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Evaluating experimental design for soil-plant model selection with Bayesian model averaging

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The objective selection of appropriate models for realistic simulations of coupled soil-plant processes is a challenging task since the processes are complex, not fully understood at larger scales, and highly non-linear. Also, comprehensive data sets are scarce, and measurements are uncertain. In the past decades, a variety of different models have been developed that exhibit a wide range of complexity regarding their approximation of processes in the coupled model compartments.
We present a method for evaluating experimental design for maximum confidence in the model selection task. The method considers uncertainty in parameters, measurements and model structures. Advancing the ideas behind Bayesian Model Averaging (BMA), the model weights in BMA are perceived as uncertain quantities with assigned probability distributions that narrow down as more data are made available. This allows assessing the power of different data types, data densities and data locations in identifying the best model structure from among a suite of plausible models.
The models considered in this study are the crop models CERES, SUCROS, GECROS and SPASS, which are coupled to identical routines for simulating soil processes within the modelling framework Expert-N. The four models considerably differ in the degree of detail at which crop growth and root water uptake are represented. Monte-Carlo simulations were conducted for each of these models considering their uncertainty in soil hydraulic properties and selected crop model parameters. The models were then conditioned on field measurements of soil moisture, leaf-area index (LAI), and evapotranspiration rates (from eddy-covariance measurements) during a vegetation period of winter wheat at the Nellingen site in Southwestern Germany.
Following our new method, we derived the BMA model weights (and their distributions) when using all data or different subsets thereof. We discuss to which degree the posterior BMA mean outperformed the prior BMA mean and all individual posterior models, how informative the data types were for reducing prediction uncertainty of selected state variables, and how well the model structure can be identified based on the different data types and subsets.