PermaNET • Permafrost long-term monitoring network

Temperature and rockfalls monitoring activities at Aiguilles Marbrées North face (Mont Blanc Massif, France)

M.Curtaz (1), M. Vagliasindi (1), U. Morra di Cella (2), P. Pogliotti (2), R. Roncella (3), A.M. Ferrero (3)

(1) Fondazione Montagna sicura, Courmayeur, Italy
(2) Agenzia Regionale per la Protezione dell'Ambiente della Valle d'Aosta, Saint-Christophe, Italy
(3) Università degli Studi di Parma - GeoDigital Solutions, Parma, Italy
contact: mcurtaz@fondms.org

Abstract: The monitoring and studying activities on a rock face where a small rockfall happened in Summer 2007 are presented. Since the rockfall bared massive ice in the detachment zone and such ice evidences can be related to ongoing processes of permafrost degradation following climate change (Gruber & Haeberli 2007), Fondazione Montagna sicura and ARPA Valle d'Aosta have started a project on this case study, in collaboration with GeoDigital Solutions (a University of Parma spin-off). The site was chosen to test innovative survey techniques coupling monitoring of rockfall activity and surface rock temperatures. The aim is to analyze possible relations between rock face dynamics and temperatures and to test survey techniques which can be useful to support risk management. To obtain a more complete knowledge of this site other studies were done parallely to monitoring activities.

1. Introduction

On September 20th 2007 a small rockfall of about 1000 m³ occurred at Aiguilles Marbrées North face leaving massive ice visible in the exposed detachment zone. The Aiguilles Marbrées is a granitic peak of 3535 m of elevation in Mont Blanc massif.
The study area is located in the lower part of the North face (Fig 1), characterized by a mean steepness of about 70° and a mean aspect of abo ut 320N. The slope is shaped by the crossing of 3 main discontinuities families which lead to the disjunction of big portions of rock face.

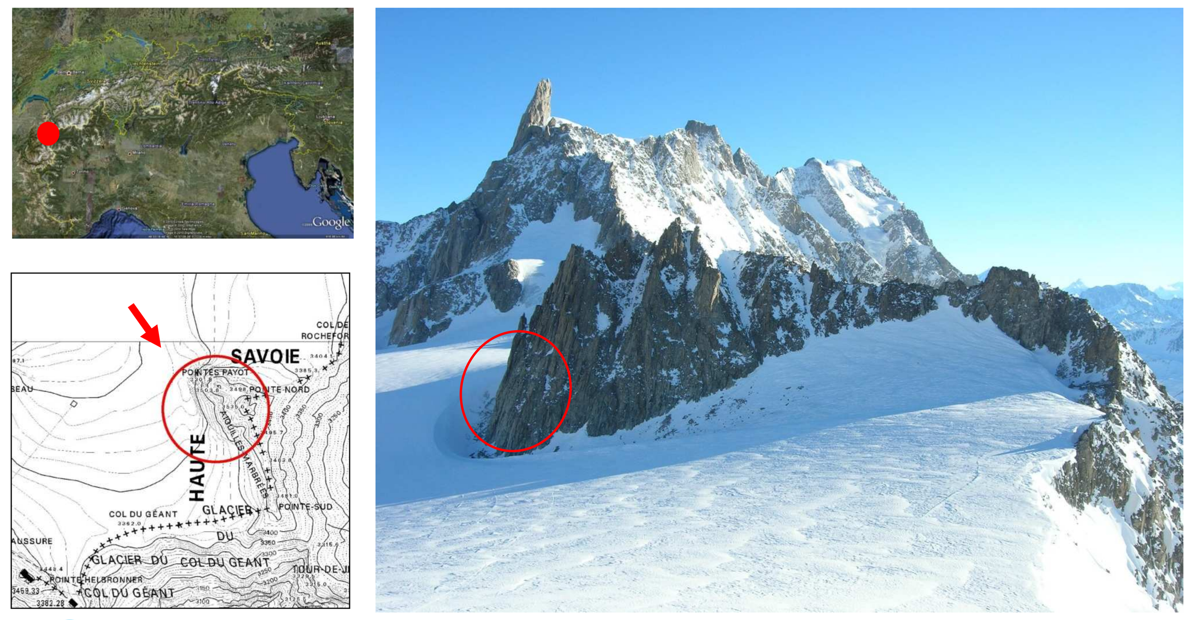


Fig 1. The Aiguilles Marbrées is in Mont Blanc massif, on the borderline between France and Italy. The red circle in the picture indicates the study area, in the lower part of the North face; in the background the Dent du Géant.

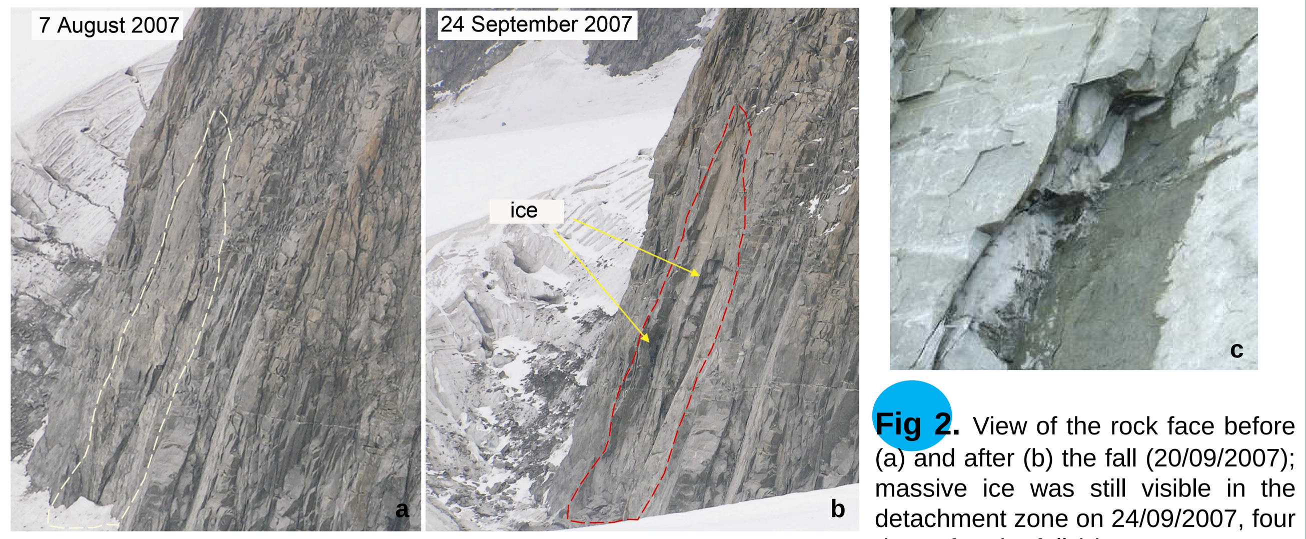
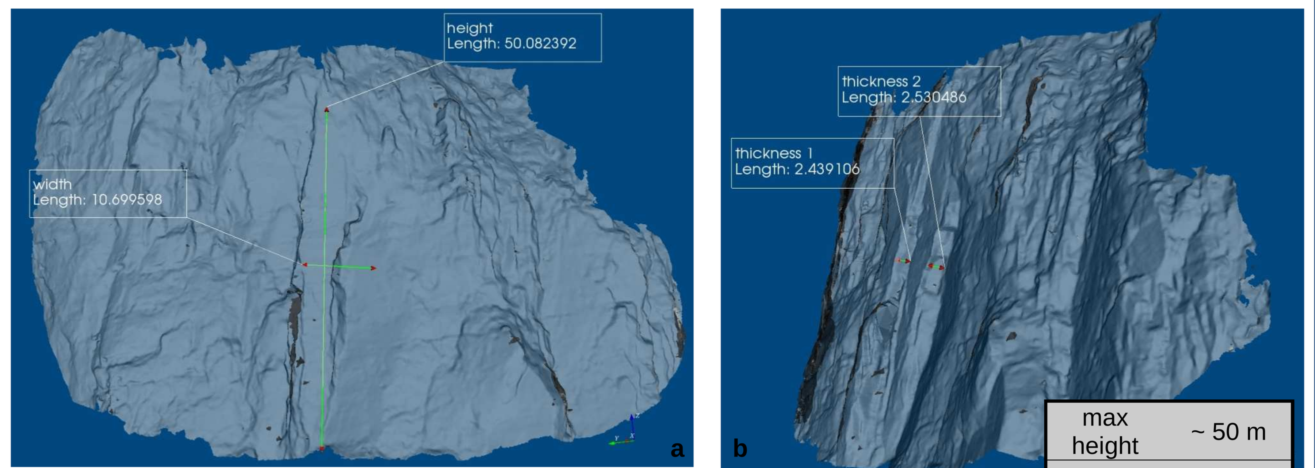


Fig 2. View of the rock face before (a) and after (b) the fall (20/09/2007); massive ice was still visible in the detachment zone on 24/09/2007, four days after the fall (c).



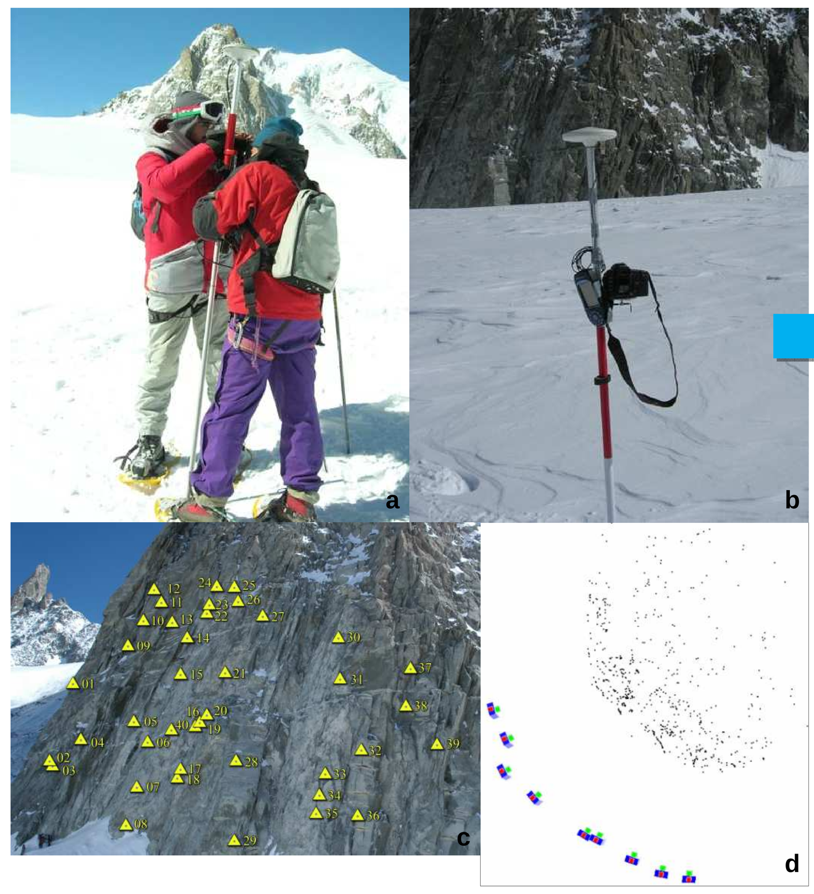
max height	~ 50 m
max width	~ 10 m
max thickness	~ 5 m

Fig 3, tab 1. Rockfall size derived using the DSM and VRmesh software: frontal (a) and lateral (b) view.

2. Photogrammetric surveys of rockfall activity

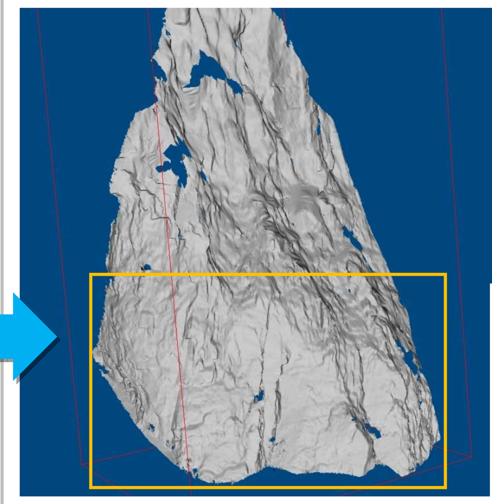
Periodical photogrammetric surveys have been done during Summer 2008 and 2009 using a Nikon D700 digital camera with calibrated 20 mm lens. Georeferencing was made coupling the first survey to *stop and go* GPS measures of the camera positions (so-called *photo-GPS* technique). Control points were derived from the first block adjustment for use in next surveys. The images sequence is automatically processed with softwares using Structure and Motion and Dense Matching algorithms to obtain a high resolution Digital Surface Model (DSM) of the rockwall. The diachronic comparison of DSM models is performed by the *VRmesh* software in order to detect geometry and volumes of eventual rockfalls.

STEP 1: PHOTOGRAMMETRIC SURVEYS



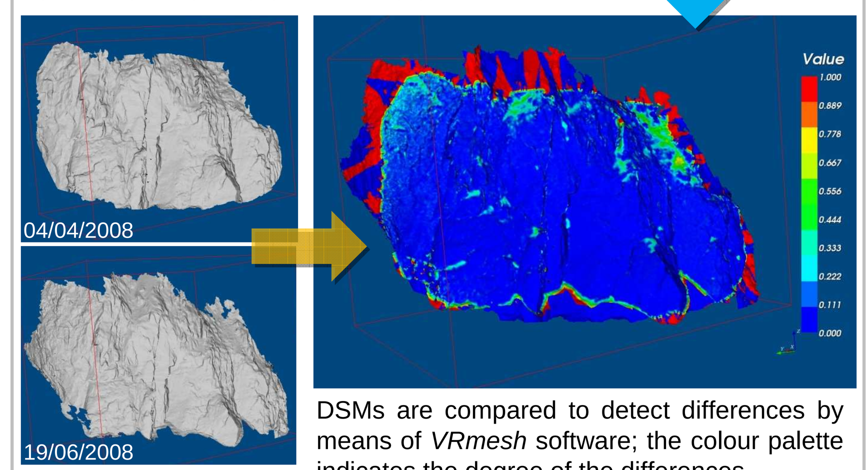
Carrying out the first photogrammetric survey with photo-GPS technique: the camera positions are measured by means of simultaneous *stop and go* GPS survey (**a, b**). Subsequent surveys were done without GPS and the adjustment was done using control points derived from the first survey (**c**). The geometry of the shots is an arc of circle parallel to the rock surface (**d**).

STEP 2: DSM ELABORATION



The images sequence is automatically processed with softwares using *Structure and Motion* and *Dense Matching* algorithms to obtain a high resolution Digital Surface Model (DSM) of the rockwall.

STEP 3: DSM COMPARISON



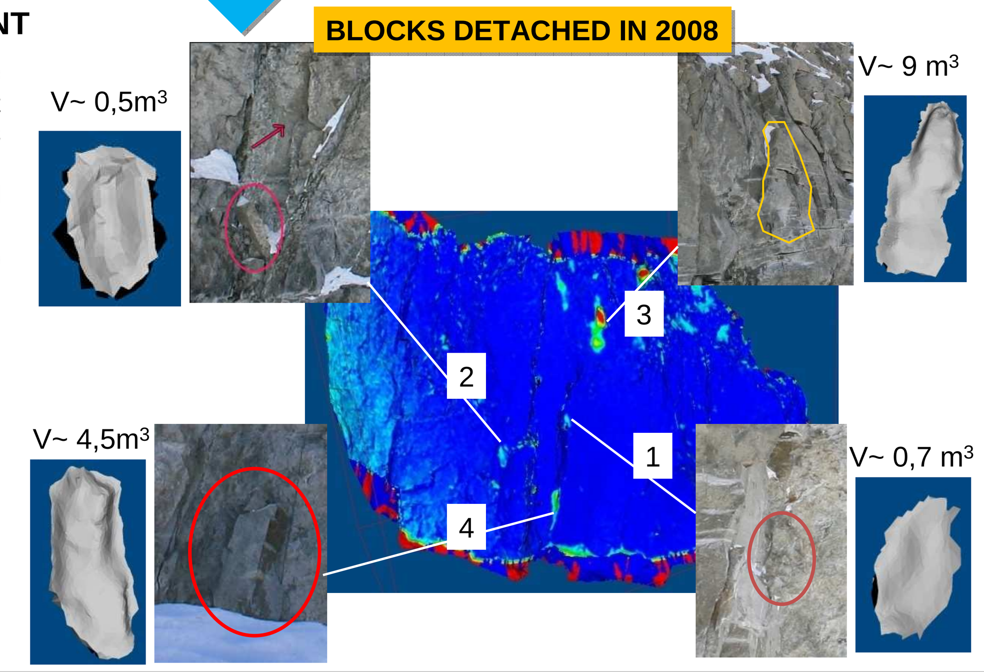
DSMs are compared to detect differences by means of *VRmesh* software; the colour palette indicates the degree of the differences.

STEP 4: ROCK BLOCKS VOLUME ASSESSMENT

DSMs differences and relatives pictures are analyzed to discriminate real falls from other changes resulting in different coloured areas from *VRMesh* (e.g. different snow cover, holes in one DSM).
Detached blocks are isolated and their volume is calculated using *VRmesh* tools.
In 2008 four small falls have been recognized (two between April and June, n°1-2; two between June and August, n°3-4) while in **2009 no fall** has been detected.

2008	2009
4 April	16 March
19 June	17 June
9 August	11 August
28 August	9 September
15 October	20 October

Dates of the photogrammetric surveys.



3. Temperature monitoring

Sensors for both rock and air temperature measurements are installed in the upper part of the 2007 detachment zone (**Fig 4**). The surface rock temperature is monitored since September 2008 at three different depths (3, 30 and 55 cm) by a PT1000 based mini-logger with a frequency of 10 minutes. To reduce data loss due to damages or malfunctions in June 2009 a new system equipped with GPRS modem was settled down (**Fig 5**). Air temperatures and humidity are measured near the rock temperature sensors and inside a radiation shield in order to avoid the influence of direct solar radiation.
Rock temperature at all depths and air temperature time series are reported in **Fig 7** and **8**. The scatter plot of **Fig 9** shows that air temperature is almost always below the surface rock temperature (3 cm depth) due to the influence of solar radiation.

Fig 4. Sensors position.

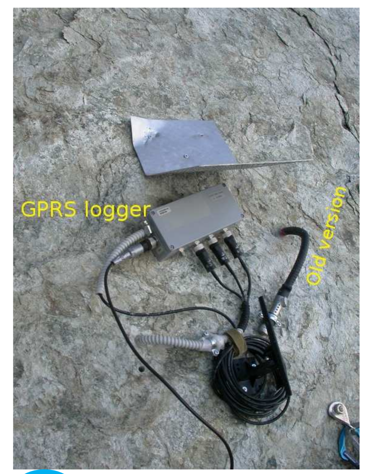


Fig 5. New system equipped with GPRS modem.

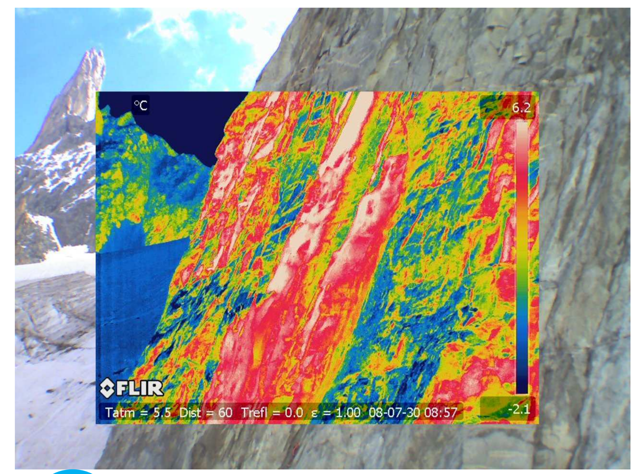


Fig 6. Example of rock face thermographic image.

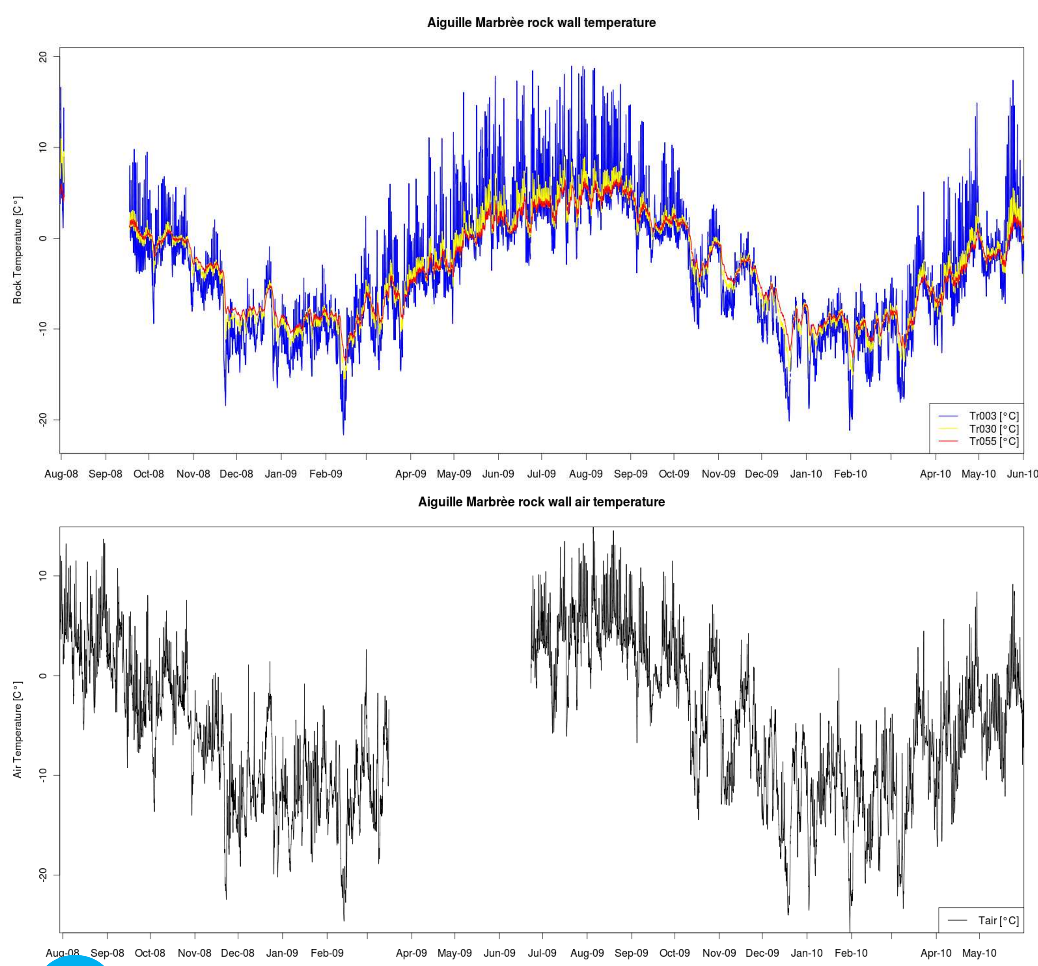


Fig 7, 8. Rock temperature at all depths and air temperature time series.

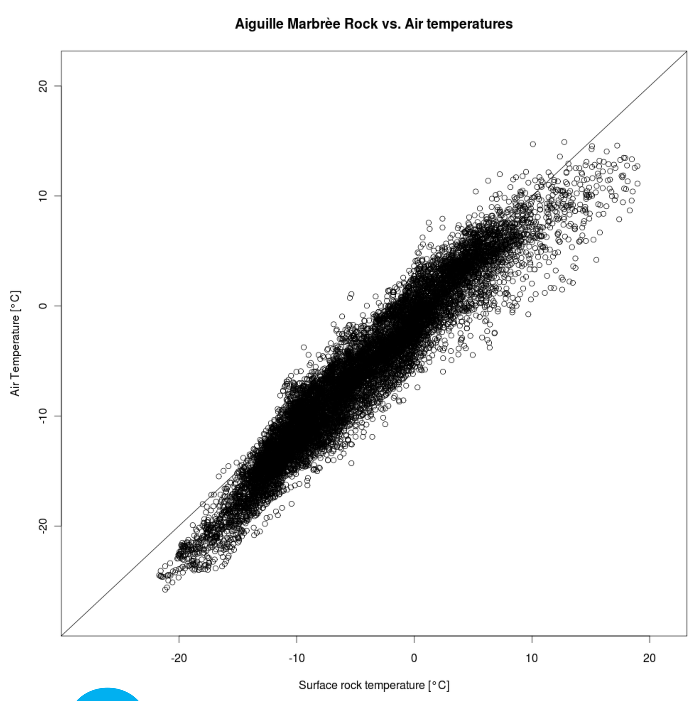


Fig 9. Scatter plot of air temperature vs surface rock face temperature.

The statistics (**Tab 2**) computed over the hydrological year 2008/2009 on all the sensors confirm the probable condition of permafrost on the rockwall (mean annual rock temperatures below -2 ℃); MAAT is around -4.6 ℃. February is the coldest month while August is the hottest. Freeze-thaw cycles (Zero crossing days) are strongly limited to rock surface while the number of frozen days (days with maximum daily temperature below zero) are quite similar at all depths.
In order to have an idea about the spatial distribution of surface rock temperature some thermographic images have been captured before the logger installation (**Fig 6**).

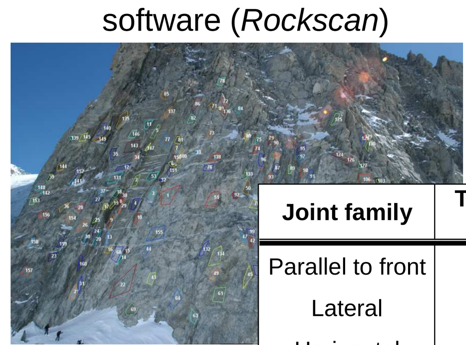
Hydrological Year 2008/2009					
		Air Temp.	Rock Temp. 3cm	Rock Temp. 30cm	Rock Temp. 55cm
MEAN	°C	-4.64	-2.4	-2.12	-2.18
MAX absolute	°C	14.91	18.97	9.01	6.7
MIN absolute	°C	-24.63	-21.68	-15.52	-13.54
MAXabs_day	Date	05/08/2009	21/07/2009	16/07/2009	25/08/2009
MINabs_day	Date	13/02/2009	13/02/2009	14/02/2009	14/02/2009
Daily range avg	°C	6	7.28	1.77	0.7
Daily range max	°C	12.04	21.09	5.13	2.68
Daily range min	°C	0.7	0.97	0.33	0.07
Pos Deg. Days	°C	376.43	-	-	-
Zero Crossing Days	days	53	112	32	11
MAX daily mean	°C	8.87	9.12	7.2	6.3
MIN daily mean	°C	-22.64	-19.69	-14.95	-13.32
MAXdaily_day	Date	06/08/2009	29/07/2009	30/07/2009	25/08/2009
MINdaily_day	Date	13/02/2009	13/02/2009	13/02/2009	14/02/2009
Days Below Zero	days	174	213	209	214
Mean 0°C Isoth. Elev.	m a.s.l.	2321.12	2771.35	2827.02	2813.56
Missing data	%	27.11	0.02	0.02	0.02

Tab 2. Statistics over the hydrological year 2008/2009.

4. Other studies

To obtain a more complete knowledge of this site other studies were conducted such as:

structural analysis by traditional method and by computer using DSM and a specific software (*Rockscan*)



Joint family	Traditional method	Rockscan	Differences
Parallel to front	82/284	75/296	(+) 7 / (-)12
Lateral	75/000	80/029	(-) 5 / (-)29
Horizontal	05/166	15/084	(-) 10 / (+)82
Others	71/323	70/325 85/254	(+) 1 / (-)2

Fig 10. Picture with joints planes measured by Rockscan. Table with joint orientation data: traditional survey vs Rockscan analysis.

schematic back analysis of the 2007 rockfall to study the relative influence of rock bridges, ice and melt water on the stability of the rock volume

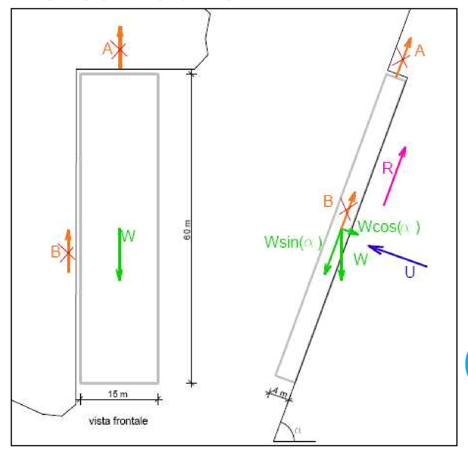


Fig 11. Diagram of forces used for the back analysis.

5. Conclusions

So far the data collected by the two monitoring activities can't be compared because the only instability events identified by the photogrammetric surveys occurred before the installation of temperature sensors.
Monitoring activities like these can give results only over a long term period: that's why Fondazione Montagna sicura and ARPA VdA have planned to continue their studies on this site for the following years during the *PermaNET* project.

References
Gruber S. & Haeberli, W. (2007). Permafrost in steep bedrock slopes and its temperature-related destabilization following climate change. *Journal of Geophysical Research*, vol 112.

This ongoing study is carried out within the project PermaNET funded by the Alpine Space program. For more information please visit **www.permanet-alpinespace.eu.**