permanet **Permafrost long-term monitoring network**

WP6 Permafrost and Natural Hazards

Action 6.1 – Comparison of methods

Terrestrial Laser Scanning / Terrestrial Photogrammetry

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Introduction

While the hypothesis of a relationship between rockfalls and permafrost degradation gains force nowadays, frequency, volume and geo-mechanical conditions of rockfalls in steep high alpine rockwalls are still poorly known because of a lack of systematic observations.
The two main applied methodologies for geomorphological monitoring of rockwalls are Terrestrial Laser Scanning (TLS) and photogrammetry. Both consist in acquiring high-resolution 3D models and comparing these diachronic models, in order to identify and to measure rock volumes that detached between two surveys.
This sheet aims at comparing these two methods in terms of advantages and limits, and at identifying the most appropriate one for geomorphological monitoring of rockwall taking into account cost, logistics, data processing and expected results.
Both methods have been used to monitor one study site, the NW face of the Aiguilles Marbrées (3535 m a.s.l.), in the Mont Blanc massif[3]. After comparing the two methods, this sheet focuses on the comparison between the obtained 3D models, and the collapsed rock volumes that could be measured. For details about the two methods, please refer to the TSL and photogrammetry Method Sheets.

Method comparison

		TLS	**T Photogrammetry**
	Category / Background	Remote sensing / LiDAR	Remote sensing / photo-GPS technique
Data acquisition	Device / Equipments	- Terrestrial laser scanner (here *Optech* Ilris 3D) - geodetic tripod - rotator (horizontal and vertical planes) - battery or generator - field computer or Palm	- Camera (here *Nikon* D700) - optic: Nikor 20mm wide-angle lens - GPS (here *Leica* GX1220) - pole
	Cost D/E	Around 100 000 € (without annual maintenance) ÚÚÚ	Around 15 000 € (including 12 000 € for GPS) ÊÊÚ
	Weight D/E	52 kg ÚÚÚ	3 kg (GPS+camera) ÊÊÊ
	Method for data acquisition	(i) Device positioning, (ii) image capture of the potential area of acquisition, (iii) determination of shooting windows on this image and the point spacing, (iv) automatic acquisition. The operation is renewed as many times as necessary depending on the dimensions of the rockwall and its remoteness. ÚÊÊ	Camera is coupled through a calibrated pole to a GPS to determine the orientation parameters of the image block. For each survey of the Aiguilles Marbrées a sequence of about 10 images is taken; distance between camera positions about 15-20 m; distance from the rock face about 60 m. ÊÊÚ

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[3] Part of the work (photogrammetric method) has been done in the framework of the project *RiskNat* (Interreg Alcotra France-Italy 2007-2013)

Data acquisition	Operator training required for acquisition	1-2 hours ÊÊÊ	1-2 hours (basis of photogrammetry) ÊÊÊ
	Acquisition time/rates	2000 pts per second. A few tens of minutes to several hours depending on the dimensions of the rockwall and the desired resolution. ÚÊÊ	1-2 hours for the first survey; 0.5 hour for next surveys (without GPS measurements). ÊÊÊ
	Resolution	Few centimeters ÊÊÊ	Few centimeters in the best conditions ÊÊÚ
	Precision	Centimeter ÊÊÊ	Few centimeters ÊÊÚ
	Range	Up to 600 m ÊÊÊ	Up to 500 m ÊÊÚ
	Type of obtained data	The scanner generates .i3d files containing the coordinates of points, their reflectivity, RGB photo of the view window and notes. These files must be processed by a Parser to be recognized by the processing software.	Images .jpg and GPS antenna position at each shot. At the end of the processing both camera centre coordinates and camera pose are estimated in a world coordinate reference system.
Data processing	Processing softwares	Polyworks (*InnovMetric*, Canada)	Different softwares are successively used: (i) Image orientation: EyeDea + PhotoGPS Module (University of Parma, Italy) (ii) DSM (Digital Surface Model) elaboration: DenseMatcher (*Geodigital Solutions*, Italy) (iii) DSM analysis: VRmesh (*VirtualGrid*, USA)
	Cost of PS	Around 20 000 € (without annual maintenance) ÚÚÚ	6000 € ÊÊÚ
	Method for data processing	(i) Alignment of the different point clouds to create the 3D models of a rockwall. (ii) Alignment of two diachronic 3D models of the rockwall. (iii) Comparison of the two diachronic models (map of differences). (iv) Identification of rockfalls occurred between the two dates. (v) Quantification of the collapsed volumes. ÚÊÊ	(i) Image orientation + DSM elaboration: homologous image point coordinates are measured in every image. Bundle block adjustment provides image orientation. Object point coordinates are determined by tri-angulation or multiple intersections. Softwares based on Dense Matching algorithms provide a high resolution 3D models or the rockwall. (ii) Comparison of the two diachronic DSM (map of differences). (iii) Identification of rockfalls occurred between the two dates. (iv) Quantification of the collapsed volumes. ÊÚÚ
	Operator training required for data processing	Given the complexity of the software and the number of steps required to process the data, training can be quite long (several days). ÚÚÊ	Given the number of software used, training can be quite long (several days). ÊÚÚ
	Processing time	About one day is required to process two sets of diachronic measurements. ÚÊÊ	About five days are required to process two sets of diachronic measurements. ÚÚÚ
	Main results	- high resolution 3D models - comparison maps of diachronic 3D models - collapsed rock volumes	

Value: ÚÚÚ: bad; ÊÚÚ: poor; ÊÊÚ: satisfying; ÊÊÊ: excellent.

Comparison of the obtained 3D models

Seven photogrammetric measurement campaigns were carried out at the Aiguilles Marbrées between August 2009 and September 2010, and two TLS campaigns in September 2009 and February 2011 (Fig. 1). Only two comparisons have been thus done between the TLS and photogrammetric models from September 2009 first (Fig. 2), and the TLS and photogrammetric models of February 2011 and September 2010 respectively secondly (Fig. 3).

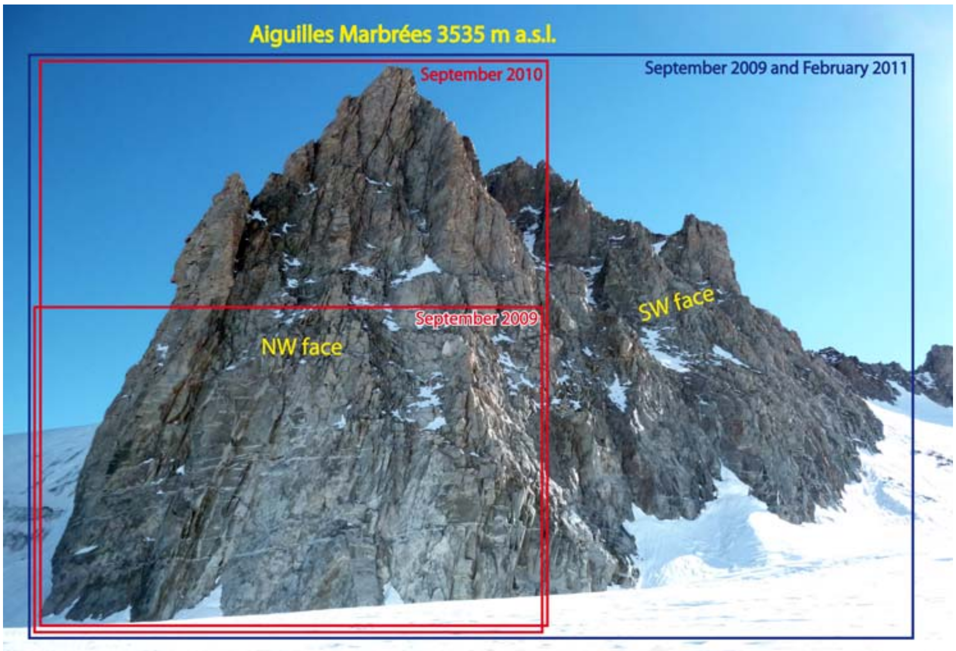

Figure 1 - The measurement campaigns carried out at the Aiguilles Marbrées that allow comparisons of the 3D models obtained by the two methods (TLS in blue, photogrammetry in red).

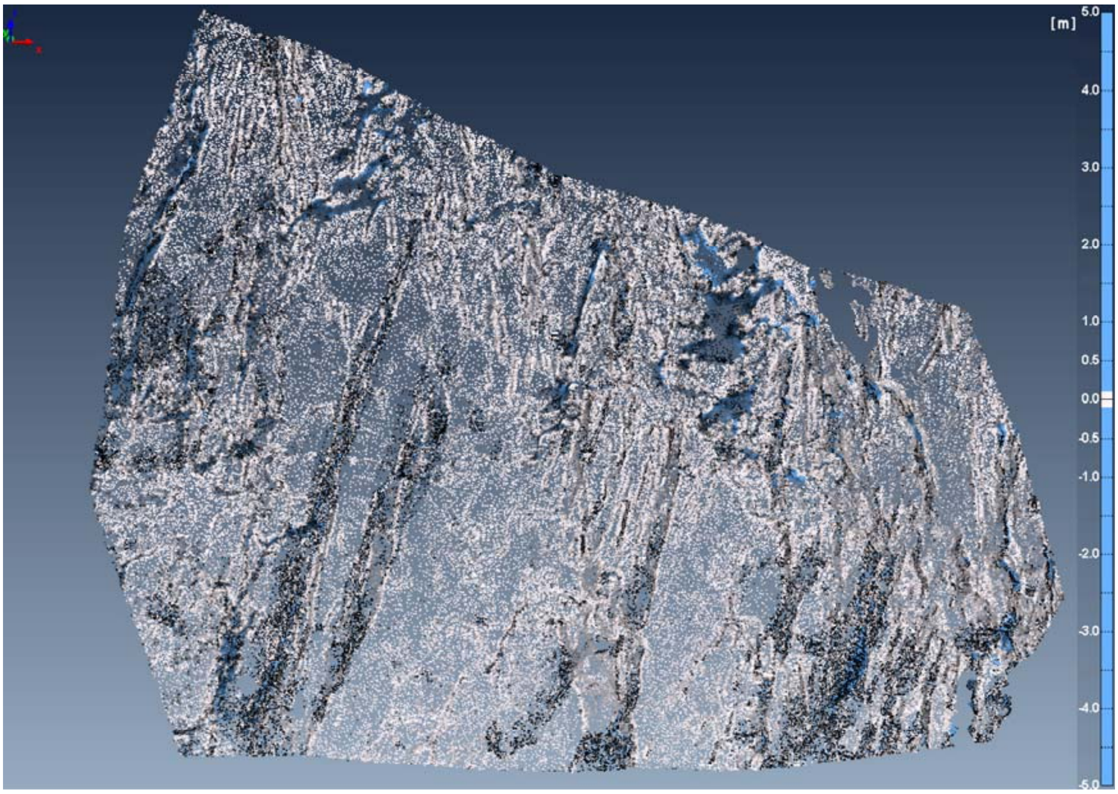

Figure 2 - Comparison (via Polyworks*) between the two 3D models of the Aiguilles Marbrées obtained in September 2009 by TLS and photogrammetry. No noticeable difference except those related to snow, or to a difference in position of the acquisition device (i.e. errors can appear when a sector is scanned or photographed during a measurement campaign and not during the next one).*

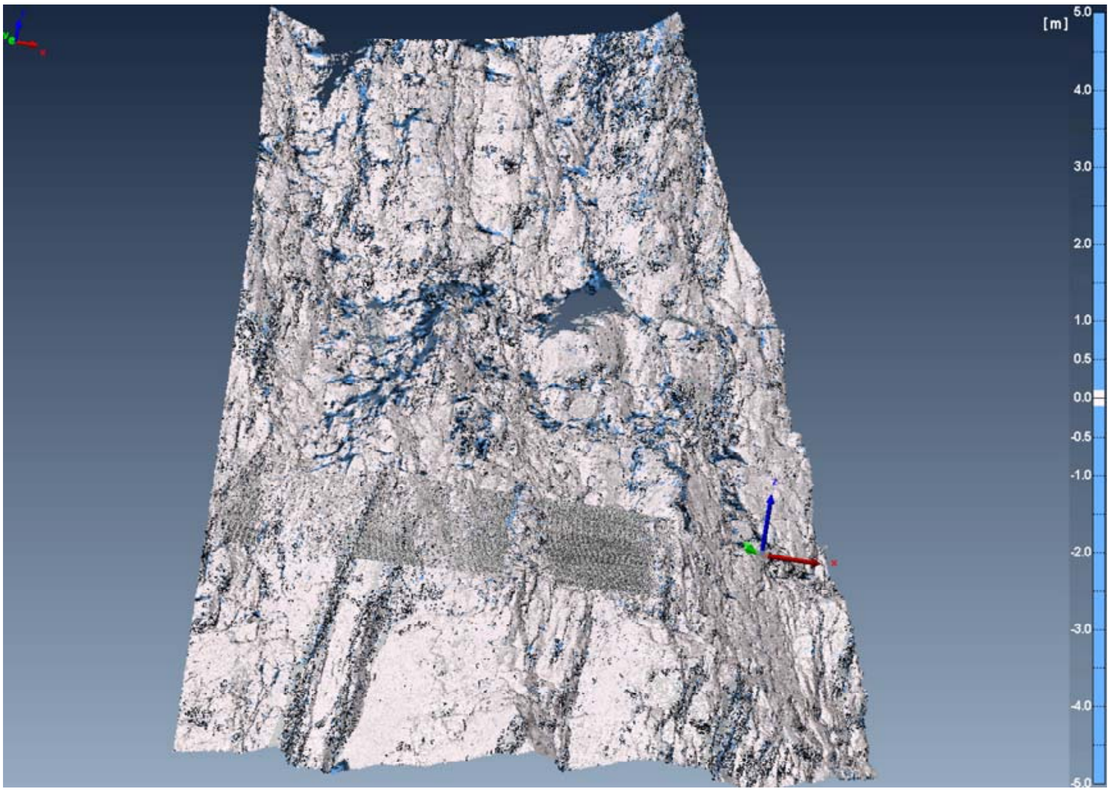

Figure 3 - Comparison (via Polyworks*) between the 3D model of February 2011 of the Aiguilles Marbrées obtained by TLS with the 3D model of September 2010 obtained by photogrammetry. No noticeable difference except those related to snow or to a difference in position of the acquisition device.*

Comparisons of the 3D models acquired by photogrammetry and TLS show their great similarity, both in resolution and accuracy.

Comparison of the results

Since only two measurement campaigns were conducted with the TLS method at the Aiguilles Marbrées, only one diachronic comparison of 3D models is possible (Fig. 4). Results of this comparison have been compared to those from the photogrammetric method (Fig. 5).

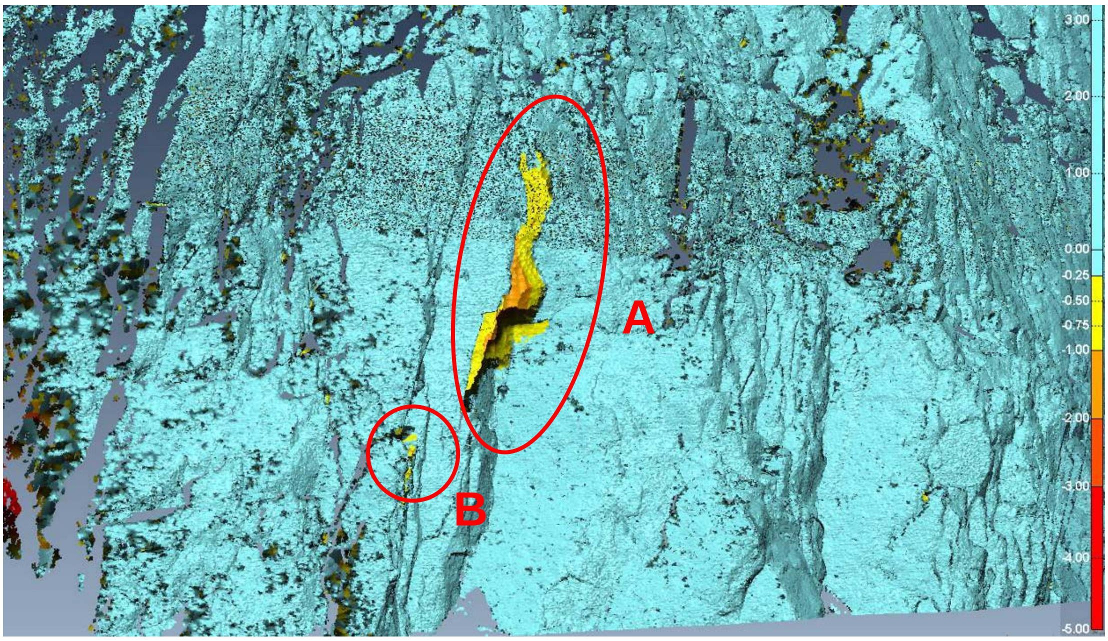

Figure 4 – Detail of the map of the differences (via Polyworks*, scale in m) obtained by comparing TLS 3D models of September 2009 and February 2011. Detachment A volume: 60.5 m^3; detachment B volume: 5.5 m^3.*

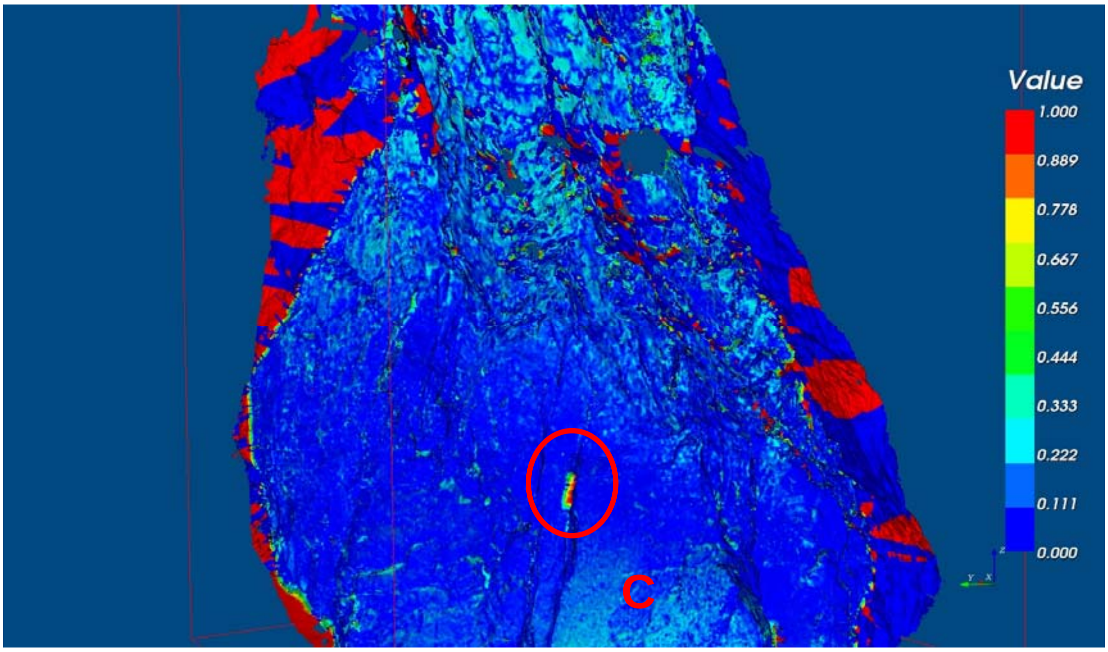

Figure 5 - Map of the differences (via VRmesh*, scale in m) obtained by comparing 3D models of July and September 2010 (photogrammetric method). Detachment C volume: about 6-7 m^3.*

Because measurement campaigns with the two methods have been carried out on different dates, it is difficult to compare results. The photogrammetric method is developed since 2008 at the Aiguilles Marbrées. Some minor detachments were identified in 2008, while no detachments where detected in 2009. One detachment of about 60 m^3 was then observed between June and July for 2010. This seems to correspond to the upper part of the detachment revealed by TLS (Fig. 4). The detachment C (Fig. 5), with a volume estimated between 6 and 7 m^3, would correspond to the lower part of this detachment A. The total collapsed volume would thus be ~ 66 m^3 according to the photogrammetric method, versus 60.5 m^3 according to the TLS one. The 10% difference is likely related to the photogrammetric method because of its precision, which seems to be slightly lower. This is reflected by the appearance of models: micro-topography seems softened with the photogrammetric method compared with the TLS method. Detachment B occurred between September 2009 and February 2011 according to the TLS method; as it occurred neither between September 2010 and February 2011 according to the comparison TLS / photogrammetry nor between July 2010 and September 2010 according to the photogrammetric method, B probably detached between September 2009 and July 2010.

Conclusions

Monitoring high mountain near vertical rockwalls can be accurately done by using ground-based methods of survey. Because of their high resolution and accuracy, TLS and photogrammetric methods begin to be commonly used to identify and quantify rockfall volumes – even small (less than 1 m^3).

At a distance of several tens of meters, the resolution of both methods is comparable. Over this range, the TLS method is more efficient. It is also more accurate. Thus, the photogrammetric method has to be reserved to small size rockwalls when very high resolution and accuracy are needed.

On the field, the operator's task is relatively simple for both methods. The TLS method is however limited by the heavy weight of the equipment, while photogrammetry is a lightweight method.

Another strong limit of the TLS method is the prohibitive cost of scanners and their maintenance, while the photogrammetric method is much more accessible.

Finally, both methods require an important training for data processing; TLS data processing is much faster than the photogrammetric one.