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Influencing factors on the cooling effect of coarse blocky top-layers on relict rock glaciers

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Coarse blocky material widely occurs in alpine landscapes particularly at the surface of bouldery rock glaciers. Such blocky layers are known to have a cooling effect on the subjacent material because of the enhanced non-conductive heat exchange with the atmosphere. This effect is used for instance by the construction of blocky embankments in the building of railways and roads in permafrost regions to prevent thawing processes. In alpine regions, this cooling effect may have a strong influence on the distribution and conservation of permafrost related to climate warming. The thermal regimes of the blocky surface layers of two comparable – in terms of size, elevation and geology – relict rock glaciers with opposing slope aspects are investigated. Therefore, the influence of the slope aspect-related climatic conditions (mainly the incident solar radiation, wind conditions and snow cover) on the cooling effect of the blocky layers is investigated. Air temperature, ground surface temperature and ground temperature at one meter depth were continuously measured over a period of four years at several locations at the NE-oriented Schöneben Rock Glacier and the adjacent SW-oriented Dürrtal Rock Glacier. At the former, additional data about wind speed and wind direction as well as precipitation are available, which are used to take wind-forced convection and snow cover into consideration. Statistical analyses of the data reveal that the blocky top layer of the Dürrtal Rock Glacier generally exhibits lower temperatures compared to the Schöneben Rock Glacier despite the more radiation-exposed aspect and the related higher solar radiation. However, the data show that the thermal regimes of the surface layers are highly heterogeneous and that data from the individual measurement sites have to be interpreted with caution. High Rayleigh numbers at both rock glaciers show that free convection occurs particularly during winter. Furthermore, wind-forced convection has a high impact on the thermal regime of the Schöneben Rock Glacier and, as the major wind direction, especially for higher wind speeds, is from west towards east, it is suspected that wind-forced convection is even more important at the Dürrtal Rock Glacier. The limited incident solar radiation at the Schöneben Rock Glacier results in a longer seasonal snow cover that appears earlier in autumn and can persist longer during the melting season. Moreover, with the predominant westerly wind, snow is supposedly transported from neighboring catchments (i.a. the Dürrtal Rock Glacier catchment) towards the Schöneben Rock Glacier catchment. Thus, in times with relatively cold air temperatures the coarse blocky surface at the Dürrtal Rock Glacier is better connected to the atmosphere than the more northern exposed Schöneben rock glacier because of the missing or only partial snow cover, which results in an enhanced cooling effect. It can be concluded that the cooling effect of coarse blocky debris is highly variable in alpine environments and can show considerable variations, depending on the heterogeneous structure of the layer itself and a complex interplay of slope aspect-related microclimatic effects such as incident solar radiation, predominant wind direction and snow cover dynamics.