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Investigation of the induced polarization effect in transient electromagnetic soundings to characterize rock glaciers

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Geophysical characterization of rock glaciers commonly relies on electrical resistivity tomography (ERT) and seismic refraction tomography (SRT). Yet, large blocks make the installation of geophones and electrodes time consuming, while bad contacts lead to reduced signal-to-noise ratios in both methods. Additionally, ERT and SRT campaigns require rather heavy equipment and need long profiles to reach large depths of investigation. Transient electromagnetic (TEM) measurements offer diverse advantages, as they do not require a galvanic contact with the ground, and can be conducted with light instruments for simplified field procedures. We propose the application of TEM measurements with a single-loop configuration for the collection of extensive data sets in alpine environments. We hypothesize that TEM measurements provide the same information as SRT and ERT, yet field procedures of the TEM method are much more efficient permitting to cover larger areas in reduced time. In particular, we present investigations conducted on the Gran Sometta rock glacier (above Cervinia, Aosta Valley, Italian Alps). The study area consists of a large active rock glacier complex composed of two main lobes with varying ice content. Our surveys aimed at: (i) estimating the depth to the bedrock below the rock glacier, (ii) identifying the degree of weathering in the underlying bedrock, and (iii) evaluating spatial variations of ice content of the rock glacier. We collected TEM data with a TEM-FAST 48 system using 4 A current and a 50 m by 50 m single loop configuration. The experimental setup fits in a single backpack and our 3-person team covered an area of approximately 75'000 m² in 2.5 days, despite the difficult terrain. We measured 28 soundings distributed over the entire site and repeated two sounding locations with a larger 75 m square loop. Complementary spectral induced polarization (SIP) data were measured using 64 electrodes with a separation of 2.5 m between electrodes along two perpendicular profiles to validate our TEM results. We used separated transmitter and receiver instruments as well as cables to reduce EM coupling effects in our SIP data. TEM data reveal sign reversals, which are caused by the induced polarization effect due to the ice content in the rock glacier. We model the TEM response with the open-source algorithm ~~EMPYMOD~~ empymod assuming a layered media. We observe that including a layer with a frequency-dependent polarization results in the signal reversals, while the geometry of such a layer also influences the TEM response. Furthermore, we observe that resistivity variations in the layer below the polarizable one can also be detected by the TEM data. Hence, our results demonstrate the applicability of TEM measurements to determine the geometry of the ice-rich layer in an active rock glacier, possible variations in ice content at the study area as well as the electrical properties of the underlying bedrock.