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Quasi-3D Resistivity Imaging – Results from Geophysical Mapping and Forward Modeling

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2D resistivity tomography has proven to be a reliable tool in detecting, characterizing and mapping of permafrost, especially in joint application with other geophysical methods, e.g. seismic refraction. For many permafrost related problems a 3D image of the subsurface is of interest. Possibilities of quasi-3D imaging by collating several 2D ERT files into one quasi-3D file were tested. Data acquisition took place on a vegetated scree slope with isolated permafrost lenses in the Bever Valley, Swiss Alps. 21 2D-electrical arrays were applied with an electrode spacing of 5 m and a parallel spacing of 20 and 30 m using the Wenner electrode configuration. Refraction seismic was applied parallel to every second ERT array, with a geophone spacing of 5 m for validation.
Results of quasi-3D imaging indicate that the most important factors influencing data quality are parallel spacing and number of right-angled crossing profiles. While the quasi-3D images generated of 2D-files with a parallel spacing of 20 m provide an interpretable image, 30 m spacing results in a blurred illustration of resistivity structures. To test the influence of crossing profiles quasi-3D images were inverted using only parallel measured data files as well as images containing right-angled crossing transects. Application of crossing profiles is of great importance, because the number of model blocks with interpolated resistivity values between parallel profiles is minimized. In case of two adjacent high resistivity anomalies a quasi-3D image consisting of parallel measured transects only illustrates one anomaly. A crossing profile provides information to differentiate the anomalies.
Forward modeling was used to prove these assumptions and to improve the application of 2D ERT with regard to quasi-3D imaging. Main focus was on electrode and parallel spacing, the influence of crossing transects and the applicability of different array types. A number of 2D ERT profiles were generated, using the forward modeling software res2Dmod. Resistivities of the modeled data were geared on the 2D measurements, containing surveys with high resistivities indicating permafrost and low resistivities for unfrozen ground. The modeled 2D files were inverted and collated into a quasi-3D file with the software res2Dinv, using the array types, Wenner, Wenner-Schlumberger and Dipole-Dipole. For each array type the quasi-3D file was modeled with double, triple and quadruple parallel spacing. To test the influence of crossing transects quasi 3D-files were modeled with a transect crossing every second, third and fourth profile as well as with no transect crossing.
Results from forward modeling support the assumptions drawn from the measurements. Parallel spacing between transects should be less than quadruple electrode spacing, while triple spacing has proven to be a good agreement between resolution and efficiency. Enlarging the distance between transects results in a loss of information value and a blurred illustration of resistivity anomalies. A high number of right-angled crossing transects is of importance for achieving a reliable quasi-3D Image. All tested array types provide good results in quasi-3D forward modeling. Known qualities of the different array types can be transferred from 2D ERT. Advantages of the Wenner array are low sensitivity to noise and error proneness; if applicable Wenner-Schlumberger and Dipole-Dipole arrays are recommendable for a higher resolution. As for 2D ERT choice of electrode spacing depends on site characteristics and objectives of the project.

Although “real” 3D techniques provide the best information of the subsurface, 2D data acquisition techniques will remain preferable in periglacial environments due to efficiency as well as logistical reasons. Quasi-3D imaging has proven to be a promising approach for resistivity measurements in periglacial environments and enhances the possibilities of data interpretation compared to 2D resistivity tomography, e.g. in terms of changing substrates, soil organic material or vegetation on a small scale and its influence on active layer thickness, as well as the visualization of isolated permafrost lenses.