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On the information content of cosmic-ray neutrons in Bayesian optimization of soil hydraulic properties

Giuseppe Brunetti (1), Jirka Šimůnek (2), Heye Bogena (3), Roland Baatz (3), Johan Alexander Huisman (3), Helen Dahlke (1), and Harry Vereecken (3)

(1) Department of Land, Air and, Water Resources, University of California, Davis, CA 95616, USA, (2) Department of Environmental Sciences, University of California, Riverside, CA, 92521, USA, (3) Agrosphere Institute, Forschusngszentrum Jülich GmbH, Germany

The accurate knowledge of soil hydraulic properties at a large scale is of crucial importance for land surface models. Non-invasive methods such as hydrogeophyscial methods, groundbased remote sensing and recently cosmic ray sensors provide near-surface estimates of soil moisture, which can be used in conjunction with hydrological models to inversely estimate soil hydraulic properties. In this view, cosmic-ray neutron sensing (CRNS) has proven to be a reliable method for the estimation of area-average soil moisture at field. Nevertheless, the assimilation of CRNS data in the Bayesian optimization of soil hydraulic properties is still unexploited. Thus, the main purpose of this study is to assess the information content of the aboveground fast-neutron count to estimate soil hydraulic parameters. The analytical model COSMIC, which is able to simulate the neutron intensity using the information about the soil moisture profiles, is externally coupled with the widely-used hydrological model HYDRUS-1D. One-month long synthetic datasets of fast-neutron counts and soil water contents are used to estimate the model predictive uncertainty. In particular, a Bayesian optimization framework based on the Affine Invariant Ensemble Sampler Monte Carlo algorithm is utilized to calculate the posterior distributions of soil hydraulic parameters, as well as the model predictive uncertainty, under different synthetic modeling scenarios. Results demonstrate that cosmic-ray neutron data provide an appreciable information content, which can be used in conjunction with another type of measurements to accurately estimate soil hydraulic properties at large scales.