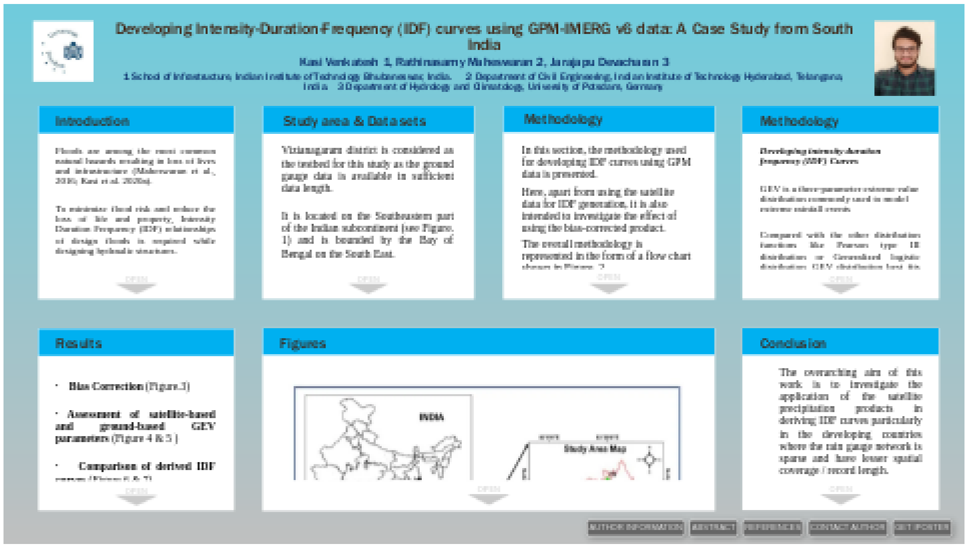
Developing Intensity-Duration-Frequency (IDF) curves using GPM-IMERG v6 data: A Case Study from South India



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PRESENTED AT:

INTRODUCTION

Floods are among the most common natural hazards resulting in loss of lives and infrastructure (Maheswaran et al., 2016; Kasi et al. 2020a).

To minimize flood risk and reduce the loss of life and property, Intensity Duration Frequency (IDF) relationships of design floods is required while designing hydraulic structures.

With the availability of satellite-based products, it is relevant to develop methods to use these data products for the IDF instead of rain gauge data.

STUDY AREA & DATA SETS

Vizianagaram district is considered as the testbed for this study as the ground gauge data is available in sufficient data length.

It is located on the Southeastern part of the Indian subcontinent (see Figure. 1) and is bounded by the Bay of Bengal on the South East.

The geographical area of the Vizianagaram district is about 6539 sq. km, and the latitude and longitude of this area are $18.12N^0$ and $83.42E^0$, respectively

Datasets:

(i) Ground-based rain gauge data

(ii)Global precipitation measurements (GPM) data

METHODOLOGY

In this section, the methodology used for developing IDF curves using GPM data is presented.

Here, apart from using the satellite data for IDF generation, it is also intended to investigate the effect of using the bias-corrected product.

The overall methodology is represented in the form of a flow chart shown in Figure. 2.

Biased correction for Satellite-based Precipitation

The error analysis of the GPM data is carried out as given below.

(i) AMS rainfall values are extracted from the ground measurement data and satellite-based precipitation product (GPM) datasets for all the locations; the length of the AMS series is 19 years extracted for the period from 2001 to 2019.

(ii) AMS obtained from the gauge and GPM rainfall datasets are given ranks and arranged in descending order.

(iii) A bias correction factor (ξ) is defined as the ratio of ground measurement to satellite-based precipitation product (GPM) that is,

$$(x, y, l) = \frac{P_{G(x,y,l)}}{P_{S(x,y,l)}} \qquad \text{(a)}$$

Where (x, y, l) is the adjustment factor for the l^{th} event in the AMS at the location (x, y),

$P_{G(x,y,l)}$ is the l^{th} ground-based rainfall event in the AMS at the location (x, y) and

$P_{S(x,y,l)}$ is the l^{th} Satellite-based rainfall event in the AMS at the location (x, y).

(iii) At each grid point location, the average value of the bias for a given location ($\bar{\xi}_{x,y}$) which represents the systematic error in the satellite precipitation product is estimated as

$$\bar{\xi}_{x,y} = \sum_{l=1}^{19} \frac{\xi(x, y, l)}{19} \qquad \text{(b)}$$

(iv) After estimating the bias in the estimates for each location, the bias-corrected satellite precipitation at a given location (x,y) is estimated by,

$$P_{s}^{corr}{}_{(x,y)} = P_{S(x,y)} \times \bar{\xi}_{x,y} \qquad \text{(c)}$$

METHODOLOGY

Developing intensity duration frequency (IDF) Curves

GEV is a three-parameter extreme value distribution commonly used to model extreme rainfall events

Compared with the other distribution functions like Pearson type III distribution or Generalized logistic distribution, GEV distribution best fits the Annual Maximum Series (AMS)

The Generalized Extreme Value (GEV) type distribution method is defined below equation (See the equations d and e)

(i) For $k \neq 0$:

$$F = (I;\ \mu;\ \sigma, k) = \exp\left\{-\left[1+\frac{k}{\sigma}(1-\mu)\right]^{-\frac{1}{k}}\right\} \quad (d)$$

(ii) For $k=0$:

$$F = (I;\ \mu;\ \sigma, k) = \exp\left\{-exp\left[-\frac{1}{\sigma}(1-\mu)\right]\right\} \quad (e)$$

Where: 'I' is the rainfall intensities derived for 1-day, 2-day, 3-day duration. The location (μ), scale (σ) and shape (k)are the GEV distribution parameters.

Comparison between for derived IDF maps

- Correlation coefficient (CC)
- Bias
- Normalized standard difference (NSD)

- Percentage relative error (RE)

RESULTS

· **Bias Correction** (Figure.3)

· **Assessment of satellite-based and ground-based GEV parameters** (Figure 4 & 5)

· **Comparison of derived IDF curves** (Figure 6 & 7)

· **Comparison of non-dimensional metrics between IDF of ground-based gauge point—GPM and ground-based gauge point—biased corrected GPM** (Figure 8)

FIGURES

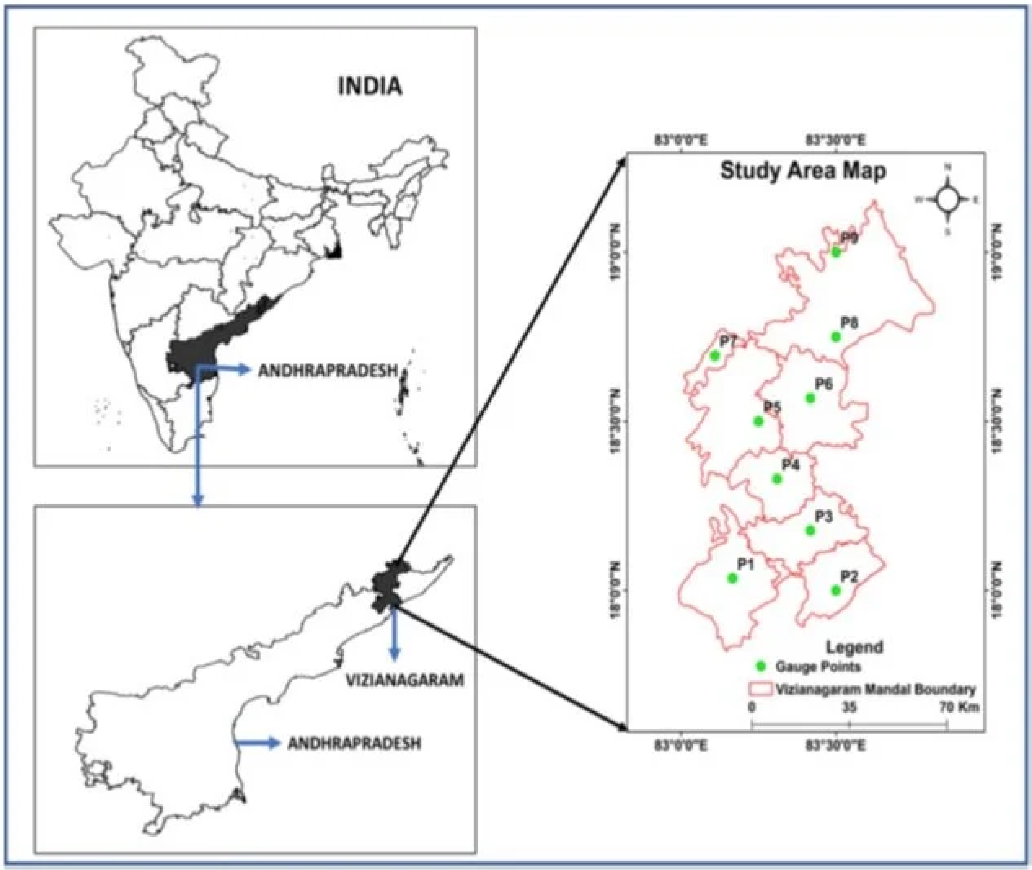

Figure 1. Geographical location of the study area. The right bottom panel shows the study area bounded in Andhra Pradesh state and the left panel show the index map of the study area of the entire Vizianagaram district covered with nine gauge point

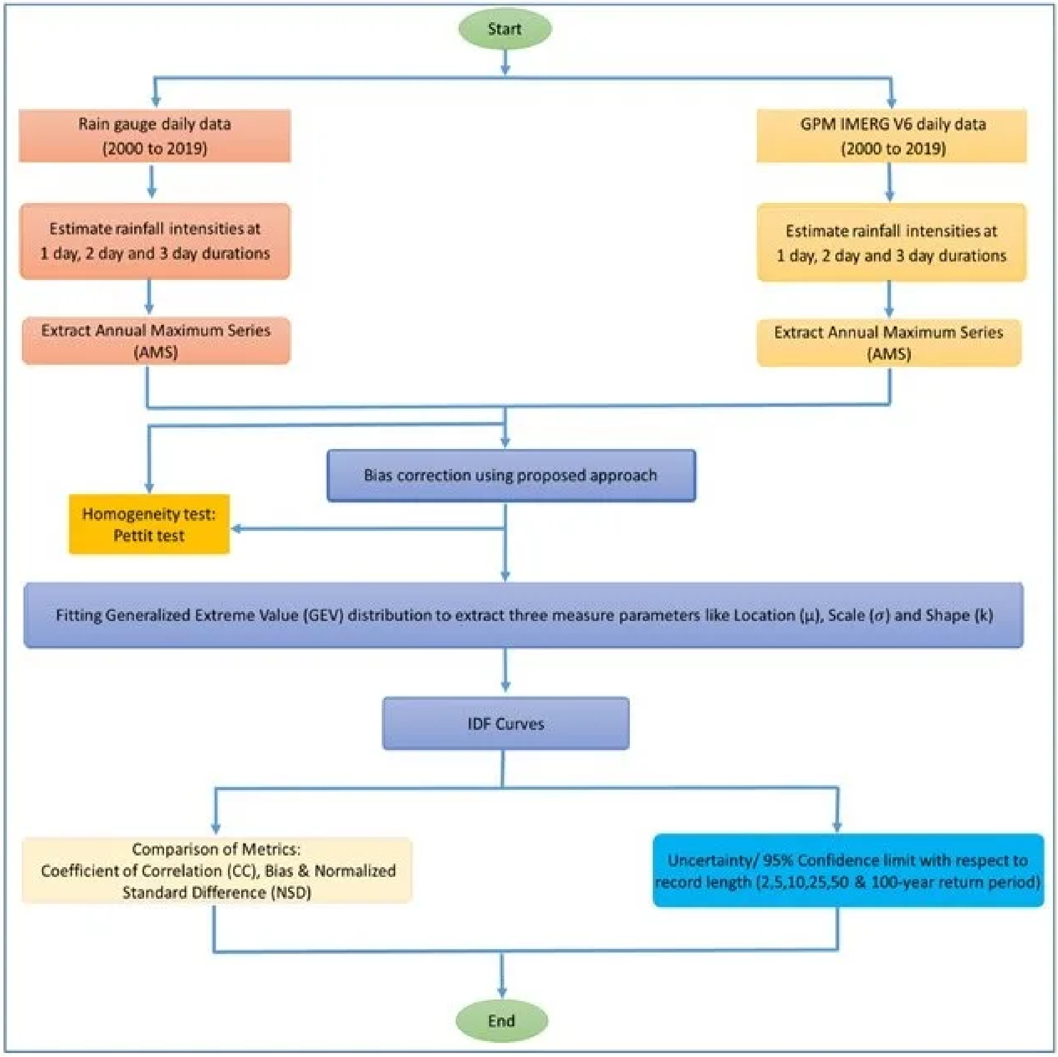

Fig. 2 Flow chart of the proposed methodology

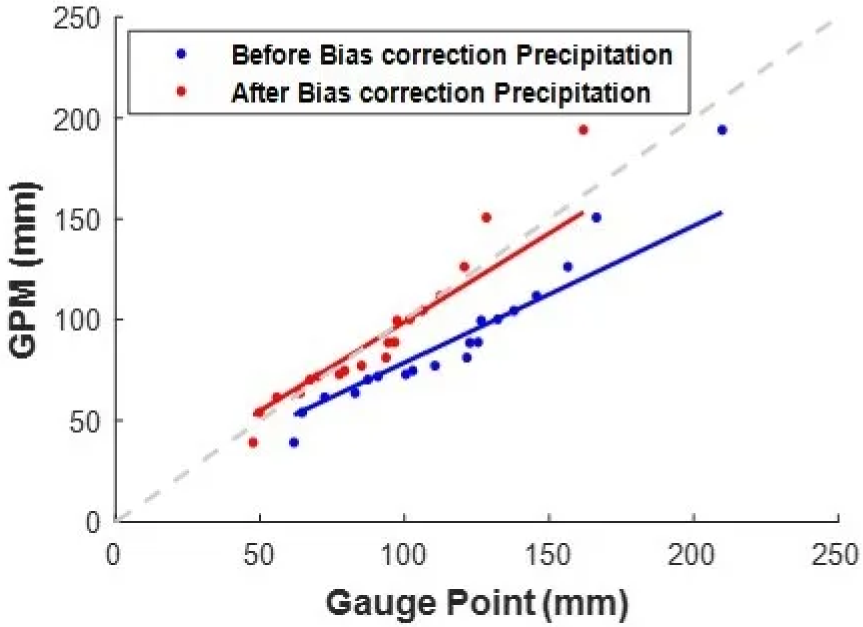

Fig. 3 Q-Q plots comparing quantiles of AMS extracted from the ground-based gauge point, GPM and biased corrected GPM. The red colour represent GPM precipitation, and blue colour represents biased corrected GPM precipitation

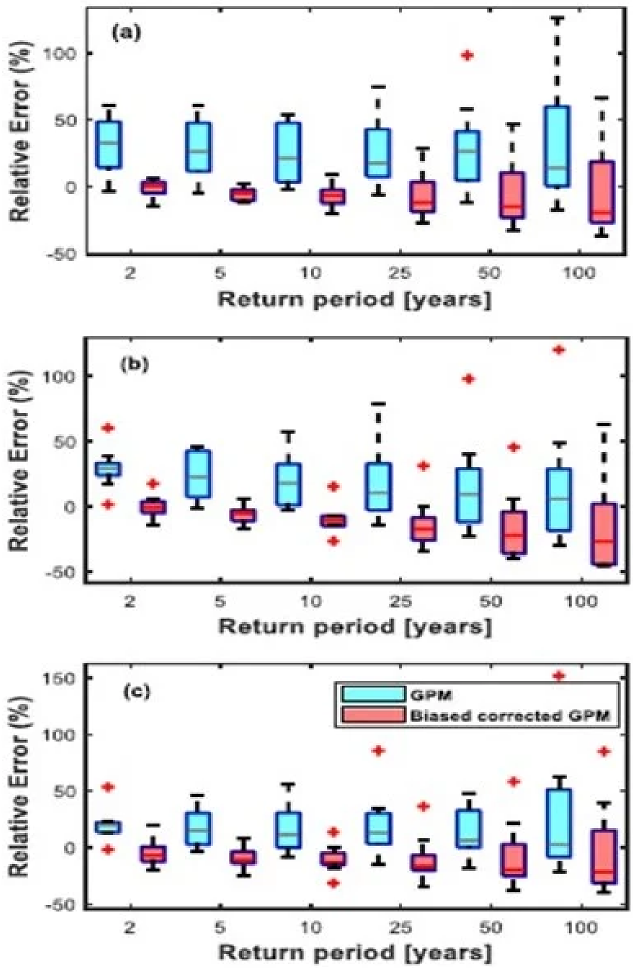

Fig. 4 Relative error present in ground-based gauge point -GPM and ground-based gauge point—biased corrected GPM IDF return period values are represented in the form of boxplot for **a** 1 day. **b** 2 day. **C** 3 day. The light blue thick line present in the box represents the median value and the boxes represent the interquartile range, and the thick dashed lines represent the range

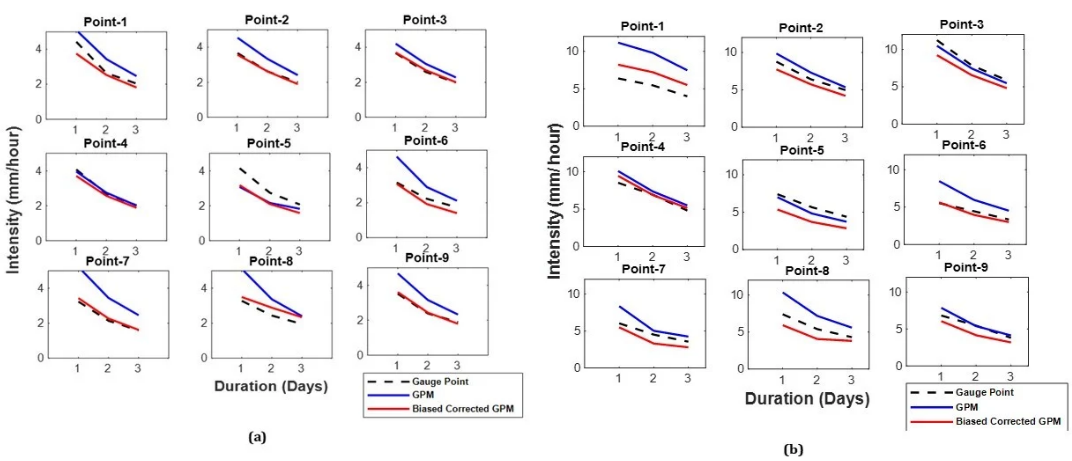

Fig. 5 Comparison of 2-year return period for 1-day, 2-day and 3-day duration for ground-based gauge point, GPM and Biased-corrected GPM for 9 grid point data and 5b: Comparison of 25-year return period for rain gauge GPM and Biased-corrected GPM for 9 grid-point data.

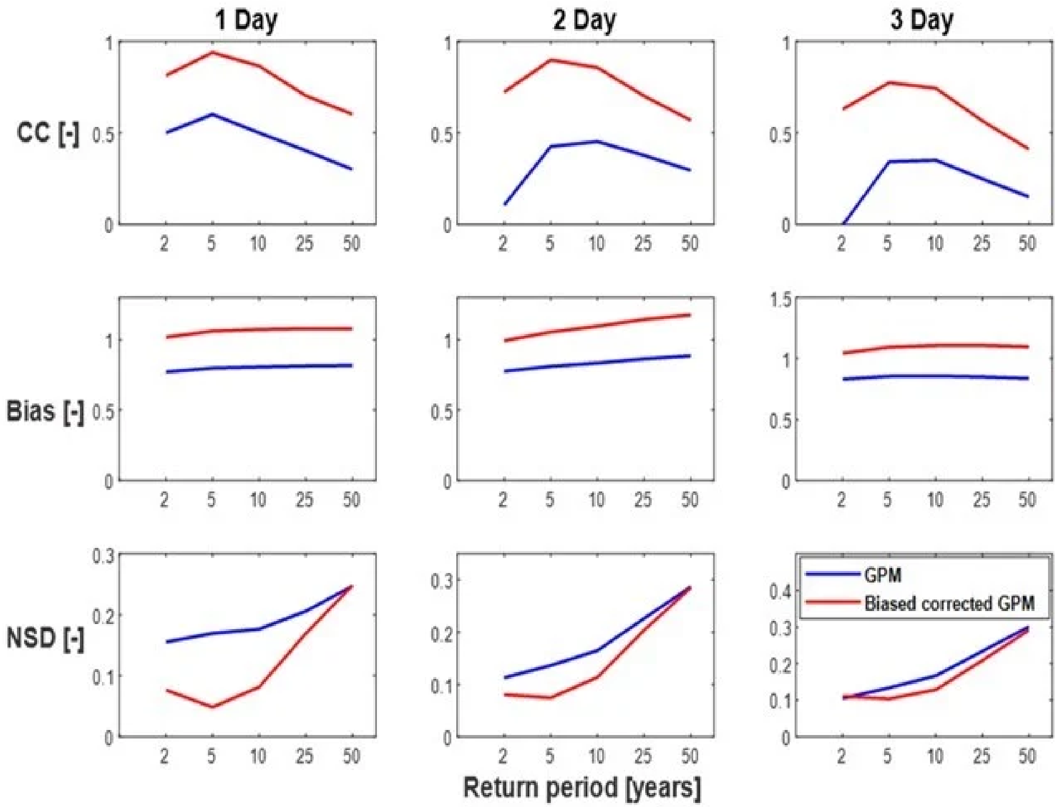

Fig. 7 Comparison of non-dimensional metric parameters of Coefficient of correlation (cc), Bias and NSD for 1-Day,2-Day and 3-Day duration. The first row represents the CC, the middle row represents the bias, and the last row represents the NSD for 1-Day,2-Day and 3-Day durations

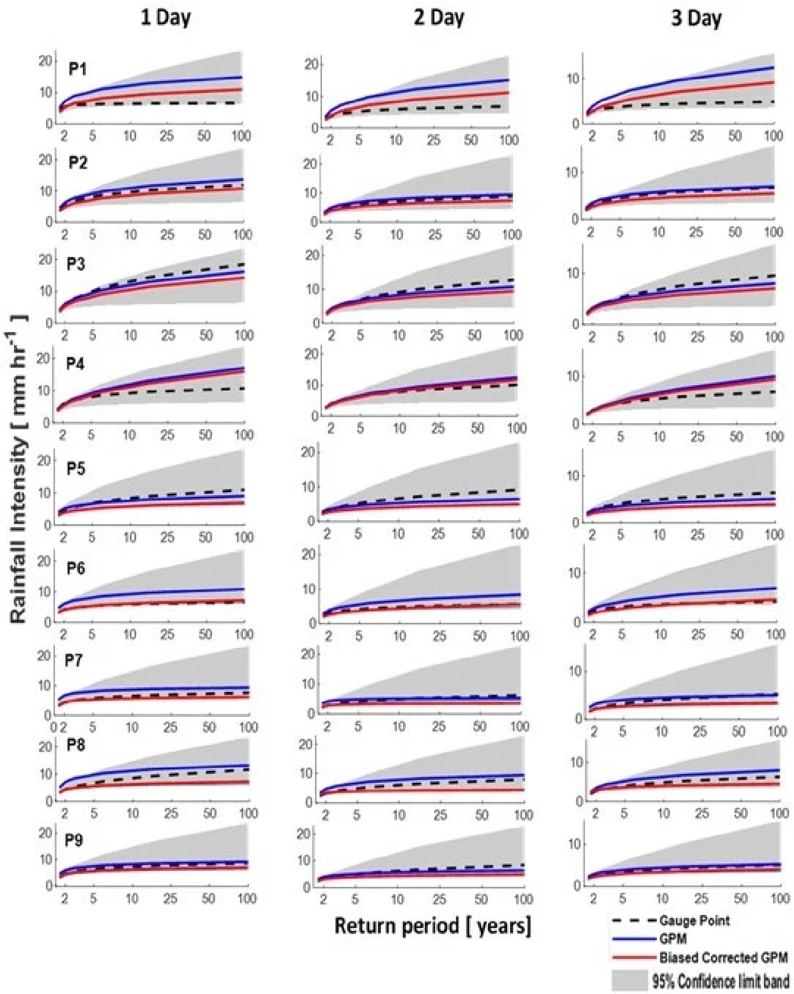

Fig. 8. Visual Comparison of IDF curves for 2-year, 5-year, 10-year, 25-year, 50-year and 100-year return period values for satellite-based precipitation GPM (red line) and bias corrected GPM data over ground-based gauge (dashed black line) data at nine location for 1-day , 2-day and 3 day durations.

CONCLUSION

- The overarching aim of this work is to investigate the application of the satellite precipitation products in deriving IDF curves particularly in the developing countries where the rain gauge network is sparse and have lesser spatial coverage / record length.
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- Overall, the study results emphasize the potential use of the GPM satellite precipitation as an alternative data for developing IDF curves in developing countries.
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- There are several future works emanate from this study.
- (i) These include quantifying the different sources of uncertainty that arise at various levels, such as estimation algorithms, bias correction methods, parameter estimation methods, etc

AUTHOR INFORMATION

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ABSTRACT

With the availability of satellite-based precipitation products, it is pertinent to develop methods to use these data products for the purpose of design of hydraulic structures. The satellite precipitation products play a vital role in ungauged locations or when information is required a catchment scale. Prior to such applications, the accuracy and uncertainty associated with the products have to be investigated. This study compares Intensity Duration Frequency (IDF) curves using the recent precipitation product Global Precipitation Measurement (GPM-IMERG V6) with ground-based gauge data over the southeastern part of India and quantifies the uncertainty associated. Further, for comparison, a bias-corrected dataset is used in the study to understand the implication of bias correction of the satellite product in the IDF generation. The spatial correlation between the satellite IDF and the gauge-based IDF improves significantly after bias correction and the value is as high as 0.75 for 2- 10 year return period. The bias between the satellite IDF and gauge IDF is low in the north part of the study region and is high in the southeastern part, prone to extreme rainfall. Further, a significant percentage of the satellite-based IDFs (with and without bias correction) lie inside the confidence interval of the gauge-based data.

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