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A first attempt to reveal hydrostatic pressure in permafrost-affected rock slopes with relative gravimetry

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Progressive failure of rock faces in periglacial environments (e.g. Piz Cengalo in 2017) are controlled by rock and ice mechanics but also by hydro- and cryostatic stresses. One of the most important but still unknown factors is the contribution of water in terms of hydrostatic pressure. Its presence has often been registered in major rock failures but it has never been quantified. Infiltration from rainfall or snow/ice melting could create extreme pressure peaks, especially when permafrost seals fractured rock. Climate change consequences like increase of air temperature and intensification of precipitations can amplify the magnitudes and pose a high risk for humans and infrastructures.

We present here a new approach to the problem, using relative gravimetry measurements. The detected changes in the local gravity field are attributed to changes in the water content of the surrounding rocks, for low-porosity rocks to water in its fractures. From 2014 to 2019 we monthly monitored relative gravimetry values on the summit of the Zugspitze (Germany, Wetterstein limestone), a few hundred meters away from an area of big touristic interest with thousands of daily visitors. In our case study a Scintrex CG-5 relative gravimeter with accuracy of 1 μGal = $10^{-8} m/s^2$ was used at 18 stations mainly located in a tunnel at 2700m above sea level, where we have been measuring permafrost since 11 years. Contemporary Electrical Resistivity Tomography allowed us to quantify precisely permafrost extension for each campaign. Additional continuous information from 25 rock and air temperature sensors, weather data from two DWD-stations and two discharge measurements in the tunnel help to describe, for the first time, the dynamic of water inside the massive and consequently estimate hydrostatic pressure.

Here we present the methodology used to detect hydrostatic pressure changes in permafrost-affected rock, the dataset obtained at our fully instrumented test site at the Zugspitze, and we evaluate the feasibility of the gravimetric approach and its potential of a joint interpretation with ERT and complementary data.