

Answer to editor's comments for "15 Years of Satellite, In Situ and Reanalyzed Salinity Data: Insights into Sea Surface Salinity Trends, Variability, and Water Cycle Links"

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Dear authors, changes made to the manuscript must be more clearly identified and linked to the reviewers' questions.

We thank the editor for their constructive comments. Below, we describe the revisions introduced in the manuscript, provide the rationale for these changes, and explain how they address the reviewers' remarks.

For clarity and ease of comparison, the tracked-changes manuscript retains the modifications introduced during the previous revision round, while the new revisions made in the current round have also been marked.

The revised text in the amended manuscript is not explicitly mentioned in the response to the reviewers; this should have been done, as it makes the review difficult to follow. L.238-248: the corrected version does not exactly correspond to the answer given to reviewer 1. L. 253-260: Idem. Please specify the exact sentences in the manuscript that address the reviewers' questions.

Regarding L.238-248 and L.253-260, the text was rephrased between the preparation of the responses to the reviewers and the submission of the revised manuscript. As a result, the wording in the manuscript does not exactly match the wording quoted in the response document, although the scientific content and the points addressed remain the same.

Lines 238-248 address the reviewer comment: *"We would expect the authors to take the analysis one step further. For example, they describe the L3G and Glorys datasets as "noisier" (line 192) but do not explain the origin of this noise—whether it is related to instrument resolution, sensitivity to sea state, data processing differences, or other error sources."*

Lines 253-260 address the reviewer comment: *"Similarly, the manuscript notes inconsistencies in 2024, 2023, and 2011 (lines 192-195) without offering hypotheses that might account for these deviations. Presenting such observations without attempting to interpret or contextualize them limits the readers' ability to understand the differences between products. Providing even brief explanations or possible causes would significantly strengthen the results analysis and improve the interpretability of the comparisons."* The corresponding revised discussion is now presented in L.249-262: *"On the other hand, some of the datasets differ from the others at certain periods of time. For instance, the CNR time series separates from the others in the Solomon Islands in 2011. ARMOR3D, based on CNR data, also follows this discrepancy (probably related to the number and treatment of in situ observations, and handling of the background field in their processing chains). In the East of Australia in the 2022-2023 period, the higher weight given to in situ observations in the CNR processing algorithm may enhance the representation of certain regional processes that are less evident in the other datasets. In this context, the stronger negative SSS anomalies observed in CNR SSS in 2022-2023 may be associated with precipitation variability affecting the western New Caledonia region and consequently the East of Australia area in that period (Blunden et al. 2023). ARMOR3D separates from the other time series in February 2023 in the Solomon Islands, the South Atlantic, the North Atlantic, and the Eastern Indian Ocean. This is because of spurious data that should have been flagged and not used in the ARMOR3D near real time (NRT) data that was used to complete the reprocessed time series in the last two years of the study. In the Eastern Indian Ocean, there is no*

SMOS or SMOS/SMAP OI data from December 2023, due to RFI contamination in the satellite data in the region. Finally, SMOS separates from the rest of the time series in the South Atlantic after 2024 for an unclear reason.”

Furthermore, the responses to the reviewers contained additional explanatory details intended to clarify how the comments were addressed, whereas the corresponding text included in the manuscript was intentionally kept more concise in order to preserve readability and flow.

Entire paragraphs and lines have been added or moved in the manuscript without any reference to a reviewer’s request. These changes must be traced back to reviewers’ requests or, alternatively, the reasons for them must be explained.

Here are a few examples: The paragraph on the long time scale of signal emergence (Vinogradova and Ponte (2017) has been displaced from the 4.3 section to the conclusions, why?. The sentence “Nevertheless, these negative trends appear on both ascending and descending SMOS passes (not shown) whereas SMOS land-sea contamination strongly varies between ascending and descending satellite passes ...” has been added from the original manuscript, does this refer to a request from a reviewer?

According to Reviewer 1, *“the Results section is difficult to read not only because of the numerous non standard acronyms, but also because it is highly descriptive and progresses in a strictly linear manner without a clear narrative thread. As a result, readers may struggle to discern the main scientific messages from secondary details. Reorganizing the section around a clearer storyline—highlighting the key results first and then supporting them with detailed descriptions—would greatly improve accessibility and impact.”* In addition, the reviewer noted that *“significant improvements in clarity, structure, and dataset documentation are needed to strengthen its readability and impact”*.

In order to address these comments, several paragraphs and lines were added, moved, or rephrased to improve the structure, readability, and narrative flow of the manuscript, particularly in Section 4 (Results). The revised organization was intended to present the main findings more clearly before moving to supporting details and exceptions. Below, we provide an explanation of the modifications that were not explicitly described in the previous responses to the reviewers or editor.

L.121-125: “To assess if the significant trends observed for the last 15 years are consistent with longer term trends, the Institute of Atmospheric Physics (IAP) global ocean salinity gridded product (Cheng, 2022), available from 1940 to present, was used. The trends and statistical significance were computed for the salinity at the surface, for different time periods: 1960-2024 (the full period of the dataset was not used as data for 1940-1959 reportedly has a large uncertainty), 2005-2024 (the Argo period) and 2011-2024 (the satellite period).”

This text was moved to the Data section following Reviewer 1’s comment: “In addition, there is also confusion regarding the IAP product: it is introduced in the manuscript and later used for long term comparisons, yet it does not appear in the Data section or Table 1. Including it alongside the other datasets, with a brief description, would greatly improve consistency.”.

L.151-158: “The agreement between the trends obtained with various products is particularly remarkable for datasets that are independent, such as SMOS (product 1) and GLORYS (product 3). We find similar results for these two datasets, especially away from the coast, and in regions where trends are statistically significant. Besides, consistent trends between SMOS/SMAP OI (product 4) and ISAS (product 2) are found, which can be partly explained by the fact that ISAS is used to constrain the large scale variability of SMOS/SMAP OI. Some similarities between CNR (product 5)

and ARMOR3D (product 6) trends are also expected, because CNR data is used as an upstream in ARMOR3D. The ARMOR3D and CNR products also include in situ observations (and weight them differently considering characteristic temperature decorrelation scales), therefore their trends are also close to ISAS and SMOS/SMAP OI.”

This paragraph was moved and slightly rephrased to the beginning of the Results section because it establishes the relationships between the datasets, which are subsequently important for interpreting the results throughout the section.

L.165-166: An example of the negative trends (“e.g. in the Pacific near the coast of South America and in the Atlantic near the coast of South Africa”) was added in order to clarify the regions being discussed.

L.167-169: “Nevertheless, these negative trends appear on both ascending and descending SMOS passes (not shown) whereas SMOS land-sea contamination strongly varies between ascending and descending satellite passes. In addition, few in situ measurements are available near land and future studies would be needed to better assess trends there.”

This addition provides further context regarding the possible origin of these negative trends, notably that they may not be attributable to land-sea contamination since they do not vary between ascending and descending passes.

L.188-190: This passage was rewritten to provide a smoother introduction to the paragraph. In addition, the sentence in L.192-194: “In general, the STD of the trends are about an order of magnitude smaller than the trends (under 0.05 pss/decade), which means that the trends derived by the different datasets are consistent with each other. However, there are some exceptions.” was moved earlier in the paragraph in order to improve the narrative flow by presenting the general result before discussing exceptions, in line with Reviewer 1’s recommendation.

L.205-206 and L.207-209: These modifications were introduced to improve transitions between paragraphs and enhance readability. The addition of the sentence “This reveals an increase in inter-basin contrasts.” was intended to highlight this important result earlier in the manuscript.

L.266-272: This section was rewritten to improve conciseness and readability and to avoid repetition. The removed text: “Trends are more intense for SMOS L3G and Glorys for the SPURS, SPCZ and EAUS regions (and for Glorys in EIND), and lower for SMOS L3G in NPAC and SALOMON. Trends are higher in ISAS for SALOMON, and lower in SASG, where the trend obtained is very close to the value obtained for SMOS/SMAP OI.” mainly repeated results already presented in Table 4 without substantially contributing to the discussion. In contrast, the following statements: “In general, results are consistent between SMOS/SMAP OI and ISAS (except for EIND), because ISAS is used to constrain the SMOS/SMAP OI. The similarities between CNR and ARMOR3D trends are also expected, because CNR data is used as upstream in ARMOR3D. However, it is important to note that even between the independent datasets, SMOS L3G and Glorys, there is a good agreement.” were moved earlier in the Results section in order to improve the logical progression of the discussion.

L.329: “The IAP product was used to assess if the results for the last 15 years are consistent with longer term trends.” This sentence was added to provide a short introduction to subsection 4.3.

L.335-336: This text was moved earlier because it directly supports the statement that follows and improves the logical structure of the paragraph.

L.339-341: This sentence was rewritten to improve clarity and strengthen the connection with the subsequent discussion.

L.370-374: The text “This was also found, for example, by Vinogradova and Ponte (2017) for the period between 1993 and 2010, which they explained by the fact that anthropogenic hydrological signals take longer to emerge in the sea surface salinity compared to the surface freshwater fluxes.” was moved from the Results section to the Conclusions section. Although this specific modification was not explicitly requested by the reviewers, it was introduced as part of the broader manuscript reorganization undertaken to address concerns regarding clarity, readability, and narrative structure. We considered the citation more appropriate in the Conclusions section, where it better supports the interpretation and contextualization of the main findings rather than the direct presentation of results. In fact, it supports the following phrase that was rewritten for better clarity as: “Indeed, comparison of our results with a long-term dataset derived from a combination of in situ observations and model outputs reveals consistent trends between the datasets over the past 15 years; however, these patterns differ from the longer-term trends.”

Other comments:

ARMOR3D data are obtained by statistical methods (multiple/linear regression) and optimal interpolation and not by assimilation method. Rephrase at various locations (L. 118, 251, 259...) in the revised manuscript.

Thank you for pointing this out. In L. 118 “assimilate” was replaced with “use”. In L. 251 “assimilates CNR data” was replaced with “based on CNR data”. In L. 259 the word “assimilated” was suppressed.

No short explanation was given to this question from the 1st reviewer on : “The authors suggest that independence is determined primarily by the absence of shared SSS inputs; however, it would be helpful to briefly justify why this criterion does not extend to other variables. For example, why are two products that assimilate the same SST field still considered independent? Providing a short explanation would prevent confusion and enhance the transparency of the dataset intercomparison.”

We thank the reviewer for this important clarification request.

In the manuscript, the term “independent” was intended specifically to refer to differences in the primary source of salinity information used to construct the products, rather than to all auxiliary variables involved in their processing chains. Additionally, the use of common SST fields does not imply equivalence in how SST contributes to SSS estimation across products, because SST is incorporated differently and serves different roles in the respective processing methodologies.

For example, in SMOS, SSS is retrieved from satellite brightness temperatures through a radiative transfer inversion in which SST acts as an auxiliary variable through its influence on seawater emissivity. Consequently, uncertainties in SST can propagate into the retrieved salinity through the inversion procedure.

In contrast, in situ-based products such as ISAS derive salinity primarily from conductivity measurements using standard salinity-conductivity relationships (PSS-78/TEOS-10 conventions). GLORYS additionally assimilates multiple observation types, including SST, into a dynamical ocean model. In this framework, SST primarily constrains the surface thermal state and influences salinity indirectly through model dynamics and air-sea interactions.

In ARMOR3D, SST is used together with Sea Level Anomaly and SSS in a multilinear regression approach to project surface signals derived from satellite observations into the ocean interior and generate first-guess temperature and salinity profiles. In contrast, in the CNR product, SST is directly incorporated into a multivariate optimal interpolation scheme. Here, SST is used as an additional variable in the covariance function, alongside space–time distance, to guide the interpolation of SSS/SSD fields. In practice, the algorithm assigns higher weights to observations that are not only close in space and time, but also exhibit similar high-pass filtered SST values (i.e., are associated with the same mesoscale thermal structures or isotherms). This approach allows the interpolation to better follow ocean mesoscale features and enhances the effective resolution of the reconstructed SSS/SSD fields.

To avoid ambiguity, we have removed the term “completely” from “completely independent” in L. 116 and L. 118, and clarified the intended meaning of “independent” in the revised manuscript by adding:

“In this context, ‘independent’ is used in a relative sense, referring to differences in the underlying salinity data sources rather than to all auxiliary variables used in the processing chains.”

Table 2 : description of product 7-IAP: Like reviewer 2, we would like to know if IAP includes TSG (thermosalinographs) measurements? please specify or answer.

Upon contacting Yuying Pan, who is responsible for the IAP dataset, we received the following clarification:

“We would like to clarify that the IAP SSS product does not systematically include TSG (thermosalinograph) measurements. This is because our data are based on WOD23. In WOD23, TSG measurements are mainly contained in the SUR dataset, while the WOD data files we routinely use to construct the IAP product focus on profile-type datasets and do not include the SUR files. Upon checking our records, we found only 179 entries labeled as TSG. The number is extremely small. These records appear to have been included through WOD metadata classification under OSD rather than via the SUR dataset.”

Therefore, although a very limited number of TSG measurements may be present indirectly through metadata classification, the IAP dataset does not include TSG observations in a significant or systematic way.

L. 249: On the other hand, some of the data sets differ from the rest at certain time periods.

Done.

L. 251: ARMOR3D, based on CNR data, also follows...

Done.

L. 252: ... and handling of the background field in their...

Done.

L. 259: to be clarified : The anomaly mentioned in the text refers instead to spurious data that should have been flagged and not used in ARMOR3D

Yes, exactly. I rephrased the sentence to make it clearer: “This is because of spurious data that should have been flagged and not used in the ARMOR3D near real time (NRT) data that was used to complete the reprocessed time series in the last two years of the study.”.

L. 260: ... for the last two years of the study.

[Done.](#)