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Improving streamflow prediction at catchment scale through the assimilation of a downscaled SMOS/MODIS soil moisture product

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Microwave remote sensing missions currently provide an increasing number of surface soil moisture (SSM) products with improved spatial and temporal resolution. These products provide reliable moisture content data, even in real-time, that when properly integrated with hydrological catchment models, they are expected to improve streamflow predictions. A main constraint for the assimilation of these remotely sensed SSM data (DA) into hydrological models is the coarse spatial resolution of the available products (25-50 km pixels). Thus, in recent years, different downscaling approaches have been developed and validated, based on different active and passive sensors retrievals.

The downscaled products are especially suited to be integrated with fully-distributed hydrological catchment models. Among many techniques applied in hydrological data assimilation, the Ensemble Kalman Filter (EnKF) and its variants are most commonly used. In this respect, different studies have demonstrated that the observed SSM data need to be re-scaled prior to the assimilation in order to solve the inherent systematic differences obtained when estimating a variable through different methods (i.e. modeling and remote sensing retrieval). This study evaluated the impact on streamflow prediction of assimilating a SMOS-based high-resolution SSM product (1 km), developed at the Barcelona SMOS Expert Center (SMOS-BEC L4 product). This product is at 10 and 1 km resolutions resulting from a downscaling scheme that improves spatial resolution of original SMOS data with the use of higher resolution visible/infrared (VIS/IR) MODIS satellite data.

The study presented here aimed to improve the hourly streamflow simulation of a 258-km2 catchment (Cidacos river), located in a Mediterranean climate area, in Northern Spain. The hydrological model used was the fully distributed mode of the physically based TOPLATS model (1 km grid). It was calibrated for a 7-year period, and data assimilation was performed and evaluated for a separate two-year period (2013-2015). Moreover, this study tested the performance of applying three different re-scaling techniques to the observed SSM data: Linear Re-scaling (LR), Variance Matching method (VM) and Cumulative Distribution Function matching (CDF). Also, to account for the possible large errors in SSM remote sensing retrievals over densely vegetated or steep relief areas, three different assimilation scenarios were tested: (1) DA over the whole catchment, (2) DA excluding densely vegetated areas and (3) DA excluding steep relief areas.

The results showed that assimilating the downscaled SMOS-BEC L4 product over the whole catchment slightly deteriorated the streamflow simulation efficiency (Nash-Sutcliffe, NSE) and generated large total simulated volume (Pbias) errors (>30%). On the other hand, SSM-DA only over cultivated or flat areas provided positive efficiency variations (i.e. NSE increased from 0.68 to 0.76/0.77, while maintaining the Pbias error within an acceptable range 12-15%). The LR outperformed the other two re-scaling techniques tested. Based on this research, it can be concluded that there is a potential to improve hydrological catchment models predictions through the assimilation of remotely sensed SSM downscaled products, but the error associated to the topography and land use conditions of the observed area needs to be adequately considered.