Geophysical Research Abstracts
Vol. 21, EGU2019-14478, 2019
EGU General Assembly 2019

Quantifying dirty ice melt rates using high-resolution repeat UAV surveys at Miage Glacier, Italy

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Rates of ablation beneath layers of thin debris cover are thought to be greater than in areas of clean ice. Thin debris covers are typically patchy rather than continuous, complicating spatial patterns of ablation. To date, attempts to directly measure, rather than model, the influence of partial debris cover on ablation are absent. As a result, the accuracy and reliability of current melt models in areas of partially debris cover is unknown. However, accurate and reliable melt models are important for a range of science and management applications in high mountain regions, including run-off modelling, water resourcing and energy planning. Here, we provide a first quantification of ablation within an area of partial debris cover (or 'dirty ice') through the use of two high-resolution UAS (Unmanned Aerial System) image surveys acquired from the Miage Glacier (Italy) over a one-month period of melt during the summer of 2017. We process the UAS imagery using Structure from Motion photogrammetry to generate high-resolution orthophotos, digital elevations models and spatially-continuous ablation maps. Extensive ground truth data, on percentage debris cover, clast size and albedo, allows an investigation of the relationship between these characteristics and ablation. We find that only the cleanest ice ($<\sim$10% debris cover) has a lower ablation than partially debris covered ice. At greater debris cover percentages, ablation rates vary very little. The ablation map also reveals the role of sub-debris streams in locally enhancing ablation. These findings provide the first quantitative assessment of the influence of partial debris cover on ablation and therefore will form the basis for modelling dirty ice ablation in future and have consequences for the assumptions employed in debris evolution models.