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Interactive comment on "Near surface meltwater storage in low-density bare ice of the Greenland ice sheet ablation zone" *by* Matthew G. Cooper et al.

Anonymous Referee #2

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This paper presents findings from a field campaign on the Western margin of the Greenland ice sheet concerning the nature of the 'weathering crust' on the bare ice in the ablation zone. The paper provides measurements from shallow ice cores of ice density and corresponding porosity as well as water content, finding surprisingly low density ice down to at least 1 meter depth. It is pointed out that the presence of this weathering crust means that (subsurface) melt does not necessarily correspond to 'surface' lowering, as might be measured by satellite altimetry.

I think this is an interesting set of measurements, and is a valuable contribution to understanding the supraglacial hydrology of the Greenland ice sheet. Meltwater storage

in the percolation zone of the Greenland ice sheet (in firn) has been well documented over the last few years, and this study suggests that a non-negligible amount of water storage and transport may occur beneath the apparent ice surface in the ablation zone too.

The paper is well written and the figures are mostly clear. I have one main comment and a number of minor comments, mostly seeking clarification.

Main comment

The measurements represent a snap-shot of the weathering crust in mid-July 2016 and it is not clear how this relates to the behaviour over the course of the melt season. I appreciate that the field campaign was limited in length so it may not be known how the crust itself evolves, but I think there needs to be more discussion of the setting for these measurement. In particular, what is the annual ablation rate in this region? At what stage of the melt season are these taken (i.e. roughly how much melting has already occurred here)? What is the ice temperature in this region? These are important issues in understanding how reflective these results are of wider spatial scales but also larger time-scales.

In particular, I think there could be more discussion of how the inferred stored water thickness (15-22cm) relates to the amount of melt that has so far been produced this season (roughly what fraction of it is this), and how the depth of the porous ice compares with the amount that melts each year. Eg. are the ice lenses that form the result of recent refreezing (i.e. earlier the same year) or some earlier time?

There could then be some discussion of how the porous ice evolves over the course of the year. Presumably all the water freezes again in winter? In which case the ice is mostly solid at the start of the melt season (except perhaps the unsaturated surface layer, which seems to have a similar porosity to snow)? If the saturated subsurface water doesn't ever run-off, it may simply be changing the quantity of runoff rather than delaying it.

Specific comments

Why are the findings frequently referred to as 'preliminary'? What are they preliminary too? If they are really preliminary, it begs the question why they are being published. I'd suggest that if the authors think the results are worth publishing they should not refer to them as preliminary (which does not preclude doing more work on the topic).

Page 1, line 29 - why does the routing of surface water to the ocean 'reinforce concerns' about contribution to global sea level rise? Isn't such melting part of the 'normal' operating cycle of an ice sheet?

Section 2.1 - it is not clear from this description how liquid water in the core is dealt with. Is it allowed to drain out? Presumably there is still quite a lot of water trapped in the core samples (due to capillary forces) and this contributes to the measured mass?

page 4, line 9 - this is a bit awkward wording, since this statement presumably assumes that the density is uniform (independent of depth). Perhaps better just to say that the geometry of the sampler means that the near-surface ice is disproportionately weighted in this average, rather than quantifying the 'center of mass'.

Section 2.3 - there is some confusion here about the 'unsaturated weathering crust depth', and how it relates to how penetrable the ice is. Reading further, it seems that the 'water table' (which I would interpret as the unsaturated depth) roughly coincides with a change in the strength of the ice that is presumably what the depth probe is detecting. It does not seem obvious to me why these two surfaces (the impenetrable ice surface and the water table) should happen to coincide - perhaps the presence of air in the pores above this allows the surface ice to 'rot' more rapidly. Or perhaps the permeability of the upper layer is sufficiently large that water in this layer readily runs off horizontally keeping it unsaturated.

Perhaps the qualitative description of the surface given on page 9, line 20, could be moved forward to the method section to help explain these issues. In any case it would

help to be clearer precisely what is meant by unsaturated - does this mean there is no liquid water, only residually-trapped water, or that water does not fill the pore space (all of which are different)?

Page 6, line 5 - why is refrozen meltwater included as water storage? If it has refrozen it is ice again and should be be thought of as storage (it requires melting again - with the associated energy implications - before it could run off).

Page 6, line 19 - is the 'potential' liquid storage capacity not just the effective porosity multiplied by depth and total area (i.e. including the currently unsaturated pore space too)?

Page 8, line 7 - there seems to be some subjectivity involved here. Why is estimating the value wrong in one direction deemed 'not problematic'? If the densities were measured including the ice lenses, would it not make sense to use the the volume including the ice lenses when converting to water content using the effective porosity? Or otherwise use a solid ice density of the ice lens to infer the density of the non-ice lens part of each segment?

Page 10, line 4 - the drill did not go below 1.8m for fear of freezing. Did you make any measurements of temperature in the porous crust? It would be helpful to know if the ice is all at the bulk melting temperature or if it goes below this at depth.

Page 10, line 20 - what is meant by a storage 'rate'? I could not work out what this number means.

Page 11, line 15 - the 'lower and upper mean' is a strange concept; perhaps the 'mean lower and upper values' would be better wording.

Page 11, line 21 (and conclusions) - why are the results not considered representative of the rest of the ablation zone? I understand the desire for caution given that this is only one location, but without other evidence (perhaps you have it?) wouldn't the default assumption be that the results do apply more widely? What do you think is special

about your field site that means the results would not apply more widely? Perhaps you could just say 'We do not know whether these findings represent typical conditions....' rather than 'not proposing' it.

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