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Interactive comment on "Optimal numerical solvers for transient simulations of ice flow using the Ice Sheet System Model (ISSM)" *by* Feras Habbal et al.

Anonymous Referee #2

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This work aims to provide insight into different solver choices for a particular full-Stokes ice sheet model (ISSM) by testing a range of iterative solver choices from the widely-available PETSc solver library on a specific test problem (ISMIP-HOM, experiment F) and contrasting with their native/default direct-solve approach (which uses MUMPS). They conclude that switching to the PETSc iterative solvers generally improves time-to-solution and scaling as the problem size (number of elements in the finite-element mesh) increases, and are able to provide some suggestions as to which solvers appear to be better suited to their needs. In my opinion, this is a useful contribution to the literature, and I found it to be well-written and well-organized. I do have a few suggestions which I think would greatly increase the usefulness of this work.

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My primary criticisms, if you can call them that, are regarding the choice of benchmark problem. While I think that the choice of ISMIP-HOM problem F is a reasonable choice for representing a fully- or mostly-grounded ice sheet (like the Greenland Ice Sheet), I wonder how extendable the results and conclusions are to systems with fast-flowing ice streams and large dynamic ice shelves as are found in Antarctica, represented, for example, by the MISMIP family of benchmarks. In our experience (admittedly not with a full-Stokes model), marine ice sheets are often much more challenging for the linear solvers due to the mathematical nature of the floating ice shelves.

My larger objection is that I strongly disagree with the choice of a linear (constant-viscosity) rheology for these experiments. In our experience (again admittedly not with a full-Stokes model), one of the hardest things for many solvers to handle is the large range of viscosities produced by the normal nonlinear rheology. We've often had the case where solvers which perform perfectly well with constant viscosities perform poorly (or fail to converge) when the nonlinear rheology is turned on. I suspect you're getting an incomplete and possibly misleading view of solver performance for "real" ice sheet problems in this case. Is there a compelling reason not to use a "standard" nonlinear rheology for these tests?

Minor points –

1. line 95 – please cite some examples of the full-Stokes solver work that you're referring to

2. line 102 – "well know" -> "well known"

3. line 108 – FS isn't a requirement for active GL dynamics, e.g. MISMIP(1,3d,++). In fact, the authors of this work routinely use SSA for GL problems...

4. line 123 – "suit" -> "suite"

5. line 145 – "period" -> "periodic"

6. line 171 – please elaborate on or clarify what you mean by "methods that naturally

fit the ISSM framework"

7. line 172 – using only the default settings for the PETSc components is likely too-limiting of a choice. I understand why you'd do that (putting yourself in the shoes of a model-user who doesn't want to fiddle with solver parameters or explore all of the options available). However, we've found that there are cases where minor changes in options result in major improvements in solver performance and robustness. I'd suggest that since the goal of this work is to be a reference for ISSM (and other ISM) users, you should make some effort (maybe by asking the PETSc developers or another linear solver expert for some advice) to make the solvers perform as well as possible. I think this work will have a much larger impact in that case. The other point, of course, is that "default" options can change. I'd suggest presenting two sets of results – one with the "default" settings, and one after some attempt has been made to tune the solver parameters. (it is, of course, possible that the default parameters *do* produce the best performance). Of course, then, you would also need to document the particular solver options you used.

8. Conclusion – To give a bit of extra weight to your conclusions, it might be useful to embed your conclusion in the larger context of what many have found to be the case in other scientific computation fields – one suggestion would be to add a statement along the lines of "the conclusion that scalable iterative methods are better suited than direct methods for solving large linear systems echoes the experience of many other researchers across a wide range of scientific disciplines".

9. line 301 – The acknowledgments end with a stray "(" after Jed's name. Perhaps they got cut off?

10. Figure 2 – I am impressed with Figures 2-4 – they do a good job of conveying a lot of information clearly. I'd suggest replacing "horizontal labels" and "vertical labels" with "horizontal rows" and "vertical columns" for clarity in the caption.

11. Figure 6 – It would be helpful to include an "ideal scaling" line in this plot for

comparison. You mention the slopes in the text, but including it on the graph itself can make things easier for the reader.

12. Figure 6 – More numbers than a single "10" on the horizontal axis would also be useful.

13. Figures 5 and 6 – If I read these plots correctly (not completely assured due to the lack of x-axis labeling in Figure 6), it appears that the number of elements per processor used for weak scaling in Figure 5 ($\sim$250) corresponds to the far-right data points (most processors/fewest elements per processor) in the strong-scaling plot in figure 6. In both of the examples, this is where it appears that you start to see a degradation in your solver scaling, which might imply that you're being a bit too aggressive when you generated figure 5 since you seem to have stepped out of your ideal scaling regime. In other words, it might be the case that if you took a look at weak scaling with more elements/processor (500, perhaps), your MUMPS weak scaling might look better.

14. Figure 6 – it would be nice to have one more data point for your strong scaling plots, since it appears that your scaling is just beginning to tail off for MUMPS at the largest number of processors. I also realize that it may be a point too far...

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