Rock-face temperature at high-elevation sites: a new measuring approach

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Rock-face temperature at high-elevation sites: a new measuring approach

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Abstract

The Alpine environment and in particular the cryosphere, is responding quickly and with great intensity to climate change. Temperature increase observed in the Alps urge the scientific community to study not only air temperature but also rock temperature, to deepen the knowledge about thermal properties of the potentially unstable geological materials. The metrological traceability of measurements is fundamental for data comparability in space and in time and this can be achieved by the use of calibrated instruments and with the evaluation of measurement uncertainties. Here we present some preliminary results of rock-face temperature analysis based on data acquired at high-elevation sites, by means of sensors with documented traceability to International System of Units Standards and evaluated measurement uncertainty. We found and quantified a strong difference in the hourly rate of temperature increase between air and rock. During summer rock temperature grows more than 8 times over air temperature.

Keywords: Rock, Temperature, Metrology for cryosphere, Permafrost, High-elevation sites, Alps.

Introduction

Cold mountain regions are responding quickly and with great intensity to climate change: the shrinkage of the glaciers, the permafrost degradation and the increase of the natural instability processes (NIP), are the main terrestrial indicators of climate warming (EEA 2017).

In the last 20 years in the Italian Alps, a growing number of NIP has been documented and some authors relate this trend to an increase of the near-surface air temperature (Chiarle *et al.,* 2017; Paranunzio et al., 2016; Turconi *et al.*, 2010). Air temperature (AT) increase can, for example, cause an increase of melting-freezing cycles, with volume change and rock mass damage (Nigrelli *et al.*, 2017). In NIP studies the knowledge of air temperature is not enough: it's necessary to acquire information about rock temperature (RT). RT is not yet widely measured and data are rare, compared to AT data. More importantly, RT data are often acquired by means of sensors with unknown measurement uncertainty. In this research field, the metrological traceability of measurements is actually missing but it is fundamental for data comparability in space and in time (Merlone *et al.*, 2015).

For studying RT at high-elevation sites, it is thus necessary to acquire data with a high level of accuracy, by means of calibrated sensors and inclusion of measurement uncertainty. The approach here proposed is intended as a case study for the adoption of common and standard procedures. Thanks to the close collaboration with the MeteoMet project (https://www.meteomet.org/) it has been possible to:

1. Measure RT by means of sensors with known uncertainty of measurements;
2. Increase knowledge about the thermal conditions of different types of rock;
3. Study relations between climate variability and morphodynamic processes at high-elevation site.

In this work we present the preliminary results of the analysis of the RT's that have been acquired in an experimental glacial basin (Balme, Italy), in the framework of the RiST project (project co-financed by Fondazione CRT).

The new measuring approach

To measure RT we use the MicroTemp sensors and data logger (TDL). Our approach consists of four steps:

1. Laboratory calibration (before and after use) of TDL, necessary to establish documented traceability to S.I. standards;

2. On-site test of TDL, necessary to evaluate components of measurement uncertainty other than the calibration ones;
3. Use of TDL for acquiring RT with known measurement uncertainty;
4. Use of our webcam for visual monitoring of the sites where TDL have been placed (https://bessanese.panomax.com/).

The TDL have been inserted into different types of rock at 10 cm depth (Fig. 1). The acquisition interval is every 10 minutes in summer and every 30 minutes in the other seasons (Fig. 1).

Figure 1. Inserting a TDL in a Calcschist rock.

Preliminary results

The total uncertainty of measurements is ±0.17 °C.

Firstly, we have examined RT during two summer seasons (2016 and 2017), during sunny days and when the rocks were directly exposed to the sun (no clouds, no topographic shadow). In relation to this criterion, we found 12 days that constitute our sample size. In these days we have only considered the hours when RT increases. The study involved two types of rocks: Calcschists and Prasinite rocks (Table 1).

Table 1. Descriptive statistics of the data.

	Sample (n)	Mean (°C/h)	St. dev. (°C/h)	Min÷Max (°C)	Curve f. (r^2)
AT	12	0.5	0.4	-0.2÷1.4	0.6
RT-C	12	3.83	0.49	3.08÷4.67	1.00
RT-P	12	3.89	0.27	3.41÷4.50	1.00

For a description of the acronyms see Fig 1.

We found a strong difference in the hourly rate of temperature increase between air and rock: RT grows more than 8 times over AT during summer, in sunny days with no clouds/shadows. The rate of temperature increase is shown in Fig. 2.

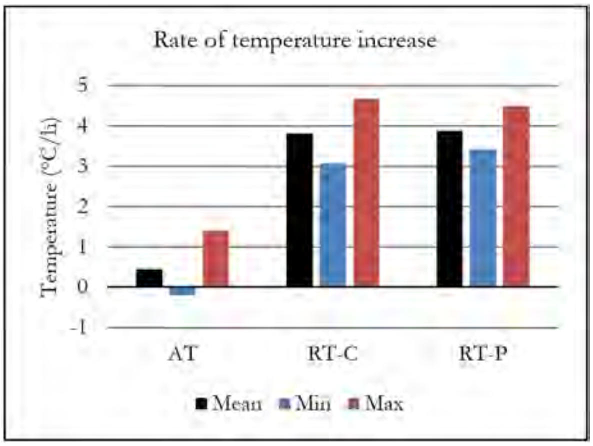

Figure 2. Rate of increase (°C/h) related to air temperature (AT, source ARPA Piemonte), Calcschists and Prasinite rock temperature (respectively RT-C and RT-P).

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