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On advances and opportunities in estimating effective parameters for land surface models

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In 1982, Jim Dooge[1] stated that ``the parameterization of hydrological processes to the grid scale of GCMs is a problem that has not been tacked, let alone solved''. Almost a decade later, Eric Wood (1990) reported that we have not performed the right experiments to address Dooge's Problem nor to solve the scale problem in hydrology. Decades later, reviews of the state of Land Surface Models (LSM) revealed that the source codes of LSMs tend to have up to hundreds of ``hidden'' parameters, many of them exhibiting large sensitivity to key fluxes and state variables like evapotranspiration, streamflow and soil moisture [3, 4]. Most of these parameters have a physical meaning, but often they are calibrated or provided to the models as inputs from look-up tables. These practices have undesirable implications such as overparameterization, lack of transferability across time, space or resolution, artifact generation, and biased predictions [5].

LSMs are currently used for high or hyper-resolution hydrological simulations that are the core of global monitoring or seasonal forecasting systems or providing boundary conditions (state variables) and land surface fluxes to GCMs. In a few years, they will become one of the main modules of existing efforts towards Digital Twins of the Earth's water cycle. Consequently, it is time to find better solutions for the old Dooge's Problem.

The parameterization of a LSM is an ill-posed problem leading to equifinal solutions [6]. Brute force calibration using only streamflow leads to non-transferable solutions [7]. An alternative approach is to use regularisation techniques (e.g., transfer functions) to reduce the degrees of freedom together with scaling operators to estimate effective parameters at the target resolution of the LSM. Multiscale Paramater Regionalization (MPR) [8] is one possible solution following this approach. Recent research have determined that the equifinality of transfer-functions and the corresponding parameters is very large [9].

In this study, we will report new attempts to find constraints in the functional space of the transfer functions and parameters that lead to physically plausible parameter fields for the mHM and HTESSEL models, both of which are used operationally across Europe and are part of the ULYSSES project (C3S) [10]. We will start by creating a catalog of existing pedo-transfer functions (PTF) for typical physical soil parameters such as soil porosity, hydrological conductivity, field capacity among others. Using the MPR stand-alone, model agnostic tool [11] we will perform a simplified sensitivity analysis to determine limiting ranges for the parameters of existing PTFs. The Soil Grids product [12] will be used as a reference to benchmark for the different PTFs.

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