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Multi-scale global reconstruction of water fluxes and states with mHM

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Land surface and hydrologic models (LSM/HMs) have been typically calibrated with streamflow for selected river basins. This procedure, although it is the current standard, it is highly disadvantageous because the resulting model 1) is not transferable to other locations and scales, 2) it underperforms against multivariate data not used during calibration, and 3) simulated fluxes do not fulfill the flux-matching closure condition [1] if compared across scales. These shortcomings lead to parameter fields exhibiting artifacts and sharp discontinuities over space (not seamless) [2] and thus, to a poor spatial representation of water fluxes and states. Existing terrestrial water cycle observations have spatial supports ranging from few hundred square meters to hundred square kilometers. Currently, most of the existing LSM/HMs are not able to assimilate simultaneously these observations because they do not have scale-invariant parameterizations. Preliminary tests at continental scale indicate that nested multiscale simulations are possible only if the model exhibits a scale-invariant parameterization [3]. In mHM [4], this capability is provided via the multiscale parameter regionalization (MPR) technique [1].

In this study, transfer-function parameters for mHM are estimated with 5500 GRDC streamflow time series, tens of FLUXNET evapotranspiration products, and the terrestrial total water storage anomaly (GRACE). This parameter estimation problem at global-scale requires a powerful supercomputer (JUWELS) [5] and the usage of recently implemented and extremely efficient parallelized algorithms [6]. The daily reconstructed high-resolution hydrologic simulations (0.25°) since 1950 reveal that the use of the MPR technique improves the overall model efficiency (compared to other global models [7]) and allows us to identify locations of consistent changes in hydrologic variables responding to long-term climate variability. The median of the NSE for the uncalibrated mHM model over the selected GRDC stations reaches a value of 0.40 for daily streamflow. Models reported in Beck et al. [7] exhibit a mean value of -0.09! This indicates the great potential of the proposed method. Comparison of terrestrial water storage (TWS) of GRACE against mHM simulations reveals hotspots of weaker model performance in regions where the water balance closure error is large.

References

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