

## ***Interactive comment on “Permafrost distribution and conditions at the headwalls of two receding glaciers (Schladminger and Hallstadt glaciers) in the Dachstein Massif, Northern Calcareous Alps, Austria” by Matthias Rode et al.***

**Anonymous Referee #3**

Received and published: 26 April 2019

In the manuscript "Permafrost distribution and conditions at the headwalls of two receding glaciers (Schladminger and Hallstadt glaciers) in the Dachstein Massif, Northern Calcareous Alps, Austria" Rode et al. investigate the distribution of permafrost occurrence in steep rock walls surrounding two retreating glaciers using a combination of measurements. Based on BTS, GST and ERT measurements the presence of permafrost in four recently deglaciated rock wall is assessed and characterized. Additionally, using historical photo and ancient topography maps, the stages of glacier retreat are reconstructed.

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The detection and the study of the evolution of permafrost in recently deglaciated rock wall are important topics especially in light of the current observed accelerated trend of glacier retreat and permafrost warming. This study is thus well within the scope of this journal. The methodology presented in this paper is sound and easy to follow and the structure of the manuscript is clear. However, after reading the manuscript I find the interpretation of the data too superficial and in some case not substantiated. Furthermore, the introduction, the results and the discussion parts need substantial rework for acceptance and a rigorous review of the English is necessary. For all these reasons I recommend accepting the paper after major revisions.

Major comments:

Introduction: The introduction gives a good general overview of the context of the present study. However, it fails to explain why the methodology of this study was selected and especially what alternatives could have been used. I think here in particular to modelling approaches, which are not mentioned. Please develop more this aspect of the introduction.

The selection of the four measurement sites needs to be explained and justified in the text. Where the four sites selected because of highly probable permafrost occurrence? Or based on accessibility and feasibility of the measurements? Or some other reason? The reason behind the choice of the sites is very important in the interpretation of the results and to what conclusions can be drawn from them.

Discussion: A large part of the discussion focuses on the comparison of the results of this study with the ones obtained by Boeckli et al. (2012) using a permafrost model. In order to follow it better and fully grasp the implications of this study it would be necessary in my opinion to include an additional figure showing the permafrost extent obtained by the model for the entire study region.

The discussion section presents and discusses the relation between the measured resistivities and the time since the deglaciation at the profile location. This is a very

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interesting point, which should be developed more in the manuscript. Furthermore, the interpretation of each tomograms has to be reviewed carefully and better substantiated. In the manuscript, high resistivity anomalies such as the one found in profile MS-K3 are solely interpreted as massive ice. However, highly resistive anomalies can also be due to the presence of large air-filled clefs. The description given in the manuscript is not sufficient to support the interpretation made of the tomograms. Please provide additional details regarding e.g. the fracturing of the rocks as well as any other relevant observation that can support the interpretation of the tomograms.

Conclusion: The statements made in the conclusion are quite general and only partially substantiated by the findings in this study. This section needs to be carefully revised to remove too general statements such as Permafrost preservation in very favorable cold conditions at shadowed higher elevations is still possible at Dachstein area... (P15 L35) and focus only on the findings from this study. More details are given in the specific comments.

Specific comments:

P2 L13: More recent references regarding the warming of permafrost are available. I would suggest to use one of them instead of Harris et al. 2003.

P5 Figure 2: On the map, the glacier retreat from 1915 to 2009 is shown. It would be very interesting to have also this information on the pictures below. For the interpretation of the ERT and temperature measurements it is important to know where is located the glacier extent of 1915. In the legend of the map, GST and BTS measurement locations are divided into PF possible and PF probable categories. Is that defined based on the temperature criteria of Haeberli (1973)? Please clarify in the text.

P6 L29-33: This section explains the concepts of zero-curtain period, basal ripening and melt out date. However, these notions are not used afterward in the manuscript and therefore do not need to be presented.

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P9 L7-19: In this section, mean values of WEqT and BTS temperatures for the different orientations are used. This is justified to analyses the temperature difference between the orientations. However, since one of the goal of this study is the delineation of the current permafrost extent in the region, an analysis of each logger is also required. This clearly has been done since results are showed in Figure 2 but they need to be better described and discussed (in the corresponding sections of the manuscript).

P10 Figure 5: The temperature above 0°C in the beginning of the time series are somewhat confusing. These were most probably measured before at the initialization of the iButtons before the installation in the shallow boreholes. Therefore, I would suggest to remove these values as they are not representative of a physical process in the subsurface. Also, it is not clear to me what the label WEqT in the plot stands for and if its location is indicative of something. Does it indicate a precise date or temperature? If so please add arrows or other visual help sign. Furthermore, in all plots the GST showed include different loggers. It is not clear to which of these loggers correspond the WEqT, RD and MD values displayed.

P10 Table 1: Please include the date of measurement in the table. This is an important information, which is necessary for an accurate interpretation of the resulting tomograms.

P11 Figure 6: The color scale is not very readable. The distinction between thawed, transition and frozen is difficult to make and should be improved. For the profiles K3 and K2, it would also be very helpful to indicate the glacier surface in 1915 as it is calculates in section 4.3

P11 L15: ... below 30 kOhmm ...

P11 L19: and ERT-MSK2 ...

P11 L19: and ERT-MSK2 is even more substantial. Unclear what is meant by substantial. Please reformulate.

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P11-12 L21-1: ...Based on this statistical analysis the existence of permafrost could not be confirmed at the measurement site ERT-MS-G... The text states that permafrost occurrence could not be confirmed at MS-G, whereas in Table 1 in the column permafrost a yes is written. This is contradictory and would need to be corrected. In the text, the interpretation of the tomogram is solely based on the statistical analysis of the specific resistivities, which are divided into categories according to the result of the small-scale test. This is fine for tomograms with homogeneous horizontal layer (e.g. MS-K) but less appropriated for localized resistive anomalies found in the tomograms MS-G or MS-K3. For these cases a more detailed interpretation of the tomograms in addition to the statistical analysis is needed. Additionally, 30kOhmm was found to be the minimum value for frozen conditions but values between 12 and 30kOhmm are in the so-called transition category, which might be frozen or unfrozen. Please review carefully the interpretation of the ERT results based on these observations.

P12 L1: ... are reached, the number of values > 30 kOhmm is too. . .

P12 L7-L16: This section presents the reconstruction of the recent deglaciation in the study area. It is somewhat disconnected from all the others. Currently the results are simply described but there is no discussion of the implication of these results for the interpretation of the ERT or temperature measurements. One of the most important point of this study is that the measurements are done in a newly deglaciated area and this section provides information on the subject. This should be discussed more in detail.

P13 L8-9: ... almost all areas are affected by permafrost in cold and permafrost favorable conditions (Boeckli et al., 2012a). Unclear what is meant here. BTS and GST measurement points classified as permafrost or in permafrost extent according to Boeckli et al. (2012)?

P13 L13: ... for the entire 2004-2015 period

P13 L15: ... At all four study sites permafrost layers with resistivities higher than 30

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kOhmm occurred. See comment above

P13 L17-18: lower WEqT temperatures under -5°C

P13 L19: This is the first mention of active layer in the text. Please develop more what it is and how it can be identified in the ERT tomograms.

P15 L21-22: ... it is assumed that permafrost is currently degrading in rock walls... What is the basis of this statement? Is it based on a specific study (if so please provide the reference) or is it based on this study? If so, it is an unsubstantiated statement, given that the ERT measurement have been performed only once and the GST temperatures only cover a 7 months period. Please reformulate.

P15 L28-29: ...At south exposed rock walls permafrost is expected at higher (2700 m asl.) elevated and colder cold conditions only... In this study, no measurements have been performed in south exposed rock wall. On what data or study is this statement based? Please provide a reference.

P16 L32-33: ... is now degrading due to the direct complying to the atmosphere... In the absence of middle to long-term observation, this statement is impossible to prove. The data presented in this study are not sufficient to support this assumption. Please reformulate.

P16 L35-37: Similar comment as above. This study cannot show clear evidences of permafrost degradation. It shows different thermal condition and resistivity values for the different orientations but the temporal aspect is not substantiated and more data are needed to support it. Please review this paragraph and carefully reformulate it.

P16 L1-4: This is a somewhat strange final statement for this paper. Given that we are now in 2019 and the borehole was drilled in 2014, technical difficulties seem to be endless. I would remove or at strongly reformulate this part.

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Interactive comment on The Cryosphere Discuss., <https://doi.org/10.5194/tc-2018-281>, 2019.

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