Assessing the Impact of Gridded Precipitation Datasets on Blue and Green Water Flow Accounting with Two Hydrological Models in the Damodar River Basin, India

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Abstract

The hydrological behavior and freshwater availability in any typical river basin are highly dependent upon precipitation making it the most crucial input variable for hydrological modelling. Precipitation as an input variable to hydrological models is available in gridded form with various spatiotemporal resolution. The variations in the model inputs could be subjected to uncertainties in the hydrological model simulation, which further affect the estimation of blue water flow (BWF) and green water flow (GWF) of a river basin. In this study, we investigated the effects of three gridded precipitation datasets [Watch forcing data ERA-Interim (WFDEI); Princeton datasets; Indian Meteorological Department (IMD)] on streamflow pattern, BWF, and GWF using a semi-distributed hydrological model [Soil and Water Assessment Tool (SWAT)] and a lumped rainfall-runoff model [Hydrological Simulation model (HYSIM)] in the Damodar river basin situated in eastern India. Both the models are simulated at daily time steps with the calibration of ten years (1994 – 2004) and validation of five years (2005 – 2010) at catchment outlet (Durgapur barrage) using three precipitation datasets. The performance of all the three precipitation products is evaluated on the basis of streamflow simulation for both HYSIM and SWAT model at the basin outlet using the performance indicators viz., Nash-Sutcliffe efficiency (NSE), coefficient of determination (R2) and percent bias (PBIAS). The seasonal and annual variation in precipitation values of the WFDEI, Princeton, and IMD dataset could attribute to the significant variations in the performance indicators. Subsequently, the best performance in streamflow simulation is achieved by HYSIM model compared to SWAT with IMD precipitation input. Both models showed remarkable differences in BWF and GWF estimation due to changes in precipitation inputs. The results also indicate that BWF is more sensitive to precipitation than GWF as BWF is directly generated from precipitation. All the above observations suggest that the choice of appropriate precipitation datasets is essential to examine the catchment hydrological behavior, and it further helps policymakers to make critical water management decisions.

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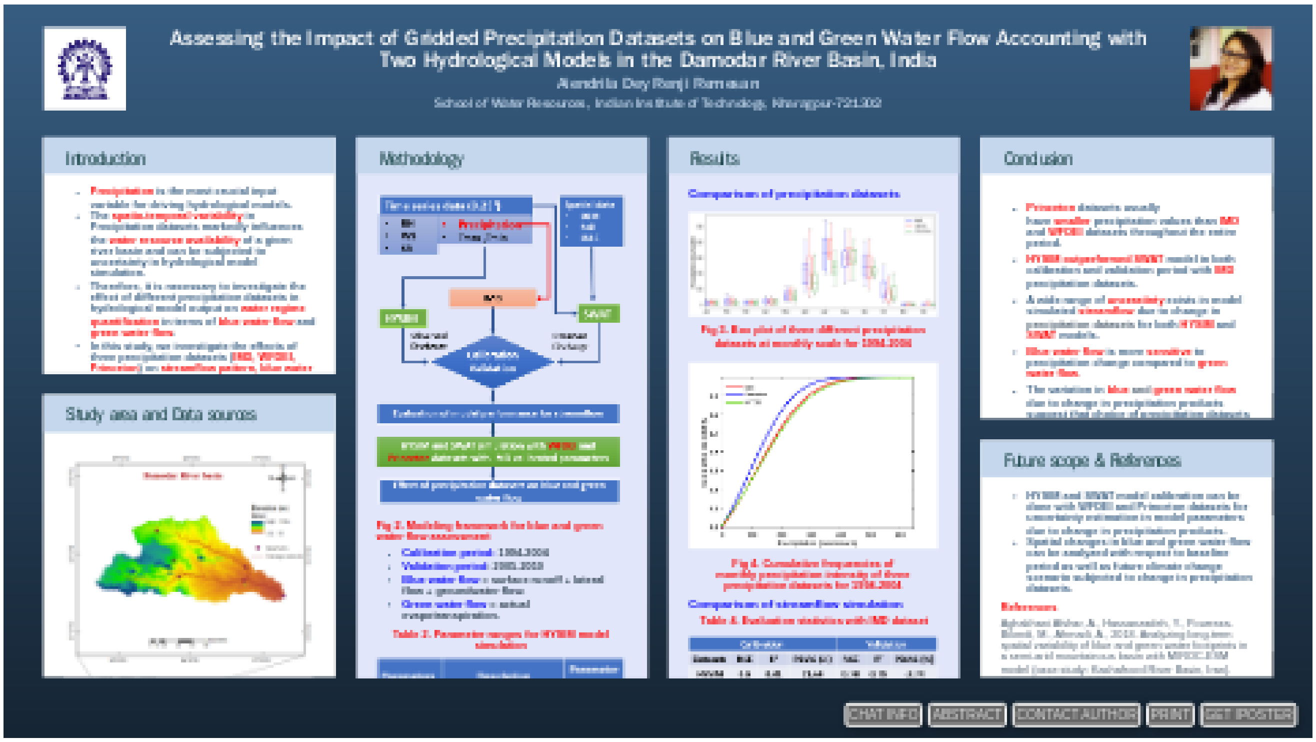

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INTRODUCTION

- **Precipitation is the most crucial input variable for driving hydrological models.**
- **The spatio-temporal variability in Precipitation datasets markedly influences the water resource availability of a given river basin and can be subjected to uncertainty in hydrological model simulation.**
- **Therefore, it is necessary to investigate the effect of different precipitation datasets in hydrological model output on water regime quantification in terms of blue water flow and green water flow.**
- **In this study, we investigate the effects of three precipitation datasets (IMD, WFDEI, Princeton) on streamflow pattern, blue water flow and green water flow using a lumped rainfall runoff model [Hydrological Simulation model (HYSIM)] and a semi-distributed hydrological model [Soil and Water Assessment Tool (SWAT)] in Damodar river basin situated in eastern India.**

STUDY AREA AND DATA SOURCES

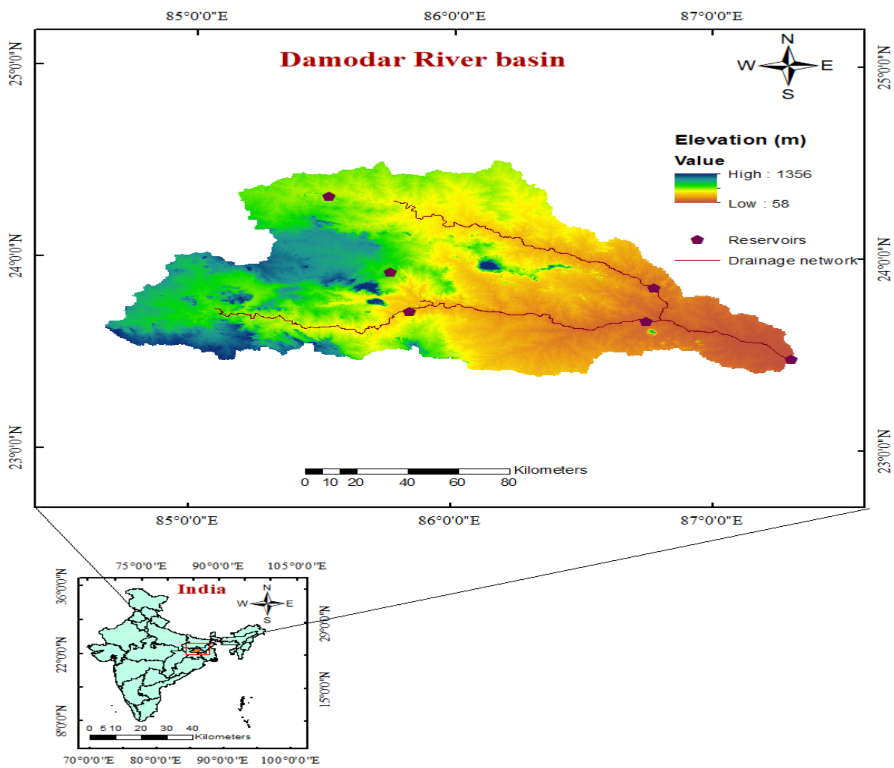

Fig 1. Index map of Damodar river basin

- **Area of the river basin: 23,370 km²**
- **Length of the river: 592 km**

Table 1. Data required and its sources

Data	Scale	Source
Digital Elevation Model	30m	Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)
Soil Map	30 m	Food and Agricultural Organization (FAO)
Land Use and Land Cover	23.5 m	National Remote Sensing Center (NRSC)
Precipitation	27.75 km	• Indian Meteorological Department (IMD) • Watch Forcing Data ERA-Interim (WFDEI) • Princeton Datasets
Temperature	38 km	Climate Forecast System Reanalysis (CFSR)
Discharge	Daily	Irrigation and Waterways Department, Govt. of West Bengal
Potential Evapotranspiration(PET)	38 km	Climate Forecast System Reanalysis (CFSR)

METHODOLOGY

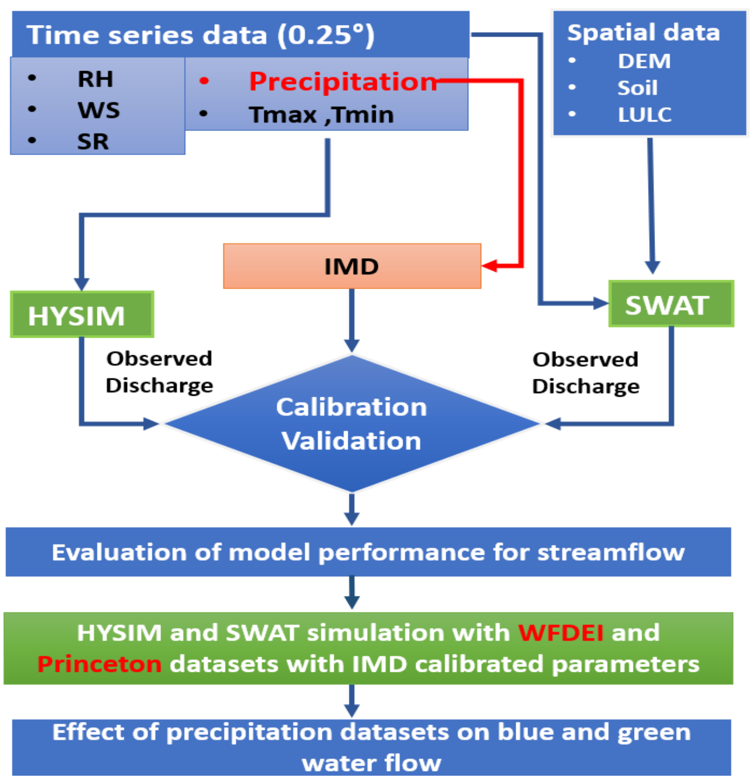

Fig 2. Modeling framework for blue and green water flow assessment

- **Calibration period: 1994-2004**
- **Validation period: 2005-2010**
- **Blue water flow = surface runoff + lateral flow + groundwater flow.**
- **Green water flow = actual evapotranspiration.**

Table 2. Parameter ranges for HYSIM model simulation

Parameters	Description	Parameter range
RD	Rooting Depth (mm)	1700-2700
PHB	Permeability-horizon boundary (mm/h)	91-230
PBLH	Permeability-base lower horizon (mm/h)	4011.11
IU	Interflow-upper (mm/h)	147-228
IL	Interflow-lower (mm/h)	9.95-15.78

Table 3. Parameter ranges and best parameters used in SWAT model simulation

Parameter	Description	Parameter range	Best parameter
v_CH_K2	Effective hydraulic conductivity in main channel alluvium	14.42-24.89	22.77
v_ALPHA_BNK	Baseflow alpha factor for bank storage	1.02-1.10	1.10
r_SOL_AWC	Saturated hydraulic conductivity	1.19-1.4	1.35
v_ALPHA_BF	Baseflow alpha factor	1.007-1.1.98	1.02
r_CN2	SCS runoff curve number	-0.02 - 0.08	0.04
v_CH_N2	Manning's n value for main channel	0.09-0.15	0.12
v_GW_DELAY	Groundwater delay time	5.45-12.27	8.16
v_GW_REVAP	Groundwater "revap" coefficient	0-0.116	0.04
v_GWQMN	Threshold depth of water in shallow aquifer required for return flow	1512.67-1598.41	1525.74
v_SURLAG	Surface runoff lag time	18.11-20.8	18.4
v_RCHRG_DP	Deep aquifer percolation fraction	0-1	0.1
v_REVAPMN	Threshold depth of water in shallow aquifer required for "revap" to occur	570.12-685.35	620.53

RESULTS

Comparison of precipitation datasets

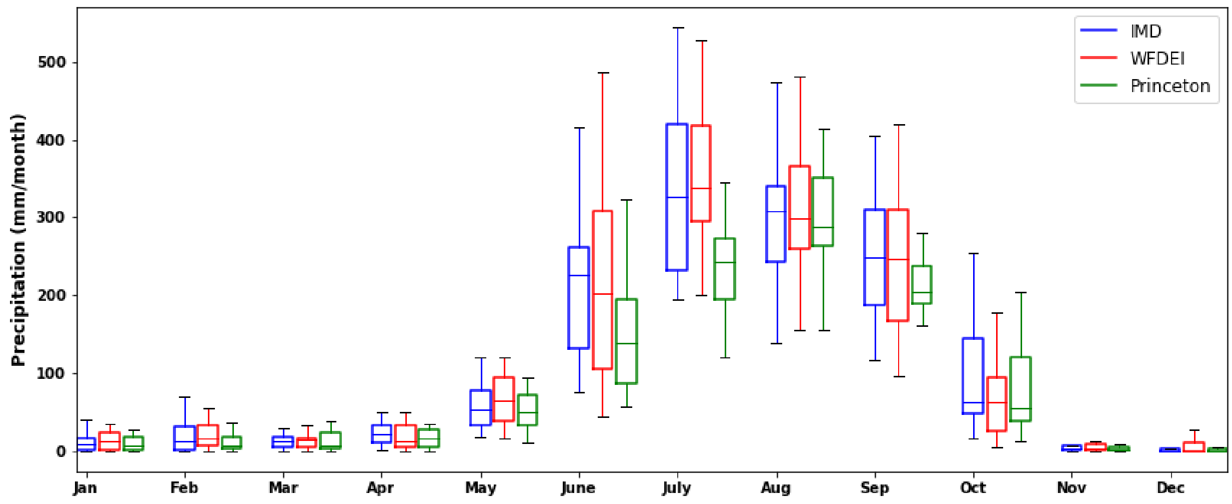

Fig 3. Box plot of three different precipitation datasets at monthly scale for 1994-2004

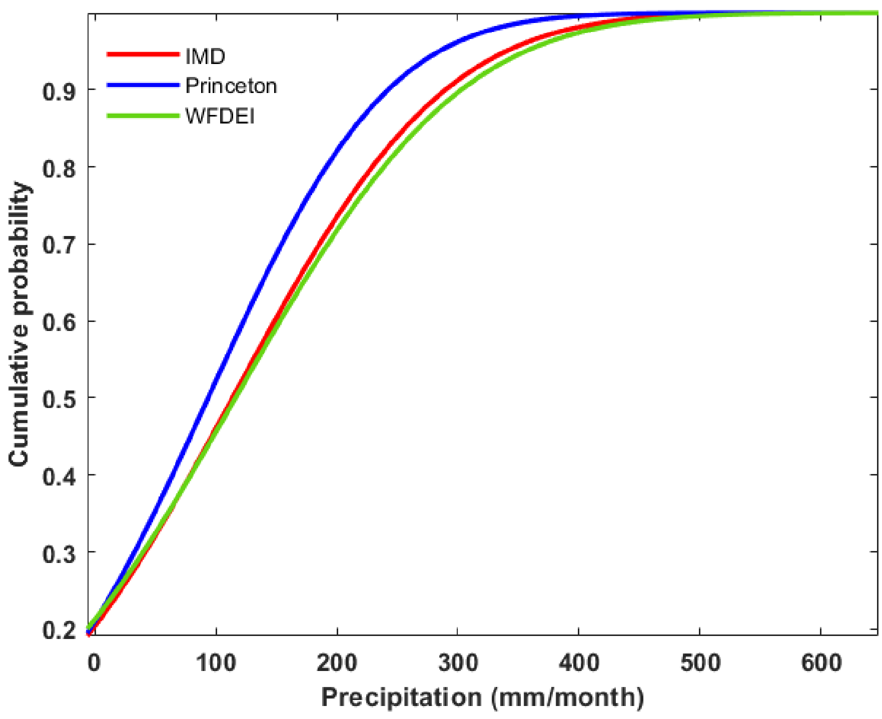

Fig 4. Cumulative frequencies of monthly precipitation intensity of three precipitation datasets for 1994-2004

Comparison of streamflow simulation

Table 4. Evaluation statistics with IMD dataset

	Calibration			Validation		
Datasets	NSE	R^2	PBIAS (%)	NSE	R^2	PBIAS (%)
HYSIM	0.8	0.81	11.69	0.78	0.78	-2.74
SWAT	0.71	0.78	6.71	0.66	0.67	-0.82

Table 5. Evaluation statistics with WFDEI and Princeton datasets

	HYSIM			SWAT		
Datasets	NSE	R^2	PBIAS (%)	NSE	R^2	PBIAS (%)
WFDEI	0.51	0.69	18.56	0.41	0.55	23.41
PRINCETON	0.45	0.63	-43	-0.16	0.64	72.91

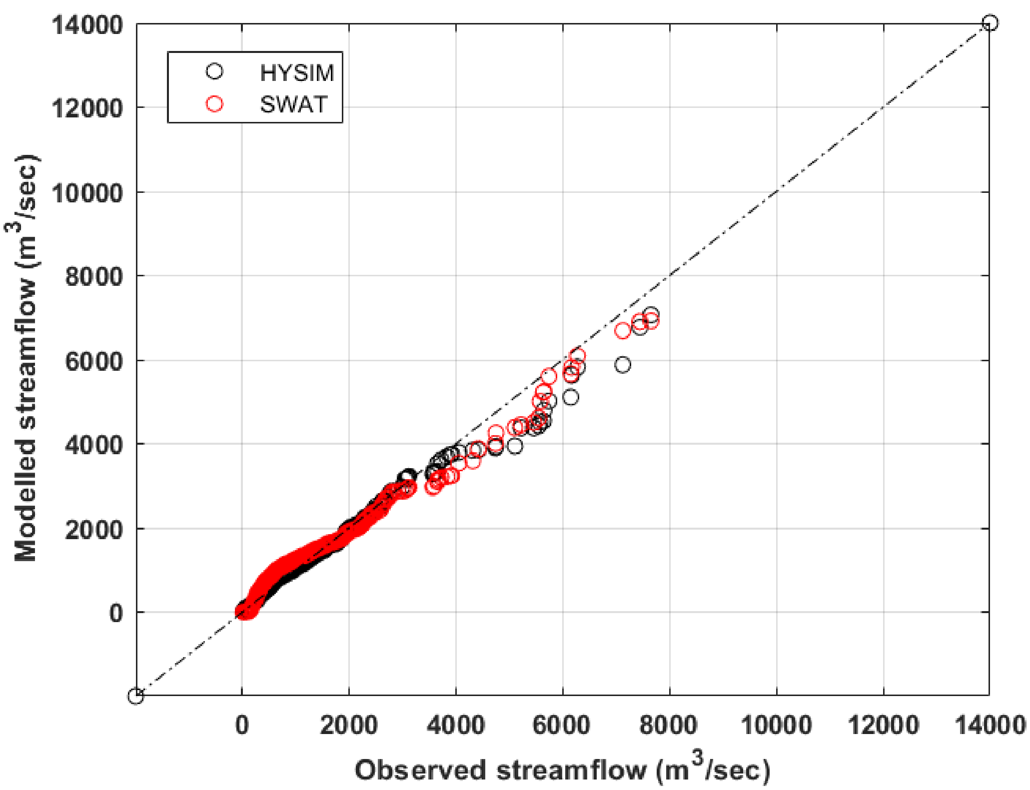

Fig 5. Q-Q plot evaluation of the modelled discharge against observed discharge data for 1994-2004 with IMD dataset

Variability in blue and green water flow due to change in precipitation datasets

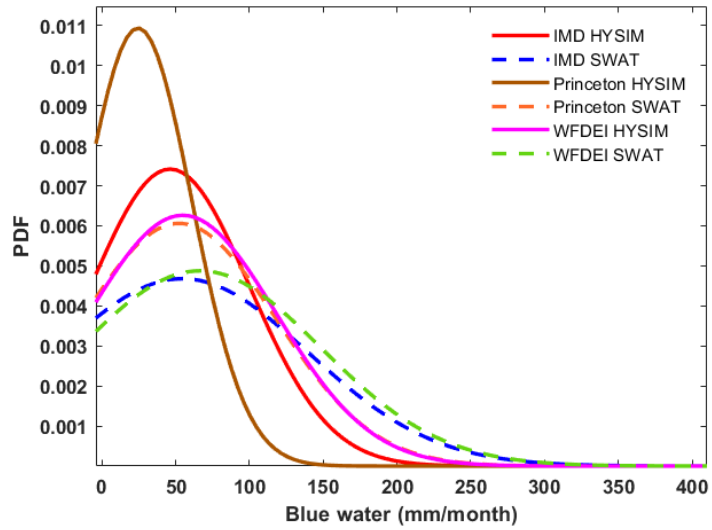

Fig 8. Probability density plot showing the uncertainty in blue water flow for the three precipitation datasets with HYSIM and SWAT model

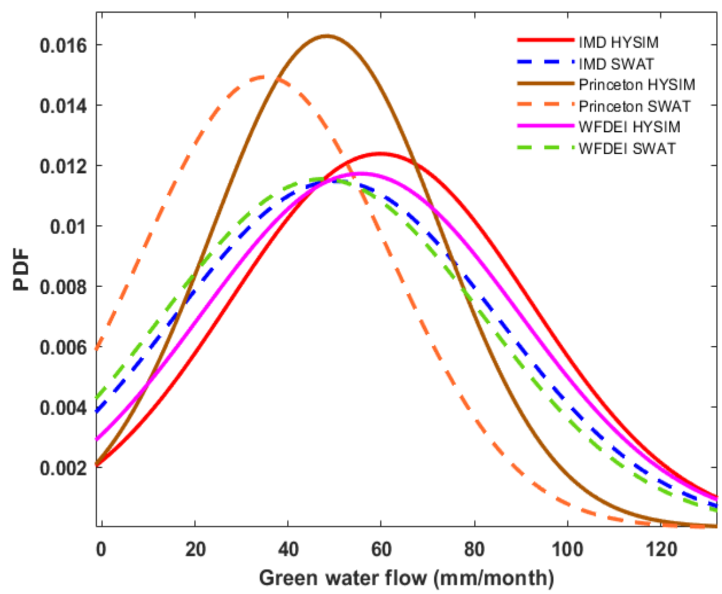

Fig 9. Probability density plot showing the uncertainty in green water flow for three precipitation datasets with HYSIM and SWAT model

CONCLUSION

- **Princeton datasets usually have smaller precipitation values than IMD and WFDEI datasets throughout the entire period.**
- **HYSIM outperformed SWAT model in both calibration and validation period with IMD precipitation datasets.**
- **A wide range of uceratinty exists in model simulated streamflow due to change in precipitation datasets for both HYSIM and SWAT models.**
- **Blue water flow is more sensitive to precipitation change compared to green water flow.**
- **The variation in blue and green water flow due to change in precipitation products suggest that choice of precipitation datasets is essential to examine catchment hydrological behavior and, it further helps policymakers to make critical water management decisions.**

FUTURE SCOPE & REFERENCES

- **HYSIM and SWAT model calibration can be done with WFDEI and Princeton datasets for uncertainty estimation in model parameters due to change in precipitation products.**
- **Spatial changes in blue and green water flow can be analyzed with respect to baseline period as well as future climate change scenario subjected to change in precipitation datasets.**

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The hydrological behavior and freshwater availability in any typical river basin are highly dependent upon precipitation making it the most crucial input variable for hydrological modelling. Precipitation as an input variable to hydrological models is available in gridded form with various spatiotemporal resolution. The variations in the model inputs could be subjected to uncertainties in the hydrological model simulation, which further affect the estimation of blue water flow (BWF) and green water flow (GWF) of a river basin. In this study, we investigated the effects of three gridded precipitation datasets [Watch forcing data ERA-Interim (WFDEI); Princeton datasets; Indian Meteorological Department (IMD)] on streamflow pattern, BWF, and GWF using a semi-distributed hydrological model [Soil and Water Assessment Tool (SWAT)] and a lumped rainfall-runoff model [Hydrological Simulation model (HYSIM)] in the Damodar river basin situated in eastern India. Both the models are simulated at daily time steps with the calibration of ten years (1994 – 2004) and validation of five years (2005 – 2010) at catchment outlet (Durgapur barrage) using three precipitation datasets. The performance of all the three precipitation products is evaluated on the basis of streamflow simulation for both HYSIM and SWAT model at the basin outlet using the performance indicators viz., Nash-Sutcliffe efficiency (NSE), coefficient of determination (R^2) and percent bias (PBIAS). The seasonal and annual variation in precipitation values of the WFDEI, Princeton, and IMD dataset could attribute to the significant variations in the performance indicators. Subsequently, the best performance in streamflow simulation is achieved by HYSIM model compared to SWAT with IMD precipitation input. Both models showed remarkable differences in BWF and GWF estimation due to changes in precipitation inputs. The results also indicate that BWF is more sensitive to precipitation than GWF as BWF is directly generated from precipitation. All the above observations suggest that the choice of appropriate precipitation datasets is essential to examine the catchment hydrological behavior, and it further helps policymakers to make critical water management decisions.