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The Cryosphere Discussions

Interactive comment on "Subglacial permafrost dynamics and erosion inside subglacial channels driven by surface events in Svalbard" *by* Andreas Alexander et al.

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We would like to thank the anonymous referee for taking the time to review our manuscript and for providing thorough and helpful feedback, which will certainly help to improve the quality of the manuscript.

In the following we present our responses to the referee comments and how we will address these in the revision of the manuscript.

The referee comments are presented in ***bold and italic***, our replies follow immediately thereafter.

Overall comments

This manuscript provides new information concerning how temperature variability in subglacial channels can impact fluvial erosion beneath cold-based glaciers in Svalbard. I'm not aware of a similar dataset and the results should be of interest to a broad community of glacier and permafrost researchers.

We thank the referee for this overall positive judgment of our dataset.

While I think the paper should be published eventually, I'd like to see the authors more closely situate their manuscript within the modern published literature on the sedimentology and hydrology of cold ice glaciers in Svalbard, provide a clearer description of the sensor installations in the methods section, and more clearly link the discussion to their results. More detailed comments are included with page and line numbers below.

We thank the referee for his feedback. We will rework the introduction of our manuscript to incorporate more modern literature, as requested both by referee 1 and 2 following their suggestions (see also response to RC1). We will further on clarify the sensor installations in the methods section and improve the discussion part following the suggestions from both referees.

Detailed comments

Page 1, Lines 15-20 – Fluvial incision of subglacial tills can erode sediment, but vertical incision of subglacial channels can become limited by boulder armoring. Fine grained materials are preferentially winnowed from till channel by flow and larger boulders and rocks accumulate on the floor (See Gulley et al., 2014). Because flow cannot mobilize these sediments, vertical incision largely ceases but the channel can still migrate and incise laterally. In the case of the till beneath

cold-based glaciers in Svalbard, much of the sediment being eroded by streams was not produced beneath cold based glaciers, as seems to be implied by the authors, but instead is derived from past temperate basal regime or perhaps surges.

This has also been remarked by referee 1 and we will rework the introduction of the manuscript to indicate the source of the subglacial sediment from past dynamic behavior.

Page 2, Lines 25 – Boulton 1972 was written when it was widely believed that cold-based glaciers lacked active subglacial hydrological systems. Hodgkins (1997) highlighted water flow and erosion beneath cold ice in Svalbard. More recent work has shown that much of the water flowing out from under cold-based glaciers is likely de-rived from subglacial channels which began life as supraglacial streams and later incised through cold ice to reach glacier beds (see Gulley et al., 2009).

We thank the referee for pointing this out. We will rework this paragraph (P2, L24-29) to remove Boulton 1972 and account for modern literature and sediment sources. See also the response to referee 1.

Page 4, Figure 1b and c – drawing an outline of the subglacial channel beneath Tellbreen in one panel and only showing the survey line of the channel beneath Larsbreen in the other panel is confusing. At first glance, the cave beneath Tellbreen looks like it is a giant loop! Also, "profile" is typically used to describe what the authors are calling "vertical cross-section (extended profile)" and cross-section is typically used to describe the cross-section of a passage segment (drawn perpendicular to the passage direction).

The reason for drawing the centerline at Larsbreen and the outline at Tellbreen is more of a technical nature. The Larsbreen cave has been mapped with a DistoX and pen and paper, whereas the Tellbreen cave has been mapped using an additional

PDA, allowing for additional survey shots. The post-processing software Speleoliti has, however, not allowed to export the centerline without the survey shots. This is the reason for the outline of the Tellbreen cave instead of the centerline on the map. We can, however, manually trace the centerline within GIS to produce a similar centerline plot as in the Larsbreen case. The naming conventions used for the cave plots originate from the software Speleoliti. We will change the names, following the suggestions from the reviewer.

Page 4, Line 7 – remove "is reported"

We will remove it.

Pages 5,6 - Figures 2 and 3 – there is too much information jammed into these figures. I recommend separating the maps from the photo panels and making the photo panels larger. The pictures are too small to see the information being described in them. For example, there is a logger setup mentioned in Fig 3C – but I can't see it.

We understand well that these figures are at the upper end busy. Reviewer 1 finds them "good", and we prefer thus to not split them up and generate more figures and thus a longer manuscript. However, we will try to make the cave maps clearer. We will also formulate the figure caption clearer, as the mentioned logger setup is indeed not in figure 3C, but in figure 3D.

Methods – HOBO pendant loggers have an accuracy of 0.53 deg C when used forabove-freezing temperatures. Accuracy decreases to 0.75 deg C between 0 and -20Chttps://www.onsetcomp.com/products/data-loggers/ua-002-64/

We thank the referee for pointing this out, as we indeed overlooked it. We will add this to the manuscript.

Page 7, line 20 and 21 – I don't understand this installation. Was the pipe filled

with silicone? If so, please make it clear why. Why were the temperature sensors not buried directly in sediment? For the logger installed into the ice, was it also installed in pvc pipe? What diameter holes were drilled in the ice and sediment and what was the diameter of the pipe? A clear line drawing showing the various types of instrumentation as installed in the caves would be very helpful in visualizing the experiment and this information is critical for interpreting the temperature signals.

Boreholes were drilled with a 20 mm diameter drill. In the case of Tellbreen PVC pipe (20 mm diameter) was used to be able to recover the sensors at the end of the measurement period. The pipes had the further benefit to allow for exact depth placement of the sensors, by fixing them in position inside the pipe. Silicone was only used to seal both ends of the PVC pipe in order to prevent water from draining into the pipe (the pipes remained air filled). Both, sediment and ice sensors, were installed in a PVC pipe. In case of Larsbreen, the sediment sensor was buried directly into sediment. We will add additional information to clarify this in the methods part (P7, L2-25). We will further on provide a line drawing outlining the instrumentation setup.

Page 7, Line 30 – please describe the calibration procedure used for the DistoX.

We followed the standard procedures for the DistoX calibration as outlined in the DistoX manual. https://paperless.bheeb.ch/download/CalibrationManual.pdf We will add according text in the manuscript.

Page 9, Fig 4 – It would really help visualize relationships between outside air temperature and the cave/sediment temperatures if they were plotted at the same scale.

We produced such a figure, see the below figure (Fig. 1). As the cave temperatures appear at the scale of the outside temperatures almost as a straight line without much information given, we prefer to leave the temperatures in Fig 4 at different scales to allow for easier interpretation of the results.

Page 14, line 5 – the authors keep referring to "winter" but the dataset only runs from March until October. It would be nice if the time series graphs could be truncated at the end of the data collection period instead of having 1/5 of each graph displaying no information.

The empty space was caused by a bug in the code producing the third y-axis. This is now fixed and the revised version of the manuscript will include figures without empty spaces (Fig 4-7).

Page 14, line 19 – considering how thin the ice is here, creep closure is probably negligible in controlling the isolation of the cave atmosphere in winter. Snow plugs in the entrances are far more likely.

We will remove the part about creep closure from the manuscript.

Page 16, Figure 9 – I don't understand the conceptual model for air flow. During summer, outside air is warmer than the cave. Air should be cooled in the upper entrance and then flow out of the lower entrance. If the cave were not plugged with snow, the opposite flow would occur in winter. I also don't understand how you have a channel in summer that lacks a stream.

This confusion is certainly caused by the round yellow circle on top of the upper entrance in Figure 9. This was indeed not meant to symbolize air flow, but heat exchange. We do agree with the way the referee describes how the air flow in the cave should work. The point we tried to make with this model, was rather to show that cave temperatures are less stable, if controlled by the air flow caused by temperature differences between surface and cave temperatures (the air flow the referee describes). Whereas they are way more stable if an additional forced convection, caused by running water, exists. The choice of figure might also be suboptimal when it comes to a cave lacking a stream during summer. The way we visualized our cave with a surface connection (upper left panel in figure 9) would almost certainly have a running stream during summer. We believe, however, that cave parts without streams do also exist during summer

(please note: we are talking about cave parts, not whole caves). In case of the studied cave system at Tellbreen, this would be the case for the dead-end, where logger 'Subglacial 2' was located. At the start of the season, no connection to the surface or to other parts existed and it is therefore unlikely that water was flowing in this part of the cave, as the water entered this cave system at location D in Figure 3. However, the meltwater from the surface formed a new channel, thereby connecting the dead-end of the cave system towards the end of the melt season, thereby changing the temperature regime in this part of the cave system. We will revise Figure 9 to avoid this kind of confusion and make it more clear.

Page 17, Figure 10 – mechanical erosion conjures images of plucking or abrasion of bedrock by suspended bed load. Perhaps fluvial erosion is a better term?

We will change the term "mechanical erosion" to "fluvial erosion".

Page 18, Lines 32-35 – maybe I'm missing something, but I cannot figure out what data the authors used to infer the rapid incision described here. Please clearly link this interpretation to the data.

We derived the rapid incision from the fact, that the sediment sensors were eroded out at the end of the melt season. In the example of the Larsbreen sediment sensor, a rapid temperature increase of about 0.8°C occurred within a few days (18.06-22.06.2016), whereas no large and rapid change occurred before (see Figure S3 in the supplementary material). After this rapid temperature increase, the sediment temperature starts fluctuating similarly to the channel air temperature. We therefore conclude, that the sediment sensor was eroded out following the 22nd of June 2016. Based on the only slow temperature increase before the 18th of June 2016, which we attribute to the general warming of the channel and heat-transfer into the ground, we conclude that not much erosion occurred before the 18th. Thus, leaving the four days between the 18th and the 22nd as time frame for the main erosion. See also the response to the short comment SC1. We will detail this more in the discussion (P18, L33 onwards) and

provide to additional plots in the supplementary material of the revised manuscript to make sure the reader can follow our argumentation.

Page 19, Lines 14-34 – Much of this is extremely improbable.....

This was also remarked by referee 1 and we will remove everything following L21 (P19. L21-34), ending the discussion at line 21 as suggested by referee 1 (see also response to RC1).

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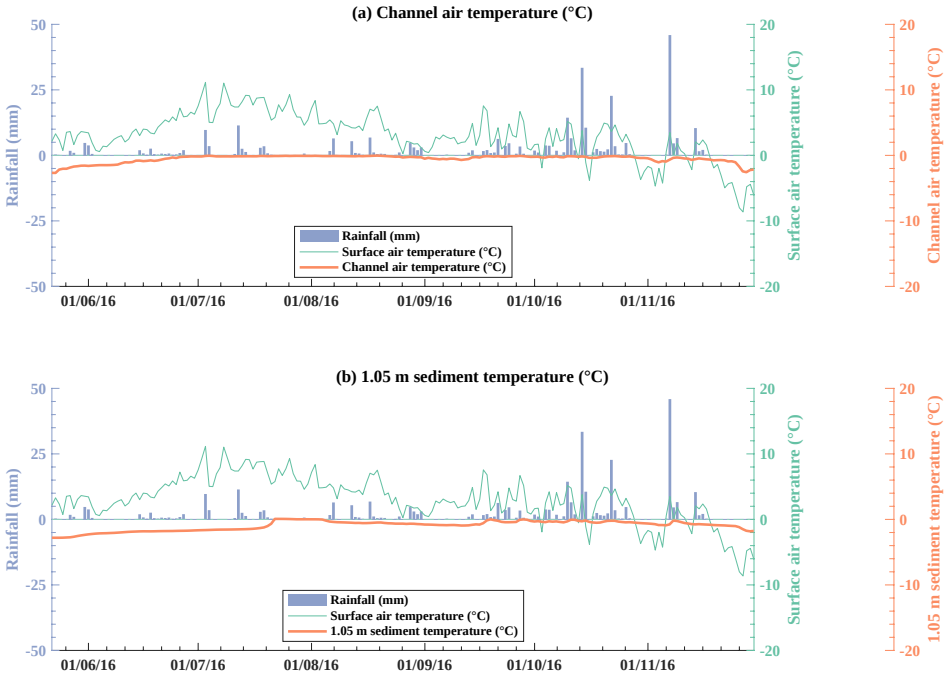

Fig. 1. Figure 4 from the manuscript with same scale for surface air and cave temperatures.