The Cryosphere Discussions

The Cryosphere Discuss., referee comment RC2
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Comment on tc-2021-179

Samuel Doyle (Referee)

Referee comment on "Generation and fate of basal meltwater during winter, western Greenland Ice Sheet" by Joel Harper et al., The Cryosphere Discuss., https://doi.org/10.5194/tc-2021-179-RC2, 2021

Review of Harper et al. "Variability of basal meltwater generation during winter, Western Greenland Ice Sheet.

This manuscript by Harper et al. brings together previously-published datasets with new data and analysis to investigate whether subglacial cavity expansion caused by basal melt can explain the often-observed – but never satisfactorily explained – winter-time acceleration of surface ice velocity in Greenland. It makes an original and important contribution to solving this problem. The hypothesis that subglacial cavities become hydraulically isolated during winter is tested and the authors suggest that some interconnections must remain as melt volumes exceed plausible cavity storage volumes. Important points are made regarding basal melt variability, particularly that the majority of total basal melt is generated in areas with low and invariable basal melt rates, and that this will result in relatively constant winter-time discharge fluxes at the terminus. It follows that substantial perturbations in basal melt must represent the sudden release of subglacially stored water (e.g. drainage of subglacial lakes). The manuscript is concise, well written, well-presented and the arguments are framed well within the inherent limitations of the dataset. I have a number of comments detailed below.

General Comments

- Further description of the GPS filtering and basal shear stress calculation are required to ensure reproducibility.
- Expansion on the application of the Kamb (1987) analysis for determining cavity size could be helpful, for example by giving some of the original equations to explain the basis of the analysis. At present the description is limited to just two equations (Eq. 2 and 3).
- Previous studies which reported and attempted to explain the winter-time acceleration in ice flow should be introduced in the Introduction – this would highlight to the reader the research gap that this investigation fills.

- The Introduction (and discussion) could be expanded slightly to introduce current theory and modelling relevant to the behaviour of subglacial cavities during winter to set the scene for this study, and to show how this study contributes to our understanding.

Specific Comments

Please find minor typographical corrections and suggestions in the marked up PDF attached.

L1 – In the title "western" should be lowercase as there is no "Western Greenland Ice Sheet". Also, this paper does more than just measure basal melt variability and its main take home point relates to cavity dynamics and subglacial hydrology – the title could be revised to reflect this better.

L15 - Can you mention in the abstract that you calculate cavity dimensions/dynamics and compare them to melt volumes to determine whether or not all basal meltwater can be accommodated by cavity growth. At present you just refer to "insights into subglacial hydrology": I think you can be more specific. You might also mention in the abstract or introduction that you specifically test the hypothesis that cavities remain hydraulically isolated in the winter.

L36 – you should introduce here previous observations of, and explanations for, winter-time acceleration in ice velocity. You currently do this on L352-358 but it should come earlier as it is key to the data and analysis presented. The winter-time acceleration is evident in most measurements of ice velocity (e.g. Sole et al., 2013). Note that there are also detailed winter velocities from near your study site but 140 km inland that show winter acceleration presented in Doyle et al. (2014). Winter acceleration in ice velocity is also presented in Phillips et al. (2013; Fig. 4), which I believe is mis-interpreted therein as being caused by increased deformation due to heating of the ice due to warming ice temperatures. The first paragraph of the introduction could introduce the literature on this topic slightly better, which would set the reader up for the analysis to come.

L69 – delete "full". All years have winter gaps due to power outage.

L73 – what is meant by "bed framework"?

Figure 1 caption and elsewhere – consistency with "basal water pressure" and "borehole water pressure" would help the reader who doesn't know these are assumed to be the same thing.

L93 – The methods used to filter and differentiate GPS position data need to be detailed to allow the study to be reproduced.

L124 – why not rearrange to get M on its own on the LHS?

L126 – More detail on how the basal shear stress was calculated (e.g. the equation used) needs to be given.

L128 – there is avoidable repetition here with L142-144 and neither spell out why basal temperate ice presents a barrier to upwards heat conduction, which is due to the Clausius-Clapeyron gradient causing a reverse (and small) temperature gradient.

L185 – add an example reference to support the statement that cavities are often assumed to become isolated during winter. In general, slightly expanding the discussion of the theoretical understanding and modelling treatment of cavities and basal melt in winter would boost the significance of this papers' findings.

Table 1 – "Site" needs to be taken out of brackets and put into a new column.

L199 – I'm not sure you mean "daily acceleration", will "acceleration" suffice?

L209 – The seasons have strict definitions in meteorology, and it would be helpful to note early on that the terms "spring" and "winter" are being used more loosely than their normal strict definitions, that is to reflect the period at melt-onset and the period when the subglacial hydrology is in its "winter-mode".

L213 – Move descriptions of water pressure results to the section on water pressure (or remove subsections altogether). It would be good to expand on the description of winter-time pressure variability due to its relevance for cavity opening.

L241, L255, L263 – "sliding friction", "basal friction", and "bed friction" should be "frictional heat from sliding".

L269 – observations of inter-annual variability in winter-time acceleration in ice flow at

140 km inland are presented in Doyle et al. (2014, Fig. 2). Can these measurements help quantify what is meant by "little to no winter acceleration"?

L323 – With the uninformed reader in mind, what are sliding speeds high relative to? Perhaps cite your previous work on this.

L328 – Note that cavities accessed (or even created) via drilling may not be representative of the majority of natural cavities. Analysis of the glacial foreground or subglacial topography in West Greenland would provide a better picture on the basal roughness; such analysis has been done (e.g. Lindback, 2015).

L367 – you could spell out for the reader even more clearly that previous explanations are not sufficient to explain all the observations.

L374/375 – mention that the studies reporting sediment are also from discrete sites (two of the references are even for the same site). The nature of the bed over large areas remains unknown. Therefore the capacity of the bed to store water in troughs and sediment also remains uncertain.

Additional References

Doyle, S. H., Hubbard, A., Fitzpatrick, A. A. W., van As, D., Mikkelsen, A. B., Pettersson, R. & Hubbard, B. Persistent flow acceleration within the interior of the Greenland ice sheet. *GRL ,* **41**, 899–905 (2014).

Lindbäck, K. & Pettersson, R. Spectral roughness and glacial erosion of a land-terminating section of the Greenland Ice Sheet, Geomorphology **238**, 149–159 (2015).

Phillips, T., Rajaram, H., Colgan, W., Steffen, K. & Abdalati, W. Evaluation of cryo-hydrologic warming as an explanation for increased ice velocities in the wet snow zone, Sermeq Avannarleq, West Greenland. JGR **118**, 1–16 (2013).

Please also note the supplement to this comment:
https://tc.copernicus.org/preprints/tc-2021-179/tc-2021-179-RC2-supplement.pdf