking algorithm …” in the revised manuscript. (Please see Line 106)

Comment 8:

Line 103:

“… and anticyclonic eddytrees structures …”

Redundancy. Should be: “… and anticyclonic eddytree structures …”

Response: Thank you for pointing out this redundancy. We have revised the phrase to “… anticyclonic eddytree structures …” in the revised manuscript. (Please see Line 111)

Comment 9:

Line 176:

“… and underscore that …” should be “… and underscores that …”

Response: Thank you for pointing out this grammatical error. We have corrected the verb form to “underscores” in the revised manuscript. (Please see Line 188)

Comment 10:

Line 214:

“… with the primary distinction arising from the spatial resolution of the dataset.”

Later you specify 0.125°×0.125°, but it may help to explicitly state how resolution affects thresholds (I, amplitude, contour interval).

Response: This comment is similar to Major Comment 3(2). Please see our response to Major Comment 2 for detailed explanations. The manuscript has been revised accordingly.

Comment 11:

Line 225:

"… area-sorted eddygroups are inputted …"

"inputted" should be "input".

Response: Thank you for pointing out this wording issue. We have corrected "inputted" to "input" in the revised manuscript. (Please see Line 245)

Comment 12:

"… points of brunches likewise …"

"brunches" should be "branches".

Response: Thank you for pointing out the typo. We have corrected "brunches" to "branches" in the revised manuscript. (Please see Line 298)

Comment 13:

Line 303 and 306:

You are discussing Figure 12 but refer to Fig. 18a/18b.

Response: Thank you for pointing out this inconsistency. The figure references have been corrected to Fig. 12a and Fig. 12b in the revised manuscript. (Please see Lines 332 and Line 335)

Comment 14:

Line 422:

"… and rotated to aligned with …"

"to aligned" should be "to align".

Response: Thank you for pointing out this grammatical error. We have corrected "to aligned" to "to align" in the revised manuscript. (Please see Line 470)

Comment 15:

Line 446:

"… the dull pole contains the …"

Should be: "… the dull pole containing the …"

Response: Thank you for pointing out this grammatical inconsistency. We have revised "contains" to "containing" in the revised manuscript to maintain parallel structure. (Please see Line 500)

Comment 16:

Line 474:

“a_1 and a_2 represent the longer and shorter major semi-axes”

Please verify whether the formula is correct. Otherwise, the value of A would always be negative.

Response： Thank you for carefully checking the formula and for pointing out this issue. We confirm that this was a typographical error in the formula. The expression has now been corrected in the revised manuscript. This correction does not affect the calculations or the results presented in the study. (Please see Line 528)

Comment 17:

Line 551:

“… However, many works remain to be done in the future.”

Suggested revision: “However, several topics remain for future work.”

Response： Thank you for the helpful suggestion. We have revised the sentence to “However, several topics remain for future work.” in the revised manuscript. (Please see Line 605)