Permafrost monitoring by reprocessing and repeating historical geoelectrical measurements

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See also call-for-collaboration on the 2nd page !

INTRODUCTION

Geophysical methods and especially electrical techniques have been used for permafrost detection and monitoring since more than 50 years. However, only after the development of 2-D tomographic measurement and processing techniques i.e. Electrical Resistivity Tomography (ERT) in the late 1990's, these methods became generally available and were applied on mountain permafrost sites worldwide. Due to the large contrast in electrical resistivity between unfrozen and frozen material, ERT is well suited to detect and monitor frozen ground and ground ice content.

Within the Swiss permafrost network PERMOS, operational ERT measurements are conducted since 2005 to monitor the ground ice content at five permafrost stations in the Swiss Alps on a yearly basis (Hilbich et al. 2008, PERMOS 2019). A thorough analysis of this data set has shown its high quality and robustness against potential error sources related to the harsh high mountain field conditions and has indicated common climatic trends at all sites, i.e. a decreasing trend of mean specific resistivity (associated with permafrost thawing) since the first measurements in 1999 (Mollaret et al. 2019).

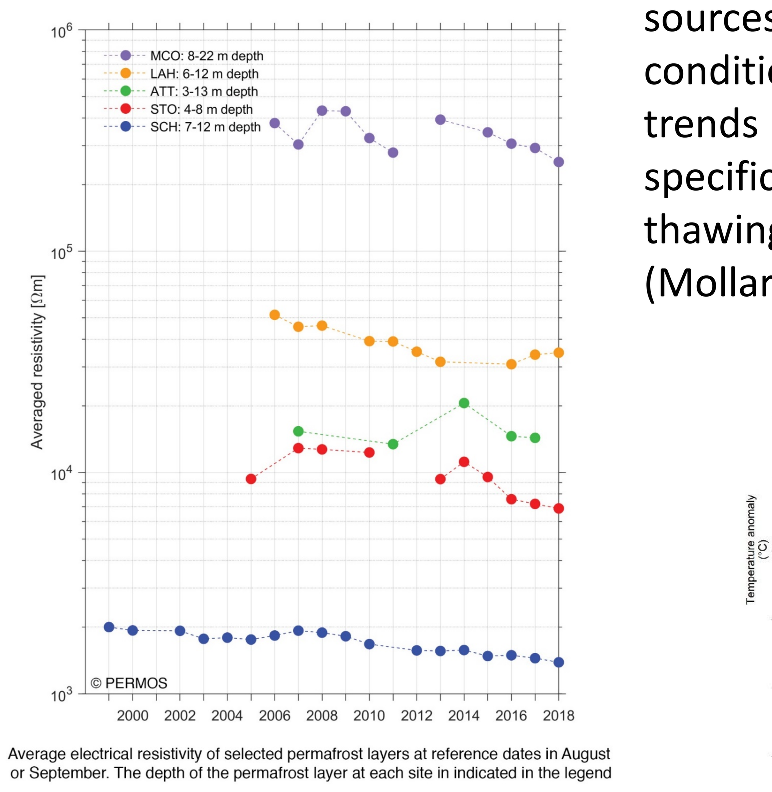


Fig. 1: Long-term ERT monitoring at five PERMOS sites

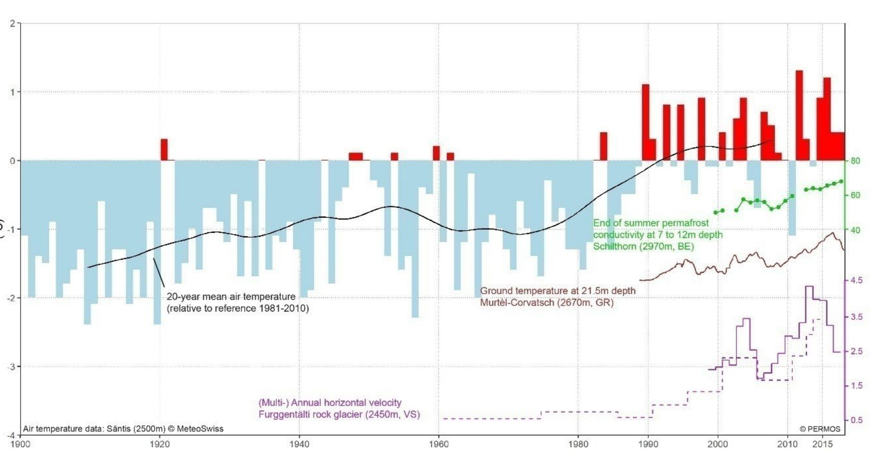


Fig. 2: composite plot of permafrost evolution (PERMOS)

GCOS SWITZERLAND PROJECT REP-ERT:

Permafrost monitoring by reprocessing and repeating historical geophysical measurements

Because of the comparatively large efforts needed for continuous and long-term ERT monitoring, only a **very small number of operational permafrost ERT monitoring sites exist** worldwide. However, **a much larger number (estimated to be > 500) of permafrost sites with singular ERT measurements exist**, many of them published in the scientific literature. These data sets are neither included in a joint database nor have they been analysed in an integrated way. Within the newly GCOS Switzerland-funded project (REP-ERT) we address this important **historical data source**. As electrical data can be used as proxies for subsurface and ice and water contents in permafrost areas we believe that a joint database will make a useful contribution to the existing borehole temperature database of GTN-P (Biskaborn et al. 2015).

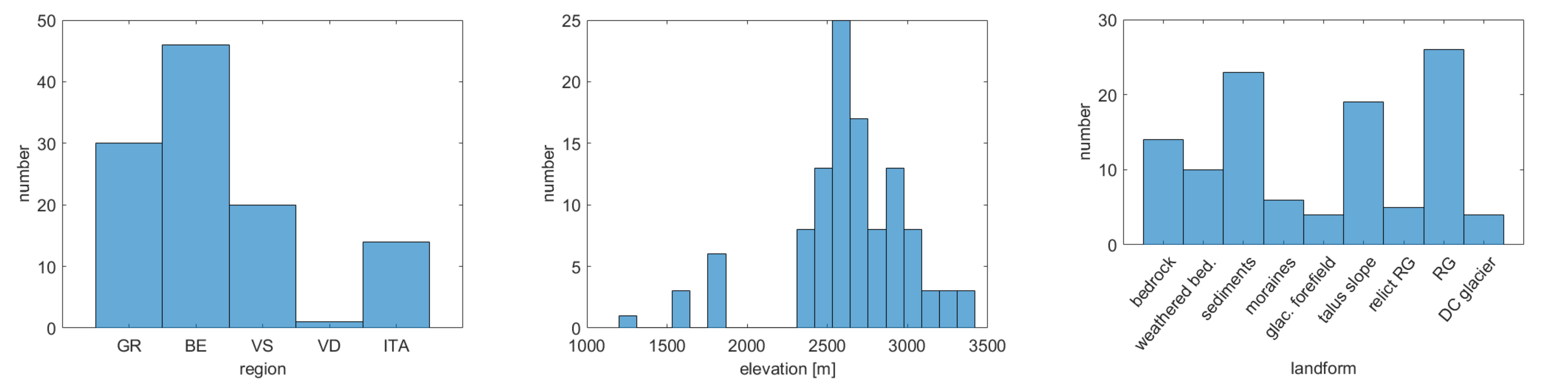


Fig. 3: ERT data distribution regarding region, elevation and landform/substrates

In a first step ~100 ERT profiles from the Swiss and Italian Alps were compiled and analyzed (Fig. 3). Landform/substrates comprise predominantly bedrock, sediments, talus slopes and rock glaciers (about equal numbers) and elevation ranges around 2600 m prevail.

AIMS OF THE REP-ERT PROJECT

1. Initiate and compile a database for historical ERT data on permafrost (Switzerland)
2. Develop and apply suitable QA/QC criteria for data filtering and inversion → **WORKSHOP 2020**
3. Develop and conduct a protocol for regular repetitions of ERT measurements in a climatic context (repetition rate > 10 years)
4. Initiate first steps to include electrical resistivities as proxy for ice content changes in the international GTN-P (Global Terrestrial Network - Permafrost) database, where up to now only borehole temperatures and active layer thicknesses are included.

ELECTRICAL RESISTIVITY

Whereas maximum resistivities from different permafrost occurrences cannot easily be used to predict ice content due to the local influence of the geologic material (Fig. 4), their use as baseline for repeated measurements and subsequent processing in a climatic context is highly promising and can be effectuated with low efforts (Figs. 5-8).

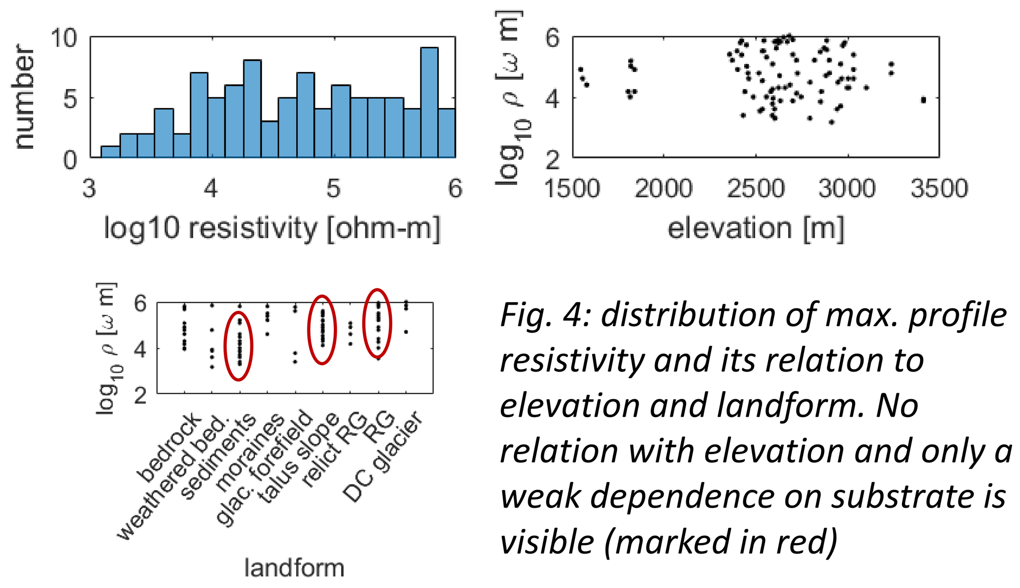


Fig. 4: distribution of max. profile resistivity and its relation to elevation and landform. No relation with elevation and only a weak dependence on substrate is visible (marked in red)

20 YEARS REPETITION EXAMPLES

A series of 20-year repetitions of singular ERT profiles are currently compiled in the context of the old EU PACE project (Permafrost and Climate in Europe). Swiss examples comprise the Schilthorn, Stockhorn and Murtèl-Corvatsch sites (Fig. 1)

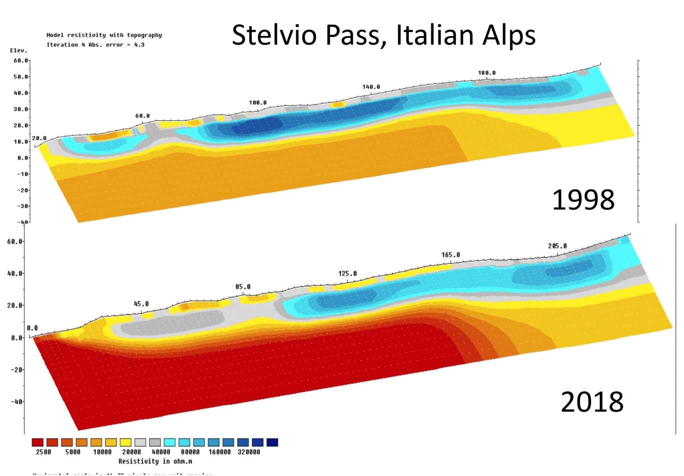
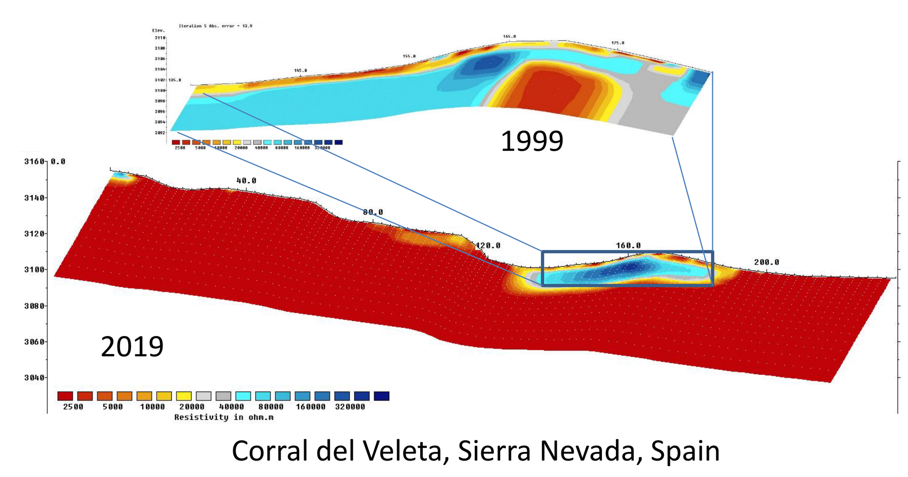


Fig. 5: 20-year examples from Italy and Spain based on old PACE profiles (Hauck 2000)



A clear decrease in resistivity (suggesting ground ice loss) was found for all Swiss and Italian sites (cf. Figs. 1, 6 and 8), to a smaller extent for the Norwegian sites (Fig. 8 and SGM 2019 Poster Hilbich et al.)

10 YEARS REPETITION EXAMPLES

Baby rock glacier/MUR, Swiss Alps, Aug 2010 Aug 2018

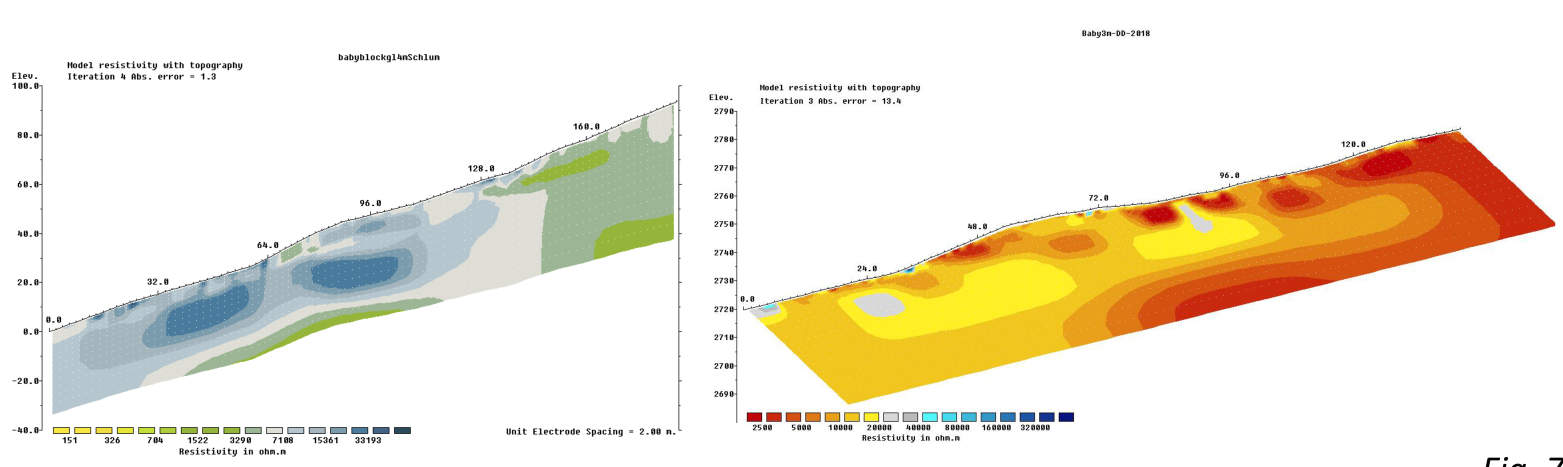


Fig. 6: eight year repetition example from a tiny rock glacier form (near the more famous rock glacier Murtèl, Upper Engadine), were different electrode configurations were used. Furthermore, the raw data from 2010 have not yet been found in the archive.

Juvvass, Southern Norway, Aug 1999 Aug 2010

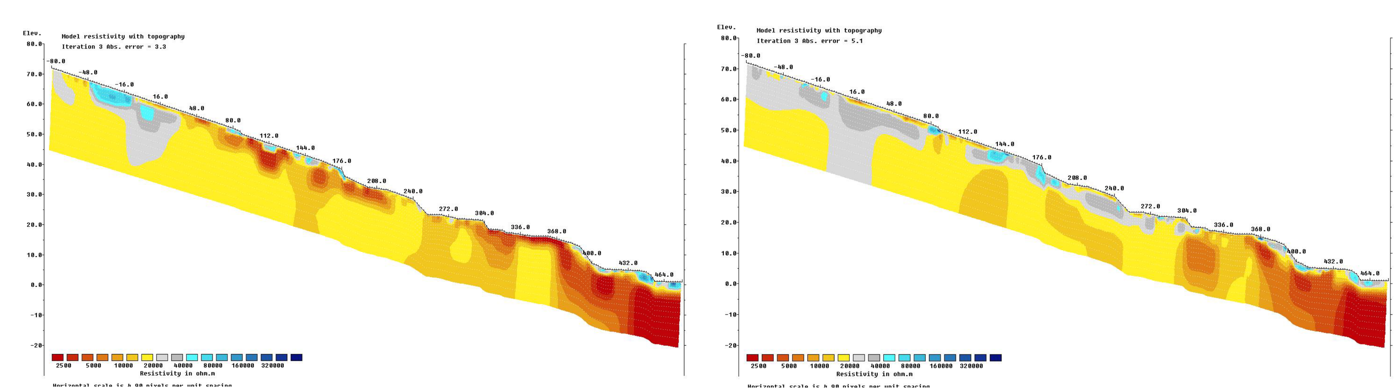


Fig. 7: eleven year repetition example from a very long transition profile from permafrost to non-permafrost conditions in Jotunheimen, Norway. This profile is regularly monitored (cf. Poster Hilbich et al., same session). Permafrost degradation is visible, but less evident from ERT, but was confirmed by borehole data.

Schilthorn, Swiss Alps, Aug 2007 Aug 2017

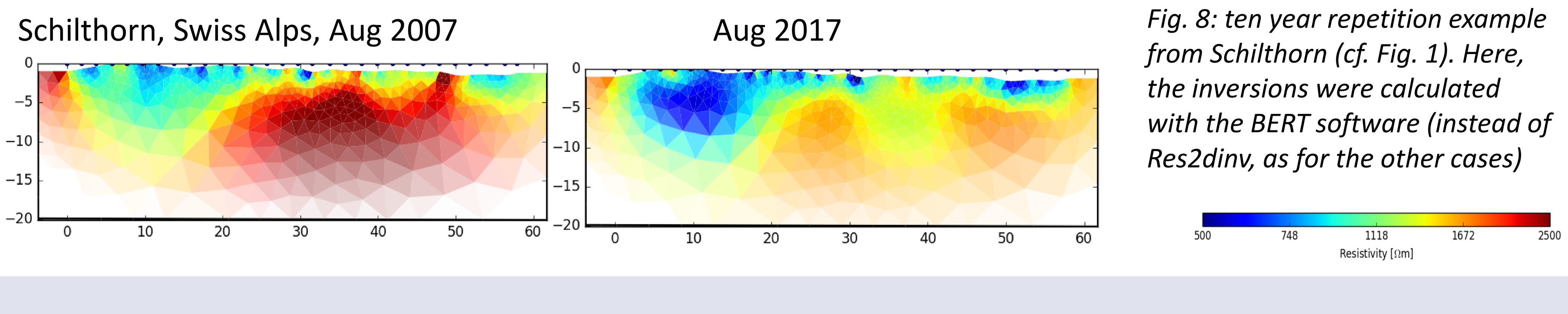


Fig. 8: ten year repetition example from Schilthorn (cf. Fig. 1). Here, the inversions were calculated with the BERT software (instead of Res2dinv, as for the other cases)

CHALLENGES & OUTLOOK

Measurements

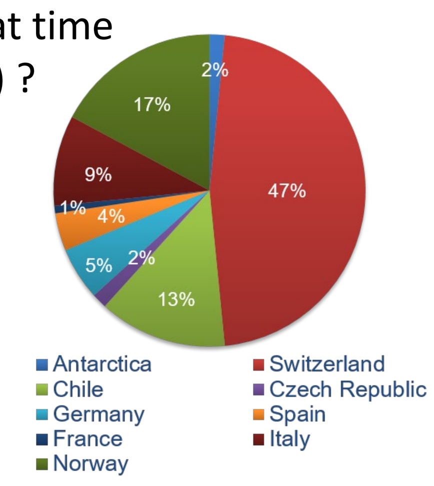
- Finding the correct profile position in the field
- Repetition measurements should be done at roughly the same date of the year
- Choice, whether to choose the old configuration or a better suited geometry e.g. longer/shorter spacing
- Matching topography of old/new data set for time-lapse inversion

Data processing

- Finding and preserving the raw data of each measurement (Fig. 6)
- Data filtering according to same standards or keep the old filtered data set, as local knowledge was used at that time
- Which inversion scheme/parameters (Fig. 8) ?

Towards an international data base

- More than 200 archived profiles so far
→ see 2nd page !



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Call for Collaboration:

Do you have old ERT survey data on permafrost ?

Are you interested to contribute to an

International Database of Geoelectric Surveys on Permafrost ?

EGU General Assembly 2020

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OVERALL AIM

Set baseline for the repetition of old geoelectrical surveys (especially Electrical Resistivity Tomography, ERT) on permafrost in the context of climate change. Joint analysis of potential ice content changes over several years from these repeated ERT surveys.

ADDITIONAL TECHNICAL OBJECTIVE

Evaluate processing techniques for jointly interpreting large data sets from different sources and initiate collaborative database ideally in the framework of IPA GTN-P. Develop guidelines for the repetition of ERT surveys on permafrost in a climate context.

FUNDING

Initial seed funding is provided by a 2-year project by the Swiss GCOS office (project REP-ERT, see poster) which could be used to initiate the database and provide help in data archiving and processing. Future collaborative funding could be sought via either European COST action or IPA action group.

PUBLICATION

A joint publication of all collaborators about the database (e.g. in ESSD) and its climate/permafrost-relevant ERT monitoring analysis (any cryospheric or geophysical journal) is foreseen.

CALL FOR COLLABORATION

If you have conducted geoelectrical surveys on permafrost in the past and if you are interested in sharing this data in a joint database within an international collaboration please contact:

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DATA

Data in the database would include raw and meta data, in order that data processing can be standardized and no historical data get lost. Every contributor would have access to the full data set.