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The Cryosphere Discussions

Interactive comment on "Evidence of meltwater retention within the Greenland ice sheet" *by* A. K. Rennermalm et al.

Anonymous Referee #2

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Rennermalm et al, The Cryosphere

This paper investigates important issues regarding meltwater fluxes from the Greenland Ice Sheet and more specifically, the rate at which meltwaters generated at the ice sheet surface are eventually evacuated from the ice sheet margin. The paper compares ice sheet runoff estimates, derived from an energy balance model, with proglacial discharge measurements in order to derive catchment scale estimates of meltwater retention/ release from the ice sheet at different time-scales. While the study produces some potentially interesting results regarding storage/release phenomena, the key issue that the authors need to be able to address concern the possible sources of error in their calculations. The modelling work is extremely complex and whilst being state of the art, it is still very difficult to estimate runoff from AWS stations that are rather distant from the catchment. Furthermore, discharge estimates are notoriously difficult to constrain accurately, especially if being determined remotely (i.e. during periods when fieldworkers are absent). These broad issues are picked up in more detail below.

AK4 river discharge estimates

Measurement of discharge in proglacial streams is difficult. While much of the method is likely fully reported in Rennermalm et al 2012, it would help to have a little more detail here given the importance of this data to the whole paper. For example, how many times was the stream manually gauged to derive the rating curve from the pressure transducer record? Furthermore, it would be useful to know when fieldworkers were present at the site as this could have serious implications for the 'winter' melt event volume calculations (see below).

How reliable is the summer rating curve for the winter period during the inferred 'release' events? All these events (or at least derived runoff volumes) are based on the pressure sensor record following periods of low temperatures (one in late Autumn, two following the winter) when air temperatures will have ensured that river ice will have built up. In the absence of any on site observations, it is very hard to be confident that the stage-discharge relationship from the summer will hold up because channel shape due to within-channel ice may make sections of the channel deep even with only a very small volume of runoff. Furthermore, if the ice has formed a 'lid' and the water is flowing beneath this, it is also possible to get erroneous pressure sensor readings. Thus without compelling evidence that the summer rating curve holds up, it is hard to be confident of the magnitude, and thus wider significance of these release events.

The three release events do appear to be very clearly related to warming events. Further to the above query regarding the volume of the meltwater, the source of the water is not clear. To relate these events to subglacial release of stored water along the lines of many of the referenced papers, it would be necessary to have some information on the water chemistry. Without these, it could be argued that the volumes of water were small (due to rating curve issues) and derived from local snowmelt.

Until these issues regarding the cold season melt release events are fully addressed, the following broader claim is unconvincing: "Thus, despite inherent uncertainties of wintertime river low-flow observations (Pelletier, 1990), existence of cold-season ice sheet meltwater discharge is evident. Measurement uncertainties and errors are unlikely given that the sensor operated as expected before and after the three river runoff events, and coherence with brief preceding ice sheet runoff events points toward broader scale events."

Melt model runoff calculations

P3375 L5 – in stating that "S5 captured 73% of daily S6 runoff variability", does this relate to the modelled runoff or surface lowering as derived from the sonic depth rangers? The description of the modelled runoff estimates needs some extra work. It appears from e.g. Figure 2a that the modelled runoff, Rw, is assumed to have an error of +/-10% which relates to the issue of subglacial topography and thus catchment size. What is the error range of the actual modelled runoff derived from the AWS data and energy balance model. This presumably increases the error of Rw to >+/-10% with implications for your inferred flux estimates and storage characteristics?

Catchment area estimates.

What are the errors on the ASTER GDEM dataset (vertical) and what is the spatial resolution? From the paper, it seems that the derived surface catchment of 64.2 km2 is assumed to be correct. However, couldn't the surface catchment be poorly delineated resulting in a substantial mismatch in runoff estimate derived from the energy balance model? The +/-10% error associated with the basal topography issue is additional to the surface catchment delineation. Furthermore, the estimate of a +/-10% error on overall catchment size due to the lack of basal topography is very approximate and were it to be much larger (e.g. to reduce the actual drainage catchment size by 30-40%), the mismatch between modelled and measured runoff would be substantially

reduced. Because of these issues regarding the size of the catchment, it is very hard to be certain that the seasonal storage volumes are reasonable estimates even if the melt-model and river discharge errors are very small.

Minor corrections/suggestions

P3371 L15 – or IS accumulated

P3372 L12 – are all these runoff estimates from the same year and if so, which? If they are not, the point that you are making needs to be clarified as you would expect runoff estimates to vary substantially between different melt-years (just as runoff itself varies between years).

P3372 L21 – not appropriate to say "absolute" when they are modelled estimates.

P3373 L1 – factorS in

P3373 L21 – you should refer to Shreve as the original source here

The general terminology used (AK1-5) is not at all helpful to an unfamiliar reader. Since they are describing very distinct data sets, couldn't more obvious acronyms be used that reflected the type of data set being referred to?

P3375 L16 – upstream OF

P3376 L13 – delete S in factorS

P3377 L1 – sentence needs editing

P3380 L1 – suggestING

Interactive comment on The Cryosphere Discuss., 6, 3369, 2012.