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Robust spatialization of soil water content at the scale of an agricultural field using geophysical and geostatistical methods

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Research on the Critical Zone (CZ) is a prerequisite for undertaking issues related to ecosystemic services that human societies rely on (nutrient cycles, water supply and quality). However, while the upper part of CZ (vegetation, soil, surface water) is readily accessible, knowledge of the subsurface remains limited, due to the point-scale character of conventional direct observations. While the potential for geophysical methods to overcome this limitation is recognized, the translation of the geophysical information into physical properties or states of interest remains a challenge (e.g. the translation of soil electrical resistivity into soil water content).

In this study, we propose a geostatistical framework using the Bayesian Maximum Entropy (BME) approach to assimilate geophysical and point-scale data. We especially focus on the prediction of the spatial distribution of soil water content using (1) TDR point-scale measurements of soil water content, which are considered as accurate data, and (2) soil water content data derived from electrical resistivity measurements, which are uncertain data but spatially dense.

We used a synthetic dataset obtained with a vertical 2D domain to evaluate the performance of this geostatistical approach. Spatio-temporal simulations of soil water content were carried out using Hydrus-software for different scenarios: homogeneous or heterogeneous hydraulic conductivity distribution, and continuous or punctual infiltration pattern. From the simulations of soil water content, conceptual soil resistivity models were built using a forward modeling approach and point sampling of water content values, vertically ranged, were done. These two datasets are similar to field measurements of soil electrical resistivity (using electrical resistivity tomography, ERT) and soil water content (using TDR probes) obtained at the Boissy-le-Chatel site, in Orgeval catchment (East of Paris, France). We then integrated them into a specialization framework to predict the soil water content distribution and the results were compared to initial simulations (Hydrus results). We obtained more reliable water content specialization models when using the BME method. The presented approach integrates ERT and TDR measurements, and results demonstrate that its use significantly improves the spatial distribution of water content estimations. The approach will be applied to the experimental dataset collected at the Boissy le Châtel site where ERT data were collected daily during one hydrological year, using Syscal pro 48 electrodes (with a financial support of Equipex-Critex) and 10 TDR probes were used to monitor water content variation. Hourly hydrological survey (tile drainage discharge, precipitation, evapotranspiration variables and water table depth) were conducted at the same site. Data analysis and the application of geostatistical framework on the experimental dataset of 2015-2016 show satisfactory results and are reliable with the hydrological behavior of the study site.