Referee comments are in blue colored fonts, and our replies in black.

Response to Referee Comments 2

The paper introduces 1/32° resolution simulations with waves and tides. I think it is a nice first effort in terms of model development. However, I don't find the results from these runs warrant a solid scientific publication. Therefore, I recommend rejection to the paper.

The conclusion on the effect of resolutions is hardly innovative: higher resolution resolves smaller scale processes, and that affects eddy-rich systems like Kuroshio and Gulf Stream. In contrast, ACC seems to get worse in 1/32°, which seems to me is a more interesting aspect, but the authors curiously left it out.

Author response: Thank you so much for pointing out that this is "a nice first effort in terms of model development" regarding the 1/32° resolution simulations with waves and tides in this paper. For responding your comments: "The conclusion on the effect of resolutions is hardly innovative: higher resolution resolves smaller scale processes, and that affects eddy-rich systems like Kuroshio and Gulf Stream", we clarify/repeat the novelty of this submission as follows:

1. It is the first try in the world for model development to couple the surface wave, tide and circulation into a high resolution model, which is emphasized by reviewer, and the model performs quite well. This innovation on ocean model development should deserve the publication on GMD. We also would like to quote the comments of another referee "adds to a small handful of similar very high-resolution simulations of the ocean which have been undertaken to date."

2. For the first time, we quantitatively demonstrated that: (1) By including tide, the generated internal tide modulates the Sea Surface Height on global scale which is the key factor contributing to the substantially improved agreement of model against satellite observations in terms of wave number spectral slopes of mesoscale range in the low latitude and low EKE regions. To our knowledge, this is the first report for the global ocean model in improving the simulation of the wave number spectral slopes of mesoscale range. (2) The non-breaking surface wave-induced mixing (Bv) is proved still to be an important contributor that improves the agreement of the simulated summer mixed layer depth against the Argo observations even with high horizontal resolution of 1/32°, with the simulated MLD mean error reduced from -4.8 m without Bv to -0.6 m in experiment with Bv. We provide a solution for accurate MLD which is crucially important for the climate system, marine ecosystem, and Tropical Cyclone evolution.

3. As an example, we quantitatively assess the improvements of simulated EKE of the developed global ocean models with horizontal resolutions of 1/10° and 1/32°. Then

we quantitatively assess the impact of horizontal resolution on the simulated paths of Kuroshio and Gulf Stream, by proposing the Integrated Circulation Route Error (ICRE) as a quantitative criteria. As far as we know, it is also the first time that this ICRE criteria for ocean model evaluation is proposed and applied.

The ACC is not specifically studied in this paper, we will look into it in the future.

Based on all the above distinct innovations, and with serious consideration, we select this highly reputed journal of GMD.

The tide part is also confusing. First, the global averaged RMS errors in the barotropic runs are suspiciously high (even higher than some of the past works with lower resolutions), which begs further investigation of the validity of the model physics and makes it hard to argue the conclusions based on these simulations. Furthermore, the 1/32° baroclinic run yields even worse tides than not only its barotropic counterpart but also the 1/10° resolution runs. In my opinion, this result alone discredits the model and the conclusions from the simulations.

Author response: We disagree with the review comments of "the global averaged RMS errors in the barotropic runs are suspiciously high". As we can see in Figures 8d and e, the simulated co-tidal charts of barotropic runs agree pretty good with that of TPXO9, and the global averaged RMS errors in the barotropic runs is 8.06 cm. It is a very reasonable statistic and laid a solid foundation for the development of high resolution surface-wave-tide-circulation coupled model. Going through the previous publications with similar model physics (Shriver et al., 2012), we noticed that their simulation errors for M_2 is 7.48 cm, while our simulation error is 8.06 cm. For global barotropic tide models, the RMSE become insensitive to the model resolution beyond ~1/10° (Egbert et al., 2004). Although we still have room to improve the accuracy (such as, changing model discretization from B-grid to C-grid, more realistic treatment of Self Atracktion and Loading effect etc), to call it "suspiciously high ... begs further investigation of the validity of the model physics and makes it hard to argue the conclusions based on these simulations" is unfair and obviously an exaggeration.

In this paper, we reported that the internal tide can modulate sea surface height, and serves as the key factor contributing to the substantially improved agreement of model against satellite observations in terms of wave number spectral slopes of mesoscale ranges. This is the first report for the global ocean model. If we are wrong, we ask Reviewer 2 to educate us. The key that we can observe the important tide-circulation coupled effects in our numerical experiments is that we have chosen the proper model settings, including normal model background viscosity, and closed topographic drag scheme used in the barotropic runs not to tune it, which is aligned with LLC4320 of MITgcm (Arbic et al., 2018). These modelling strategies pursue honest representation

of the tide-circulation coupled processes, not just the accuracy of the tide. As shown in Fig. 8f, the pattern of the 1/32° baroclinic run agrees well with that of TPXO9. Since a large portion of tidal energy conversion is resolved by the model, the tidal dissipation parameterization for the 1/32° baroclinic run must be able to distinguish the unresolved and resolved tidal energy dissipation/conversion. To our knowledge, this kind of tidal dissipation scheme still does not exist in the present publications and is a daunting challenge for the ocean model scientific community. If the reviewer knows some publication, please let us know. Hence we choose to disable the topographic drag scheme used in the barotropic runs not to tune it, which is aligned with LLC4320 of MITgcm (Arbic et al., 2018). Although this leads to larger errors in simulated global tide, we believe that in the current stage, the representation of tide-circulation coupled processes will benefit from this strategy just as shown in Figure 14c.

In addition, I find the draft poorly written. There are numerous grammar mistakes, and many sentences are either confusing or awkward.

Author response: We have invited a native English speaker to polish the draft. The certificate is attached here. The corresponding author is the co-editor-in-chief of Ocean Modelling, and have actively taken part in international cooperation including as the Decade Advisory Board member of United Nations Decade of Ocean Science for Sustainable Development. Our English is far from perfect or beautiful, but should be okay for scientific understanding. If the reviewer could provide detailed comments on which sentence should be polished, that will be highly appreciated.

Reference

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