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From 1D-Multi-Layer-Conductivity-Inversion to Pseudo-3D-Imaging of Quantified Electromagnetic Induction Data Acquired at a Heterogeneous Test Site

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Electromagnetic induction (EMI) systems enable the non-invasive spatial characterization of soil structural and hydrogeological variations, since the measured apparent electrical conductivity (ECa) can be related to changes in soil moisture, soil water, clay content and/or salinity. Due to the contactless operation, ECa maps of relatively large areas, i.e. field to (small) catchment scale, can be measured in reasonably short times. A multi-configuration EMI system with one electromagnetic field transmitter and various receivers with different offsets provide simultaneous ECa measurements that are representative of different sensing depths. Unfortunately, measured ECa values can only be considered as qualitative values due to external influences like the operator, cables or other metal objects. Of course, a better vertical characterization of the subsurface is possible when quantitative measurement values could be obtained. To obtain such quantitative ECa values, the measured EMI apparent conductivities are calibrated using a linear regression approach with predicted apparent conductivities obtained from a Maxwell-based full-solution forward model using inverted electrical resistivity tomography (ERT) data as input. These calibrated apparent conductivities enable a quantitative multi-layer-inversion to resolve for the electrical conductivity of certain layers. To invert for a large scale three-layer model, a one-dimensional (1D) shuffled-complex-evolution inversion scheme was parallelized and run on JUROPA – one of the supercomputers of the Forschungszentrum Jülich. This novel inversion routine was applied to calibrated electromagnetic induction data acquired at the Selhausen test site (Germany), which has a size of about 190 x 70 m. The test site is weakly inclined and a distinct gradient in soil texture is present with considerably higher gravel content at the upper part of the field. Parallel profiles with approximately three meter distance were measured using three different coil offsets in HCP and VCP measurement modes. This resulted in six high spatial resolution data sets of approximately 60000 measurements with different sensing depths. A 5 m block-kriging was applied to all six data sets to re-grid the sampling points on the same regular grid. For each grid node, the six measured apparent conductivities were used in a three-layer inversion. The three-layer inversion results of electrical conductivity thus obtained were used to derive a three-dimensional (3D) model of subsurface heterogeneity, which clearly indicated lateral and vertical conductivity changes of the subsurface that are related to changes in soil texture and soil water content.