Answers to referee #1

We are indebted for the comments. Below we present answers and descriptions of the changes made.

Comment:
-Throughout the text, I found equations presented outside paragraphs without numbering. Is this a decision by authors, the technical editor or a software glitch? p.872-873 seem the worse. My personal preference is to use the numbering extensively whether the equation is referenced or not in the text, but I leave the final decision to the technical editor.

Answer:
The absence of numbers with some equations was our intention -- we numbered only those that are referenced in the text. We think it is a matter of personal preference, or the standard accepted by the journal. We are ready to change this if it is required by the journal, but otherwise we do not see an immediate need in numbering equations that are only used as auxiliary.

Comment:
-p.864, line 18, is it possible to add a reference for the FE Taylor-Galerkin method?

Answer:
We added the reference. The method is explained in many places, so we cite the classical book of Zienkiewicz and Taylor where it is discussed in detail.

Zienkiewicz, O.C., Taylor, R. L., 2000. The Finite Element Method, Fifth Edition, V. 3: Fluid Dynamics, Oxford: Butterworth-Heinemann (p. 47)

Comment:
-p.876, lines 13-14. The statement "variable resolution serves only to illustrate that FESIM works on unstructured meshes" undervalues the discussion on resolution on p.873 lines 19-25 and p.877 at lines 7-12. Would it be possible to modify this statement?

Answer:
We edited the text accordingly. It was meant that the issues of specific issues in a systematic way. The text in the revised manuscript is as follows: "...and the resolution is varied from approximately 40 to 10 km from the south to the north, as shown in Fig. 1. It will be seen below that noise, if excited, appears at the fine mesh part, as could be anticipated. Apart from this,

no other implications of mesh unstructuredness will be mentioned here to keep discussion concise and concentrated on the algorithm performance issues."

Comment:
-p.877, line 3, I am not clear what the authors means by "additional Picard iterations". Is it Np=2+10 when 10 additional iterations are done?

Answer:
Yes, 2 are done always, and "additional" are 10 (N_p=12). We modified the text to clarify it

Comment:
-p.878, line 5, is "VPb" is equivalent "VP2p" of p.877? If so, can a more homogeneous notation be chosen? Same comment at line 6 about "additional" as previous point.

Answer:
In Vpb "b" is for basic, it is just N_p=2 of the standard scheme. "VP2p" means N_p=4.

Comment:
-p.880, line 24: "it looks like" may be to colloquium...

Answer:
The text is modified as "We therefore conclude that it is the difference in
the damping rates in the equations for stresses (Eqs. 4-6_ in the standard EVP which is the main factor ..."

Comment:
-The plots in Figures 7 and 8 are inverted!
Many thanks, they were OK in the original pdf file we have submitted. The problem
occurred when it was converted to the Discussion format by the journal,
it escaped our attention.

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Answers to referee #2

We are indebted for the comments. Below we present answers and descriptions
of the changes made.

Comment:
Computation times. In Section 5.3 there is only a global discussion about computing times. In the conclusion is stated that the CPU efficiency is the criterion to select between methods, because the performance of the three methods is rather similar. However, in this paper no CPU times are specified. So,

please add a table with actual computation times, for example by specifying total computations times as well as the computing time required by the solver(s) and the evaluation of the right-hand side.

Answer:
We were not willing to present such a table because the computational times are rather sensitive to the ice configuration and mesh geometry, and to the fact whether the simulations are run to full convergence (which will be done not always in practice). For orientation, the time step of mEVP500 with N_EVP=1000 on the mesh used for tests here takes 0.55s on 8 cores of old IBM BladeCenter JS22 to be compared with
0.88 s for VP25p and only 0.065 s for VPb. Since VPb provides a very reasonable solution for ice mean thickness, and its field of Δ, while not converged, is without noise, it can still be used and will be a faster option than mEVP500 with N_{EVP}=1000 (but they will be close to each other if we run mEVP500 with N_{EVP}=120 sacrificing convergence but keeping stability). On meshes that are larger and of more complex geometry, reaching the prescribed tolerance by the iterative matrix solver requires more iterations, making the entire procedure relatively more expensive.

We added this explanation to the text now. Also we would like to note that as a part of FESOM, FESIM takes about 10 to 15 \% of the full time step for N_{EVP}
about 100-150. It is called on each ocean time step, and is run on the same partitioning, implying that generally many cores are just idle within the ice step. We expect that with future finer meshes, N_{EVP} will be increasing making the cost of ice model comparable to that of the ocean if run on the same partition.

Comment:
Potential of unstructured modeling is not fully used. In the setup of the Box test case the islands have been removed in comparison with Hunke (2001); see page 875. Why didn’t the authors also conduct simulations with the complete test case including the islands? This is also important since the performance of the solvers seem to depend on the domain complexity; see page 883. Unstructured grid modelling is meant for such applications, but the authors seem to ‘avoid’ this. At least an explanation is needed why complex geometries/islands have not been tested.

Answer:
The potential of unstructured meshes is illustrated by other papers based on FESOM, see, in particular, Wekerle et al. 2013, where ice is simulated on a highly variable mesh of intricate geometry. FESIM is not a brand-new model, and as a component of FESOM it was used in many applications (partly published), which is the reason why we do not concentrate on the "unstructured" issues. In contrast, the numerical principles of FESIM were

described only schematically. The present paper only intends to fill this gap and demonstrate that mEVP and VP lead to nearly the same result if run to convergence. Keeping islands is not necessary for that, and they were removed. The illustration of the fact that mEVP and VP work similar was included to alert the reader that distinctions between the methods should be interpreted as indication of lacking convergence. The comparison of the performance of VP, EVP and mEVP for realistic geometry on highly variable and high-resolution meshes (up to 4.5 km in Arctic) is a subject of current work and will be published elsewhere when completed.

Comment:
Figure of the model grid. Although the applied Box test case has been applied in several earlier papers, a figure with the unstructured model grid of the Box test case will enhance the readability of the paper. So, please add such a figure.

Answer:
Such a figure is added.