We sincerely thank you for the careful reading of our revised manuscript and for the constructive and insightful comments. We greatly appreciate your recognition of the value of the long-term, high-frequency mooring observations of the NPIW and the improvements made in the previous revision. The additional comments are very helpful for further strengthening the quantitative rigor, physical interpretation, and scientific balance of the manuscript.

Reponse to Reviewer 3

I have carefully read the revised manuscript and the authors' responses to the previous reviewers. First, I would like to commend the authors on presenting a highly valuable and interesting dataset. Long-term, high-frequency mooring observations of the North Pacific Intermediate Water (NPIW) are rare. The manuscript has been improved during the revision process (at least on 25th May); however, I believe there are still a few critical points that need to be addressed to further strengthen the scientific validity and depth of the discussion.

Below are my major comments, which build upon and extend some of the concerns raised in the previous review round.

1. Quantitative Comparison with CMEMS Data (Related to the general validation of reanalysis data and Reviewer 2's concerns regarding analytical rigor)

In the revised manuscript, the authors added T-S scatter plots using CMEMS data (Figure 7d-f) to validate its consistency with the in-situ observations. While this is a good addition to demonstrate qualitative agreement (e.g., the positive correlation between SLA and temperature/salinity), it currently lacks a quantitative comparison of the variation amplitudes. For instance, the mooring at M2 observed large salinity fluctuations (e.g., a standard deviation of 0.7 psu). The authors should quantitatively discuss how well the CMEMS data reproduces the actual magnitude of these variations. Comparing the amplitude or variance between the observations and the CMEMS data would provide a more rigorous justification for using the reanalysis data to explain the physical mechanisms in Section 4.3.

Response:

We sincerely thank you for this careful and important comment. Your's comment prompted us to recheck the statistical calculations of salinity variability in the manuscript. We found that the previously reported value of 0.7 psu for the salinity standard deviation at M2 was incorrect and clearly unrealistic for the intermediate-layer salinity range considered here. Given that the NPIW salinity is generally around 34.2 psu, a standard deviation of 0.7 psu would imply unrealistically large salinity excursions approaching values near 35 psu.

In the revised manuscript, we have recalculated the salinity variability using consistent definitions for both the mooring observations and CMEMS data. We now distinguish clearly between salinity amplitude and standard deviation. The salinity amplitude is defined as the difference between the maximum and minimum salinity at each depth, whereas the standard deviation represents the temporal variability around the mean state. The corrected results show that, at M2, the mooring-derived salinity amplitude ranges from 0.15 to 0.30 psu, with standard deviations of 0.03–0.06 psu. The corresponding CMEMS-derived salinity amplitude ranges from 0.10 to 0.22 psu, with a maximum standard deviation of approximately 0.04 psu. At M3, the mooring-derived salinity amplitude ranges from 0.05 to 0.25 psu, with standard deviations of 0.01–0.04 psu, while the CMEMS-derived amplitude ranges from 0.09 to 0.17 psu, also with a maximum standard deviation of approximately 0.04 psu.

These quantitative comparisons indicate that CMEMS reproduces the intermediate-layer salinity variability at the same order of magnitude as the mooring observations. However, CMEMS tends to underestimate the amplitude at M2, especially during stronger variability events near the western boundary. This underestimation may be related to the 7-day temporal resolution of CMEMS and the smoothing effect of gridded reanalysis products.

We have corrected the erroneous standard deviation values throughout the revised manuscript and added this quantitative comparison between CMEMS and the mooring observations. This correction improves the quantitative rigor of the manuscript. Importantly, it does not change the main conclusion that mesoscale eddies modulate the salinity and thickness structure of the NPIW. Instead, the revised comparison more clearly shows that CMEMS provides useful support for analyzing the spatial structure and eddy-related mechanisms, while the exact magnitude of high-frequency salinity fluctuations is better constrained by the mooring observations.

We sincerely thank you again for this valuable comment, which helped us correct the statistical description and present the supporting evidence for our conclusions more clearly.

And this paragraph has been added into revised manuscript in Section 4.3:

To quantitatively evaluate the ability of CMEMS to represent intermediate-layer salinity variability, we compared the salinity amplitude and standard deviation between CMEMS and the mooring observations at M2 and M3. Here, the salinity amplitude is defined as the difference between the maximum and minimum salinity at each depth, whereas the standard deviation describes the temporal variability around the mean state. The corresponding CMEMS-derived max standard deviations are 0.04 psu at M2 and 0.04 psu at M3. At M2, the CMEMS-derived salinity amplitude ranges from 0.10 to 0.22 psu, which is smaller than the mooring-derived amplitude of 0.15–0.30 psu. At M3, the CMEMS-derived amplitude ranges from 0.09 to 0.17 psu, generally comparable to the mooring-derived amplitude of 0.05–0.25 psu. These results indicate that CMEMS reproduces the observed intermediate-layer salinity variability at the same order of magnitude, although it tends to underestimate the amplitude at M2. This underestimation may be related to the 7-day temporal resolution of CMEMS and the smoothing effect of gridded reanalysis products. Therefore, its representation of the intraseasonal signals and variability amplitudes provides useful support for the subsequent analysis of the spatial structure and eddy-related mechanisms.

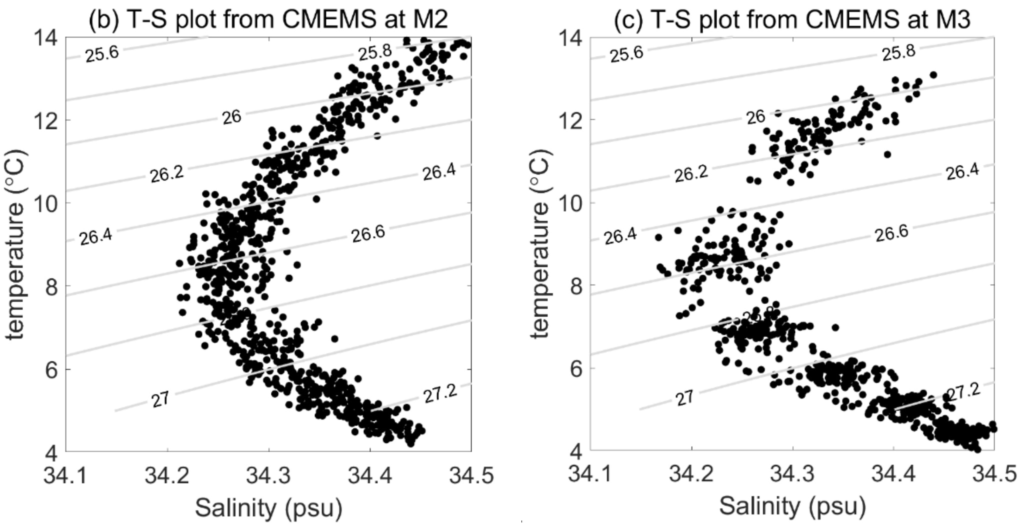

Figure. The T-S plot from CMEMS dateset at M2 and M3 mooring site.

2. 3D Structure of Eddies and Phase Relationships using CMEMS Data (Directly related to Reviewer 1's comment on 3D lens-shaped structures and Reviewer 3's comment on using phase relationships to distinguish mechanisms). In response to Reviewer 1 (regarding 3D eddy structures) and Reviewer 3 (who perceptively asked if "phase relationships" could help distinguish between vertical displacement and horizontal advection/mixing), the authors stated that their 1D mooring observations limit such 3D or quantitative separations. While this is true for the mooring data alone, the authors incorporate 3D CMEMS reanalysis data in Section 4.3, meaning this limitation no longer fully applies. Currently, Figures 12-14 only show 2D horizontal composite maps at specific depth ranges. To convincingly demonstrate the structural modulation by eddies, the authors should utilize the 3D nature of the CMEMS data to present vertical cross-sections (zonal and/or meridional composites) across the eddy center. Furthermore, by investigating the time lags relative to the SSHA peaks (e.g., creating cross-sectional composites before, during, and after the passage of SSHA peaks), the authors could effectively examine the phase differences between isopycnal heaving and the lateral intrusion of high-salinity waters. Addressing this would directly answer Reviewer 3's excellent point and allow for a much more conclusive, quantitative discussion on the mechanisms driving the anomalies at different sites.

Response:

We sincerely thank the reviewer for this insightful and constructive suggestion. We agree that the three-dimensional CMEMS fields can provide useful additional information for examining the structural modulation of the NPIW by mesoscale eddies, beyond the one-dimensional mooring observations and the two-dimensional horizontal composites.

In the revised manuscript, we have added new CMEMS-based vertical composite sections of temperature and salinity along the M2 transect under anticyclonic and cyclonic eddy conditions. The new figure shows the vertical thermohaline structure, potential-density contours, and the 34.3 psu isohaline boundary. These vertical sections provide more direct evidence for the different structural responses of the NPIW under the two eddy conditions. Specifically, under anticyclonic conditions, the intermediate-layer isopycnals are displaced downward, and the 34.3 psu isohaline encloses a thinner low-salinity layer near the M2 mooring. This compressed structure is accompanied by higher salinity around the mooring. In contrast, under cyclonic conditions, the 34.3 psu-bounded low-salinity layer is thicker and the salinity near M2 is lower. These results provide three-dimensional structural evidence that the inverse relationship between NPIW thickness and salinity is closely related to eddy-associated vertical displacement and compression or expansion of the intermediate low-salinity layer.

In addition, the salinity section under anticyclonic conditions shows relatively high salinity on the western side of the M2 transect. This feature is consistent with the horizontal salinity composite, which shows a high-salinity band extending toward the M2 region. Therefore, the elevated salinity near M2 may be associated not only with vertical compression of the low-salinity NPIW layer, but also with lateral redistribution of surrounding higher-salinity intermediate waters, possibly related to regional water-mass exchange involving the SCSIW and KIW. Thus, the newly added vertical sections, together with the horizontal composites, strengthen the interpretation that vertical displacement primarily controls the thickness response, whereas lateral water-mass redistribution may further enhance salinity anomalies near the western boundary.

Regarding the reviewer's suggestion to examine phase relationships or lagged composites relative to SSHA peaks, we agree that such an analysis would be valuable for distinguishing the timing between isopycnal heaving and lateral salinity intrusion.

We explored this possibility using the CMEMS fields. However, because the CMEMS data used in this study have a temporal resolution of 7 days, it may be difficult to reliably resolve short phase differences between SSHA extrema, isopycnal displacement, and salinity anomalies, which may occur on timescales of several days to about one week. In our examination, the lagged vertical structures did not show a sufficiently consistent or systematic phase relationship to support a robust quantitative lag estimate. Therefore, to avoid over-interpreting temporal phase relationships from weekly reanalysis fields, we did not include a quantitative lag analysis in the revised manuscript.

Nevertheless, the absence of a robust lag estimate does not preclude a physically meaningful interpretation of the surrounding water-mass influence. The newly added vertical composite sections show clear state-dependent differences between anticyclonic and cyclonic conditions. Under anticyclonic conditions, the 34.3 psu-bounded NPIW layer near M2 becomes thinner, and the salinity around the mooring, particularly on the western side of the section, is higher. In contrast, under cyclonic conditions, the low-salinity layer becomes thicker and the salinity near M2 is lower. This vertical structure is consistent with the horizontal salinity composite, which shows a high-salinity band extending toward the M2 region. Taken together, these vertical and horizontal composite patterns suggest that the salinity increase at M2 may be related not only to vertical compression of the low-salinity NPIW layer, but also to lateral redistribution of surrounding higher-salinity intermediate waters, possibly involving regional water-mass exchange associated with the SCSIW and KIW.

This paragraph has been added into the revised manuscript:

To further examine the three-dimensional structure of the eddy-related NPIW response, CMEMS-based composite vertical sections of temperature and salinity were constructed along the M2 transect under anticyclonic and cyclonic eddy conditions (Fig. 15). The sections show clear differences in the vertical structure of the intermediate layer between the two eddy states. During anticyclonic eddy conditions, the intermediate-layer isopycnals are displaced downward, and the 34.3 psu isohaline encloses a relatively thinner low-salinity layer near the M2 mooring. This compressed structure is accompanied by higher salinity within the intermediate layer, especially on the western side of the section. This feature is consistent with the horizontal salinity composite, which shows a high-salinity band extending toward the M2 region. Therefore, the elevated salinity at M2 may be associated not only with vertical compression of the low-salinity NPIW layer, but also with lateral redistribution of surrounding higher-salinity intermediate waters, possibly related to regional water-mass exchange involving the South China Sea Intermediate Water (SCSIW). In contrast, during cyclonic eddy conditions, the 34.3 psu isohaline extends over a thicker vertical range near M2, indicating expansion of the low-salinity NPIW layer, with relatively lower salinity. These vertical composite structures provide additional evidence that the inverse relationship between NPIW thickness and salinity is closely related to eddy-induced vertical displacement and compression or expansion of the intermediate low-salinity layer. Similar vertical compression and expansion characteristics are also found at the other mooring sites, but M2 is shown here as a representative example because the western-boundary water-mass interaction is most evident at this site.

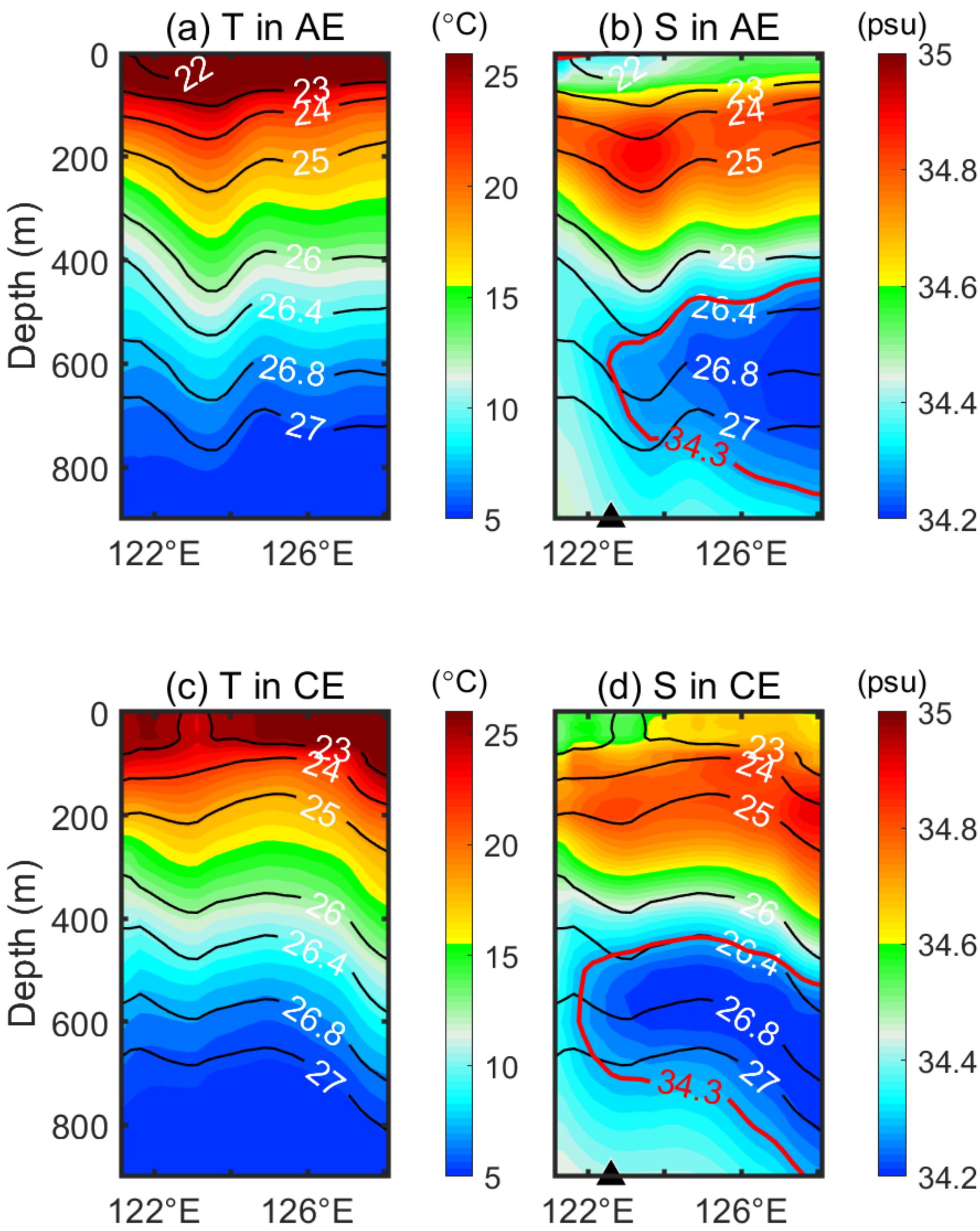

Figure 15. Composite vertical sections of temperature and salinity along the M2 transect during anticyclonic and cyclonic eddy form CMEMS data. (a, b) Temperature and salinity sections during anticyclonic eddy, respectively. (c, d) Same as (a, b), but for cyclonic eddy. Color shading represents temperature in (a, c) and salinity in (b, d). Black contours indicate potential density, and red contours in (b, d) denote the 34.3 psu isohaline. The black triangle indicates the location of the M2 mooring.

3. Implications of Non-overlapping Observation Periods (A crucial point largely overlooked in the previous review round) The observation periods for the three moorings do not overlap: M3 (2016-2017), M1 (2017-2018), and M2 (2019-2020). The

manuscript currently attributes the differences in NPIW variability among the sites entirely to spatial heterogeneity (i.e., open ocean vs. western boundary). However, because the measurements were taken in completely different years, there is a strong possibility that interannual variability (e.g., different climate phases, background hydrographic shifts, or year-to-year differences in regional eddy kinetic energy) also contributes to the observed differences. While this does not negate the study's general findings regarding the eddy-induced modulation, the potential influence of interannual variability due to the asynchronous observation periods must be explicitly acknowledged and discussed in the Discussion section to ensure scientific rigor.

Response:

We sincerely thank you for raising this important and thoughtful point. We agree that the non-overlapping observation periods of the three moorings introduce an additional source of uncertainty in the site-to-site comparison. In the previous version, the differences among M1, M2, and M3 were mainly discussed in terms of spatial heterogeneity, such as the contrast between the open-ocean environment and the western boundary region. We agree that this interpretation should be made more cautious because the three records were obtained during different years.

In the revised manuscript, we have explicitly acknowledged this limitation in the Discussion section. We now state that the differences among the three mooring sites should not be interpreted as purely spatial contrasts. Interannual variability in the background hydrographic state, regional eddy activity, and large-scale circulation may also contribute to the observed differences. This is particularly relevant in the western North Pacific, where previous studies have shown interannual to decadal variability in NPIW salinity, water-mass properties, and eddy activity in the Kuroshio Extension region.

At the same time, we clarified that the main focus of this study is the intraseasonal variability within each individual mooring record and its relationship with mesoscale eddy signals. The inverse relationship between NPIW thickness and salinity, as well as the coherent association among SLA, salinity, and thickness, is identified within each observational period. Therefore, the asynchronous observation periods do not alter the main conclusion that mesoscale eddies modulate the NPIW structure. However, they do imply that the cross-site comparison should be interpreted as reflecting both regional hydrographic differences and possible interannual modulation.

We have revised the Discussion accordingly and softened statements that previously attributed the site-to-site differences solely to spatial heterogeneity.

We sincerely thank you again for this valuable comment, which helped us recognize an important limitation in the original interpretation and improve the rigor and balance of the revised manuscript.

And follow paragraphs has been added into revised manuscript in Section 4.3:

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. In addition, the three mooring records were obtained during different periods, with M3 during 2016–2017, M1 during 2017–2018, and M2 during 2019–2020. Therefore, the differences among the three mooring sites should not be interpreted as purely spatial contrasts. Interannual variability in the background hydrographic state, regional eddy activity, and large-scale circulation may also contribute to the observed site-to-site differences. Previous studies have shown that the salinity minimum of the NPIW, water-mass properties in the western North Pacific, and eddy activity in the Kuroshio Extension region can vary on interannual to decadal timescales.

Nevertheless, the main focus of this study is the intraseasonal variability within each mooring record and its relationship with mesoscale eddy signals. The inverse relationship between NPIW thickness and salinity, together with the coherent association among SLA, salinity, and thickness at individual sites, remains evident within each observational period. Therefore, the non-overlapping observation periods do not alter the conclusion that mesoscale eddies modulate the NPIW structure, but they do imply that the cross-site comparison reflects both regional hydrographic differences and possible interannual modulation. This limitation has been considered in the interpretation of the spatial heterogeneity discussed above.