Climate-change-induced changes in steep alpine permafrost bedrock.

13 years of ERT can tell us.

What’s happening inside steep permafrost bedrock?

Which changes are visible in mountain permafrost areas?

Example: Zugspitze (D-2962 m a.s.l.)

BZB "up to 5,000 visitors per day" (without Corona) → increased risk of avalanches.

Can we detect changes in the last decade with ERT?

Mt. Rothorn 3'150 m a.s.l.

Vallis, Switzerland

Steintälli ridge

Quarz slate

Measurements in 2006 / 07 / 08 and then in 2019

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Study site

Laboratory test / Calibration from Krautblatter (2009)

Isolated box, temperature-controlled (-20° C to +8° C)

Automated resistivity measurements

Cooling and freezing curves

Multiple arrays

Aspaas bi-linear relation Ω °C

Aspaas A-2006: influence of ice in clefts - resistivities above 100 kΩ m in transect 1 and 5

B-2007 / 2008: already strong decrease in PF extension in transect 1, 3 and 5

C-2019: overall dramatic decrease in PF extension and ρA

Irregular behaviour on the surface → short-term influence

Consistent strong decrease in all deeper layers → long-term trend

-22% average resistivity change

Long-term changes: 2019 compared to 2007

Each transect is 1 x 300 m²

5 parallel transects 4 m spacing

41 electrodes 2 m spacing

stainless steel Wenner (& Schlumberger) ERT transects - quasi 3D

ERT results

1-3-5-7-9

Classification frozen/unfrozen … for detection of changes

FROZEN TRANSIENT UNFROZEN

Check Calibration section

Quantify PF degradation

- + ° ° °

Locate PF loss

Melting reached also the north side, on the surface and at depth, in transect 1 and 5.

Deep-seated south side of PF lens suffers overall unfreezing.

Transect 1

Areal loss % of total area

9 & 1 170 m² 14%

7 & 3 300 m² 22%

5 & 1 500 m² 38%

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Future steps

• 3D analysis of data to obtain volumetric losses

• Direct link to mechanical changes measured with tape extensometer

• Comparison of repeated hourly measurements as well as the IGSSE 3D tomography data

Take home 

Thanks to the available data set we show that ERT is able to reveal long and short-term permafrost changes.

Thanks to the longest time series of measurements with this time & spatial resolution in bedrock we can also precisely locate and quantify changes.

Detected variations in permafrost extension in more than a decade can reach up to -38%.

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