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Calibration and large-scale inversion of fixed-boom multi-configuration electromagnetic induction data for soil characterization

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Fixed-boom multi-configuration electromagnetic induction (EMI) devices can be used as non-invasive large-scale shallow subsurface imaging tools. Commercially available devices convert the measured magnetic fields into an apparent electrical conductivity (ECa), which can be shifted due to the presence of the operator and the system setup, e.g., GPS, cables, etc. When measuring the same transect either by hand or by using a sled using an EMI device with coil offsets between 32 and 118 cm oriented vertical or horizontal coplanar (VCP, HCP), we found significant ECa shifts up to 12 mS/m, i.e. 70% of maximum measured ECa. To investigate and remove these ECa shifts, 43 collocated EMI and electrical resistivity tomography (ERT) measurements were performed using different field setups, where 18 data sets using the identical sled setup showed consistent shifts that were largest for VCP and small coil offsets and decreased for increasing coil offsets and HCP mode. The ERT data were used to calibrate and thus obtain quantitative ECa values. In this way, multi-layered EMI inversions could be successfully performed, which would not have been possible without the calibration.

By combining multiple multi-configuration EMI devices having different coil offsets and orientations, the initial three-layer inversion using six EMI coil configurations (offsets between 32 und 118 cm) for the upper 2 meter has been extended to a five-layer inversion using 24 EMI coil configurations (offsets between 32 and 410 cm) for the upper 4 meter. The multi-layer inversion uses the L1-norm and a global optimization algorithm that respects the non-linearity that is present between the magnetic fields and the electrical conductivity as described by the Maxwell's equations. In this way, no low induction number approximation is made such that the approach is accurate for a wide range of subsurface electrical conductivities. The parallelized inversion scheme inverts each measurement position separately such that large-scale quasi-3D results are obtained by stitching the individual inversion results together.

Quasi-3D inversion results of quantitative large-scale multi-configuration EMI measurements of a 2.5 ha field with buried paleo-river channels return accurate electrical conductivity images that explain different crop behavior observed at the field due to the pathways of the buried paleo-river channels. This approach can be used for many large-scale 3D investigations such as soil salinity, soil water content and/or soil textural changes.