Application of a Unified Land Model for Estimation of the Terrestrial Water Balance

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ABSTRACT

The modeling component of this study is focused on Unified Land Model (ULM; Livneh et al., 2010). Figure 1 highlights the components that were preserved from the two parent models (Noah and Sac). The key aspects of the merger were: (i) introducing the Noah vegetation scheme into the Sac model structure, hence allowing for physically-based moisture extraction and interception as well as a dynamic potential evapotranspiration (PET) estimation; and (ii) simulating the component of conceptual moisture storages into physical layers of soil (as opposed to a layer of water with variable ET), which allows for interactive ET, soil moisture, and snow sub-basins, a lagged water balance, and exchange, via an adaptation of the method of Koster et al. (1990). Evaluation of the terrestrial water budget with focus on ET

The focus of this study is to estimate areal ET at the land surface using three independent methods. First, at large scales (≥ 100,000 km²) ET can be estimated through an atmospheric water balance as the residual term between precipitation, changes in precipitable water and moisture content in an evolving atmospheric column, as shown in Figure 5. The domain for large-scale ET estimation is shown in Figure 6 along with stream gauges by basin. Second, we consider an entirely satellite-based estimate of ET following Tang et al., 2009, that utilizes an empirical relationship between vegetation cover and surface temperature (V–T) as shown in Figure 7. Third, ET is estimated from ULM simulation, which is the sum of resistance-based estimates of soil and canopy evaporation, whilst using a Jarvis-type transpiration formulation. This final method allows for an examination of other water budget terms to assess the overall partitioning of each component in the balance. Figure 8 compares these sources. The first two methods agree on the peak magnitude of ET for western basins, although peak timing is always sooner in the first method. For basins with large disparities in the first two methods, ULM shows even larger differences, generally underestimated peak monthly ET, suggesting that parameter calibrations could be beneficial.

Initial model evaluation

ULM was evaluated at a set of river basins that span a range of hydroclimatic regimes (Figure 2). Initial testing used a priori parameters from the each parent model (Noah-NLDAS; Sac-Koren et al., 2003), followed by and assessments of ULM parameter sensitivity and limited calibration, primarily focusing on streamflow performance. Figure 3 shows that streamflow prediction improvements were most notable for less-arid basins, while parameter tunings were necessary to achieve improvements over all study basins, the majority of which were obtained through adjusting only the 3 most sensitive model parameters (not shown).

Partitions of net radiation into surface heat fluxes was done at 4 locations (Figure 4). In general, ULM performed similarly to Noah, or slightly better as compared with observations. More limited soil moisture testing was done, due to lack of quality data at these sites, where ULM was again similar to Noah, with the exception of improved performance during the soil drying phase. Attempts were made to transfer model parameters from streamflow tunings to heat flux and soil moisture simulation, without a conclusive addition in model performance.

Calibrations, stream flow and further testing

Preliminary results are for model simulations using a priori parameters only. Model residuals are shown in Figure 9. ULM generally under predicts peak (summer) ET, reflecting a lag in peak timing. For basins where snowmelt contributes a large portion of the hydrograph, the timing and magnitude of peak ULM runoff is notably different from the gauge value, likely attributable to differences in timing of peak SW, as well as adjustments needed in model parameters to more adequately store and transmit runoff. Figure 9 shows a CDF of annual peak flows, indicating a greater overestimation of low flow events by ULM. The domain for upcoming catchment-scale analysis is given in Figure 10.

References

Livneh, B., P.J. Restrepo, and D.P. Lettenmaier, 2010: Development of a Unified Land Model. J. Hydrometeorol. (submitted), and proceedings of symposium S7 held during the Seventh IAHS Scientific Assembly at Foz do Iguacu, Brazil, April 2005). Progress (Proceedings of symposium S7 held during the Seventh IAHS Scientific Assembly at Foz do Iguacu, Brazil, April 2005), IAHS Publ. 303, 125-133.
