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Ground surface thermal regime of rock glaciers in the High Tatra Mts., Slovakia

Tomáš Uxa (1,2) and Peter Mida (1)

(1) Department of Physical Geography and Geoecology, Faculty of Science, Charles University, Praha, Czech Republic, (2) Department of Geothermics, Institute of Geophysics, Academy of Sciences of the Czech Republic, Praha, Czech Republic

Numerous lobate- or tongue-shaped debris accumulations, mostly interpreted as rock glaciers, have recently been recognized in the High Tatra Mts., Slovakia (49˚10' N, 20˚08' E). These prominent landforms arise due to creep of voluminous debris-ice mixtures, and as such they are excellent indicators of present or past permafrost existence. Hence rock glaciers are extensively utilized to model the distribution of permafrost in mountain areas. However, commonly applied rules of thumb may not be entirely indicative to discriminate particularly between the inactive (permafrost in disequilibrium with present climate) and relict (without permafrost) rock glaciers, which may substantially complicate permafrost modelling. Accordingly, the information about their thermal state is essential to calibrate and validate regional permafrost models. Limited ground temperature data have been, however, available from the High Tatra Mts. to date and therefore, we bring the updated and enhanced results from the thermal investigations of eleven rock glaciers located in the Slavkovská dolina and Veľká Studená dolina valleys at elevations between 1832 and 2090 m asl.

Ground surface temperature (GST) has been continuously monitored at seven rock glaciers between October 2014 and September 2016 using nine Minikin Tie (EMS Brno Inc.) and iButton DS1922L (Maxim Integrated Inc.) loggers with an accuracy of ±0.2 and ±0.5 ˚C, respectively. In addition, the bottom temperature of snow (BTS) was measured at 306 locations during spring of 2015 and 2016 to map potential permafrost occurrence within all the surveyed rock glaciers and in their immediate surroundings.

Mean annual ground surface temperature (MAGST) of the rock glaciers ranged between -1.3 ˚C and +2.6 ˚C and averaged +1.0 ˚C and +0.8 ˚C in 2014-2015 and 2015-2016, respectively. Two sites continually showed negative MAGST and two other sites were below +0.5 ˚C and +1.0 ˚C, respectively. This strongly contrasts with mean annual air temperature (MAAT), which averaged +2.3 ˚C in both years (estimated from nearby Lomnický štít station using a lapse rate of 6.5 ˚C/km). Accordingly, GSTs showed negative surface offset (MAGST-MAAT) of -1.3 ˚C and -1.5 ˚C in 2014-2015 and 2015-2016, respectively. At the coldest sites, the surface offset regularly reached values well below -2 ˚C and dropped up to -3.3 ˚C. GSTs recorded prior to the onset of snow melting (i.e. BTS) averaged -3.8 ˚C and -3.2 ˚C in spring of 2015 and 2016, respectively, and varied between -5.8 ˚C and -1.6 ˚C. One-time BTS values showed the average of -2.8 ˚C, but relatively high short-distance heterogeneity of BTS values, ranging between -8.3 ˚C and 0.0 ˚C, was encountered across the rock-glacier surfaces.

The results suggest that permafrost occurrence is probable or possible in a total of ten rock glaciers, while its absence is probable only in one of the investigated landforms. We classify the latter form as relict and other two rock glaciers are suggested to be in inactive/relict state. Six rock glaciers are believed to be inactive and two even active/inactive. In most cases, however, permafrost likely occurs in a form of isolated patches or discontinuously and presumably degrades under present climate conditions.