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Self-potential monitoring of water flux at the HOBE agricultural site, Voulund, Denmark

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Body: The self-potential (SP) method is of interest in hydrology and environmental sciences because of its non-invasive nature and its sensitivity to flow and transport processes in the subsurface. The contribution to the SP signal by water flux is referred to as the streaming potential and is due to the presence of an electrical double layer at the mineral-pore water interface. When water flows through the pore, it gives rise to a streaming current and a resulting measurable electrical voltage between non-polarizable electrodes placed at different locations. This electrokinetic behavior is well understood in water saturated porous media, but the best way to model streaming currents under partial saturation is still under discussion. To better understand SP data within the vadose zone, we conducted field-based monitoring of the vertical distribution of the SP signal following different hydrologic events. The investigations were carried out at the Voulund agricultural test site that is part of the Danish hydrological observatory, HOBE, located in the Skjern river catchment (Denmark) in the middle of a cultivated area. It has been instrumented since 2010 to monitor suction, water content and temperature down to a depth of 3 m, together with meteorological variables and repeated geophysical campaigns (cross borehole electrical resistivity tomography and ground penetrating radar). In July 2011, we installed 15 non-polarizable electrodes at 10 depths within the vadose zone (from 0.25 to 3.10 m) and a reference electrode below the water table (7.30 m). More than 2 years of data acquired at a measurement period of 5 minutes are now available with periods indicative of various hydrologic events, such as natural infiltration, water table rises and a high salinity tracer test. We performed wavelet-based signal analysis and investigated the wavelet coherency of the SP data with other measurement variables. The wavelet coherency analysis displays an anti-correlation between SP and water content at high frequencies (periods smaller than 1 day) and between SP and temperature at lower frequencies. For the high salinity tracer test, the continuous wavelet power spectra of the SP time series indicate that most signal energy is initially located in the higher frequencies at the top of the soil profile and later at lower frequencies at depth as the plume migrates downwards. We use a numerical model of the test site to simulate water fluxes, ionic transport and SP during different hydrological events. The first simulation results compare fairly well to the measured data. These initial results will serve as starting point for a detailed assessment of the value of SP data in vadose zone hydrology, particularly as a tool for in situ monitoring of water flux.