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Characterization of soil electrical conductivity from Chicken Creek Catchment using deep learning inversion of geophysical data

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Exploring hydrological and ecological processes plays a key role in understanding ecosystem developments. In this respect, the constructed catchment, Chicken Creek (Brandenburg, Germany), has been established for fundamental and interdisciplinary scientific research. The main components of the site include a base soil which is followed by a Tertiary clay layer (aquiclude) and sand layer (aquifer) on the top of the domain. In general, the soil mediates many of the processes that govern water resources and quality, such as the partition of precipitation into infiltration and runoff, groundwater recharge, contaminant transport, plant growth, evaporation and energy exchanges between the Earth's surface and its atmosphere. In this respect, characterization of the soil electrical conductivity (EC) is important, since it is highly correlated with different chemical and physical soil properties.

Low frequency loop-loop electromagnetic induction (EMI) techniques have found widespread application for non-invasive delineation of the subsurface EC structures at different spatial scales. However, successful inversion of EMI data has been a major challenge for decades, due to the non-linearity, non-uniqueness and dimensionality of the inverse problem. Here, a novel approach based on deep learning inversion via convolutional neural networks is proposed to instantaneously estimate subsurface EC layering from EMI data. In this respect, a fully convolutional network was trained on a large synthetic data set generated based on one-dimensional EMI forward model. The trained network was used to find subsurface electromagnetic conductivity images from EMI data measured along two transect from Chicken Creek catchment. Dipole-dipole electrical resistivity tomography data were measured as well to obtain reference subsurface EC distributions down to a 6 m depth. The inversely estimated models were juxtaposed and compared with their counterparts obtained from a spatially constrained deterministic algorithm as a standard code. Application of the deep learning inversion for subsurface imaging from Chicken Creek catchment manifested the accuracy and robustness of the proposed approach for EMI inversion. This approach returns subsurface EC distribution directly from EMI data in a single step without any iterations. The proposed strategy simplifies considerably EMI inversion and allows for rapid and accurate estimation of subsurface electromagnetic conductivity images from multi-configuration EMI data.