Investigating permafrost degradation by using geophysical imaging

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Introduction

Context & Relevance

Increase of temperature due to climate change is not only in the air, but also in the subsurface; thus affecting all hydrogeological and biogeochemical processes taking place in the soil. Moreover, large parts of the European Alps are covered by a permafrost layer, which are areas with temperatures below 0°C for at least 2 years. The thawing of permafrost in rockwalls can lead to rock instability and mass movements, posing a threat for high-mountain infrastructure and life.

Main objective

To delineate the presence of ground ice in solid rock permafrost using the non-invasive spectral induced polarization (SIP) method.

Study Areas

- ***Hoher Sonnblick (3106 m):*** Sonnblick Observatory in the Eastern Alps, built on gneiss rocks.
- ***Matterhorn (3829 m):*** Carrel hut below Matterhorn in the Western Alps, built on gneiss rocks.
- ***Val d'Ayas (3425 m):*** Lambronecca hut in Val d'Ayas on a steep rock ledge in the Western Alps, built on Amphibolites.

Methods & Laboratory experiments

Spectral Induced Polarization (SIP) method

The SIP method provides the electrical resistivity (energy loss) and capacitive (energy storage) properties at low frequencies (< 100 kHz) of the subsurface. Laboratory investigations (samples in Fig. 1) have shown an increase of both resistivity (Fig. 2) and capacitive properties with decreasing temperature and increasing ice content. Resistivity models can then be used to identify ice-rich areas in permafrost areas (Fig. 3)

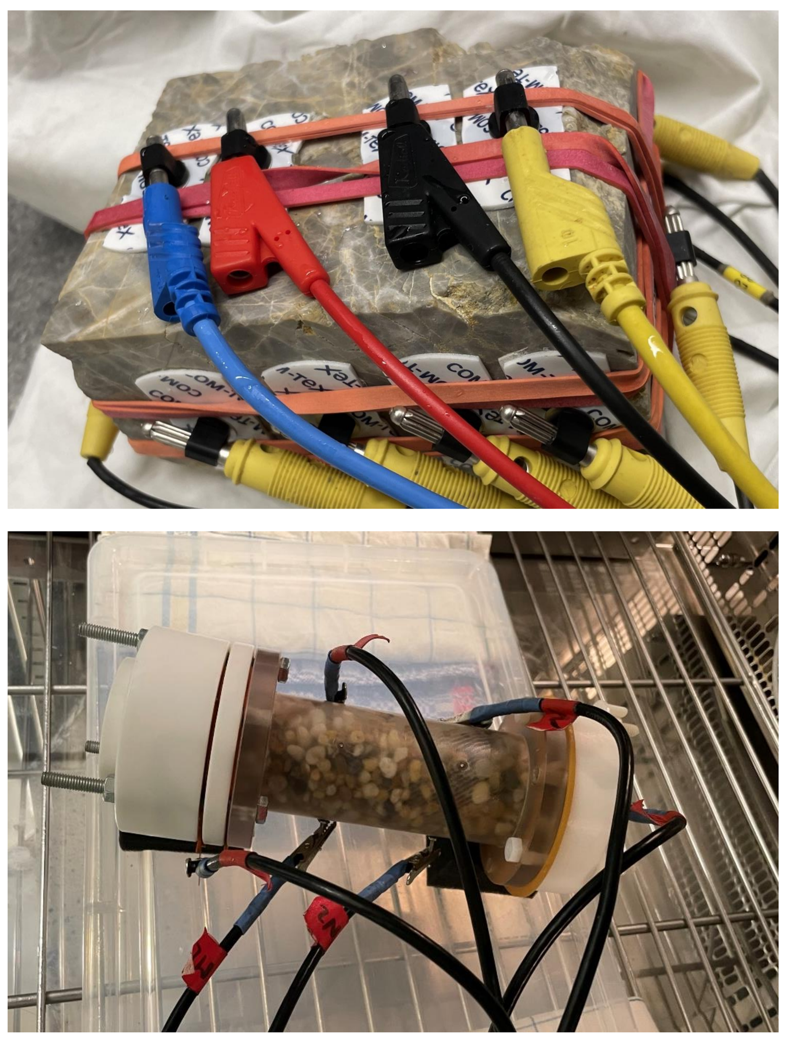


Fig. 1: Limestone rock sample (top) and gravel sample (bottom) investigated in the laboratory.

Apparent resistivities vs. temperature collected in the laboratory

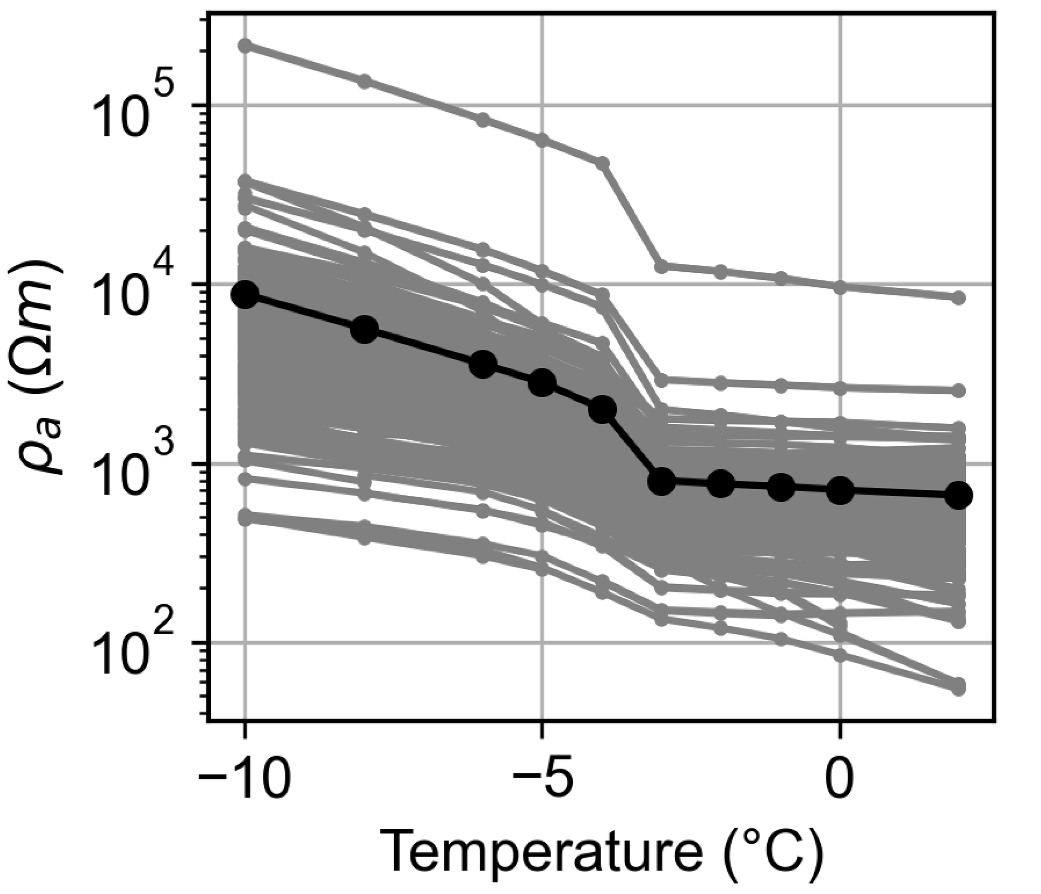
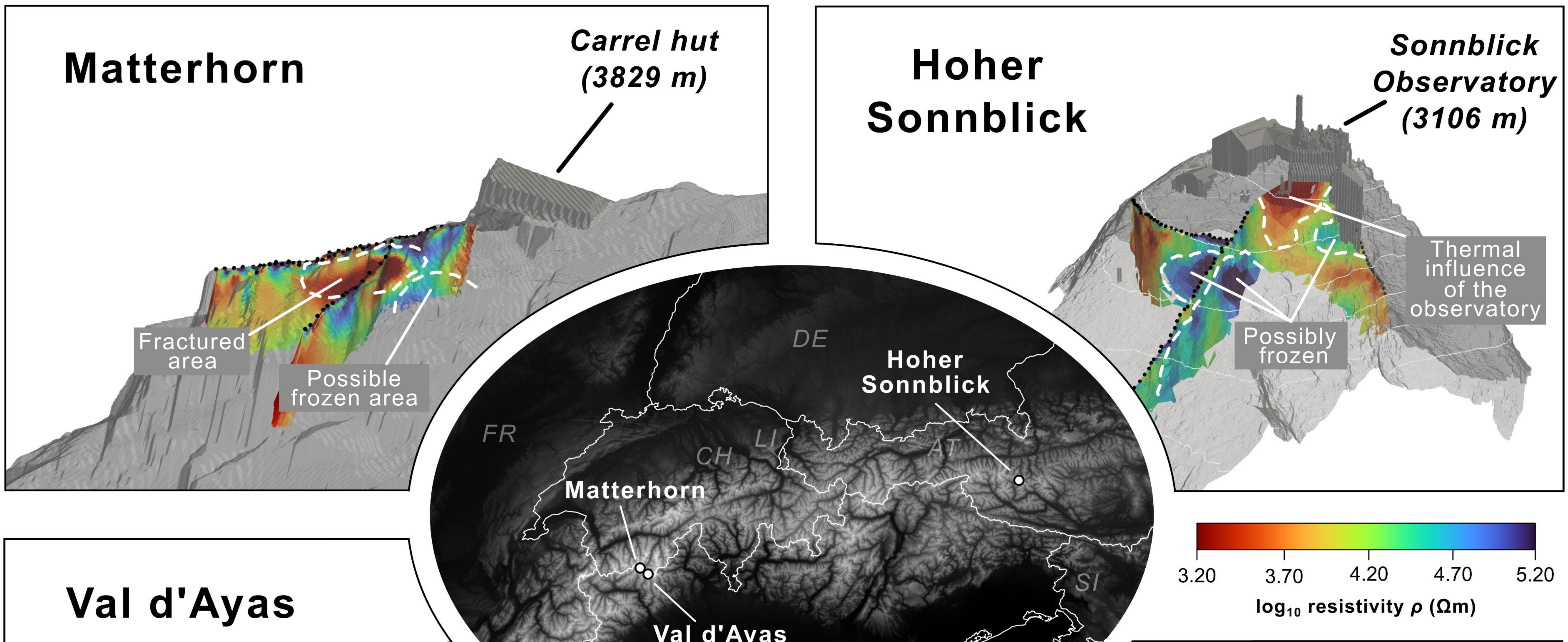
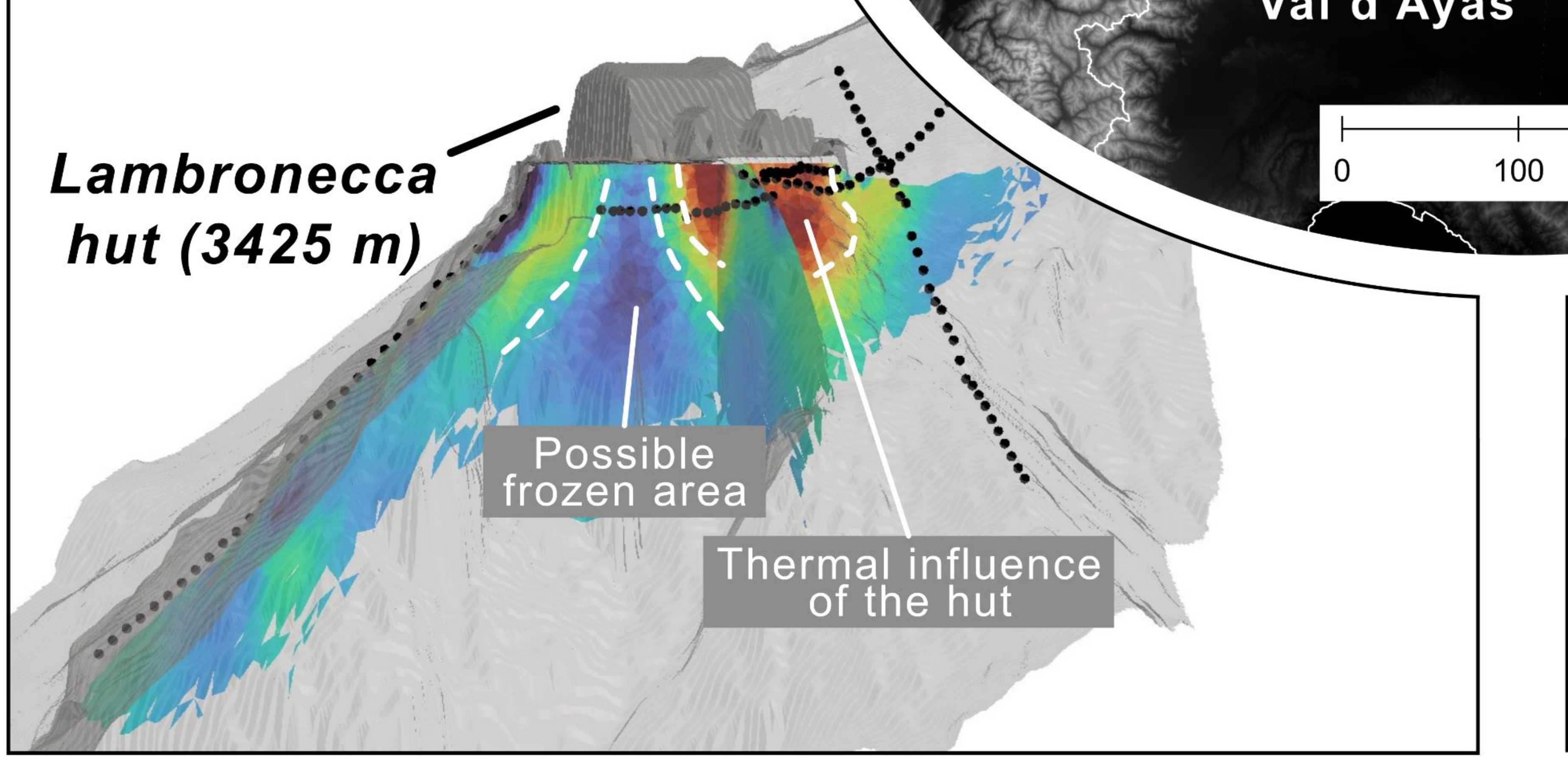


Fig. 2: Apparent resistivities vs. temperature measured on a solid rock sample under controlled conditions in the laboratory.





Main findings & conclusions

- Images of the electrical properties of the subsurface (resistivity) are able to provide spatial information about the extent of frozen areas in high-mountain environments.
- Spatial knowledge about frozen ground helps to evaluate potential risks for high-mountain infrastructure, such as mountain huts and observatories.
- Resistivity images give additional insight in potential thermal heat and water flow paths.

Fig. 3: Map of the three different study sites (center) and corresponding resistivity models in Matterhorn (upper left), Hoher Sonnblick (upper right) and Val d'Ayas (lower left). Electrode positions are indicated by black dots.

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