Earth Surf. Dynam. Discuss., 3, C397–C401, 2015
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Earth Surface Dynamics Discussions

Interactive comment on "Basal shear stress under alpine glaciers: Insights from experiments using the iSOSIA and Elmer/ICE models" *by* C. F. Brædstrup et al.

Anonymous Referee #2

Received and published: 5 November 2015

Major comments:

This is a useful and straightforward study that aims primarily to compare simulated fields of basal shear stress and sliding speed between two different models, for the purpose of informing landscape evolution models that employ glacial erosion. The 2-D depth-integrated high-order model iSOSIA (the 'home team' in this case) is compared to the 3-D Stokes model Elmer/Ice in two steady-state experiments, while sliding laws and erosion rules are compared in a third transient experiment that is restricted, for computational reasons, to iSOSIA.

The study is worthwhile, the results useful and the paper itself clear. The only scientific

objection I have is in the design of the experiments themselves, or perhaps in the justification of the experimental design:

(1) I understand the rationale for using only iSOSIA in Experiment 3, but I don't understand why at least 2 sliding laws (Weertman/Budd-style and Coulomb friction) were not used with both models in Experiments 1 and 2. Using only the Weertman-style law for these experiments might limit the discrepancy between model results. Was the choice to exclude the Coulomb-friction law from Experiments 1 and 2 made for scientific or technical reasons?

(2) I also wonder why two of three sliding laws tested were essentially the same, rather than choosing one in which sliding is linearly related to basal shear stress for example. Given the assumption of a uniform flotation fraction of 80% in order to compute N in (7), the Weertman law and the Budd law differ only by a factor that depends more or less on ice thickness (unless I have misunderstood something about the implementation here). One could argue that testing m=1 versus m=2 in the erosion law takes care of this, but only for the computed erosion rate rather than for the computed basal shear stress and sliding fields. Another means of differentiating the first two sliding laws would be to adopt a different flotation fraction to compute N. Does it make a difference?

(3) Finally, I wonder what difference it would make if the glacier geometry for Experiments 1 and 2 were created with Elmer/Ice rather than iSOSIA. Could the current methodology (creating topography with iSOSIA and then computing steady-state/diagnostic fields with both models for comparison) be responsible for some of the short-wavelength heterogeneity in the Elmer/Ice results (e.g. Fig. 2b and 2c)? The explanation given for the heterogeneity was that iSOSIA, due to its depth-averaging, would be expected to produce smoother results. It wasn't clear to me whether this was just a plausible explanation or one that had been demonstrated by the authors as the leading explanation.

I imagine that the authors may have done some of the tests suggested above already,

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and that there may be reasons not obvious to the reader (or this one at least) that the results were not mentioned or included. I think the paper would make a stronger case for the robustness of iSOSIA if it were put to what would seem more rigorous (though not more difficult or complicated) tests, as outlined above. At the very least, a better justification for the present experimental design would be appreciated.

Minor comments (page.line):

1144.1: Suggest 'partially controls basal sliding' or 'exerts a significant control on basal sliding', since basal hydrology also plays a major (arguably dominant) role in some environments.

Nice introduction.

1149 (Section 2.3). The experimental set-up is generally described in this section and some differences between Expts 1-3 are mentioned (e.g. steady-state vs. transient). It would help to know exactly what the three experiments are in this section (e.g. purpose, which models), rather than having to wait until the beginning of each subsection of the results to find out.

1150.5: Figure 1b shows ice thickness, so might be better to say 'ice thickness distribution' than 'ice surface configuration'.

1150.6-8: Given that the mass balance is specified as a function of bed topography (through the dependence of temperature on bed topography), it is unclear why there would be any mass-balanceâĂŤelevation feedback in the model unless the bed topography changes through time with isostasy.

1151. Given that most of the paper focuses on modeled basal shear stress and sliding, it seems different exponents for (6) or (7) would be as or more important than different exponents for (9).

1154.3: Would be good to have this basic information on purpose and set-up of the Expt. before Results (i.e. in section 2.3).

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1155.13-14 ‘reflects the influence of pressure. . .as well as vertical shear stress components’ I’m not sure what this explains. The basal shear stress dominates the force balance, as expected for a valley glacier, but. . . ?

1156.19: ‘rather uniform’. Here and elsewhere there is room for quantification of results. Reporting the mean and standard deviation, for example, would be a better way of establishing this. See also paragraph below: ‘regional misfit remains small’.

1157. Figure 6 could use an additional panel showing the difference between the two, or some field that would better convey the features mentioned in the text. Even annotating the existing figure would make it more instructive.

1158.8-10: The increased uniformity of basal shear stress only appears visibly obvious for the Weertman case. Perhaps some quantification of this effect would support the text that this effect is strongest for both Weertman and Coulomb-friction cases.

Technical details (page.line):

1144.13: suble => subtle

1148.18: Stoke => Stokes

Eqn 1: divergence, not curl, of the flux

1149.17: ‘Ablation and accumulation are’

1152.2: ‘sliding-based erosion laws’

1155.2: correlate with => have

1155.18: remarkable => remarkably

1155.26: ‘driving stress . . . shows’

1156.7: Seems like both Figure 4b and 4c should be referenced here for ‘drainage patterns’, not just the sliding component (4b).

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Interactive Comment

1156.14: ‘magnitude . . . increases’

1157.3: ‘in the order’ => ‘on the order’

1157.11: ‘costs . . . prevent’

1157.25: ‘development . . . causes’

1160.7-8: ‘bends ... that form’ ? [note sure to what ‘interlocking spurs’ refers]

1160.9-10: ‘erosion . . . removes’

1160.21: ‘features that resemble’

1160.22: reasonably => reasonable

1161.8: smoothened => smoothed

1162.3: suggest omitting ‘three-dimensional’. Not relevant to sentence, especially since some variables were depth-averaged for comparison with iSOSIA.

1162.11: ‘reduction in’

1169.Table1: Coulomb mis-spelled

1174.Fig5 caption: Forth => Fourth

Interactive comment on Earth Surf. Dynam. Discuss., 3, 1143, 2015.