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Repeated electromagnetic induction measurements for mapping soil moisture at the field scale: comparison with data from a wireless soil moisture monitoring network

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Electromagnetic induction (EMI) methods are widely used for soil mapping, as they allow fast and relatively low-cost surveys of soil apparent electrical conductivity (ECa) at various scales. Soil ECa is well known to be influenced by both the volumetric content and the electrical conductivity (EC) of soil water, as well as by soil temperature and by the volume of the solid particles and their EC. Among other applications, EMI has become widely used to determine soil water content or to study hydrological processes within the field of hydrogeophysics. Although the use of non-invasive EMI for imaging soil spatial properties is very attractive, the dependence of ECa on several properties and states challenges any interpretation with respect to individual soil properties or states such as θ. The major aim of this study was to further investigate the potential of repeated EMI measurements to map soil moisture at the hillslope scale, with particular focus on the temporal variability of the spatial patterns of ECa and soil moisture, respectively, and on the stability of the ECa-soil moisture relationship over time. To this end, we compared time series of EMI measurements with high-resolution soil moisture data for a non-intensively managed hillslope area in the Schäfertal catchment (Central Germany) for which the spatial distribution of soil properties and soil water dynamics were known in detail. Soil water and temperature dynamics were observed in 40 soil profiles at hourly resolution during 14 months using a wireless monitoring network. During this period of time, ECa was mapped on seven occasions using an EM38-DD device. For the investigated site, ECa showed small temporal variations (ranging between 0 and 24 mS/m) whereas the temporal range of soil moisture was very large (from very dry to soil saturation). Furthermore, temporal changes of the spatial pattern of ECa differed from temporal changes of the spatial pattern of soil moisture. The ECa-soil moisture relationship varied with time, regardless the soil moisture state (dry, intermediate, or wet). Detailed information on soil water dynamics and the varying importance of the factors controlling the spatial distribution of soil moisture allowed explaining the temporal variability of the ECa-soil moisture relationship. Measurements indicate that spatial variations of ECa respond mostly to local soil properties (such as texture and clay content), and that ECa is correlated to the volumetric soil moisture only when local soil properties control the spatial pattern of soil moisture, but not when other factors such as topography play a major role. As a consequence, at the investigated site, temporal variations of the ECa-soil moisture relationship for soils with moderate clay content are presumed to be attributed to changes of background variables other than soil moisture such as pore water electrical conductivity. Further, the study gave us the opportunity to discuss the complex interplay between factors controlling ECa and soil moisture, and the use of EMI-based ECa data with respect to hydrological applications.