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Ice cliff ablation derived from high resolution surface models, based on close-range photogrammetry

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Ice ablation in general is governed by air temperature and solar radiation. On debris covered glaciers melt rates are usually reduced by the debris layer, if this layer is more than a few centimeters thick. Steep ice cliffs, where supra-glacial debris is not able to establish, are usually only covered by a thin film of sand and tilt which enhances melt relative to the ablation of clean ice. These ice cliffs therefore account for a considerable part of the total ablation on debris covered glacier tongues. Bulk estimates of sub-debris ablation usually do not include these effects, because measurements are difficult and mapping of ice cliffs is only possible in the field or on high resolution imagery.

This study concentrates on the determination of ice melt and its spatial variability on such steep ice surfaces, surrounded by supra-glacial debris. For this purpose control stakes have been drilled into the ice cliffs at different levels for obtaining reference values at the top, in the upper and lower slope and at the bottom of the ice cliffs. The same strategy was applied to ice cliffs of different exposition, in order to investigate the influence of direct solar radiation on the melt process. The cliffs then were surveyed by terrestrial close-range photogrammetry at three different epochs, resulting in two periods for which geometry changes could be calculated. The spatial resolution of the generated digital surface models of the cliffs is in the order of centimeters, allowing a highly resolved determination of changes in the cliff geometry.

The investigations show that ice ablation not even is much higher than for the surrounding debris covered glacier parts, it is also more intensive than for clean ice conditions, depending on the slope and exposition. The seemingly rather stable features of ice cliffs show a large temporal variability and the flat top part tends to melt faster than the flat glacier surface at the bottom of the cliff, where debris accumulation occurs. Ablation is highest close to the foot of the cliffs and geometry changes show a maximum there, despite a compensating effect from ice deformation. The combined effect of melt on the cliff top and debris accumulation at the bottom can account for a reduction of the cliff height of several meters during one ablation season. During the same time, the differential ablation leads to steeper cliff slopes. Therefore ice cliffs are highly dynamical features which cannot be neglected, when estimating total melt on debris covered glacier tongues.