

Response to reviewers

We appreciate the time and thoughtful comments that the reviewers have provided for our submission to *Geoscientific Model Development*. Please below see for a point by point response to your comments. Comments are noted in blue, our responses are noted in black.

Sincerely,
Kyle Hinson

Comments to the author

Reviewer 2

- RC:** *This manuscript presents a systematic comparison of MPAS-O and ROMS simulations over a wide range of horizontal resolutions. The experiments are computationally substantial, and the comparison of frontal statistics and physical and numerical mixing is potentially useful for the development of high-resolution unstructured-grid ocean models. The manuscript is generally well organized, but the central claim concerning the representation of submesoscale baroclinic instability requires stronger dynamical support. I recommend revision before publication.*
- AR:** Thank you for your review and comments on the manuscript, we have responded to each of the points of feedback below.
- RC:** *The title and stated objective emphasize coastal submesoscale baroclinic instabilities, whereas most analyses focus on kinematic and statistical characteristics, including surface kinetic energy, vorticity, divergence, strain, frontal velocity gradients, and tracer mixing. Similar submesoscale intensity or flow statistics do not necessarily imply that the two models represent the underlying instability dynamics similarly. In particular, comparable kinetic energy may result from different balances among available-potential-energy release, baroclinic conversion, wind input, and physical or numerical dissipation. This possibility is especially relevant because the two models show different instability timing and mixing behavior. The authors should therefore provide a more direct comparison of the instability energetics, such as the evolution of available potential energy and eddy kinetic energy, baroclinic conversion or vertical buoyancy flux, and relevant dissipation terms, at least for representative resolutions.*
- AR:** Thank you for this comment and suggestion. This work is in many ways a continuation of earlier research conducted by Hetland (2017), which more conclusively demonstrates that this class of instabilities is definitively baroclinic. Further elaborating upon this point in this manuscript would be somewhat didactic, and would also contribute less to the main thesis of the research. Still, the comment was interesting to consider and to more fully address it we have undertaken additional analyses to compute time series of eddy kinetic energy,

the results of which have been added to Figure 3 (for formatting purposes, we have now also chosen to split out the KE spectra into a separate, smaller Figure 4). The methodology for computation of both time series have also been added to the methods (Section 2.4.1). These findings support many of our previous results, with important differences noted in the results and discussion sections, especially regarding the apparent spurious mode in the MPAS-O 100 m solution activated at approximately day 25 and its correspondence with a large spike in negative numerical mixing (now Figure 10c).

RC: *Line 52: “ROMS; Shchepetkin and McWilliams, 2005”.*

AR: This has been corrected.

RC: *Line 192: “tracer advection schemes”.*

AR: Thank you for catching this error, which has been corrected.

RC: *Line 203: it should be Table 1.*

AR: Thank you for catching this error, this has been corrected.

RC: *Line 227: “vertical velocity cell phases” should likely be “vertical velocity cell faces”.*

AR: Thank you for catching this error, this has been corrected.

RC: *Line 241: Please define explicitly how the frontal angle α is determined and how points with weak gradients are treated.*

AR: We have further noted in the text that the frontal angle α follows the definition and schematic of Figure 1 in Hetland et al. (2025). Points with weak gradients are treated equivalently because the purpose of this analysis is to determine the direction of frontal dynamics. The text has also been modified to remove the phrase "largest positive gradients" in order to avoid confusion.

RC: *Figure 4 caption: please explain “Negative relative vorticity values correspond to a greater number of eddies, while positive vorticity values indicate a greater number of fronts.”*

AR: Thank you for pointing this out. The text has been amended to, "Negative relative vorticity values correspond to a greater amount of anticyclonic flows characterized by eddy activity, while positive vorticity values are associated with frontal processes." which we believe more accurately describes the results. The baroclinic instabilities in the idealized simulations mimic the frontal eddies found on the real Texas-Louisiana shelf. These frontal eddies have anticyclonic cores and cyclonic fronts, see Hetland (2017) and Schlichting et al. (2023) for examples.

RC: *Lines 353–355: it would be better to use $|\delta/f|$, with convergence and divergence treated separately.*

AR: Thank you for this comment, this appears to have been a typo and has been corrected in the manuscript such that it now shows the absolute value of δf^{-1} rather than the absolute value of 1. As seen in (now) Figure 5e-f, we do in fact treat convergence and divergence separately in our analyses.

RC: *Figure 6 caption: The ROMS panels should be cited as (e–h).*

AR: This has been corrected.

RC: *Line 378: “principal component”.*

AR: This has been corrected.

RC: *Line 473: “certainly due to”.*

AR: This has been modified as suggested.

RC: *Figure A1 caption: “and (b) MPAS-O”.*

AR: This has been modified as suggested.

References

- Hetland, R. D. (2017). Suppression of baroclinic instabilities in buoyancy-driven flow over sloping bathymetry. *Journal of Physical Oceanography*, 47(1):49–68.
- Hetland, R. D., Qu, L., and Hinson, K. E. (2025). Frontal maintenance in submesoscale flows. *Journal of Physical Oceanography*.
- Schlichting, D., Qu, L., Kobashi, D., and Hetland, R. (2023). Quantification of physical and numerical mixing in a coastal ocean model using salinity variance budgets. *Journal of Advances in Modeling Earth Systems*, 15(4):e2022MS003380.