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Sensitivity Analysis and Parameter Identifiability of the Land Surface Model JULES at the point scale in permeable catchments

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Land surface models (LSMs) are recognised as important components of Global Circulation Models (GCMs). Simulating exchanges of the moisture, carbon and energy between land surface and atmosphere in a consistent manner requires physics-based LSMs of high complexity, fine vertical resolution and a large number of parameters that need to be estimated. The "physics" that is incorporated in such models is generally based on our knowledge of point (or very small) scale hydrological processes. Therefore, while larger GCM grid-scale performance may be the ultimate goal, the ability of the model to simulate the point-scale processes is, intuitively, a pre-requisite for its reliable use at larger scales. Critical evaluation of model performance and parameter uncertainty at point scales is therefore a rational starting point for critical evaluation of LSMs; and identification of optimal parameter sets at the point scale is a significant stage of the model evaluation at larger scales.

The Joint UK Land Environment Simulator (JULES) is a complex LSM, which is used to represent surface exchanges in the UK Met Office's forecast and climate change models. This complexity necessitates a large number of model parameters (in total 108) some of which are incapable of being measured directly at large (i.e. kilometer) scales. For this reason, a parameter sensitivity analysis is a vital confidence building process within the framework of every LSM, and as a part of the calibration strategy. The problem of JULES parameter estimation and uncertainty at the point scale with a view to assessing the accuracy and the uncertainty in the default parameter values is addressed. The sensitivity of the JULES output of soil moisture is examined using parameter response surface analysis. The implemented technique is based on the Regional Sensitivity Analysis method (RSA), which evaluates the model response surface over a region of parameter space using Monte Carlo sampling. The modified version of RSA used here takes into account a multiobjective approach, which means that more than one objective functions are evaluated. These are the Nash-Sutcliffe efficiency (NSE) and the Absolute value of the relative bias (Absr-bias). The sensitivity analysis also provided an approximation of the optimal parameter sets so that the residual model error would originate mainly from the datasets and the model structure. JULES performance at the point scale using the default recommended parameter values was variable. The case study area is focused on the Thames catchment and more specifically on the Pang and Lambourn catchments. The examined areas are located in the WarrenFarm site, a grassland livestock site that is high on Lambourn Downs, and the Frilsham Meadow site, a grassland recharge site next to the River Pang.

With the incorporation of the optimised parameters the soil moisture performance was considered reasonable so that there is no evidence that the model structure is insufficient in these catchments, and that the challenge is parameter estimation. The greater problem of parameter estimation at larger operational scales is discussed.