REVIEW of

" Assessment of the Finite VolumE Sea Ice Ocean Model (FESOM2.0), Part II: Partial bottom cells, embedded sea ice and vertical mixing library CVMIX" by Scholz et al., 2021.

The presented manuscript describes and evaluates the application of the recently developed unstructured-mesh Finite-volumE Sea ice-Ocean Model version 2.0 (FESOM2.0). The current state of the art FESOM2.0 model include multiple options and the authors analyze the impact of the partial cell, embedded sea ice-ocean model coupling and several mixing parameterizations from the Community Vertical Mixing (CVMIX) project library on the performance of the coarse resolution global sea ice FESOM2.0 model.

During the last decades the FESOM model was actively developed and applied for sea ice modeling in multiple publications. Therefore, the detailed analysis of different FESOM2.0 options is a necessary step and will be extremely useful for potential FESOM users. The manuscript is relatively well written and provides many Figures which illustrate the impact of different options on the model solution. Meanwhile, I find that the authors provide only "technical and qualitative comparison" and that makes this manuscript to be very similar to a technical report but not a research paper.

Thus, I definitely may recommend the manuscript for publication in the Geoscientific Model Development Journal, but recommend adding some *quantitative* comparison between different FESOM2.0 options and provide at least a *qualitative physical explanation* of the revealed differences. This is especially important towards understanding the impact of the partial cells and embedded sea ice options.
Below, I provide my comments and remarks which I would suggest should be taken into account.

Line 54-55 - *"Embedded Sea ice … "*

As I remember, the first understanding of the importance of the Embedded Sea ice was provided by Hibler et al., 1998, and after that, was used in several publications (e.g. Hutchings et al, 2005). I guess Hibler's embedded ice models are different from FESOM2.0, but these publications are also related to the embedded sea ice and should be at least cited.

Line *57* *"implementation of embedded sea ice relies on the zstar vertical-coordinate option in FESOM2 and also on the fact that the sea ice component is called on each time step of the ocean model"*

As I understand FESOM2 uses an EVP solver (or its modification) and this suggests the application of two time steps. Which time steps do you mean for the ocean and sea ice models? Also, the modern sea ice model (e.g. CICE6, MIT ocean model) typically includes explicit and implicit solvers: EVP, different VP solvers (GMRES, Newtonian..)? Do you plan to include an implicit VP solver? If so, it could be expensive to use a VP solver for each time step of the ocean model.

Line 151 *we limited the thickness of the partial bottom cell to be at least half of the full cell layer thickness to reduce the possibility of violating the vertical Courant–Friedrichs–Lewy (CFL) criterion.*

It looks like a strong limitation: usually the CFL is defined by dz near the surface, so it looks strange to not allow the near bottom dz to be about 0.25 from the full dz. Did you observe any instability in the FESOM numerical scheme?

Liner 159-184
In order to demonstrate the effect of the partial cells on the simulated ocean state we performed two model simulations using the full cell and partial cell approaches, respectively. We investigate, first, the temperature biases of the full cell approach with respect to the data of the World Ocean Atlas 2018 (WOA18, Locarnini et al., 2018; Zweng et al., 2018, in the left column of Fig. 1) and, second, the temperature differences between partial cell and full cell (partial-full) averaged over five different depth ranges 0-250m, 250-500m, 500-1000m, 1000-2000m and 2000-4000m (in the right column of Fig. 1)

When you compare the FESOM2 performance in this (or similar) figure, you provide only a qualitative comparison ,which sometimes looks subjective. You need to provide some quantitative criteria (e.g. STD from WOA) for each (0-250m, 250-500m, 500-1000m, 1000-2000m and 2000-4000m) layer and include these numbers into the Figures. This will provide real estimates of the positive impact of the partial cells and/or other FESOM2 options.

Lines: 168-174 + *Figure 1*

This is a very interesting figure, could you please explain the intensive zonal features in Full Cell cases? Note, sometime these features change the sign between 0-250m and 250-500m.
I see some “correlation” with figure 12, from Adcroft et al., 1997, so, some analysis would be very useful.

Figure 4

Could you please provide the reference related to the intensive convection in the Weddell Sea and south from Greenland?

Line 216-217 **–** “*One can summarize that partial cells lead to a clear improvement of the circulation pattern, especially regarding the branch of the Gulf Stream and NAC even in rather coarse resolved configurations.”*

Where can I see that? Maybe anadditional plot?

Line 222 (*linfs*)
(linfs)-> LinFS?

Line 234 *“… reality sea ice and ocean velocities are rarely identical especially in the presence of high frequency wind”*

Not accurate: even if wind is 0, there is a turning angle in the ocean forcing, so, ice will be flowing in a different direction.

Line 236*;* *variability especially near the ice-edge where ice divergence/convergence is large (Campin et al., 2008).*

Are you talking about MIZ? In the miz, the concentration is low and ice is especially thin. Not sure that may provide significant impact into the overall sea ice dynamics.

Line 247; Figure 6f.
As I see, the embedded ice model provides less ice in the deep Beaufort Sea and more ice in the shallow ESS sea. Could you please provide any explanations?
The same for the Figure 6e – anomaly in the Greenland Sea in March. Why?

Lines 261- 263? *The temperature and salinity differences reveal that a significant warming of up to 0.5°C and a salinification of up to 0.10 psu occurs in almost the entire AO due to embedded sea ice, except in a thin stripe along the eastern continental shelf of the AO that shows negative anomalies in the depth ranges of 0-250 m, 250-500 m and 500-1000 m*

Question: I always suggested that embedded sea ice provides a stronger divergence/convergence due to stronger ocean forcing, and that the embedded sea ice should provide more "open" water or polynyas and that should cool the near surface layer. Am I wrong? Did you estimate the "embedding" impact on the sea ice divergence/convergence?

Line 265-… : *The changes in temperature and salinity can be explained by the changes in ocean currents.*

Do I understand this correctly: you explain the temperature/salinity increase due to stronger inflow of the Atlantic water into the AO? If so, you need to estimate this inflow through the Fram strait and provide the numbers.

Figure 7; -
You analyze the impact of the embedded sea ice in the AO and Southern Ocean. Why do you need the area between 60S and 60N? It is hard to see any features in the AO. Could you please re-plot this figure and remove the area 60S-60N and increase the AO /Antarctic region?

Line 393: "… all topographic features which is induced by the tidal vertical mixing parameterization"

Which topography features? What does it mean ALL? Besides, you may mention the increase of diffusivity mixing in the Indonesian region where internal waves are well-known features of the local dynamics.

Figure 14 ….
Something wrong with capture… Check it.

Figure 15

I see a strong increase in Weddell Sea in the Antarctica> ? Any evidence /references that tides are active in this area?

Lines 437-439-
Discussion of figure 18 should be NOT be before the discussion of figure 17.!
Change the order of the figures.

Line 477 + Figure 17
Figure 17 should be Figure 18. See above.

For all figures:

1)How is it possible that the coastline for 2000-4000m is the same as for 0.50m? Strange.

2) As I mentioned above, the disruption of these figures require some numbers which will allow you to estimate the difference between different mixing and numerical schemes utilized in FESOM2.0. It is reasonable to provide these quantitative differences for each layer.
3) Physical explanations of the observed differences between different schemes/options is necessary, as well, in most of the cases.

References:

Hibler W., P. Heil, and V. I. Lytle, 1998: On simulating high-frequency variability in Antarctic sea-ice dynamics models. Ann. Glaciol., 27, 443–448

Hutchings et al, 2005, Modeling Linear Kinematic Features in Sea Ice, Mon. Wea Rev, 3481-3497, 2005.