Reply on Report #1

Thank you for your new comments concerning our manuscript. Those comments are all valuable and very helpful for revising and improving our paper. We have studied comments carefully and have made correction which we hope meet with your approval. The main corrections in the paper and the responses to your comments are highlighted in blue and are as follows:

1) Thanks for using a later version of SWOT data. I noticed that some figures have changed from previous version (Fig. 3 and 4) by selecting other dates as examples. Is this due to the difference in SWOT version ?

Response: Thank you for your question, and we apologize for any lack of clarity in our previous explanation. Regarding Figure 3, we recognize that the initially selected dates (September 12, September 13, and September 17) were too close together, which did not fully utilize the entire SWOT dataset. In addition, although the height map in Figure 3c (September 17) of the previous version showed some eddy-like features, the eddy detection algorithm was not able to successfully capture eddies consistent with the merged map due to limitations in the SWOT data. To ensure a broader representation of satellite cycles and spatial variability than the last version, we have increased the temporal intervals between the selected cases. Therefore, we have reselected examples from September 7, September 12, and September 30 for demonstration and have revised the corresponding results description, which is provided below.

As for Figure 4, following Reviewer #2's suggestion, we added the SWOT-derived eddies to the figure and found that shifting the display by one day better captures the temporal evolution of both cyclonic and anticyclonic eddies. The previous version did not sufficiently illustrate the development of the cyclonic eddy.

Line 245-254: The 2DVAR product demonstrates strong agreement with SWOT-derived anticyclonic eddies at 116° E, 21° N in Fig. 3(a1), 112° E, 17.5° N and 112° E, 16° N in Fig. 3(b1), and 113° E, 18° N in Fig. 3(c1), as well as with the cyclonic eddy at 111.5° E, 16.5° N in Fig. 3(b1). In contrast, the AVISO product fails to accurately match the cyclonic eddy at 111.5° E, 16.5° N with the SWOT observations in Fig. 3(b2). Additionally, the AVISO product captures an eddy at 116° E, 21° N in Fig. 3(a2) that only partially overlaps with the corresponding SWOT eddy, with minimal spatial correspondence. For other eddies where both merged products exhibit agreement, the radii of the AVISO eddies are notably larger than those identified by 2DVAR. Although the AVISO product exhibits lower consistency with SWOT observations compared to 2DVAR, it still captures a considerable number of eddies that align with SWOT, thereby maintaining its fundamental utility as a merged product for eddy identification. However, both products fail to detect certain small eddies in SWOT observations, such as the cyclonic eddy at 112.5° E, 17° N in

Fig. 3(c).

Line 270-279: In the 2DVAR maps, two closely spaced mesoscale anticyclones were identified at 110° E, 15° N, and 110.5° E, 16.2° N in Figs. 4(a1) – (e1), along with an anticyclone at 110.5° E, 13.2° N in Figs. 4(b1, d1 and e1), and a smaller-scale cyclone at 110.5° E, 14.8° N in Figs. 4(b1) – (e1). These eddies derived from 2DVAR exhibit discrepancies when compared to the SWOT-derived eddies, particularly in the case of the eddy at 110.5° E, 16.2° N whose radius varies daily in the 2DVAR results and represented by a colored circle on the map rather than being identified as a distinct eddy in the SWOT data. Similar to as Fig. 3, the 2DVAR method outperforms AVISO, which erroneously merges the two closely spaced anticyclones into a single larger eddy and fails to capture the eddies at 110.5° E, 14.8° N and 110.5° E, 13.2° N. Notably, by accurately matching the emergence and dissipation of SWOT eddies at 110.5° E, 14.8° N and 110.5° E, 13.2° N, the 2DVAR method demonstrates its capability to reconstruct eddies that evolve over time, despite some relative positional deviations from the actual eddy location.

2) Section 3.2 still lack from statistical evidences. As far as I am concerned, it only shows few visual examples of section 3.1 results. For instance, the dates of the data shown are completely arbitrary (or not ?) so one might wonder how would it look like if another period is taken. Also only one drifter trajectory is used so one might think that the authors only show an example of 2DVAR performing better than AVISO. Can we find examples of AVISO performing better than 2DVAR ? Presented as is, it seems the authors chose the right example to illustrate what they want to demonstrate but is it statistically true ? I do not question the authors scientific integrity here but it seems to me this section provides insufficient evidences as compared to the other sections presenting more robust (statistically) results.

Response: It is certain that, in selecting the cases for Figures 3 and 4, we chose time points from the dataset that are representative of the eddy boundary reconstruction capabilities of both AVISO and 2DVAR. Although in these examples, AVISO performs less effectively than 2DVAR in representing eddy boundaries, it still retains the ability to capture eddies. The differences between AVISO and 2DVAR primarily lie in the accuracy of eddy radius and positional representation, which aligns with the statistical characteristics discussed in section 3.1. These examples represent the best cases we could select to illustrate these differences. The observed discrepancies do not arise from biased selection but rather reflect statistical differences in the eddy reconstruction performance between the two products, as demonstrated in Sections 3.1 and 3.3. Sections 3.1 and 3.3 comprehensively illustrate how AVISO eddies are statistically larger in scale compared to those identified by 2DVAR, while Section 3.2 focuses on a detailed comparison of the actual boundaries of individual eddies. The purpose of Figure 5 is primarily to highlight the differences in eddy assessment efficiency between drifter buoys and SWOT observations.

Similar to Figures 3 and 4, we aimed to select cases that are representative of both products. However, due to the limited spatial distribution and low observational frequency of the drifter data, the number of valid eddy detection cases available for analysis is highly constrained. In other instances, the differences between 2DVAR and AVISO in comparison with the drifter data are not significant (either both match the drifter trajectories or neither does). The case involving drifter 300534064134530 stands out as the only example demonstrating a clear and favorable comparison.

Line 255-260: It is important to emphasize that the examples presented in this section are representative of the eddy boundary reconstruction capabilities of both AVISO and 2DVAR. While these examples show that AVISO performs slightly worse than 2DVAR in terms of eddy radius and positional accuracy, they nonetheless represent some of the best-case scenarios for the AVISO product. This conclusion is not influenced by selective bias in the examples chosen but rather reflects the inherent performance differences between the two merged products, which is consistent with the statistical findings presented in section 3.1.

Line 293-297: Similar to Figures 3 and 4, we have endeavored to select cases of eddy detection that are representative for both products. However, due to the limited spatial distribution and low observational frequency of the drifter data, the number of valid eddy detection cases available for analysis is highly constrained. In other instances, the differences between 2DVAR and AVISO in comparison with the drifter data are not significant (either both match the drifter trajectories or neither does). The case involving drifter 300534064134530 stands out as the only example demonstrating a clear and favorable comparison.

3) L 24-25: "The SWOT data provide a greater potential for resolving fine-scale to mesoscale eddies in the South China Sea compared with conventional in-situ data, such as drifting buoys." This sentence has not been changed in the revised manuscript although it is in the "diff" file. The response given to Reviewer#2 is clear and the suggested modification should appear in the revised version of the manuscript.

Response: Thank you for your question. We acknowledge this oversight and have made the necessary revisions, including adjustments to the wording for improved clarity and precision.

Line 24-25: SWOT data are more likely to provide detailed comparisons of eddy boundaries for fine- to meso-scale structures compared with conventional in-situ data (e.g., drifting buoys).

4) L 59-60: "Fine-scale..": I think this sentence would better fit in the text at lines 32-33.

Response: Thank you for your valuable suggestions. We have incorporated the necessary revisions accordingly.

Line32-33: Fine-scale ocean processes are characterized by spatial variability of 1 to 100 kilometres and temporal variability of days to months (Lévy et al., 2024).

5) L63: "diverse merging methods". Please specify here which one will be tested in the study for clarity.

Response: Thank you for your valuable suggestions. We have incorporated the necessary revisions accordingly.

Line 63-67: This study aimed to validate the accuracy and reliability of different merging methods, specifically 2DVAR and AVISO, in reconstructing oceanic dynamic signals, with a particular focus on fine-scale eddies.

6) L80: "11219285" Is it a reference ?

Response: We apologize for the inclusion of redundant numbers, which has now been removed.

Line 83-83: The first ADT product (Fig. 1b) was produced using a ±11 days time window Near Real-Time (NRT) Two-Dimensional Variation (2DVAR) method with a 1/12° grid resolution.

7) L84: Specifically they include SWOT nadir data.

Response: Thank you for your correction. We have made the necessary revisions accordingly.

Line 88-91: During the science phase of the SWOT mission, the AVISO merged map Delayed Time (DT) products utilized SWOT nadir data as an input source (Copernicus Marine Service repository, 2023b). To maintain the independence of the datasets, we employed NRT products, which do not include SWOT nadir data (Copernicus Marine Service repository, 2023a).

8) Figure 1: Caption should be updated since on the new version (a) SWOT, (b) 2DVAR …

Response: Thank you for your correction. We have made the necessary revisions accordingly.

Line 113-114: Figure 1. Four datasets of absolute dynamic topography (ADT) in the

South China Sea. (a) SWOT, (b) 2DVAR, (c) AVISO, and (d) GDP. The ADT data in (a), (b), and (c) were obtained on September 12, 2023, and (d) covers the entire period of the Science phase.

9) L126: Typo: "a difference".

Response: Thank you for your correction. We have made the necessary revisions accordingly.

Line 131-132: All possible eddies with a difference in ADT between the eddy center and the boundary contour line of less than ±2 cm were excluded from further analysis.

10) Figure 3 and 4: How did the author fill the gap between SWOT swaths (linear interpolation..)? Also in the caption of Figure 4 it is mentioned that nadir data from swot are used, however on lines 75-77 it is stated they were excluded.

Response: Thank you for your question. We acknowledge this oversight and have made the necessary revisions. To ensure consistency in data resolution and to focus the current study on the fine-scale to mesoscale, we employed a regional averaging method to reduce the resolution of the SWOT data from the original 2-km sampling interval to 1/12°. Owing to the inclination angle between the SWOT satellite orbital plane and the equatorial plane, each downsampled square region is covered by observations. Consequently, interpolation across swath gaps is unnecessary, thereby avoiding the substantial errors that associated with interpolating these gaps.

We apologize for the oversight in the title of Figure 4, which has now been corrected.

Line 78-82: To ensure consistency in data resolution and to focus the current study on the fine-scale to mesoscale, we employed a regional averaging method to reduce the resolution of the SWOT data from the original 2-km sampling interval to 1/12°. Owing to the inclination angle between the SWOT satellite orbital plane and the equatorial plane, each downsampled square region is covered by observations. Consequently, interpolation across swath gaps is unnecessary, thereby avoiding the substantial errors that associated with interpolating these gaps.

Line 265-267: Figure 4. Observation data of SWOT (in red) with the 2DVAR (in black, a1-e1) and AVISO (in black, a2-e2) merged maps from 2023/04/06 to 04/10. The solid line (dashed) represents the anticyclonic (cyclonic) eddy, and the colour-filled plot contains the KaRIn data from SWOT.

11) L280: "However, due to being constantly entrained by a single eddy and rotating within it, the number of eddies that can be detected by a drifter buoy is limited compared to the rapid mapping provided by SWOT". These observation

platforms are inherently different so by definition a single buoy cannot sample as many eddies as SWOT. However, by using a sufficiently high number of drifters one can catch a similar number of eddies as SWOT. This sentence is not relevant, I suggest to remove it.

Response: Thank you for your suggestion. This sentence was indeed redundant and has now been removed.

12) Figure 7: How did the authors get a gridded SWOT map of eddy radius? Is using several SWOT tracks filling the entire area ? The methodology here needs to be clearly stated.

Response: Yes, we utilized data spanning several times the satellite observation period within the scientific phase, ensuring comprehensive coverage of the South China Sea region. Based on this dataset, we generated a distribution map of eddy radii.

Line 305-307: In this section, we utilized data spanning several times the satellite observation period within the scientific phase, ensuring comprehensive coverage of the South China Sea region. Based on this dataset, we generated a distribution map of eddy characteristics.

13) L322: "the method is validated through in-situ observations". If the authors refers to SWOT observations I would not use "in situ". If the authors refer to the drifter observation, it is only one observation.

Response: Thank you for your valuable feedback. The relevant content has now been removed.

Line 340-341: Finally, the method is validated through observations, ensuring robustness and reliability.

14) L353: Typo: "ot"

Response: Thank you for your correction. We have made the necessary revisions accordingly.

Line 371-372: Also, ignoration of non-closure of contour lines in SWOT maps might be a deficiency too.