

Remarks on the manuscript by Wang et al. entitled

“Mapping and inventorying active rock glaciers in the Northern Tien Shan (China) using satellite SAR interferometry”

submitted to The Cryosphere

General:

The authors present a new rock glacier inventory for the Northeastern Tien Shan which they derived from InSAR data and Google earth imagery. Moreover they analyze the topographic characteristics of the rock glaciers and use the rock glacier inventory to estimate the permafrost distribution in the study region.

The approach to map the creeping permafrost features is interesting and promising and has rarely been applied so far. The inventory is the first of its kind in Northwestern China and the topographic and climatic analysis provide useful insights. I (and surely the scientific community also) appreciate very much that the inventory is made available as supplementary material.

However, there are some issues which need to be improved from my point of view before the manuscript can be published.

The most important issues are:

- The delineation of the rock glaciers seems to be unprecise as e.g. visible from the figures: The upper boundary may be hard to define precisely but some more efforts should be made; is it not clear from Fig. 2 which criteria was used and the boundary is very probably not rectangular. It seems to me from Figs. 2b and 4 that exposed rocks are included. The lower boundary visible in Fig. 2b is also too rough as parts which clearly belong to the rock glacier are missed while others (e.g. even a part of the river were included). This needs to be improved as good as possible for all outlines so that at least no obvious errors are made.
- Rock glaciers provide a hint where the lower limit of permafrost is located. However, the lower limit of rock glaciers varies significant due to topographic factors and the blocky material favours cooler temperatures allowing rock glaciers to exist at elevations where permafrost is otherwise unlikely (see. e.g. modelling studies for the Northern Tien Shan in Kazakhstan/Kyrgyzstan, see references). I'd therefore suggest rather to discuss the suitability of rock glaciers for investigation the permafrost occurrence (as you partly already did) than presenting new results of a lower limit of the permafrost occurrence which is highly uncertain. The authors should also keep in mind that there is no clear limit but that especially in mountains the permafrost occurrence is very heterogeneous.
- There is limited discussion where the authors put their approach and results into context. There are several studies existing which were presenting rock glacier inventories and further information in the neighbouring Kazakh and Kyrgyz Tien Shan. Several ones are in Russian which might be difficult to understand (but may still be considered as they provide valuable information) but there are also several published in English (especially by A. Gorbunov, see references). One more recent paper co-authored by Gorbunov presents also a topographic analysis which would be very interesting to compare your results to.
- Recent findings show a clear seasonal behaviour of the surface velocity (e.g. Wirz et al. 2016). Hence, it is important to mention the acquisition period of the data used to calculate the velocity also in the text. The seasonal effect should also be considered in the discussion.

- With respect to the discussion I suggest to include a separate discussion section where you put your approach and results into context of the existing literature. Currently, the discussion section contains only a comparison of the rock glacier derived permafrost estimates to permafrost distribution estimates.
- A minor but important point: The Tien Shan is a large mountain range stretching from Uzbekistan into China. Considering the Tien Shan as a whole using “Northern Tien Shan” is not correct. You should rather use “Northeastern Tien Shan” in the title and elsewhere.

Specific comments:

Abstract:

L10: Rock glaciers are widespread not only in western China but in the whole of Tien Shan.

L11: There are few recent studies, but your statement is true for Western China. Please correct.

L24: The approach is interesting for global rock glacier mapping and not only for western China.

1. Introduction:

L28: I am missing the classical monography by Barsch (Barsch 1996) in the references. I'd rather cite Haeberli et al. (2006) instead of 2010 here.

L36: Not sure if a definition of inactive and relict rock glaciers are needed here. This is a cryospheric journal where the readers should know such basic knowledge.

L45: Brenning (2005) already mentioned it and used the term intact for active and inactive rock glaciers. You would be able to distinguish which is a major advantage.

L47ff: You should mention also somewhere that multi-temporal optical images can and were also used to investigate rock glacier velocity (e.g. Gorbunov et al. 1992, by visual interpretation; Kääh et al. 1997 by feature tracking).

L68: Mention here at least one of the existing studies.

L74: Include here few of the existing studies of the Kazakh and Kyrgyz Tien Shan.

L80: You may mention here the study by Bolch and Gorbunov for the nearby Northern Tien Shan in Kazakhstan and Kyrgyzstan and maybe also Schmid et al. (2015)

2. Study area:

General: Provide more details about the general characteristics of the Tien Shan, the subdivision, and especially the climatic conditions.

L97: Be more specific about the annual precipitation amount. The west is wetter than the east but not really wet. The climate is only relative humid for the continental conditions.

L102: You cite here almost the same studies than in L75 in the introduction. I suggest to cite in the intro those which provide information about the larger regions or from surrounding ranges and in the study region section the specific ones.

3. Methodology:

General: The other reviewers are more experts in SAR processing. Therefore I will not comment on the technical aspects here. However, I'd like to see a better figure where the authors present the identification of moving surface based on the wrapped interferometric phase. Fig. 3 is interesting in this regard but I find it hard to understand how you identified surface displacements based on this image. Maybe a larger image or a zoom would help.

Provide a short information about the quality and suitability of the images available at the time of the study in google earth, e.g. had all images good snow conditions and where all of very high resolution?

L148: I agree that active rock glaciers have usually little or no vegetation, but not always (e.g. there are trees on rock glaciers in other parts of the Tien Shan). Hence, write "have usually little or no vegetation" or similar.

L151: It is not true that debris-covered glaciers "are usually covered with uniformly thin debris layer". There are manifold studies which show that the debris thickness usually increases towards the terminus and that the surface of a debris-covered glaciers is characterised by ice cliffs and supraglacial lakes. It is partly hard to distinguish clearly between debris-covered glaciers and rock glaciers as gradual transitions to moraine-derived rock glaciers exist especially in continental conditions.

L161: What is a rooting zone "Z" and where is it in Fig. 1?

L184f: I find the abbreviations ILP (initial line point) and FLP (front line point) not intuitive as you are mainly interested in the altitude. Humlum (1998) uses RILA (rock glacier initiation line altitude). As you are referring to the maximum and minimum altitude I'd use h_{min} and h_{max} . But you may decide.

L197f: It can be quite difficult to identify the upper boundary. Hence, InSAR is quite promising. Provide more details and examples for how you identified the upper boundary. Ridges and furrows are typical for compressive flow in the lower rock glacier area and, hence, you might have missed parts if you only use these criteria.

L200: Should be Gruber (2012).

L206: Why do you mention "lower limit of the permafrost distribution" here. You are quantifying the rock glacier parameters.

4. Results:

L222f: Move to methods.

L250ff: What is about the influence of the general topography? It could be worth to compare the aspects of the rock glaciers to the aspect distribution of the investigated mountain ranges. The aspect distribution of the rock glaciers in Kazakh and Kyrgyz Northern Tien Shan is clearly influenced by the topography.

L252: Kaldybayev et al. (2016) investigate glaciers in Dzhungar Alatau which is close to your study region but is not the Northern Tien Shan.

L266: Be careful with the statement about the lower limit. See my general comment above.

L270: What is about the precipitation? I would assume the precip is also of importance.

L278f: This is an important point and should be discussed more in detail.

L280ff: You need to consider that the temperature in the blocky material of the rock glaciers can be significantly colder than the MAAT (e.g. Gorbunov et al. 2004).

L287ff: The first lines of this section describe methods and should be presented in the methods section. In addition, as mentioned information about the time of the year when the velocity was measured are required.

L302f: The presence of water (e.g. from snow melt or heavy rain fall) has a strong influence on the short term variation. This should be mentioned and discussed along with the acquisition period of the data.

5. Discussion

I suggest a separate discussion section where you put your results into context. I suggest to slightly shorten the discussion about the comparison to the existing permafrost maps.

6. Conclusions

Readers often read the abstract and look at the figures conclusion only before they decide to read the entire paper. I would therefore not use non-common abbreviations in the conclusions and figure captions.

L434: Use one decimal digit only. The exact area is quite uncertain.

L442ff: Conclusion 4 is hard to understand.

L446: The methods cannot only applied in China...

L450: Reformulate the last sentence. Rock glaciers provide a hint for permafrost occurrence but should be used with care when modelling permafrost distribution.

Do not hesitate to ask in case you have any questions to my review or need additional information.

Best regards,

Tobias Bolch

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