# Author reply to the comments to the TCD manuscript "Assessment of permafrost distribution maps in the Hindu Kush Himalayan region using rock glaciers mapped in Google Earth" by M. O. Schmid et al.

We would like to thank the referee for his constructive comments which helped to improve this paper.

**Referee comments are in bold**, author reply's without formatting and *changes to the manuscript in italic.* From the feedback of the Referees two common main points were:

**A) The relation rock glaciers and permafrost**

The initial manuscript may have been misleading in a way that Referees were doubtful if rock glaciers really delineated the lower limits of permafrost existence, when in fact we purposefully avoided the term and concept of permafrost limits. Our understanding is, that rock glaciers are not suitable to delineate the boundaries of permafrost, as ground thermal conditions are spatially too heterogeneous. Extensive research has shown, however, that rock glaciers frequently occur near the lowermost regional occurrence of permafrost in mountains. The manuscript reads now as the following:

*The occurrence of rock glaciers is governed by the ground thermal regime and by the availability of subsurface ice derived from snow avalanches, glaciers, or ice formation within the ground. Furthermore sufficient supply of debris as well as topography steep enough to promote significant movement is required. As intact rock glaciers contain ice (latent heat) and move downslope, their termini can be surrounded by permafrost-free ground. The frequently occurring cover of coarse clasts, promotes relatively low ground temperatures and thereby further retards the melting of the ice within the rock glacier. This makes termini of rock glaciers local-scale indications for the presence of permafrost, frequently occurring at an elevation indicative of the lowermost regional occurrence of permafrost in mountains (Haeberli et al., 2006). This tendency of begin among the lowermost occurrences of permafrost in an area is exploited in this mapping exercise. The spatially heterogeneous ground thermal regime and the frequent existence of permafrost-free areas directly adjacent to rock glaciers makes the concept of "permafrost limits" impractical as these limits are neither measureable nor clearly defined and consequently we avoid this concept despite its prevalence in the literature. In more gentle terrain, such as parts of the Tibetan Plateau, not the ground thermal conditions (i.e. the presence of permafrost), but the slope angle is the*

*limiting factor. Therefore, the presence of rock glaciers can be used as an indicator of permafrost occurrence, but the absence of rock glaciers does not indicate the absence of permafrost. Mapped rock glaciers will thus result in a conservative estimate of the actual permafrost distribution, as over large areas of permafrost no rock glaciers can be present due to the lack of debris, low slope angles, lack of avalanche snow or the elevation of the valley floor*

**B) Difficulties to understand to concept of a mapped candidate area (Fig. 6, 7 and 8)**

The rock glacier mapping in our study is only meaningful for areas where rock glaciers can potentially exist. There are most likely vast regions in the HKH region, mainly on the Tibetan Plateau, where rock glaciers are absent because of the lack of topography and debris. For those we can not perform an assessment of the available permafrost distribution maps. To exclude such areas we created the mapped candidate area, which includes only the area where we can potentially expect the presence of rock glaciers. This reduced investigation area includes not all mapped samples anymore, but only the sample areas which fulfil certain criteria concerning topography, satellite image quality and glacier coverage. This mapped candidate area is then the basic for the assessment of the available permafrost distribution maps. The manuscript reads now as the following:

Rock glaciers outside the signatures for permafrost provided by the evaluated maps indicate false negatives, as the map indicates the likely absence of permafrost, but the existence of permafrost was inferred based on mapped rock glaciers. A comparison of mapped rock glaciers with predicted permafrost extent, however, is only informative in situations where the formation and observation of rock glaciers can be expected. *In the further analysis we excluded all parts of the initial samples where no rock glaciers can be expected. This subset of our mapping was named potential candidate area and includes only sample areas which fulfil the following three criteria*: (a) Topography: Only sample polygons where the vertical standard deviation of the SRTM 90m DEM is larger than 85 m. This threshold was chosen so as to be smaller than the lowest observed value where rock glaciers were mapped, which is 89.5 m. (b) Image quality: Only samples with sufficient image quality in Google Earth were taken into account. (c) Absence of glaciers: Glacier covered areas were excluded based on the glacier inventory published by Bajracharya and Shrestha (2011), which largely covers the HKH region with the exception of parts of China.