Ablation and debris cover formation in dirty ice areas

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Introduction

Areas of discontinuously debris-covered ice (dirty ice) are regions of high melt on debris-covered glaciers and are associated with the upglacier expanse of the debris cover. Modelling suggests that partial debris cover may increase melt compared to both clean and continuously debris-covered ice, although this has yet to be proven quantitatively. The aims of the project are to: 1. Validate and improve melt modelling techniques for dirty ice areas using remote sensing and field data and 2. Increase the understanding of the processes of debris supply and remobilisation which lead to debris cover formation.

Methodology

UAV imagery was collected using a DJI Phantom 4 Pro quadcopter on the 17th of July and 22nd of August 2017, over a dirty ice area of Miage Glacier, Italy. The imagery was processed using SfM photogrammetry to produce a DEM (0.04 m GSD[1]) and orthophoto (0.009 m GSD) for each survey date. Sixteen ablation stakes were drilled into the ice and surveyed using GNSS. Stake positions were marked using ground control points and used for georeferencing of the UAV-SfM data. Debris characteristics were determined using ground photographs of 50 georeferenced 0.5 x 0.5 m quadrats, with albedo also measured at 26 of those plots. The August DEM was corrected for horizontal ice movement and elevation change (as a result of downslope ice movement and ice emergence), using the change in location of the georeferenced ablation stakes. Distributed ablation was calculated by subtracting the corrected August DEM from the July DEM, with mean ablation then calculated at a range of scales (10, 50 and 100 x orthophoto GSD). The percentage debris cover was calculated from the July orthophoto after classification into debris or ice using a maximum probability method.

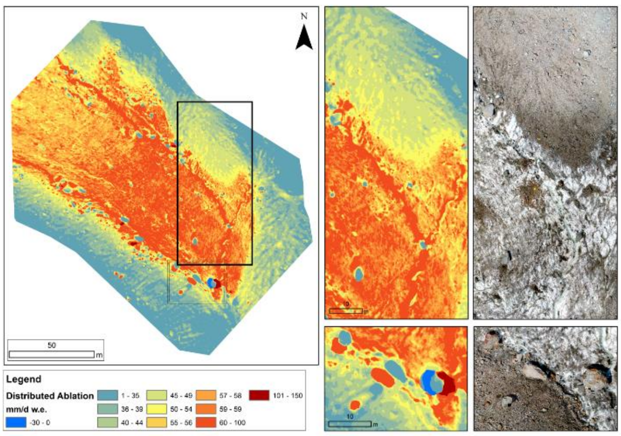

Figure 1 Distributed ablation. Insets show a subset of the ablation map with the right hand panels showing the orthophoto for the same area.

Results

The high resolution ablation map (0.04 m GSD) reveals novel characteristics of ablation. In areas of continuous debris, ablation is increased following drainage lines, such as in the radial pattern shown in . Supraglacial drainage therefore increases melt, possibly due to heating from meltwater or the hydraulic removal of debris reducing debris thickness. The main supraglacial stream shows particularly high ablation rates (around 65 mm d^{-1} w.e.). Ablation rates are highest for areas of partial debris cover (15-80%), and lower for clean ice and continuous debris (Fig 2).

Future Work

Forthcoming work will determine the influence of clast thickness and albedo on ablation (with variation in these characteristics the likely explanation for the broad 'maximum' in the ablation/ percentage cover relationship – Fig 2). This understanding will then be used to improve melt modelling. Furthermore, feature tracking of clasts and changes in the percentage debris cover between surveys will allow quantification of debris cover remobilisation.

The work was presented at the 2017 AGU Fall Meeting and has been accepted for presentation at EGU 2018. The first paper *'A new type of Østrem curve: insights from distributed ablation over dirty ice areas of debris-covered glaciers'* will be submitted to ESPL this summer. Subsequent work will determine debris parameters from coarser imagery and integrate improved modelling schemes into catchment scale models. Findings will feed into a bid to the Royal Society focussing on debris-covered glacier runoff. We thank the BSG for their support in funding this research.

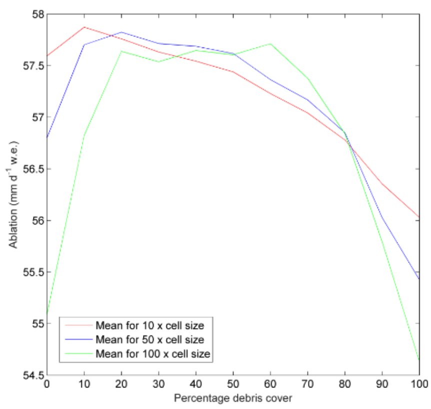

Figure 2 Relationship between mean ablation and percentage debris cover rounded to the nearest 10%.

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[1] Ground sample distance (also known as cell/pixel size or spatial resolution)