

Review of Jordan et al.: “A constraint upon basal water distribution and basal thermal state of the Greenland Ice Sheet from radar bed-echoes”

General Impression:

Jordan et al. analyze an extensive radar dataset covering large parts of Greenland. They introduce a novel metric (“the bed reflectivity variability”) to locate basal water at the ice-bed interface. This is potentially a sufficient (but not a necessary) condition for water at the ice-sheet base. The results can, for example, be used as a constraint for modelling the evolution of the Greenland Ice Sheet, which critically depends on the conditions at the basal boundary (wet vs. dry).

I have read this paper with great interest, and the authors do an excellent job in guiding the reader through the manuscript. Basic methodology is explained succinctly (incl. appropriate references), and novel parts are correspondingly highlighted and more detailed. All Figures are informative and of high quality. I am impressed with the scope of the analysis, which includes a very rich radar dataset, and the careful interpretation of the “basal reflectivity variability” as a new (but not the only) metric for basal water. In the following, I have a number of comments which should be addressed, and which hopefully will make the paper stronger. I believe that this paper will be useful for other researchers in the future, and apologize to the authors, and to the editor, for the delayed submission of this review.

Kind regards,

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Comments:

1. Interpretation of basal reflectivity variability:

The authors make it clear (in l. 368) that reflectivity variability above the chosen threshold is a sufficient criterion for basal water. However, the converse argument (that is: low reflectivity variability, hence, absence of basal water) does not hold. It is very important that people using the results of this study are aware of this, and it should be mentioned more clearly (i.e. in the abstract and elsewhere). The importance of this point is highlighted because the authors themselves misinterpret their own results in this regard. The inference that “...basal water is often concentrated in the fast-flow onset regions and tributaries whilst it is **absent** from the main trunk.” (l. 457) is not valid, because the absence of elevated bed reflectivity does not necessitate the absence of basal water (it could simply be homogeneously distributed and thus not be visible with this metric). I see much potential for misinterpretation here, and the authors should describe the limitations of this novel metric in a more pronounced way.

2. Derivation of basal reflectivity variability:

Does it matter that only log-transformed variables are used? I wonder this, because:

$$VAR(10 \log_{10}(X)) \neq 10 \log_{10}(VAR(X))$$

I can see the convenience of the log-transform when interpreting the reflection amplitudes, but I am unsure if this causes problems when calculating variances (and variance of multiplicative variables). Is there an underlying assumption about the statistics/uncertainties that was not explicitly mentioned? I understand this is a somewhat diffuse comment.

3. Crossing-Over Analysis of the bed reflectivity variability

The authors should do a crossing-over analysis of the bed reflectivity variability. This would strengthen the argument that birefringence and radar system specifics are small. It will also more clearly demonstrate the robustness of the new metric and highlight its advantages (which is that radar data collected over multiple field seasons and with various radar systems can efficiently be combined).

4. Discrimination between water patches and smooth--rough transitions

Variability in bed roughness is a competing mechanism which would also result in elevated bed-reflectivity variability. The authors are aware of this and suggest that the threshold is well tuned to discriminate between these two scenarios. However, I did not fully understand why this is the case and the manuscript is in this regard unfortunately too vague (e.g. “..we demonstrate later ...” (l. 309) but where is this actually done?). This is important, because interpretation of the “bed reflectivity variability” as a proxy for basal water is a central conclusion of this paper, and other options must be convincingly excluded.

5. Temperature profile near ice divides

I disagree that in the interior of ice sheets GHF and vertical diffusion are the dominant processes. What about vertical advection? In Greenland the surface mass balance is significant in the interior and thus I would expect a (strongly) non-linear temperature profile with depth (which would not be the case if only diffusion was important). A quick-look at the NGRIP profile does confirm this. Can you comment on this?

6. Attenuation correction using modelled temperatures

Briefly explain what the modelled temperature field of Goelzer et al., 2013 is based on, (how it compares to in-situ measurements), and how it may impact your results. Is it possible that temperature variations near the coast (where ice streaming is significant) are smoothed out, and thus do not correctly cancel the attenuation in your approach?

7. Ice Fabric Variations

I agree that fabric variations are a small component in the overall backscattered power budget. However, could it be that the “corridor” along the central ice divide is to some degree linked to ice anisotropy? Across a divide, ice fabric can change abruptly (compared to your 5 km window) (e.g. Martin et al., J. Geophys. Res., 2009; Drews et al., J. Glac., 2012) and potentially this may impact the inferred “bed reflectivity variability”.

Minor Suggestions

Maybe “A sufficient constraint upon basal water distribution beneath the Greenland Ice Sheet from radar bed echo variability” would be a better (and slightly shorter) title?

l. 320 There is a missing section number in the internal reference.

l. 580 Basal ‘freeze-on’ is one, but not the only explanation for the disturbances seen at larger depth. Concerns about this (e.g. Dow et al., *Geophys. Res. Lett.*, 2018) or other explanations (e.g. Bons et al., *Nat. Comms.*, 2016) should also be mentioned here.

Fig. 5b add y-label ([R] (db))