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Interactive comment on "Modelling thermomechanical ice deformation using a GPU-based implicit pseudo-transient method (FastICE v1.0)" *by* Ludovic Räss et al.

Anonymous Referee #1

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The authors present a new GPU-accelerated, 3D ice-sheet model and they test its performance against established benchmark tests from the ice-sheet modelling community. The new ice-sheet model is a full-Stokes variant, and will, in principle, be capable of handling the complex dynamics of rapidly flowing ice-streams and outlet glaciers.

The manuscript is well-written, and the governing equations are clearly presented. Overall the manuscript was enjoyable to read, and I learned a lot. The tests were also convincing – as convincing as visual comparisons of results can be. In general, the structure of the manuscript is traditional: Introduce new model, explain the basic principles and the implementation, and test the model against other models. This is

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Discussion paper

fine, and it provides a convenient reference for later work. However, as a reader I would have liked to see a demonstration of what the new model can really do – just a sneak peek into the suite of problems that the authors hope to address with this new model. There are so many ice models being presented, but it is unfortunately surprisingly rare that we see ice-sheet models applied in ways that make us wiser. So, if possible, I encourage the authors to include a demonstration of the model toward the end of the manuscript – something that is visually, and intellectually, more appealing than the benchmark tests.

Specific comments:

Line 36: The GPU-acceleration is very interesting and, as far as I know, rather new in ice-sheet models. However, a quick search leads to Braedstrup et al. (2014) "Ice-sheet modelling accelerated by graphic cards" in Computers & Geosciences 72, 210-220. This paper is not cited here, although it covers some of the same challenges and principles of GPU-acceleration.

line 42: Also, regarding GPU-acceleration, it would be good to see reference to other flow problems that have successfully been GPU accelerated. What problems and models have inspired the authors?

line 122: The comment on single-precision calculations leaves me confused. Are the GPU-calculations single precision? Or does it depend on the specific GPU architecture? Please clarify.

line 163: Braedstrup et al has a nice description of staggered grids and GPU acceleration – must be cited here.

line 175: Even up-wind advection schemes are going to suffer from numerical diffusion – and high numerical resolution is just making it worse. Please discuss this here.

line 182: The matrix-free solver using pseudo-time is nicely explained. However, it would be good to see exactly how the residuals propagate in the grid. Many similar matrix-free relaxation schemes use multi-grid setups to make the residuals decay faster – these could be discussed.

Eqn. 15: I believe that theta < 1 is often referred to as underrelaxation.

Eqn. 19: Again, I miss information on how the residuals decay in the grid – particularly when using this stabilizing scheme. Also, I could not find previous reference to alpha, but I might have missed it.

line 299: I can see how the non-dimensional equation makes the implementation simpler, but is it necessary to present results in the non-dimensional form? It just makes the output harder to understand.

Section 5: There is some repetition of captions in the text. “In Figure 4, we plot...”; “Figure 5 shows...”; “Figure 6 shows...” etc. This could be skipped to make the text smoother.

line 308: Why are the benchmark tests performed at different resolutions? Does the GPU-model require order-of-magnitude more DOFs to yield the same accuracy as the FEM model? The comparisons give leave me with that impression, and then what is the advantage of the PT setup?

line 314: “numerical resolution grid resolution”

line 333: The authors are right to address the discrepancies between the model results – but why not follow up on the idea to pin nodes in the FEM mesh?

Fig. 15: The performance diagrams are very convincing – however, the use of widely different DOFs for the FEM and PT models in the benchmark tests makes we wonder if the speedup is real?

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