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Estimation of effective soil hydraulic properties at field scale via ground albedo neutron sensing

C. A. Rivera Villarreyes, G. Baroni, and S. E. Oswald
University of Potsdam, Institute of Earth and Environmental Science, Potsdam, Germany (crivera@uni-potsdam.de)

Upscaling of soil hydraulic parameters is a big challenge in hydrological research, especially in model applications of water and solute transport processes. In this contest, numerous attempts have been made to optimize soil hydraulic properties using observations of state variables such as soil moisture. However, in most of the cases the observations are limited at the point-scale and then transferred to the model scale. In this way inherent small-scale soil heterogeneities and non-linearity of dominate processes introduce sources of error that can produce significant misinterpretation of hydrological scenarios and unrealistic predictions. On the other hand, remote-sensed soil moisture over large areas is also a new promising approach to derive effective soil hydraulic properties over its observation footprint, but it is still limited to the soil surface.
In this study we present a new methodology to derive soil moisture at the intermediate scale between point-scale observations and estimations at the remote-sensed scale. The data are then used for the estimation of effective soil hydraulic parameters. In particular, ground albedo neutron sensing (GANS) was used to derive non-invasive soil water content in a footprint of ca. 600 m diameter and a depth of few decimeters. This approach is based on the crucial role of hydrogen compared to other landscape materials as neutron moderator. As natural neutron measured aboveground depends on soil water content, the vertical footprint of the GANS method, i.e. its penetration depth, does also. Firstly, this study was designed to evaluate the dynamics of GANS vertical footprint and derive a mathematical model for its prediction. To test GANS-soil moisture and its penetration depth, it was accompanied by other soil moisture measurements (FDR) located at 5, 20 and 40 cm depths over the GANS horizontal footprint in a sunflower field (Brandenburg, Germany). Secondly, a HYDRUS-1D model was set up with monitored values of crop height and meteorological variables as input during a four-month period. Parameter estimation (PEST) software was coupled to HYDRUS-1D in order to calibrate soil hydraulic properties based on soil water content data. Thirdly, effective soil hydraulic properties were derived from GANS-soil moisture.
Our observations show the potential of GANS to compensate the lack of information at the intermediate scale, soil water content estimation and effective soil properties. Despite measurement volumes, GANS-derived soil water content compared quantitatively to FDRs at several depths. For one-hour estimations, root mean square error was estimated as 0.019, 0.029 and 0.036 m3/m3 for 5 cm, 20 cm and 40 cm depths, respectively. In the context of soil hydraulic properties, this first application of GANS method succeed and its estimations were comparable to those derived by other approaches.