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IMPROVEMENT OF THE HYDROLOGICAL PERFORMANCE OF LAND SURFACE PARAMETERIZATION: AN APPLICATION TO THE NILE BASIN

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ABSTRACT

This thesis investigates the hydrological performance of land surface schemes (LSSs) and attempts to improve current schemes via calibration at the global circulation model (GCM) scale and via simple modification to represent hydrological features such as routing and lakes. The Nile basin has been used thought this study as a large hydrological basin for the evaluation of a selected LSS (the UK Met Office Surface Exchange Scheme, MOSES) and for assessing the impacts of the proposed modifications on the performance.

This thesis used a relatively uncommon approach to evaluate the hydrological performance of MOSES. This approach utilized the local knowledge of the Nile basin, in the form of results from a fine-resolution calibrated model (the Nile Forecasting System, NFS), to aid in the evaluation and calibration of MOSES at the GCM scale. This approach can be generalised to make use of operational models of the different rivers, which will generally be well-calibrated and validated for their sub-basins, to improve the performance of global models. This can also help overcome the scarcity of data often encountered in global hydrological applications.

In order to be able to compare MOSES results to those of the NFS, both models have to be forced with the same meteological inputs, primarily rainfall. Therefore, a disaggregation scheme capable of disaggregating rainfall, amongst other meteorological variables, is investigated using raingauge data from the Nile basin and the Blackwater Catchment (UK). Whilst the model preserves the mean properties of rainfall occurrence and depth, it significantly overestimates rainfall variability. Regional calibration and better formulation of the rainfall generator improve the simulation of variability as well as other aspects of rainfall properties. The assessment of the generator emphasizes the spatial dependence of rainfall properties, which may be utilized to transfer data from one spatial scale to another.

This study assesses the performance of MOSES for two regions in the Nile basin using quasi-observed runoff series from the NFS, which is first assessed to ensure its reliability in simulating streamflow at key locations within the basin. Calibration of MOSES using the NFS quasi-observed runoff series improves its performance. Calibrating the large number of MOSES parameters requires large computational resources to conduct calibration at the global scale. This study shows that the high dimensionality of the LSS calibration problem can be greatly reduced via a simple sensitivity analysis to reduce the number of sampled parameters and thus the number of required samples. The saved computational resources can be directed to calibrate

the scheme for other regions or to regionalize the calibration results. The selection of proper calibration criteria is vital to obtain a parameter set that performs well for the different modes of the hydrograph and the different output fluxes of the LSS. The choice of the sensitive parameters is very important for the success of the limited sampling scheme. While total runoff may show little sensitivity to one parameter, runoff components (surface and subsurface) may show higher sensitivities to that parameter affecting the hydrograph shape. In addition, the relationships between runoff (or other fluxes) and the parameters may change from one year to another (i.e. non-stationary) and this should be considered when selecting the sensitive parameters.

The study also shows that simple conceptual extensions to LSSs, such as linear reservoirs or lake water balance models, can be used to better represent the hydrological features that are missing in most LSSs. They are computationally efficient as required for global scale applications and require only few parameters that can be obtained from local knowledge, or through calibration. These findings can have significant impacts on the future development of land surface schemes.