APPLICABILITY OF SATELLITE RAINFALL OBSERVATION FOR FLOOD FORECASTING IN A TRANS BOUNDARY BASIN, PAKISTAN

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ABSTRACT

Mangla basin is the trans boundary basin of river Jhelum, a northeastern tributary of Indus River System. Almost 45% area is in Pakistan while rest of the basin is in Indian part of Kashmir. GSMaP was expected to be used for the purpose to get rainfall across the border but the GSMaP often underestimate thus a correction method developed by JAXA was used. In addition to JAXA correction the offset value and the scale factors were calculated by comparing GSMaP and GSMaP corrected by JAXA method in Pakistan side of the basin and then applied across the border. To find the better performance of the correction technique used, first of all IFAS model was calibrated by using corrected rainfall by offset value and corrected by scale factor for flood event 2014, but later it was found that the response of the parameters calibrated with corrected rain by scale factor provided little response for small rainfall events thus these parameters were not used for validation. The IFAS model was validated for both the rainfall corrected by offset value and scale factor for three flood events 2010, 2011 and 2013. The NSE, r and r^2 values showed that the rainfall corrected by scale factor provided reasonable results in the validation process. For real time flood forecasting the IFAS model showed better results by extending the one month period keeping the default initial conditions. The study revealed that the corrected rainfall by applying the scale factor provided better results than the offset corrected rainfall during the validation period.

Keywords: Trans boundary, Satellite rainfall correction, Flood forecasting, IFAS, GSMaP

1. INTRODUCTION

Floods are no doubt the natural hazards that can be posed as disasters if not forecasted well before hand. Out of all the population that is affected by the natural hazards 90% are affected by floods (Haider, 2006). Pakistan is a flood prone country and the upper catchments of Northeastern Rivers lies in India. In order to predict the floods the accurate and timely rainfall information is required but the rainfall data on the part of Indian side cannot be obtained that is a bottleneck for the development of an early warning system. The Satellite rainfall data such as GSMaP was expected to be utilized for flood forecasting by estimating the rainfall across the border but this product often underestimate that needs to be corrected. The main purpose of this study was the application of a methodology for flood forecasting by which the rainfall across the border can be estimated reasonably so that on the basis of which the flood forecast/warning could be issued. This study required a method in which satellite rainfall rate and the rainfall area far away from gauged location can be corrected. The predictions of rainfall runoff models also greatly affected by the accuracy of rainfall estimates (Duncan et al., 1993).JAXA method was likely to be used in this study for rainfall correction.

1. THEORY AND METHODOLOGY

The upper catchment of River Jhelum, with outlet point at Mangla Dam, is located both in Indian and

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Pakistan Kashmir. The GSMaP was used for this study to estimate the rainfall across the border while to correct the rainfall the JAXA correction method was used. The JAXA correction method correct the GSMaP by using ground rainfall data synchronously by comparison between the two data sets. As the JAXA method correct the rainfall by combining the weighted mean (distance and topography) only at each observatory as shown in Figure 1(b) but the problem of the study was to estimate the reasonable rainfall amount across the border. To overcome this discrepancy an additional correction was applied by applying offset value and scale factor across the border as shown in Figure 2. Then by using the average of GSMaP and the average of JAXA corrected GSMaP over the reference area the offset value and the scale factor were calculated by using the following equation over the reference area on daily basis.

Reference Area

Offset value = avg [GSMaP(corr)]-avg[GSMaP(org)]

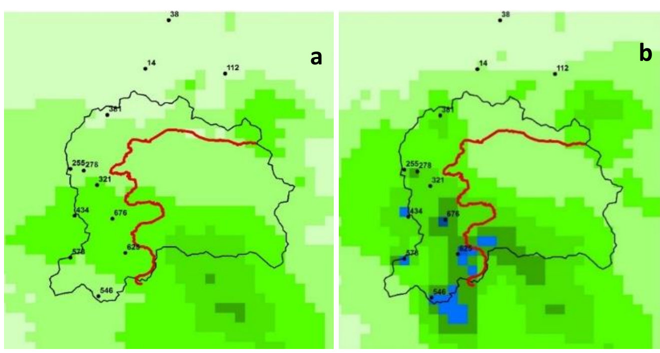
Scale factor = avg[GSMaP(corr)]/avg[GSMaP(org)]

Then these values were applied to the target area grid by grid by using the following equation

Target Area

Corr GSMaP(Offset)= GSMaP (org)+Offset value

Corr GSMaP(Scale)= GSMaP (org)*Scale factor



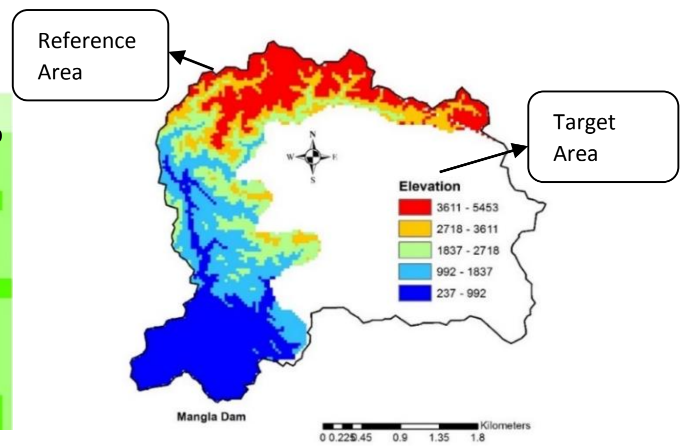


Figure 1 Accumulated rainfall before and after JAXA correction   Figure 2 Reference and Target area map

A catchment average rainfall approach was used for this study for the rainfall comparison and to understand the hydrological effect of the basin. The catchment average rainfall approach allows a more direct inference on the hydrological impact of the satellite rainfall estimation and also the catchment size influences the satellite rainfall errors (Mei et al., 2014). The IFAS model was used to generate the daily average catchment rainfall for ground, GSMaP, GSMaP corrected by JAXA method and GSMaP corrected by offset value and scale factor. Firstly the sensitivity analysis was done for tuning the IFAS model by using the gauged rainfall data in Pakistan. After tuning the model the model was simulated and the results were compared with the observed one by using GSMaP, GSMaP JAXA corrected and corrected by offset value and scale factor. Then the IFAS model was calibrated and validated by using the rainfall corrected by offset value and scale factor over the entire basin. The values of calibrated parameters are shown in the Table 1 for flood 2014. Finally the model was simulated for real time flood forecasting.

2. DATA

Rainfall data for the twelve stations and the discharge data at the site of Mangla was used to achieve the goals of the study. The discharge data was provided by Water and Power Development Authority (WAPDA) and rainfall data was provided by PMD (Pakistan Meteorological Department). The GSMaP data was also used after necessary corrections for the study period.

Table 1 Parameters set by calibration by using scale rain and offset rain

Tanks	Parameters		Classes	Unit	Simulation		
					Tuned(gauged)	Calibrated(O)	Calibrated(S)
Surface	Final infiltration capacity	SKF	2	cm/s	0.00002	0.000002	0.00002
			3		0.00001	0.000001	0.00001
	Max Water Height	HFMXD	2	m	0.175	0.04	0.175
			3		0.175	0.04	0.195
	Height rapid intermediate flow	HFMND	2	m	0.01	0.01	0.005
			3		0.01	0.01	0.005
	Roughness Coefficient	SNF	2	$m^{-1/3}/s$	2.00	1.50	1.00
			3		2.00	1.50	1.00
	Initial water height	HIFD	1	m	0.00	0.05	0.00
Aquifer	Confined aquifer flow	AGD	1	l/day	0.003	0.001	0.003
	Unconfined aquifer flow	AUD	1	$(l/mm/day)^{1/2}$	0.01	0.13	0.00001
	Initial water height	HIGD	1	m	2.00	1.9	2.00

3. RESULTS AND DISCUSSION

First of all the sensitivity analysis for parameter tuning of IFAS model was done by using the gauge rainfall data on Pakistan side and on the basis of this analysis the model was tuned by keeping maximum water height (HFMXD) in the surface tank to 0.175 m and unconfined aquifer flow (AUD) in the aquifer tank to 0.01 $(l/mm/day)^{1/2}$. The accumulated rainfall of (a) GSMaP-NRT, (b) GSMaP-NRT Corrected by JAXA method and (c) GSMaP-NRT corrected by offset value and (d) scale factor were analyzed for flood event 2014 during the period from 1st August to 15th September 2014 as shown in the Figure 3 and the IFAS model was simulated by using tuned parameters during sensitivity analysis for each of the rainfall product as shown in Figure 4.

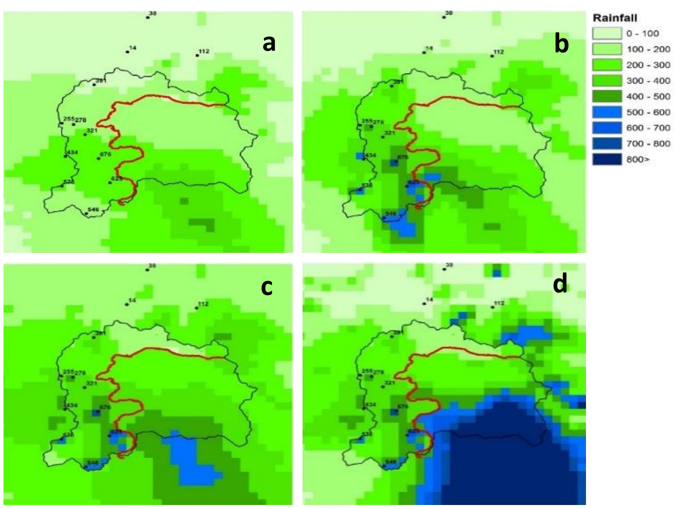


Figure 3 Accumulated rainfall GSMaP NRT

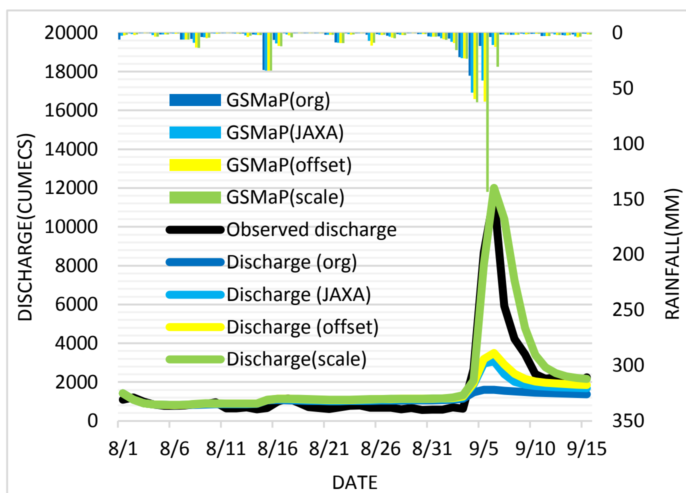


Figure 4 Hydrograph comparison with observed

The coefficient of determination r^2 for GSMaP, GSMaP corrected by JAXA method, corrected by offset value and scale factor were calculated as 0.19, 0.58, 0.72 and 0.91 respectively. Then the IFAS model was calibrated only by using the rainfall products after correcting by offset value and scale factor as shown in Figure 5.

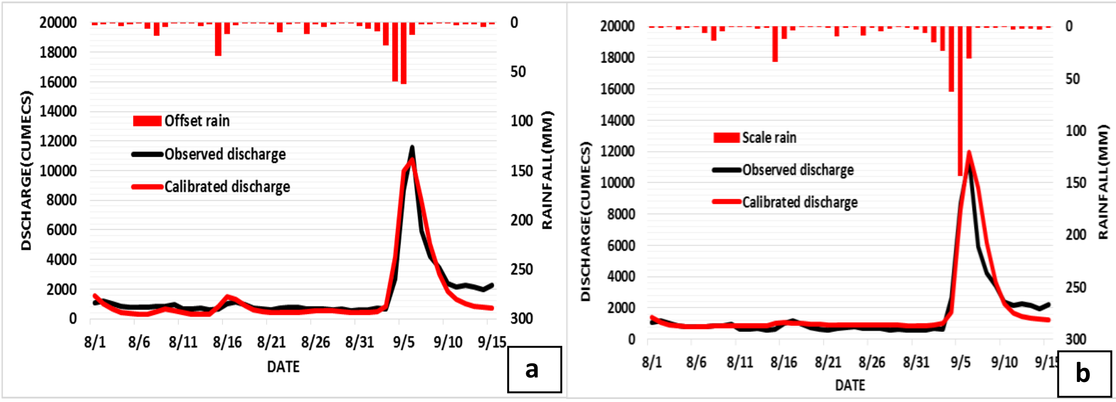


Figure 5 Calibration of IFAS model by using satellite rainfall after applying (a) Offset correction (b) Scale correction

The Nash–Sutcliffe Efficiency (NSE) by calibrated parameters using offset and scale rain were calculated as 0.89 and 0.88 respectively and the coefficient of determination r^2 value were calculated as 0.92 and 0.91 respectively for flood event 2014. For validation three flood events were selected for the years 2010, 2011 and 2013. In the validation process of the study when the calibrated model by scale rain was tested the results were not good. The reason may be the little response for moderate rainfall events. Thus the model calibrated with scale rain will not be used in the next stage of the study. Now onwards the model calibrated with offset rain will be used for validation for both the rainfall corrected by offset value and scale factors. The IFAS model was simulated for corrected rainfall by offset value and scale factor for validation and Nash–Sutcliffe Efficiency (NSE) were calculated as 0.38 and 0.51 respectively and the r^2 value were calculated as 0.53 and 0.72 respectively for the 2010 flood event. The IFAS model simulated results provided NSE value for offset and scale rain as -0.21 and 0.35 respectively while r^2 value as 0.25 and 0.56 respectively for 2011 case. For 2013 case the IFAS simulation provided NSE values for offset and scale rain as -0.04 and 0.21 respectively while the r^2 value were calculated as 0.23 and 0.42 respectively. For 2010 flood event the initial condition was set to 1.9m for water height in the aquifer tank including the calibrated parameters. The hydrograph for this flood event is shown in the Figure 6. In case of 2011 flood event the calibrated parameters and the initial conditions of the aquifer tank water height 2.0m were used for the validation and the hydrograph is shown in Figure 7. For 2013 case the model was simulated by setting the initial condition of the aquifer water height to 1.9m and the hydrograph is shown by the Figure 8.

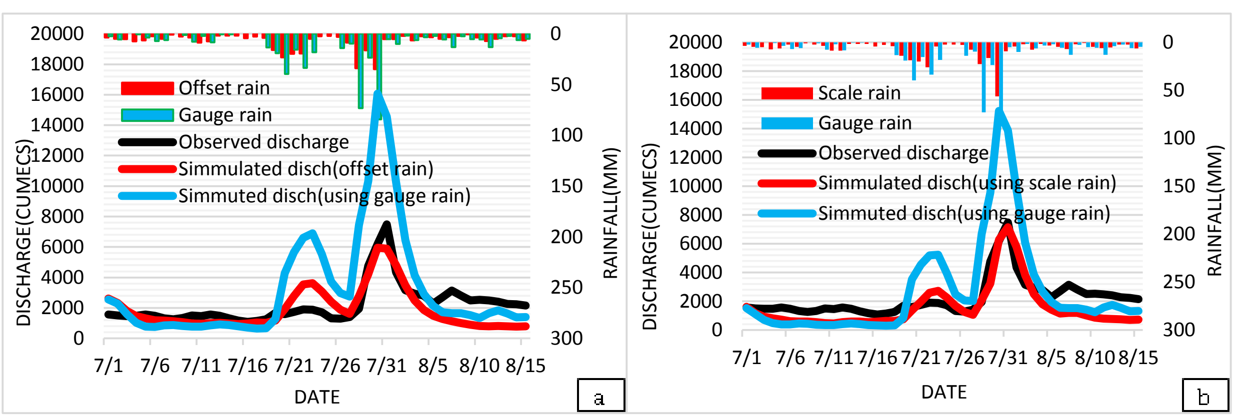


Figure 6 Validation using (a) offset rain (b) scale rain for flood event 2010

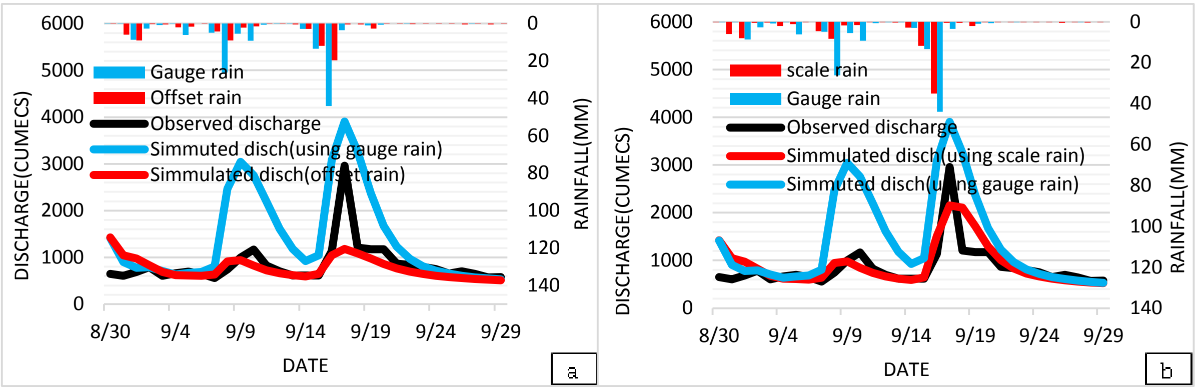


Figure 7 Validation using (a) offset and (b) scale rain for flood event 2011

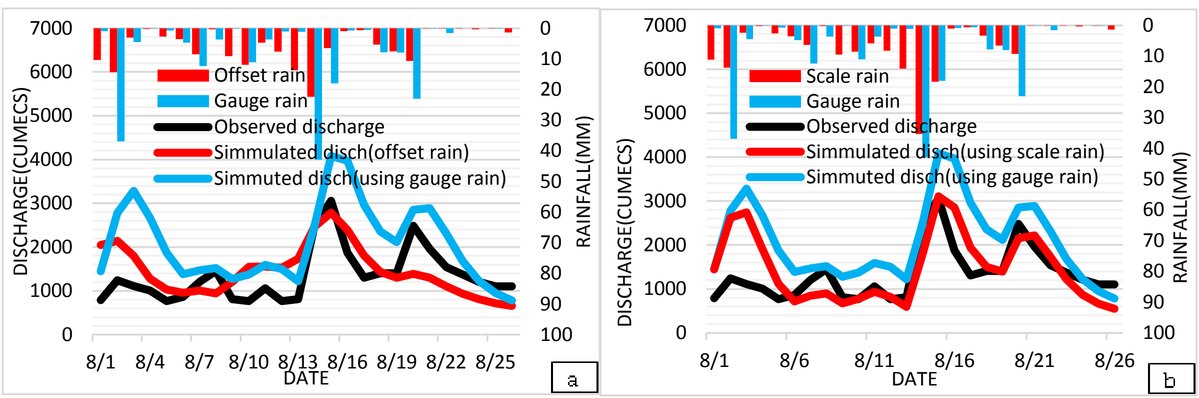


Figure 8 Validation using (a) offset and (b) scale rain for flood event 2013

In all of the three validated flood events the results by using the scale rainfall provided the better performance than the offset value rainfall. Finally the IFAS model was simulated for real time flood forecasting just by extending the period by one month before the validation period for all the three flood events for 2010, 2011 and 2013. It was observed that there was no change in the discharge values after simulation for the forecasted period by taking the initial conditions of the tanks as default values as shown in Figure 9.

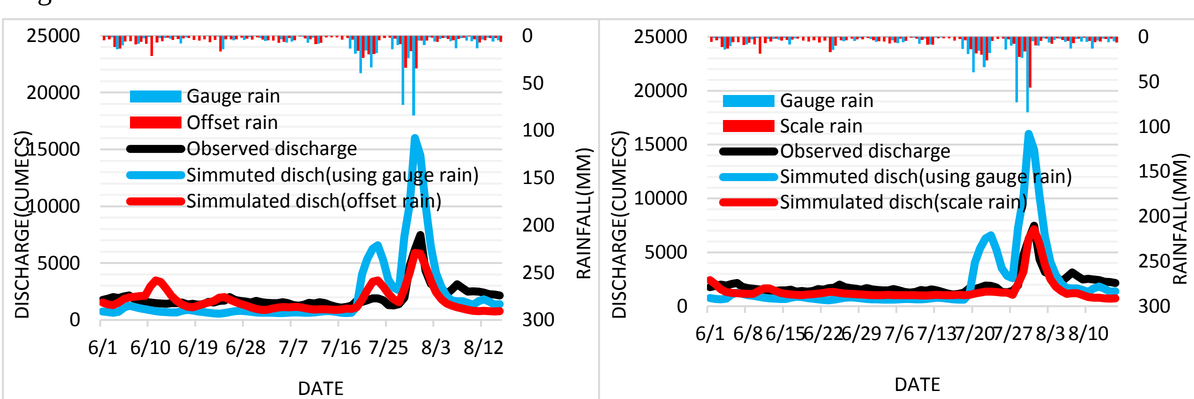


Figure 9 Real time forecasting for validated period using (a) offset and (b) scale rain for flood event 2010

5. RECOMMENDATIONS

The following recommendations are made for future work and studies.
1) In this study only one of the northeastern river upstream basin was considered but this technique can be applied to the other northeastern rivers of Pakistan.
2) The newly developed technique by applying scale and offset concept should be considered as by using such approach the rainfall across the border can be corrected in northeastern and eastern parts of Pakistan
3) As the percentage correction of the rainfall were found to be different for each of the study case thus care should be taken in adopting the correction methodology.

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