TOWARDS SOIL HYDRAULIC PARAMETER RETRIEVAL FROM A LAND SURFACE MODEL UNDER DIFFERENT METEOROLOGICAL CONDITIONS

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1. INTRODUCTION

The soil moisture content imposes a significant control on evaporation and partitioning of rainfall into streamflow. However, temporal soil moisture evolution is not easy to measure or monitor at large scales due to its spatial variability, which is largely driven by the local variation in soil properties and the vegetation cover. Hence, soil moisture dynamics are often estimated using land surface models, with model physics based on low-resolution soil property maps which are normally prepared using pedotransfer functions [1]. Extrapolation over large areas yields crude estimates of soil hydraulic properties with large standard deviations, the accuracy of which deteriorates with the extent of the extrapolation, and consequently the accuracy of the model simulations. In order to achieve more reliable model predictions, there is a demonstrated need for more accurate and detailed soil parameter data sets than are currently available. To overcome this limitation, it is proposed that soil hydraulic properties be estimated through model calibration to remotely sensed near-surface soil moisture observations. Such a methodology is tested here through a synthetic twin experiment using the Particle Swarm Optimizing (PSO) [2, 3] method and the Joint UK Land Exchange Simulator (JULES) [4] land surface model. This study explores the capability of the model to retrieve soil hydraulic parameters through five different scenarios: (a) short dry-down period (SDD), (b) short dry period (SD), (c) short wet-up period (SWU), (d) short wet period (SW) and (e) full 12-months (LT) with multiple wet and dry periods, for four soil types: (a) homogeneous column of clay, (b) silty sand/clay, (c) clay/sand and, (d) homogenous column of sand.

2. METHODOLOGY

To achieve the objective of identifying the best meteorological conditions for the proposed methodology, parameters were initially retrieved one at a time. Firstly, using a set of hydraulic parameters which were identified as "true", JULES was used to simulate soil moisture for the selected time period. Based on the assumption that only the near-surface initial conditions were known, the model was first spun up so as to obtain the initial conditions of the profile. After simulating the truth soil moisture using the "true" parameters, soil hydraulic parameters were perturbed one at a time, representing the uncertainty in published soil hydraulic parameter maps.

Table 1: Matrix of the "retrieval" of individual parameters for each soil type under the different meteorological conditions.

Parameter	Sand					Silty Sand/Clay					Clay/Sand					Clay				
	SWU	SW	SDD	SD	LT	SWU	SW	SDD	SD	LT	SWU	SW	SDD	SD	LT	SWU	SW	SDD	SD	LT
b	○	○	●	●	●	●	●	●	●	●	○	○	○	○	●	●	●	●	●	●
Ks	●	○	○	●	●	○	●	○	●	●	●	○	○	○	●	●	●	●	●	●
suc	●	●	●	●	●	●	●	●	●	○	○	○	●	○	●	●	●	●	●	●
θ_s	●	●	●	●	●	○	●	●	●	●	○	○	○	●	●	●	●	○	○	○
θ_c	●	●	●	○	●	○	○	●	○	●	○	○	○	○	●	●	●	●	●	●
θ_w	○	○	○	○	○	○	○	○	○	●	○	○	○	○	●	○	○	○	○	●

● – Instances when each of the parameters have been retrieved (a) within 5% of the "true" value, (b) E>0.9 and, (c) RMSE < 0.009 m^3/m^3, ○ – Instances when either (a), (b) or (c) has not been fulfilled.

b - Clapp and Hornberger exponent (-), **Ks**, - Hydraulic conductivity at saturation (mm/s), **suc** - Soil matric suction at air entry (mm/s), **θ_s** - Volumetric fraction of soil moisture at saturation (m^3/m^3), **θ_c** - Volumetric fraction of soil moisture at critical point (for a soil suction of 3.364 m) (m^3/m^3), **θ_w** - Volumetric fraction of soil moisture at wilting point (for a soil suction of 152.9 m) (m^3/m^3)

Since only the remotely sensed near-surface soil moisture was assumed available for setting the initial conditions during parameter retrieval, the states for the rest of the profile was established through the spin-up of the model. The perturbed soil hydraulic parameter(s) were then retrieved according to A and B horizons. The retrieval was undertaken using the PSO algorithm, which changed the specified parameter(s) by minimizing an objective function, the root mean square error between the simulated soil moisture using the “true” parameter()s and “retrieved” parameter(s) in this instance. All four soil types were tested under the five different meteorological conditions, and the corresponding RMSE in predicted soil moisture calculated from the "true" and "retrieved" soil hydraulic parameters. The Nash-Sutcliffe coefficient [5] was then used to assess the predictive power of the hydrological model, corresponding to all soil types and meteorological conditions.

3. RESULTS AND DISCUSSION

Table 1 summarizes the reliability with which each parameter has been “retrieved”, taking into consideration the "true" value of the parameter, the Nash-Sutcliff model efficiency values and the Root Mean Square Errors (RMSEs), as explained in the caption. It is observed that some parameters (examples are the Clapp and Hornberger exponent and the suction at air entry) could be retrieved under a wide range of conditions, while some could only be retrieved under very specific conditions. For example, if the soil is a homogeneous column of clay, it was found that soil hydraulic parameters could be retrieved under all meteorological conditions, while the converse is true for a mixed soil column comprising of clay/sand, with soil hydraulic parameter retrieval only possible during the long term period. For the mixed column of silty loam/clay, successful retrieval was possible under two scenarios, the long term period and a short dry-down period. For a homogeneous column of sand, all

meteorological conditions apart from the short dry period showed good results. The wilting point moisture content is a parameter that has proved difficult to retrieve and the homogeneous column of sand is in fact incapable of allowing the retrieval under any meteorological condition. However, the other three soil types allow the retrieval of the wilting point moisture content only during the 12-month period. The Nash-Sutcliffe model efficiency parameter (*E*) for the volumetric fraction of water at wilting point was unity in most cases (not shown here), indicating that the simulation and "true" observations are a perfect match.

4. CONCLUSIONS

The overall observation was that soil hydraulic parameters were most likely to be retrieved accurately when using a long period of observation (ie 12-months), including several wetting and drying cycles. It was also observed that when there is a higher percentage of clay in the soil column, parameters are better retrieved than for a more sandy soil. This may be explained by the differences in the physical properties of the soil and subsequent characteristics. In a clay soil, the particles are smaller with a low permeability, and takes quite a while for any changes to be reflected. On the other hand, a sandy soil is more dynamic and hence rapid changes occur through the profile, in terms of fluxes, drainage and so on, that contributes towards soil moisture dynamics, thereby influencing the soil hydraulic parameter retrieval. Additionally, the best retrieval of soil parameters is obtained for the homogeneous columns of soil than for the mixed columns. This can be explained with the fact that when the soil column consists of two or more profiles, the optimizer has a choice of several parameters to change and when one parameter is changed significantly, it could push the objective function to a minimum even while the other parameters may have not been changed much.

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