

## Reviewer 2

<https://sp.copernicus.org/preprints/sp-2025-17/#RC2>

This manuscript offers a crucial comparison between a traditional altimetry product, and an innovative one that includes SWOT in the west Mediterranean Sea. It provides interesting findings and, most importantly, it includes the results into a broader policy and environmental perspective.

Although I find the study very relevant and important for the community, I think the demonstrations of some important points were slightly overlooked. Also, I advise to read again carefully the entire manuscript because sentences are sometimes unclear and the points could better illustrated.

### General:

1. The introduction presents some very interesting points and generally the relevance of the study. I feel that many of the ideas are repeated multiple times in different paragraphs, which makes the whole message scattered and less powerful. I suggest keeping the same information, revising the structure of the introduction. Often sentences begin with “this variability” or “this impact”... and it is unclear what the words “this” or “its” are referring to

We thank the reviewer for the comment. We revised the introduction to improve the overall structure and readability by reducing repetitive statements and improving the logical flow between paragraphs. We also clarified several ambiguous references (e.g. ‘this variability’, ‘this impact’, ‘its’) to make the corresponding processes and implications more explicit throughout the text.” These improvements were implemented throughout the revised introduction and are further detailed in the responses to the specific comments below.

2. In general, it should be better clarified how the authors separate the contribution of SWOT and of the interpolation methodology to the overall better performance of the MIOST-K product

We thank the reviewer for the comment. We agree that separating the respective contributions of SWOT observations and the MIOST reconstruction methodology is an important point. We clarified in the revised manuscript that the improvements identified in MIOST-K arise from the combined effect of the SWOT KaRIn observations and the multiscale MIOST reconstruction framework. However, previous comparisons between DUACS-OI and MIOST products based solely on nadir altimetry showed relatively small differences in the Mediterranean Sea (Ballarotta et al., 2023; Verbrugge et al., 2024), suggesting that the larger mesoscale and coastal differences identified here are strongly influenced by the inclusion of SWOT wide-swath observations. We also expanded the methodological description of the MIOST-K reconstruction, the SWOT sampling contribution, and the associated limitations in the revised manuscript. These aspects are further discussed in the responses to the specific comments below.

3. The study should quantify some basic differences between the three products, such as spatial and temporal resolution. This information is the minimum to start understanding the impact of SWOT in the dataset

We thank the reviewer for the suggestion. We agree that clearly describing the characteristics of the different products helps contextualize the results. The manuscript already specified that the MIOST-K product is available at 1/8° spatial resolution and daily temporal frequency in subsection 2.2. Section 2.1 described this for DUACS-OI products but we modified it to make the temporal resolution more explicit too:

“The European Seas Gridded L4 Sea Surface Height dataset (Table 1, product reference 1 and 2) from the Copernicus Marine Service provides Sea Level Anomaly (SLA) fields at 1/8° resolution over European regional seas, at a daily temporal frequency.”

We also expanded the methodological description of the MIOST-K reconstruction and SWOT observational sampling in the revised manuscript.

We also would like to clarify that the third product, DUACS-OI DT, is only used in Fig. 1 as a long-term reference circulation field, while the main comparison throughout the study focuses on the DUACS-OI NRT and MIOST-K products. This is due to the temporal coverage of the DUACS-OI products as described at the end of section 2.1.

## Specific:

1. 33 : “*Mesoscale eddies are key drivers of this variability*” unclear. What variability are you referring to?

To improve clarity, we rephrased the sentence as : “Mesoscale eddies are key drivers of these ocean dynamics, and their observation...”

2. 42: “*To evaluate this impact*” unclear what impact you are referring to. Please rephrase

We clarified the sentence by explicitly specifying the impact being referred to: “To evaluate the implications of these differences for transport and retention processes”

3. 67 “*high environmental interest areas*” phrasing not clear

We rephrased this to: “...towards environmentally vulnerable areas of high biodiversity importance, such as the Cabrera National Park marine protected area and nearby regions...”

4. 68-72: meaning is clear but the sentence is very convoluted. Please rephrase

We clarified the sentence by rephrasing it to: “In this region, mesoscale dynamics, particularly eddy-driven transport and retention, have been identified as key facilitators of plastic pollution transport from the southern Mediterranean coast (Compa et al., 2020). Several media reports (e.g. 20minutos, 2015; Última Hora, 2015; Diario de Mallorca, 2022) have documented large quantities of marine debris reaching Cabrera National

Park, underscoring the vulnerability of this protected area to pollution transported by regional ocean circulation.”

5. 81-85 and I.86-91 present some common concepts like the importance of the work for marine operations, spatial planning etc. I feel they could be compacted in one single paragraph so the information is less dispersed.

We have taken into account the reviewer’s suggestion and combined the paragraphs as follows:

“This study evaluates how SWOT KaRIn observations affect the representation of surface mesoscale activity in gridded altimetric products over the western Mediterranean. By comparing eddy fields derived from legacy and SWOT-enhanced datasets, we assess differences in the representation of surface circulation, focusing particularly on Eddy Kinetic Energy (EKE) and eddy retention capacity. More accurate surface mesoscale information can support route planning strategies aimed at reducing ship emissions (e.g. Wang et al., 2023) and improve the identification of pollutant transport pathways toward ecologically sensitive areas such as Cabrera National Park. Beyond improving our understanding of mesoscale dynamics, the overarching objective is to evaluate the added value of high-resolution SWOT-enhanced altimetry for applications ranging from marine pollution mitigation to improved maritime operations and ecosystem management.”

6. 94: Is there a reason why the table is shown so early in the paper? It could be presented at the end of the methods section, so the reader know what it is about

We thank the reviewer for the suggestion. The placement of Table 1 early in the manuscript follows the formatting conventions commonly adopted in the *State of the Planet: Ocean State Report* special issue, where summary tables describing datasets and products are typically introduced near the beginning of the paper to provide readers with an overview of the data sources before entering the methodological details. This structure is followed by most contributions in previous OSR editions (e.g. OSR9: [State of the Planet – Ocean State Report 9](#)), with the exception of some chapter-opening overview articles. We nevertheless agree that the table could also fit naturally within the Methods section; however, for consistency with the special issue style and related contributions, we preferred to retain its current position.

7. 125: “and further details can be found in Mason et al. (2014)”. Further details about the contours? At least a basic explanation of the two contours, and why they are interested in them, should be provided

We thank the reviewer for the suggestion. We clarified the physical meaning of both contours in the revised manuscript to:

“Two types of contours are identified by the algorithm: the effective contour (outermost closed contour defining the eddy extent) and the speed contour (inner contour

corresponding to the region of maximum mean azimuthal geostrophic velocity). Further details can be found in Mason et al. (2014).”

8. 126: why does SLA provide more reliable eddy identification compared to ADT?  
Please add a brief justification

We thank the reviewer for the comment. We added a brief justification explaining why ADT is preferred over SLA for eddy identification in the Mediterranean Sea. In particular, regarding that ADT includes both the mean dynamic topography and its temporal variability:

“Compared to SLA, ADT provides more reliable eddy identification, especially in the Mediterranean Sea (Pegliasco et al., 2021, 2022), because it includes both the mean dynamic topography and its temporal variability, helping distinguish mesoscale eddies from variations in persistent jets and recurrent circulation patterns included in the MDT.”

9. 124-127 present a series of disconnected sentences. Please rephrase to add some logical transitions between the sentences

We have rephrased this section to: “The py-eddy-tracker is an eddy tracking algorithm based on geometric and physical techniques. It was firstly developed by Mason et al. (2014) and later updated by Delepouille et al. (2022). Since then, it has been widely used to study eddies and for the generation of updated eddy field datasets (e.g. Pegliasco et al. 2022). In this study, we use version 3.6.1 of the algorithm (Delepouille et al., 2022) to identify eddies from daily snapshots of Absolute Dynamic Topography (ADT) fields. Two types of contours are identified by the algorithm: the effective contour (outermost closed contour defining the eddy extent) and the speed contour (inner contour corresponding to the region of maximum mean azimuthal geostrophic velocity), and . Further details can be found in Mason et al. (2014). Compared to SLA, ADT provides more reliable eddy identification, especially in the Mediterranean Sea (Pegliasco et al., 2021, 2022).”

10. 132: sentence somewhat confusing. Maybe some commas are missing

We have clarified the text and rephrased it to: “A detection step of 0.002 m was used between consecutive isolines. This corresponds to the height difference between contour levels used to identify eddy boundaries. Starting from the eddy center (defined by a minimum value for cyclonic eddies and a maximum value for anticyclonic eddies), closed ADT isolines are identified outward at intervals of 0.002 m until the eddy edge is reached (Cui et al., 2025).”

11. 140: impact of the eddy characteristics on what?

We have clarified the text and rephrased it to: “We calculate eddy particle retention to quantify how differences in eddy properties, such as size, intensity, and associated kinetic energy, influence particle transport and trapping.”

12. Fig 1: The explanation of this figure should be clearer.

- a) You insert panel A to show that the average circulation over the 20 is well represented by the shorter time averages. Panel A is used as kind of a reference of the mean circulation. Correct?

Yes, panel A is intended as a reference representation of the average circulation over 20 years in the western Mediterranean, allowing comparison with the shorter-term averages derived from the DUACS-OI NRT and MIOST-K products during the SWOT science phase. We clarified this intention in the revised manuscript: "Fig. 1A is included as a reference representation of the mean circulation over 20 years in the western Mediterranean. The main circulation features shown in Fig. 1A are also observed in the shorter-term averages shown in panels B and C, indicating that the large-scale circulation is consistently represented in both datasets."

- b) Panel B and C represent an average over 17 months. You say that the differences between the two arise in the small scales and in the characteristics of the mesoscale structure. What characteristics are you referring to? Can you either point at something in the Figures, or quantify the differences in terms of energy at different scales, average size of the structures, speed... Just from the image it is not possible to understand what you mean.

We thank the reviewer for the comment. We agree that the original wording was too qualitative and that the differences between the two products were not sufficiently highlighted in the figure. Following also Reviewer 1's suggestion, we revised Fig. 1 by adding a new difference panel (Fig. 1D), showing the differences in mean ADT between MIOST-K and DUACS-OI. This additional panel helps better visualize the impact of SWOT observations on the representation of smaller-scale mesoscale and coastal structures. We also clarified the text to better specify the types of mesoscale differences being referred to:

"Differences between Figs. 1B and C arise mainly at the smaller-scale features and in the characteristics of the mesoscale structures, already suggesting that the inclusion of SWOT observations impacts the representation of mesoscale circulation. These differences are further highlighted in the mean ADT difference field shown in Fig. 1D, particularly in coastal regions and along energetic circulation pathways (e.g. Alboran Sea and Algerian Current)."

Furthermore, the quantitative characterization of these differences is explored in the following sections through analyses of eddy counts, Eddy Kinetic Energy (EKE), and eddy retention properties.

- c) You say "*already giving us a first insight that at the mesoscale the circulation will be impacted by the inclusion of the new SWOT observations.*". Two remarks on this:
  - i) What you show is an average. How can you be sure that the impact of SWOT will be clearly visible in a 17-month average? If we don't know what are the day-to-day differences is hard to judge

The temporal averaging shown here can smooth part of the day-to-day mesoscale variability. However, differences between the products are already expected from the different spatial sampling characteristics of conventional nadir altimetry and SWOT wide-swath observations. Compared to nadir altimetry, SWOT provides substantially enhanced spatial coverage over short temporal windows (e.g. López-Radcenco et al., 2019; Ballarotta et al., 2025), allowing improved sampling of mesoscale and coastal structures (e.g. Dibarboure et al., 2024). Although SWOT sampling is spatially heterogeneous due to its orbital geometry and revisit pattern (Dirbabaure et al., 2024), the increased spatial sampling can still influence time-averaged diagnostics by improving the representation of recurrent mesoscale features and coastal eddies over the study period. We revised the text to better explain this point and clarified that DUACS-OI relies on the effectively one-dimensional along-track sampling of conventional nadir altimetry, while MIOST-K additionally benefits from the two-dimensional wide-swath observations provided by SWOT. The following text was added:

“This is expected from the enhanced spatial sampling provided by SWOT wide-swath observations compared to conventional nadir altimetry (e.g. Lopez-Radcenco et al., 2019; Ballarotta et al., 2025), particularly for mesoscale and coastal structures (e.g. Dibarboure et al., 2024). In contrast to the effectively one-dimensional along-track sampling of nadir altimeters, SWOT provides two-dimensional swath measurements, and the implications of these differences are further explored through the analysis of daily eddy variability in the following sections.”

- ii) How can you be sure that the differences are given by the fact that we include SWOT and not in the intrinsic differences of the two methods? (DUACS vs MIOST)

We agree that differences may also arise from intrinsic methodological differences between the DUACS and MIOST reconstruction approaches. However, previous comparisons between DUACS-OI and MIOST products based solely on nadir altimetry have shown relatively small differences in the Mediterranean Sea (Ballarotta et al., 2023 and Verbrugge et al., 2024\*). This suggests that the larger differences observed here, particularly at mesoscale and coastal scales, are likely strongly influenced by the inclusion of SWOT wide-swath observations in MIOST-K. We clarified this point in the revised manuscript:

“Although part of these differences may also arise from intrinsic methodological differences between the DUACS-OI and MIOST reconstruction approaches, previous comparisons based solely on nadir altimetry showed relatively small differences between the two products in the Mediterranean (Ballarotta et al., 2023; report reference). This suggests that the higher differences observed here are strongly influenced by the inclusion of SWOT wide-swath observations in MIOST-K.”

\* Verbrugge, N., Greiner E., Augot, J., Sammartino, M., Colella, S., Buongiorno-Nardelli, B., Hernandez-Carrasco, I., Falcini, F., Rossi, V. and Lacorata, G.: Algorithm Theoretical Baseline Document for 4DMED-SEA Project, version 2, ESA,

[http://ricerca.ismar.cnr.it/4DMED/docs/4DMED-SEA-D2\\_ATBD\\_v2.0-signed.pdf](http://ricerca.ismar.cnr.it/4DMED/docs/4DMED-SEA-D2_ATBD_v2.0-signed.pdf), last access: 15 June 2026, 2024.

13. 172: please quantify the “high temporal variability” in terms of mean, std of the two cases, and correlation between the two time series. Both for cyclonic and anticyclonic eddies

We added the requested mean and standard deviation values for both cyclonic and anticyclonic eddy counts. We also computed the temporal correlations between the daily eddy-count time series from both products. These correlations are low ( $r = 0.013$  for anticyclonic eddies and  $r = 0.148$  for cyclonic eddies), which we interpret cautiously because daily eddy counts are highly sensitive to product-dependent differences in eddy detection, splitting/merging, and eddy lifetime. We therefore report the correlations but avoid overinterpreting them, since the study period is too short to support a robust seasonal correlation analysis.

“Despite high temporal variability, MIOST-K consistently identifies a larger number of eddies than DUACS-OI throughout most of the analysis period. For anticyclonic eddies, MIOST-K detects on average  $19.0 \pm 2.0$  eddies per day (mean  $\pm$  standard deviation), compared to  $12.5 \pm 2.0$  for DUACS-OI. For cyclonic eddies, the mean daily counts are  $20.4 \pm 3.1$  and  $16.6 \pm 2.4$  for MIOST-K and DUACS-OI, respectively. The temporal correlation between the two daily eddy-count time series is low for both anticyclonic ( $r = 0.253$ ) and cyclonic eddies ( $r = 0.165$ ). This likely reflects the sensitivity of daily eddy counts to product-dependent differences not only in eddy detection, but also splitting, merging, and lifetime, rather than fundamental differences in the temporal variability of mesoscale activity.”

14. Why is the difference in the eddy count larger for anticyclonic eddies?

We thank the reviewer for raising this interesting point. We do not directly investigate the origin of this asymmetry in the present study, but one possible explanation is that the SWOT-enhanced MIOST-K product improves the detection of smaller-scale and coastal eddies, where the differences between the products are most pronounced. In the western Mediterranean, anticyclonic eddies also tend to be more persistent and dynamically coherent than cyclonic eddies, which may increase the likelihood of their detection in the enhanced MIOST-K reconstruction. This could partly explain why the increase in eddy counts is more pronounced for anticyclonic eddies. The following paragraph was included in the discussion:

“The increase in eddy detections with MIOST-K is more pronounced for anticyclonic eddies than for cyclonic eddies. Although the origin of this eddy asymmetry was not specifically investigated here, it may be related to the improved detection of smaller-scale and coastal eddies, where the differences between the products are strongest. In the western Mediterranean, anticyclonic eddies tend to be more persistent, coherent, and longer-lived than cyclonic eddies (Stegner et al., 2021), potentially increasing their detectability in SWOT products. Similar asymmetries have also been observed by SWOT in other regions, and are generally explained by the greater stability and propagation capacity of anticyclonic eddies, allowing them to persist longer and propagate farther (de Marez et al., 2026). This enhanced detection of anticyclonic eddies

may also be relevant for the monitoring of long-lasting surface temperature anomalies associated with these structures, which could contribute to the development of local marine heatwaves (Aguiar et al., 2022).”

15. 187: please quantify in the text the most important EKE values, so the reader can easily compare the two products

We thank the reviewer for the suggestion. While the percentages of days with higher EKE values in MIOST-K were already included, we now additionally report the timing and magnitude of the maximum EKE event in both datasets to provide a clearer quantitative comparison between the products:

“Both datasets reach their maximum daily mean EKE on 25/04/2024, although the magnitude is higher in MIOST-K (303 cm<sup>2</sup>/s<sup>2</sup>) than in DUACS-OI (285 cm<sup>2</sup>/s<sup>2</sup>).”

16. 189: “*This may be due to enhanced signal capture*”: is this a hypothesis or is it verified? What could be the other reasons why the EKE behaves this way?

We therefore revised the text to clarify that this is an interpretation of the results based on mechanisms and expectations described in the existing literature, rather than a conclusion explicitly demonstrated within the scope of this study. In the revised manuscript, we now discuss that the enhanced EKE representation likely results from a combination of factors associated with SWOT observations, including improved spatial sampling, the two-dimensional wide-swath geometry, enhanced representation of higher-wavenumber variability, and potentially lower noise levels compared to conventional nadir altimeters (e.g. Vergara et al., 2023). The following text was added:

“This enhanced EKE representation is likely associated with the improved spatial sampling, two-dimensional swath geometry, and enhanced representation of higher-wavenumber variability enabled by SWOT observations. Furthermore, SWOT observations are expected to exhibit substantially lower noise levels than conventional nadir altimeters (Vergara et al., 2023), which may also contribute to the differences observed.”

17. 190-194: the EKE analysis feels like a central point in the study. Especially because of the impact that it might have for climate applications. It would be beneficial to close this paragraph by adding how, in view of what the references you mention have found, your results could impact the understanding of the ocean’s carbon and heat sink in this region

We have revised the text and modified it to: “For example, Hogg et al. (2015) mention the significant impact EKE trend variations have on the ocean’s carbon and heat sinks in regions like the Southern Ocean, where increasing EKE has been associated with changes in the efficacy of these sinks and the consequent global climatic implications. In the western Mediterranean Sea, where mesoscale eddies strongly influence transport and exchanges between subbasins, the enhanced EKE representation identified in MIOST-K may similarly have important implications for regional heat, salt, and carbon-related transport processes. For example, the higher EKE observed in the energetic Alboran Sea eddies shown in Fig. 3 could affect the representation of heat and

salt exchanges through the Strait of Gibraltar (e.g. Bryden et al., 1994; Tsimplis and Bryden, 2000; Sánchez-Román et al., 2009; Hargous et al., 2026).”

18. If the objective is to show the importance of the EKE for monitoring studies and environmental planning, having a mid to long term view is fundamental. What is the difference in the strongest EKE occurrence between the two products over the available time series? How could that difference impact the spatial planning for aquaculture, or the planning of safer marine routes? This work, between Figure 3 and the discussion, mentions that the physics and policies could be connected, but it does not provide a tangible example. Without an example we cannot really demonstrate why this innovative product is crucial for future studies.

We thank the reviewer for the comment. To better quantify the differences between the two products, we now explicitly report the magnitude of the strongest EKE events over the study period. In particular, we added the following text:

“Both datasets reach their maximum daily mean eddy EKE during the same energetic event on 25/04/2024, although the MIOST-K value is approximately 6% higher than in DUACS-OI. More importantly, individual daily differences between the products can be substantially larger, with MIOST-K exhibiting increases of up to 78% relative to DUACS-OI during certain energetic mesoscale events, such as on 16/09/23.”

We also clarified the potential operational implications of these differences by explicitly linking the enhanced EKE representation to the transport and retention analyses presented later in the manuscript. The following sentence was added:

“Such differences in EKE and mesoscale structure representation may also influence particle transport and retention estimates, with implications for marine pollution management and offshore spatial planning, as explored in the Algerian eddy case study presented in the following section.”

The end of the results concerning figure 4 was also modified to further develop this and to link it to the EKE results:

“This demonstrates an important impact of the differences in eddy properties identified between the operational DUACS-OI and the new dataset, MIOST-K. Despite only subtle qualitative differences in eddy contours (Fig. 2), the particle retention over just 20 days shows high variability, likely linked to the higher EKE structures observed in the SWOT-enhanced product (Fig. 3). These differences are not only scientifically relevant but may also have practical implications for environmental monitoring and marine spatial planning. The same eddy can exhibit opposite retention and leakage behaviours depending on the product used. If applied operationally, such contrasting representations could lead to substantially different estimates of the transport and accumulation of pollutants, marine litter, nutrients, fish larvae, or aquaculture-derived waste, potentially influencing pollutant dispersion assessments, aquaculture site suitability, or ecosystem management strategies.”

This provides a more tangible example of how improved mesoscale representation in SWOT-enhanced products could impact future environmental monitoring and planning applications.

19. Fig4 explanation: How do you explain the variability between eddies with the same product? Why are the eddy dynamics so different? This is important to know because it shows the reliability of the product. If we expected the eddies to behave the same in the three cases, and retain the same number of particles, then there would be an issue with the product. The paragraph explaining this figure goes too fast

We thank the reviewer for the comment. We agree that the original paragraph described the three eddy examples too briefly and did not sufficiently explain why their retention behaviors differ for the same product. We clarified the text to better emphasize that Fig. 4 presents three different Algerian eddy examples, each compared between the two products (DUACS-OI NRT and MIOST-K). Such variability in retention behavior is physically expected between different eddies, as retention capacity depends on several dynamical characteristics including eddy intensity, coherence, deformation, interaction with the surrounding circulation, and eddy lifetime stage. We also clarified that the key result is that relatively subtle differences in eddy representation between the two products can lead to substantially different transport and retention estimates. The new paragraph is:

“Figure 4 illustrates three examples of Algerian Eddies and their retention capacity. After 20 days, the eddies retain substantially different percentages of particles, reflecting the strong variability in mesoscale transport and retention processes. Such differences are expected between Algerian eddies, as their retention capacity can depend on their dynamical state, including eddy intensity, coherence, deformation, interaction with the surrounding circulation, and eddy lifetime stage. We therefore consider three different eddy examples to illustrate how differences in mesoscale representation between DUACS-OI and MIOST-K can impact transport and retention estimates under different dynamical conditions. In Eddy 1, the DUACS-OI eddy shows leakage, while the MIOST-K eddy retains and even increases the number of particles inside the eddy contour. In Eddy 2, both products retain more particles, although retention is slightly higher in MIOST-K. In contrast, Eddy 3 exhibits stronger leakage in MIOST-K, while DUACS-OI retains slightly more particles. This demonstrates an important impact of the differences in eddy properties observed so far with operational datasets such as DUACS-OI and the new dataset, MIOST-K. Despite only subtle qualitative differences in eddy contours (Fig. 2), the particle retention over just 20 days shows a high variability.”

20. 259-261: How is it possible that this study does not aim to compare the datasets? In the introduction, lines 61 to 63 state exactly the opposite. In general, this sentence is very vague and should be rephrased

We thank the reviewer for the comment. We agree that the original phrasing was misleading and appeared contradictory with the objectives stated in the introduction. Our intention was to clarify that, although the study includes comparisons between DUACS-OI and MIOST-K, its primary goal is not to perform a dedicated intercomparison

of the two products themselves, but rather to assess how the inclusion of SWOT observations affects the representation of mesoscale circulation and associated transport processes. We therefore revised the sentence as follows:

“While this study is not intended as a dedicated intercomparison of the DUACS-OI and MIOST-K products, it ....implications.”