The Suitability of Eight Spatial Rainfall Products to Simulate Daily Streamflow in Semi-Arid Watersheds using the HBV model

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Accurate rainfall measurements are crucial for hydrologic modeling. They are mainly provided by rain gauges (RGs), which cover only limited areas. Thus, the gauging network density and distribution can be real constraints in water-related studies, particularly in semi-arid regions. This is the case of Ait-Ouchene and Tilouguite, two mountainous sub-watersheds of the Oum-Rr-Rbia river basin, located in Morocco. Several freely available Spatial Rainfall Products (SRP), with quasi-global coverage, provide rainfall estimates that can constitute a potential complement to the RGs. In this context, we intend to investigate the suitability of eight SRPs (ARC2, CHIRPSp25km, CHIRPSp5km, CMORPH-CRT-V1, GPM-IMERG-V6, PERSIANN-CDR, RFE2, and TRMM-3B42-V7) for daily streamflow simulation in Ait-Ouchene and Tillouguite for the period 2001-2010. We proceeded by a pixel-wise and watershed-wise comparison against data of twenty-six RGs in Oum-Rr-Rbia, using the PCC (Pearson Correlation Coefficient), RMSE, Bias, POD (Detection Probability), and FAR (False Alarms Ratio) metrics. Then, the SRPs were used to annually calibrate the HBV conceptual rainfall-runoff model in Ait-Ouchene and Tillouguite. The SRP-driven simulations’ accuracy was assessed against the gauged streamflow using the NSE metric.

Primarily, the model was tested in Ait-Ouchene through cross-validation, parameter sensitivity, and parameter interdependency analyses, using the RG and MODIS-SCA observations. The results showed that the HBV model can fairly reproduce the observed streamflow, with year-to-year variable reliability. Additionally, the hydroclimatic changes appeared to actuate the model parameters’ interdependency. The latter were found to combine either to shrink the storage capacity of the model’s reservoirs under extremely high streamflow or enlarge them under overestimated water supply, mainly from snow cover. Thus, the snowmelt sub-routine was deactivated, during the evaluation process, to avoid the SWE compensating the bias in the SRP estimates.

Regarding the SRPs evaluation, the rainfall estimates performed relatively poorly for both direct comparison and hydrologic modeling. Most SRPs yielded PCCs below 0.5, except for IMERG and RFE. They exhibited PCCs between 0.54-0.62 (IMERG) and 0.47-0.71 (RFE) at 50% of the RGs, with
IMERG performing the best at eighteen out of the twenty-six RGs. IMERG prevalence was also observed in terms of detection capacity showing the highest PODs alongside PERSIANN. The SRPs detected many rainfall events as false alarms, with median FARs greater than 0.52. However, an analysis, where we considered only the grid-cells encompassing more than one RG, revealed that a portion of the false alarms were rainfalls that fell in the RGs' vicinity. Moreover, the rainfall estimates were substantially biased, where the large rainfall totals were predominantly underestimated. For streamflow simulation, the SRPs' performance seemed unsteady and varied depending on years and products. While IMERG and RFE frequently produced the best NSEs, CMORPH consistently showed the weakest results. In addition to the important bias contained in the SRP estimates, the low performance in hydrologic modeling can be related to the abundance of insignificant false alarms. Nevertheless, the SRPs provided better streamflow estimates than the RGs in Tillouguite, which has an unevenly distributed gauging network concentrated near the outlet.