

Interactive comment on “Surface mass budget and meltwater discharge from the Kangerlussuaq sector of the Greenland ice sheet during record-warm year 2010” by D. van As et al.

D. van As et al.

dva@geus.dk

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DVA: I thank Ian Batholomew for a well-formulated and constructive review. Below I reply to all comments.

IB: This section compares predicted runoff, calculated using a surface energy balance model, with observed discharge in the proglacial river, which was measured in Kangerlussuaq, approximately 25 km from the ice sheet margin. There is reasonable agreement between the two records, although there is some mismatch which is explained by uncertainty about the size of the catchment area. The authors observe that there is a lag between peaks in calculated runoff production and peaks in observed discharge

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in both 2009 and 2010, and argue that this reflects the time taken for meltwater to move through the glacier drainage system. It is then stated that the lag between meltwater production and observed runoff decreases over the course of each summer melt season. The authors state that the late summer decrease in this lag is explained by an evolving subglacial drainage system, which becomes more efficient in response to inputs of meltwater from the ice sheet surface, allowing meltwater to be transported to the ice margin more quickly. I agree that seasonal development in the structure of the subglacial drainage system occurs in this section of the Greenland Ice Sheet margin. This has been indicated by a number of ice dynamics studies (e.g. Van de Wal et al., 2008, Bartholomew et al., 2010, Sundal et al., 2011, Bartholomew et al., 2011a), the preliminary borehole work which is referred to (Harper et al., 2011) as well as a detailed hydrological study at Leverett Glacier (which is within the catchment in this paper) from 2009 (Bartholomew et al., 2011b). I do not think, however, that the data presented in this study can be used to support these studies. Firstly, the change in lag between peak meltwater production and runoff is only addressed qualitatively and is not clear to me from visual inspection of Figure 7. Secondly, any change in lag between these two records must also reflect changing supraglacial conditions (such as snowpack removal), englacial drainage conditions, distance which meltwater has to travel (as melt occurs at higher elevations), and transport in the proglacial river. It is difficult, therefore, to ascribe these observations to changes in the subglacial drainage system alone.

DVA: I agree. Quite frankly, we have taken the discussion of the glacier hydrology too far. Since this is a study of meltwater production that we validate using discharge measurements, which is comparing the water at the main source to that what enters the ocean, we felt we had to briefly discuss the route that the water takes in between, and explain differences in the calculated meltwater production and measured discharge. As I do not want this to be a study focused on meltwater routing I will not try to quantify changes in lag between the time series, which may not even be a possibility. Instead, I will remove all the text that deals with this topic.

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IB: It is stated that "the smeared-out freshwater discharge" which is observed at Kangerlussuaq is "regulated in a funnel-like fashion by the drainage system of the ice sheet". In a study at Leverett Glacier in 2009, however, we found significant short-term variations in runoff at a location <2km from the glacier snout that are not evident in Figure 7a (compare with Figure 2 in Bartholomew et al., 2011b). This suggests that a lot of the "smearing out" also happens in the proglacial stream and that it is difficult to make inferences about the ice sheet drainage system using hydrological observations at such a large distance (>25km) from the ice sheet margin.

DVA: Yes, I agree, also based on what you state here, that I should refrain from making statements dealing with the efficiency of the drainage system as our data cannot support such statements. I will considerably shorten the text on glacier hydrology, and not mention diffusion of meltwater peaks any more.

IB: Overall, this section seems to be a bit of an afterthought: the data are not thoroughly investigated and it is not particularly clearly written. The data do not provide any new insights into subglacial drainage system development and, for the reasons outlined above, I do not think that they can be used to support existing hypotheses.

DVA: And overall, I agree with your assessment. I will remove all text in the abstract and conclusions dealing with glacier hydrology. In section 3.5 ('Surface meltwater production') I will remove or modify all sentences that you commented on. There will be just one paragraph left that mentions meltwater routing, but that will mostly sum up previous results like yours. The changes in time lag between the calculated meltwater production and measured discharge will not be mentioned any more. The same goes for melt peak diffusion. I will still mention the lag between the two records plotted in Fig. 7, but without any speculation or attempts to support major findings by others.

Specific comments: IB: p2333/19: It would be useful to see the catchment delineated on a map (e.g. in Figure 1) p2334/20-29: again, it is important to actually see the extent of the catchment.

DVA: I agree, and I'll include the catchment on the map.

IB: p2333/21-22: "There are no fair-sized streams near the ice margin". What is meant by 'fair-sized streams'? We have seen streams carrying 1-2 cumecs within 8 km from the margin near Leverett Glacier and much larger streams within 35 km of the margin.

DVA: I realize that 'fair-sized' and 'near' are no quantitative terms and not very useful in this paragraph, so I will remove the sentence. I have observed distinct differences in surface meltwater streams in various regions of the entire Greenland ice sheet, but neither can I quantify these differences, nor would it fit the scope of this study. The subject is best left for a friendly discussion in person.

IB: p2333/23: "virtually the entire ablation zone, efficiently draining meltwater". Do you mean the entire Greenland Ice Sheet ablation zone? This is quite a large area for such observations. It also seems likely that the efficiency of englacial transport is spatially and temporally variable.

DVA: No, this is not what I mean, and such a statement would be far from the truth. In the new manuscript version I will state: "the ablation zone of the Kangerlussuaq catchment area".

IB: p2335/10-11: Please refer to the recent hydrological study of Leverett Glacier in 2009 (Bartholome et al., 2011b) which investigates drainage system development in this section of the ice sheet.

DVA: Thank you – I will do so.

IB: p2335/11: "continuously increases its capacity" - it also increases in size over the course of a melt season, with upglacier extension of efficient drainage at the expense of a distributed system. Again, see Bartholomew et al., 2011b.

DVA: I will make changes to this sentence and insert your reference after quoting you on this interesting result.

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