Author’s General Response to Reviewer Matthew Harrison

We sincerely thank the reviewer for their thoughtful and constructive comments. The reviewer’s questions and suggestions have helped us improve the clarity and depth of our analysis, particularly regarding the influence of the vertical coordinate system on stratification, MLD, and strait transports. We have carefully revised the manuscript to address all comments, and we believe these revisions have strengthened the overall quality of the paper. Detailed responses to each comment are provided below.

We have incorporated these new results into the revised manuscript. Overall, the reviewer’s comments have led to a more balanced and comprehensive assessment of the vertical coordinate sensitivity in the regional MOM6 framework.

The detailed responses to the reviewer’s specific comments are provided below.

1. **Figure 1: Spelling correction. “East Chania Sea” should be “East China Sea”**

➔ We thank the reviewer for pointing this out. The spelling error in Figure 1 has been corrected — “East Chania Sea” has been revised to “East China Sea.”

2. **L110: Reference Ilicak, 2012, Ocean Modeling.**

➔ We thank the reviewer for the suggestion. The reference to Ilicak et al. (2012, Ocean Modelling) has been added in the revised manuscript. (line 109)

3. **L143: How does limiting the depth to 5000m reduce the model’s computational burden?**

➔ We thank the reviewer for this insightful comment. In the original manuscript, the term computational efficiency was used to describe the benefit of limiting the maximum model depth to 5000 m. However, as the reviewer correctly points out, this change does not primarily reduce computational cost but rather improves the efficiency of the vertical grid design. Specifically, limiting the depth avoids allocating unnecessary vertical layers in dynamically inactive deep basins and allows more effective use of vertical resolution in the upper and intermediate layers. Accordingly, we have replaced computational efficiency with efficiency of vertical grid utilization in the revised manuscript to better reflect the intended meaning. (line 154)

4. **The “background” vertical viscosities and diffusivities are less than molecular (1.e-6 m2 s-1) values. Are MOM6 configurations typically using such small values? This appears to be a departure from typical ocean configurations which would typically rely on background values an order of magnitude higher. Please discuss the rationale for using such a small value.**

➔ We thank the reviewer for this valuable comment. The small background vertical viscosity and diffusivity values (1×10^{-6} m^2 s^{-1}) used in this study follow the rationale that in MOM6, these parameters represent only a residual background contribution, as the dominant mixing processes are already parameterized through the energetic Planetary Boundary Layer (ePBL; Reichl & Hallberg, 2018) and the shear-driven mixing scheme (Jackson et al., 2008). Because these parameterizations explicitly represent vertical mixing and turbulence, the background values mainly serve to maintain numerical stability rather than to control mixing intensity. Sensitivity tests comparing 1×10^{-5} m^2 s^{-1} and 1×10^{-6} m^2 s^{-1} showed no significant differences in the large-scale circulation or tracer distribution, and therefore the smaller value was adopted for consistency and to minimize artificial diffusion.

5. **Table 1 could be reformatted, since the third column is empty with the exception of the first row.**

➔ We thank the reviewer for this suggestion. Table 1 has been reformatted to remove the empty third column and improve readability. The revised version now presents the information in a more concise and visually clear layout.

6. **L201: For clarification, are you applying discharge adjustments at the Yangtze river only?**

➔ We thank the reviewer for this helpful question. In the initial setup, discharge adjustments were applied only to the Yangtze River, which has the largest freshwater influence in the Northwest Pacific region. However, despite this correction, the model still exhibited low-salinity biases along the Chinese coast. To address this issue, we recently extended the discharge bias correction to include the Yellow River as well.

7. **L237-241: This paragraph is redundant with the previous one.**

→ We thank the reviewer for pointing this out. The paragraph at Lines 237–241 overlapped with the preceding one, and we have removed the redundancy by merging the relevant information into a single, concise paragraph in the revised manuscript.

8. **L352-366: The differences in wintertime MLD between HYBRID and ZSTAR are most prominent South of the Kuroshio extension between 25N-35N and in the Okhotsk Sea. In the first case, is this a result of enhanced stratification below the actively mixed layer prior to the onset of wintertime convection, for example? In the latter case, is this a result of poor representation (fewer active layers) due to the use of sigma2? It would be helpful to see the seasonal evolution of the stratification and/or the actual internal layer representation in the model for these regions. These questions could be addressed later in the text as well.**

→ We thank the reviewer for this insightful question. In the region south of the Kuroshio Extension (25°–35°N), the comparison of buoyancy frequency squared (N^2) between ZSTAR and HYBRID (Fig. S6) indicates that both configurations capture strong stratification beneath the mixed layer, but the vertical structure differs. HYBRID shows stronger stratification slightly deeper (below about 100 m) from late summer to early winter, whereas ZSTAR exhibits stronger stratification just below the mixed layer (around 50–100 m). The deeper stratification maximum in HYBRID stabilizes the upper ocean and suppresses excessive convective deepening during winter, resulting in a shallower and more realistic MLD compared to ZSTAR, which tends to overestimate MLDs because of weaker near-surface stratification. Although the magnitude of the N^2 differences (~10^{-5} s^{-2}) is modest, it is seasonally consistent and sufficient to influence the mixed-layer evolution. (line 698-708)

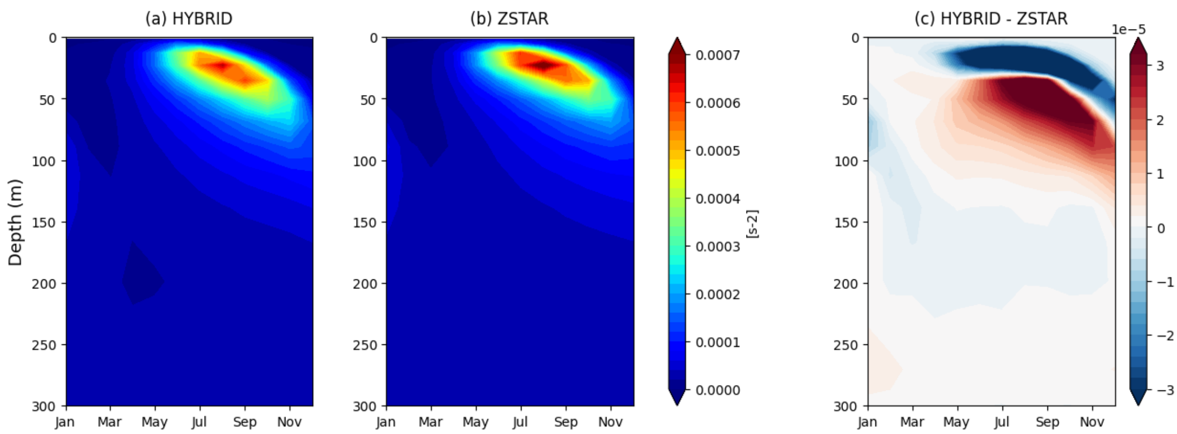

Figure 1 Seasonal evolution of buoyancy frequency squared (N^2, s^{-2}) averaged over 25°–35°N and

140°–160°E for (a) HYBRID, (b) ZSTAR, and (c) their difference (HYBRID － ZSTAR).

➔ In the Sea of Okhotsk, the MLD differences primarily arise from the vertical layer representation (Fig. S7). In this region, the σ_2-based HYBRID coordinate produces thicker layers in weakly stratified waters, reducing vertical resolution below roughly 80–200 m and leading to slightly deeper MLDs than ZSTAR. (line 698-708)

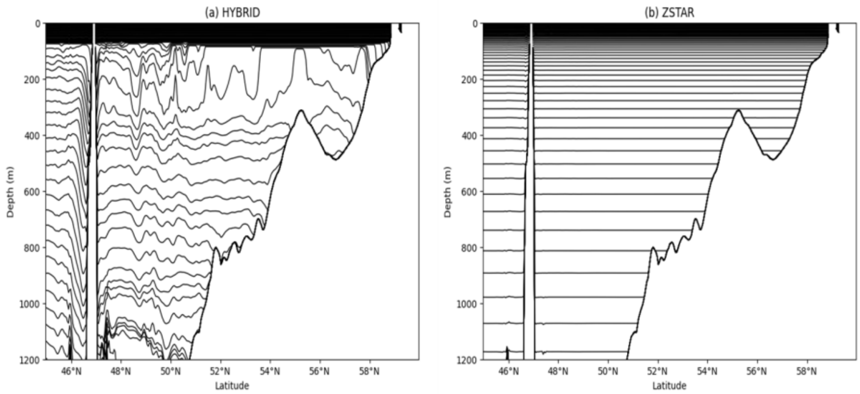

Figure 2 Model interfaces along 152°E in the Sea of Okhotsk for (a) HYBRID and (b) ZSTAR.

9. **Fig15: salinity differences on sigma2 can be mostly estimated from the temperature differences, so this figure and the previous one are redundant. Suggest removing this figure.**

➔ We thank the reviewer for this helpful suggestion. Since the salinity differences on σ_2 surfaces were largely consistent with the temperature-induced density variations, we agree that Fig. 15 conveyed redundant information. To streamline the main text while retaining the supporting analysis, this figure has been moved to the Supplementary Material, and only a brief reference to it remains in the revised manuscript.

10. **L592. Did the authors evaluate simulations without explicit tides and using parameterized tides instead and did this reveal differences in YBCMW?**

➔ We thank the reviewer for this insightful question. In our previous MOM5-based configuration, explicit tidal forcing was not included, and tidal effects were represented through parameterized mixing schemes. To examine their impact on the formation of the Yellow Sea Bottom Cold Water Mass (YBCWM), additional experiments were conducted. The results showed that, without data assimilation, the model using parameterized tides was unable to reproduce the YBCWM structure. This indicates that the explicit representation of tides and associated mixing processes plays an essential role in maintaining the cold, dense bottom water in the Yellow Sea.

11. **L622. Can you provide additional comments on the role of the vertical coordinate in impacting the volume transport through straits? The connection is not immediately obvious.**

➔ We thank the reviewer for this valuable question. As also noted by another reviewer, the vertical coordinate system can influence the simulated volume transport through narrow straits by modifying the local representation of stratification and pressure gradients. In our simulations, both configurations used identical bottom drag formulations and free-slip lateral boundary conditions; therefore, the transport differences are not attributed to frictional effects. Instead, sectional analyses across the Tsugaru Strait revealed that HYBRID preserved steeper isopycnal slopes and stronger density gradients than ZSTAR, which may enhance the baroclinic pressure-gradient force and lead to stronger along-strait velocities. In narrow passages where bathymetry changes abruptly and density structures differ across the strait, HYBRID's isopycnal alignment can locally amplify the horizontal density gradient ($\partial\rho/\partial x$) and thus the transport. Conversely, ZSTAR's smoother vertical discretization dampens sharp density gradients, producing weaker baroclinic pressure gradients and smaller transports. These findings suggest that the differences in volume transport between HYBRID and ZSTAR primarily arise from how each vertical coordinate system represents stratification and baroclinic structure, rather than from differences in friction or boundary formulations. We have clarified this interpretation and added the relevant explanation in the revised manuscript. (line 758-764)

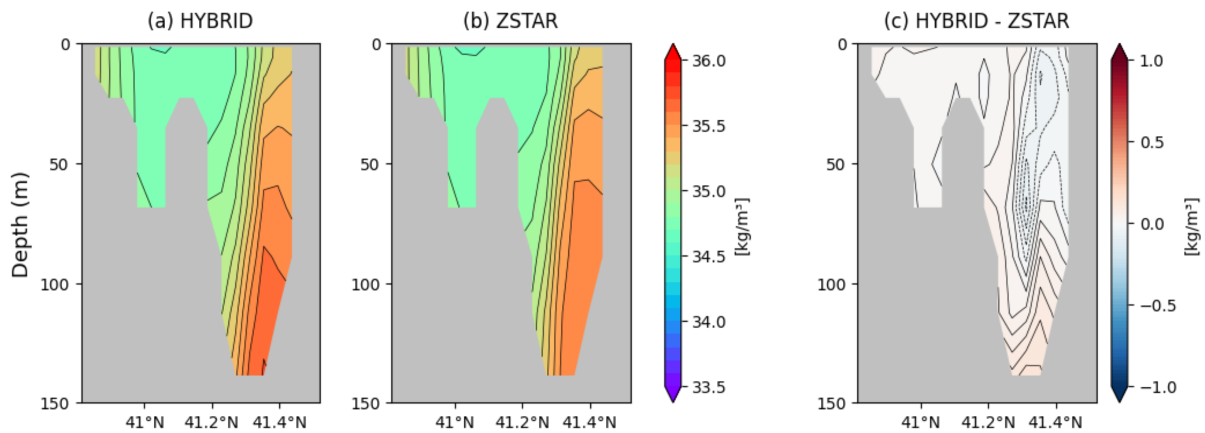

Figure 3 Meridional section of potential density (σ_2, referenced to 2000 m) across the Tsugaru Strait, averaged over 2012. (a) ZSTAR, (b) HYBRID, and (c) HYBRID–ZSTAR difference.

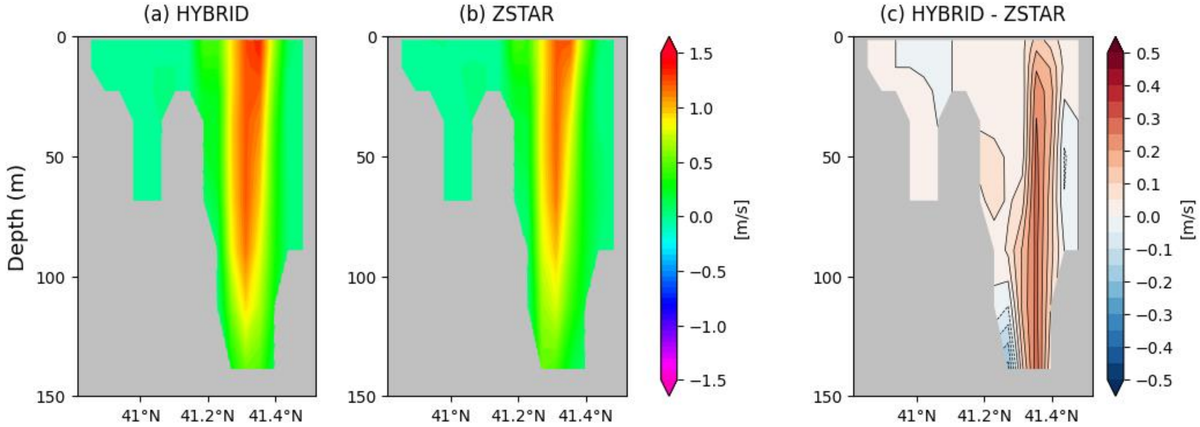

Figure 4 Meridional section of along-strait velocity (U) across the Tsugaru Strait, averaged over 2012. (a) ZSTAR, (b) HYBRID, and (c) HYBRID–ZSTAR difference.