Geophysical Research Abstracts
Vol. 17, EGU2015-6780, 2015
EGU General Assembly 2015

Influence of simulation time-step (temporal-scale) on optimal parameter estimation and runoff prediction performance in hydrological modeling

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Nowadays, most hydrological catchment models are designed to allow their use for streamflow simulation at different time-scales. While this permits models to be applied for broader purposes, it can also be a source of error in hydrological processes simulation at catchment scale. Those errors seem not to affect significantly simple conceptual models, but this flexibility may lead to large behavior errors in physically based models. Equations used in processes such as those related to soil moisture time-variation are usually representative at certain time-scales but they may not characterize properly water transfer in soil layers at larger scales. This effect is especially relevant as we move from detailed hourly scale to daily time-step, which are common time scales used at catchment streamflow simulation for different research and management practices purposes. This study aims to provide an objective methodology to identify the degree of similarity of optimal parameter values when hydrological catchment model calibration is developed at different time-scales. Thus, providing information for an informed discussion of physical parameter significance on hydrological models.

In this research, we analyze the influence of time scale simulation on: 1) the optimal values of six highly sensitive parameters of the TOPLATS model and 2) the streamflow simulation efficiency, while optimization is carried out at different time scales. TOPLATS (TOPMODEL-based Land-Atmosphere Transfer Scheme) has been applied on its lumped version on three catchments of varying size located in northern Spain. The model has its basis on shallow groundwater gradients (related to local topography) that set up spatial patterns of soil moisture and are assumed to control infiltration and runoff during storm events and evaporation and drainage in between storm events. The model calculates the saturated portion of the catchment at each time step based on Topographical Index (TI) intervals. Surface runoff is then calculated at rainfall events proportionally to the saturation degree of the catchment. Separately, baseflow is calculated based on the distance between catchment average water table depth and specific depth at each TI interval. This study focuses on the comparison of hourly and daily simulations for the 2000-2007 time period.

An optimization algorithm has been applied to identify the optimal values of the following four soil properties: 1) Brooks-Corey pore size distribution index (β), 2) Bubbling pressure (ψc), 3) Saturated soil moisture (θs), 4) Surface saturated hydraulic conductivity (Ks), and two subsurface flow controlling parameters: 1) Subsurface flow at complete saturation (Q0), and 2) Exponential coefficient for TOPMODEL baseflow equation (f). The algorithm was set up to maximize Nash-Sutcliffe Efficiency (NSE) at the catchment outlet.

Results presented include the optimal values of each parameter at both hourly and daily time scale. These values provided valuable information to discuss the relative importance of each soil-related model parameter for enhanced streamflow simulation and adequate model response to both surface runoff and baseflow simulation. Catchment baseflow magnitude (Q0) and decay behavior (f) are also proved to require detailed analysis depending on the selected hydrological modeling purpose and corresponding selected time-step.

Obtained results showed that different time-scale simulations may require different parameter values for soil properties and catchment behavior characterization in order to properly simulate streamflow at catchment scale. Despite calibrated parameters were soil properties and water flow quantities with physical meaning and defined units, optimum values differed with time-scale and were not always similar to field observations.