This document includes the author's comments *(italic font)* to the review (normal font) RC1 of Anonymous Referee #1, from 27 Jun 2020. Planned changes in the revised documente are mentioned in […].

Review of "Insights in a remote cryosphere: A multi method approach to assess permafrost occurrence at the Qugaqie basin, western Nyaingéntanglha Range, Tibetan Plateau" by Johannes Buckel et al.

The authors integrated three distinct methods, including geomorphological mapping, geophysical (ERT) survey, and radar remote sensing to infer the lower altitudinal limit of permafrost based on periglacial landforms their surface movements in the remote Qugaqie basin in Tibet. As well-dressed in this manuscript, each method suffers its intrinsic limitations and their combination makes a strong and convincing case towards a quantitative, detailed, and comprehensive assessment of permafrost occurrence within a basin where no borehole measurements are available. In addition to this success in method integration, I would also commend the author's efforts of conducting field mapping and geophysical surveys in this remote and harsh environment. Overall, periglacial geomorphology in Tibet is poorly studied. This work provides a valuable set of observations and datasets which hopefully will be published and help to generate more interest in studying geomorphology in this area.

However, I would raise a few issues regarding the scientific meanings, the added value of combining three methods, some details of methodology, and clarity in writing. I also provide a long but incomplete list of editorial comments. A careful proofread is needed.

1. Scientific meanings. Even though three research questions are listed in the introduction, it is unclear to me why the authors wanted to assess permafrost occurrence in this particular basin and why we should care. Moreover, what are the implications of the inferred altitude limit of around 5400 m. And how does the limit in this basin compared with other places in Tibet (this comparison is hinted, but not explicitly addressed). Lastly, please define what do you mean by 'probable permafrost'? Why and what part of your assessment is 'probable', not deterministic?

Authors comment: This particular basin is used for permafrost research because of its high elevation and the location in a mountain range at the TP. In general, Permafrost research at the TP is strongly connected to infrastructure and anthropogenic implications. Aside from this, permafrost-related data is lacking, especially in mountainous regions. We will modify the introduction to stress these aspects more clearly.
We will add in L 67: [Large scale modelling of PF-conditions on the TP (Sun et al., 2020) show that the study area (Figure 1, B) is located at the interface between continuous permafrost and seasonally frozen ground (Figure 1, C), which makes it a suitable environment to validate such large-scale models and to precise the interface with ground-truthed data. The validation is important, because the final conclusion would be that the TP is not completely underlying permafrost conditions, unlike expected and modelled at other places in Tibet (Cao et al., 2019; Ran et al., 2012)].

We agree that the term "probable permafrost" is not well defined, and that the lack of a precise definition might cause confusion. Therefore, we change the term to "probable occurrence of permafrost". The use of the term "probable" is motivated by the fact that we do not have borehole-data (MAGST) and a modelled permafrost distribution and we can only assess the occurrence indirectly. The spatial *heterogeneity of our data (mapping, InSar and ERT) and of natural variations in permafrost occurence also prevents us from providing precise limits.*

We will change in L 67-69: [~~*This study aims to complement the summarized, previous results with the occurrence of permafrost in remote high mountain regions away from the engineering corridors and to provide an important supplement and ground truth for existing permafrost studies at the TP*~~. *This study aims to supplement the previously summarized studies with an assessment of probable occurrence of permafrost in remote high mountain regions away from the Tibetan engineering corridors and to provide a ground truthing for existing permafrost studies and maps at the TP. The use of the term "probable" is motivated by the fact that we do not have borehole-data (Mean annual ground surface temperature) and no modelled permafrost distribution is available. So, we can only assess the occurrence indirectly. The spatial heterogeneity of our data (mapping, InSar and ERT) and of natural variations in permafrost occurrence also prevents us from providing precise elevational limits, so we provide an assessment of probable occurrence of permafrost in a range according to the findings of the three methods]*

We will change in L 87: [As an assessment, the study provides probable occurrence of permafrost by combining these three methods for a catchment in an high-altitude mountain range of the TP.]

2. The authors explained complementary nature of the three methods very well in the introduction section and beginning of section 3 with figure 2. My question remains in the quantitative interpretation of the elevation (or elevation ranges) as inferred from each method (e.g., lines 26-28 in the abstract and summarized in the first three bullet points in the conclusion section). Here is a list of related sub-questions.

We answer the reviewer's remaining question in the final manuscript as follows. Each result section of the corresponding methods will receive a concluding sentence indicating the inferred elevation of probable permafrost occurrence.

We will add in L 324: [The meso-scaled periglacial landforms (mean elevation) are situated between 5300 and 5600 m a.s.l. This altitudinal distribution serves as one component of the three methods for assessing the probable occurrence of permafrost in the catchment.]

We will add in L 364: [The detection of subsurface ice is the second component of the three methods for estimating the probable occurrence of permafrost. Inferred by ERT-data subsurface ice can be expected at selected locations from an altitude of 5450 m and higher].

We will add in L 403: [The third component for assessing the occurrence of permafrost is based on the movement rates of periglacial landforms. Based on the assumption that a measurable movement rate is determined by perennial ice in the subsurface, an active status allows the conclusion of permafrost occurrence in the corresponding landform.

2a. What was the exact reason to give one single value (namely 5400 m) for the lower limit of 'probable permafrost'? What about the two protalus ramparts mapped that are located between 5300 m to 5400 m?

One aspect of our study is that it provides localised ground-truth data in an area that is otherwise only accessible by simulation or theoretical considerations within large-scale models. Therefore, in order to compare the result with existing literature, we find it useful to infer one single value. In reality, the occurrence of permafrost naturally varies depending on topo-climatic factors. To take this into account, the single value is transformed into a range, which also includes the two lowest, active protalus ramparts.

We state out as a general outcome of the publication "the probable occurrence permafrost is higher than 5300 - 5450 m. a.s.l"

The following Changes will be made:

L 25: [~~to assess the lower occurrence of the probable permafrost around 5400 m a.s.l. in the Qugaqie basin~~ to assess the probable occurrence permafrost in the Qugaqie basin]

L 31: [~~potential~~ probable]

L 70: ~~We use periglacial landforms, subsurface ice and surface creeping rates on these landforms to assess the lower occurrence of probable permafrost.~~ The identification of periglacial landforms, subsurface ice and surface creeping rates on these landforms leads to an assessment of the probable occurrence of permafrost.

L 306: [We conclude from this altitudinal distribution ~~that the lower occurrence of probable permafrost of around 5400 m a.s.l., which has to be supported by ice occurrence and the status of activity~~.a probable occurrence of permafrost higher than 5300 m.a.s.l., which has to be supported by validating ice occurrence and the status of activity of these landforms.]

L 493:[~~ The lower occurrence of probable permafrost is supposed at an elevation around 5400 m a.s.l. in the Qugaqie basin.~~ The probable occurrence of permafrost ranges higher than 5300 – 5450 m. a.s.l.]

2b. Quantitively, what are the added values of the ERT results? Are these localized site surveys critical or supplementary for arriving the 5300 m estimate?

ERT is a common method to detect ground-ice in the subsurface, inferring permafrost conditions (Lewkowicz et al., 2011), if ground ice is present for two consecutive years. Therefore, ERT supplements InSar-findings and vice versa. Surface creep without ice could happen without permafrost conditions and subsurface ice without creep over 2 consecutive years is not related to permafrost. With the help of ERT we were able to provide evidence for the existence of ground ice at specific test sites. The localized site surveys are critical for arriving at the 5300 – 5450 m estimate. Profile A (Fig. 8) ranges from 5090 to 5230m and no subsurface ice content was detected in the lateral moraine, which could be supposed.

We will add in L 325: [ERT is a common method to detect ground-ice in the subsurface, inferring permafrost conditions (Lewkowicz et al., 2011), if ground ice is present for two consecutive years. With the help of ERT we were able to provide evidence for the existence of ground ice at specific test sites. The localized site surveys are critical for arriving at the 5300 – 5450 m estimate because no high resistivity values representing subsurface ice content were measured. Profile A (Fig. 8) ranges from 5090 to 5230m and represents subsurface conditions in the lower altitudinal areas of the catchment, for example in a lateral moraine.]

2c. As the InSAR measurements only provide information on surface movement, am I right to interpret that InSAR is marginally supplementary for estimating permafrost occurrence in this study? And it is not very clear what the authors mean by InSAR "allows a transfer and an extrapolation of our findings about ice occurrence from geophysical measurements to other periglacialcial landformsm (Line 84). How exactly did you transfer and extrapolate using the InSAR-measured surface movement?

Surface movement is one key parameter of periglacial landscapes (Eckerstorfer et al., 2018) and is used to infer permafrost conditions (Kneisel and Kääb, 2007; Strozzi et al., 2004). Therefore, InSar-data plays

a major role in this study, because this data validates the two-years rule of frozen ground (=permafrost) through the creeping behavior (compare Fig. 10A).
We will delete the thought of transfer (line 84) because of possible confusion.

We will add in L.152 [Although the continuous movement of periglacial landforms and the presence of ice can be implied from InSar data alone, ground truth at selected locations by ERT is essential to exclude other possible explanations.]

3a. I wish the authors could provide more details of the geomorphological mapping section 3.1. In particular, how did you distinguish periglacial landforms that are characteristics of seasonally-frozen ground and permafrost (Line 168)?

A differentiation of seasonal and perennial frozen ground of the study area is given by Reinosch et al. (2020). Based on InSar time series analyses of the typical periglacial surface changes the authors developed a model to distinguish annual surface changes (seasonal frozen ground) from perennial, more or less constant creeping surface changes (perennial frozen ground) for the study area. We focus directly on periglacial landforms according to perennial creep caused by down moving ice content.

To clarify this issue, we add in L 169: [A differentiation from seasonally-frozen and perennially-frozen movement behavior is given by the data and a derived model by Reinosch et al. (2020). This data was provided for the preparation for the periglacial landform inventory.]

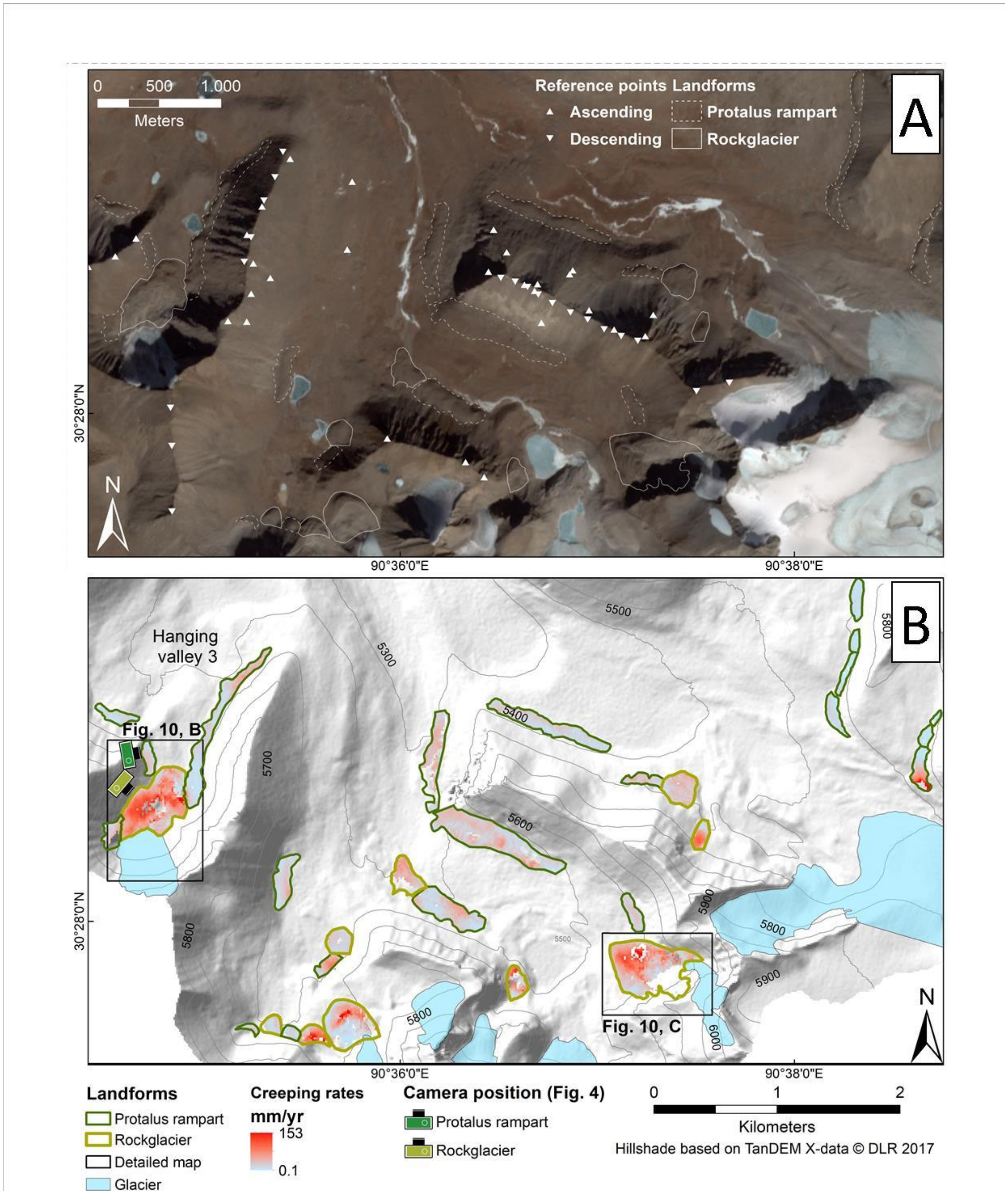
How did you make use of the DEM and optical imagery to map rock glaciers and protalus ramparts, or were they mapped mainly based on field observations?
This question will be answered below the next question.

Why did you need to use optical images from various sources? What are their spatial resolutions? BTW, the Digital Globe, BING, and Google Earth images were mostly likely taken by satellites, therefore not aerial images (Line 165). Is it possible that some landforms were missed and not included in the geomorphological mapping?

The periglacial landforms were mapped at first mainly based on field observations. Back at the office the digitizing procedure started. Therefore, different optical imagery was used because of differing cloud and snow cover to ensure identifying periglacial features clearly. A slope and a hillshade map help to identify landform features more accurately.
To map smaller landforms more time would be needed. Therefore, smaller landforms could be missed, instead the meso-scalled landforms in focus are completely mapped. The DEM originates from TanDEM-X data (2015) with a resolution of 12 m (©DLR). The optical imagery based on BING maps (2013, 15m resolution of TerraColor imagery and 2.5m SPOT Imagery) and Google Earth data (2007-2012) provided by digital globe in a resolution between 0.5 and 5 m resolution depending on the satellite. We will add more detailed information in the revised manuscript.

It might be useful to show optical images/DEMs/DEM over some of the rock glaciers and protalus ramparts (e.g., next to figure 6 or 9, or as background for figure 10).

In the revised version, we will split Figure 9 in Part A and B. Both Parts show the same map extent. Part A displays a Landsat 8 image with the focus on the image, B focusses on the features and their creeping rates.



In Line 385 the following text will be added: [Figure 9, A: Landsat 8 satellite image, recorded 30-01-2018. Triangles indicate stable reference points. Dashed lines indicate the outlines of the periglacial *landforms. B: Creeping rates from periglacial landforms move in slope direction over the observation period 2015 - 2018. Black rectangles display the two fastest rockglaciers in Figure 10. Camera position shows the Photographs in Figure 4*

3b. It would be helpful if the authors could add a brief description of the roll-along procedure illustrated in figure 5..

In Line 210 will be added: [For this procedure, two cables were available (denoted A and B), each equipped with 50 channels. First, both are connected with the control unit to obtain pseudosection number 1 (Figure 5). Next, cable B (and all connected electrodes) remains at the same location, whereas cable A is moved to the right of cable B to measure the Preudosection number 2, and so on.]

Table 2 and associated text fit better in section 3.2.

The location of table 2 is probably debatable, but since the compiled resistivity values are results and are needed for the explanation of the ERT results, we would prefer to leave the table in section 4.2. We hope that the proximity of the table to the ERT discussion will help the reader to follow our arguments more easily.

We will change the headline of Table 2: [Resistivity values for different materials derived by field measurement. The used terms of the interpreted material followed Hauck and Kneisel (2008) and Mewes et al. (2017).]

3c. The authors first reported low InSAR coherence in spring and summer (line 239), but later stated as in spring and autumn (line 270). Did I miss anything? And could the authors add some description of the intermittent SBAS approach? Could you also include velocity ranges in Table 3?

Thank you for pointing out this inconsistency, it should read spring and summer in both cases. We will add a few sentences to explain the intermittent SBAS approach more clearly and we will adapt Table 3 to include velocity ranges.

Figure 1: I cannot find blue, red, or black arrows in 1A. Label “Namco”should be “Nam Co”

Figure 1 will be adapted according the suggestions by the reviewer. By converting a doc-file in a pdf-file these features had been lost.

Figure 6: The black rectangle is labeled as Figure 10, but should be Figure 9. The colors for lakes and glaciers are very similar (can set a darker color for lakes). It would be ideal to use an identical set of colors for the landforms in both figures 6 and 9.

Figure 6 will be adapted according the suggestions by the reviewer.

Figure 9: (this is a minorvisualization issue). InSAR-measured creeping rates show how as light yellow in some landforms (e.g. the two lowest ramparts and in the middle of some rock glaciers), which are not well distinguishable from the light--yellow elevation mask.

According to this point and the reviewers's point 2, a visual illustration of a lower permafrost limit was dispensed with in Figure 9 due to the new range of 5300 to 5450 m. Instead, a concluding sentence after the corresponding result section will be inserted. Additionally, a small subchapter in L 403 will be inserted:

[4.4 Assessement of the lower permafrost limit of the Qugaqie valley

The active status, the altitudinal distribution and validated ice-occurrence by ERT of the periglacial landforms display a range of probable permafrost between 5300 – 5450 m a.s.l. This range includes ice lenses detected by ERT-data as well as all creeping landforms indicating an active status and therefore an existence of ice.]

Editorial comments:
All editorial comments will be implemented according the suggestions.

No need to capitalize permafrost if it is not at the beginning of a sentence.

L17: play should be plays

L19: at should be in

L50: decrease should be decreased

L55: spell out ERT here, at its first appearance in the text

L56:part should be parts

L61 & L69:at the TP should be on the TP

L79: which should be what

L93: cretaceous should be Cretaceous

L96: In should be On

L97: spell out ISM here at its first appearance in the text

L118: 'the'' GLIMSdatabase (can also spell out GLIMS)

L120: then should be than

L128: two-years should be two-year

L152: "derived the from the mean"?mean'?

L190:is 'pronival rampart' interchangeable with protalus rampart? If so, it is better to stick with protalus rampart..
[An incorrect determination as pronival ramparts -a similar looking landform like protalus rampart- can be minimized…]

L235: changes should be change

L328: "in terms their interpretation in terms of material characteristics"?

L405: are should be is

L408: regimes should be regime

L409: effect should be effects

L410: an should be and?

L410: cower should be cover

L411: delete one 'at'

L412: cause should be because

L418: method should be methods

L431: delete 'the'' before this

L466: of should be away

L466: routing should be rooting?

L469: occurence should be occurrence

L472: scalled should be scaled (or large-scale)

L473: probabilities should be probability

L478: insight is a noun

L483:- asses should be assess

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