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LINKS AMONG ROCK THERMAL PROPERTIES, CLIMATIC DATA AND GEOMORPHOLOGICAL PROCESSES IN A HIGH-ELEVATION INSTRUMENTED SITE (W-ALPS, ITALY)

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INTRODUCTION

The frequency of slope instabilities in high-mountain areas is increasing because of cryosphere degradation due to global warming.
Among slope instability processes, **small-size rockfalls** (< 10^3 m^3) received little attention although they play an important role in rock wall erosion and landscape evolution.
Unravelling the **relationships between climate elements** (in particular temperature) **and slope instability** is crucial to understand the impact of global warming on natural hazards, and assess future scenarios.

OBJECTIVES

The aim of the present research is to contribute to advance the knowledge on **slope instability initiation** (in particular small-size rockfalls < 10^3 m^3) in high mountain areas by an **integrated and holistic approach**, exploring a spectrum of different methodologies and merging various sources of information.

METHODS

Rock and air temperature measurements

- 7 MicroTemp Dataloggers (**MTs**) with known measurement uncertainty, placed in 2016 at 10 cm depth
- Automated Weather Station (**AWS**) of ARPA Piemonte installed since 1988

MT No.	Site	Topographic position	Geology	Elevation (m a.s.l.)	Aspect (class)	Slope (°)	Data series (DDMMYY)
1	A	Outcrop	CS	2667	W	75	200716-160718
2	A	Outcrop	CS	2666	NE	85	200716-160718
3	B	Boulder	P	2594	E	30	200716-150818
4	B	Boulder	P	2586	NE	80	200716-150818
5	B	Boulder	P	2586	SW	80	200716-150818
6	C	Outcrop	PCSI	2772	SE	80	170817-150818
7	C	Outcrop	PCSI	2790	S	80	170816-150818

Table 1. MTs' sites characteristics. P=prasinite;s CS=calcschists; PCSI=prasinites with calcschists intercalations

Rock physical properties assessment

Laboratory determination of colour, bulk density and specific heat capacity of the rocks of the study area.

Rockfall events identification

Different data sources have been analysed in order to identify rockfall events.
Precisely dated events have been investigated from a climate perspective by applying the statistical-based method described in Paranunzio et al. (2018).

Evaluation of the Bessanese Glacier changes

Areal and elevation changes of the glacier have been evaluated by orthophotos, temporally distanced DEMs and in-situ measurements by the CGI operator.

STUDY AREA

Location of the study area:	Western Italian Alps Graian Alps, Val d'Ala Bessanese glacial basin
Elevation range:	from 2586 to 3620 m a.s.l.
Geomorphological elements:	**Bessanese Glacier** Huge **left LIA lateral moraine** Crot del Ciaussinet **rock glacier** **Uja di Bessanese** 1000 m rock wall cut by several incisions
Geology:	three main lithologies: calcschists (CS), prasinites (P) and prasinites with calcschists intercalations (PCSI).

Fig. 1. Location of the study area.

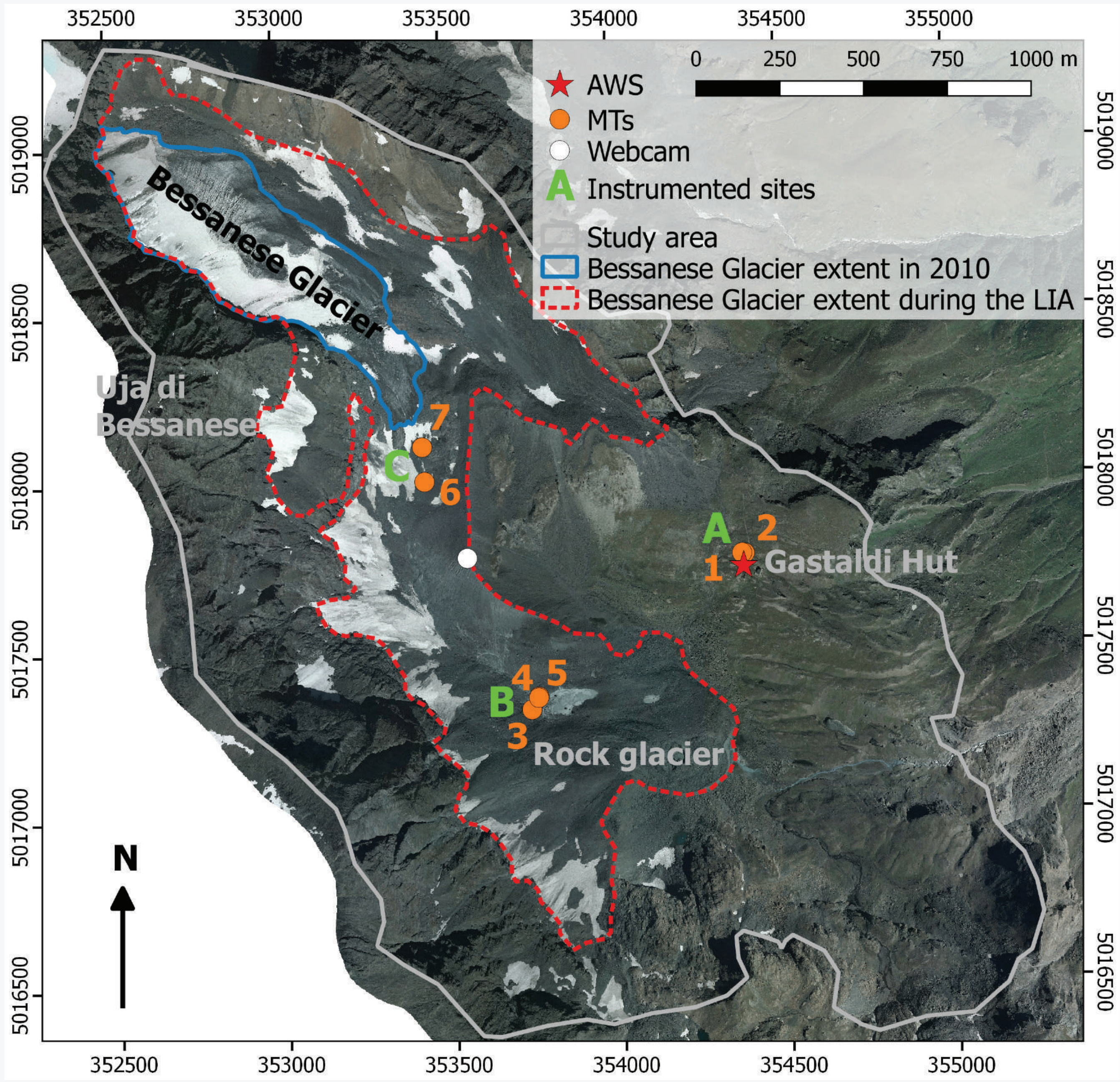


Fig. 2. Map of the study area.
Base map: Piemonte Region 2010 orthophoto; Reference system: WGS84 / UTM 32N.

RESULTS and DISCUSSION

Rockfall events

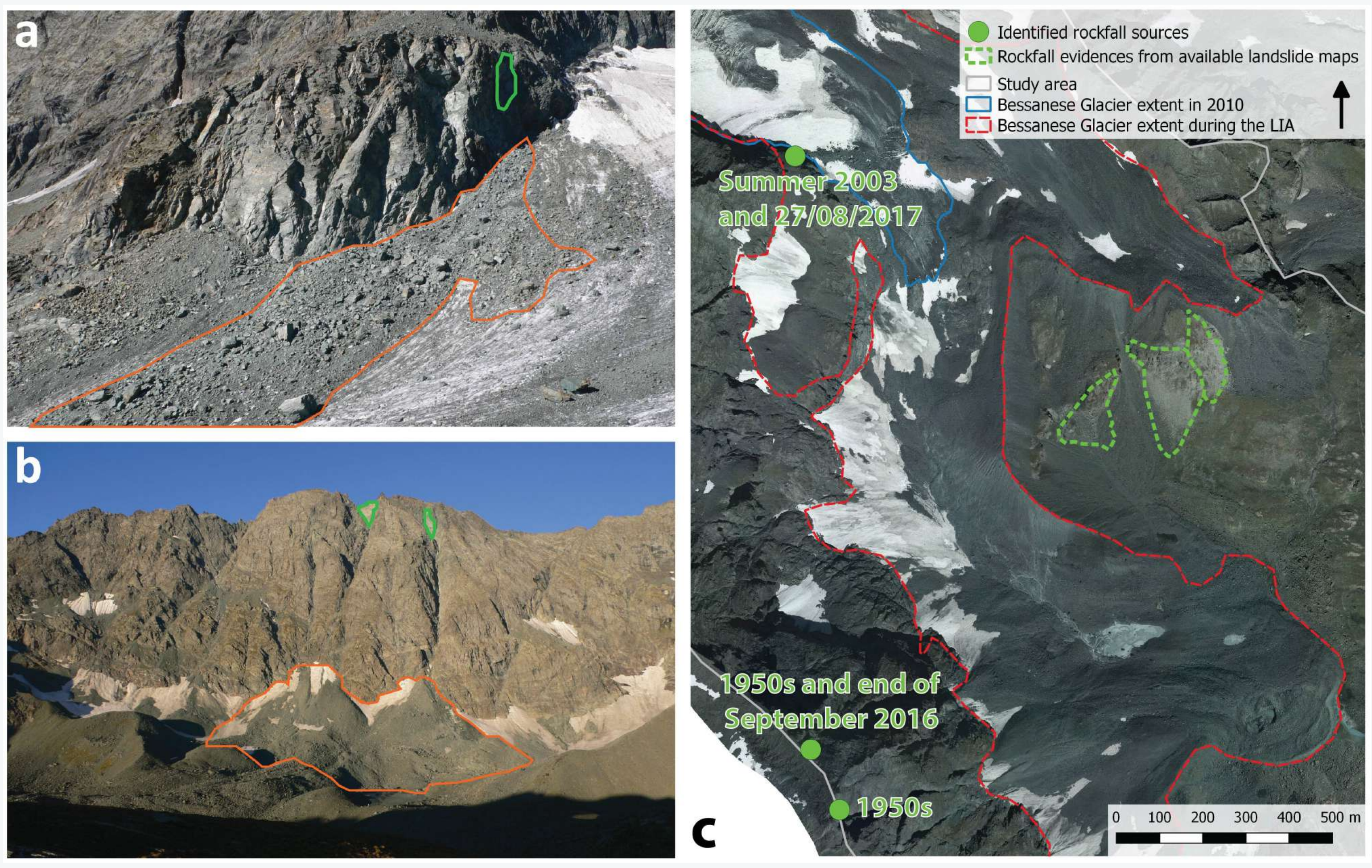


Fig.4. Rockfall detachment (green) and accumulation (orange) zones (a and b); map of the identified rockfall events (c).

The identified events (c) are concentrated in **summer** and occurred from the **NE** ridge of the Uja di Bessanese (a) and from the channels cutting the Bessanese rock wall facing **E** (b).

Rockfall area sources:
- are carved in **Prasinites**;
- have a **convex topography** (ridge and crest) and the effects of the insolation are higher;
- E face of the Uja di Bessanese rock wall is characterized by **discontinuous permafrost**;
- NE ridge of the Uja di Bessanese has experienced in recent years a rapid and significant (tens of meters) reduction of the glacier thickness, being probably affected by **debuttressing phenomena**.
- the August 27th 2017 rockfall shows a significant **positive air temperature anomaly**.

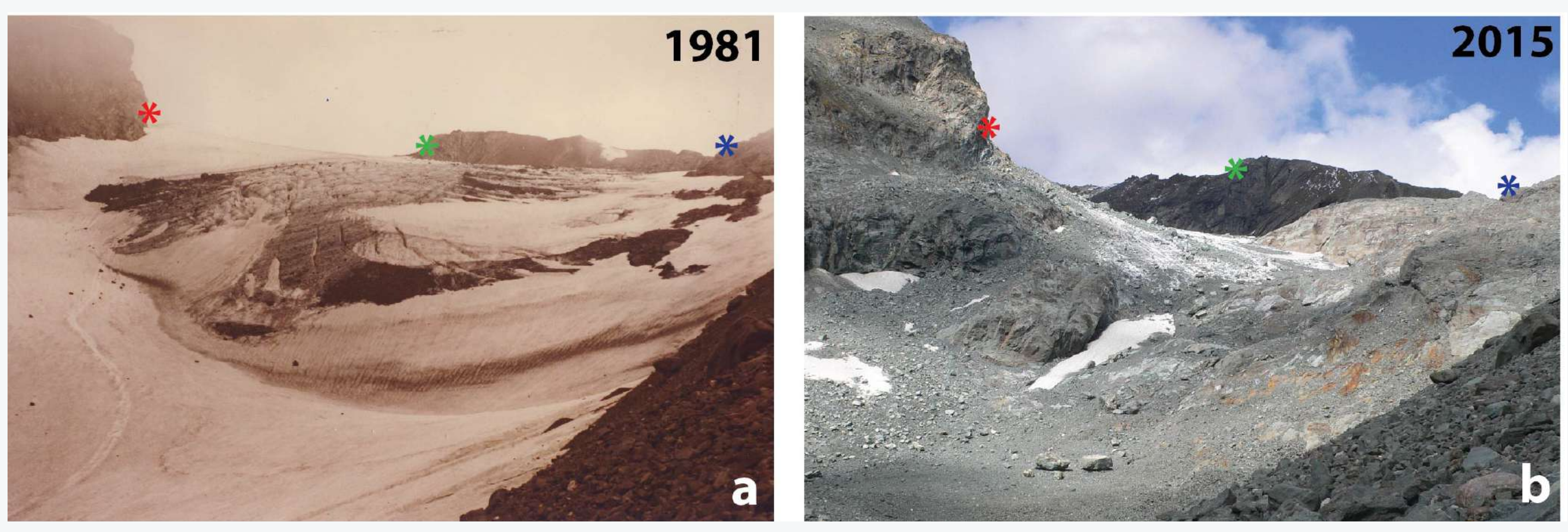
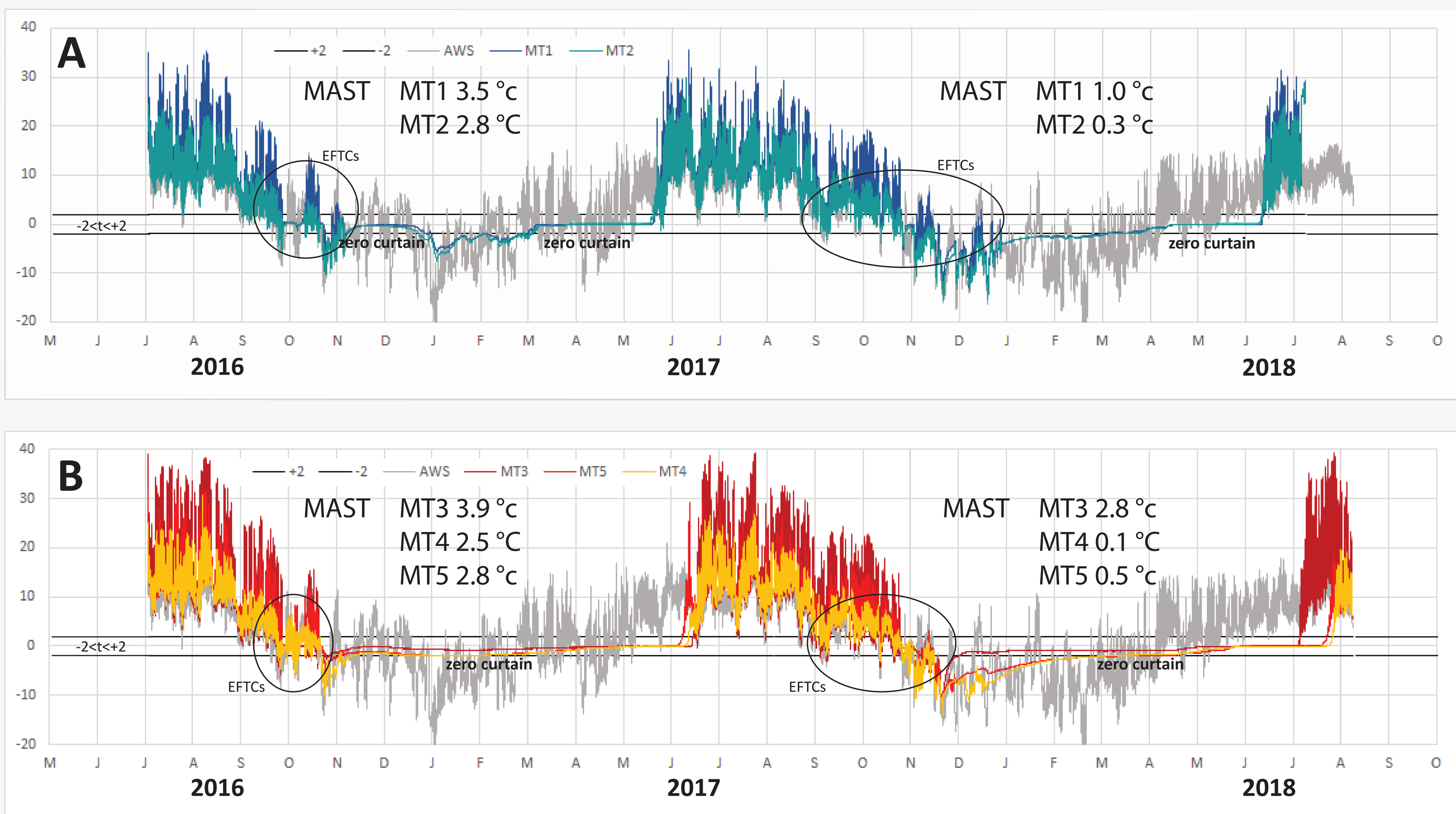


Fig.5. Bessanese Glacier in 1981 (a, photo D. Marangoni, CGI archive); Bessanese Glacier in 2015 (b).

Rock thermal behaviour



(1) **Specific heat**: Prasinites are more sensitive to thermal stress (780.3 J/kg K) than Calcschists (818.3 J/kg K). **Colour**: Prasinites are darker and Calcschists are lighter.

(2) The **sensitivity to thermal stress** can be recognized also in the annual trend and fluctuation of near-surface rock temperature.

(3) **Positive MAST** suggest that in the instrumented sites there are not the conditions for permafrost occurrence.

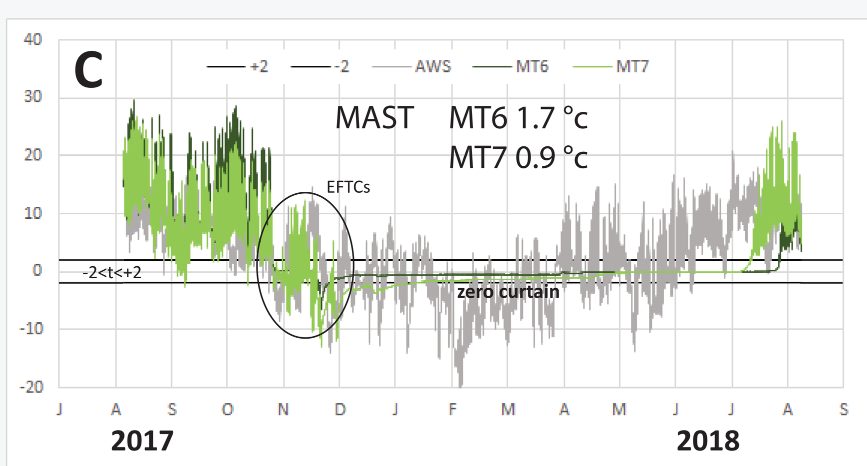


Fig.3. Rock and air temperature trends at the 3 instrumented sites.

MTs	Elevation	Aspect	2016 Sept.	2016 Oct.	2016 Nov.	Total EFTC	2017 Sept.	2017 Oct.	2017 Nov.	Total EFTC
Air temperature										
AWS	2659		0	5	8	13	3	5	8	16
Rock temperature at 10 cm depth										
1	2667	W	0	2	5	7	1	1	7	9
2	2666	NE	0	4	0	4	2	2	0	4
3	2594	E	0	9	2	11	3	3	2	8
4	2586	NE	0	10	2	12	1	1	1	3
5	2586	SW	0	4	0	4	0	0	1	1
6	2772	SE	na	na	na	na	1	0	1	2
7	2790	E	na	na	na	na	1	1	13	15

Table 2. Number of EFTCs measured by the AWS and the 7 MTs.

(4) From September to November, MTs experienced several **effective freeze-thaw cycles**.

(5) After, a **progressive cooling to sub-freezing conditions** took place.

(6) Successively, seven (2016-17) or eight (2017-18) months of stable thermal conditions, between 0 and 2 °C (**zero curtain periods**) in snow covered sites occurred.

CONCLUDING REMARKS

In the investigation of slope instabilities in high mountain areas under warming climate, it is important to take also into account the **thermal properties of the rock wall source areas** besides **climatic and meteorological triggering events**. Likewise, particular attention has to be given to **cryospheric factors**: presence and state of permafrost and glacier evolution.

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Fondazione CRT

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