Review of "Constructing a SWOT Internal Wave Dataset using deep learning"

by Xinyuan Xi et al, for publication in EGU ESSD.

This paper presents a dataset of internal solitary waves in thirteen hotspots for such signals in the world's oceans, created using a new deep-learning algorithm (SWOT_IWD) on SWOT KaRIN data. The resulting dataset contains SWOT L2 passes with detected ISW packets, as well as the corresponding detection bounding box. These results are of great interest to the physical oceanography community, as ISWs play a key role in ocean dynamics, impacting energy transfer and dissipation, associated mixing and ocean biogeochemistry. As far as I can tell, the dataset and proposed methodology are valuable and the manuscript worthy of publication as a data paper describing the dataset and underlying methodology. However, the paper contains many imprecisions and a few incorrect (or ambiguous) statements regarding ISW dynamics. It also contains a lot of irrelevant information or information that is very poorly organised. Consequently, the paper is much longer than necessary. A critical issue is section 4 (and more specifically section 4.1), which is very long without providing any new information and contains many imprecise statements and insufficient or inadequate references. Furthermore, this section sits between a detailed presentation of the dataset, which is within the scope of the journal, and some unclear interpretations of the results, which are outside the scope of the manuscript. This section renders the paper not suitable for publication in its current form. My detailed comments are below.

[Response]:

We sincerely thank the reviewer for the thorough and constructive evaluation of our manuscript. We greatly appreciate the positive assessment of the value of our dataset and methodology, as well as the recognition that the manuscript is potentially suitable for publication as a data paper. We also thank the reviewer for carefully identifying the imprecise statements, organizational issues, and aspects requiring clarification and revision. Following these valuable suggestions, we have thoroughly revised the manuscript, including improving the scientific accuracy of the descriptions, reorganizing the manuscript structure, removing or simplifying redundant content, revising Section 4 accordingly, and strengthening the supporting references where appropriate. We believe these revisions have substantially improved the quality and clarity of the manuscript.

Our detailed responses to each comment are provided below.

Major comments

1. Title, line 15, and throughout the rest of the paper: 'Internal solitary waves' (ISW) are a specific type of 'internal waves' (IW), which are non-linear and behave like solitons. There is a whole continuum of internal waves, including internal tides, which are mostly linear and cannot be called internal solitary waves. The authors should make it very clear that this dataset is about internal solitary wave packets and not internal waves in general. For example, they could replace 'IW' with 'ISW' or 'NLIW' throughout the text and rewrite the first sentence of the introduction.

   [Response]:

   We thank the reviewer for raising this critical terminological issue. We fully agree that "internal solitary waves" (ISW) are a specific subset of "internal waves" (IW)—the former are nonlinear and soliton-like, whereas the internal wave continuum also includes linear internal tides, which should not be referred to as ISWs. In the original manuscript, the repeated use of "internal waves" as a shorthand for "internal solitary waves" was imprecise and could mislead readers into thinking that the dataset covers all types of internal waves. We apologize for this lack of clarity.

Following the reviewer's suggestion, we have systematically revised the title, abstract, introduction, and the entire paper: all instances where "internal waves" were used but actually referred to "internal solitary waves" have been uniformly changed to "internal solitary waves (ISW)". In addition, we have rewritten the first sentence of the introduction to clearly state that this paper focuses on internal solitary waves, not on internal waves in general.

We are grateful to the reviewer for this rigorous correction, which has significantly improved the scientific accuracy of our paper and prevented potential misinterpretation of the dataset. The changes have been made in the revised manuscript, and we hope the reviewer finds them satisfactory. For clarity, the detailed revisions to the title, abstract, and the first paragraph of the Introduction are provided below.

Constructing a SWOT Internal Solitary Wave Dataset Using Deep Learning

Abstract

Internal solitary waves(ISW) play a crucial role in energy transfer and vertical mixing as key dynamical processes. The Surface Water and Ocean Topography (SWOT) satellite, with its high-resolution sea surface height (SSH) observations, provides new data source for ISW detecting. This study develops a multi-region automatic ISW recognition framework named SWOT_IWD and constructs a SWOT ISW detection dataset (https://doi.org/10.5281/zenodo.17666852, Xi et al. (2025)) covering 13 ISW-prone regions worldwide from 2023 to 2025. A total of 21,682 SWOT passes are downloaded and processed for ISW detection across different regions, identifying 2,011 passes containing ISW signals and detecting a total of 3,264 ISW signals. The dataset consists of SWOT data and IW labels, and includes visualized ISW detection result images. The validation results confirm that the average accuracy of the SWOT ISW dataset is 91.21%. The study analyzes the spatial distribution, activity frequency, and the relationship between ISW and topographic coupling across 13 regions included in the dataset. We also conducted a quantitative comparison of three data sources: SWOT, Sentinel-1 C-SAR, and Sentinel-3 OLCI. The results indicated that up to 29.78% of SWOT observation passes contained detectable ISW signatures. The study demonstrates that this dataset can provide high-quality sample data to support ISW detection based on deep learning. Furthermore, two cases were presented to illustrate the potential of this dataset for ISW tracking using multi-source remote sensing data.

1 Introduction

Internal solitary wave (ISW), a specific type of ISW that are nonlinear and behave like solitons, are ubiquitous dynamic phenomena. ISWs can drive significant vertical mixing and energy flux, with profound implications for oceanic military, engineering, and resource development applications. While the peaks of Internal solitary waves can extend over hundreds of kilometers, their wavelengths along the propagation direction range from several hundred meters to a few kilometers, often exhibiting solitary and non-periodic characteristics.

2. SWOT_IWD: It is unclear whether this is a new algorithm, in which case validation is lacking, or an adaptation of an existing algorithm, for which the corresponding references are missing. The only validation metric proposed in the paper is "detection availability" and average accuracy (i.e. detections that are not false positives), as discussed in Sect. 2.4. Crucially, I could not find any information on how this number is computed. Section 3 is entitled 'IW signature extraction and validation', but does not discuss validation thoroughly. Has the produced dataset been compared with an existing dataset (such as the one distributed by the Internal Wave Service)? Finally, to ensure reproducibility of the results, is the deep-learning model also accessible? Looking at the different detections in the dataset (see also Fig. 7), I noticed that: 1) Some ISW packets are not detected, a topic that is not discussed at all; 2) Different ISW packets are detected in a single bounding box. This topic would be interesting to discuss, even if the authors' scientific objective is not to separate distinct wave packets; 3) In some cases, a single ISW has two bounding boxes attached, meaning a detection is counted twice.

[Response]:

(1) Algorithm

We thank the reviewer for raising this question regarding the algorithm. To clarify: the SWOT_IWD algorithm is not a completely new method developed from scratch, but rather a systematic extension and upgrade of our previously published work. Specifically, in our earlier study, we conducted regional experiments and validation of the algorithm, with the results published in the International Journal of Digital Earth (Xi, Xinyuan, Ge Chen, Jiahui Chen, Zhanwen Gao, and Chunyong Ma. 2026. "Intelligent Detection of Internal Waves Based on SWOT Satellite Observations. " Vol. 19 (1). doi:10.1080/17538947.2026.2654254). In that prior work, we first proposed an intelligent detection framework for internal waves using SWOT observations, and carried out experimental validation and accuracy assessment over typical internal-wave hotspot regions.

In the present paper, we extend this algorithm from regional applications to 13 global internal-wave hotspot regions, and systematically construct a global SWOT-based internal solitary wave dataset. Consequently, the "detection availability" and the average accuracy (91.21%) reported in Section 2.4 are comprehensive performance metrics derived from the previously validated methodological framework. We will add the appropriate citation to the above-mentioned reference in the revised manuscript.

We again thank the reviewer for their careful and constructive comment. The specific changes are located in the revised manuscript as follows:

2.4 Post-processing (Paragraph 1)

Traditional methods, The SWOT_IWD framework was previously evaluated through regional experiments in the Sulu Sea, a well-known internal-wave hotspot, where its detection performance was systematically validated (Xi et al. (2026)). Building on this regional validation, the present study extends the framework to 13 global ISW-prone regions for the construction of a SWOT-based ISW dataset.

References

Xi, Xinyuan, Ge Chen, Jiahui Chen, Zhanwen Gao, and Chunyong Ma. 2026. “Intelligent Detection of Internal Waves Based on SWOT Satellite Observations.” Vol. 19 (1). doi:10.1080/17538947.2026.2654254

(2) Validation metrics

We thank the reviewer for pointing out that Section 2.4 lacked detailed information on how the validation metrics were computed. We apologize for this omission, which may have caused confusion. In the revised manuscript, we will add the following detailed explanation.

2.4 Post-processing (Paragraph 1)

To evaluate the detection performance of the SWOT_IWD algorithm, we defined two core metrics: Accuracy (ACC) and False Discovery Rate (FDR).

ACC represents the proportion of true ISW samples and non-ISW samples that are correctly identified by the model, reflecting its ability to detect genuine ISW signals:

$$\mathrm{ACC} = \frac{\mathrm{ISW\_TP}}{\mathrm{ISW\_TP} + \mathrm{ISW\_FP}}$$

FDR represents the proportion of non-ISW signals that are incorrectly identified as ISW:

$$\mathrm{FDR} = \frac{\mathrm{ISW\_FP}}{\mathrm{ISW\_FP} + \mathrm{ISW\_TP}}$$

Where ISW_TP (True Positive) denotes the number of samples in which internal solitary waves (ISWs) are present and correctly detected by the model, and ISW_FP (False Positive) denotes the number of samples that do not contain ISW signals but are incorrectly identified as ISWs by the model.

To obtain the values of the above evaluation metrics, a subset of data was randomly selected from the study area for manual visual inspection. This validation process was conducted to verify the authenticity of ISW signals and assess the accuracy of the detection results. Six representative regions were selected, including the Andaman Sea, Celebes Sea, Indonesia, Sulu Sea, Western Equatorial Atlantic, and Western Equatorial Indian Ocean. A total of 1,244 samples were manually examined, comprising 152 samples from the Andaman Sea, 187 from the Celebes Sea, 280 from Indonesia, 143 from the Sulu Sea, 309 from the Western Equatorial Atlantic, and 173 from the Western Equatorial Indian Ocean. The evaluation metrics calculated based on the manual validation results are presented in Table 2.

Table 2. Quantitative evaluation results of ISW detection based on manual validation

	ACC(%)	FDR(%)
Andaman Sea	98.71	4.29
Celebes Sea	77.56	22.44
Indonesia	89.37	10.63
Sulu Sea	95.58	4.42
Western Equatorial Atlantic	98.94	1.06
Western Equatorial Indian	90.10	9.9

Average	91.21	8.79

(3) Validation and comparison with existing datasets

We thank the reviewer for pointing out that Section 3, titled "IW signature extraction and validation", does not provide a sufficiently thorough discussion of validation. We apologize for the overly brief description of the validation methods and results in the original manuscript.

The reviewer also raises an important question: whether the produced dataset has been compared with an existing dataset, such as the one distributed by the Internal Wave Service. We would like to clarify that the present study has not yet conducted a systematic quantitative comparison with existing datasets (e.g., the ISW database from the Internal Wave Service). The main reason is that most publicly available internal-wave datasets—such as those derived from SAR or optical imagery—differ from SWOT data in terms of spatiotemporal coverage and physical characteristics. Direct comparison against a unified benchmark is challenging. We will explicitly state this limitation in the revised manuscript and identify a systematic cross-dataset comparison as a priority for future work.

Regarding the reviewer's specific suggestion: we have thoroughly reviewed several public internal-wave datasets, including that from the Internal Wave Service, during our preliminary investigation. However, systematic quantitative intercomparison is difficult due to several factors: differences in observation times, sensor types, limited public accessibility, and inconsistencies in annotation standards and quality across datasets. Therefore, the primary validation strategy in this study does not rely on direct comparison with any single existing dataset. Instead, we adopt a multi-source remote sensing synergistic validation framework to cross-validate the SWOT internal-wave dataset. The validation data include both synthetic aperture radar (Sentinel-1 C-SAR) and optical remote sensing (Sentinel-3 OLCI) high-resolution observations. In Section 3, we provide several representative examples of such multi-source validation. By comparing the SWOT detection results with the internal solitary wave signatures observed in SAR/optical images over the same region and similar time frames, we confirm good consistency in spatial location and morphology between the wave packets detected by the SWOT_IWD algorithm and the independent remote sensing data. We thank the reviewer again for their rigorous and constructive feedback.

(4) The ISW Detection Results

1) We acknowledge that, despite achieving a relatively high detection accuracy, some ISWs are still missed. This limitation is inherent to deep-learning-based detection models and has been discussed in the manuscript. Several factors may contribute to missed detections. First, SWOT KaRIN observations in certain regions may be affected by environmental conditions such as strong winds, precipitation, variations in sea surface roughness, or instrumental noise. These factors can weaken the signatures of ISWs in interferometric images, resulting in confidence scores below the detection threshold of the model. Second, our model was trained with an emphasis on achieving high precision and reducing false positives. As a consequence, some weak-signal ISWs may be excluded during the detection process. In addition, certain ISWs may exhibit morphologies that differ substantially from those represented in the training dataset due to variations in propagation stage (e.g., near dissipation) or local oceanographic conditions. Such cases remain challenging for the current model and may exceed its present generalization capability. We have discussed these limitations in the manuscript and consider them an important direction for future improvement.

2) We thank the reviewer for this valuable comment and agree that this issue deserves further discussion, even though the primary objective of this study is not to separate individual ISW wave packets.

The purpose of the dataset is to identify and localize regions containing internal solitary wave (ISW) activity, thereby providing a foundation for large-scale statistical analyses and related scientific studies, rather than performing precise delineation of every individual wave packet. In real observations, multiple ISW wave packets are often located in close spatial proximity, particularly near generation sites, in regions influenced by complex topography, or where wave-packet interactions occur. Under such circumstances, the wave signatures in SWOT KaRIN imagery may appear continuous or partially overlapping, making it difficult to define clear boundaries between adjacent wave packets. As a result, both manual annotation and automated detection models may reasonably assign a single larger bounding box to encompass the entire wave-activity region rather than forcing multiple neighboring wave packets to be separated into individual targets. This strategy helps maintain annotation consistency and reduces uncertainty arising from subjective interpretation. Moreover, for a dataset primarily intended for event detection and spatial distribution analysis, identifying the presence of ISW activity is generally more important than precisely separating every individual wave packet.

We believe that this representation does not compromise the utility of the dataset for applications such as ISW occurrence statistics, activity mapping, and large-scale automated detection. However, for studies focusing on individual wave-packet evolution, wave-packet interactions, or precise extraction of wave parameters, users may further process the detected regions using more advanced approaches, such as image segmentation, instance segmentation, or other fine-scale post-processing techniques.

3) We thank the reviewer for this valuable comment. The occurrence of two bounding boxes being assigned to a single ISW is mainly related to the inherent mechanism of deep-learning-based object detection models. During the detection process, the model may generate multiple high-confidence predictions for the same physical wave packet from different receptive fields or feature maps at different scales. To preserve potentially valid targets and avoid excessive suppression of adjacent or partially overlapping ISWs, a relatively relaxed Non-Maximum Suppression (NMS) strategy was adopted during dataset generation and post-processing. Consequently, some highly overlapped predictions that did not meet the merging criterion were retained, resulting in occasional cases where a single ISW was associated with multiple bounding boxes.

It should be noted that this phenomenon is common in multi-scale object detection tasks and reflects the trade-off between detection completeness and duplicate suppression. Although a more stringent NMS threshold could further reduce duplicate detections, it may also increase the risk of missing adjacent ISWs or ISWs with complex morphologies, particularly in regions where wave packets are densely distributed, partially overlapping, or have ambiguous boundaries. Therefore, the present study prioritizes detection completeness and accepts a small number of duplicate detections as a reasonable compromise. Furthermore, such cases account for only a very small fraction of the total detections. Their influence on the overall detection performance and statistical analysis is negligible and does not affect the main conclusions of this study.

3. Section 4.1 (pp. 13-20) is very long, brings very little essential information. Furthermore, it might be partially out of scope. Indeed, according to the official journal webpage (https://www.earth-system-science-data.net/about/aims_and_scope.html),'Any interpretation of data is outside the scope of regular articles.' This section appears to offer a statistical analysis of the dataset combined with interpretations of the results in relation to the underlying dynamics, but it contains little new information. The section mostly reviews the various hotspots of ISWs and reminds the reader of the topographic features responsible for their generation. There are many vague considerations, such as 'when tidal currents interact with underwater ridges, the originally linear internal tide waves become steeper and eventually evolve into internal wave packets', which then repeated in several locations. Similar explanations of the generation of NLIWs are not very precise or referenced, and should only appear once in the introduction, if at all. In my opinion, this section should be significantly shortened and rewritten to highlight that the model enables the recovery of the ISW signature in all well-known hotspots, while retaining a few metrics that provide information on the method's performance.

[Response]:

We thank the reviewer for the detailed critique of Section 4.1. We fully agree that this section was excessively long, contained repetitive statements, and that some data interpretation fell outside the scope of Earth System Science Data. We apologize for this shortcoming and have substantially rewritten and shortened this section following the reviewer's suggestions.

Specifically, we have:

Removed vague and repetitive dynamical statements such as “when tidal currents interact with underwater ridges, the originally linear internal tide waves become steeper and eventually evolve into internal wave packets”. These general descriptions have been consolidated into the introduction (with appropriate references added).

Strictly adhered to the journal's scope (which excludes data interpretation) by removing all statistical interpretations linking ISW generation mechanisms to topography or tides, retaining only objective metrics directly relevant to dataset performance.

Restructured the revised Section 4.1 to highlight the capability of the SWOT_IWD algorithm in recovering ISW signals across all 13 well-known hotspot regions, while keeping only a small set of quantitative metrics for evaluating method performance (e.g., detection counts per region, average confidence scores).

Compressed the original length from approximately eight pages to fewer than two pages, presenting only geographical distribution maps, a detection statistics table, and brief captions, fully in line with the standard format of a data paper.

Once again, thank you for your thorough review and valuable suggestions. In response to your comments, **we have added detailed discussions in Sections 4.1.** The specific changes are located in the revised manuscript as follows:

4.1 SWOT IW spatial distributions (Paragraph 1)

This study utilized SWOT data from 2023 to 2025 to detect internal solitary waves (ISWs) across 13 global marine regions. Figure 8 visualizes the centroids of ISW signal locations for each region, illustrating the spatial distribution of SWOT-observed ISW signals in different oceanic areas.

In the Andaman Sea, SWOT-detected ISW signals densely cover most of the region, exhibiting a continuous spatial distribution. The signals are concentrated between 5°N and 13°N, particularly on both sides of the strait between Car Nicobar and Teresa Island, where the surrounding seabed topography varies significantly. This indicates that SWOT effectively captures ISW signals associated with seafloor topographic variations in this region (Mandal, A. K., 2024; Sun L., 2024; Yu Y., 2023). In the South China Sea, ISW signals are widely distributed, with higher densities in the northern and western parts, mainly between 15°N and 20°N. By utilizing high-resolution sea surface height data, SWOT successfully captures ISW signals over a large extent in the South China Sea, demonstrating its advantages in high-precision ISW monitoring (Z. Li et al., 2024; Bai, X., 2023; Wang J., 2013). In the Sulu Sea, ISW observation points are relatively concentrated, primarily located in areas with greater bottom depths between 7°N and 10°N. In the Celebes Sea, SWOT-detected ISW signals are densely distributed near straits and in regions connecting the Sulu Sea and the Makassar Strait. Successful observations from SWOT data in these two regions demonstrate its applicability to mesoscale and submesoscale oceanic processes (Huang L., 2024; Huang L., 2025; Rong Y., 2025; Hu B., 2021; Chen X., 2018).

Off Northwest Australia, ISWs are mainly distributed in the transition zone between the continental shelf and the deep-sea basin, especially near straits and submarine ridges (Holloway P. E., 2023; Whitwell C. A., 2024; Rayson M. D., 2019). In Indonesian waters, ISWs exhibit an extremely broad distribution, covering almost the entire Indonesian archipelago and adjacent seas. Dense ISW signals are concentrated in the Celebes Sea, Sulu Sea, Makassar Strait, and Banda Sea, and SWOT data reveal the distribution characteristics of ISWs transitioning from deep water to shallow-water shelves in this region (Purwandana A., 2023; As-Syakur A. R., 2025; Purwandana A., 2022). In the Eastern Equatorial Indian Ocean, SWOT detects widely distributed ISW signals, mainly concentrated in the equatorial region between 0° and 10°N, covering waters from 86°E to 94°E, with particularly high observation densities near the Seychelles and the Maldives (Meng J., 2022; Zhuang Z., 2022; Da Silva J. C. B., 2015; Morozov E. G., 1999). In the Western Equatorial Atlantic, the spatial distribution of ISWs is mainly concentrated in the equatorial region between 3°N and 13°N, spanning a wide area from 30°W to 50°W. Off West Central Africa, ISWs are mainly concentrated in the region between 5°N and 13°N, covering a vast area from 14°E to 29°W. The ISW signals detected by SWOT in open-ocean regions are spatially correlated with straits, deep-sea basins, and continental shelf boundaries, with distribution ranges extending up to hundreds of kilometers (Santos-Ferreira A. M., 2022; Da Silva J. C. B., 2025). In the Eastern Equatorial Pacific, SWOT-observed ISW signals are mainly concentrated near the equator, covering a broad area from 87°W to 137°W. Additionally, along the Pacific coast of Central America in deep-water regions and near the continental shelf, as well as in areas connecting Northwest South America with the Peru and Colombia straits, SWOT also detects ISW signals (da Silva J., 2025; Santos-Ferreira A. M., 2023; Johnston T. M. S., 2022; van Haren H., 2022).

Overall, the ISW signals successfully detected by the SWOT satellite across the 13 global marine regions exhibit spatial distributions that are in good agreement with ISW hotspots documented in the existing literature. These observations confirm the effectiveness and coverage capability of SWOT for high-resolution ISW monitoring over vast oceanic areas.

4. The most relevant information in this subsection is the geographical distribution of detections, compared with state-of-the-art knowledge, and it could be summarised in one page of text. Some of the sentences in this subsection are incorrect. For example, line 274 states: 'The generation of internal waves is intensified by nonlinear amplification of internal tides' - > non-linear internal waves result from non-linear effects either modifying internal tide generation (baroclinic conversion) or propagation (after generation); line 366: 'As tidal currents pass over seafloor undulations, [...] causing internal tides to evolve into internal waves' — vertical stratification and non-linear effects do not increase as a result of tidal currents passing over seafloor undulations, and ITs do not evolve into non-linear IWs.

[Response]:

We thank the reviewer for further pointing out the specific incorrect sentences in Section 4.1 (e.g., line 274 and line 366), as well as the suggestion to condense the comparison between the geographical distribution of detections and state-of-the-art knowledge into one page of text. We fully accept these criticisms and apologize for the errors.

Regarding the two incorrect statements identified by the reviewer:

The original sentence at line 274 and line 366 has been deleted, because vertical stratification and non-linear effects do not increase as a result of tidal currents passing over seafloor undulations, and internal tides do not simply “evolve” into non-linear internal waves.

In addition, following the reviewer's suggestion, we have condensed the comparison between the geographical distribution of detections and existing prior knowledge to less than one page, retaining only the core comparative conclusions and key statistical metrics, without repeating lengthy descriptions of each hotspot.

We thank the reviewer again for their rigorous and constructive feedback.

5. sect. 4.3: It is unclear whether the same machine-learning detection algorithm is used for SAR and optical images as for SWOT KaRIN data. If so, is it trained differently? Is it

intended to work optimally with this type of data?

[Response]:

We thank the reviewer for this valuable comment. We realize that the description in the manuscript may not have been sufficiently clear and could have led readers to assume that the same machine-learning algorithm was applied to SWOT KaRIN, SAR, and optical imagery. However, this is not the case.

For SWOT KaRIN data, we developed and trained a dedicated deep-learning detection model (SWOT_IWD). The model was trained using sea surface height anomaly (SSHA) observations derived from the SWOT interferometric altimeter and was specifically optimized to capture the characteristic signatures of internal solitary waves (ISWs) in SWOT data. As a result, it can effectively detect the submesoscale sea-surface perturbations induced by ISWs.

For SAR and optical imagery, no machine-learning detection algorithm was applied in this study, and the SWOT_IWD model was not transferred to these datasets. The primary reason is that the sensing mechanisms of these sensors differ substantially. SWOT KaRIN measures sea surface height anomalies, whereas SAR and optical imagery mainly capture surface roughness modulation and reflectance-related features. Owing to these fundamental differences in observation physics, directly applying a model trained on SWOT data to SAR or optical imagery would likely result in significantly degraded performance.

Therefore, SAR and optical datasets were analyzed using a combination of manual visual interpretation and previously published ISW event databases. We first collected ISW events that had been confirmed in the literature or public datasets and then conducted additional visual inspections to ensure the reliability and completeness of the regional statistics. These high-confidence reference samples were also used for quality control of the SWOT detection results, including the addition of missed ISW events and the removal of obvious false detections.

It should be emphasized that this study does not claim to provide an optimal detection algorithm for SAR or optical imagery. Instead, the primary objective of the multi-sensor comparison is to use high-confidence reference samples to evaluate the performance of the SWOT dataset and to assess the spatial and temporal observational capabilities of different sensors for ISW detection. The development of a unified cross-sensor detection framework is beyond the scope of the present study and will be explored in future work.

6. I think these statements are incorrect with regard to SWOT capacities. It does not improve the temporal resolution (lines 69, 521 and 559): the revisit time remains very long at 21 days, the same as for conventional altimeters. Furthermore, it is sensitive to weather conditions; in particular, data are unavailable under heavy rain (line 524), although not as sensitive as optical images, for example.

[Response]:

We thank the reviewer for this valuable comment and agree that the original statements regarding SWOT's temporal resolution and all-weather observational capability were not sufficiently accurate and could be misleading.

Regarding the statement that SWOT improves temporal resolution, our original intention was to emphasize that SWOT observations can partially complement the spatial and temporal coverage gaps of existing optical and SAR observations, thereby enhancing the overall continuity of multi-sensor monitoring of internal solitary waves (ISWs). However, as correctly pointed out by the reviewer, SWOT retains a revisit period of approximately 21 days, which is comparable to that of conventional satellite altimeters and does not fundamentally improve temporal resolution. Therefore, we have revised the relevant statements throughout the manuscript and removed wording suggesting an increase in temporal resolution. Instead, we now emphasize the complementary role of SWOT relative to SAR and optical observations.

Following the reviewer's suggestion, we have revised the relevant statements in Lines 69, 521, and 559. In response to the reviewer's comment, the statement has been revised as follows:

Line 69:

SWOT can obtain high-resolution SSH observations over a wide swath, helping to overcome limitations of traditional observations in spatial coverage and providing new opportunities for investigating the spatiotemporal distribution and dynamics of large-scale internal waves.

Line 521:

These findings highlight the capability of SWOT to provide high-resolution SSH observations with broad spatial coverage and offer valuable new datasets for ISW research.

Line 559:

Overall, SWOT provides unique capabilities for ISW monitoring through its wide-swath, high-resolution SSH observations. As a complementary observation platform to existing optical and SAR sensors, it offers valuable support for the spatiotemporal analysis of ISW.

We also appreciate the reviewer's comment regarding the sensitivity of SWOT observations to weather conditions. We agree that KaRIN measurements can be significantly degraded under heavy rainfall conditions and may become unsuitable for reliable ISW detection. Consequently, we have revised the manuscript to explicitly acknowledge this limitation and clarify that SWOT is not a completely weather-independent observing system.

At the same time, we note that SWOT is generally less sensitive to weather conditions than optical remote sensing. Optical imagery is often unavailable under cloud-covered conditions, whereas SWOT observations remain usable under most weather conditions except during intense precipitation events. Accordingly, we have revised the manuscript to state more accurately that SWOT can partially fill observational gaps associated with cloud contamination in optical imagery, rather than claiming a fully all-weather observational capability.

Following the reviewer's suggestion, we have added a discussion in Line 524 describing the limitations of SWOT observations under heavy rainfall conditions.

Line 524:

Additionally, although SWOT observations can be affected by heavy precipitation, they are generally less sensitive to atmospheric conditions than optical observations. Combined with its high-precision imaging capability, SWOT provides valuable support for internal wave observation and analysis.

7. l.566-568: This statement about transitioning from 2D to 3D (spatially?) characterisation based on remote observations is highly speculative and not supported by any references or evidence to suggest that it is plausible. Please consider either removing this statement or providing additional evidence.

[Response]:

We thank the reviewer for pointing out that the original statement about "transitioning from 2D to 3D characterisation" (lines 566–568) was insufficiently supported by references and appeared speculative. We fully agree with this criticism, and we apologise for the lack of rigour in the original wording. In the revised manuscript, we have rewritten this statement and added proper citations to provide a solid scientific basis.

To clarify what we mean by "the third dimension": Conventional optical and SAR images provide only two-dimensional plan-view information on sea surface brightness or roughness contrasts, with no direct observation of the vertical dimension. Traditional satellite altimeters (e.g., Jason series, Sentinel-3) measure vertical sea surface height but only along one-dimensional nadir tracks, lacking spatially continuous sea surface topography and offering very limited spatial resolution. In contrast, SWOT differs fundamentally from these conventional sensors: it provides high-precision Sea Surface Height Anomaly (SSHA) data in a continuous two-dimensional grid format. This effectively upgrades the observational dimension from "2D sea surface texture" to "3D sea surface topography (2D + SSH)". The "third dimension" we refer to is precisely this vertical sea surface elevation information.

The following peer-reviewed studies directly support this statement and have been added to the reference list:

1) Zhang et al. (2024, Journal of Oceanology and Limnology) explicitly states: "The transition from two-dimensional to three-dimensional sea surface observational information offers new perspectives for internal solitary wave research" and "SWOT's capability to capture three-dimensional sea surface information represents a significant advancement".

2) Wang et al. (2026, JGR Oceans) demonstrates that the three-dimensional sea surface observations provided by SWOT offer crucial observational data for ISW amplitude inversion.

3) Wang et al. (2026, Journal of Oceanology and Limnology) explicitly states that "SWOT can generate high-precision three-dimensional sea surface topography" and directly uses SWOT three-dimensional sea surface topography data to invert the along-crest distribution of ISW amplitude.

References

Zhang X, Li X. Unveiling three-dimensional sea surface signatures caused by internal solitary waves: insights from the surface water ocean topography mission[J]. Journal of Oceanology and Limnology, 2024, 42(3): 709-714.

Wang T, Huang X, Yang Y, et al. Three-dimensional evolution of internal solitary waves in the northern South China Sea revealed by SWOT observations[J]. Journal of Geophysical Research: Oceans, 2025, 130(12): e2025JC023050.

Wang X, Wang J, Zhang X, et al. SWOT observation revealed internal solitary wave characteristic variations in the Lombok Strait[J]. Journal of Oceanology and Limnology, 2026, 44(1): 71-84.

Minor comments

1. 1.6: "downloaded" is not very relevant for the abstract

[Response]:

We thank the reviewer for the comment. We agree that the term "downloaded" is not appropriate in the context of the abstract, as it emphasizes the data acquisition process rather than the scientific content of the study. Accordingly, we have revised the sentence to focus on the dataset size and subsequent analysis. In response to the reviewer's comment, the statement has been revised as follows:

A total of 21,682 SWOT passes were analyzed for internal wave detection across different regions, identifying 2,011 passes containing ISW signals and detecting a total of 3,264 ISW signals.

2. 1.12: "detection availability" is not very clear as it has not been defined yet

[Response]:

We thank the reviewer for the comment. We agree that the term "detection availability" is not sufficiently clear when first introduced in the abstract and may lead to ambiguity. The metric refers to the proportion of SWOT observation passes in which at least one ISW was detected. To improve clarity, we have replaced the original term with a more explicit description in the revised manuscript. In response to the reviewer's comment, the statement has been revised as follows:

The results indicated that up to 29.78% of SWOT observation passes contained detectable ISW signatures.

3. 1.12: I do not understand this sentence: this is a deep-learning based ISW dataset that can provide support for deep-learning based ISW detection?

[Response]:

We thank the reviewer for pointing out that the original sentence was confusing. We agree that the logic was unclear and could easily mislead readers. We have rewritten this sentence in the revised manuscript as follows:

"The dataset is not only constructed using a deep-learning method, but is also publicly released in a standard deep-learning format (images with bounding-box labels), which can provide training and test samples for other deep-learning models aimed at internal solitary wave detection."

To clarify: we originally intended to convey two points, but failed to separate them clearly:

Construction method: The dataset was built by automatically detecting and annotating

ISW packets from SWOT data using a deep-learning algorithm (SWOT_IWD). Deep learning served as a tool for constructing the dataset.

Reuse value: The dataset itself (image patches and corresponding bounding-box labels) can serve as training/validation/test samples for other researchers to train or evaluate their own deep-learning models for different scientific problems (e.g., improving detection accuracy, transferring to other regions, or fusing multi-source data).

High-quality, well-labeled deep-learning datasets are still relatively scarce in the field of ocean remote sensing, especially for internal solitary waves. The initial label set we generated using a carefully designed model does not preclude its use for training other models. In fact, any supervised learning dataset must be constructed by some method (manual, semi-automatic, or fully automatic). Our dataset has high confidence (thanks to post-processing quality control) and follows a standard format, which is precisely one of its core values: it can be independently used by third parties.

We have revised the sentence accordingly in the manuscript. Thank you again for the helpful comment.

4. l.25: "three-dimensional" can be misleading: is it 2D + time?

[Response]:

We thank the reviewer for raising this important point. We agree that the term “three-dimensional” may be ambiguous and could be interpreted in different ways, including as “2D + time”. Our original intention was to refer to the combination of horizontal spatial information (longitude and latitude) with sea surface height anomaly (SSHA) measurements provided by SWOT, rather than a temporal dimension or direct three-dimensional observations of the ocean interior.

5. l.95: since this is a data paper, and SWOT is central here, I guess the authors want to be very precise. I suggest mentioning that the KaRIN swath is not continuous, but rather consists of two 50 km-wide swaths separated by a 20 km gap (with a NADIR altimetry track at its center, which is not used here as far as I understand).

[Response]:

We thank the reviewer for this valuable suggestion. To ensure the highest precision in this data paper, we have revised the description of the SWOT KaRIN swath accordingly. Specifically, we now explicitly state that the KaRIN swath is not continuous but consists of two 50 km-wide swaths separated by a 20 km gap, with a nadir altimetry track located at the center of the gap. We also clarify that the nadir altimetry data are not used in this study. The relevant text has been amended in the revised manuscript. We appreciate the reviewer’s careful reading and helpful suggestion. In response to the reviewer's comment, the statement has been revised as follows:

Its primary payload is the Ka-band Radar Interferometer (KaRIN), which adopts a dual-antenna interferometric configuration with a 10 m baseline and a central frequency of 35.75 GHz. KaRIN provides high-resolution sea surface height observations over two approximately 50-km-wide swaths separated by a central gap of approximately 20 km. A nadir altimetry track is located within the gap, this observing geometry enables high-resolution two-dimensional measurements of sea surface height over a broad spatial extent. However, nadir altimetry measurements are outside the scope of the present study and were therefore not included in the data processing or subsequent analysis.

6. Figure 1: what is the duration corresponding to this orbit coverage? One full cycle (21 days)?

[Response]:

We thank the reviewer for this helpful question. Yes, Figure 1 represents the orbit coverage of one complete SWOT repeat cycle. Specifically, the figure was generated using data from Cycle 014, including Pass 001 to Pass 584, covering the period from 17 April 2024 to 8 May 2024. This corresponds to one full SWOT repeat cycle of approximately 21 days. To improve clarity, we have added this information to the figure caption in the revised manuscript. In response to the reviewer's comment, the statement has been revised as follows:

Figure 1: SWOT orbit coverage and distribution map of ISW-prone regions. The orbit coverage is derived from SWOT Cycle 014 (Pass 001–584), corresponding to one complete 21-day repeat cycle from 17 April 2024 to 8 May 2024. The highlighted regions indicate major global hotspots of ISW activity used in this study.

7. Figure 2: although informative, this kind of composite image can be a bit misleading, as it corresponds to non-sequential paths merged together. Please add further information, at least the time of the different paths (e.g. min and max), and/or the cycles included.

[Response]:

We thank the reviewer for this important comment. We agree that composite images generated from multiple non-continuous SWOT passes may potentially give the impression that all features were observed simultaneously.

To clarify, Figure 2 is indeed a composite visualization constructed from multiple SWOT passes over the same region rather than a single overpass. The purpose of this figure is to illustrate the spatial characteristics and coverage of SWOT KaRIN sea surface height anomaly (SSHA) observations in representative internal-wave-prone regions, rather than to represent a temporally continuous ocean state. Specifically, Figure 2(a) was generated using ascending-pass observations from SWOT Cycle 037 over the Western Equatorial Indian Ocean, while Figure 2(b) was generated using ascending-pass observations from SWOT Cycle 037 over the Western Equatorial Atlantic Ocean. Areas without valid observations correspond to missing KaRIN measurements in the original data. In response to the reviewer's comment, the statement has been revised as follows:

Figure 2: Composite SWOT KaRIN SSHA observations in representative ISW-prone regions. (a) Western Equatorial Indian Ocean and (b) Western Equatorial Atlantic Ocean. Each panel is constructed by combining multiple ascending SWOT passes from Cycle 037 and is intended to illustrate the spatial coverage and characteristics of the observations rather than a simultaneous ocean state. Blank areas indicate locations with no valid KaRIN measurements.

8. 1.140: I think it is widely accepted, or at least debatable, that the term 'artificial intelligence' is inappropriately used to refer to the concept of 'intelligence'. Therefore, I would strongly advise against using the adjective 'intelligent' in any scientific paper when referring to an automated machine learning algorithm, such as the one presented in your

study and used to build the NLIW dataset.

[Response]:

We thank the reviewer for this valuable comment. We agree that the term “intelligent” may be inappropriate or potentially misleading when referring to machine learning–based detection algorithms. To improve scientific accuracy and avoid anthropomorphic interpretations, we have revised the manuscript and replaced such expressions with more precise terms, including “machine learning–based”, “deep learning–based”, or “automated” detection methods where appropriate. In response to the reviewer's comment, the statement has been revised as follows:

To enable deep learning–based detection of ISW from SWOT data, this study introduces the SWOT_IWD model, specifically designed for SWOT altimeter data.

9. l.218 - 223: please add details about the FFT and DWTs used in the study: first, is it 1D or 2D. l.221: spatiotemporal is likely wrong (it is just "spatial", isn't it?).

[Response]:

We thank the reviewer for this valuable comment. We apologize that the description of the FFT and DWT image enhancement procedures was not sufficiently detailed in the original manuscript. To clarify, both the Fast Fourier Transform (FFT) and the Discrete Wavelet Transform (DWT) used in this study were implemented as two-dimensional (2D) image-processing operations applied to SWOT sea surface height anomaly (SSHA) images.

For the FFT-based enhancement, a 2D Fourier transform was first applied to the input image. Low-frequency components located near the center of the frequency spectrum were then suppressed by setting the central frequency region to zero. Specifically, a 10 × 10 window centered on the spectrum origin (implemented as dft_shift[crow-5:crow+5, ccol-5:ccol+5] = 0) was removed. After inverse Fourier transformation, the resulting image exhibited enhanced high-frequency features, such as internal wave edges and texture patterns.

For the DWT-based enhancement, a two-dimensional Discrete Wavelet Transform using the Haar wavelet was applied to the input image. The decomposition generated one approximation coefficient component (cA) and three detail coefficient components corresponding to horizontal (cH), vertical (cV), and diagonal (cD) high-frequency information. Different coefficient maps were evaluated for internal wave feature enhancement, and the horizontal detail coefficient (cH) was ultimately selected because it provided the clearest representation of internal wave texture features in the SWOT images.

To improve reproducibility, we have added these implementation details to the revised manuscript. In response to the reviewer's comment, the statement has been revised as follows:

2.4.1 SWOT ISW imagery

To enhance the banded texture characteristics of internal solitary waves (ISWs), two-dimensional Fast Fourier Transform (2D FFT) and two-dimensional Discrete Wavelet Transform (2D DWT) were applied to SWOT Sea Surface Height Anomaly (SSHA) images. For the FFT-based enhancement, the image was transformed from the spatial domain into the frequency domain, where low-frequency components near the center of the spectrum were suppressed to reduce large-scale background signals and enhance high-frequency features associated with ISW textures and edges. The enhanced image was then reconstructed through the inverse Fourier transform. For the DWT-based enhancement, a two-dimensional Haar wavelet decomposition was performed, producing one approximation coefficient component (cA) and three detail coefficient components corresponding to horizontal (cH), vertical (cV), and diagonal (cD) high-frequency information. After comparing the enhancement performance of different coefficient components, the horizontal detail coefficient (cH), which provided the clearest representation of ISW banded structures, was selected as the output feature image. The combination of FFT-based frequency-domain enhancement and DWT-based multi-scale feature extraction improves the visibility and contrast of ISW signatures while suppressing non-ISW background signals.

It should be noted that the generated three-channel composite TIFF images are used solely for visualization and quality control of ISW detection results and are not included as image layers in the released dataset. The dataset itself is derived exclusively from the SWOT L2 LR SSH Expert.nc product. The composite images are intended only to provide a clearer visual representation of sea surface height features after frequency-domain and multi-scale enhancement, thereby facilitating ISW identification and manual verification.

10. Figure 5: I cannot really see any NLIW packet except in the upper half of the red box. Is there something else to see?

[Response]:

We thank the reviewer for this careful observation. We agree that the internal solitary wave (ISW) signature is most clearly visible in the upper portion of the red bounding box, while the features in the lower portion are comparatively weaker and less visually apparent. However, after careful examination, we found that additional wave-like structures are present in the lower part of the detection box, although their contrast is lower in the SWOT image. To further verify the interpretation, we compared the SWOT observations with nearly coincident optical imagery and identified ISW signatures at approximately the same location. This independent evidence supports the presence of an ISW packet extending beyond the most visually prominent portion of the feature.

11. 1.398: I think you are describing the generation of internal tides, but not of solitary waves, which are also generated at the Amazon shelf break.

[Response]:

We thank the reviewer for pointing out this important distinction. We agree that the original text primarily described the generation mechanism of internal tides rather than that of internal solitary waves (ISWs). The original wording was therefore not sufficiently accurate and could potentially lead to confusion between the generation of internal tides and the subsequent formation of ISWs. Following the reviewer's suggestion, we have thoroughly revised the relevant section.

12. 1.409: Grigorenko et al 2016, Vic & Ferron 2023 are not about ISWs.

[Response]:

We thank the reviewer for identifying this issue. We agree that the references by Grigorenko et al. (2016) and Vic & Ferron (2023) are not specifically related to internal solitary waves (ISWs) and were therefore not appropriate citations in this context. This was an oversight on our part, and we apologize for the mistake. Following the reviewer's suggestion, we have carefully reviewed the relevant references and revised the corresponding text. The inappropriate citations have been removed.

13. 1.417: Authors claim that (nonlinear) IW can be generated by TIWs. I was not aware of that. Is there any reference on the subject?

[Response]:

We thank the reviewer for pointing out this issue. We agree that our original statement regarding the generation of (nonlinear) internal waves by tropical instability waves (TIWs) was not sufficiently supported by the available literature. This was an error on our part, and we apologize for the inaccurate statement. Following the reviewer's comment, we have carefully re-examined the relevant literature and thoroughly revised Section 4.1. The unsupported statement has been removed, and the corresponding discussion has been rewritten to ensure consistency with the current scientific understanding and available references.

14. 1.477: the fact that "a single remote sensing dataset is inadequate for monitoring the continuous variation of (nonlinear) internal waves" has not been explicitly discussed, and by no means "demonstrated".

[Response]:

We thank the reviewer for this insightful comment. We agree that the original wording was too strong and that our analysis does not strictly "demonstrate" the inability of a single satellite dataset to monitor the continuous variation of internal solitary waves.

Our intention was to highlight the practical limitations of individual remote sensing datasets in achieving continuous observational coverage of ISWs. Factors such as revisit intervals, cloud contamination in optical imagery, weather-related data gaps, and spatial coverage limitations may result in incomplete observations when relying on a single sensor. To avoid overstatement, we have revised the corresponding sentence to emphasize the complementary nature of different remote sensing datasets rather than claiming that the limitation was explicitly demonstrated by our results.

4.4 Internal Wave Tracking Using Multi-Source Data

The statistical results from different remote sensing datasets suggest that no single satellite sensor can provide complete and continuous observational coverage of internal solitary waves. Limitations associated with revisit intervals, weather conditions, and data availability may result in observational gaps when relying on a single data source. The inclusion of SWOT data complements existing optical and SAR observations, improving the temporal continuity and spatial completeness of multi-source ISW monitoring and enhancing the capability to track ISW events across different regions and observation periods.

15. Fig. 10 and 11: Fig 11 is not very informative compare with Fig 10. Maybe the paper could be shortened by merging the two figures (or removing Fig 11). Besides, I do not see the point of the (very short) discussion dedicated to Fig 10 (l. 482 - 484). Besides, Fig 12 and text 1. 510 to 517 is also redundant with these 2 Figures and associated discussion (apart from the fact that it compares SWOT to optical images, not SAR images)

[Response]:

We thank the reviewer for the constructive comments regarding the redundancy among Figures 10–11 and the clarity of Figure 12.

Following the reviewer's recommendation, we have merged Figures 10 and 11 into a single figure and reorganized the corresponding discussion. The revised figure provides a more concise and integrated presentation while preserving the key information required to support our conclusions. We have also shortened and streamlined the discussion associated with the original Figures 10 and 11 to reduce redundancy.

We also acknowledge the reviewer's comment regarding the clarity of Figure 12. We agree that the distinction of the internal wave signal in the original version was not sufficiently clear. To address this issue, we have revised Figure 12 to improve its interpretability. In the updated version, clearer visual indicators (yellow dashed lines) have been added to explicitly highlight the regions where differences between SWOT and Sentinel-3 OLCI observations are observed. These modifications enhance the visual clarity of the figure and make the comparison between the two datasets more explicit and easier to interpret. In addition, because the original Figures 10 and 11 have been merged into a single figure, the original Figure 12 has been renumbered as Figure 11 in the revised manuscript. In response to this suggestion, the specific modifications made in the revised manuscript are as follows:

4.4 Internal Wave Tracking Using Multi-Source Data

As shown in Figure 10, on 11 March 2024 at 09:18:39 UTC, SWOT detected an internal solitary wave signal. Figure 10(a) presents the SWOT sea surface height anomaly (SSHA) observation, while Figure 10(b) shows the corresponding Sentinel-1 C-SAR image acquired on 12 March 2024 at 21:48:55 UTC. Figure 10(c) provides a combined visualization of the two datasets, with the red box indicating the region where the internal wave signal is observed. Figures 10(d–g) present a quantitative profile-based comparison of two representative internal wave locations. Figures 10(d–e) show SSHA variations extracted from SWOT data at ISW1 and ISW2, respectively, while Figures 10(f–g) present the corresponding Sentinel-1 Sigma0 backscatter profiles at the same locations. The results indicate that the SWOT SSHA profiles and SAR Sigma0 profiles exhibit consistent spatial patterns, including comparable peak-to-trough structures and similar phase variation tendencies, demonstrating the coherence of internal wave signatures across the two independent remote sensing datasets.

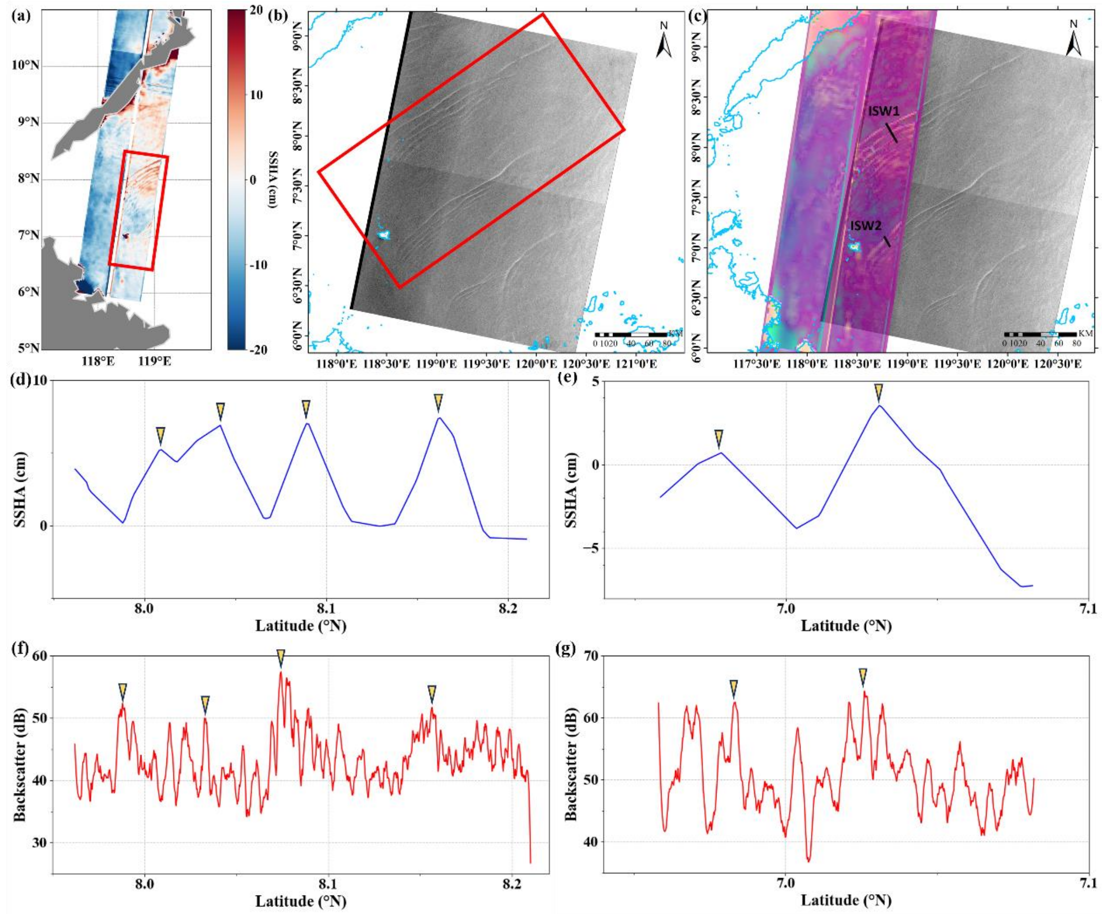

Figure 10. Multi-source analysis of an internal solitary wave (ISW) event detected by SWOT on 11 March 2024 at 09:18:39 UTC. (a) SWOT sea surface height anomaly (SSHA) observation; (b) corresponding Sentinel-1 C-SAR backscatter image acquired on 12 March 2024 at 21:48:55 UTC; (c) overlay of SWOT and SAR observations highlighting the ISW location (red box). (d–e) SSHA profiles extracted from SWOT data at two ISW locations (ISW1 and ISW2); (f–g) Sentinel-1 normalized radar cross-section (Sigma0) profiles at the same locations, showing the corresponding internal wave signatures in SAR observations.

4.5 Unique Signals Observed by SWOT

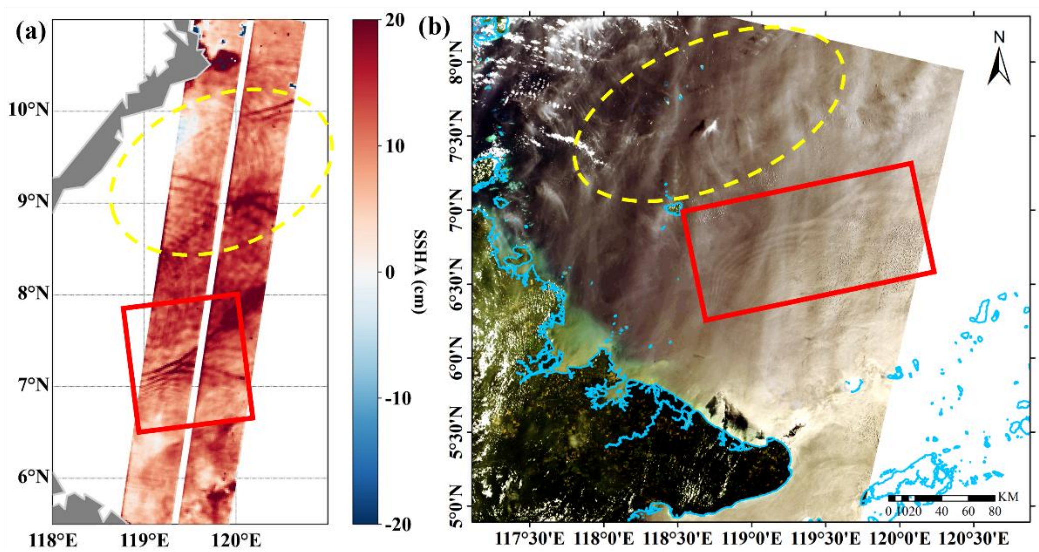

Figure 11. An example of an internal solitary wave (ISW) detected by SWOT on 04 September 2024 at 05:40 UTC. (a) SWOT sea surface height anomaly (SSHA) observation; (b) corresponding Sentinel-3 OLCI optical image acquired at 02:15 UTC on the same day. The red box indicates the region where the internal wave signal is observed. The yellow dashed lines highlight the internal wave-related features that are clearly captured in the SWOT observation but are not distinctly visible in the optical image.

16. l.492: It should be made very clear as soon as possible that the different snapshots show different ISW packets as these propagate fairly rapidly (a few metres per second). This is the first explicit mention of this and it may mislead the reader. In particular, this information is lacking in l.255 and below, and the captions of Figures 5, 6 and 7 are strongly misleading in this regard.

[Response]:

We thank the reviewer for pointing out this important issue. We agree that the original wording could mislead readers into interpreting the SWOT and Sentinel-1 observations as representing the same ISW packet. Given that internal solitary waves typically propagate at speeds of several meters per second, a wave packet observed 36 hours later would have travelled far from the original location.

Our intention was not to imply that the two observations correspond to the same ISW packet, but rather to highlight the recurrence of ISW generation in this region under similar tidal forcing conditions. Following the reviewer's suggestion, we have revised the text to explicitly clarify that the SWOT and Sentinel-1 observations likely correspond to different ISW packets generated during successive tidal cycles. We also emphasize that the observed similarity in spatial distribution and morphology reflects the reproducibility of ISW generation and propagation patterns in the region, rather than the persistence of an individual wave packet.

In addition, we have carefully reviewed the related descriptions, including the text around Line 255 and the captions of Figures 5–7, to avoid similar ambiguity elsewhere in the manuscript.

3 ISW signature extraction and validation

It should be noted that the multi-sensor comparisons shown here involve observations acquired at different times, which is an inherent limitation of such synergy. Given that internal solitary waves typically propagate at speeds of several meters per second, we consider that ISW packets observed within the same semi-diurnal tidal cycle are likely the same packet, whereas those separated by more than one semi-diurnal cycle are treated as distinct packets generated in the region under successive tidal forcings. This temporal mismatch does not undermine the qualitative value of these comparisons, as the recurring spatial patterns still support the reproducibility of ISW generation in this region.

Figure 5. Example of an ISW detected by SWOT on 02 January 2024 at 07:50 UTC. (a) corresponds to the SWOT data, while (b) shows the optical image (from Sentinel-3 OLCI, 01 January 2024 at 02:15 and 02:18 UTC). The red boxes indicate the locations of the ISW in the corresponding data.

Figure 6. Example of an ISW detected by SWOT on 13 January 2024 at 06:13 UTC. (a) corresponds to the SWOT data, while (b) shows the SAR image (from Sentinel-1 C-SAR, 12

January 2024 at 21:49 UTC). The red boxes indicate the locations of the ISW in the corresponding data.

Figure 7. Example of an ISW detected by SWOT on 25 March 2024 at 03:09 UTC. (a) corresponds to the SWOT data, (b) shows the SAR image (from Sentinel-1 C-SAR, 12 March 2024 at 21:49 UTC), and (c) displays the optical image (from Sentinel-3 OLCI, 26 March 2024 at 02:15 UTC). The red boxes indicate the locations of the ISW in the corresponding data.

4.4 Internal Wave Tracking Using Multi-Source Data

A comparison reveals that the ISW signatures observed by SWOT and Sentinel-1 C-SAR, although acquired approximately 36 hours apart, exhibit similar spatial distributions and morphological characteristics. It should be noted that these observations do not correspond to the same internal wave packet, as internal solitary waves propagate rapidly and would have travelled far from the observed region during this time interval. Instead, the two observations likely represent different ISW packets generated during successive tidal cycles. The recurrence of wave signatures in similar locations, together with their comparable spatial patterns, suggests that ISW generation and propagation in this region are strongly controlled by semi-diurnal tidal forcing, resulting in recurrent wave events with relatively stable spatial characteristics.

17. 1.511: 'Surprisingly': this is not surprising at all. The paper refers to the periodicity of ISW packet generation multiple times (essentially reflecting the period of barotropic tidal forcing), so this repeatability at one M2 time period interval is very much expected. Line 528: Is it Level 3 or Level 2 SWOT data? Line 97: The authors mention that Level 2 data is used in this study.

[Response]:

We thank the reviewer for this careful and helpful comment. We agree that the use of “Surprisingly” was inappropriate. Given the approximately semi-diurnal periodicity of ISW packet generation associated with barotropic tidal forcing, the occurrence of a similar ISW signature after an interval close to one M2 tidal period is expected rather than unexpected. We have therefore revised the corresponding text to remove the term “Surprisingly” and to clarify that the two observations likely represent different ISW packets generated during successive tidal cycles, rather than the same propagating wave packet.

We also thank the reviewer for identifying the inconsistency in the description of the SWOT data product level. The SWOT dataset used throughout this study is the Level 2 product, as stated in Section 2. The reference to Level 3 data in the original manuscript was an error and has been corrected to Level 2 in the revised manuscript.

4.5 Unique Signals Observed by SWOT

Approximately 12 hours later, on 26 April 2024 at 02:11:29 UTC, a similar internal wave signature was observed in the Sentinel-3 OLCI optical image (Figure 13(b)). This time interval is close to one M2 tidal period; therefore, the two observations likely represent different ISW packets generated during successive tidal cycles rather than the same propagating wave packet. Figure 13(c) shows an overlay of the two observations, illustrating their similar spatial distributions and morphological characteristics.

5 Data availability

The SWOT Level-3 KaRIn SSH data are available from the AVISO+ repository for ocean products: https://aviso-data-center.cnes.fr/user/ssalto/modules/3652.

18. l.541: The 'complexity of the internal wave generation mechanism' does not favour observations of nonlinear internal wave (IW) packets. IW generation can be fairly complex while remaining in the linear regime, or it can occur in fairly simple situations (strong tidal flow and marked topography) and consistently give rise to nonlinear internal wave (NLIW) packets.

[Response]:

We thank the reviewer for this important clarification. We agree that the original statement was imprecise, as the complexity of internal-wave generation mechanisms does not necessarily favor the occurrence or observation of nonlinear internal-wave packets. To avoid an unsupported causal interpretation, we have removed the relevant conclusion from the revised manuscript.

Typos, etc.

1. l.120: replace comma by a point at the end of the line

[Response]:

We thank the reviewer for this careful observation. The comma at the end of Line 120 has been replaced with a full stop. In addition, we have carefully checked the revised manuscript to ensure that no similar punctuation errors remain. We appreciate the reviewer's attention to detail.

2. l.156: math mode is missing for "pt"

[Response]:

We thank the reviewer for this careful observation. The unit "pt" at Line 156 has been corrected by formatting it in math mode. In addition, we have carefully checked the revised manuscript to ensure that all units and mathematical notation are formatted consistently. We appreciate the reviewer's attention to detail.