MODELING OF DEBRIS-COVERED GLACIERS: MODELING SYSTEMS TO DETERMINE THE MELT WATER PRODUCTION OF DEBRIS-COVERED GLACIERS AT A RANGE OF SPATIAL AND TEMPORAL SCALES

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Melt water production from glaciers derives primarily from the glacier ablation area. In some mountain regions debris-covered ice comprises 40-70% of the ablation area, so understanding the impact of surface debris on ice ablation is essential for quantifying the melt water contribution from mountain glaciers to regional water resources and global sea level rise. Conventional wisdom is that beyond a thickness of a few centimeters, supra-glacial debris slows down ablation compared to that of clean ice, and thus 'protects' the debris-covered ice during periods of negative mass balance. Contradictorily, satellite studies show glacier-wide lowering of debris-covered ice matches, or even exceeds, that of comparable clean ice surfaces. The premise of this research is that previously unaccounted for processes associated with the surface properties of the debris-covered area are responsible for the rapid rates of ice loss observed at the glacier scale, and the research aims to quantify the impact of these processes.

Firstly, the most appropriate mathematical model of sub-debris ice ablation is chosen on the basis of an objective model inter-comparison, evaluated against laboratory cases. The sensitivity of the sub-debris ice ablation to varying climate and debris conditions over daily, seasonal and annual timescales is then quantified in order to generate factors that describe how supra-glacial debris modifies ice ablation under a full range of possible conditions. Secondly, the impact of (i) local surface relief, (ii) debris thickness variability and (iii) the occurrence of exposed ice faces within the debris covered zone, on spatially-averaged ice ablation are quantified. Thirdly, the timescales over which properties (i)-(iii) evolve over time are quantified by modeling the evolution of ablation topography and gravitational reworking of the debris cover to expose ice faces. A novel satellite approach is used to determine the surface textures and properties within the debris-covered ice area, and how they change over space and time. Finally, the parameterized values of the effect of debris cover, its varying surface properties and the evolution of these properties through time will be used to calculate spatially weighted glacier mass balance profiles for debris- covered glaciers that are coupled to a glacier flow line model. This model system is then used to explore the ice flow and melt response of glaciers to varying debris configurations and their evolution in time.

At each step the modeling work is constrained and evaluated by different sets of laboratory, field or satellite data. Model experiments with idealized components of the systems are used to quantify errors associated with each component of the modeling chain, so that the final product is a well-constrained glacier modeling tool that will be made available for subsequent studies of hazard assessment and melt water production associated with debris- covered glaciers.