Response to the Editor and Reviewer’s

Manuscript Title: *Intraseasonal Variability and Eddy-Induced Structural Modulation of the North Pacific Intermediate Water Revealed by Multi-Mooring Observations*

Dear Editor and Reviewers,

We sincerely thank the Editor and the three anonymous reviewers for their careful evaluation of our manuscript and for their constructive and insightful comments. These comments have been extremely valuable in helping us improve the clarity, methodological rigor, and scientific quality of the manuscript.

Following the Editor and reviewer’s suggestions, we have carefully revised the manuscript. The major revisions include clarifying the definition of the North Pacific Intermediate Water (NPIW), providing a more detailed description of the mooring data processing and interpolation procedures, improving the explanation of NPIW thickness estimation, refining the interpretation of the relationships among mesoscale eddies, sea level anomaly (SLA), salinity, and NPIW thickness, and strengthening the discussion of the relative roles of vertical isopycnal displacement and horizontal water-mass redistribution/mixing. We have also revised the figures, figure captions, references, and grammatical expressions throughout the manuscript.

Below, we provide a point-by-point response to each comment. For clarity, each comment is followed by our corresponding response and, where appropriate, a description of the revisions made in the manuscript.

We hope that the revised manuscript has adequately addressed the Editor and reviewer’s concerns. We are grateful for the opportunity to revise and improve our work.

Sincerely,
The Authors

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1. Response to Reviewer 1

This is my second review of the manuscript "Intraseasonal Variability and eddy-induced structural modulation of the North Pacific Intermediate Water revealed by multi-mooring observations". The authors have made many changes since last version, so I took it as a new paper for my review. I see that great improvements have been made to make the paper stronger. However, some points still to be addressed before I can recommend the acceptance of this manuscript. Some points that have been partly brought up in my previous review may still need some clarification.

1.1 Major Comments

1. The authors have made quite some improvements in the introduction as suggested in my previous review. I have some further comments to paragraph one: Can authors be more specific about the implications and importance of NPIW? These texts in the current version is high-level, and it would be helpful to include some details. The texts can be used on many objects other than NPIW.

Response:
We thank you for the helpful suggestion. In the revised manuscript, we have further specified the importance of NPIW by highlighting its unique role in intermediate-layer ventilation and water mass structure.
The North Pacific Intermediate Water (NPIW) is a pivotal component of the North Pacific's water mass and extensively studied due to its significant role in climate dynamics and oceanic processes (Talley, 1993; Masuda et al., 2003; You et al., 2003; Gong et al., 2019; Nishioka et al., 2020). This water mass originates in the northwestern subtropical gyre, within the transition zone between the Kuroshio Extension and the Oyashio front, is characterized by its low salinity and relatively cooler temperatures at depths of approximately 400 to 1200 meters, also its density is centered around 26.8 σ_θ isopycnal, with a salinity minimum about 34.1 to 34.3. (Talley, 1993, 1995; Yasuda et al., 1997; You et al., 2003; Masujima et al., 2009). NPIW is a key component of the intermediate circulation in the North Pacific and plays an important role in ventilating the thermocline and intermediate layers (Talley, 1997; You, 2003). It forms the prominent salinity minimum layer and contributes to the redistribution of heat, freshwater, and dissolved substances such as oxygen and nutrients (Talley et al., 1993; Hansell et al., 2002; Auad et al., 2003; Zhou et al., 2022). Variability in NPIW can therefore influence both physical circulation and biogeochemical processes in the mid-depth ocean (Tsunogai et al., 2002; Ohkushi et al., 2003).
We have revised the introduction accordingly to better emphasize the specific dynamical and structural importance of NPIW, rather than using general descriptions applicable to other water masses.

2. Line 101-105: It helps clarity to define NPIW. The authors did mention the depth, TS, and density of NPIW in line 82-84. However, after reading these sentences in line

101-105, I only have a vague idea about how NPIW is defined, because NPIW seems to be defined in di erent criteria across literature. If the definition is not a consensus, then explain it and introduce di erent kinds of definitions. For example, water mass within 34.3 isohalines like Figure 2 and section 3.2 is considered as NPIW. In Figure 3, the water mass with minimum temperature and salinity is NPIW. In section 3.2, the water mass between density of 26.4 and 26.9 is NPIW. It also helps to refer to a figure in the introduction about where NPIW is.

Response:

We thank the you for this important comment. As you say, we agree that the definition of NPIW is not entirely uniform in the literature and can be based on different criteria, including salinity minimum, density range, and characteristic isohalines. In the revised manuscript, we have clarified this issue by explicitly distinguishing between different definitions and their respective purposes. Specifically:

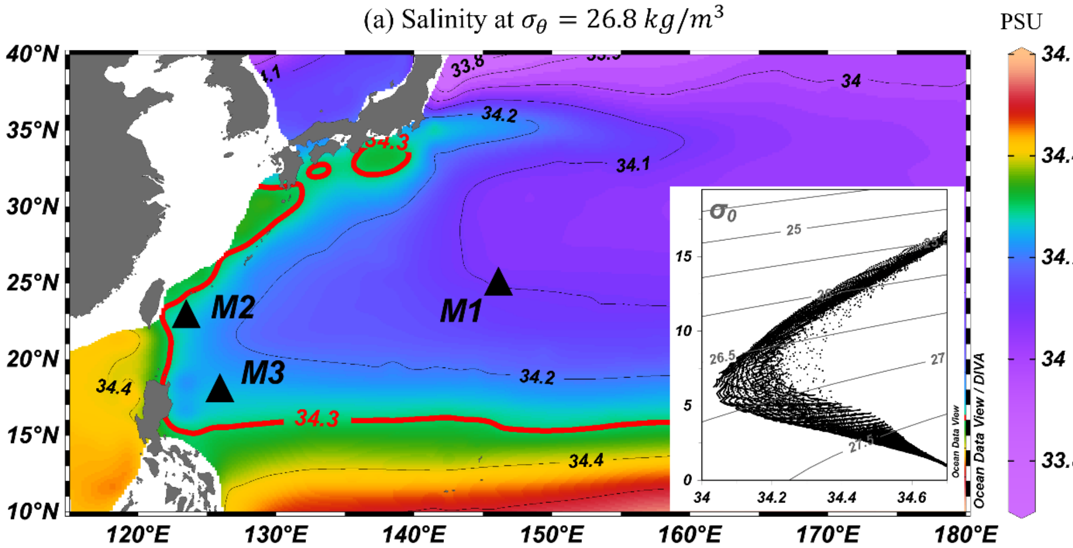
(1) The density range (26.4–26.9 σθ) is used to represent the dynamical layer of NPIW, consistent with previous studies (e.g., Talley, 1993; You et al., 2000).

(2) The salinity minimum is used to identify the core of NPIW, which reflects its characteristic low-salinity signature.

(3) The 34.3 psu isohaline is adopted as a practical boundary to quantify the vertical extent (thickness) of the NPIW layer, representing the upper limit of the low-salinity core.

These definitions are not contradictory but complementary, as they describe different aspects of the same water mass: core properties, dynamical range, and structural extent. To improve clarity, we have revised the manuscripts to explicitly introduce these definitions and their relationships in section 2, and we have added a reference figure showing the typical vertical structure of NPIW.

(a) Salinity at $\sigma_\theta = 26.8\ kg/m^3$



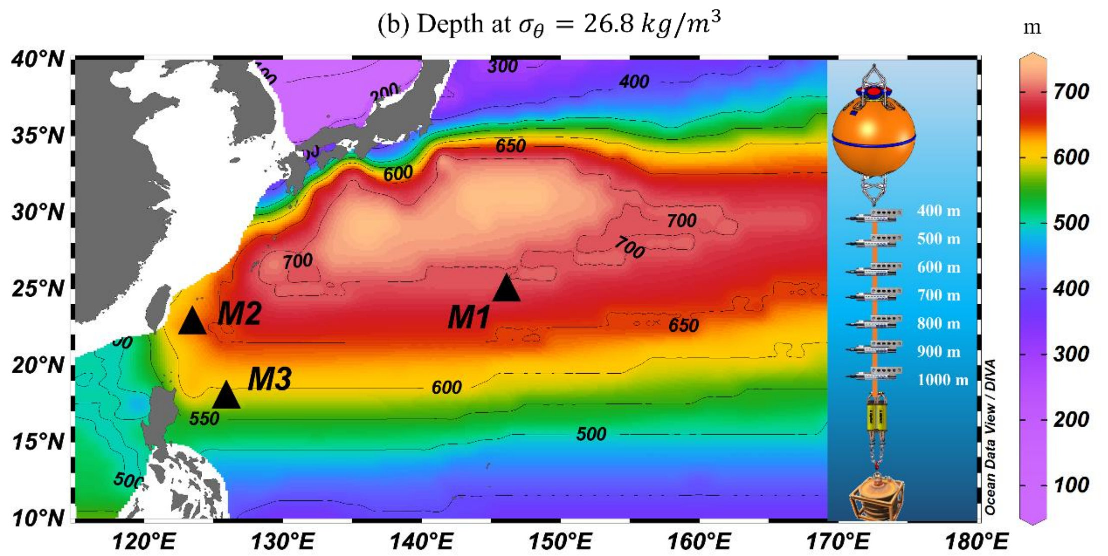


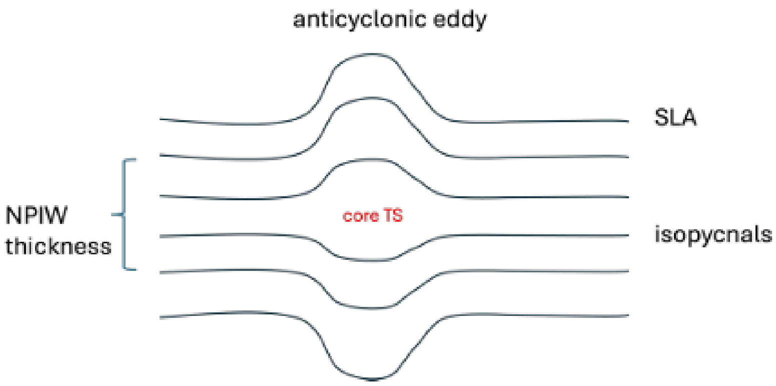
Figure 1. Distribution of salinity (a) and depth (b) along the 26.8σ_θ isopycnals at Northwestern Pacific. The T-S scatter plot in the lower-right corner of (a) illustrates the vertical distribution of NPIW. The color shading and black line in (a) and (b) represent the salinity and depth, respectively. The right-hand side of (b) shows a schematic diagram of the CTD deployment with mooring. The red contours of 34.3 psu is represent the NPIW range from Talley et al. (1993) and You et al. (2003). The black triangle is the mooring location: Mooring 1 (M1), Mooring 2 (M2) and Mooring 3 (M3). Salinity and depth in the Fig. 1 are taken from climatological averaged data from World Ocean Atlas 23, and plot with *Ocean Data View.*

Based on your suggestions, the following content has been added to the revised manuscript:

Despite its broad distribution of NPIW, the definition of NPIW is not entirely uniform in previous studies. It has been identified using different criteria, including the salinity minimum, density ranges (typically 26.4–26.9 σθ), and characteristic isohalines (Talley, 1993; You et al., 2000). These definitions emphasize different aspects of the same water mass, namely its core properties, dynamical layer, and vertical structure. Based on these previous studies, we use the WOA data to illustrate the climatological distribution of NPIW, as shown in Fig. 1. The spatial pattern is consistent with earlier findings (e.g., You, 2003), showing that the NPIW exhibits significant regional variability in its vertical structure. Specifically, the NPIW layer is relatively shallow in the western boundary region, while it deepens toward the interior of the North Pacific. This spatial variability provides an important background for interpreting the mooring observations in this study.

3. The relationship between eddies, SLA, and NPIW thickness need some clarification. In line 352, if the inverse relationship between thickness and salinity is due to mesoscale eddies, does it mean that AE has fresher core and CE and saltier core given their isopycnal shape (see the schematic diagram below)? For example, is it right to consider that AE has convex lens-shaped isopycnals and thus increase the thickness, therefore

the core salinity should be fresher than surroundings so that salinity decreases? Given that the NPIW has fresher cores, should the mixing of water mass always increase the salinity? Then can I interpret that the decrease in core salinity is not related to water mass mixing? The correlation analyses between TS and SLA seems to show that high S corresponds to high SLA, which may suggest that AE has saltier cores. How to reconcile these points?



Response:
We sincerely thank you for your thoughtful and important comment. We agree that the relationships among mesoscale eddies, SLA, salinity variability, and NPIW thickness require a clearer physical interpretation. In the previous version, we did not sufficiently distinguish between different eddy-induced processes, particularly vertical isopycnal displacement and lateral water-mass redistribution/mixing, which may have caused confusion. We have therefore substantially revised Section 4.3 to clarify these mechanisms.
First, we would like to point out that the schematic you have drawn in the Figure represents an important eddy, this lens-shaped isopycnal structure is commonly associated with some subsurface eddies also called thermocline eddies. However, the mesoscale eddies discussed in this study are identified primarily from satellite altimetric SLA signals and are therefore interpreted as surface mesoscale eddies. Within this framework, positive SLA associated with anticyclonic eddy conditions generally corresponds to downward displacement of intermediate-layer isopycnals, whereas negative SLA associated with cyclonic eddy conditions corresponds to upward displacement. Therefore, in the context of the present SLA-based analysis, the anticyclonic eddy conditions are more appropriately interpreted as being associated with downward displacement of intermediate-layer isopycnals.
Second, the observed inverse relationship between NPIW thickness and salinity does not imply that anticyclonic eddies contain fresher cores or that cyclonic eddies contain saltier cores. Instead, this relationship mainly reflects the compression and expansion of the low-salinity NPIW layer under eddy-associated isopycnal displacement. Under anticyclonic conditions, downward displacement of intermediate-layer isopycnals

compresses the low-salinity NPIW layer, resulting in reduced NPIW thickness and relatively higher salinity within the observed depth range. Under cyclonic conditions, upward displacement of isopycnals expands the low-salinity layer and helps preserve the relatively fresher NPIW signal, leading to larger thickness and lower salinity relative to anticyclonic conditions.

We also agree with your point that, since the NPIW is characterized by the lowest salinity, lateral mixing with surrounding waters typically results in an increase in salinity rather than a decrease. Therefore, the lower salinity observed under cyclonic conditions should not be interpreted as freshening caused by mixing. Rather, it is better understood as the preservation or relative enhancement of the pre-existing low-salinity NPIW signal due to isopycnal uplift and reduced intrusion of surrounding higher-salinity waters. In contrast, under anticyclonic conditions, compression of the low-salinity layer, together with possible lateral redistribution and mixing of surrounding higher-salinity waters especially near the western boundary, can lead to elevated salinity within the fixed observational depth range.

Thus, the positive correlation between SLA and salinity in our results is physically consistent: positive SLA/anticyclonic conditions are associated with downward isopycnal displacement, compressed NPIW structure, and relatively higher salinity, whereas negative SLA/cyclonic conditions correspond to upward isopycnal displacement, expanded NPIW structure, and relatively lower salinity. In the revised manuscript, we have clarified that the salinity anomalies discussed here primarily represent structural responses within a fixed-depth intermediate layer, rather than intrinsic salty or fresh cores of individual eddies.

Finally, we appreciate your perspective regarding subsurface lens-like eddies. Such subsurface eddies may indeed have important effects on the structure and low-salinity core of the NPIW. However, identifying and diagnosing such eddies would require higher vertical-resolution hydrographic profiles, velocity observations, and three-dimensional eddy-structure analyses, which are beyond the scope of the present study based on mooring observations. We have therefore avoided extending our interpretation to subsurface eddies in the revised manuscript, and we agree that the influence of different types of eddies on NPIW structure deserves further investigation in future work.

1.2 Minor Comments

Line 85: helps to refer to figure 1 to let readers know the location of this region

Response:

We thank the you for this suggestion. We have added a reference to Fig. 1 to help readers locate the region discussed in the Introduction.

Line 103: I don’t understand what this sentence means here, with the grammar mistake.

Response:

We thank the you for pointing this out. We agree that the original sentence was unclear and grammatically incorrect. In the revised manuscript, we have rewritten this sentence

to clarify the logic. Specifically, we now state that previous studies have shown the broad distribution and regional depth differences of NPIW, and that the WOA-derived distribution shown in Fig. 1 is used to provide hydrographic background for the mooring observations. The revised wording avoids the ambiguous expression and improves the logical flow of the Introduction.
This sentence has been rewritten as:
Previous studies have shown that NPIW spreads widely through the North Pacific and exhibits clear regional differences in its vertical distribution (You, 2003; Fujii et al., 2013). To provide hydrographic background for the present mooring observations, we used WOA data to illustrate the climatological distribution of NPIW in the study region (Fig. 1). The resulting distribution is generally consistent with previous studies, showing that NPIW is relatively shallow near the western boundary and deeper in the interior North Pacific.

Line 111-113: This sentence seems to state that previous studies mostly focus on long time scales, and yet long-term observations are limited. Then what previous studies use to study the NPIW variability over long time scales? Models? This point needs to be clarified.
Response:
We thank the you for pointing out this ambiguity. We agree that the original sentence did not clearly distinguish between previous studies of long-timescale NPIW variability and the lack of continuous high-frequency in situ observations.
In the revised manuscript, we clarified that previous studies on seasonal to interannual or longer-term NPIW variability have mainly relied on hydrographic observations, climatological datasets, Argo profiles, reanalysis products, and numerical models. In contrast, continuous high-temporal-resolution mooring observations remain scarce in the intermediate ocean where the NPIW resides. We also revised the sentence to note that gridded and model-based products may contain uncertainties in representing intermediate-layer salinity structures, which limits their ability to resolve short-term water-mass variability.
The revised text now better explains why the intraseasonal variability and structural adjustment of NPIW remain insufficiently constrained by observations.
The revised sentence is as follows:
However, most previous studies have focused on variability over seasonal to interannual or longer timescales, using hydrographic observations, climatological datasets, Argo profiles, reanalysis products, or numerical models. In contrast, direct long-term observations with sufficiently high temporal resolution remain limited in the intermediate ocean, where the NPIW is located. Moreover, salinity structures in the intermediate layer are not always accurately represented in gridded or model-based products, which may limit their ability to resolve short-term water-mass variability. Therefore, the intraseasonal variability of the NPIW and its structural response to mesoscale processes remain insufficiently understood.

Line 184-188: can authors explain in more detail about the fixed-depth? Previous sentence suggests that CTDs are installed at 100 m vertical spacing, so the fixed depths are every 100 m?

Response:

We thank the you for this helpful comment. We agree that the term "fixed-depth" was not sufficiently clear and could be misleading. In the revised manuscript, we have clarified that the CTD sensors were designed to be deployed between 400 and 1000 m at nominal 100 m vertical intervals, but the actual sampling depths varied slightly with time because of mooring motion under changing currents. The pressure records from each CTD were therefore first used to determine the actual sampling depths at each time step. The temperature and salinity observations were then linearly interpolated onto a common set of standard depth levels for contour plots and depth-dependent analyses. We have revised the wording to describe this as interpolation onto standard depth levels in a unified vertical coordinate system.

The revised paragraphy is as follows:

The deployment depths were carefully designed to span the upper and lower boundaries of the NPIW, ensuring adequate vertical coverage of its structure. The CTD data were first quality controlled before further analysis. Obvious abnormal values and isolated spikes were removed based on instrument records and physically reasonable ranges of temperature, salinity, and pressure. Because slight vertical movement of the mooring line may occur under strong currents, the recorded pressure data were used to determine the actual sampling depths of each CTD at each time step. To obtain uniformly gridded vertical profiles for subsequent analyses including contour plots and depth-dependent temperature/salinity variability, the observations were linearly interpolated between vertically adjacent CTD measurements on the same mooring line onto a common set of standard depth levels.

In addition, local linear interpolation was applied between vertically adjacent CTD sensors on the same mooring line that bracketed the 34.3 psu value to estimate the depths of the upper and lower isohalines used for NPIW thickness calculation. The thickness was then defined as the vertical distance between these two interpolated isohaline depths. After quality control and interpolation, the 10-min observations were averaged into daily means for all subsequent analyses.

Line 189: Do the adjacent CTD sensors refer to spatial domain? So the interpolation is done between the three moorings?

Response:

In the revised manuscript, we have clarified that "adjacent CTD sensors" refers to vertically adjacent CTD sensors installed on the same mooring line, rather than sensors from different mooring sites. The interpolation was performed only in the vertical direction within each individual mooring. Specifically, temperature and salinity observations were linearly interpolated between vertically adjacent CTD measurements onto a common set of standard depth levels for contour plots and depth-dependent analyses. For NPIW thickness estimation, local linear interpolation was applied between vertically adjacent CTD sensors on the same mooring line that bracketed the target salinity value. No interpolation was performed between different mooring sites.

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This clarification has been added to the Data and Methods section.

Figure 3 legend: the black line should be M1 not M2.
Response:
The Figure 3 has been replot, and the legend in Figure 3 has been corrected, the black line is now properly labeled as M1.
We replot the Fig.3 as follows:

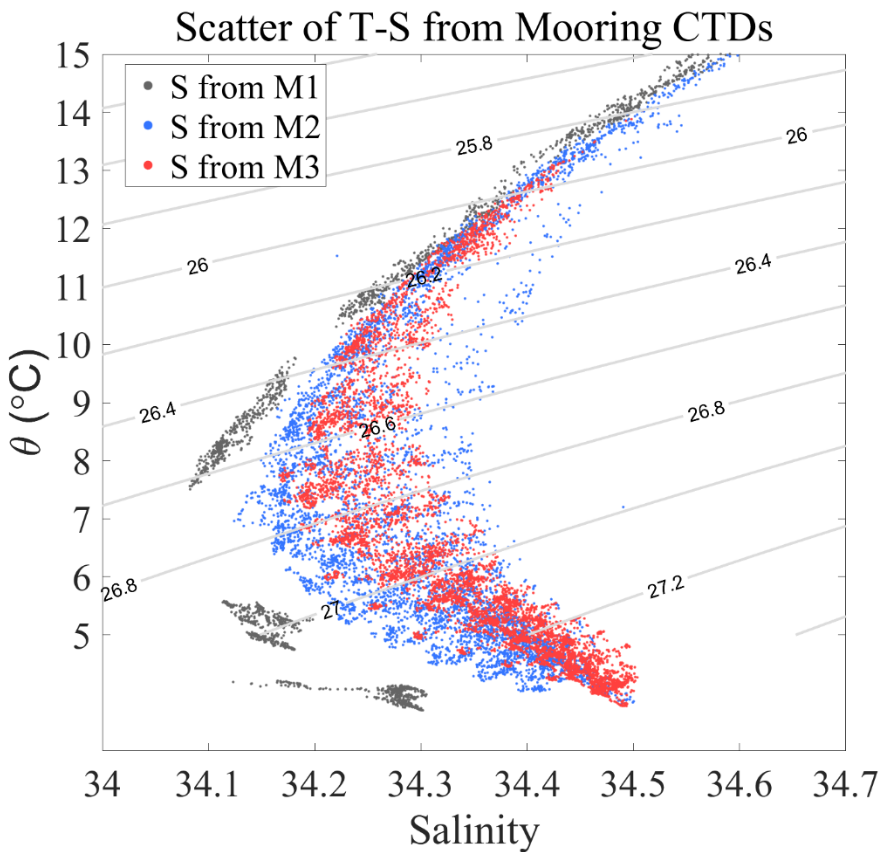

Figure 3. (a) The Temperature-Salinity plot from mooring CTDs. The black, green, and red points are representing the M1, M2 and M3 measurements temperature and salinity, respectively.

Figure 7 lower panels: add "theta" to the y axis of (d).
Response:
We have replotted the Fig.7 in the revised manuscripts.

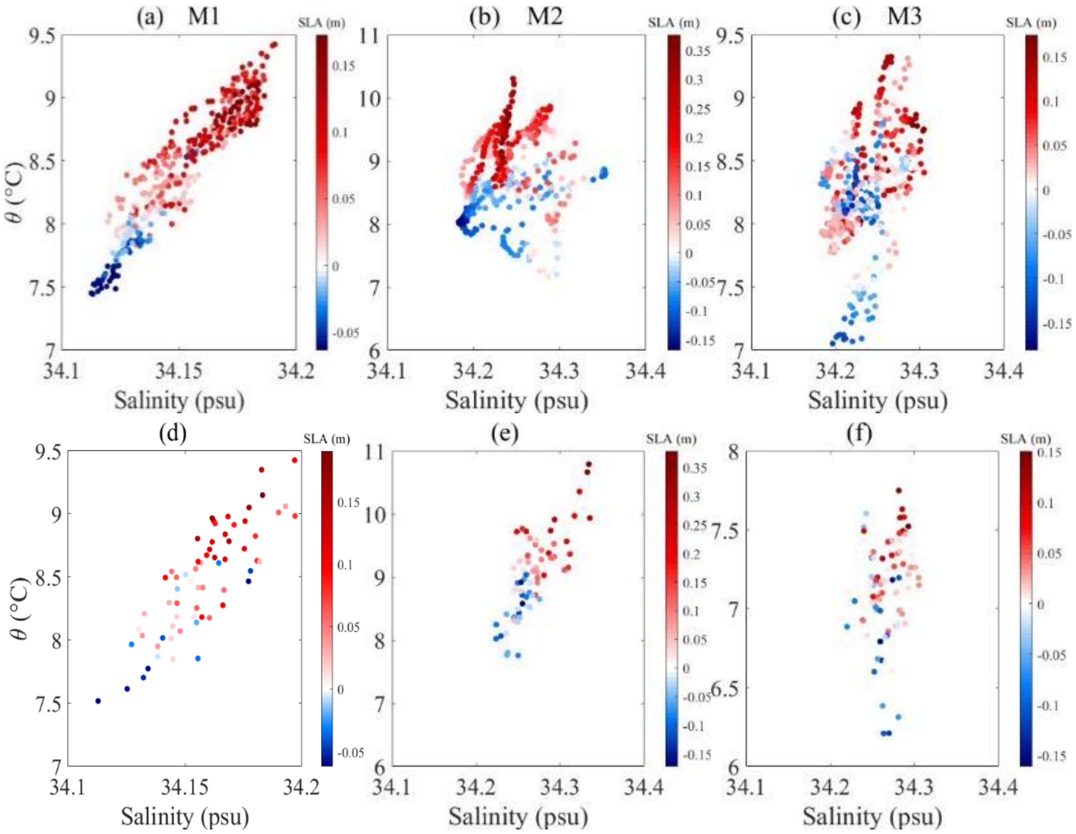

Figure 7. (a) The salinity and temperature data at M1 are displayed in a T–S scatter diagram with colors denoting the associated sea level anomalies (SLAs). (b) and (c) are same as (a), but for M2 and M3. (d), (e) and (f) are T-S plots of 500-800 m averaged temperature and salinity data from CMEMS product in the intermediate layer corresponding to the locations of M1, M2, and M3, respectively.

Line 472: It's interesting that in M1, correlation between salinity and layer thickness is weakest, but correlation between salinity and SLA is the strongest. One would assume that eddies have imprints on SLA, so that SLA and layer thickness should be comparable if eddies are considered. How to reconcile these two points? Maybe it helps to see depth time figure with isopycnals and TS for individual eddy events.

Response:

We sincerely thank you for pointing out this interesting and important feature, which we had not sufficiently emphasized in the original manuscript.

We agree that the apparently different correlation behavior at M1 requires clarification. In the revised manuscript, we clarified that SLA is used as a surface indicator of mesoscale eddy activity, rather than as a direct forcing variable. Therefore, the SLA–salinity correlation reflects the linkage between eddy activity and intermediate-layer thermohaline variability, whereas the salinity–thickness correlation represents the structural covariability between the vertical extent of the low-salinity NPIW layer and its mean salinity.

At M1, the NPIW layer is deeper, thicker, and located in a relatively homogeneous open-ocean environment. Mesoscale eddies mainly induce vertical displacement of isopycnals, producing salinity variations associated with the SLA signal. However,

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because horizontal salinity gradients and external high-salinity water sources are relatively weak at M1, salinity variations are not necessarily accompanied by proportional changes in NPIW thickness.

In addition, we clarified that the thickness at M1 was estimated using the 34.2 psu isohaline because the lower 34.3 psu boundary was not continuously captured by the deepest CTD observations. The 34.2 psu threshold lies closer to the low-salinity core, where vertical salinity gradients are weaker, and may therefore be less sensitive to layer compression and expansion than the 34.3 psu boundary used at M2 and M3. This may partly explain why the SLA–salinity correlation is relatively strong, whereas the salinity–thickness correlation is weaker at M1. We have added this explanation to the revised manuscript.

Nevertheless, the time series at M1 still shows a clear out-of-phase relationship between salinity and thickness, with thicker NPIW generally corresponding to lower salinity and thinner NPIW corresponding to higher salinity. More detailed budget analyses and higher-resolution vertical observations will be needed in future studies to further quantify the relative contributions of vertical displacement, lateral advection, and mixing.

You comment helped us recognize that these two relationships reflect different physical aspects of the eddy-related response of the NPIW, and we have therefore added a clarification in the revised manuscript.

This paragraph was added into the section 4.1:

The relatively lower thickness–salinity correlation at M1 may be attributed to multiple factors. First, the NPIW core at M1 is located at greater depths, typically deeper than 600 m, and the salinity remained consistently below 34.2 psu throughout most of the observation period, exhibiting limited temporal variability. Such weak salinity fluctuations reduce the sensitivity of the thickness–salinity relationship and therefore weaken the linear correlation. In addition, because the lower 34.3 psu boundary was not continuously captured by the deepest CTD observations at M1, the NPIW thickness there was estimated using the 34.2 psu isohaline. This threshold lies closer to the low-salinity core, where the vertical salinity gradient is weaker, and may therefore be less sensitive to layer compression and expansion than the 34.3 psu boundary used at M2 and M3.

This weaker thickness–salinity correlation does not contradict the stronger SLA–salinity relationship at M1. SLA is used here as a surface indicator of mesoscale eddy activity, and the SLA–salinity correlation mainly reflects the linkage between eddy activity and intermediate-layer thermohaline variability. In contrast, the thickness–salinity correlation describes the structural covariability between the vertical extent of the low-salinity layer and its mean salinity. Thus, although M1 shows a relatively strong association between SLA and salinity, the salinity variations are not necessarily accompanied by proportional changes in the 34.2 psu-based thickness index. Nevertheless, the M1 time series still shows a clear out-of-phase relationship between salinity and NPIW thickness, with thicker layers generally corresponding to lower salinity and thinner layers corresponding to higher salinity. In contrast, M2 and M3 are located in regions characterized by more dynamic water-mass interactions, including the influence of the Kuroshio, South China Sea Intermediate Water (SCSIW) (Menash et al., 2015). The stronger thermohaline variability in these regions enhances the responsiveness of NPIW structure to salinity changes, thereby strengthening the statistical coupling between thickness and salinity.

1.3 Grammar Comments

Line 82: remove "is"
Response: This sentence has been rewritten.

Line 83: grammar problem
Response: This sentence has been rewritten as follows:
This water mass originates in the northwestern subtropical gyre, within the transition zone between the Kuroshio Extension and the Oyashio front (Fig. 1). The NPIW is characterized by a salinity minimum of about 34.1–34.3 and relatively cool temperatures at depths of approximately 400–1200 m, with its core density centered around the 26.8 σθ isopycnal. (Talley, 1993, 1995; Yasuda et al., 1997; You et al., 2003; Masujima et al., 2009).

Line 93: should be period between "research" and "many", or change "," to ";". One rule to help is that only one verb should be found in one sentence, and each sentence should have one verb. Many such grammar mistakes are found throughout the manuscript.
Response:
We thank the you for pointing out this grammatical issue. We have corrected the sentence near Line 93 by separating the two independent clauses into two sentences. In addition, we have carefully checked the manuscript for similar comma-splice and sentence-structure problems and revised the text to improve grammatical accuracy and readability.

Line 194: should be "deleting".
Response: This sentence has been rewritten.

2. Response to Reviewer 2

This study investigates the intraseasonal variability of the North Pacific Intermediate Water (NPIW) and its modulation by mesoscale eddies, using high resolution, long-term mooring observations collected from three distinct in-situ sites in the western Pacific. By defining the thickness of the NPIW layer, the authors identify a pronounced dominant periodicity of 60-80 days in NPIW variability, and reveal a significant inverse correlation between NPIW thickness and isopycnal-averaged salinity. Through quantifying the vertical response of the intermediate water layer to mesoscale forcing, the authors conclude that surface mesoscale processes can drive structural variations of the NPIW over the 400–900 m depth range. Overall, the core conclusions of this paper are scientifically reasonable. Nevertheless, several key issues regarding the methodology, data analysis, and mechanistic interpretation remain to be clarified to further improve the scientific rigor of the work. I recommend that this manuscript be considered for publication following a major revision.

2.1 Major Comments

1. The definition of the NPIW appears inconsistent across different sections of the manuscript, with criteria cited including the salinity minimum, depth range, density range, and the 34.3 psu isohaline. This inconsistency introduces unnecessary ambiguity and markedly undermines the readability and academic rigor of the manuscript. Specifically, the authors are strongly recommended to add a dedicated Methods section in Chapter 2 of the manuscript. This section should explicitly and systematically document all core definitions and analytical methodologies adopted in the study, including but not limited to the formal quantitative definition of NPIW, the implementation details of the composite analysis, and the technical specifications of the wavelet analysis.

Response:

We thank the you for this important and constructive suggestion. We agree that the use of multiple NPIW-related criteria in the previous version may have caused ambiguity.

In the revised manuscript, we have clarified this issue by explicitly distinguishing between different definitions and their respective purposes. Specifically:

(1) The density range (26.4–26.9 $\sigma\theta$) is used to represent the dynamical layer of NPIW, consistent with previous studies (e.g., Talley, 1993; You et al., 2000).

(2) The salinity minimum is used to identify the core of NPIW, which reflects its characteristic low-salinity signature.

(3) The 34.3 psu isohaline is adopted as a practical boundary to quantify the vertical extent (thickness) of the NPIW layer, representing the upper limit of the low-salinity core.

These definitions are not contradictory but complementary, as they describe different aspects of the same water mass: core properties, dynamical range, and structural extent. To improve clarity, we have revised the manuscripts to explicitly introduce these definitions and their relationships in section 2, and we have added a reference figure showing the typical vertical structure of NPIW.

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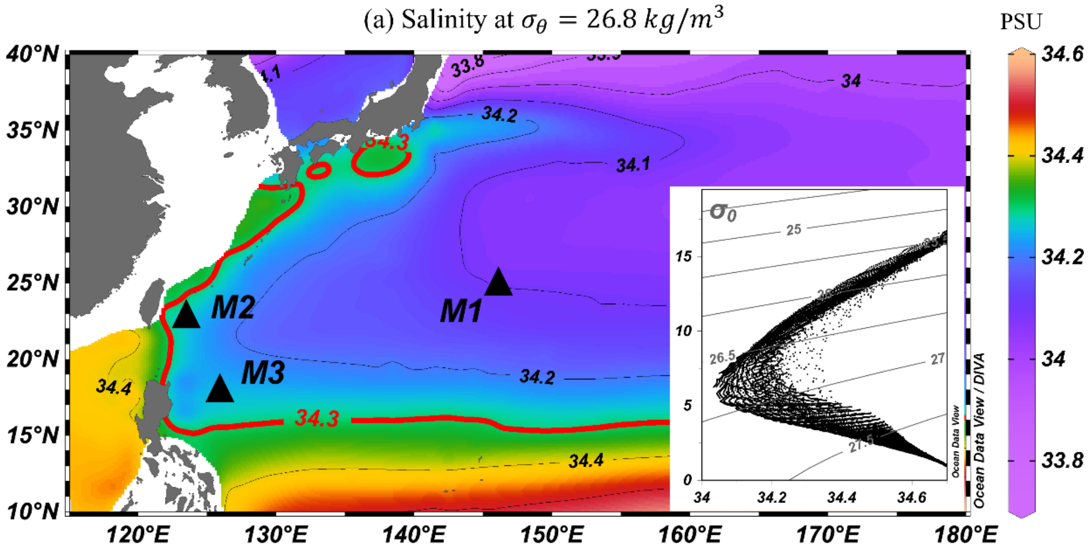

Figure 1. Distribution of salinity (a) and depth (b) along the 26.8 isopycnals at Northwestern Pacific. The TS scatter plot in the lower-right corner of (a) illustrates the vertical distribution of NPIW. The color shading and black line in (a) and (b) represent the salinity and depth, respectively. The red contours of 34.3 psu is represent the NPIW range from Talley et al. (1993) and You et al. (2003). The black triangle is the mooring location: Mooring 1 (M1), Mooring 2 (M2) and Mooring 3 (M3). Salinity and depth in the Fig. 1 are taken from climatological averaged data from World Ocean Atlas 23, and plot with Ocean Data View.

2. The authors establish an inverse correlation between the salinity and thickness of the NPIW via statistical analysis of observations from three mooring sites. However, the manuscript lacks an explicit discussion of the spatial representativeness of these three mooring locations. Notably, the findings and conclusions of this study are extrapolated to a broader spatial domain across the North Pacific. Accordingly, the authors are required to add a dedicated assessment of whether these three mooring sites can adequately represent the larger-scale variability of NPIW, and to explicitly justify the generalizability of their statistical results to the wider study region.

Response:

We thank you for this important comment regarding the spatial representativeness of the three mooring sites. We agree that observations from three moorings cannot fully represent the entire North Pacific basin, and the previous wording may have overextended the spatial implications of our results.

In the revised manuscript, we have clarified that the primary objective of this study is to investigate regional contrasts in the intraseasonal variability and structural response of the NPIW under different dynamical environments, rather than to characterize the full basin-scale variability of the North Pacific.

The three mooring sites were intentionally deployed across distinct hydrographic regimes in the western North Pacific, including the open-ocean NPIW core region (M1), the western boundary transition zone (M2), and the mixing-influenced region near the

Kuroshio pathway (M3). These sites therefore provide representative observations of how mesoscale eddies modulate NPIW structure under different environmental conditions.

We have revised the Introduction and Discussion sections to explicitly acknowledge the regional nature of the observations and to avoid overgeneralization of the conclusions to the entire North Pacific basin. The revised text now emphasizes that the identified relationships between salinity, thickness, and mesoscale eddies are most representative of the western North Pacific intermediate-water.

In ending of section 4.3, follow paragraph is added:

It should be noted that the three mooring observations analyzed in this study do not fully represent the entire North Pacific basin. Instead, the moorings were strategically deployed across different hydrographic environments in the western North Pacific, including the open-ocean NPIW core region and the western boundary mixing region. Therefore, the results presented here should primarily be interpreted as representative of regional intermediate-water variability in the western North Pacific. Nevertheless, the coherent relationships observed among SLA, salinity, and NPIW thickness across all three sites suggest that mesoscale eddies play an important role in modulating the structural variability of intermediate water in this region.

3. The authors have calculated numerous correlation coefficients throughout the manuscript, most notably the correlation between the salinity and thickness of the NPIW. However, the raw time series used for these correlation analyses contain superimposed variability across multiple timescales, including diurnal, monthly, and intraseasonal fluctuations. Critically, signals from different time scales may have confounding effects on the calculated correlation coefficients, making it impossible to verify whether the reported correlations originate specifically from the intraseasonal variability that is the core focus of this study. All correlation analyses should be re-conducted exclusively using the filtered intraseasonal time series, to ensure the results directly align with the study's core scientific focus. Detailed specifications of the filtering procedure, including the selected passband, filter type, and implementation steps, must be fully documented in the dedicated Methods section recommended in prior comments. In addition, a rigorous statistical significance test is mandatory for all correlation coefficient calculations and must be supplemented in the revised manuscript.

Response:

We thank you for this important methodological comment. We agree that correlation analyses involving temporal variability, especially those between SLA and hydrographic variables, should be conducted using intraseasonal-filtered time series to avoid contamination from signals at other timescales. Following the reviewer's suggestion, we rechecked the correlation analyses between SLA, temperature, salinity, and thickness using the 20–120 day band-pass filtered time series, and the main relationships remain statistically significant.

However, we would like to clarify that the thickness–salinity relationship shown in Fig. 8 is not intended as a frequency-domain correlation analysis. Rather, it represents a point-by-point structural relationship based on simultaneous daily values of NPIW thickness and isopycnal-averaged salinity. This scatter relationship is used to quantify the overall structural variability between the vertical extent of the low-salinity NPIW layer and its salinity characteristics. Applying band-pass filtering to this diagnostic relationship would remove part of the physically meaningful low-frequency structural variability and may distort the interpretation of thickness as a structural indicator.

To address the reviewer's concern, we have clarified this distinction in the revised manuscript. The thickness–salinity scatter relationship is retained as an overall structural diagnostic, while all time-dependent correlation analyses related to SLA and intraseasonal variability have been checked using 20–120 day band-pass filtered time series. We have also added details of the filtering procedure and statistical significance tests in the Methods section.

4. The interpretation of salinity variability in relation to mesoscale eddies could be further clarified. The manuscript suggests a positive relationship between SLA and salinity, implying that anticyclonic eddies are associated with higher salinity. However, given that NPIW is characterized by a salinity minimum, it would be helpful to explicitly clarify whether the observed changes represent modification of the NPIW core, vertical displacement of isohalines, or lateral mixing with surrounding waters.

Response:

We sincerely thank you for this insightful and important comment. We agree that the physical interpretation of the salinity variability associated with mesoscale eddies required further clarification in the previous version of the manuscript.

In the revised manuscript, we now explicitly distinguish among three different processes that may contribute to the observed salinity variability: (1) modification of the intrinsic NPIW core properties, (2) vertical displacement of isopycnals, and (3) lateral advection and mixing with surrounding waters.

We would like to clarify that the positive relationship between SLA and intermediate-layer salinity observed in this study, imply that the observed salinity anomalies primarily reflect structural responses of the intermediate layer within a fixed-depth observational range. Under anticyclonic eddy conditions associated with positive SLA, the isopycnals are displaced downward, compressing the low-salinity NPIW layer and increasing the relative contribution of surrounding higher-salinity waters within the observed depth range. This results in elevated salinity and reduced NPIW thickness.

In addition, particularly at the western boundary sites (M2 and M3), enhanced lateral advection and mixing may further increase salinity through intrusion of surrounding saline waters, which can weaken or obscure the low-salinity signature of the NPIW. Conversely, cyclonic eddies induce upward displacement of isopycnals and help preserve the low-salinity characteristics of the NPIW layer.

To avoid ambiguity, we have substantially revised Section 4.3 to clearly distinguish vertical structural modulation from horizontal mixing processes, and to clarify that the observed salinity changes mainly represent fixed-depth structural responses of the intermediate layer rather than intrinsic salinity properties of eddy cores.

5. Site M2 is located near the western boundary where the Kuroshio exerts dominant

control over the local circulation. The interaction between westward-propagating eddies and the Kuroshio likely plays a significant role in the structural modulation of the NPIW. Has the potential effect of Kuroshio shear been considered, particularly in terms of its ability to deform eddies and modify mixing efficiency of intermediate water masses in this region?

Response:

We sincerely thank you for this insightful suggestion. We agree that the western boundary circulation associated with the Kuroshio may influence the structural variability of the NPIW near site M2.

However, we would like to clarify that M2 is not located directly within the Kuroshio main axis, but rather in a region influenced by the broader western boundary circulation and adjacent water-mass exchange processes. Therefore, while the Kuroshio likely contributes to the regional hydrographic environment and intermediate-water mixing, the direct effect of strong Kuroshio shear on eddy deformation at M2 may be relatively limited.

In the revised manuscript, we therefore emphasize that the stronger variability observed at M2 is more likely associated with enhanced lateral water-mass exchange and mixing processes in the western boundary transition region, potentially influenced by both mesoscale eddies and the surrounding Kuroshio-related circulation.

We have added a corresponding discussion in Section 4.3 and avoided overinterpreting the direct role of Kuroshio shear due to the lack of dedicated dynamical analyses in the present study.

2.2 Minor Comments

L80~81: There is an inconsistency in font size.

Response:

We have carefully checked Lines 80~81 and corrected the font-size inconsistency in the revised manuscript. We also checked the surrounding text to ensure that the font style, symbol formatting, and line spacing are consistent throughout the paragraph.

2. Line 101: No specific citations are given for the claim "Based on previous studies". Please add the corresponding references to the relevant works.

Response:

We agree that the previous claim "Based on previous studies" was too vague and lacked explicit references. In the revised manuscript, we have replaced this statement with specific citations to previous studies describing the origin, distribution, and transport pathways of the NPIW, including You (2003), Yasuda (2004), and Fujii et al. (2013). We also revised the corresponding sentence to directly compare the WOA13-derived distribution with the conclusions of these studies, thereby improving the clarity and academic rigor of the Introduction.

3. Line 102: The authors state that the results shown in Fig. 1 are similar to those reported in You (2003). First, it is unclear whether the Fig. 1 referenced here is the

Figure 1 presented on pages 5–6 of the manuscript, as there is an excessive distance between this line and the figure's location, which disrupts the logical flow and readability of the text. Directly citing the results and conclusions from You (2003) to support the statement here is far more appropriate and consistent with standard academic writing conventions.

Response:

We agree that the previous wording was not sufficiently clear and that directly comparing Fig. 1 with You (2003) was not the most appropriate academic expression. In the revised manuscript, we have rewritten the corresponding text to directly cite the conclusions of previous studies regarding the regional depth distribution of the NPIW, particularly the shallower distribution near the western boundary and deeper distribution in the open North Pacific. We then clarify that the WOA13-derived climatological distribution obtained in this study is consistent with these previous findings. This revision improves both the logical flow and readability of the Introduction.

4. Throughout the manuscript (e.g., Line 135, Line 145): Inconsistent use of abbreviations. Some abbreviations (e.g., "IW" in Line 135) are used without defining their full names, while already defined abbreviations (e.g., NPIW in Line 145) are redundantly reintroduced with their full terms.

Response:

We thank you for pointing out the inconsistency in abbreviation usage. In the revised manuscript, we have carefully checked the entire text and standardized all abbreviations. Undefined abbreviations such as "IW" have been removed or replaced with their full terms where appropriate, while already defined abbreviations such as "NPIW" are now used consistently throughout the manuscript without redundant redefinition. These revisions improve the clarity and readability of the manuscript.

5. Lines 187–188: No technical details are provided for the depth conversion procedure described here. Please explicitly specify the interpolation method used for this step (e.g., linear interpolation or spline interpolation), and supplement the full processing details in the Methods section.

Response:

In the revised manuscript, we have added more technical details regarding the depth-conversion and interpolation procedures in the Methods section. Because the moored CTD sensors were deployed at discrete depths and experienced slight vertical movement associated with mooring motion, all observations were first converted to pressure-based depths using the recorded pressure data. The observations were then linearly interpolated between adjacent CTD levels onto fixed-depth coordinates for subsequent analyses, including contour plots and fixed-depth temperature/salinity variability analyses. These additions improve the clarity and reproducibility of the data-processing procedures.

6. Figure 3: The referenced "green points" and "blue dashed box" are entirely absent

from the submitted figure.

Response:

These descriptions have now been removed from the revised manuscript to ensure consistency between the figure and its corresponding description.

7. Line 325: No specific citations are provided for the vague reference to "previous studies".

Response:

We agree that the previous wording was not sufficiently precise in distinguishing the different definitions used to characterize the NPIW. In the revised manuscript, we clarified that the 26.4–26.9 $\sigma\theta$ density range is not intended to define the NPIW core itself, but rather to represent the dynamical intermediate-water layer associated with the NPIW and its surrounding transition waters.

We have also replaced the vague phrase "widely recognized in previous studies" with explicit citations to previous studies, including Talley (1993), You et al. (2000), and Yasuda (2004), to improve the scientific rigor and clarity of the manuscript.

8. Lines 329-333: Inconsistent salinity thresholds (34.2 psu for M1, 34.3 psu for M2 and M3) are used to define NPIW across the three mooring sites. This non-uniform definition undermines the credibility of the subsequent analysis of NPIW thickness variability.

Response:

We thank you for this important comment. We agree that the use of different salinity thresholds among the mooring sites requires further clarification.

At sites M2 and M3, the 34.3 psu isohaline could be clearly identified within the observed depth range and was therefore used to estimate the NPIW thickness. However, at M1, the NPIW layer is substantially thicker and extends deeper than at the other two sites. During some periods, the lower 34.3 psu boundary was located below the deepest CTD observations (~900–1000 m), making it difficult to continuously resolve the full thickness of the low-salinity layer using the 34.3 psu criterion alone.

Therefore, a slightly lower threshold (34.2 psu) was adopted at M1 to ensure that the low-salinity intermediate layer could be consistently captured within the observational range. We emphasize that this adjustment was introduced due to observational constraints associated with the deeper NPIW structure at M1, rather than an arbitrary redefinition of the NPIW.

In addition, although the absolute thickness values estimated using 34.2 psu may differ slightly from those based on 34.3 psu, the 34.2 psu isohaline remains located within the low-salinity NPIW layer and therefore still effectively reflects the relative compression and expansion of the intermediate-water structure associated with mesoscale variability. The temporal variability and structural modulation identified at M1 are thus physically consistent with those derived from the 34.3 psu boundary at the other two sites.

We have clarified these points in the revised manuscript and added corresponding explanations in the Methods section.

9. Figure 4: Inconsistent color is present throughout the figure.

Response:

We thank you for pointing out the inconsistency in Figure 4. In the revised manuscript, we have carefully checked and standardized the color scheme, line styles, and figure formatting throughout the figure to ensure consistency and improve visual clarity.

10. Figure 5: Inconsistent depth ranges are used for the averaged salinity calculations in this figure. Please unify the depth range definition to ensure valid cross-site comparison, and explicitly document the exact depth ranges used in the main text (and dedicated Methods section) in the revision.

Response:

We agree that the averaging ranges used in different analyses should be more clearly documented and physically justified.

In the revised manuscript, we clarified that different averaging ranges were adopted for different analytical purposes. The 26.4–26.9 σθ density range was primarily used to characterize the dynamical intermediate-water layer associated with the NPIW, while fixed-depth averages were used in some figures to describe local salinity variability within the observational range at individual mooring sites.

Initially, a unified fixed-depth range was considered for all sites. However, the vertical position and thickness of the NPIW differ substantially among M1–M3. In particular, the NPIW at M1 and M2 is generally deeper than at M3. If the same depth range were uniformly applied to all sites, the averaged salinity at M3 would include a larger contribution from deeper surrounding waters beneath the principal NPIW layer, thereby weakening the representativeness of the NPIW signal. Therefore, the depth ranges were adjusted according to the local hydrographic structure at each site to better represent the dominant low-salinity intermediate layer.

We have now explicitly documented the exact averaging ranges used in each analysis in the Methods section and corresponding figure captions to improve consistency and readability.

11. Line 379: No discussion of eddy processes has been provided prior to this line, making the "eddy-related" premature and uncontextualized. It is recommended that this descriptor be deleted from the sentence in the revision.

Response:

We agree that the term “eddy-related” was introduced prematurely before the corresponding eddy analyses and discussions were formally presented. In the revised manuscript, we have removed this descriptor and revised the sentence accordingly to improve the logical flow and readability of the text.

12. Lines 427-432: No statistical significance test results are provided for the correlation coefficients calculated in this section. Please explicitly report whether these correlation coefficients pass the 95% confidence level significance test

Response:

In the revised manuscript, statistical significance tests have been added for all reported correlation coefficients.

13. Lines 511-512: The authors claim the 60–80 day periodic variability aligns with the westward-propagating mesoscale eddy signals in the region, but do not confirm whether these eddy signals also have a 60–80 day dominant period, nor provide any supporting references for this statement.

Response:

We agree that the previous version did not provide sufficient support for linking the observed 60–80 day variability directly to mesoscale eddy signals.

In the revised manuscript, we have softened the corresponding statement and clarified that the observed periodicity is broadly consistent with the typical intraseasonal timescales of westward-propagating mesoscale eddies reported in previous studies, rather than claiming a direct one-to-one correspondence. We have also added supporting references, including Qiu and Chen (2005) and Ren et al., (2020), to better support this interpretation.

The revised text now emphasizes that mesoscale eddies are a plausible and physically consistent mechanism contributing to the observed intraseasonal variability of the NPIW.

14. Figure 9: The data source for the results in this figure is not clearly documented.

Response:

Information about the data sources has been added to Figure 9.

15. Throughout the manuscript: Three inconsistent definitions are used for depth averaging calculations (500 – 800m, 26.4 – 26.9 σθ, 500 – 700 m), with no explanation provided for these repeated changes. This severely undermines readability and analytical consistency. Please either unify the depth-averaging definition across the full manuscript, or provide a clear physical justification for each definition.

Response:

We thank you for this important comment. The use of multiple averaging definitions in the original manuscript was insufficiently explained and may have reduced the overall readability and consistency of the analyses.

In the revised manuscript, we have clarified that the different averaging ranges were adopted for different physical purposes rather than representing inconsistent definitions of the NPIW. Specifically, the 26.4–26.9 σθ density range was used to characterize the dynamical intermediate-water layer associated with the NPIW and to reduce the influence of vertical isopycnal displacement. In contrast, fixed-depth averages were used to describe local salinity variability within the observational range at individual mooring sites.

Because the vertical position and thickness of the NPIW differ substantially among the three mooring sites, the fixed-depth ranges were selected according to the local hydrographic structure. The NPIW at M1 and M2 is generally deeper and thicker than at M3; therefore, the 500–800 m layer was used at M1 and M2, while the 500–700 m layer was used at M3. If a unified 500–800 m range were applied to M3, the averaged salinity would include a larger contribution from deeper surrounding waters beneath the principal NPIW layer, thereby weakening the representativeness of the NPIW signal. We have now added detailed explanations of these definitions and their physical motivations in the Methods section and corresponding figure captions to improve analytical consistency and readability throughout the manuscript.

The following content has been added to the revised manuscript:

Different averaging definitions were adopted in this study according to the specific physical quantity being analyzed. The 26.4–26.9 σθ density range was used to characterize the dynamical intermediate-water layer associated with the NPIW and to reduce the influence of vertical isopycnal displacement. In contrast, fixed-depth averages were used to describe local salinity variability within the observational range at individual mooring sites. For fixed-depth salinity analyses, different averaging ranges were adopted according to the local vertical distribution of the NPIW at each mooring site. The NPIW at M1 and M2 is generally deeper and thicker than at M3; therefore, the 500–800 m layer was used at M1 and M2, while the 500–700 m layer was used at M3. Initially, a unified depth range was considered for all sites. However, if the same depth range (e.g., 500–800 m) were applied to M3, the averaged salinity would include a larger contribution from deeper surrounding waters beneath the principal NPIW layer, thereby weakening the representativeness of the NPIW signal. The selected depth ranges were therefore adjusted to better capture the dominant low-salinity intermediate layer at each site.

16. Throughout the manuscript: Two inconsistent salinity thresholds (34.2 psu and 34.3 psu) are used to define NPIW layer thickness across different analyses, with no explanation provided for this discrepancy. This non-uniform definition eliminates the consistent baseline required for valid cross-site and cross-analysis comparisons of NPIW thickness. Please either unify the NPIW thickness definition across the full manuscript, or provide a clear physical justification for the divergent thresholds.

Response:

This issue is closely related to Comment 8, and we have clarified the rationale for using different salinity thresholds in the revised manuscript.

Specifically, the 34.3 psu isohaline was used at M2 and M3 because it could be continuously identified within the observational depth range and effectively represents the structural boundary of the low-salinity NPIW layer. At M1, however, the NPIW is substantially deeper and thicker, and the lower 34.3 psu boundary extended below the deepest CTD observations during some periods. Therefore, a slightly lower threshold (34.2 psu) was adopted to ensure continuous representation of the low-salinity intermediate layer within the available observations.

We further clarified that the 34.2 psu isohaline remains within the low-salinity NPIW layer and can still effectively capture the relative compression and expansion of the intermediate-water structure associated with mesoscale variability. The corresponding explanations have now been added to the Methods section and relevant figure descriptions to improve consistency throughout the manuscript.

17. Figure 11: It is not explicitly stated whether the data in this figure has undergone

20–120 day band-pass filtering. Please clearly clarify the filtering processing status of the data used for Figure 11.

Response:

The data shown in Figure 11 were not processed using the 20–120 day band-pass filter. Figure 11 presents the spectral analysis results based on the original reanalysis dataset, and the purpose of this figure is to identify the dominant periodic signals in the variability rather than to display filtered intraseasonal components.

18. Line 542: For Figure 9e, ensure that the color bar for SLA is consistent across all panels to allow for direct comparison of eddy intensity between sites.

Response:

In the revised manuscript, the SLA color bar in Figure 9 has been standardized across all panels as follows to ensure direct comparison of eddy intensity among the different mooring sites and to improve the overall consistency and readability of the figure.

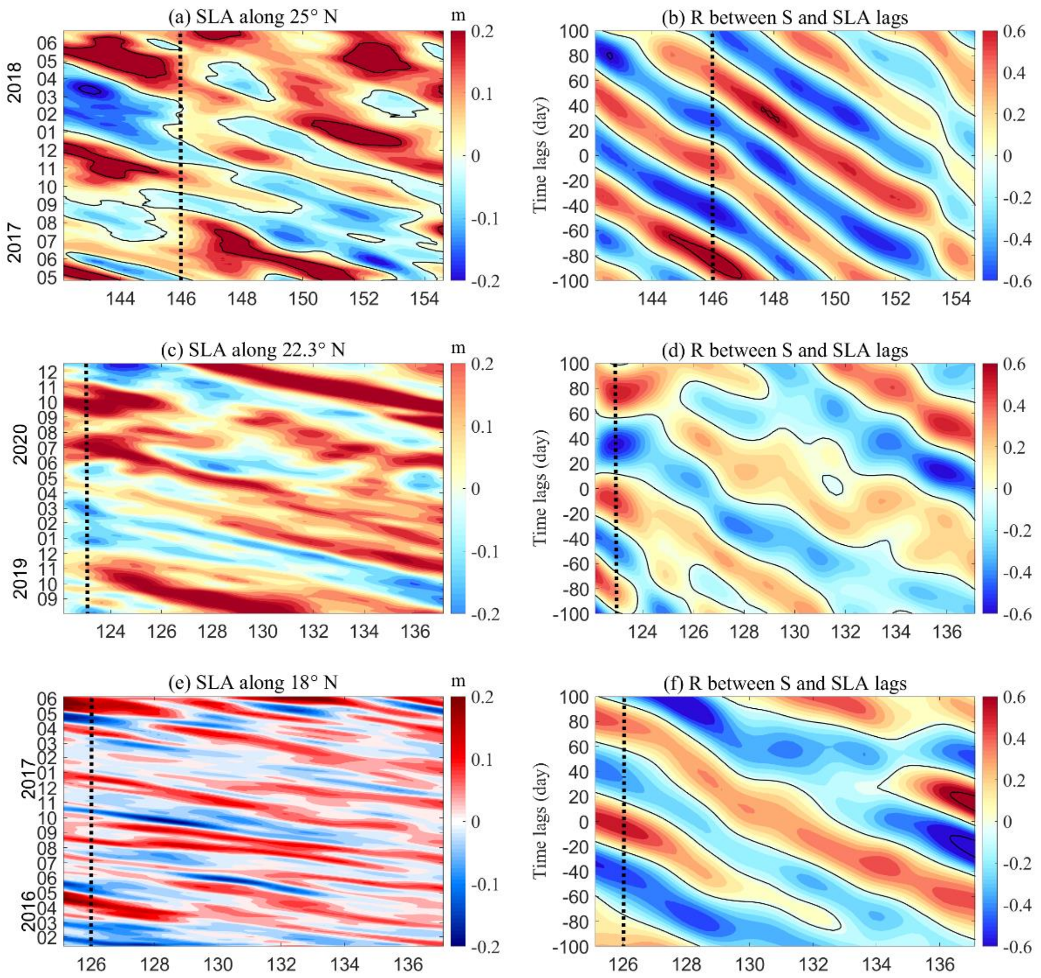

Figure 9. (a) Temporal evolution of sea level anomalies (SLAs) across longitudes at 25°N, as illustrated by the contour plots.; (b) The correlation coefficient between salinity at M1 and SLA at different time lags, the vertical coordinates -100 to 100 days in (b) represent SLA lagging salinity for 100 days and SLA exceeding salinity for 100 days, respectively. (c) and (e) are same as (a), but its along 22.3°N and 18°N,

respectively. (d) and (f) are same as (b), but for salinity from M2 and M3, respectively. Black contours in Fig. 9b, 9d, and 9f represent the zero isolines. The black dash line represents the location of M1, M2 and M3, respectively. The SLA data shown in this figure were obtained from the CMEMS dataset introduced in the Methods section.

19. Figures 11–13: No detailed methodological specifications are provided for the composite analysis used to generate these figures. It is unclear whether the composites were constructed based on all AE and CE events at each mooring site; the expected AE/CE features are not evident in Figure 13, and the figure captions use the 'High-salinity/Low-salinity event' terminology with no explicit link to AE/CE processes. Please comprehensively document the full implementation workflow of the composite analysis, and clarify the correspondence between all event types in Figure 13, supplement all methodological details in the Methods section.

Response:

We thank the reviewer for this important and insightful comment. We agree that the original manuscript did not provide sufficient explanation of the composite analysis procedure or the correspondence between different event types.

In the revised manuscript, we have supplemented Section 4.3 with a more detailed description of the composite analysis workflow. Specifically, the composite fields in Figures 12–14 were constructed for high-salinity and low-salinity events near each mooring site, which are generally associated with anticyclonic and cyclonic conditions, respectively, based on the corresponding SLA patterns. Positive SLA indicates anticyclonic conditions, whereas negative SLA indicates cyclonic conditions.

We also clarified that the expected AE/CE-like structure is less evident in Figure 13 than in the other composite analyses. M2 is located east of Taiwan, where westward-propagating mesoscale eddies interact with the Kuroshio and the western boundary circulation. Previous studies have shown that eddy–Kuroshio interactions in this region can deform, weaken, or reorganize mesoscale eddy structures (e.g., Zhang et al., 2001; Yin et al., 2017), which may obscure the idealized eddy signature in the composite thickness field.

Nevertheless, despite the less distinct horizontal eddy pattern, significant differences in NPIW thickness and salinity are still observed between the composite states. Therefore, the purpose of Figure 13 is not to identify a perfectly isolated eddy structure, but rather to compare the hydrographic responses of the NPIW under different mesoscale dynamical conditions. We have clarified this interpretation in the revised manuscript and corresponding figure caption.

Zhang, D., T. N. Lee, W. E. Johns, C. Liu, and R. Zantopp, 2001: The Kuroshio East of Taiwan: Modes of Variability and Relationship to Interior Ocean Mesoscale Eddies. J. Phys. Oceanogr., 31, 1054–1074.

Yin, Y., X. Lin, R. He, and Y.Hou (2017), Impact of mesoscale eddies on Kuroshio intrusion variability northeast of Taiwan, J. Geophys. Res. Oceans, 122, 3021–3040.

The following content has been added to Section 4.3 in the revised manuscript:

At M2, the composite thickness field does not exhibit a well-defined eddy-like structure as clearly as at the other sites. This may be related to the complex dynamical environment east of Taiwan, where westward-propagating mesoscale eddies interact strongly with the Kuroshio and the western boundary circulation. Previous studies have shown that such eddy–Kuroshio interactions can deform, weaken, or reorganize mesoscale eddy structures in this region (Zhang et al., 2001; Yin et al., 2017). As a result, the composite horizontal structure may not retain an idealized cyclonic or anticyclonic eddy pattern in Fig.13. Nevertheless, significant differences in NPIW thickness and salinity are still observed between the two composite states, indicating that mesoscale variability continues to modulate the intermediate-water structure in this region.

20. Section 4.3: The authors state that NPIW salinity changes are driven by horizontal transport and mixing processes, but provide no supporting evidence for this core mechanistic claim.

Response:

The previous wording regarding horizontal transport and mixing processes was too strong relative to the observational evidence presented in this study.

In the revised manuscript, we have softened the corresponding statements and clarified that the observed salinity variability may be associated with mesoscale eddy-induced horizontal redistribution of surrounding water masses and possible mixing processes, rather than claiming a directly demonstrated mechanism.

We further clarified that the present study is primarily based on mooring observations and statistical analyses, and therefore cannot quantitatively separate the relative contributions of lateral advection, vertical displacement, and mixing processes. Corresponding revisions have been added to Section 4.3 to improve the rigor and accuracy of the mechanistic interpretation.

The following content has been added to Section 4.3 in the revised manuscript:

These spatial features suggest that mesoscale eddies modulate the NPIW through multiple dynamical processes, whose relative importance differs among the three mooring sites. At M1, the observed variability is characterized by pronounced thickness fluctuations but relatively weak salinity anomalies, indicating that vertical displacement of isopycnals plays a dominant role. In contrast, M2 and M3 exhibit substantially stronger salinity anomalies together with pronounced thickness variability, suggesting enhanced horizontal redistribution of surrounding water masses and possible mixing processes in the western boundary environment. Several observational features support this interpretation. The strong inverse relationship between NPIW thickness and salinity observed at all three sites indicates that vertical displacement contributes importantly to the structural variability of the intermediate layer. Meanwhile, the stronger salinity anomalies and more complex hydrographic structures observed near the western boundary imply enhanced lateral exchange processes in these regions. The combined influence of these processes likely contributes to the observed intraseasonal co-variability of salinity and thickness. The inclusion of thickness analysis therefore provides a more comprehensive dynamical perspective for understanding how mesoscale variability influences the NPIW structure and properties. However, because the present study is primarily based on mooring observations and statistical analyses, the relative contributions of lateral advection, vertical displacement, and mixing processes cannot yet be quantitatively separated.

3. Response to Reviewer 3

This manuscript investigates the intraseasonal variability of the North Pacific Intermediate Water (NPIW) using multi-mooring observations. Considering the limited availability of long-term in situ measurements in the intermediate ocean, the dataset presented here is valuable and provides useful observational constraints on subsurface variability. The analyses are generally reasonable and the results contribute to a better understanding of NPIW variability. The introduction of NPIW thickness as a structural indicator is particularly interesting and represents a useful extension beyond traditional thermohaline analyses. This perspective helps to better interpret the response of intermediate water to mesoscale processes. But I have a few comments regarding clarity of definitions, and methodological description that should be addressed.

3.1 Main Comments

1. The definition of NPIW could be clarified. Different criteria are used in the manuscript (e.g., 34.3 psu isohaline vs. salinity minimum). It would be helpful to briefly explain why 34.3 psu is chosen to define thickness. Is this threshold robust across regions? Would similar results be obtained with a slightly different value? A short discussion would improve clarity.

Reponse:

We thank you for this helpful comment. We agree that the different definitions of the NPIW used in the original manuscript required clearer explanation.

In the revised manuscript, we clarified that different criteria were adopted for different physical purposes. Specifically, the salinity minimum is used to characterize the core properties of the NPIW, whereas the 34.3 psu isohaline is used to describe the thickness of the low-salinity intermediate layer. The 34.3 psu boundary approximately corresponds to the outer edge of the NPIW low-salinity structure in the study region and therefore serves as a useful indicator of layer compression and expansion associated with mesoscale variability.

We further clarified that although the absolute thickness may vary slightly under different salinity thresholds, the major temporal variability and relative structural changes remain generally consistent. In addition, we explained that a 34.2 psu threshold was adopted at M1 because the deeper and thicker NPIW structure occasionally caused the lower 34.3 psu boundary to extend below the deepest CTD observations. Corresponding explanations have now been added to the revised manuscript.

Follow sentence was added in to Section 2.2:

Despite its broad distribution of NPIW, the definition of NPIW is not entirely uniform in previous studies. It has been identified using different criteria, including the salinity minimum, density ranges (typically 26.4–26.9 σθ), and characteristic isohalines (Talley, 1993; You et al., 2000). These definitions emphasize different aspects of the same water mass, namely its core properties, dynamical layer, and vertical structure. Based on these previous studies, we use the WOA data to illustrate the climatological distribution of NPIW, as shown in Fig. 1. The spatial pattern is consistent with earlier findings (e.g., You, 2003), showing that the NPIW exhibits significant regional variability in its vertical structure. Specifically, the NPIW layer is relatively shallow in the western boundary region, while it deepens toward the interior of the North Pacific. This spatial variability provides an important background for interpreting the mooring observations in this study. In this study, these criteria are used in a complementary manner: the salinity minimum is used to describe the core property of the NPIW, the density range is used to characterize the intermediate dynamical layer, and the 34.3 psu isohaline is adopted to estimate the structural thickness of the low-salinity NPIW layer.

2. In the Data and Methods section, three moorings are used. A schematic showing the vertical configuration of CTD sensors would be very helpful. This would allow readers to better evaluate whether the vertical resolution is sufficient. In addition, please provide a bit more detail on data processing (e.g., interpolation and filtering methods).
Response:
In the revised manuscript, we have added a more detailed description of the mooring configuration and data-processing procedures in the Data and Methods section. Specifically, we clarified the vertical deployment of the CTD sensors, which were installed at approximately 100 m intervals between 400 and 1000 m to adequately resolve the vertical structure of the NPIW layer.
We also added additional details regarding the data-processing procedures, including the conversion of observations to fixed pressure-based depths using pressure records, the application of local linear interpolation between adjacent CTD sensors, and the filtering and averaging procedures used in the analyses.
In addition, a schematic diagram illustrating the vertical configuration of the mooring systems and CTD sensor depths has been added to the revised manuscript to improve clarity and reproducibility.

3. In Section 3.2, the salinity variability at M1 (34.12–34.16 psu) is much smaller than at M2 and M3. A brief explanation would be useful. This could be related to regional hydrographic conditions or differences in dynamical influence.
Response:
We thank you for this helpful suggestion. In the revised manuscript, we have added a brief discussion to explain the relatively weaker salinity variability observed at M1.
Specifically, M1 is located farther from the western boundary region, where the NPIW layer is generally deeper and thicker. In this region, mesoscale variability mainly manifests as vertical displacement of isopycnals, while the surrounding horizontal salinity gradients are relatively weak compared with those near M2 and M3. As a result, lateral redistribution and possible mixing of higher-salinity waters are less pronounced, leading to smaller salinity anomalies at M1. Corresponding explanations have now been

added to Section 3.2.
Following sentence was added in to section 3.2:
Compared with M2 and M3, the salinity variability at M1 was substantially weaker. This difference is likely related to the distinct hydrographic and dynamical environment at M1, where the NPIW layer is generally deeper and thicker. In this region, mesoscale variability mainly manifests as vertical displacement of isopycnals, while the surrounding horizontal salinity gradients are relatively weak compared with those near the western boundary. As a result, lateral redistribution and possible mixing of higher-salinity waters are less pronounced, leading to smaller salinity anomalies at M1.

4. The variability is mainly attributed to mesoscale eddies, which is reasonable. However, it would strengthen the paper to briefly discuss other possible contributors. For example, could remotely forced signals (e.g., Rossby waves) also play a role at similar timescales? A short discussion would help justify the interpretation.
Response:
We thank you for this helpful suggestion. We agree that processes other than mesoscale eddies may also contribute to intraseasonal variability of the NPIW. In the revised manuscript, we have added a brief discussion noting that remotely forced signals, such as baroclinic Rossby waves, may occur on comparable timescales and potentially influence sea level and subsurface isopycnal displacement in the western North Pacific. However, the coherent variability observed among SLA, salinity, and NPIW thickness, together with the contrasting responses under anticyclonic and cyclonic conditions, suggests that mesoscale variability is likely the dominant contributor in the present observations. We have revised the discussion accordingly to avoid over-attributing the observed variability solely to mesoscale eddies.
This paragraph is added in to the discussion section:
Although the present results suggest a close association between mesoscale eddies and the observed intraseasonal variability of the NPIW, other processes may also contribute to variability on similar timescales. For example, remotely forced baroclinic Rossby waves may influence sea level and subsurface isopycnal displacement in the western North Pacific. However, the coherent variability observed among SLA, salinity, and NPIW thickness, together with the contrasting responses under anticyclonic and cyclonic conditions, suggests that mesoscale variability is likely the dominant contributor in the present observations.

5. The discussion would benefit from a clearer assessment of the relative roles of vertical displacement (isopycnal heaving) and horizontal advection/mixing in driving the observed NPIW variability. In particular, can the authors further clarify under what conditions (or at which mooring sites) each mechanism is dominant? Additionally, are there observational indicators (e.g., phase relationships, vertical coherence, or spatial patterns) that could help distinguish between these processes?
Response:
We thank you for this insightful comment. In the revised manuscript, we have added a more detailed discussion regarding the relative roles of vertical displacement and

horizontal redistribution processes in modulating NPIW variability at the three mooring sites. Specifically, we clarified that the variability at M1 is more consistent with isopycnal heaving, as indicated by the pronounced thickness fluctuations together with relatively weak salinity anomalies. In contrast, M2 and M3 exhibit substantially stronger salinity anomalies and more complex boundary-current environments, suggesting that horizontal redistribution of surrounding water masses and possible mixing processes play a larger role in these regions.

We further discussed several observational indicators supporting this interpretation, including the inverse relationship between NPIW thickness and salinity, the spatial differences in salinity variability among the mooring sites, and the stronger horizontal salinity gradients near the western boundary. We also clarified that, although the present observations do not allow a quantitative separation of the relative contributions from vertical displacement, lateral advection, and mixing, the observed spatial patterns provide useful qualitative constraints on the dominant mechanisms. Corresponding discussions have been added to the revised manuscript.

This paragraphy is added into the section 4.3:

These spatial features suggest that mesoscale eddies modulate the NPIW through multiple dynamical processes, whose relative importance differs among the three mooring sites. At M1, the observed variability is characterized by pronounced thickness fluctuations but relatively weak salinity anomalies, indicating that vertical displacement of isopycnals plays a dominant role. In contrast, M2 and M3 exhibit substantially stronger salinity anomalies together with pronounced thickness variability, suggesting enhanced horizontal redistribution of surrounding water masses and possible mixing processes in the western boundary environment. Several observational features support this interpretation. The strong inverse relationship between NPIW thickness and salinity observed at all three sites indicates that vertical displacement contributes importantly to the structural variability of the intermediate layer. Meanwhile, the stronger salinity anomalies and more complex hydrographic structures observed near the western boundary imply enhanced lateral exchange processes in these regions. The combined influence of these processes likely contributes to the observed intraseasonal co-variability of salinity and thickness. The inclusion of thickness analysis therefore provides a more comprehensive dynamical perspective for understanding how mesoscale variability influences the NPIW structure and properties. However, because the present study is primarily based on mooring observations and statistical analyses, the relative contributions of lateral advection, vertical displacement, and mixing processes cannot yet be quantitatively separated.

3.2 Minor Comments

1. The line color in Fig. 4b is inconsistent with Fig. 4a. Please revise for consistency.

Response:

Figure 4 has been redrawn accordingly based on the suggestions.

2. In Fig. 3, the salinity shading at M1 appears discontinuous. This may be due to the

sparse vertical resolution of the CTDs, which might not fully capture the salinity minimum. In this case, the averaged line may be misleading. It is suggested to reconsider or remove the averaged salinity line for clarity.

Response:

We agree that the relatively sparse vertical spacing of the CTD sensors may limit the ability to fully resolve the detailed salinity minimum structure at M1, which could affect the continuity of the interpolated salinity field.

To avoid potential misinterpretation, we have removed the averaged salinity line from Fig. 3 in the revised manuscript. The main conclusions of this study are based primarily on the temporal variability of layer thickness and isopycnal-averaged salinity, and are therefore not affected by this modification.

We replot the Fig.3 as follows:

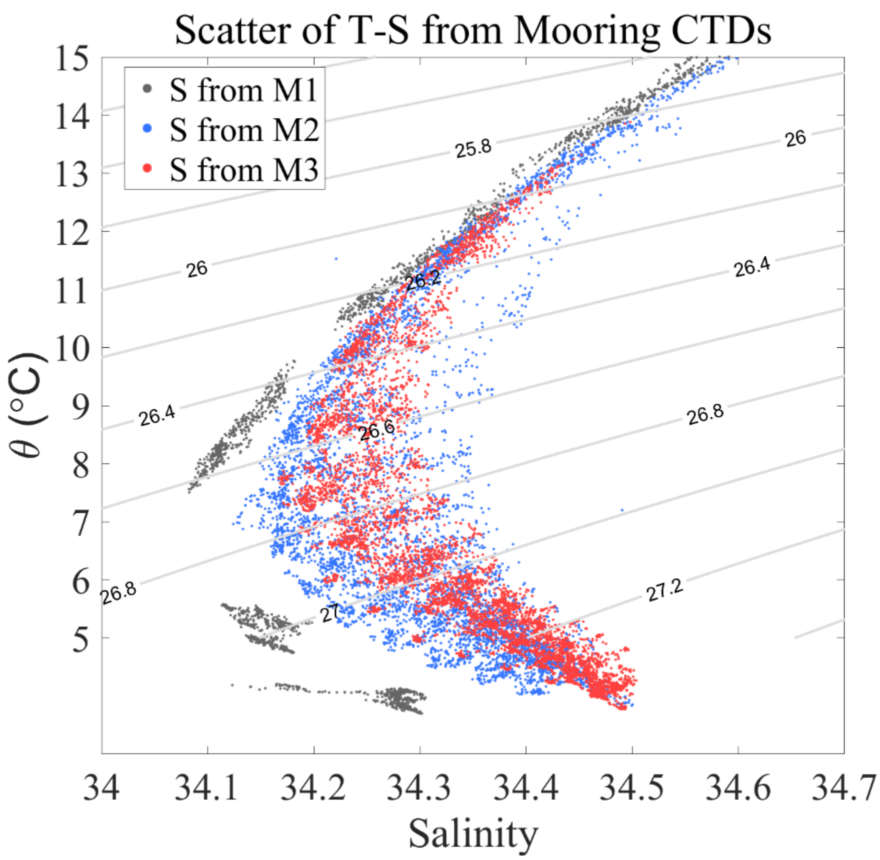

Figure 3. (a) The Temperature-Salinity plot from mooring CTDs. The black, green and red points are represent the M1, M2 and M3 measurements temperature and salinity, respectively.

3. Line 438: the symbol “/” better replaced with “and”

Response:

The symbol “/” has been replaced with “and” in the revised manuscript for improved clarity and consistency.