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# *Interactive comment on* "Predicting subglacial lakes and meltwater drainage pathways beneath the Antarctic and Greenland ice sheets" *by* S. J. Livingstone et al.

**Anonymous Referee #2**

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General appreciation and overall remarks

This paper touches upon the very interesting subject of (i) predicting subglacial lake positions underneath the Antarctic and Greenland ice sheet, and (ii) investigating the subglacial lake distribution underneath both ice sheets during the deglaciation period since last glacial maximum. The authors bring together a series of datasets (both based on observation and modelling), use a simple algorithm to derive basal hydraulics, and use GIS operations to reach their goal. While the subject is very interesting and intrigues scientists over the last 40 years, the methodology exhibits a series of flaws, which are listed below:

1. Subglacial drainage cannot be decoupled from the ice flow model: GIS is not a modelling technique. Bringing data together from different sources and doing an overlay analysis is not the same thing as a dynamic model that solves for ice flow dynamics, thermodynamics and basal hydrology based on conservation laws. For instance, using model data from a thermodynamical model (using different initial datasets) cannot be simply applied as an overlay operation with other modeled properties; best would be to use a thermomechanical model and calculate the full flow field, temperature field, hydrology). The same applies with the use of paleo model results that are not in full agreement with the datasets used.

2. The way smoothing is introduced is very unclear: the authors apply smoothing of the surface to get rid of known positions of subglacial lakes (which normally flat out the surface because of the vanishing friction at the ice-water interface). However, such smoothing will be a function of the size of the lakes. In order to get rid of the flatness of subglacial Lake Vostok, a substantial amount of smoothing is necessary. Maybe this is why Lake Vostok can be easily retrieved. The authors should clearly explain what the smoothing effect is on the routing of the subglacial water.

3. In fact the whole methodology section is not well worked out. For instance, what is the rationale behind the choice of convergence of 5000 grid cells to define a subglacial lake position? What is the sensitivity of this choice?

4. The routing algorithm stems from GIS software, and no further details are given. In fact, there are many ways by which routing can be defined. See therefore discussion in papers by Wright et al., as well as LeBrocq et al (2006). While the latter is on balance flux algorithms, the flow concentrations algorithm is basically the same. Results can be quite diverging depending on the method used. Very little (or no) information on this is found in the paper.

5. The fact that the Greenland ice sheet has lost subglacial lakes through drainage since LGM has already been pointed out by Pattyn (2008, JGLAC), where a full-Stokes



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model including basal hydrology and subglacial lake discharge was used to test the sensitivity of ice sheet geometry on subglacial lake drainage. It was shown in that paper that the mean surface slope of an ice sheet (or region of an ice sheet) is a decisive factor in subglacial lake stability, and therefore argued that the Greenland ice sheet lacks an extensive network of subglacial lakes because of drainage due to deglaciation (hence larger surface slopes).

6. Only 36% of BEDMAP2 grid cells is covered by a measurement. However, the major effect on subglacial lake position and basal hydrology is the surface topography. The bed is known to a much lower resolution. Of the 36% coverage, most subglacial lakes lie outside of these regions, mostly in the interior of the ice sheet, which is either harder to reach or not so interesting as fast-flowing ice streams. In reality, the ice sheet surface reacts to the bed conditions (and not the other way around). This means that any paleao reconstruction or other model run output deals with a completely different spatial resolution, depending on both the bed resolution and the spatial resolution of the model through which the calculation is done. this could introduce a serious bias that has not been discussed.

7. The GIS technique is capable of retrieving 70% of the known lakes. However, the more lakes you predict, the higher the probability that a predicted lake coincides with an existing one. This sensitivity should be tested.

Smaller remarks

P1186: i wonder why the model is better at predicting subglacial lakes underneath ice streams. Is it because those are susceptible to discharge and are detected by IceSat changes at the surface (not necessarily detected via radar) and many more could potentially exist, while for the interior ones, the majority has been detected via radar, which in some areas has been done on a quite detailed scale.

P1187: The pathways of the deglacial time slices are very model-outcome dependent; the problem is that the pathways do not interact actively with the ice sheet during the



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deglaciation and melt patterns provoked by hydrological changes may influence the surface topography at any stage as well. Therefore, the description of the results given is very outcome dependent and lacks any broader discussion.

P1190: The authors should question the reason why Lake Vostok can be reconstructed in the experiments based on the lake/ice reflector: this surface is in hydrostatic equilibrium, for which the hydraulic potential reaches a minimum. I find their explanation quite difficult to understand and slightly outside the scope. One thing has not been mentioned: smoothing will change this hydrostatic equilibrium ad hoc, and probably only the larger lakes will come out, while smaller ones are automatically removed by that procedure.

References: Paper Livingstone 2012: Volume 53 instead of 55

1. Does the paper address relevant scientific questions within the scope of TC? YES

2. Does the paper present novel concepts, ideas, tools, or data? SOME, YES

3. Are substantial conclusions reached? YES

4. Are the scientific methods and assumptions valid and clearly outlined? NO

5. Are the results sufficient to support the interpretations and conclusions? NO

6. Is the description of experiments and calculations sufficiently complete and precise to allow their reproduction by fellow scientists (traceability of results)? NO

7. Do the authors give proper credit to related work and clearly indicate their own new/original contribution? NO

8. Does the title clearly reflect the contents of the paper? YES

9. Does the abstract provide a concise and complete summary? YES

10. Is the overall presentation well structured and clear? MORE OR LESS

11. Is the language fluent and precise? FLUENT, BUT NOT PRECISE



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12. Are mathematical formulae, symbols, abbreviations, and units correctly defined and used? YES

13. Should any parts of the paper (text, formulae, figures, tables) be clarified, reduced, combined, or eliminated? YES

14. Are the number and quality of references appropriate? SOME, YES

15. Is the amount and quality of supplementary material appropriate? N/A

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Interactive comment on The Cryosphere Discuss., 7, 1177, 2013.