Inferred basal friction and surface mass balance of North-East Greenland Ice Stream using data assimilation of ICESat-1 surface altimetry and ISSM

Initialization remains a serious challenge in ice sheet modeling, and Larour et al. address this challenge by presenting the first use of time-dependent surface altimetry data from ICESat as part of the data assimilation process. Indeed, I'm not aware of any other study to do time-dependent data assimilation. The paper is very well written and structured, it's easy to read and understand. Adding the temporal dimension to data assimilation opens exiting new capabilities along with many new questions. Therefore I don't expect the manuscript to answer more questions than the topic raises; and the authors discuss in detail what should be done next. I'm looking forward to read any follow-up papers. The study is certainly worth publishing, and I only have a few comments that I wish to be addressed.

For diagnostic (non-transient) case, using surface elevation to constrain the initialization is similar to, but more sophisticated and principled than, flux correction methods used by, e.g. Price et al. (2011) and Aschwanden et al. (2013). A study worth mentioning is Habermann et al. (2013) as they present snapshots of the evolution of basal yield stress at Jakobshavn Isbræ by inverting surface velocities for a number of years, and find that the observed speed-up is possibly linked to a drop in yield stress. This could be considered as a pre-stage to transient assimilation.

I'm not an expert in inverse methods myself so I'm not able to judge any technical aspects of the methods presented in the manuscript. It appears all sound to me, but maybe another reviewer could provide more insight.

Technical Comments

Equations need proper punctuation (mostly commas are missing after an equation).

P. 2335, L. 14–22 Change "in the first section" to "in the next section", and adjust the remainder of the paragraph accordingly.

P. 2340, L. 24 You've already used n for the exponent of the flow law. It's clear from the context, but you may want to use a different variable.

P. 2344, L. 20 Maybe I'm missing the obvious, but how can a firn compaction rate be negative?

P. 2347, L. 20–23 I'm not sure I understand what you mean with "adjust the overall mean of the entire time series so as to center it…". Could you clarify and add a sentence on how this influences the results?

P. 2348, L. 26 . "Matches" sounds very strong and assumes that both variabilities are exactly the same. Are they?

P. 2350, L. 12 "significantly well" is awkward.

P. 2351, L. 17 "iteration on iteration" is awkward.

P. 2352, L. 6 check units, it should be $\mathrm{kg\,m^{-3}}$.

P. 2352, L. 7 remove "therefore".

P. 2352, L. 23–26 Split into two sentences.

Fig. 1 I believe it's EPSG:3413.

Figures For readers who are not so familiar with NE Greenland, I suggest to indicate on the figures the locations of the outlet glaciers discussed in the manuscript (such as Storstrommen).

References

Aschwanden, A., G. Aðalgeirsdóttir, and C. Khroulev (2013). Hindcasting to measure ice sheet model sensitivity to initial states. *The Cryosphere*, **7**, 1083–1093. doi:10.5194/tc-7-1083-2013.

Habermann, M., M. Truffer, and D. Maxwell (2013). Changing basal conditions during the speed-up of Jakobshavn Isbræ, Greenland. *The Cryosphere*, **7**(6), 1679–1692. doi:10.5194/tc-7-1679-2013. URL http://www.the-cryosphere.net/7/1679/2013/.

Price, S. F., A. J. Payne, I. M. Howat, and B. E. Smith (2011). Committed sea-level rise for the next century from Greenland ice sheet dynamics during the past decade. *P. Natl. Acad. Sci. USA*, **108**(22). doi:10.1073/pnas.1017313108.