Interactive comment on "Sensitivity of subglacial drainage to water supply distribution at the Kongsfjord basin, Svalbard"

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Authors' response to Anonymous Referee #1

We thank the reviewer for their thorough and helpful review. We addressed their comments (shown in bold) point by point. Please also note the figure at the end of the document.

General comments

(1) It seems like some of the findings are in line with those of Koziol and Arnold 2018 (modelling seasonal meltwater forcing on the velocity of land-terminating margins of the Greenland ice-sheet). In this paper they consider how a subglacial drainage system might contribute to decadal-timescale slowdown of ice in the ablation zone. One theory is that if a more efficient drainage system develops in the summer, the effective pressure throughout the winter will be higher (i.e. the water pressure will be lower), leading to slow down. Your results (figure 3b) seem to suggest that supraglacial-meltwater configurations that produce more efficient drainage (in summer) lead to lower water pressures in winter (as Koziol and Arnold suggest).

Response: We thank the reviewer for mentioning this paper. Our results are indeed in accordance with those of Koziol and Arnold (2018) in that the configurations that produce more efficient drainage in summer lead to lower water pressures in winter. This is mainly visible in Experiment 1, which, compared to the other three configurations, leads to higher water pressures during both summer and winter due to less channelization. This paper has been appropriately referenced in the revised manuscript to highlight this point.

(2) You conclude that the resulting subglacial drainage systems that evolve are inefficient. I think here efficiency refers to how the water pressure responds to meltwater input. It seems though (I may be wrong) that the drainage systems are efficient enough to entirely drain the meltwater before the next melt season. Thus, we have the "worst of both worlds" in that the drainage system is inefficient enough for a spike in water pressure at the start of every melt season, but efficient enough to completely drain and revert to it's original (most inefficient) state before the start of the next melt season.

Response: Following the comments of the reviewers on the possible impact of a too high hydraulic conductivity on our results, we repeated our simulations with a new value for the sheet conductivity parameter, ks = $1.0e^{-4}$ $m^{7/4}$ $kg^{-1/2}$ (for more details, see response to next comment below).

In contrast to our previous results, in our new simulations (Fig. S1) mean water pressures are higher (above 50% of overburden pressure, compared to near 0% in the previous simulations) throughout winter, suggesting that the subglacial drainage system remains too inefficient to entirely drain the meltwater before the start of the next melt season. However, the wintertime subglacial drainage system is not sufficiently pressurized and its discharge is too low to sustain year-round channels.

Specific comments

(3) How much of an influence do your parameter choices (hydraulic conductivities) have on the qualitative behaviour of your results?

Response: Our value for the sheet conductivity (ks) is lower than the one originally proposed by Werder et al. (2013), but inspection of current literature revealed that others find better agreement to observations by using lower values (e.g. Dow et al., 2020) or even suggest a seasonally variable conductivity (Downs et al., 2018). Werder et al. (2013) simulated a single melt season and hence they did not experience the sheet running dry over winter (although they discuss this shortcoming), whereas multi-year simulations by the other studies explicitly address this problem. We agree with the reviewer that too high values for the sheet conductivity (ks) may thus lead to unrealistic results, mainly with regard to the basal water pressure that can also impact the degree of channelization of the subglacial hydrological system. However, we would like to emphasize that the aim of our study is to investigate the effect of different input configurations during the melt season rather than to obtain most realistic winter pressures.

Nevertheless, to test whether our results would be affected by adopting different values for ks and kc, we conducted sensitivity tests over the first three years of our 15-year long simulations. Whereas the overall results are largely insensitive to the choice of kc within reasonable limits (ks/kc ratio > $1.0e^{-2}$, with ks = [$1.0e^{-3}$; $1.0e^{-4}$] $m^{7/4}$ $kg^{-1/2}$ and kc = [$1.0e^{-1}$; $1.0e^{-2}$] $m^{3/2}$ $kg^{-1/2}$), lowering ks results in higher mean water pressures (above 50% of overburden pressure) throughout winter (Fig. S1), as well as in a more developed channel network (longer channels and higher connectivity) during the melt season. However, lowering ks also leads to substantially higher mean water pressures (above 60% of overburden pressure) during the entire melt season (Fig. S1), suggesting that the channelized drainage system indeed lacks efficiency and can only exist at high water pressure. While this increases the realism of our simulations, we also find that our original conclusions about limited influence of channelization and anti-clockwise pressure-input—hysteresis are robust, and hence are also the conclusions about the role of different recharge configurations.

We are now running the full 15-year simulations for all four experiments with a sheet conductivity (ks) of $1.0e^{-4}$ $m^{7/4}$ $kg^{-1/2}$, which yields more realistic winter water pressures, and we will update our results with these model outputs.

(4) A final question that, again I just wonder if you have any thoughts on, is what is the missing ingredient that would produce more efficient drainage systems at the Kongsfjord basin? Is it simply that the meltwater supplied to the subglacial hydrology system is too small, or that the parameter values are insufficient. If, for example, you could choose conductivity values that would give "efficient drainage", are they too far away from the physical values to be plausible?

Response: Our sensitivity tests revealed that changing the value of the sheet and channel conductivities has limited effects on the efficiency of the channelized drainage system. Glacier geometry (gentle slopes and relatively thick ice) and the short duration and low intensity of meltwater production are more likely the main limiting factors of channel efficiency. It might be interesting to further investigate these effects in order to quantify them, however this is outside the scope of this study.

Technical corrections

Line 69) Colon misuse, I think you can just remove it.

Response: Colon was removed.

Line 70) I think "approximations on" should be something more like "approximations about" or "approximations of".

Response: “Approximations on” was changed to “approximations about”.

Line 98) Should be a double hyphen (en dash) between "balance" and "snow".

Response: Fixed.

Line 151) Colon misuse (clause before colon should be independent). I also think semicolons should be used to separate list items here because there is internal grammar in each of the items (commas).

Response: Colon was removed.

Line 323) "channels do no align"-> "channels do not align".

Response: Fixed.

Line 434 + 502) Capitalisation of "arctic" (-> "Arctic").

Response: Fixed.

Line 434) "disadvantages chanelization" seems a bit awkward, maybe "inhibits chanelization" or "prevents chanelization" (I think this one is just personal taste so happy for it to be ignored).

Response: “disadvantages channelization” was changed to “inhibits channelization”.

References

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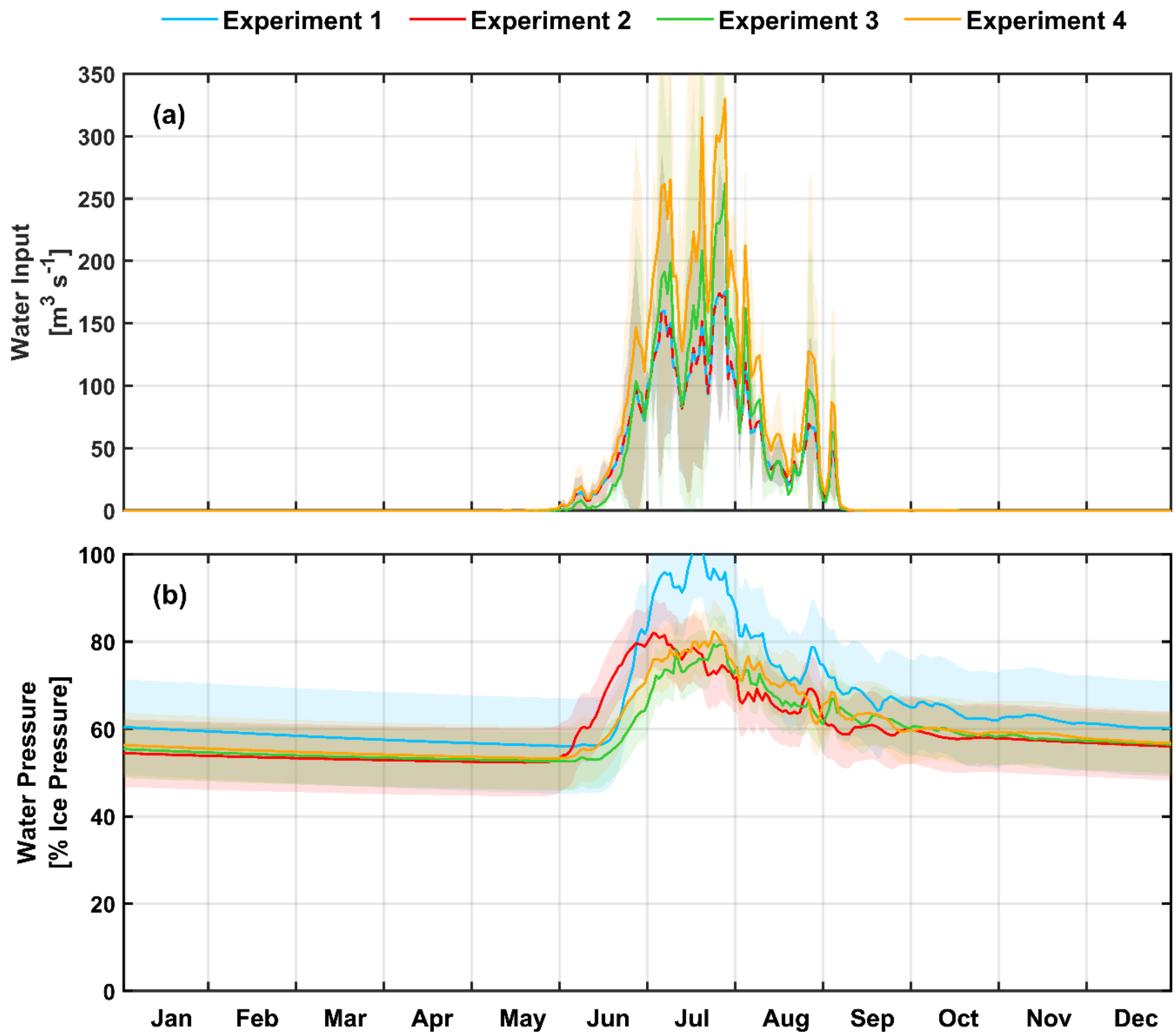

Figure S1. Mean (2004–2005) annual **(a)** water input and **(b)** basal water pressure averaged over the whole model domain for each experiment. The shaded area is the standard deviation showing the interannual variability of water input and water pressure for each experiment. Based on Figure 3 from the manuscript.