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

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1 Motivation

Quantification of the debris supply to glaciers, and the variation in both the spatial and temporal patterns is important for developing accurate predictions of the spatial distribution and volume of debris layers – in turn, increasing the accuracy of ablation modelling and future melt predictions for these systems.

2 Where does the debris come from?

There are several potential sources of debris within a glacial catchment. Figure 1 shows a summary of these sources.

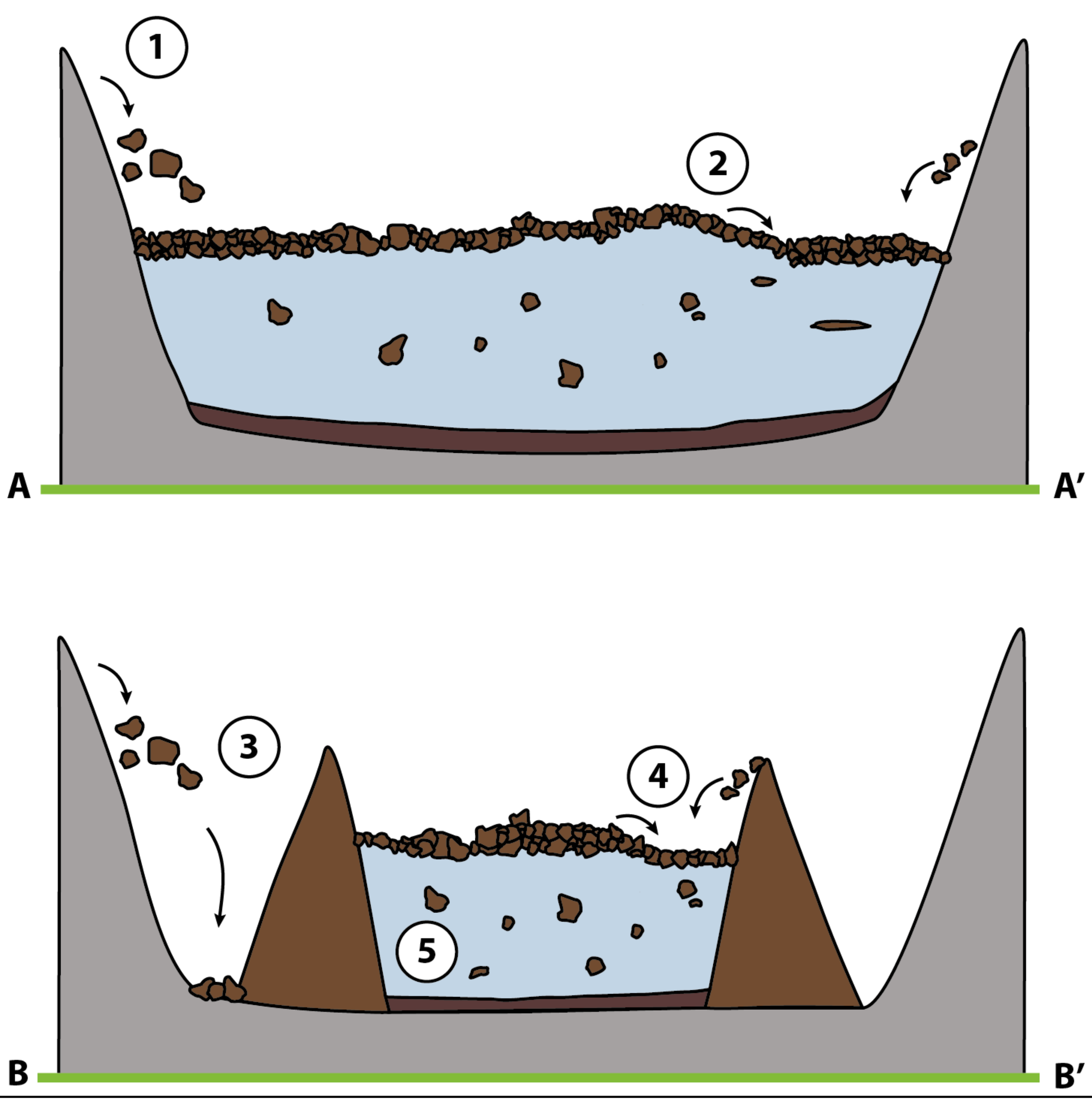

Figure 1: 1) Debris contributed to the glacier surface from headwalls and valley flanks due to weathering, erosion and rockfall events. 2) Redistribution of debris on the surface of the glacier. 3) Weathering, erosion or a rockfall event cause debris to fall on the outside of lateral moraines. 4) Redistribution of debris from lateral moraines due to gradual or mass movement. 5) Englacial debris melt-out also contributes debris to the surface of the glacier.

3 Study Site

Miage Glacier, Italy.

45° 47' N, 6° 51' E (Fig. 2)

Surveys of ablation zone valley flanks were undertaken in July 2019 and September 2019. These scans were then aligned using ICP adjustment and segmented both vertically and horizontally for processing purposes (Fig. 3)

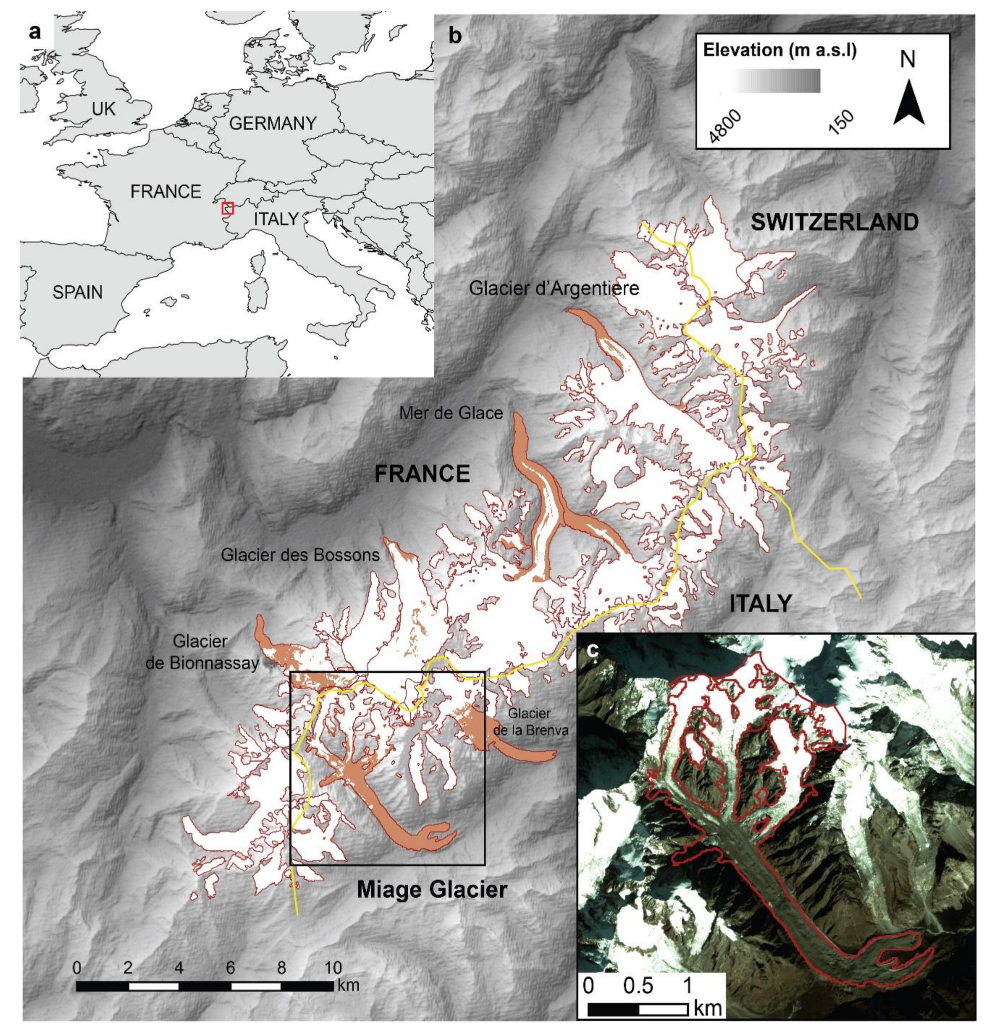

Figure 2: Miage Glacier is located on the Italian side of the Mont Blanc massif. 42% of the surface is covered in supraglacial debris (Fyffe et al. 2014), 75% of which is thought to originate from rockfalls (Deline et al. 2012).

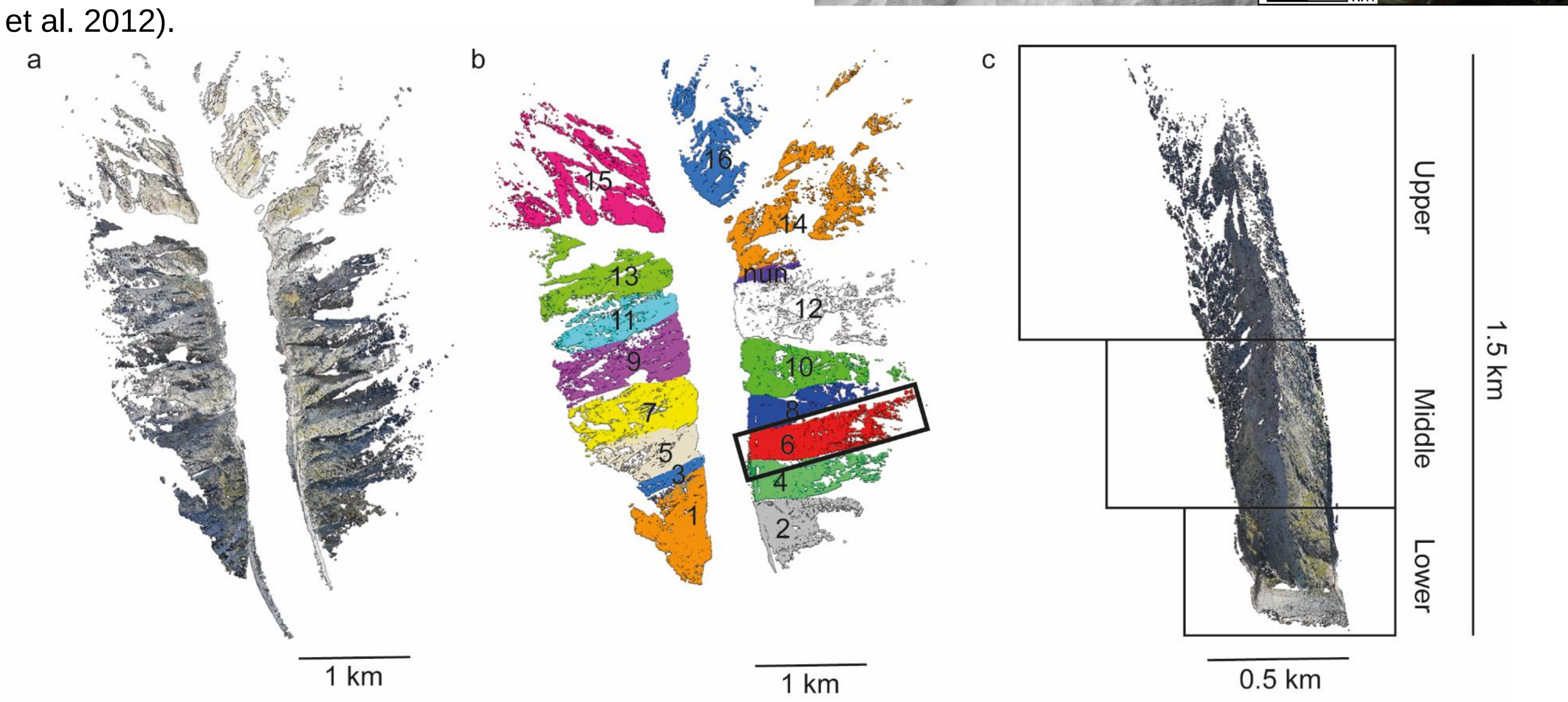

Figure 3: > 1 billion points per survey epoch meant that in order to be able to process the data effectively, the point clouds were segmented both horizontally and vertically.

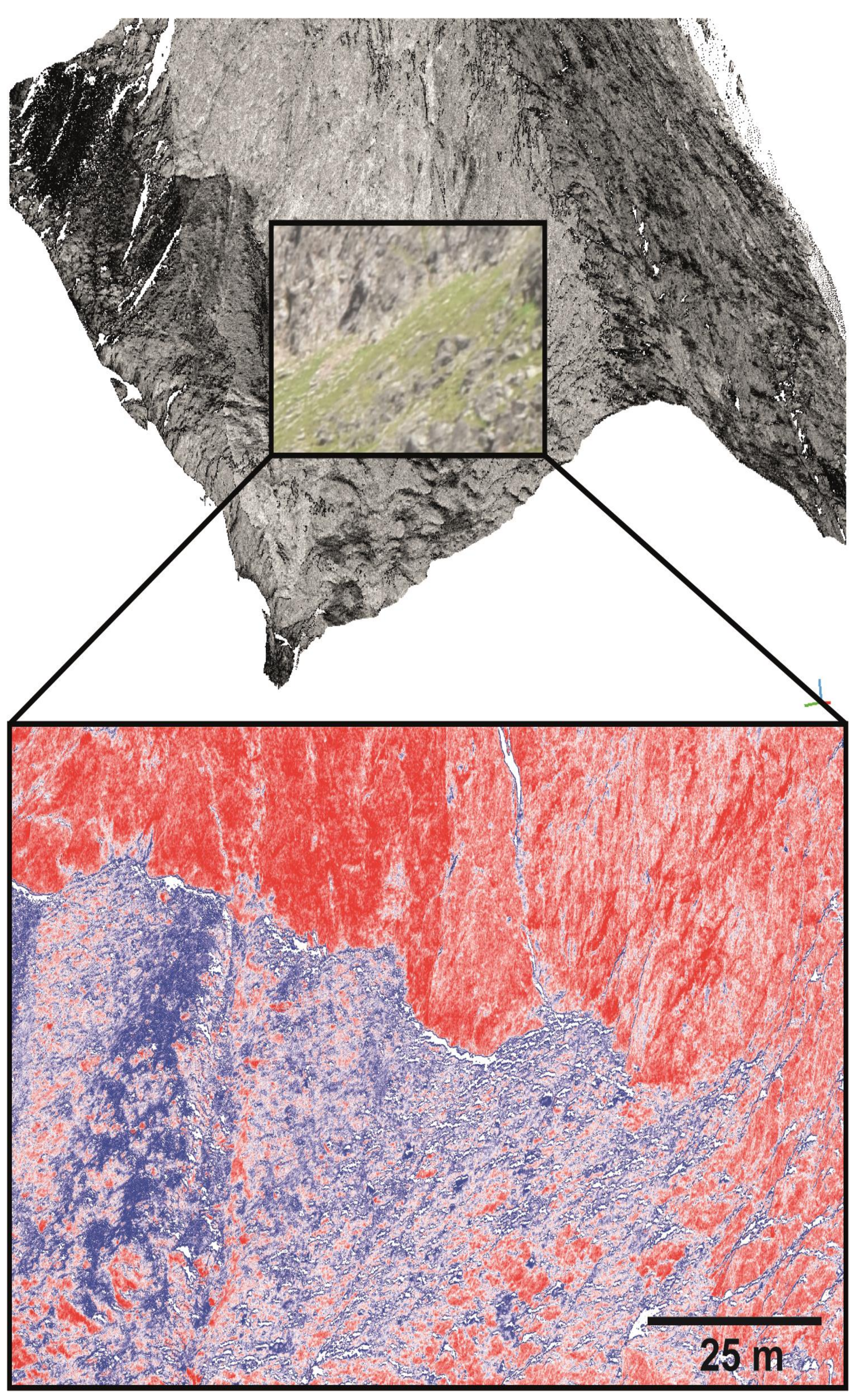

Figure 4: Identification of vegetated areas using intensity as a visual identifier alongside CANUPO, an automatic vegetation detector – non-rock wall points are then removed during the filtering process

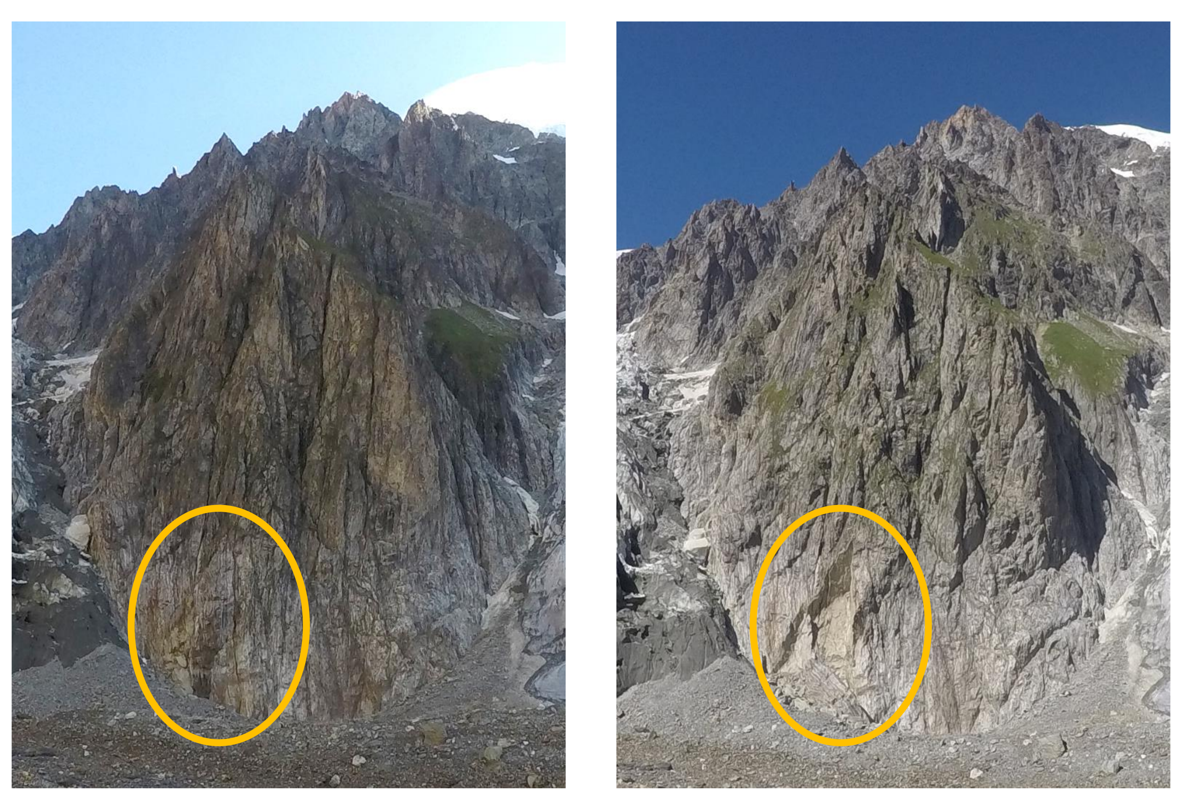

Figure 5: A three stage failure was observed by an in-situ time-lapse camera. This is detected as a large (~ 1 x 10^6 m^3) failure in the laser scan data which we are able to split into the component stages in processing (see Fig. 6 for stage one)

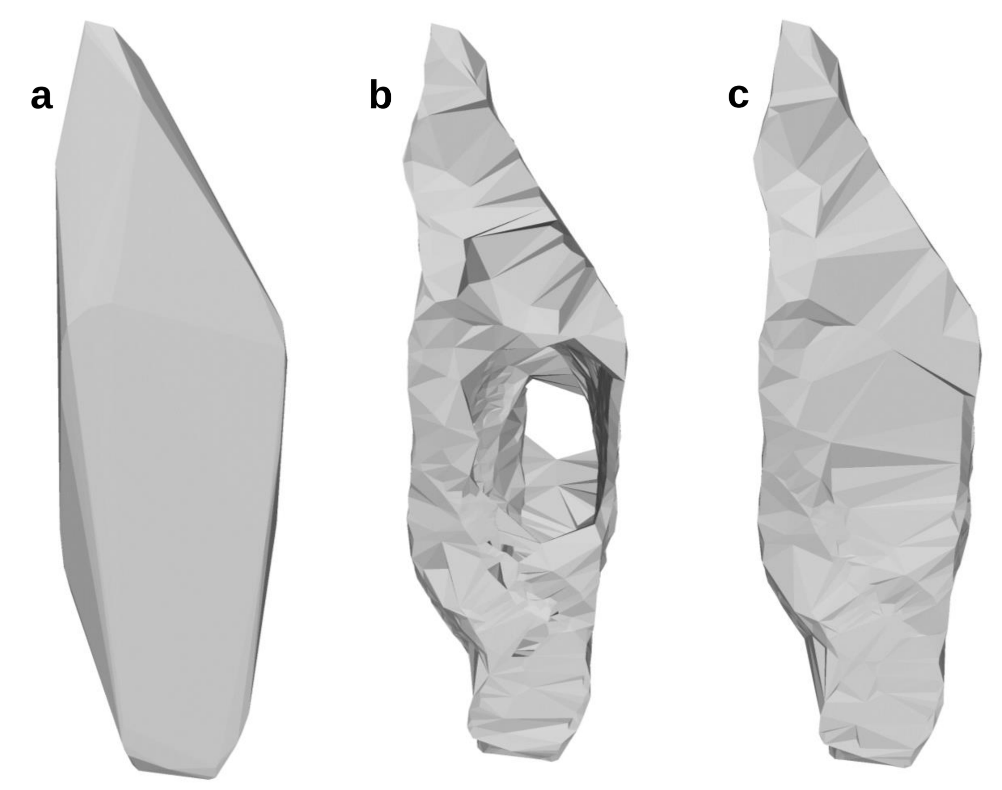

Figure 6: Comparison of meshes produced using three different methods of surface reconstruction, a) convex hull, b) alpha shapes default, and c) alpha shapes iterative

4 Methods and Preliminary Results

- CANUPO (Brodu and Lague, 2012) was used to classify point clouds into vegetation, rock walls and other (e.g. snow cover). This was validated manually using high resolution RGB imagery (Fig. 4).
- M3C2 (Lague et al. 2013) was used to identify areas of rockfall. These were classified as rockfall using the connected components tool in CloudCompare using a minimum of 12 points. At least one large scale failure has been observed within the catchment (Fig. 5).
- These rockfalls were then converted to a 3D mesh using MATLAB and a comparison of the volume reconstruction methods (convex hull, and alpha shapes) was conducted (Fig. 6), this produced results in line with Bonneau et al 2019.

5 Conclusions and next steps:

- An iterative alpha shapes approach is best for deriving rockfall volumes over the catchment scale
- Despite only a 3 month period between scans, there is evidence that multi-stage rockfalls are detected as single large rockfalls within the catchment
- A rockfall inventory will be compiled for the catchment allowing quantification of short-term contemporary debris supply to Miage Glacier and areas of likely future rockfall will be determined
- Areas of rockfall accumulation on the glacier surface and debris transport pathways will be identified

R. L. Stewart is funded by a Northumbria University studentship. Fieldwork in September 2019 was funded by an IAS Postgraduate Fieldwork Grant.

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Bonneau, D., DiFrancesco, P.M. and Hutchinson, D.J., 2019. *ISPRS International Journal of Geo-Information*, *8*(12), p.548.
Brodu, N. and Lague, D., 2012. *ISPRS Journal of Photogrammetry and Remote Sensing*, *68*, pp.121-134.
Deline, P., Gardent, M., Magnin, F. and Ravanel, L., 2012. *Geografiska Annaler: Series A, Physical Geography*, *94*(2), pp.265-283.
Fyffe, C.L., Reid, T.D., Brock, B.W., Kirkbride, M.P., Diolaiuti, G., Smiraglia, C. and Diotri, F., 2014. *Journal of Glaciology*, *60*(221), pp.587-602.
Lague, D., Brodu, N. and Leroux, J., 2013. *ISPRS journal of photogrammetry and remote sensing*, *82*, pp.10-26.