Response Document

We would like to thank the editor and both reviewers for their overall assessment and for their constructive feedback on our research. We have carefully addressed each concern in the detailed responses below. Overall, we have improved the writing part in the revised manuscript and addressed the editor's and reviewers' comments.

Editor's comments

Dear authors,

after considering your responses to reviewers' concerns I would like to invite you to submit a revised manuscript.

However, I would like to strongly encourage you to address the concern of a reviewer 2 on the need of validation of the VIC simulations more rigorously. Even if only 5 stations are available, spatial validation of the model, as well as evaluation of its performance specifically for the flood events analyzed (i.e., their timing, magnitude, volume) is urgently needed. The whole added value of the analysis rests on model reliability and therefore there should be absolutely no doubt in its performance for the actual target variables (i.e. runoff and soil moisture).

Thank you for your concerns and suggestions. In the updated response and revised manuscript, we included additional analysis of model performance under extreme flow conditions (specifically during flood years and at high-flow percentiles).

We found that the model maintains an acceptable performance during the top five flood years (Figure S3):

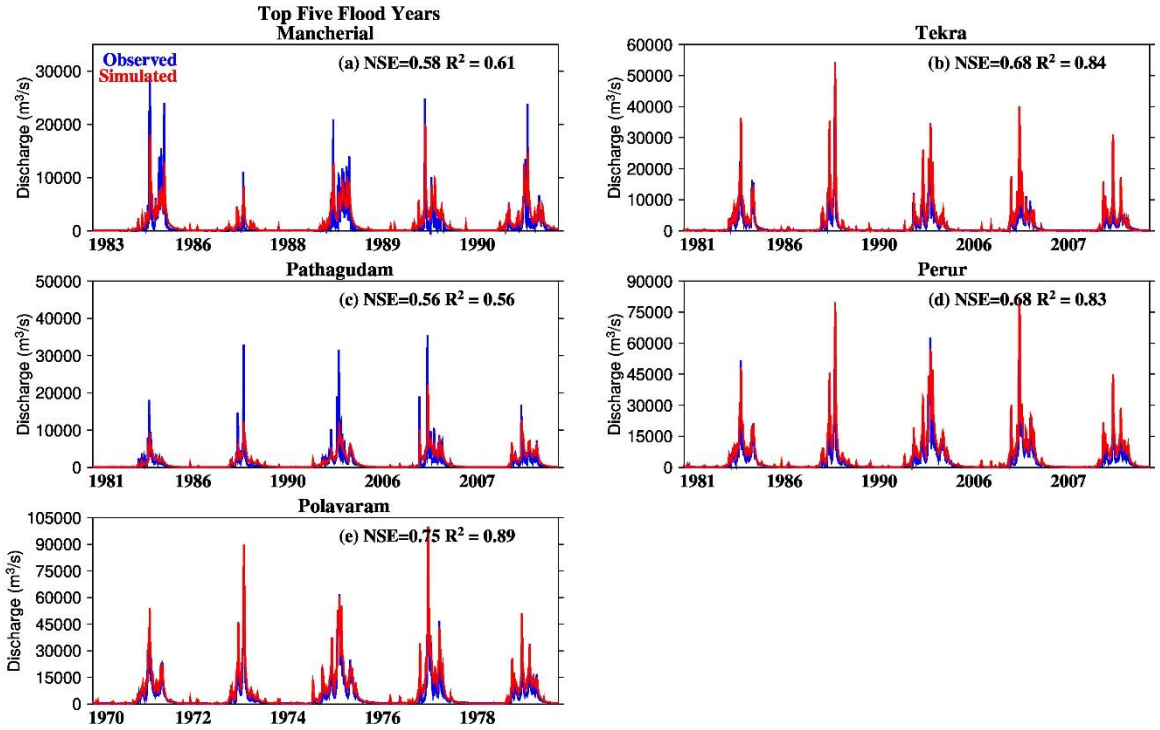


Figure S3. *(a–e) Comparison of daily observed (blue) and VIC- simulated (red) streamflow (m^3/s) for the top five major flood years at Mancherial, Tekra, Pathagudam, Perur, and Polavaram during the validation period 1980-2014 (except for the Mancherial station, which was validated for 1980-1993).*

Table R1: Values of performance indices [NSE and Coefficient of determination (R^2)] during the top five flood years of VIC simulated discharge (against the observed discharge data).

Stations	*Top Five Flood Years*	
	NSE	*R^2*
Mancherial	*0.58*	*0.61*
Tekra	*0.68*	*0.84*
Pathagudam	*0.56*	*0.56*
Perur	*0.68*	*0.83*
Polavaram	*0.75*	*0.89*

Additionally, we evaluated model bias under extreme conditions. The bias at the 95th percentile of streamflow (Bias_Q95, reported in Tables S1 and S2) indicates that the VIC model reproduces

high-flow magnitudes with acceptable accuracy at most stations. Moreover, the bias at the 95th percentile is lower than the bias in mean discharge at most stations (Table S2).

Table S1: Values of performance indices [NSE, Coefficient of determination (R^2), high flow bias (Bias_Q95), low flow bias (Bias_Q5) and bias of the mean (Bias_mean)] during the calibration of VIC simulated discharge (against the observed discharge data) for the period 1970-1979.

Calibration (1970-1979)					
Station	*NSE*	*R^2*	*Bias_Q95 (%)*	*Bias_Q5 (%)*	*Bias_mean (%)*
Mancherial	*0.66*	*0.67*	*6.29*	*250.21*	*16.94*
Tekra	*0.8*	*0.86*	*39.57*	*-62.85*	*28*
Pathagudam	*0.6*	*0.61*	*18.45*	*-5.66*	*17.66*
Perur	*0.81*	*0.86*	*19.59*	*43.3*	*35.27*
Polavaram	*0.81*	*0.9*	*25.16*	*-41.43*	*37.44*

Table S2: Values of performance indices [NSE, Coefficient of determination (R^2), and Bias] during the validation of VIC simulated discharge (against the observed discharge data) for the period 1980-2014 (except Mancherial station; 1980-1993 for Mancherial sub-basin).

Validation (1980-2014)					
Station	*NSE*	*R^2*	*Bias_Q95 (%)*	*Bias_Q5 (%)*	*Bias_mean (%)*
*Mancherial**	*0.52*	*0.59*	*88.52*	*190.3*	*79.26*
Tekra	*0.58*	*0.83*	*55.18*	*-74.17*	*53.76*
Pathagudam	*0.6*	*0.62*	*17.44*	*188.08*	*21.47*
Perur	*0.59*	*0.82*	*50.43*	*89.53*	*63.7*
Polavaram	*0.63*	*0.88*	*45.63*	*-55.78*	*56.37*

**validated for 1980-1993*

Moreover, according to the reviewer's suggestion, we have included a dedicated paragraph in the "Discussion and Conclusions" section of the revised manuscript, acknowledging the limitations of our study (including VIC model limitations). Please refer to the following lines in the revised manuscript:

Lines 582-590: *"In this study, we used the calibrated-VIC model for streamflow and runoff simulations, which also exhibits several structural and parametric limitations when applied to predict extreme streamflow events (Abdulla and Lettenmaier, 1997; Liang et al., 2003; Tsai et al., 2021). The VIC model simulates runoff using a saturated-excess mechanism (Liang et al., 1994), which underestimates excess runoff and infiltration estimations during intense monsoon events (Beven, 2012). By considering multiple hydrological models (including human influence) for streamflow prediction, we can reduce model limitations and develop a robust understanding of flood-generating mechanisms across India in the future."*

Moreover, I would also like to bring your attention to the request of the reviewer 2 that calls for more clear novelty representation. I support the opinion of the reviewer that the novelty is not clearly articulated in the manuscript, and in the response I did not yet see convincing arguments addressing this issue. All three novelty points listed in the response have been previously touched upon in previous studies. In line with the reviewer suggestion, I encourage the authors to highlight how their findings are new compared to what was known before about flood generation processes in this area.

Thank you for your comment. In the updated response document and revised manuscript, we have mentioned the novel contribution of our work in the abstract and other sections. Additionally, we would like to highlight two specific contributions of our work that have not been previously addressed, particularly for large river basins in a monsoonal climate and also appreciated by reviewer 1:

(i) Flood-generating mechanisms across different climate zones:

Here, we systematically distinguish flood-generating mechanisms across different climate zones (from semi-arid to semi-humid) within a single large basin. We highlighted that the *majority of floods in the semi-humid regions predominantly occur due to multiple high-intensity rainfall days (10-11 days), and floods in the semi-arid Mancherial sub-basin are triggered by a single high-intensity precipitation event*.

(ii) Flood-dominant catchment area delineation using EOF analysis:

While previous studies established multiday precipitation as a flood driver and examined the role of initial conditions in flooding, neither study explicitly identified which specific regions dominate flood generation through spatial EOF analysis and pixel-based runoff analysis. Our study is the first to quantitatively identify (as per our understanding) the flood-dominant spatial areas in the Godavari basin using EOF analysis and pixel-based runoff analysis. We highlighted that the *central and downstream areas of the Godavari River basin dominate flood occurrence (specifically, the role of the Tekra sub-basin as a disproportionate contributor to runoff).* This is a novel finding for the Godavari basin and offers directly actionable information for flood management.

Updated Abstract:

*"Indian River basins experience frequent flooding during the Indian summer monsoon and pose several challenges for the region's large population, yet the hydrometeorological and catchment-scale drivers that control flood processes remain poorly explored across India. To effectively manage flood risk in the densely populated Indian region, it is essential to **understand how the temporal properties of precipitation and runoff generate floods across different aridity regimes within a large catchment, and which specific areas of a large, climatically heterogeneous basin generate the runoff that drives downstream flood peaks.** In this study, we address these gaps and examine the role of hydrometeorological variables (such as precipitation and surface runoff) and catchment area in the flood occurrence in the Godavari River basin (one of the largest river basins in the Indian Subcontinent) using observed and VIC-simulated datasets. Based on the temporal analysis of precipitation, runoff, and streamflow, we show that **the majority of floods in the semi-humid sub-basins (Tekra, Pathagudam, Perur, and Polavaram) are predominantly associated with 10 to 11 days of accumulated precipitation, having multiple high-intensity precipitation events prior to flood. In contrast, the floods in the semi-arid region of Godavari (Mancherial sub-basin) are triggered by a single high-intensity precipitation day and are associated with short-duration (2 days) accumulated precipitation.** In addition to temporal analysis, we performed Empirical Orthogonal Function (EOF) analysis using precipitation, runoff, and streamflow data to identify the specific sub-regions that*

disproportionately generate flood-causing runoff (flood-dominant catchment areas). Our results demonstrate that ***central and downstream areas of the basin contribute dominantly to flood occurrence, generating substantially higher runoff in the Tekra sub-basin****. Overall, this study moves beyond basin-averaged flood attribution and advances understanding of flood-generating mechanisms over the Godavari River basin, which can be helpful for duration-informed forecasting and catchment-scale flood management during the monsoonal climate of the Indian Subcontinent."*

Please also make sure that all figures are generated using color-blind pallets (particularly avoiding red and green combinations).

Thank you for this valuable suggestion. We have reviewed all figures using the Coblis-Color Blindness Simulator to verify their accessibility for readers with color vision deficiencies. Figure 1 has been revised accordingly and now employs a color-blind-friendly palette.

I am looking forward for your revised manuscript!

Kind regards,
Larisa Tarasova

Referee 1 Comments and Responses

It was a pleasure to read the manuscript on "Role of hydrometeorological variables and catchment area to flood generation over the monsoonal climate region of India" by Aadhar et al.

The manuscript does an extensive investigation on the flood generating mechanisms in the Godavari River basin, focusing on the rainfall characteristics and identification of catchment area that predominantly contributes to flooding in different subbasins in the Godavari River. The authors rely on an event-based approach wherein independent flood events are identified using a POT approach, and the characteristics of rainfall and antecedent soil moisture conditions prior to the flood events are assessed. The authors identify the time window of rainfall duration which is most correlated with the flood events in each subbasin and classify the triggering rainfall event into one-day extreme, multiday extreme and moderate rainfall events. Using an EOF analysis and correlation they also identify the regions in the catchment with higher runoff coefficient or significant contribution to runoff generation. While the role of rainfall duration(Nanditha & Mishra, 2022), and catchment area on flood generation (Nanditha & Mishra, 2024) is well established in the Indian region, the second part of the study demarcating the flood-dominating catchment area in different subbasins is novel and the methodological aspect exhibits rigour and consistency. I only have a few suggestions and clarification to improve the readability and reproducibility of the manuscript.

We thank the reviewer for the valuable assessment of our work and the detailed, constructive suggestions. Below, we addressed each comment individually.

Methodology

I would expect more detailing on the EOF approach employed. Please provide the relevant equations. Did the authors use accumulated rainfall and runoff for the most correlated window for each pixel for the analysis? I have some reservations on using accumulated runoff. Though runoff measured in mm (length scale) can be treated as an accumulated quantity, the way the VIC model represents it can be different. For instance, the runoff generated at timestep t may not entirely rout to the downstream cell at the end of the day due to the time lag in the routing process (the hill slope routing uses a unit hydrograph approach). So, the runoff generated for the timestep t+1 could have contribution from the previous day. I would suggest using mean runoff instead of accumulated runoff for each cell.

Similarly, peak discharge should be correlated with the mean runoff and not the accumulated runoff. I would suggest consistently use mean runoff throughout the manuscript.

Thank you for this constructive comment. We agree with the reviewer's concern regarding the use of accumulated runoff in the context of VIC routing. As highlighted, VIC's hillslope routing uses a unit hydrograph approach, meaning that runoff generated at timestep *t* may carry contributions from the previous timestep. We have therefore revised the analysis and now use mean runoff (mean daily surface runoff over the most correlated time window) consistently throughout the manuscript, for both the pixel-based EOF analysis and the correlation with peak discharge.

Moreover, we have added the relevant equations for EOF analysis to the revised manuscript.

Lines 296-320: *"Next, we evaluated the dominated catchment area in flood generation by examining the spatial variability of precipitation and runoff (Figure 2). For that, we used the empirical orthogonal function (EOF) analysis and obtained the leading modes of spatial variability in precipitation and surface runoff (Mishra et al., 2012). EOF analysis identifies the dominant modes of spatio-temporal variability in a dataset by solving an eigenvalue problem derived from the spatio-temporal covariance matrix (Lorenz, 1956; Preisendorfer, 1988; Wilks, 2006; Navarra and Simoncini, 2010; Joliffe, 1986; Hannachi, 2022). Here, we first estimated the dominant spatiotemporal modes of variability in the gridded precipitation (surface runoff) to assess its coupling with peak discharge. To do so, we formed the spatial covariance matrix of N x N (where N is the number of grid points) using the following equation:*

$$C = \frac{1}{t-1} P' P'^{T}$$

where P' is precipitation (runoff) anomaly; t is the number of peak events; and T represents the transpose matrix.

Further, the spatial covariance matrix (C) was decomposed as:

$$C e_k = \lambda_k e_k$$

where e_k and λ_k are the k^{th} spatial EOF and its associated eigenvalue, respectively (Lorenz, 1956). The fraction of total variance explained by each mode is $\lambda_k / \Sigma\lambda_j$. We also obtained the Principal Component (PC) time series by projecting the anomaly field onto each EOF:

$$a_k(t) = \sum_{i=1}^{N} P'_{i,t} . e_{k,i}$$

Finally, the coupling between each PC time series and the peak discharge anomaly was quantified using the Pearson correlation coefficient. In the EOF analysis, we used accumulated precipitation and mean surface runoff at each pixel for the time windows that were most strongly correlated with peak discharge, as identified in step 1 above."

Figures

The caption of Figures 4-6 is disordered. The top panel in the current figure is explained as the last panel.

Thank you for carefully reviewing the figure captions. We apologise for this oversight. We have carefully revised the captions of Figures 4, 5, and 6, as well as a few supplementary figures, in the revised manuscript to ensure that the panel descriptions follow the correct order.

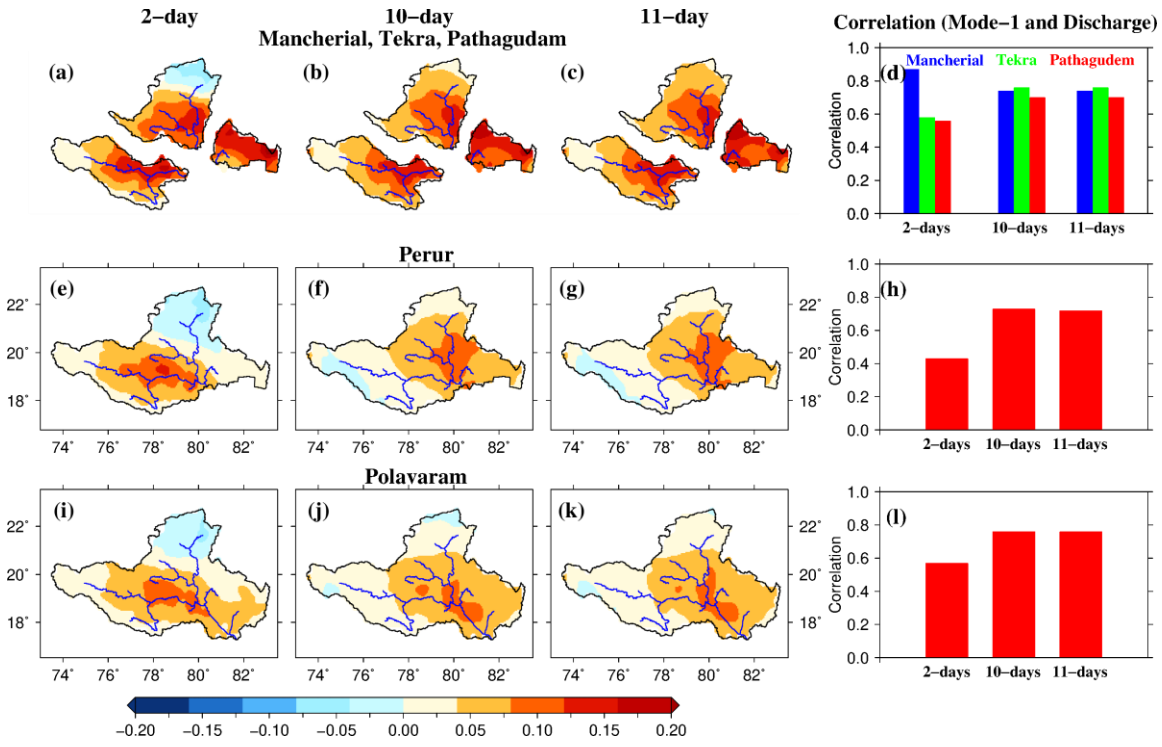


Figure 4: *The leading mode of variability in the accumulated precipitation during the high streamflow events for the period 1967-2019 using the method of empirical orthogonal function (EOF). (a-c) The first leading EOF mode of (a) 2 days, (b) 10 days, and (c) 11 days accumulated precipitation for Mancherial (left), Tekra (middle), and Pathagudam (right) sub-basins. (d) Correlation between the first*

leading mode and flood peak at Mancherial (left), Tekra (middle), and Pathagudam (right) stations. (e-h) same as (a-d) but for the Perur sub-basin. (i-l) same as (a-d) but for the Polavaram sub-basin.

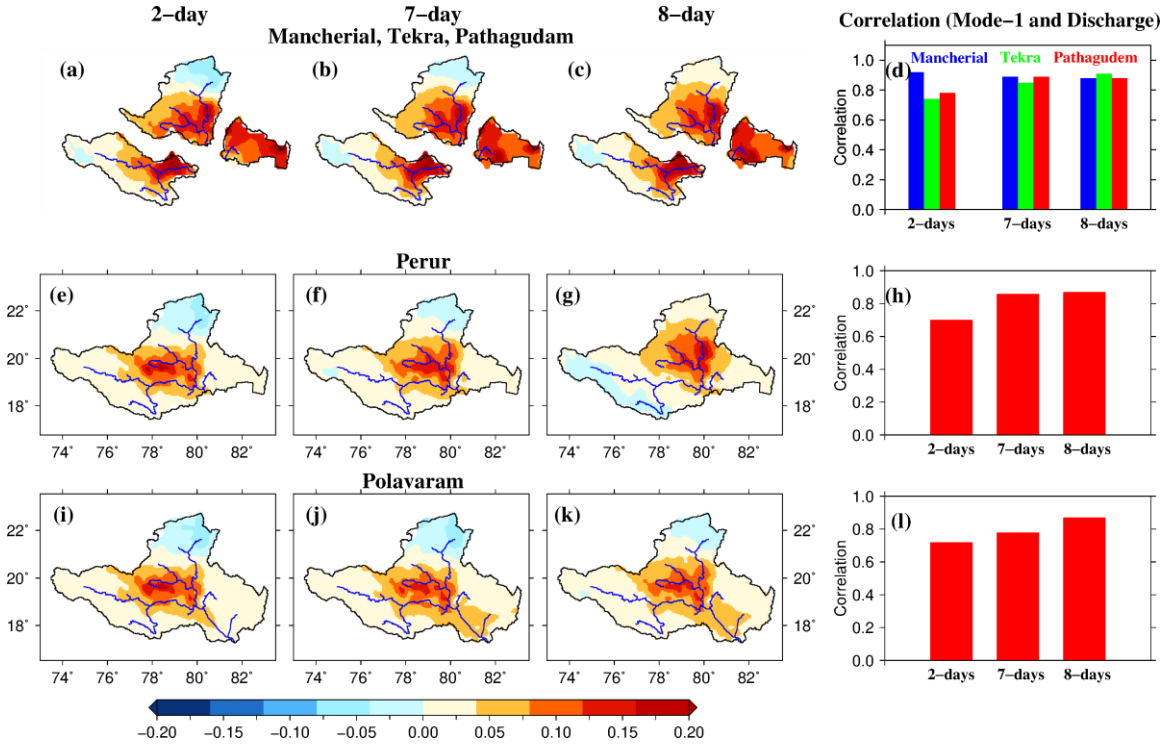


Figure 5. *The leading mode of variability in the mean runoff (excess precipitation) during the extreme floods for the period 1967-2019 using the method of empirical orthogonal function (EOF). (a-c) The first leading EOF mode of (a) 2 days, (b) 7 days, and (c) 8 days mean runoff for Mancherial (left), Tekra (middle), and Pathagudam (right) sub-basins. (d) Correlation between the first leading principal component (PC-1) and extreme floods at Mancherial (left), Tekra (middle), and Pathagudam (right) stations during 1967-2019 for 2, 7, and 8 days mean runoff. (e-h) same as (a-d) but for the Perur sub-basin. (i-l) same as (a-d) but for the Polavaram sub-basin.*

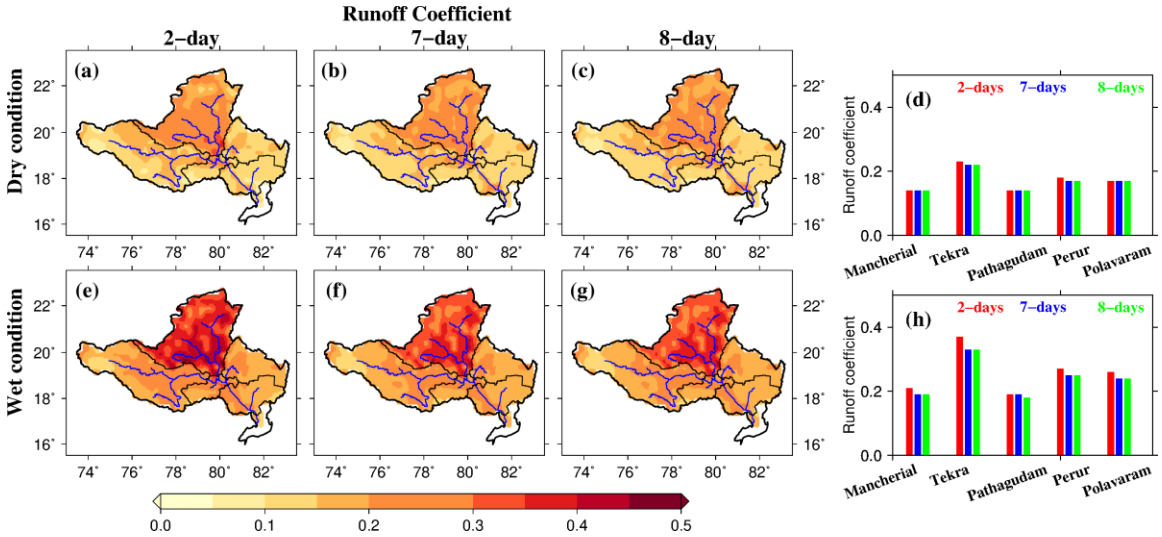


Figure 6. *Runoff coefficient over the Godavari basin during the flood events in the period 1967-2019. (a-c) Variability in runoff coefficient values using (a) 2 days, (b) 7 days, and (c) 8 days cumulative precipitation and mean runoff during dry condition flood events. (e-g) Similar to (a-c), but with variability in runoff coefficient values during wet condition flood events.*

Other suggestions

Line 145. No need of Moreover here.

Thank you. Removed.

Line.295 - Is this surface runoff alone? Did you consider the 75th percentile of entire timeseries or seasonality is taken into account?

Thank you for your comment. Yes, this is surface runoff alone, as simulated by the VIC model (baseflow is not included). The 75th percentile threshold for soil moisture was estimated by considering all occurrences of the same calendar day across the study period (1967–2019) that coincided with high streamflow events. For instance, if a high streamflow event occurred on 23 July in a given year, all 23 July values from 1967 to 2019 were considered in computing the soil-moisture threshold.

Line 299: What is the thickness of soil moisture considered?

Thanks. We have mentioned the soil layer thickness in the revised manuscript. It is 60 cm.

95th percentile is considered as the flood peak; this may include flows which are not exactly extreme. Could you please conduct a sensitivity analysis by considering other POT thresholds, say 99 percentile and see if it affects the findings of the manuscript.

Thank you for your concern and constructive suggestion. We have conducted the analysis considering the annual block maximum and different threshold values for high-discharge time series, and observed similar results and conclusions. For instance, we estimated the occurrence of high-intensity precipitation (P_{99}) and streamflow (Q_{99}) events during the period 1967-2019 (Figure R1) and found a similar pattern compared to the 95th percentile threshold (Figure S3). The number of independent extreme events is lower under the 99th percentile threshold compared to the 95th percentile threshold, but the key conclusions are qualitatively unchanged.

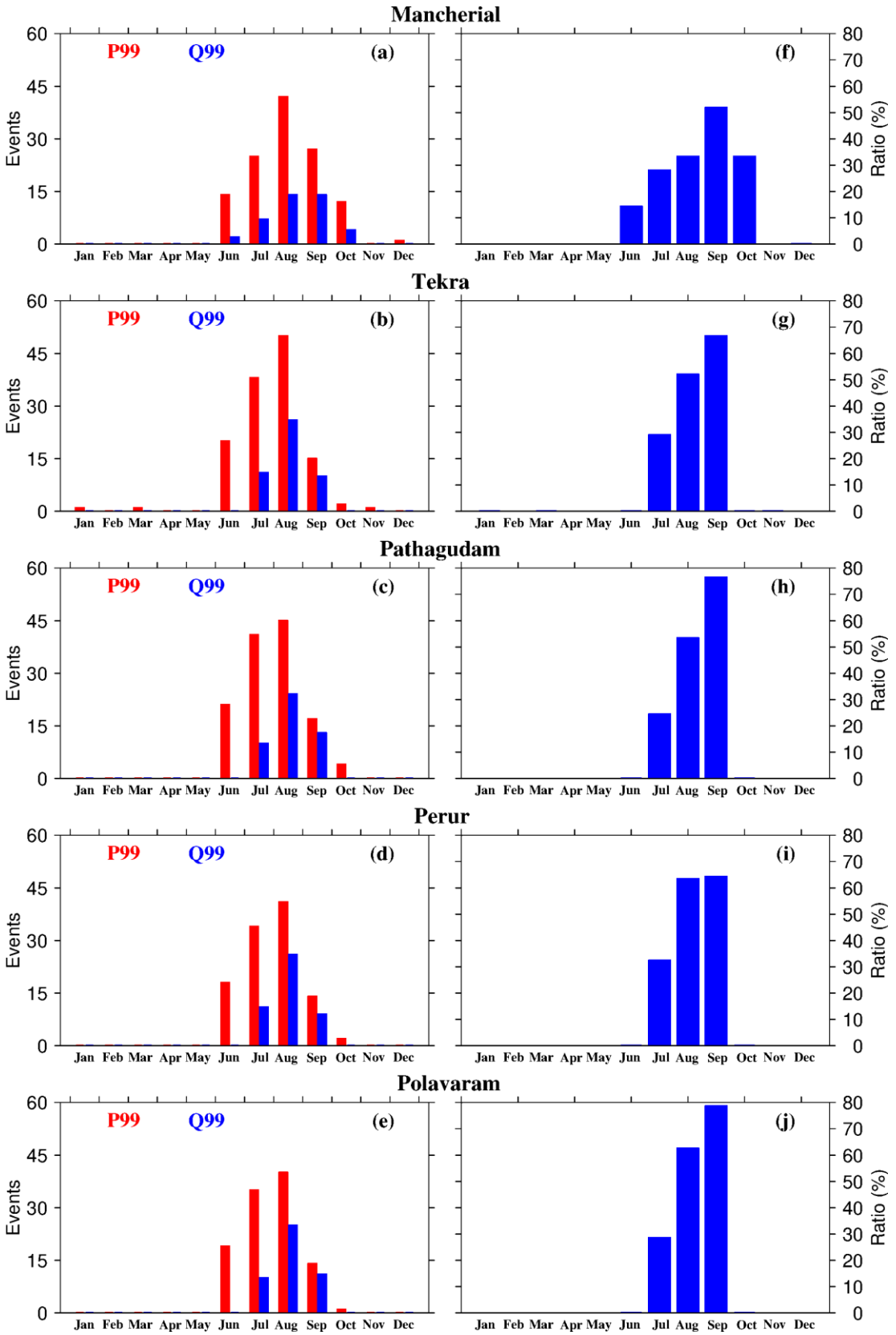


Figure R1. (a-e) Occurrence of high-intensity precipitation (P_{99}) and streamflow (Q_{99}) events (above 99th percentile) during 1967-2019 in each month at (a) Mancherial, (b) Tekra, (c) Pathagudam, (d) Perur, and (e) Polavaram stations. (f-j) Ratio of the number of extreme

streamflow and precipitation events in each month at Mancherial, Tekra, Pathagudam, Perur, and Polavaram stations, respectively.

Additionally, we also evaluated the correlations between simulated streamflow peak and basin-averaged accumulated observed precipitation (prior to the flood peak) for different durations (days) and lags (days) and observed the same outcome. The high discharge events are associated with short-duration (2 days) rainfall.

Table R2. Correlations between simulated streamflow peak (above 99th percentile events) and basin-averaged accumulated observed precipitation (prior to the flood peak) for different durations (days) and lags (days). The analysis is for high streamflow events at the Mancherial station for the period 1969-2019. Highlighted number is the best correlation value.

Lag / Duration	0	1	2	3	4	5	6	7
1	0.049	0.194	0.724	0.324	0.211	-0.009	-0.101	0.049
2	0.173	0.656	0.766	0.339	0.136	-0.061	0.010	0.173
3	0.642	0.719	0.759	0.310	0.070	0.003	-0.033	0.642
4	0.702	0.714	0.734	0.254	0.102	-0.029	-0.008	0.702
5	0.694	0.692	0.692	0.267	0.066	-0.010	-0.014	0.694
6	0.669	0.655	0.692	0.229	0.070	-0.014	0.003	0.669
7	0.631	0.664	0.649	0.220	0.060	0.000	0.040	0.631
8	0.639	0.632	0.606	0.207	0.065	0.033	0.056	0.639
9	0.607	0.597	0.585	0.200	0.088	0.047	0.049	0.607
10	0.578	0.577	0.570	0.212	0.099	0.042	0.012	0.578
11	0.561	0.568	0.566	0.217	0.094	0.009	0.030	0.561
12	0.553	0.567	0.566	0.211	0.064	0.026	0.031	0.553
13	0.553	0.567	0.560	0.184	0.077	0.028	0.035	0.553
14	0.554	0.564	0.545	0.193	0.076	0.031	0.060	0.554
15	0.552	0.554	0.548	0.187	0.078	0.056	0.074	0.552
16	0.542	0.561	0.538	0.187	0.098	0.070	0.069	0.542
17	0.547	0.554	0.529	0.202	0.109	0.066	0.062	0.547

18	0.541	0.544	0.522	0.207	0.103	0.059	0.044	0.541
19	0.531	0.538	0.509	0.198	0.097	0.042	0.042	0.531
20	0.526	0.524	0.494	0.191	0.080	0.040	0.045	0.526

Line 377: is located instead of reside

Thanks. Done. We have updated it in the revised manuscript.

Lines 384-386: The correlation is estimated here between the peak discharge and accumulated rainfall in the relevant regions.

Thank you for your comment. Here, we estimated the correlation (as mentioned in the manuscript) between the first principal component (PC-1) of the EOF analysis of spatially distributed accumulated precipitation (or mean runoff) over the sub-basin and the observed peak discharge at the respective gauging station.

Lines 405-409: The duration mentioned here is different for different subbasins right? If the rainfall occurs for multiple day duration on dry soil vs wet soil it is expected to have difference in runoff coefficient. Are you here comparing different duration scenarios for the same subbasins, if so, multiday duration can increase runoff coefficient compared to single day duration rainfall for dry conditions. I feel there is some lack of clarity here.

Thank you for your comment. No, we have used three durations (2, 7, and 8 days) in Figure 6 (identified from our temporal analysis across all sub-basins; Table 2). We compute the runoff coefficient (mean surface runoff / mean precipitation) for each of these three fixed durations, consistently across all sub-basins, and compare the results under both dry and wet antecedent soil moisture conditions.

For multiday events on dry soil, a longer accumulation window should have a higher runoff coefficient than a single-day event because prolonged rainfall progressively saturates the soil and increases runoff generation. However, here we showed variation in the runoff coefficient across durations under both dry and wet conditions.

Line 432: Initial hydrologic conditions instead of pre

Done.

Lines 474-476: Please explain this is not clear to me. In this manuscript, the authors have not considered the spatial pattern of soil moisture wetness as far as my understanding. the soil moisture pattern will also be related to the rainfall pattern in a catchment, and I do not understand how this conclusion of "soil moisture pattern may not affect the pre-event hydrometeorological patterns" is arrived at. What exactly the authors imply by hydrometeorological patterns?

Thank you for your comment. We have removed these lines from the revised manuscript.

Line 481: Did you mean forest to crop land conversion? If so, please mention it explicitly.

Thanks. We have updated it in the revised manuscript.

A possible extension is to explore if the identified flood-dominating area is also associated with the spatial rainfall pattern anomalies. That is, to explore if the region is receiving higher intensity rainfall than other parts of the catchment which leads to infiltration excess runoff generation. I would like to see such an analysis if it won't take much time and effort to corroborate the conclusion of the manuscript that the catchment hydrologic partitioning is the cause for the increase runoff contribution and to rule out that it is not related to the spatial heterogeneity in rainfall distribution.

Thank you for your comment and suggestion. We have already estimated the dominant rainfall pattern over the Godavari River Basin using EOF analysis to identify regions of high rainfall occurrence. Please check Figure 4, the leading mode of variability in the accumulated precipitation during the high streamflow events for the period 1967-2019.

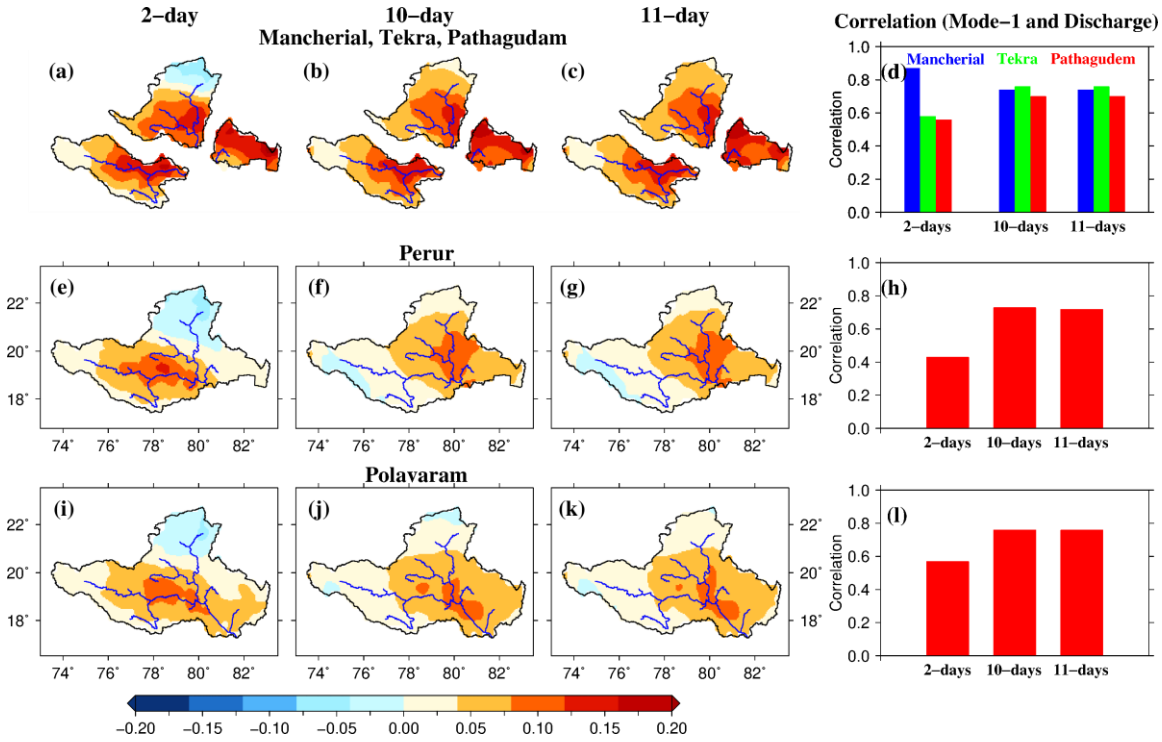


Figure 4: *The leading mode of variability in the accumulated precipitation during the high streamflow events for the period 1967-2019 using the method of empirical orthogonal function (EOF). (a-c) The first leading EOF mode of (a) 2 days, (b) 10 days, and (c) 11 days accumulated precipitation for Mancherial (left), Tekra (middle), and Pathagudam (right) sub-basins. (d) Correlation between the first leading mode and flood peak at Mancherial (left), Tekra (middle), and Pathagudam (right) stations. (e-h) same as (a-d) but for the Perur sub-basin. (i-l) same as (a-d) but for the Polavaram sub-basin.*

References

Nanditha, J. S., & Mishra, V. (2022). Multiday Precipitation Is a Prominent Driver of Floods in Indian River Basins. *Water Resources Research*, *58*(7), e2022WR032723. https://doi.org/10.1029/2022WR032723

Nanditha, J. S., & Mishra, V. (2024). Projected increase in widespread riverine floods in India under a warming climate. *Journal of Hydrology*, *630*, 130734. https://doi.org/10.1016/J.JHYDROL.2024.130734

Thanks. We have cited the above relevant papers in the revised manuscript.

Referee 2 Comments and Responses

General Remarks

The manuscript investigates the flood-generating mechanisms in the Godavari basin using hydroclimatic variables and catchment characteristics. The topic is relevant for monsoon-dominated regions and large basin flood dynamics. The integration of temporal analysis and EOF-based spatial attribution is a strength, and the findings are potentially useful. Overall, the manuscript is scientifically promising; however, it currently needs revision to explicitly highlight the novelty, provide scientific justification on use of only 5 stations, neglect of the role of human interventions, reliance on VIC outputs and ignoring the use of groundwater on flood generation in the study region.

We would like to thank the reviewer for their overall assessment and for their constructive feedback on our research. We have carefully addressed each concern in the detailed responses below, including novel contributions, station justification, human interventions, VIC model limitations, and groundwater. Overall, we have improved the writing part in the revised manuscript and addressed the reviewer's comments.

Major Comments

- The manuscript largely confirms known concepts: Long-duration vs short-duration flood regimes, role of antecedent soil moisture and spatial heterogeneity in runoff contribution. Suggesting authors to clearly articulate what is fundamentally new for large basin of India and why this is beyond previous works.

  Thank you for this important comment. We acknowledge that some individual concepts, such as long-duration vs. short-duration flood regimes, the role of antecedent soil moisture, have been explored in previous studies (Garg and Mishra, 2019; Keller et al., 2018; Nanditha et al., 2022; Nanditha and Mishra, 2022; Nied et al., 2014; Tarasova et al., 2019). However, the novelty of this manuscript lies in two specific contributions that have not been previously addressed, particularly for large river basins in a monsoonal climate:

  (i) Flood-generating mechanisms across different climate zones:

  Here, we systematically distinguish flood-generating mechanisms across different climate zones (from semi-arid to semi-humid) within a single large basin. We highlighted that the *majority of floods in the semi-humid regions predominantly occur due to multiple high-intensity rainfall days (10-11 days), and floods in the semi-arid Mancherial sub-basin are triggered by a single high-intensity precipitation event*.

  (ii) Flood-dominant catchment area delineation using EOF analysis:

While previous studies established multiday precipitation as a flood driver and examined the role of initial conditions in flooding, neither study explicitly identified which specific regions dominate flood generation through spatial EOF analysis and pixel-based runoff analysis. Our study is the first to quantitatively identify (as per our understanding) the flood-dominant spatial areas in the Godavari basin using EOF analysis and pixel-based runoff analysis. We highlighted that the *central and downstream areas of the Godavari River basin dominate flood occurrence (specifically, the role of the Tekra sub-basin as a disproportionate contributor to runoff).* This is a novel finding for the Godavari basin and offers directly actionable information for flood management.

We have highlighted these points in the abstract and discussion sections of the manuscript to clearly articulate these two specific novel contributions and explicitly position them relative to prior work.

- The study depends on VIC-simulated runoff and soil moisture without robust validation of extremes. Add a discussion of limitations of VIC in monsoon-dominated basins.

Thank you for your comment and suggestion. We acknowledge that our study relies on VIC-simulated surface runoff and soil moisture, and that model performance under extreme flow conditions may differ from that under daily mean conditions. Regarding the validation of extremes, we have also evaluated the VIC model's performance under extreme conditions (specifically during flood years and at high-flow percentiles).

During the top five flood years, the model maintains an acceptable performance (Figure S3):

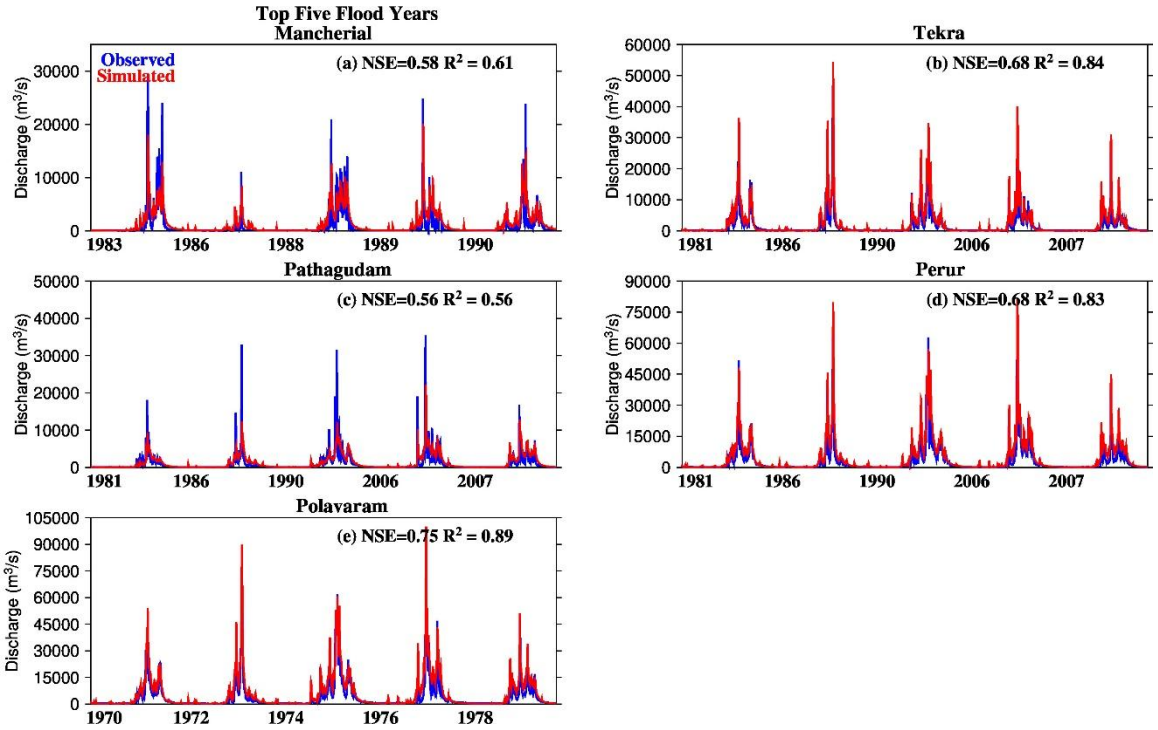


Figure S3. *(a–e) Comparison of daily observed (blue) and VIC- simulated (red) streamflow (m^3/s) for the top five major flood years at Mancherial, Tekra, Pathagudam, Perur, and Polavaram during the validation period 1980-2014 (except for the Mancherial station, which was validated for 1980-1993).*

Table R1: Values of performance indices [NSE and Coefficient of determination (R^2)] during the top five flood years of VIC simulated discharge (against the observed discharge data).

Stations	*Top Five Flood Years*	
	NSE	*R^2*
Mancherial	*0.58*	*0.61*
Tekra	*0.68*	*0.84*
Pathagudam	*0.56*	*0.56*
Perur	*0.68*	*0.83*
Polavaram	*0.75*	*0.89*

Additionally, we evaluated model bias under extreme conditions. The bias at the 95th percentile of streamflow (Bias_Q95, reported in Tables S1 and S2) indicates that the VIC model reproduces high-flow magnitudes with acceptable accuracy at most stations. Moreover, the bias at the 95th percentile is lower than the bias in mean discharge at most stations (Table S2).

Table S1: Values of performance indices [NSE, Coefficient of determination (R^2), high flow bias (Bias_Q95), low flow bias (Bias_Q5) and bias of the mean (Bias_mean)] during the calibration of VIC simulated discharge (against the observed discharge data) for the period 1970-1979.

Calibration (1970-1979)					
Station	*NSE*	*R^2*	*Bias_Q95 (%)*	*Bias_Q5 (%)*	*Bias_mean (%)*
Mancherial	*0.66*	*0.67*	*6.29*	*250.21*	*16.94*
Tekra	*0.8*	*0.86*	*39.57*	*-62.85*	*28*
Pathagudam	*0.6*	*0.61*	*18.45*	*-5.66*	*17.66*
Perur	*0.81*	*0.86*	*19.59*	*43.3*	*35.27*
Polavaram	*0.81*	*0.9*	*25.16*	*-41.43*	*37.44*

Table S2: Values of performance indices [NSE, Coefficient of determination (R^2), and Bias] during the validation of VIC simulated discharge (against the observed discharge data) for the period 1980-2014 (except Mancherial station; 1980-1993 for Mancherial sub-basin).

Validation (1980-2014)					
Station	*NSE*	*R^2*	*Bias_Q95 (%)*	*Bias_Q5 (%)*	*Bias_mean (%)*
*Mancherial**	*0.52*	*0.59*	*88.52*	*190.3*	*79.26*
Tekra	*0.58*	*0.83*	*55.18*	*-74.17*	*53.76*

Pathagudam	*0.6*	*0.62*	*17.44*	*188.08*	*21.47*
Perur	*0.59*	*0.82*	*50.43*	*89.53*	*63.7*
Polavaram	*0.63*	*0.88*	*45.63*	*-55.78*	*56.37*

**validated for 1980-1993*

Moreover, according to your suggestions, we have included a dedicated paragraph in the "Discussion and Conclusions" section of the revised manuscript, acknowledging the limitations of our study (including VIC model limitations). Please refer to the following lines in the revised manuscript:

Lines 582-590: *"In this study, we used the calibrated-VIC model for streamflow and runoff simulations, which also exhibits several structural and parametric limitations when applied to predict extreme streamflow events (Abdulla and Lettenmaier, 1997; Liang et al., 2003; Tsai et al., 2021). The VIC model simulates runoff using a saturated-excess mechanism (Liang et al., 1994), which underestimates excess runoff and infiltration estimations during intense monsoon events (Beven, 2012). By considering multiple hydrological models (including human influence) for streamflow prediction, we can reduce model limitations and develop a robust understanding of flood-generating mechanisms across India in the future."*

- The study analyzes flood mechanisms using only 5 gauging stations across a very large heterogeneous basin (312, 800 km^2). Can these 5 stations (selected on major river reaches) capture the spatial heterogeneity of the Godavari basin? Further, the stations are nested, and the results are not independent samples. Clearly state the limitations in extrapolating the findings to the entire basin.

  Thank you for raising this critical concern and your suggestion. In this study, we considered the observed streamflow data from five stations (Mancherial, Tekra, Pathagudam, Perur, and Polavaram), which are located at major river reaches and collectively drain sub-basins ranging from 35,625 km² (Pathagudam) to 257,500 km² (Polavaram), spanning the basin from semi-arid upper reaches to the semi-humid lower reaches. Since long-term daily discharge data from the Central Water Commission (CWC) (with acceptable data quality) are limited and unavailable for other minor independent streams, we considered the limited number of stations for our study. According to your suggestion, we have added the limitation of our results (based on limited observed datasets) in the "Discussion and Conclusions" section of the revised manuscript. Please see the following write-up in the revised manuscript:

Lines 576-590: *"Additionally, our study currently considers a limited number of observed streamflow stations (five) on five major tributaries of the Godavari River Basin, which provides only a limited understanding of flood mechanisms at a fine resolution (sub-catchment level) for more robust flood mitigation measures. Based on the availability of long-term streamflow data for other Godavari River streams, we can further improve understanding of flood mechanisms and the dominant catchment-area contribution to flood generation in the future using the framework discussed in our study. In this study, we used the calibrated-VIC model for streamflow and runoff simulations, which also exhibits several structural and parametric limitations when applied to predict extreme streamflow events (Abdulla and Lettenmaier, 1997; Liang et al., 2003; Tsai et al., 2021). The VIC model simulates runoff using a saturated-excess mechanism (Liang et al., 1994), which underestimates excess runoff and infiltration estimations during intense monsoon events (Beven, 2012). By considering multiple hydrological models (including human influence) for streamflow prediction, we can reduce model limitations and develop a robust understanding of flood-generating mechanisms across India in the future."*

- The manuscript does not consider baseflow contributions in the analysis, despite using the VIC model which simulated surface runoff and baseflow. For long-duration floods in large monsoonal basins, particularly under wet antecedent conditions, baseflow can significantly contribute to peak discharge. The authors are encouraged to consider separating baseflow and quickflow components or explicitly discuss this limitation.

Thank you for your comment. The VIC model simulates runoff and baseflow (simulated using nonlinear baseflow parameterization from the bottom soil layer) separately for each grid. In this study, we used the baseflow during the streamflow routing. Therefore, our analysis considers the baseflow contribution in the extreme streamflow events. However, we have not performed the separate baseflow analysis and its role on river floods. In this study, we primarily focus on the two major hydrometeorological variables (precipitation and surface runoff). Previously, Sharma and Mujumdar (2024) demonstrated the role of baseflow on floods in Peninsular India. We have discussed their work in the revised manuscript. Please refer to the "Discussion and Conclusions" Section in the revised manuscript:

Lines 453-461: *"In our analysis, we considered two hydrometeorological variables, precipitation and surface runoff, across the basin to evaluate the flood-generation mechanism, in which high-*

intensity precipitation is the primary driver of flood occurrence. However, previous studies (Garg and Mishra, 2019; Sharma et al., 2018; Sharma and Mujumdar, 2024) showed that high-intensity precipitation and floods are not always linked due to initial hydrological conditions over the catchment. There is only 50 to 70% of high-intensity precipitation, which causes flooding in a basin (Garg and Mishra, 2019; Wasko and Sharma, 2017). Moreover, Sharma and Mujumdar (2024) showed that baseflow has a substantially stronger influence on flood magnitudes than soil moisture."

- EOF used to identify "flood-dominated areas"; however, EOF identifies variance patterns not causality. Please clarify the physical representation of modes.

  Thank you for your comment. In this study, we did not perform any analysis for the causal attribution. EOF analysis conducted in this study identifies dominant modes of spatial variance and does not directly imply causality. We have carefully reviewed the relevant sections (Sections 3.3.2 and 4.3) and updated them in the revised manuscript to clarify the physical interpretation. Please refer to the following sections/lines in the revised manuscript:

  Section 3.3.2: Lines 296-320: *"Next, we evaluated the dominated catchment area in flood generation by examining the spatial variability of precipitation and runoff (Figure 2). For that, we used the empirical orthogonal function (EOF) analysis and obtained the leading modes of spatial variability in precipitation and surface runoff (Mishra et al., 2012). EOF analysis identifies the dominant modes of spatio-temporal variability in a dataset by solving an eigenvalue problem derived from the spatio-temporal covariance matrix (Lorenz, 1956; Preisendorfer, 1988; Wilks, 2006; Navarra and Simoncini, 2010; Joliffe, 1986; Hannachi, 2022). Here, we first estimated the dominant spatiotemporal modes of variability in the gridded precipitation (surface runoff) to assess its coupling with peak discharge. To do so, we formed the spatial covariance matrix of N x N (where N is the number of grid points) using the following equation:*

$$C = \frac{1}{t-1} P' P'^{T}$$

where P' is precipitation (runoff) anomaly; t is the number of peak events; and T represents the transpose matrix.

Further, the spatial covariance matrix (C) was decomposed as:

$$Ce_k = \lambda_k e_k$$

where e_k and λ_k are the k^{th} spatial EOF and its associated eigenvalue, respectively (Lorenz, 1956). The fraction of total variance explained by each mode is $\lambda_k / \Sigma\lambda_j$. We also obtained the Principal Component (PC) time series by projecting the anomaly field onto each EOF:

$$a_k(t) = \sum_{i=1}^{N} P'_{i,t} . e_{k,i}$$

Finally, the coupling between each PC time series and the peak discharge anomaly was quantified using the Pearson correlation coefficient. In the EOF analysis, we used accumulated precipitation and mean surface runoff at each pixel for the time windows that were most strongly correlated with peak discharge, as identified in step 1 above."

Section 4.3 (Lines 401-424)

"Based on the EOF analysis, we captured the dominant pattern of accumulated precipitation during the flood events. We found that floods in the Mancherial and Tekra sub-basins are associated with precipitation occurring over the downstream areas of these sub-basins, which are located in the central part of the Godavari basin (Figure 4a-c). However, the leading spatial pattern (Mode-1) of accumulated precipitation covers the entire region of Pathagudam (Figure 4a-c). The Perur sub-basin also showed a similar spatial pattern in the EOF analysis for 10 and 11 days of accumulated precipitation and indicated high weightage over the central and downstream parts of the sub-basin during flood generation (Figure 4e-h). For the Polavaram sub-basin, we found a high dominance of the central and downstream part of the Godavari basin in the flooding mechanism (Figure 4i-k). Moreover, the correlation between peak streamflow and the leading mode (mode-1) of 10 or 11 days of accumulated precipitation is higher at Tekra, Pathagudam, Perur, and Polavaram sub-basins than the leading mode of 2 days of accumulated

precipitation in the same basins (Figure 4d) due to long-rain type floods (Table 1). Furthermore, EOF analysis of mean surface runoff (Figure 5) showed a similar leading spatial pattern, although the area is slightly smaller than that of precipitation (Figure 4). In addition to EOF analysis, we computed pixel-based correlations between accumulated precipitation and peak streamflow (Figure S5), and between mean runoff and peak streamflow (Figure S5), for each sub-basin over the relevant duration. Our results showed spatial correlation patterns similar to those obtained from the EOF analysis. In addition, our analysis (Figure S5 and Figure S6) confirms the previous finding (Figure 4 and Figure 5) where higher correlations of peak streamflow in the Tekra, Pathagudam, Perur, and Polavaram sub-basins are with long-duration precipitation and runoff, compared to short-duration, while for the Mancherial station, the opposite behavior was found."

- Godavari basin is heavily regulated and these structures attenuate flood peaks, alter timing of peak discharge and modify flow accumulation downstream. The assumption that human impacts are negligible is not sufficiently justified especially for downstream stations.

  Thank you for your comment and feedback. We agree that the Godavari basin and other Indian River basins are significantly regulated and affected by human activities. In the present study, we did not consider the interventions of human activities in the water cycle due to the limited availability of human intervention datasets, which is a limitation of our study. Therefore, we have added the study limitations (related to human influence) in the "Discussion and Conclusions" section of the revised manuscript. Please refer to the following lines in the revised manuscript:

  Lines 566-575: *"The flood-generating mechanisms cannot be fully understood by natural drivers of floods (such as climate) and static catchment attributes alone. The current study does not consider the extensive role of human activities on water resources and the simulation of hydrological components, which can affect the flood-generating mechanisms (flood propagation and attenuation) in the catchment (Boulange et al., 2021; Haddeland et al., 2014). For instance, previous studies (Boulange et al., 2021; Han et al., 2019; Ruan et al., 2024) have shown the roles of human activities and dynamic catchment attributes in flood severity and exposure. Therefore, a similar study can be conducted separately in the future to analyse the role of human activities (intensive agricultural practices, reservoir operations, groundwater depletion, urbanization, etc.) in the occurrence of flood events."*

- Discussion section can be strengthened by adding comparison with global studies, process understanding and implications for forecasting systems.

Thank you for your suggestions. We have substantially updated the discussion section of the revised manuscript and included three suggested dimensions (global studies, process understanding, and implications for forecasting systems). Please refer to the following "Discussion and Conclusions" section:

Lines 444-590: "*Floods pose severe challenges to the infrastructure, ecology, and socio-economic development of the largely populated Indian Subcontinent. Moreover, the risk of floods has increased significantly under global warming (Ali et al., 2019; Arnell and Gosling, 2016; Dottori et al., 2018; Hirabayashi et al., 2013; Milly et al., 2002). Thus, efforts are required to better understand flood-generation mechanisms in the large river basins of the Indian Subcontinent during the monsoonal climate to support effective flood management. In this study, we examined the temporal and spatial variability of hydrometeorological variables to identify the dominant flood-generating mechanisms and flood-contributing areas using the observed and VIC-simulated hydrological variables.*

In our analysis, we considered two hydrometeorological variables, precipitation and surface runoff, across the basin to evaluate the flood-generation mechanism, in which high-intensity precipitation is the primary driver of flood occurrence. However, previous studies (Garg and Mishra, 2019; Sharma et al., 2018; Sharma and Mujumdar, 2024) showed that high-intensity precipitation and floods are not always linked due to initial hydrological conditions over the catchment. There is only 50 to 70% of high-intensity precipitation, which causes flooding in a basin (Garg and Mishra, 2019; Wasko and Sharma, 2017). Moreover, Sharma and Mujumdar (2024) showed that baseflow has a substantially stronger influence on flood magnitudes than soil moisture. Our results show that the attribution of high-intensity precipitation to flood generation varies with time. For instance, the majority of high-intensity precipitation events during the late monsoon season (August-September) cause flooding in the Godavari basin (Figure S3) due to wetter soil

moisture conditions. Therefore, we used a bottom-up approach in our study to examine the temporal and spatial variability of hydrometeorological variables, i.e., we first identified the flood events, and then precipitation and surface runoff variables before the flood events were evaluated to understand their role in the flooding mechanism.

We evaluated the temporal properties of hydrometeorological variables (precipitation and surface runoff) to identify the flood types and processes (Keller et al., 2018; Merz and Blöschl, 2003) that predominantly occur over the Godavari basin in the monsoonal climate. We found that the majority of floods in the Godavari basin (except Mancherial Basin) are long-rain type floods (Keller et al., 2018; Merz and Blöschl, 2003), which are associated with the 10 to 11 (7 to 8) days long precipitation (mean surface runoff) with multiple high-intensity precipitation events. However, the majority of floods in the semi-arid Mancherial sub-basin are short-rain type. The majority area of the Godavari basin, associated with long-duration precipitation (surface runoff), falls in the semi-humid climate. The rivers in the humid climate can carry a large volume of water (or have a large storage capacity); therefore, a significant amount of rainfall is required for the flood occurrence (Merz and Blöschl, 2003). Previous studies (Hirschboeck et al., 2000; Merz and Blöschl, 2003; Nanditha and Mishra, 2022) have found that persistent rainfall in the region is the primary factor in generating long-rain type floods. Consistent with our results, Nandith and Mishra, (2024) showed that Multiday precipitation is the predominant driver of floods over the Indian Subcontinent. Similar to long-rain type floods (associated with humid climate), we observed that the short-rain type floods in the semi-arid Mancherial region are associated with the small storage capacity of the river in the region, which can be easily achieved with shorter rainfall. Therefore, to minimize the risk of flooding in the region, we require a forecasting system that can predict rainfall for 10 to 11 days duration in the semi-humid climate region. Moreover, we need to understand the

occurrence of multiple concurrent extreme precipitation events in the future changing climate.

While the temporal properties of hydrometeorological variables have been widely evaluated to identify flood processes (Keller et al., 2018; Merz and Blöschl, 2003; Nanditha and Mishra, 2022), the spatial patterns of hydrometeorological variables and catchment conditions prior to peak streamflow are often overlooked. This study also evaluated the spatial variability of precipitation and surface runoff prior to peak streamflow to delineate the dominant flood-generating areas using EOF and correlation analyses. We showed that accumulated precipitation (long- or short-duration) and mean surface runoff before peak streamflow predominantly occur over the central and downstream areas of the Godavari basin, which contribute to flood generation.

Apart from spatial patterns of precipitation and surface runoff prior to the flood, catchment properties also play an essential role in flood generation. We found that the majority area of the Tekra sub-basin generates more runoff compared to the other sub-basins. The high runoff ratio in the Tekra sub-basin can be associated with various catchment characteristics (such as high slope, conversion of forest to cropland (agricultural land cover), clay-dominant soils, etc.) in this semi-humid region, which results in a large fraction of precipitation contributing to the surface runoff and causing flooding in the downstream areas. Previous studies (Boardman et al., 2003; Holman et al., 2003; Lane, 2017; Marc and Robinson, 2007) showed that the high irrigation area, deforestation, and high slope accelerate the runoff generation mechanism, which causes high runoff in the basin.

With a limited understanding of flood processes in the Indian Subcontinent under monsoonal conditions, this study initiates a new discussion to better comprehend the

mechanisms of flood generation in India, aiming to improve flood management. Using the same approach, we can identify the temporal and spatial variability of hydrometeorological variables in other Indian River basins, which can be used for numerous flood-control applications. Overall, our findings provide a better insight into the flood generation mechanism over a large river basin of the Indian Subcontinent during the monsoonal climate. Based on our study, we conclude the following:

1. *The majority of floods in the Godavari river basin occurred during the monsoon season. However, during the late monsoon, the ratio of high flood events to high precipitation events is higher due to wet soil moisture conditions.*
2. *Four out of five sub-basins (except the Mancherial sub-basin) showed the dominance of long-duration type floods in the period 1967-2019. Long-duration rainfall (10-11 days) causes floods in the semi-humid regions of the Tekra, Pathagudam, Perur, and Polavaram sub-basins. However, Floods in the semi-arid Mancherial sub-basin are associated with short-duration (2 days) precipitation and surface runoff.*
3. *Floods in the Tekra, Pathagudam, Perur, and Polavaram sub-basins predominantly occur due to multiple high-intensity rainfall days. Therefore, long-duration type floods occurred in these sub-basins. Moreover, our analysis revealed that short-duration floods in the semi-arid Mancherial sub-basin are primarily associated with single-day high-intensity precipitation.*
4. *Based on the EOF and correlation analyses of precipitation and surface runoff, central and downstream areas of the basin dominate in the flood generation mechanism in the Godavari River, which highlights the importance of these areas in flood management in a future warming climate. Moreover, medium-term (10 to*

11 days lead) precipitation forecasts in these regions will be useful for flood and reservoir management forecasting.

5. *Our analysis also indicated the importance of the Tekra sub-basin in the high runoff generation in the Godavari basin. Due to favorable catchment characteristics, a large fraction of precipitation contributes to the surface runoff in the Tekra sub-basin. Therefore, additional efforts (e.g., afforestation and sustainable infrastructure development) are needed in the Tekra sub-basin to improve flood management in the downstream region.*

In the changing climate and land use land cover (urbanization and deforestation), the risk of floods is projected to increase over the Indian Subcontinent (Ali et al., 2019; Gosain et al., 2006; Gupta and Nair, 2011; Rogger et al., 2017; Shah et al., 2019). Moreover, the moisture-holding capacity of the atmosphere increases (Karl and Trenberth, 2003; Kharin et al., 2007) due to a warming climate, which leads to frequent, intense, and more extended extreme precipitation events (Ali et al., 2019, 2014; Roxy et al., 2017; Vittal et al., 2013). Therefore, reliable information on precipitation and runoff forecasts in the basin is crucial for effective flood mitigation. Since floods in semi-humid regions of the Godavari basin result from multiple high-intensity rainfall days, there is a need for high-skill medium-range precipitation forecasting (especially over the central and downstream regions of the basin) to mitigate flood risk in a warming climate. Moreover, a real-time soil moisture monitoring system is required in the Tekra basin (which experiences high runoff during the monsoon season) to mitigate flooding. In addition to a real-time monitoring and forecasting system, significant steps are needed to reduce the rapid runoff generation in the Tekra sub-basin using natural flood management methods for flood control in the downstream area of the basin (Lane, 2017). For instance, attenuation of surface runoff can be achieved through afforestation (Marc and Robinson, 2007), changes

in arable land-use practices (Boardman et al., 2003), reductions in livestock density (Orr and Carling, 2006), and changes in tillage practices (Holman et al., 2003).

The flood-generating mechanisms cannot be fully understood by natural drivers of floods (such as climate) and static catchment attributes alone. The current study does not consider the extensive role of human activities on water resources and the simulation of hydrological components, which can affect the flood-generating mechanisms (flood propagation and attenuation) in the catchment (Boulange et al., 2021; Haddeland et al., 2014). For instance, previous studies (Boulange et al., 2021; Han et al., 2019; Ruan et al., 2024) have shown the roles of human activities and dynamic catchment attributes in flood severity and exposure. Therefore, a similar study can be conducted separately in the future to analyse the role of human activities (intensive agricultural practices, reservoir operations, groundwater depletion, urbanization, etc.) in the occurrence of flood events. Additionally, our study currently considers a limited number of observed streamflow stations (five) on five major tributaries of the Godavari River Basin, which provides only a limited understanding of flood mechanisms at a fine resolution (sub-catchment level) for more robust flood mitigation measures. Based on the availability of long-term streamflow data for other Godavari River streams, we can further improve understanding of flood mechanisms and the dominant catchment-area contribution to flood generation in the future using the framework discussed in our study. In this study, we used the calibrated-VIC model for streamflow and runoff simulations, which also exhibits several structural and parametric limitations when applied to predict extreme streamflow events (Abdulla and Lettenmaier, 1997; Liang et al., 2003; Tsai et al., 2021). The VIC model simulates runoff using a saturated-excess mechanism (Liang et al., 1994), which underestimates excess runoff and infiltration estimations during intense monsoon events (Beven, 2012). By considering multiple hydrological models (including human influence) for streamflow

prediction, we can reduce model limitations and develop a robust understanding of flood-generating mechanisms across India in the future."

Minor Comments

- Cleary describe the novelty in the abstract.

  Thank you for your comment. We have revised the abstract and underlined specific novel contributions:

  "Indian River basins experience frequent flooding during the Indian summer monsoon and pose several challenges for the region's large population, yet the hydrometeorological and catchment-scale drivers that control flood processes remain poorly explored across India. To effectively manage flood risk in the densely populated Indian region, it is essential to ***understand how the temporal properties of precipitation and runoff generate floods across different aridity regimes within a large catchment, and which specific areas of a large, climatically heterogeneous basin generate the runoff that drives downstream flood peaks.*** *In this study, we address these gaps and examine the role of hydrometeorological variables (such as precipitation and surface runoff) and catchment area in the flood occurrence in the Godavari River basin (one of the largest river basins in the Indian Subcontinent) using observed and VIC-simulated datasets. Based on the temporal analysis of precipitation, runoff, and streamflow, we show that* ***the majority of floods in the semi-humid sub-basins (Tekra, Pathagudam, Perur, and Polavaram) are predominantly associated with 10 to 11 days of accumulated precipitation, having multiple high-intensity precipitation events prior to flood. In contrast, the floods in the semi-arid region of Godavari (Mancherial sub-basin) are triggered by a single high-intensity precipitation day and are associated with short-duration (2 days) accumulated precipitation.*** *In addition to temporal analysis, we performed Empirical Orthogonal Function (EOF) analysis using precipitation, runoff, and streamflow data to identify the specific sub-regions that disproportionately generate flood-causing runoff (flood-dominant catchment areas). Our results demonstrate that* ***central and downstream areas of the basin contribute dominantly to flood occurrence, generating substantially higher runoff in the***

Tekra sub-basin. *Overall, this study moves beyond basin-averaged flood attribution and advances understanding of flood-generating mechanisms over the Godavari River basin, which can be helpful for duration-informed forecasting and catchment-scale flood management during the monsoonal climate of the Indian Subcontinent."*

- Literature review in the introduction section is generic and global, with limited focus on Indian basins. Recent works can be added to sharply define the motivation to this study.

  Thank you for your comment and suggestion. We have revised the Introduction and included additional regional studies on flood mechanisms over Indian basins (such as Sharma and Mujumdar (2024), Nanditha and Mishra (2022), Nanditha et al. (2022), etc.)