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Calibration and multi-layer inversion of multiple electromagnetic induction sensor data

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Multi-coil electromagnetic induction (EMI) sensors record simultaneously the apparent electrical conductivity (ECa) distribution of different integrated depths that can principally be used to invert for hydrologically relevant subsurface structures. However, EMI sensors induce not only magnetic fields in the subsurface but external conditions, e.g. the field setup, generate additional fields that shift the recorded ECa values. To obtain quantitative multi-coil EMI-ECa that make a multi-layer inversion possible, a post-calibration is required. Calibration for each coil configuration is performed using linear regressions between measured and predicted ECa that were obtained by inserting the electrical conductivities of inverted electrical resistivity tomography (ERT) data into a Maxwell-based EMI forward model. We measured 43 of these calibration lines using different field setups at various test sites and dates. Analyzing the data, we found a well-working calibration and a successful subsequent multi-layer inversion when relatively large lateral and vertical ECa values were found along the calibration line. However, we observed failure when either the measured or the predicted ECa range is < 3 mS/m and/or when the ground electrical conductivity is < 5 mS/m. Using selected calibration lines with coefficients of determination $R2 > 0.75$ in the linear regression equations, universal calibration parameters were obtained. Since the inversion of universally calibrated EMI-ECa returned similar subsurface structures as the ERT images, the results indicate that future ERT calibration measurements might become unnecessary. We also extended our three-layer inversion using one EMI sensor with 6 coil configurations to a combined multi-layer inversion of multiple sensors. Here, we preliminary show 4 and 5 layer inversion results of post-calibrated EMI-ECa measured above paleo-river channels with 24 coil configurations, i.e. DualEM plus a three- and a six coil CMD-MiniExplorer. Conclusively, the post-calibrated EMI-ECa data enable quantitative inversions reflecting large-scale vadose zone properties.