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Rock wall permafrost monitoring with high-resolution 2D-ERT: lessons learnt from error estimates and a comparison of Wenner, Schlumberger, Gradient and Dipole-type arrays

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ERT is a newly established method for the monitoring of permafrost-affected rock-walls. 2D and 3D-ERT are prone to play a key role in the calibration and validation of thermal modelling approaches and may contribute to the spatial interpretation of borehole data. To better link and compare ERT to such approaches, a systematic survey of detectable properties, resolvable units and error sources is necessary. Here, we will compare systematic errors associated with conventional arrays and various electrode spacings and will assess the potential of high-resolution ERT to overcome these problems.

Test transects with well detectable properties in galleries adjacent to the Zugspitze North Face (2800 m a.s.l.) were chosen which monitor a 20m * 40m rock permafrost body and its surroundings. Their electrode contacts show low temporal variation in contact properties as they are not influenced by meteorological factors. We conducted more than 20 simultaneous datasets in May, June, July, September, and October with four different arrays, three different electrode spacings and three different topographies along the same rock sections. Apart from these measurement parameters all other factors were kept constant.

Therefore, we can compare the following measurement parameters in terms of error-proneness: (i) Conventional Wenner, Schlumberger, Gradient and Dipole-Dipole arrays were conducted simultaneously along the same transects. Even if a Gradient array could theoretically include all Wenner and Schlumberger electrode combinations, conventional arrays involve certain electrode combinations that are different for Gradient, Schlumberger and Wenner arrays. (ii) Measurements with 1.53 m, 4.6 m and 10 m electrode spacing were conducted. (iii) Straight-line transects and right-angled topography transects were recorded that cover the same rock section to evaluate the impact of topography on spatial interpretability.

The quality can thus be judged according to (i) deviation of resistivity values of subsequent measurements with the same electrodes, (ii) deviation from other array types, (iii) spatial fit of topography-corrected data from right-angled transects with non-corrected data from identical transects without topography, (iv) RMS-errors in data processing (v) and due to the accordance with temperature logger data.

Our data indicate that conventional Wenner, Schlumberger and Gradient arrays provide more stable resistivity data, when measured repeatedly, provide similar results and result in better RMS errors than Dipole-Dipole arrays. Raw data quality and RMS-errors are strongly linked to electrode spacing and thus limit maximum array extent and propagation depth of ERT methods, more or less independently of applied voltage. Extreme topography still causes significant distortions in ERT inversion software such as RES2Dinv, which can be restricted by certain software settings.

High resolution 2D-ERT measurements (up to 1100 datum points per array) appear to combine the high surface resolution of conventional Gradient/Schlumberger arrays with the more stable depth information of conventional Wenner arrays under difficult conditions and may contribute significantly to an enhanced data yield of rock permafrost transects.