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Forward and Inverse Modeling of Frequency-Domain Electromagnetic Data Applied to the Study of Alpine Aquifers

Melchior Grab, Thomas Kalscheuer, and Lasse Rabenstein
Institute of Geophysics, ETH Zürich, Zürich, Switzerland

One of the most important purposes of geophysical applications is the non-invasive investigation of vertically varying soil and rock properties. This can be attended with a vertical sounding, where a series of measurements is performed, each with a different set of instrument parameters to illuminate different depth ranges in the subsurface. For frequency domain electromagnetic small coil systems, the instrument orientation, the instrument height above the earth's surface, the source-receiver offset or the frequency are the most common parameters to vary. The acquired data are then converted into an earth model using an inversion program.
We enhanced an existing 1D inversion program written in Fortran to allow for the inversion of in-phase and quadrature data measured with variable instrument height, source-receiver offset, source-receiver orientation and frequency. After the program was successfully tested, it was used for different studies with synthetic data and field data.
The first study was based on synthetic data simulating a survey with the Geonics EM31 instrument with variable tool orientation and tool height above the surface. It was shown, that with a sounding with variable height, a significantly higher resolution can be achieved compared to a sounding with zero instrument height, what demonstrated the benefits of the enhanced inversion program.
The second study compared the EM31 sounding, including two different instrument heights and instrument orientations, with a sounding using different frequencies. Here the drawbacks of the Geonics EM31 in terms of resolution and exploration depth were pointed out: With the frequency sounding, geological structures above the maximum depth of sounding (defined as the depth at which the deepest sensitivity maximum of all applied measurement modes occurs) were well resolved, whereas the EM31 sounding continuously lost resolution with depth, already above the maximum depth of sounding.
The expertise of the second study is then used in the third study, where a data set, acquired in a hydrological field survey using the Geonics EM31 instrument, was analyzed. Here, some of the expected geological structures were successfully detected, although the uncertainty was relatively high due to the limitations of the Geonics EM31 instrument. It was concluded, that in combination with other sounding techniques, such as the frequency sounding, the possibilities of the enhanced inversion program would be better exploited.