Review of "The tidal effects in the FInite-volumeE Sea ice-Ocean Model (FESOM2.1): a comparison between parameterised tidal mixing and explicit tidal forcing" by Song et al

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This manuscript compares three different simulations with an ocean general circulation model: a control simulation without the effect of tides (NOTIDE), a simulation with parameterised tidal mixing (CVTIDE), and a simulation with explicit tidal forcing (LSTIDE). The differences are in general rather small. Perhaps the most interesting and significant ones are seen in the meridional overturning in Fig 11. CVTIDE has a stronger deep cell involving AABW, while LSTIDE has a stronger AMOC and a stronger cell in the North Pacific, with upwelling around 50°N.

The are major problems, both with the setup of the simulations and with the analysis of the results, and I therefore do not recommend publication of this manuscript.

Detailed comments:

- The tidal parameterisation in CVTIDE is very crude. It is based on a simple scaling estimate of the tidal generation of internal waves, but, for example, does not distinguish regions where these waves are trapped or propagating. There are more serious calculations of the tidal generation of internal waves by, for example, de Lavergne et al. (2019), with data available at https://www.seanoe.org/data/00470/58153/.

- As noted in the manuscript, the horizontal resolution is insufficient to resolve the internal tides in most of the ocean. It is therefore clear already from the outset that the tidal mixing can not be captured correctly. It should also be remembered that resolving the generation of internal tides is a necessary but not sufficient condition to describe tidal mixing. To do that, you must also describe the breaking of the internal waves, not just their generation. If, because of insufficient resolution, they decay by viscous dissipation instead of by breaking, the mixing is not captured.

- It is unclear how the tidal motion in LSTIDE leads to vertical mixing, i.e. larger vertical diffusivity.

- In Figs 3-6 the hydrography in the simulations is compared to the observationally based data set WOA18. The results are mixed, and the differences between the different simulations are generally small compared to the bias of the control simulation. It is clear that neither CVTIDE nor LSTIDE gives any decisive improvement, and the improvements that exist in som regions may well be for the wrong reason. For example, biases caused by the background diffusivity, the K-profile parameterisation or the GM-parameterisation might be compensated by the parameterisation of tidal mixing. It is therefore difficult to draw any conclusion at all from these figures. CVTIDE and LSTIDE should instead be regarded as sensitivity tests, and the interesting question is not whether they decrease the bias, but how they modify the hydrography compared to NOTIDE.

- The key to understanding the effect on hydrography is the vertical diffusivity. Its geographical distribution is shown in Fig 12, but this should be complemented by plots with the vertical profile of the diffusivity, along with the vertical hydrographic profiles.

- In my view, the clearest and most interesting effect in LSTIDE is the strongly increased strength of the overturning cell in the North Pacific seen in Fig 11f. What evidence shows that this is an improvement?

- To explain the increased strength of the overturning cell in the North Pacific, the authors invoke the increased vertical diffusivity at the Kuril Ridge and Aleutian Ridge seen in Fig 12l and probably caused by trapped internal tides. This might be correct, but no strong support for this explanation is shown. Here are some problems. i) According to Fig 12 the vertical diffusivity in the Northern Pacific increases much more in CVTIDE than in LSTIDE, and yet there is much less upwelling in CVTIDE. In order to make the explanation credible, the pattern of vertical diffusivity (geographical and vertical) in the Northern Pacific should be studied in detail. ii) The strong diffusivity could be caused by resonant trapped waves, but it could also be caused simply by strong shear of the barotropic tide caused by bottom friction on the continental shelf. It should be possible to check which alternative is correct.

- In section 5.2 it is argued that the stronger AMOC in LSTIDE is caused by increased upwelling in North Pacific and the Indonesian Archipelago. This seems far-fetched. An alternative explanation is that it is caused by increased vertical diffusivity in upper 3000 m of the Atlantic itself, but this is difficult to judge since vertical diffusivity profiles are not shown.

- The energy diagnostics in Table 3 are potentially interesting, but unfortunately incomplete. The surface energy input, bottom drag, viscous dissipation, buoyancy flux and barotropic tide power are terms in the budget for kinetic energy. However, the budget is far from closed, particularly in LSTIDE. (Note that the sign of the buoyancy flux should be changed when calculating the budget, since a positive $\overline{\rho w}$ is a conversion from kinetic energy to potential energy, i.e. a sink of kinetic energy.) It is striking that the barotropic tide power in LSTIDE is much larger than the increase of the sinks. The main missing term is probably energy loss due to horizontal viscosity, which should therefore also be diagnosed. If there are no more missing terms, the remaining residual will then be due to numerical errors. This is essential to know.

References

de Lavergne, C., S. Falahat, G. Madec, F. Roquet, J. Nycander and C. Vic, 2019: Toward global maps of internal tide energy sinks. *Ocean Model.*, **137**, 52–75.