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Hydrological simulations at basin scale using distributed model and remote sensing with a focus of soil moisture

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Abstract

Remotely-sensed precipitation and soil moisture products are becoming increasingly important sources of information in earth science system. However, there are still high degree of uncertainties inherited in remotely-sensed precipitation and soil moisture products, and limited studies have focused on evaluation of these products. In this study, GEOtop model (Rigon et al. 2006), which is physically-based distributed hydrological model, is used to assess the use of remotely-sensed precipitation and soil moisture products for hydrological applications. The study area is Little Washita watershed (583 km2), Oklahoma, USA. To assess these products, the model has to be first calibrated and validated at different locations in the watershed using extensive ground-based measurements. The Southern Great Plains 1997 (SGP97) and SGP99 Hydrology Experiment are used for model calibration and validation, respectively. The model is reasonably calibrated and validated at watershed scale at different locations in the watershed for: heat fluxes, soil temperature profiles, soil moisture profiles, and streamflows. Regarding soil moisture evolution, we studied the spatial variability of the near-surface soil moisture from GEOtop simulations and estimates from Electronically Scanned Thinned Array Radiometer (ESTAR). Results show that GEOtop simulations and ESTAR estimates show very different magnitude and spatial patterns of near-surface soil moisture. Spatial patterns derived from GEOtop simulations are in agreement with the previous findings obtained from the same study area using ground-based measurements of soil moisture and theoretical model simulations. We conclude that GEOtop simulation results are more accurate and that ESTAR estimates are not a reliable source of data for characterizing the spatial variability of near-surface soil moisture. GEOtop simulations show that the spatial distribution of near-surface soil moisture is highly controlled by soil texture and river network. Furthermore, we investigated the effect of vegetation, surface roughness, and topography on ESTAR. Results show that there are insignificant effects of vegetation except for interception, surface roughness, and topography on ESTAR. In addition, we investigated the scaling properties of near-surface soil moisture. Results show that near-surface soil moisture has multiscaling behaviour. On the other hand, spatial soil moisture patterns are studied using geostatistical techniques: Ordinary kriging, external drift kriging and conditional Gaussian simulations (CGSs). Krigings show that soil moisture patterns in the watershed are highly controlled by gradient and cosine aspect. All CGSs clearly show soil moisture patterns. Spatial soil moisture patterns produced by CGSs are much better than the patterns reproduced by kriging algorithms. Regarding remotely-sensed precipitation products, we have investigated the utility of these products for hydrological simulations during non-winter seasons. Results show that all remotely-sensed precipitation products (Climate Prediction Center's morphing technique (CMORPH), Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks - Cloud Classification System (PERSIANN-CCS)- and Next Generation Weather Radar (NEXRAD Stage III)) are fairly reproducing the streamflows, but CMORPH often overestimates streamflows. Thus it concluded that all the above mentioned remotely-sensed precipitation products have value for streamflow simulations.

Keywords: Distributed hydrological model; GEOtop, passive microwave radiometer soil moistures(ESTAR), space-time soil moisture variability, remotely-sensed precipitation, Little Washita watershed.