Quantitative two-layer inversion for multi-configuration electromagnetic induction tools

J. van der Kruk, A. Mester, S. Rudolph, C. von Hebel, L. Weihermüller, H. Vereecken

Electromagnetic induction (EMI) is a powerful tool to map the electrical conductivity on large scales due to the noninvasive character and the fairly quick measurement acquisition. These conductivity maps can be used to estimate soil properties (e.g. clay content) or hydrological state variables (e.g. soil water content). EMI measurements return an apparent electrical conductivity that represents a weighted average of the electrical conductivity distribution over a certain depth range. Recently, multi-array systems became commercially available and corresponding inversion algorithms are being developed that explore the different sensing depths obtained for different coil orientations and offsets. However, in most cases the EMI systems do not provide absolute values of electrical conductivity due to calibration problems, which hinders a quantitative analysis of the measurement and can complicate a quantitative multi-layer inversion.

Recently, a new calibration method for EMI was introduced that uses electrical resistivity tomography (ERT) inversion results as input in an electromagnetic forward modeling tool for magnetic dipoles over a horizontally layered medium considering the frequencies and offsets used by the EM induction instruments. Comparison of the calculated and measured EMI apparent electrical conductivities shows very similar trends but a shift in absolute values, which is attributed to system calibration problems. The observed shift can be corrected for by linear regression.

Electrical resistivity tomography data were measured at the Selhausen testsite with 120 electrodes and an electrode separation of 0.25 m (see Figure 1a). Seven profiles, each 30 m long were measured in dipole–dipole configuration with an overlap of 15 m resulting in an overall profile of 120 m. The RES2DINV inversion returns conductivity values for every meter at nine depth levels down to a depth of 1.4 m. Six different EMI datasets were measured along the reference profile. The EM38 system with 1-m coil offset and 14.6 kHz and the Profiler system with 1.22-m offset and 8 and 15 kHz were used to measure in both HCP and VCP orientations. The multi-layer ERT conductivity distribution is used as input in an EM forward model using the same EMI configurations as used for the experimental measurements and the obtained results are used to calibrate the measured EMI data using a linear regression.

The calibrated experimental EMI data are inverted by a novel two-layer inversion algorithm that uses the different sensing depths of the different configurations and minimizing the misfit between the measured and modeled magnetic field using a combined global and local search approach. Here, the forward model is based on Maxwell's full solution for the magnetic field measured over a horizontally layered medium. The obtained two-layer inversion results in Figure 1b show similar structures and quantitative conductivity values as the ERT inversion results shown in Figure 1a.

Recently, more large-scale multi-configuration measurements have been performed. Here, corresponding ERT-EMI calibration transects were measured along strong gradients that were visible in the conductivity maps to ensure a wide range in conductivity values needed for the calibration. Currently these results are being inverted for two-layer structures.

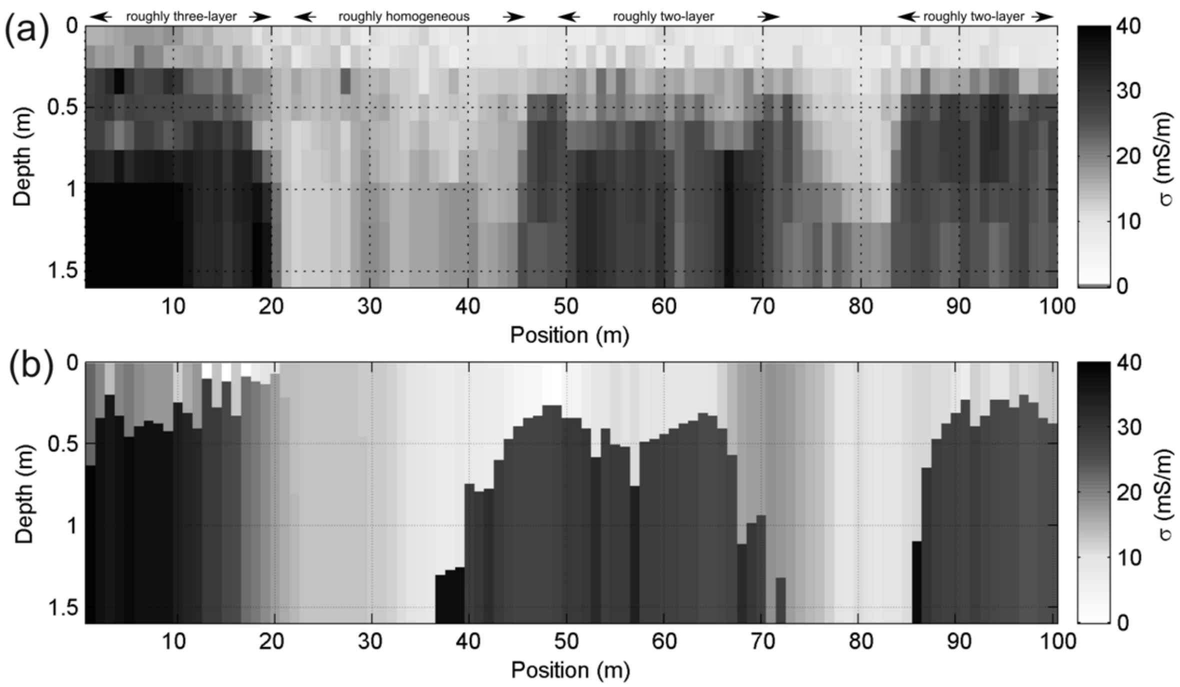

Fig. 1 (a) ERT inversion result, (b) quantitative two-layer EMI inversion