Do satellite precipitation datasets capture flash flood–producing cloudburst events?

Nandana Dilip K · Vimal Mishra | Water & Climate Lab, IIT Gandhinagar

EGU26-6612

OBSERVATIONS (2000–2024)

243

flash flood-producing cloudburst events

Observed cloudburst events compiled from EM-DAT and the India flood inventory.

78

in Himachal Pradesh alone

Himachal Pradesh leads, followed by J&K (36) and Assam (30). Kullu district tops at 15 events.

45.7%

in flash flood-prone basins

111 of 243 events fall inside flash-flood-prone sub-basins — peaking at 68% in 2010–2015.

THE QUESTION

Cloudbursts cause flash floods, and heavy casualty, yet rain-gauge networks are sparse in the Himalayan and hilly terrains where most events occur. **Can global satellite precipitation products serve as a reliable observational backstop?**

IMD defines cloudburst as 100 mm rainfall in 1 hour over 20–30 km²

Do satellite precipitation datasets capture flash flood–producing cloudburst events?

Nandana Dilip K · Vimal Mishra | Water & Climate Lab, IIT Gandhinagar

EGU26-6612

IMERG and ERA5-Land misses the cloudburst signal.

OF 202 EVENTS

5.5%

captured by IMERG at the IMD threshold

Only 11 of 202 observed cloudburst events between 2001–2024 reach >100 mm in one hour in the IMERG record.

MEDIAN PRECIPITATION AT EVENT LOCATIONS

Duration	IMERG (mm)	ERA5-Land (mm)	Max IMERG (mm)
1 h	22.6	11.7	140.7
3 h	41.3	27.8	297.2
6 h	53.3	42.7	409.5
12 h	63.0	63.4	488.9
24 h	80.5	86.9	544.0

TAKEAWAY

Satellite precipitation datasets systematically under-detect cloudburst-scale rainfall over India. Areal-reduction adjustment narrows but does not close the gap. Operational flash-flood early warning in the Himalaya cannot rely on IMERG or ERA5-land alone — gauge-blended or radar-augmented products are essential.

Even maximum IMERG totals stay well below the 100 mm/h cloudburst threshold for nearly every event.

EGU26-6612

Do satellite precipitation datasets capture flash flood–producing cloudburst events?

Nandana Dilip K · Vimal Mishra | Water & Climate Lab, IIT Gandhinagar

What is cloudburst?

- Cloudburst is 100 mm or more of rainfall in an hour over 20-30 km^2 (IMD).
- They occur primarily in the summer monsoon season.
- The Himalayas and hilly terrains are hotspots.

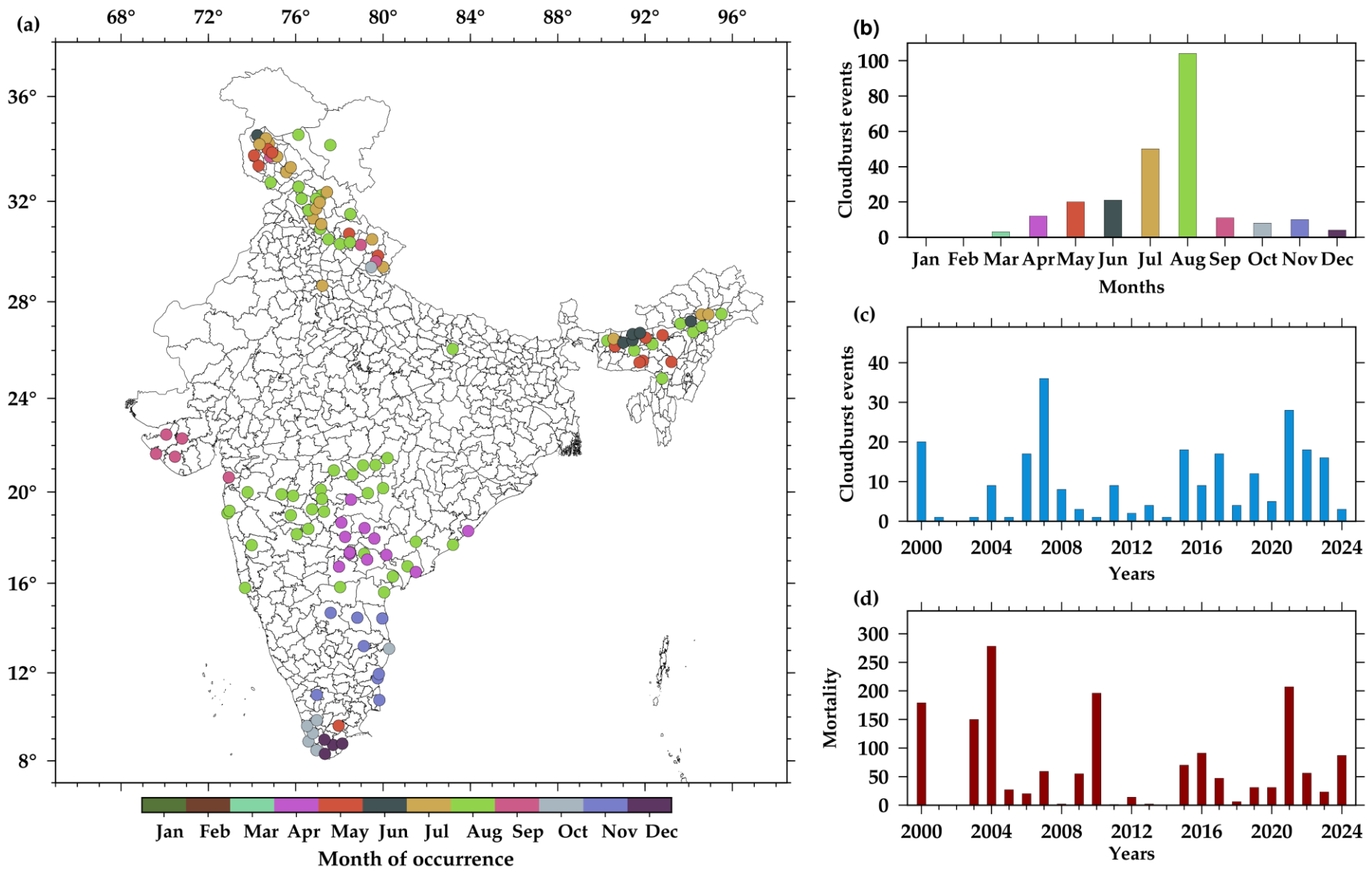


Figure1: (a) Observed cloudburst events that occurred in the period 2000-2024 across India using EM-DAT and India flood inventory. (b) Seasonality of the events. (c) Year-wise distribution of events. (d) Year-wise mortality due to cloudburst events.

Scientific question

RESEARCH GAP

IMD REPORTS

Cloudbursts are reported within **24 hours.**

CHALLENGE

Sparse station networks limit accurate detection, especially in **complex terrain.**

Accurate identification and categorization remain challenging in several regions due to sparse observations, particularly in complex terrain.

SATELLITES

Provide wide coverage of intense clouding or heavy rainfall events.

LIMITATION

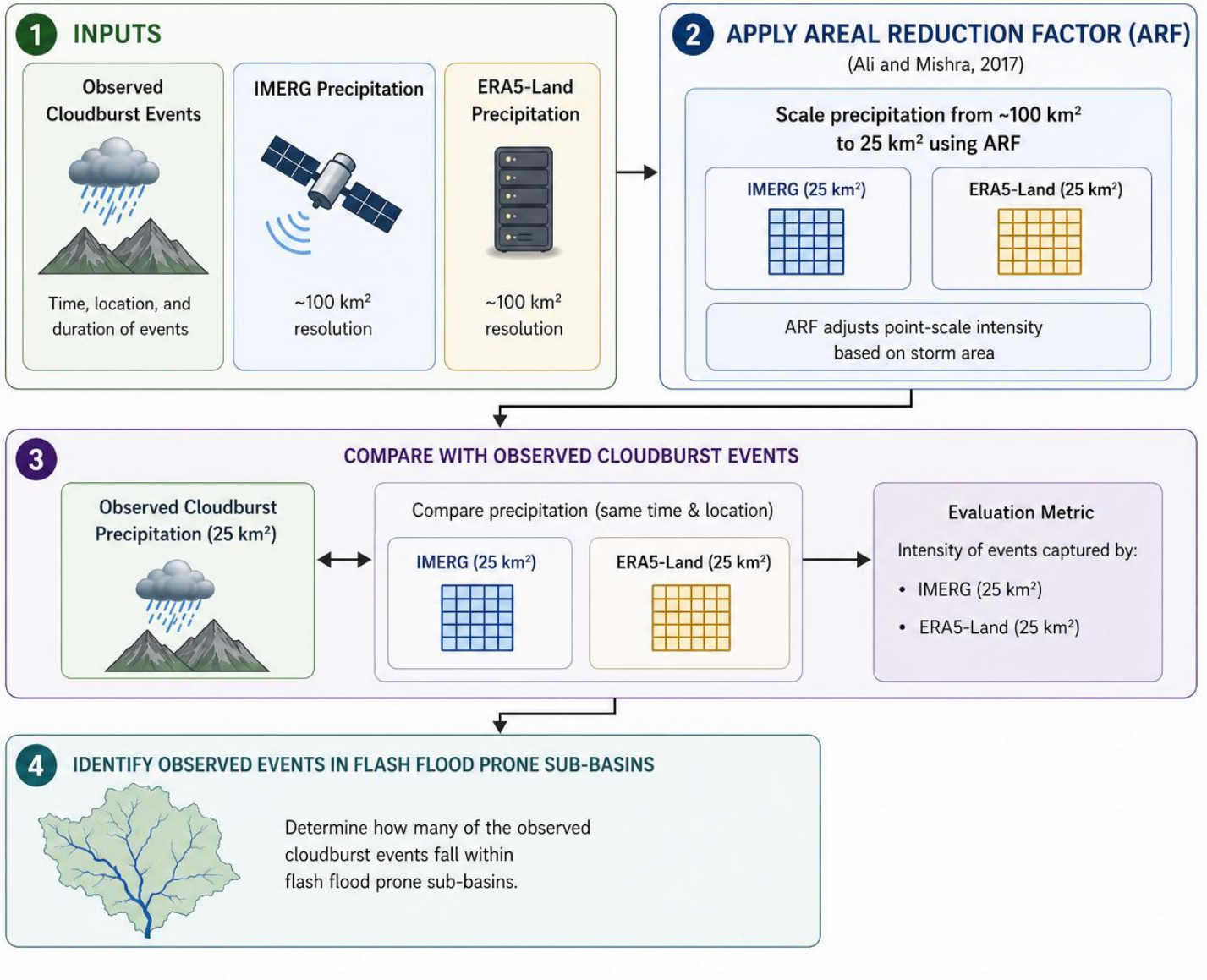
Satellites rely on radiance-based inference, introducing uncertainties compared to direct ground measurements.

OBJECTIVE

To evaluate the performance of satellite-based precipitation datasets and identify regions where satellites successfully detect cloudburst events and regions where their performance is limited.

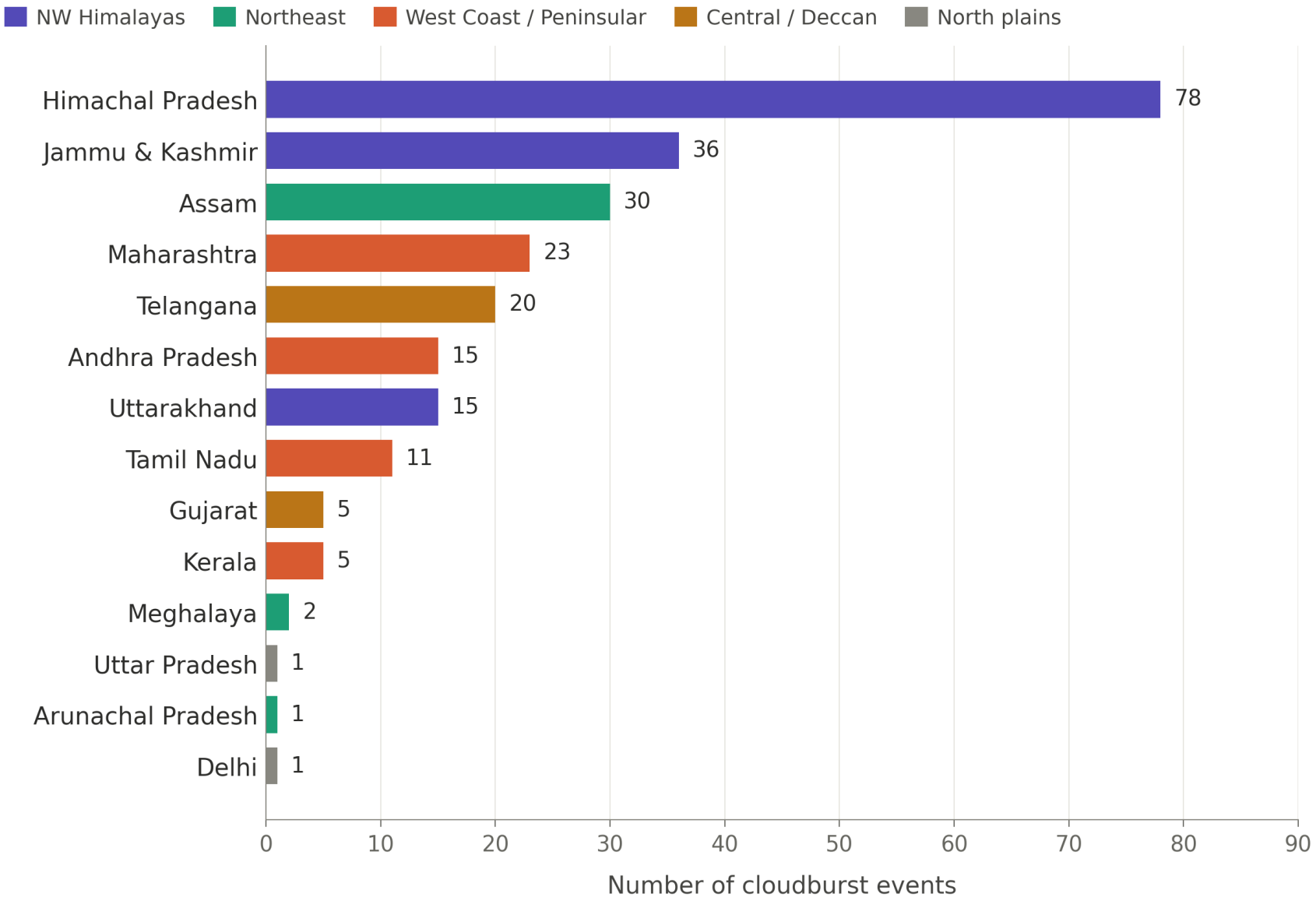
Data and Method

Type of data	Resolution	Source
Precipitation	0.1°/Half-Hourly	IMERG (Huffman et al., 2023)
Precipitation	0.1°/Hourly	ERA5-Land (Muñoz Sabater, J., 2019)
Observed flash flood-producing cloudburst dataset	-	Emergency Events Database (EM-DAT), India flood inventory (Saharia et.al, 2021)
Flash flood-prone sub-basins	Level 06-HydroSHEDS	Dilip K et al. (2025)



Observed Cloudburst Events

Top states and districts affected by cloudburst events (2000-2024):



District	No. of events
Kullu	15
Chamba	10
Mandi	9
Shimla	9
Kangra	8
Anantnag	7
Kinnaur	7
Doda	5
Hamirpur	5
Pulwama	5
Chamoli	4
Lahul and Spiti	4
Sirmaur	4
Solan	4
Baramulla	3
Goalpara	3
Kishtwar	3
Lakhimpur	3
Pithoragarh	3

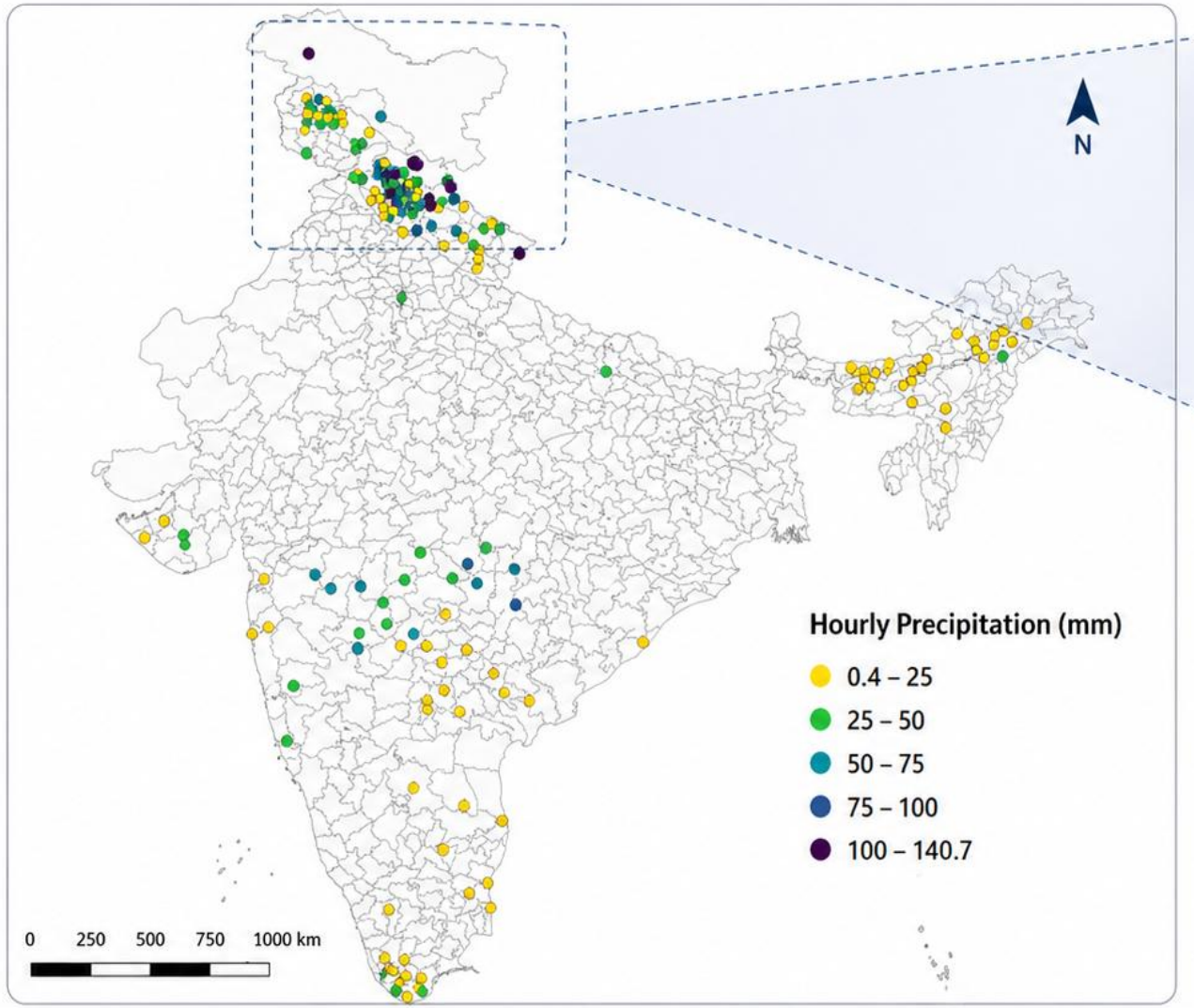
IMERG and ERA5-Land Performance

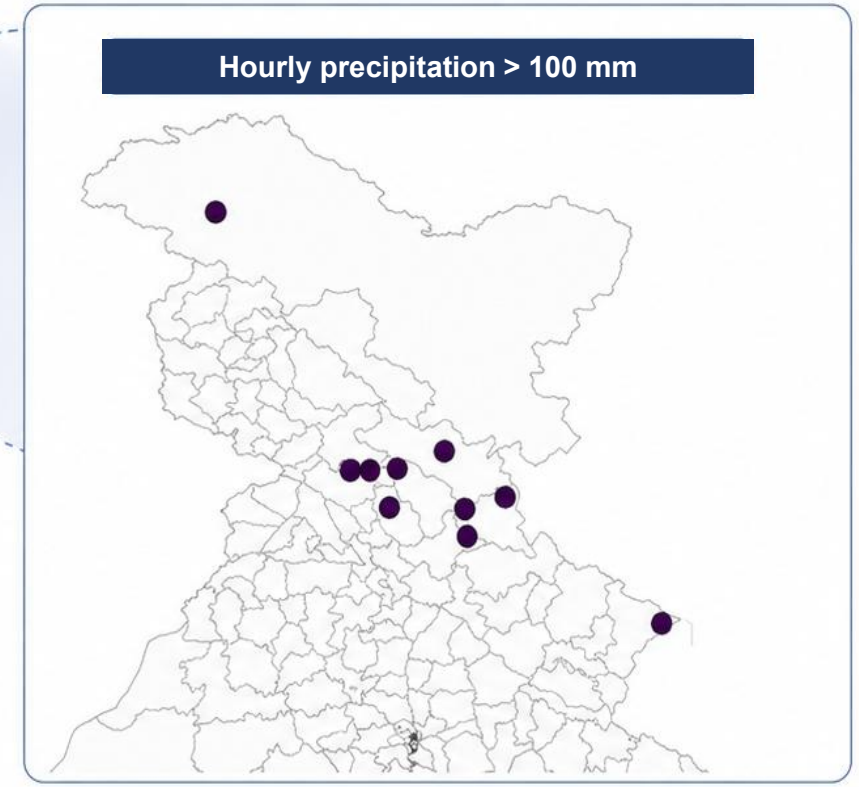
Duration	IMERG			ERA5-Land		
	Median Precipitation (mm)	Median Precipitation Percentile (%)	Maximum Precipitation (mm)	Median Precipitation (mm)	Median Precipitation Percentile (%)	Maximum Precipitation (mm)
30 min	12.97	99.60	72.20	-	-	-
1 h	**22.57**	**99.54**	**140.66**	**11.74**	**99.96**	**46.02**
3 h	41.31	99.21	297.19	27.78	99.94	132.60
6 h	53.34	98.86	409.51	42.72	99.91	213.47
12 h	62.95	97.88	488.90	63.43	99.84	331.18
24 h	80.45	96.86	543.97	86.92	99.73	497.94

- IMERG and ERA5-Land under-detect cloudburst-scale rainfall over India.
- ERA5-Land captures all the event occurrence. IMERG miss few events completely.

- ERA5-Land captures the timing and peaks of the cloudburst events well across India.
- IMERG captures the intensity of some cloudburst events over the north-western Himalayas.

IMERG Spatial Performance



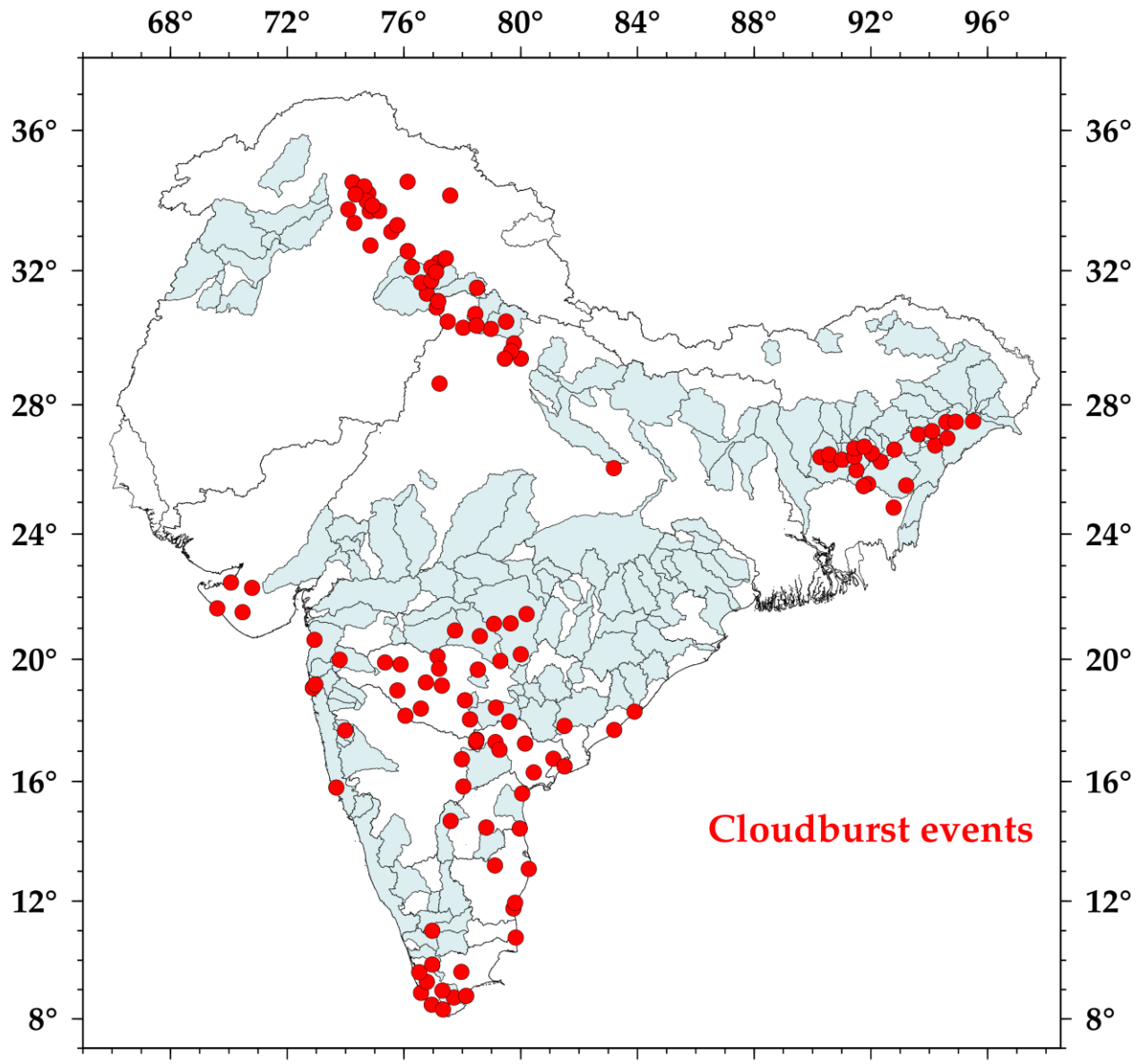


Only 11 events (5.5% of events) are captured by the satellite.

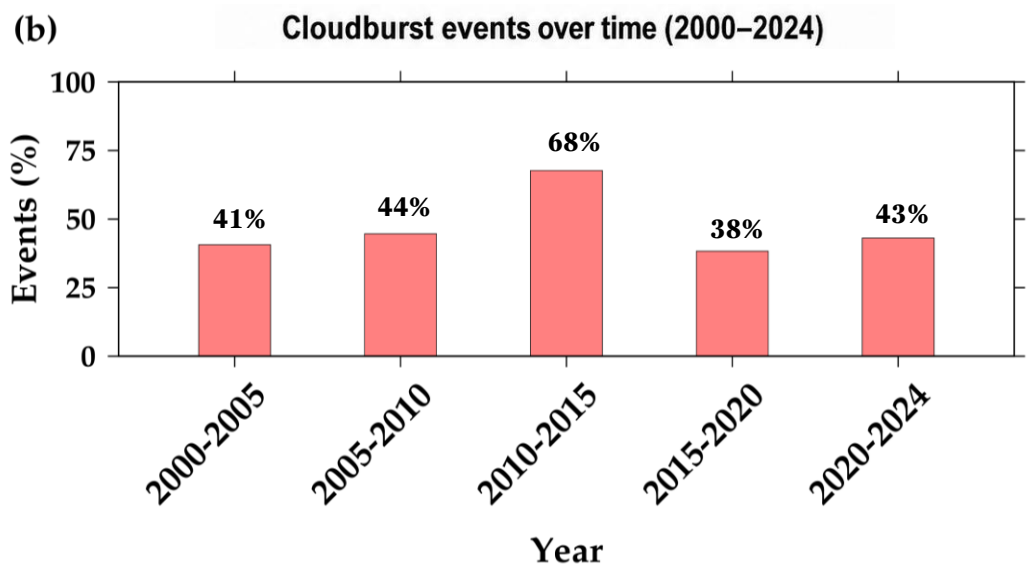
(Considering cloudburst definition of >100 mm in an hour).

How many cloudbursts fall in flash flood-prone subbasins?

(a)



(b)



45.7% of cloudbursts occur in flash flood–prone sub-basins

111 out of **243** cloudburst events (2000–2024) occurred in flash flood–prone sub-basins.

Conclusions

- Cloudbursts occur most frequently in the northwestern Himalayas, with a strong seasonal concentration in summer and a peak in August.
- Satellite-based precipitation datasets under-detect cloudburst-scale rainfall over India.
- Even though ERA5-Land underestimates the intensity of cloudbursts, it captures all the cloudburst events occurrence, timing and peaks across India.
- IMERG captures the intensity of some cloudburst events over the northwestern Himalayas. However, IMERG miss few events completely.
- Operational flash-flood early warning in India cannot rely fully on IMERG or ERA5-land alone, gauge-blended or radar-augmented products are essential.

References

- Ali, H., Mishra, V. Contrasting response of rainfall extremes to increase in surface air and dewpoint temperatures at urban locations in India. Sci Rep 7, 1228 (2017). https://doi.org/10.1038/s41598-017-01306-1

- Muñoz Sabater, J. (2019): ERA5-Land hourly data from 1950 to present. Copernicus Climate Change Service (C3S) Climate Data Store (CDS). DOI: 10.24381/cds.e2161bac

- Huffman, G.J., E.F. Stocker, D.T. Bolvin, E.J. Nelkin, J. Tan (2024), GPM IMERG Final Precipitation L3 Half Hourly 0.1 degree x 0.1 degree V07, Greenbelt, MD, Goddard Earth Sciences Data and Information Services Center (GES DISC), DOI:10.5067/GPM/IMERG/3B-HH/07.

- Saharia, M., Jain, A., Baishya, R.R. et al. India flood inventory: creation of a multi-source national geospatial database to facilitate comprehensive flood research. Nat Hazards 108, 619–633 (2021). https://doi.org/10.1007/s11069-021-04698-6

- Dilip K, N., Vegad, U. & Mishra, V. Drivers of flash floods in the Indian sub-continental river basins. npj Nat. Hazards 2, 62 (2025). https://doi.org/10.1038/s44304-025-00121-3