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Coupled fluid flow and electrokinetic model for evaluation of time-lapse self-potential (SP) measurements

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Movement of soil moisture associated with tree root-water uptake is ecologically important, but technically challenging to measure using traditional hydrological methods. Instead, we use the self-potential (SP) method to characterize water flow in situ. Unlike tensiometers and other point sensors, which use the measurement of state (e.g. matric pressure) at two locations to infer the intervening processes, the SP method measures signals generated by the dynamic process (e.g. water movement) occurring between two points. However, the strength (amplitude) of the SP signal is dependent on multiple soil properties, including effective excess charge, Qv, which is further dependent to soil moisture content.

We use a coupled fluid flow and electrokinetic model in COMSOL Multiphysics to evaluate field SP measurements collected in a two-dimensional array at the base of a Douglas-fir tree (*Psuedotsuga menziesii*) in the H.J. Andrews Experimental Forest in central Oregon, USA. We collected SP measurements over five months to provide insight on the propagation of transpiration signals into the subsurface with depth and under variable soil moisture. Our model is parameterized using a soil-specific petrophysical model to determine the value of Qv for varying soil saturations. The coupled model, which includes a root-water uptake term linked to measured sap flux, reproduced both the long-term and diel variations in SP measurements, thus confirming that SP has potential to provide spatially and temporally dense measurements of transpiration-induced changes in water flow.