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Sensitivity Analysis of the Land Surface Model NOAH-MP for Different Model Fluxes

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Land Surface Models (LSMs) use a plenitude of process descriptions to represent the carbon, energy and water cycles. They are highly complex and computationally expensive. Practitioners, however, are often only interested in specific outputs of the model such as latent heat or surface runoff. In model applications like parameter estimation, the most important parameters are then chosen by experience or expert knowledge. Hydrologists interested in surface runoff therefore chose mostly soil parameters while biogeochemists interested in carbon fluxes focus on vegetation parameters. However, this might lead to the omission of parameters that are important, for example, through strong interactions with the parameters chosen. It also happens during model development that some process descriptions contain fixed values, which are supposedly unimportant parameters. However, these hidden parameters remain normally undetected although they might be highly relevant during model calibration.

Sensitivity analyses are used to identify informative model parameters for a specific model output. Standard methods for sensitivity analysis such as Sobol indexes require large amounts of model evaluations, specifically in case of many model parameters. We hence propose to first use a recently developed inexpensive sequential screening method based on Elementary Effects that has proven to identify the relevant informative parameters. This reduces the number parameters and therefore model evaluations for subsequent analyses such as sensitivity analysis or model calibration.

In this study, we quantify parametric sensitivities of the land surface model NOAH-MP that is a state-of-the-art LSM and used at regional scale as the land surface scheme of the atmospheric Weather Research and Forecasting Model (WRF). NOAH-MP contains multiple process parameterizations yielding a considerable amount of parameters ($\approx$ 100). Sensitivities for the three model outputs (a) surface runoff, (b) soil drainage and (c) latent heat are calculated on twelve Model Parameter Estimation Experiment (MOPEX) catchments ranging in size from 1020 to 4421 km^2. This allows investigation of parametric sensitivities for distinct hydro-climatic characteristics, emphasizing different land-surface processes.

The sequential screening identifies the most informative parameters of NOAH-MP for different model output variables. The number of parameters is reduced substantially for all of the three model outputs to approximately 25. The subsequent Sobol method quantifies the sensitivities of these informative parameters. The study demonstrates the existence of sensitive, important parameters in almost all parts of the model irrespective of the considered output. Soil parameters, e.g., are informative for all three output variables whereas plant parameters are not only informative for latent heat but also for soil drainage because soil drainage is strongly coupled to transpiration through the soil water balance. These results contrast to the choice of only soil parameters in hydrological studies and only plant parameters in biogeochemical ones. The sequential screening identified several important hidden parameters that carry large sensitivities and have hence to be included during model calibration.