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**Geoscientific
Model Development
Discussions**

Interactive comment on "Capabilities and performance of Elmer/Ice, a new generation ice-sheet model" *by* O. Gagliardini et al.

Anonymous Referee #1

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This paper describes in detail the formulation of the Elmer/Ice ice sheet model. As discussed in the paper, this is one of a new generation of models aimed at better simulating future ice-sheet changes, with full-Stokes dynamics, unstructured horizontal grid meshes, sophisticated linear solvers with massively parallel capability, and inverse methods for internal-flow enhancement factors and basal sliding coefficients. The model formulation is described in highly technical and terse mathematical style, which will be fully accessible only to a subset of readers, but it is a rigorous and comprehensive record of the model physics and numerics. Given the terseness, some sections would benefit from a few non-mathematical sentences providing perspective, justification, or purpose of the following material, as noted below. Apart from that caveat, the paper is well written and clear, and the sections are nicely organized, stepping through the individual processes and functions of the model.

The paper is strictly limited to the model formulation and aspects of numerical solutions, and does not contain any examples of applications to real glaciers or ice sheets. This is justified because such applications are readily available in other publications, as noted on pg. 1693 (lines 26-29).

Specific comments:

Abstract: Most of the abstract, except for the last 2 sentences, sounds more like background material and perspective on Elmer/Ice's role. This is valuable information, but belongs more in the Introduction. Perhaps the abstract could open with one sentence in that vein, but it would be more usual and useful for the bulk of the abstract to summarize the main content of the paper. This could be like a simplified and shortened version of the concluding paragraph in section 9.

Section 2.2: Some sentences justifying the inclusion of the two anisotropic flow laws (GOLF and CAFFE) would be helpful. Do they have significant effects on predicted fields of interest, compared to using simple spatial variations of enhancement coefficients? What are those fields, and is this information in other papers?

Section 2.3: There is some discussion (pg. 1699, top) where the surface accumulation and ablation come from. But there is no corresponding mention of where the sub-ice-shelf oceanic melting/accretion or calving rates come from, that enter in Eqs. (11) and (13). This is discussed in "Outlooks" in section 8, mainly as future work. It would help (i) to add a sentence on pg. 1699 referring to the later discussion, and (ii) to briefly describe how ocean melt/accretion and calving have been prescribed in the executed Elmer/Ice simulations of future Greenland (abstract, and pg. 1693 line 20).

Section 6.1: pg. 1713, line 22: At the start of this paragraph, make clear that the following page, describing re-arrangement of the nodes, is to allow changing ice boundaries in long-term simulations (e.g., growth for ice caps to a full ice sheet). This basic perspective sometimes gets lost in the mathematical terseness of the presentation. More sentences like pg. 1715, line 6-7, would be helpful.

Section 6.2: Similarly, it would help to open this section by stating its basic purpose or function, even if it is somewhat obvious. Here, say that this is the basic way that Elmer/Ice solves the main equations (Stokes, and transport) - by casting them in variational form. And say why this is done, as opposed to non-variational methods - to lead to linear systems, as noted at the start of Section 6.3?

Technical comments:

pg. 1691, line 27: "opens" should be "open".

pg. 1694, line 2: Change "ice age equation" to "age equation", to avoid possible confusion at first sight with "Ice Ages (Quaternary, etc)".

pg. 1696, line 5: Change "knowing of" to "knowledge of" or "knowing".

pg. 1711, line 10: Change "best with to" to ?

pg. 1716, line 19: Change "ice the" to "the ice".

pg. 1721, line 8. Perhaps use different symbols for the general u,v terms in Eq. (65), to avoid initial reader confusion with the actual velocities u and v.

Fig. 1: Associated with Fig. 1, would it be possible to indicate the dimensional mesh values (km) associated with the x axis, and typical magnitudes of velocity differences (m/year) associated with the y axis? This could be summarized in words on pg. 1721, or in the caption.

Fig. 1: It seems disconcerting that there is no levelling off of the Lˆ2 error as the dof ($\sim$mesh size) decreases. In general, a test of adequate model resolution is that errors level off (or are close to it) for finer resolutions than the one used. Is this relevant here?

Figs. 3,4: Define Acceleration and Efficiency (y-axes), even though they may be basic concepts in computer parallelism.

Section 7.4: It would be interesting to add a figure showing the prescribed sinusoidal

forms of beta and eta (Eqs. 66, 67), and their final estimated forms (or the difference), as functions of x. Unless they are virtually the same (?)

pg. 1726, line 17: "filed" should be "field".

Interactive comment on Geosci. Model Dev. Discuss., 6, 1689, 2013.