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Ice melt underneath a supra-glacial debris cover: interactions between meteorology and debris properties based on field experiments

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During the last decade a trend towards negative mass balances is detectable for almost all glacier covered mountain ranges in the world. Especially in the regions of Central Asia and the Himalaya a high percentage of glacier tongues are debris covered, thus representing special conditions for the interaction between atmospheric conditions and the resulting ablation of glacier ice. Also in the European Alps glacier tongues in several regions accumulate supra-glacial debris at an increasing rate. Therefore, the evolution of the debris cover and the processes involved in ice melt generation on such glacier tongues need to be considered in future predictions of ice loss from mountain glaciers.

In general, very thin dust layers increase ice melt due to a lower surface albedo and an effective heat transfer to the ice surface. In contrast, already a few centimeters of debris cover is sufficient to reduce the ice melt below the values for clean ice by reduced absorption of SW-radiation. For natural conditions it is rather difficult to determine the governing processes, because of the rather inhomogeneous nature of the debris cover. Ablation generally is controlled by two independent factors: 1) the atmospheric conditions, such as air temperature, air moisture, solar radiation, wind and 2) the physical characteristics of the debris cover (e.g., thickness, grain-size and surface reflectance).

In order to provide controlled conditions for the influence of the debris cover on glacier melt, we prepared eleven different test fields at an elevation of 3000 m on the Vernagtferner in the Austrian Alps and observed the ice melt and the meteorological conditions during the ablation season 2010. The test fields were designed in a way that the effects of the type of lithology (albedo), the grain size, and the debris cover thickness on the ice melt could be investigated. The main meteorological parameters were recorded at several locations at the test fields, on clean glacier ice and just in front of the glacier terminus, in order to determine the specific meteorological boundary conditions for the test site.

We used three different lithologies: mica schist (MS), which typifies the local lithology; black, basaltic tephra (EB) of the Etna volcano (Italy); and grey, trachytic pumice (SC) of the Sete Cidades volcano (Azores, Portugal). The test fields were created using different grain sizes, all in the sand and gravel fraction and layer thicknesses were (3 - 18 cm). In addition to regular ablation readings at the test fields, the clean ice ablation was measured continuously with a sonic ranger. Within the first four weeks the glacier lost 1.55 m of ice at the natural site, while the minimum ablation at the test fields was only 0.78 m. The results from our experiment clearly provide information about the significance of grain size, debris colour and debris thickness on the ice ablation rates. Investigations of the thermal conditions within the debris cover provide insight into the energy exchange at the debris surface and the energy transport through the debris cover to the debris/ice interface.