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Analysing the Information Content of Point Measurements of the Soil Hydraulic State Variables by Global Sensitivity Analysis and Multiobjective Parameter Estimation

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Inverse modeling has become a common approach to infer the parameters of the water retention and hydraulic conductivity functions from observations of the vadose zone state variables during dynamic experiments under varying boundary conditions. This study focuses on the estimation and investigation of the feasibility of effective soil hydraulic properties to describe the soil water flow in an undisturbed $1m^3$ lysimeter. The lysimeter is equipped with 6 one-dimensional observation arrays consisting of 4 tensiometers and 4 water content probes each, leading to 6 replicated one-dimensional observations which establish the calibration data base.

Methods of global sensitivity analysis and multiobjective calibration strategies have been applied to examine the information content about the soil hydraulic parameters of the Mualem-van Genuchten (MvG) model contained in the individual data sets, to assess the tradeoffs between the different calibration data sets and to infer effective soil hydraulic properties for each of the arrays. The results show that (1) information about the MvG model parameters decreases with increasing depth, due to effects of overlapping soil layers and reduced soil water dynamics, (2) parameter uncertainty is affected by correlation between the individual parameters. Despite these difficulties, (3) effective one-dimensional parameter sets, which produce satisfying fits and have acceptable trade-offs, can be identified for all arrays, but (4) the array specific parameter sets vary significantly and cannot be transferred to simulate the water flow in other arrays, and (5) none of the parameter sets is suitable to simulate the integral water flow within the lysimeter.

The results of the study challenge the feasibility of the inversely estimated soil hydraulic properties from multiple point measurements of the soil hydraulic state variables. Relying only on point measurements inverse modeling can lead to promising results regarding the observations, while the model fails to simulate the integral soil water flow, which is hidden from the modeler. This underlines the need for more integral observation techniques in order to be able to estimate representative and robust effective soil hydraulic properties.