EVALUATION OF SATELLITE PRECIPITATION PRODUCTS THROUGH HYDROLOGIC SIMULATION UNDER DATA-SCARCE ENVIRONMENT

by

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ABSTRACT

A watershed normally receives precipitation in the form of rainwater or snow melts and disposes of it to the water body. Hydrological modelling provides quick responses to a variety of hydrological scenarios in a watershed and helps in decision making processes. Precipitation is a critical for hydrological studies because of its spatio-temporal variations that traditional rain gauges and radar networks cannot record. It necessitates such a technique that supplements the rain-gauge assessments. The precipitation datasets collected from remote sensing satellite are now a days used for flood forecasting in gauged and ungauged catchment. In this study, three high-resolution Satellite Precipitation Products (SPP) i.e., Integrated Multi-satellite Retrievals for GPM (IMERG), Global Satellite Mapping of Precipitation (GSMaP) and Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) have been evaluated statistically and hydrologically in a data scars region, i.e., the Chenab River catchment of Pakistan.

The considered categorical statistical metrics were Probability of Detection (POD), Critical Success Index (CSI) and False Alarm Ratio (FAR). Continuous statistical metrics applied were correlation coefficient (CC), root mean square error (RMSE), Bias (B) and coefficient of determination (R^2), and for intercomparison, Taylor diagram was used to obtain standard deviation of the used SPP based datasets. Hydrological assessments were done through different calibration scenarios and hydrological signatures. Physically distributed hydrological model, i.e., The Integrated Flood Analysis System (IFAS) with a two-layer and three tank system was employed for hydrological modelling. The most sensitive calibrating parameter was identified with sensitivity analysis by simulating the model using ±20% of calibrated parameters. Three calibration scenarios for simulating streamflow were considered

using each CHIRPS, GSMaP, and IMERG precipitation datasets. All datasets were validated against each calibration scenario. The model performance indicators were coefficient of determination (R^2), Nash–Sutcliffe Efficiency (NSE), and Percentage Bias (PBIAS).

The consistency of daily gauge rainfall data of four stations, Gujrat, Sialkot, Sargodha, and Jhang, has been evaluated annually through a double mass curve (DMC) from 2015 to 2020. The R^2 values were found in the range of 0.98 to 0.99 for all gauging stations, indicating that the rain gauge-based precipitation dataset was consistent.

Statistical analysis for categorical metrics revealed that the mean POD of GSMaP was superior to that of CHIRPS and IMERG for all time scales. The mean POD of CHIRPS and IMERG was 52% and 21% less for monsoon, and 66 and 38% less for western disturbance than that of GSMaP. The slight difference between GSMaP and IMERG performance was revealed for FAR evaluation across all time scales, whereas CHIRPS underperformed. In terms of bias, satellite products performed better at 10-daily and monthly scales. More bias was observed during monsoon season than during western disturbance season. All SPP produced lower RMSE during the western disturbance season. Similarly, the mean CC-value for GSMaP was higher during monsoon, western disturbance, and daily scale, while IMERG had higher CC on a 10-daily and monthly scale. Inter-comparison statistical evaluation revealed the capability of GSMaP to detect rainfall was superior to other. IMERG secured second position and CHIRPS at the end with higher bias, RMSE, FAR and lowered CC, POD, CSI values.

Sensitivity analysis for surface tank parameters revealed that the surface tank height (HFMND) and final infiltration capacity of the soil were the two most sensitive parameters. Similarly, the effect of storage height to generate base flow (AGD) and the initial value used for calculation (HIGD) were the most sensitive parameters for the aquifer tank. For the river tank parameters, the parameters related to cross section i.e., RLCOF and RBS were more sensitive. Overall, the base flow coefficient (AGD) was the most sensitive parameter for the IFAS model.

The hydrological assessment revealed that the statistical indicators R^2, NSE and PBIAS were in the range of 0.89-97, 0.86-96 and -0.03- -0.16, respectively, for the calibration period. In the validation/application year 2017, the GSMaP followed the trend of observed flows but could not capture the flood peaks greater than 3000 cumecs. Hydrographic comparisons between observed and simulated flows by the IMERG and the CHIRPS were identical. The inter-comparison of statistical indicators revealed the comparatively better performance of the GSMaP dataset with the highest R^2 (0.85), NSE (0.80) and PBIAS (0.16) values, respectively, among the used satellite products. The flow duration curve (FDC results displayed that the selected satellite dataset has relatively inferior performance in capturing extreme flooding conditions and low flows. While considering the medium flow, all datasets showed excellent performance in the range of 20% to 40% exceedance time.