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Quantifying contemporary debris supply in a debris-covered glacier catchment using high-resolution repeat terrestrial LiDAR

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Glacial debris cover is increasing at a global scale in response to increasing temperatures and negative glacier mass balance. The last decade or so has seen an abundance of research which focuses on debris-covered glacier dynamics and supraglacial processes, such as ice-cliff back wasting and the development of supraglacial ponds. However, far fewer studies have focussed on improving understanding of debris supply to these systems over short- (months-years) or long (centennial-millennial) timescales. Existing work has attempted to quantify headwall erosion by calculating the ratio of supraglacial debris flux (the product of debris thickness and supraglacial velocity) to the headwall catchment area. Whilst these studies provide estimates of headwall erosion rates over long timescales, they are unable to capture subtle (or extreme) spatial and temporal variations in debris supply that operate over shorter timescales. Capturing this variation is important because it will allow predictions of the spatial distribution and volume of debris layers on debris-covered glaciers, which in turn will increase the accuracy of ablation modelling and future melt predictions for these systems. To quantify such variability, we conducted terrestrial LiDAR surveys of potential debris slopes at Miage Glacier, Italy, between July – September 2019. We acquired > 1.8 billion 3D points per catchment survey covering an approximate slope area of 7.7 km^2, which supplies debris to ~33% of the glacierised area. Sequential 3D point clouds were co-registered using iterative closest point adjustment. Vegetated surfaces were automatically detected using the CloudCompare plugin CANUPO and removed from further analysis. The M3C2 change detection algorithm was used to calculate 3D change normal to the surface plane, and a 95th percentile confidence interval was applied to eliminate non-significant change. Connected components analysis was used to identify discrete rockfall events, estimate their dimensions, explore their magnitude-frequency and quantify their spatial distribution. We find at least one large failure which developed over a period of two weeks (validated by in situ time-lapse footage) and comprised an estimated volume of around 1 x 10^6 m^3. This particular failure occurred from a recently (<10 years) deglaciated slope, lending support to the theory that large-scale slope response to glacial erosion can be rapid.