Geophysical Research Abstracts
Vol. 18, EGU2016-6533-1, 2016
EGU General Assembly 2016

ASCAT soil moisture data assimilation through the Ensemble Kalman Filter for improving streamflow simulation in Mediterranean catchments

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Assimilation of Surface Soil Moisture (SSM) observations obtained from remote sensing techniques have been shown to improve streamflow prediction at different time scales of hydrological modeling. Different sensors and methods have been tested for their application in SSM estimation, especially in the microwave region of the electromagnetic spectrum. The available observation devices include passive microwave sensors such as the Advanced Microwave Scanning Radiometer – Earth Observation System (AMSR-E) onboard the Aqua satellite and the Soil Moisture and Ocean Salinity (SMOS) mission. On the other hand, active microwave systems include Scatterometers (SCAT) onboard the European Remote Sensing satellites (ERS-1/2) and the Advanced Scatterometer (ASCAT) onboard MetOp-A satellite.

Data assimilation (DA) include different techniques that have been applied in hydrology and other fields for decades. These techniques include, among others, Kalman Filtering (KF), Variational Assimilation or Particle Filtering. From the initial KF method, different techniques were developed to suit its application to different systems. The Ensemble Kalman Filter (EnKF), extensively applied in hydrological modeling improvement, shows its capability to deal with nonlinear model dynamics without linearizing model equations, as its main advantage.

The objective of this study was to investigate whether data assimilation of SSM ASCAT observations, through the EnKF method, could improve streamflow simulation of mediterranean catchments with TOPLATS hydrological complex model. The DA technique was programmed in FORTRAN, and applied to hourly simulations of TOPLATS catchment model. TOPLATS (TOPMODEL-based Land-Atmosphere Transfer Scheme) was applied on its lumped version for two mediterranean catchments of similar size, located in northern Spain (Arga, 741 km2) and central Italy (Nestore, 720 km2). The model performs a separated computation of energy and water balances. In those balances, the soil is divided into two layers, the upper Surface Zone (SZ), and the deeper Transmission Zone (TZ). In this study, the SZ depth was fixed to 5 cm, for adequate assimilation of observed data.

Available data was distributed as follows: first, the model was calibrated for the 2001-2007 period; then the 2007-2010 period was used for satellite data rescaling purposes. Finally, data assimilation was applied during the validation (2010-2013) period. Application of the EnKF required the following steps: 1) rescaling of satellite data, 2) transformation of rescaled data into Soil Water Index (SWI) through a moving average filter, where a T = 9 calibrated value was applied, 3) generation of a 50 member ensemble through perturbation of inputs (rainfall and temperature) and three selected parameters, 4) validation of the ensemble through the compliance of two criteria based on ensemble's spread, mean square error and skill and, 5) Kalman Gain calculation. In this work, comparison of three satellite data rescaling techniques: 1) cumulative distribution Function (CDF) matching, 2) variance matching and 3) linear least square regression was also performed.

Results obtained in this study showed slight improvements of hourly Nash-Sutcliffe Efficiency (NSE) in both catchments, with the different rescaling methods evaluated. Larger improvements were found in terms of seasonal simulated volume error reduction.