Picture: Manon Cramer 2023
Text: Dr. Johannes Buckel & Tamara Köhler

Measuring twice - why students repeat field measurements at the same location and timing. Continuation of permafrost monitoring at the Glatzbach catchment, Austria.

Climate warming causes severe changes in high mountain environments. This is particularly evident by the rapid melting of glaciers, the formation of new proglacial lakes and the increase in rockfalls and rockslides due to slope instability. But how does global warming affect the subsurface on a local scale? And how does it affect the periglacial zone, where the perennially frozen ground, the so-called permafrost, occurs?

To find this out, geography students accompany the research group *Geomorphology and Environmental Systems* at the University of Bonn, headed by Prof. Lothar Schrott, to the Großglockner region. Almost every year they carry out field measurements that reveal the existence and status of alpine permafrost.

In September 2023, a team of bachelor's and master's students, research assistants and associates continued their ongoing research at the Glorer hut (47°01'51''N, 12°42'56''E) in the Hohe Tauern range of the Austrian Alps. The Glatzbach catchment is a unique study area in which periglacial processes have been investigated for over 20 years (e.g. Jaesche et al., 2003, Otto et al., 2012; Keusching, 2016; Buckel et al., 2023). They cover a wide range of methods for detecting periglacial and permafrost processes such as ground temperature monitoring, bottom temperature of snow measurements, analyzes of the velocity of solifluction lobes and geophysical prospection. The ongoing research integrates and builds on these results, using established and new methodological approaches. Repeated measurements are conducted almost every year, with data often being collected during excursions and seminars as part of the methodological training in Physical Geography.

The focus of this multi-year study is the continuous monitoring of the periglacial environment within the Glatzbach catchment. Due to its altitude and exposition, this catchment area is appropriate for investigating the effects of global warming on permafrost and its ice content. We use geophysical methods (electrical resistivity tomography (ERT) and seismic refraction tomography (SRT)) to reveal the contrasts between frozen and non-frozen patches and layers of the subsurface. Remote sensing methods (Uncrewed Areal Vehicles, (UAV)) are applied to achieve a high-resolution image of the earth's surface. By repeating both methods at the same location and along existing profile lines, a long-term measurement series on horizontal and vertical displacement rates and subsurface ice changes can be established. While the geophysical surveys provide information on (changing) subsurface conditions of a rock glacier in the catchment (see Fig. 1a), UAV are used to create high resolution digital elevation models (DEM) and to analyze the kinematics of this landform. All measurements are recorded with a Differential GPS for precise positioning and change detection on centimeter-level. In September 2023, new geophysical equipment was additionally tested, like the application of textile electrodes (Fig. 1b) to induce current to the ground resulting in resistivity anomalies caused by ground ice. These electrodes are quicker and easier to install than classic steel spikes (Fig. 1c), especially on blocky surfaces like rock glaciers.

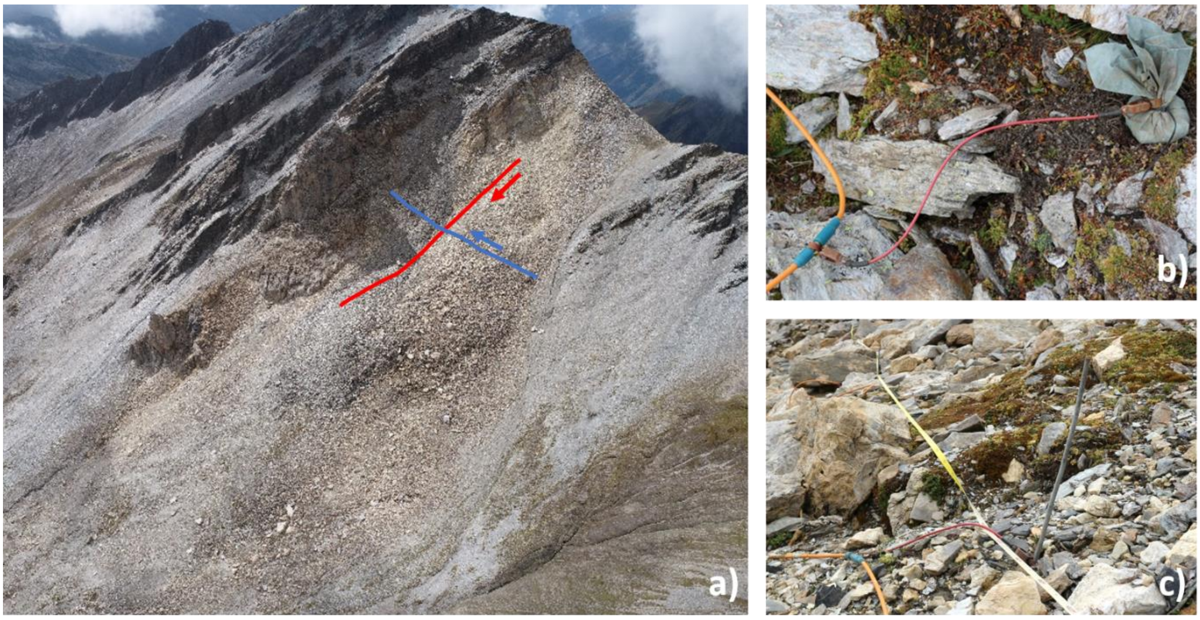

Fig. 1: a) View towards SW on a rock glacier in the Glatzbach catchment in the Hohe Tauern range of the Austrian Alps. Here, repeated geophysical measurements have been carried out over the past years, such as electrical resistivity tomography with textile electrodes (b) and conventional steel electrodes (c). The red line in a) indicates the location of a longitudinal profile, hereafter referred to as profile 1, the blue line a cross profile (profile 2). Both of which were repeatedly measured using Electrical Resistivity Tomography (see Fig. 2). Arrows show the profile direction (Picture a: Adrian Grainer 2023, b & c: Matthias Michalczyk 2023)

The ERT-tomograms provide insights into the subsurface structures down to a maximum of 10 to 15 m below the surface in the profile center (Fig. 2). The comparison of the recent tomograms with the older ones from 2020 reveal changes over the past three years in the internal structure of the rock glacier. Resistivity values greater than 10 kOhm indicate an ice content displayed by the dark blue patches in the tomograms. Compared to 2020, profile 1 only contains two small blue patches at the surface in 2023 and overall smaller resistivity values, which indicates thawing at this profile location. The resistivity values of the second profile are also significantly reduced which is apparent from the brighter appearance and the overall lower subsurface distribution of the color blue. Here, we still assume the existence of frozen subsurface conditions in the state of thawing. So, not only the superficial glaciers are melting, but also subsurface ice content is diminishing due to the overall global warming.

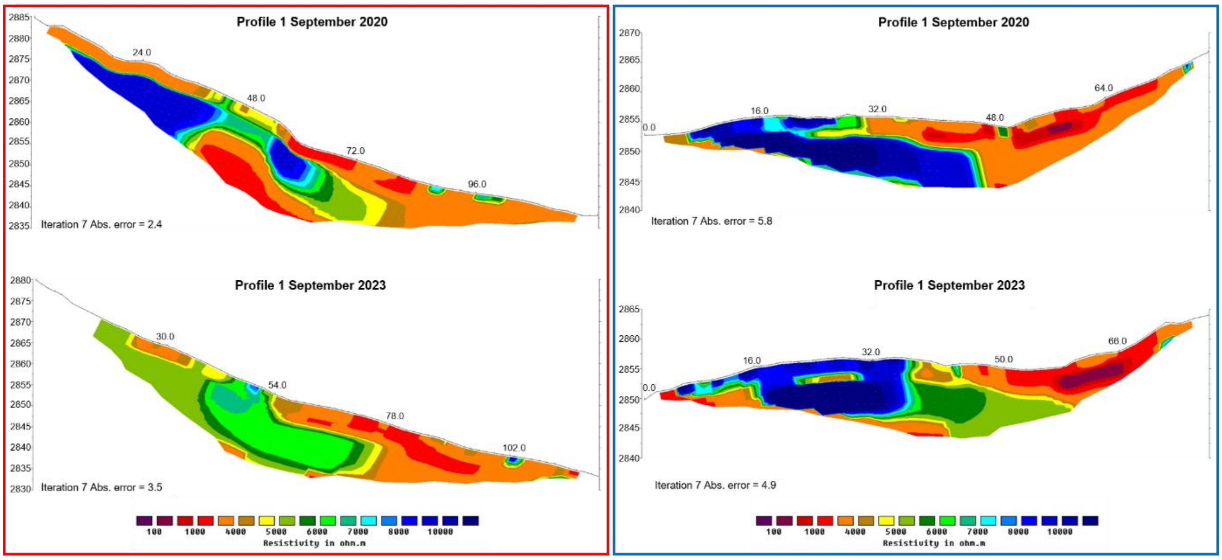

Fig. 2: Comparison of the ERT-tomograms 1 (red) and 2 (blue) measured in 2020 and 2023 (see Fig. 1 for profile locations) (data processing by Matthias Michalczyk). Note the different scalings of x- and y-axes.

In the recent field phase, drone flights and geophysical investigations were additionally conducted on a landslide below the Glorer hut, which is intersected at several points by a frequented hiking trail (see Fig. 3). Since nothing is known about the landslide mass, the movement (rate), thickness, moisture and internal waterways, information on the internal structure is needed to assess its hazard potential.

Fig. 3: Drone footage of the studied landslide along the hiking trail to the Glorer hut (Picture: Adrian Grainer 2023)

The creation of long-term (dis)continuous time series based on repeated (measuring a minimum of twice) field measurements plays a key role in Earth sciences to understand geomorphological systems and their process dynamics. Especially in the context of global warming, continuous monitoring is crucial to capture their response and assessing the consequences for frozen water reservoirs in our alpine permafrost regions.

Three bachelor and master students participated in the field campaign and are now analyzing part of the data within their theses. We are looking forward to continuing our research at the Glorer hut in September 2024! If you are interested to work in the field of high mountain research and permafrost by applying new field techniques, please send a message to schrott@uni-bonn.de.

Fig. 4: Drone footage towards N on the Großglockner (3798 m asl.) on the left and the overcast Eiskeller cirque on the right (Picture: Adrian Grainer 2023)

Literature

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