Cloudbursts: A Growing Weather Challenge in a Changing Climate

Abhishek Dhir[1]* and K K Gill[2]

[1]ICAR - Central Research Institute for Dryland Agriculture (CRIDA)
Santoshnagar, Hyderabad, India – 500059
[2]Department of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana-141004, Punjab, India

Corresponding Author
Abhishek Dhir
Email: abhishekdhir34@gmail.com

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ABSTRACT

Hydrometeorological extremes are becoming a significant challenge under changing climate, particularly in regions with complex terrain and high environmental sensitivity. Among these extremes, localized intense rainfall events, known as cloudbursts, have gained attention due to their sudden occurrence and ability to trigger flash floods, landslides and widespread damage. This study examines cloudburst events in Northwest India, focusing on the Himalayan states of Uttarakhand, Himachal Pradesh and Jammu & Kashmir, along with their downstream impacts on adjoining plains. The northwestern Himalaya act as hotspots for cloudbursts due to moisture transport, atmospheric instability and orographic uplift. These events can cause rapid runoff, debris flows and severe impacts on settlements, infrastructure, agriculture and ecosystems. The article highlights cloudburst mechanisms, increasing vulnerability due to land-use changes, forecasting challenges and the role of advanced technologies such as Doppler Weather Radar, satellite observations and numerical models. It also emphasizes the emerging occurrence of cloudburst-like events and other abnormal weather phenomena in traditionally less vulnerable plains regions, driven by changing climatic conditions and evolving rainfall patterns. Thus, comprehensive understanding of changing precipitation patterns, improved prediction systems and climate-adaptive management approaches are essential to minimize the impacts of future extreme

rainfall events across Northwest India.

INTRODUCTION:

Nature's extreme often arrives without warning and few weather phenomena demonstrate this better than a cloudburst. In a matter of minutes, an intense burst of rainfall confined to a small region can overwhelm rivers, trigger flash floods and alter landscapes, leaving behind widespread destruction. Although cloudbursts have traditionally been associated with the Himalayan region, recent extreme rainfall events in other parts of India have increased public attention towards this phenomenon because of their sudden occurrence, and destructive potential (Dar and Azis, 2025). Extreme rainfall events are not merely rainfall anomalies, act as growing challenge in managing climate-related risks.

Rapid urban expansion, changes in land use, fragile mountain environments and increasing exposure of populations have amplified the consequences of such short-duration extreme events. Roads, bridges, agricultural fields and settlements located near rivers and steep slopes become highly vulnerable when large quantities of water arrive within a limited time period. Understanding cloudbursts has therefore become essential, not only from a scientific perspective but also for disaster preparedness and climate adaptation. Although cloudbursts are natural atmospheric phenomena, their impacts depend greatly on where and how they occur. Improved knowledge about their formation, changing patterns and prediction capabilities can help common people, policymakers and disaster management agencies develop better strategies to reduce losses and protect lives.

What is a Cloudburst?

Generally, cloudburst is one of the most intense forms of localized rainfall, where more than 100 mm of rain can occur within one hour over a small area. According to the India Meteorological Department (IMD), a cloudburst is identified when rainfall exceeds 100 mm in one hour at a particular location approximately 20-30 km^2. The term "cloudburst" does not indicate the literal bursting of cloud; it describes the highly concentrated release of rainfall.

Mechanism of cloud burst formation

The process generally begins with the transport of moisture-rich air towards elevated regions, where, forced uplift causes cooling and condensation, leading to the rapid development of convective clouds (Dimri *et al.,* 2017). Under strong upward motion, condensed water droplets remain suspended and accumulate within the cloud system until the atmospheric support weakens, resulting in the sudden release of a large amount of rainfall over a limited area (Fig. 1).

Traditionally, cloudbursts have been strongly associated with the Himalayan region, where steep slopes, narrow valleys and unstable terrain rapidly convert intense rainfall into destructive flash floods and landslides. In these regions, even a short period of extreme rainfall can generate sudden water surges carrying soil, rocks and debris, causing severe damage to infrastructure, agricultural land and settlements. Many Himalayan cloudburst events are reported in the elevation range of approximately 1000-2500 metres, where atmospheric convection interacts strongly with complex mountain terrain. Earlier, cloudburst-like events were mainly considered a Himalayan problem, but their occurrence in plains and other regions shows that localized extreme rainfall is becoming a wider national concern.

Fig1: Mechanism of formation of cloud burst event

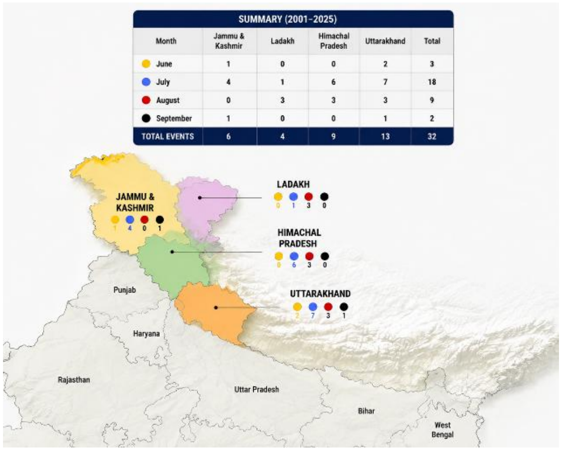
Mini-Cloudburst

While studying extreme rainfall events, researchers found that many intense rainfall episodes did not fulfil the strict definition of a cloudburst but were still capable of producing flash floods and significant damage. These intermediate events were termed "mini-cloudbursts" (MCBs), defined as rainfall events receiving 50 mm or more rainfall within two consecutive rain hours. Although less intense than cloudbursts, mini-cloudbursts can overwhelm soil and drainage systems, causing flooding and disruption. Their occurrence is linked with moisture availability, atmospheric instability and convective activity, with studies reporting increasing trends at several locations across India. These changes indicate a shift towards more variable extreme rainfall behaviour under a warming climate.

Changing Cloudburst Dynamics in Northwest India

Among the regions most affected by cloudburst events, the northwestern Himalaya occupies a particularly vulnerable position. Uttarakhand, Jammu & Kashmir and Himachal Pradesh, remains highly vulnerable due to the combined influence of monsoon moisture, atmospheric instability and fragile mountain landscapes (Fig. 2). In these regions, even a short-duration cloudburst can transform vulnerable landscapes into zones of widespread destruction.

Furthermore, the impact of Himalayan cloudbursts is not limited to the locations where they occur. Intense rainfall in upper mountain catchments can rapidly increase river discharge by generating flash floods and sudden water surges that travel downstream into foothill and plain regions. Recent extreme rainfall events in Himachal Pradesh, Jammu & Kashmir have demonstrated how heavy rainfall in upstream areas can affect neighbouring lowland regions through overflowing rivers such as the Sutlej, Beas and Ravi**.** These downstream impacts have caused flooding, waterlogging, agricultural losses and infrastructure damage in parts of Punjab and adjoining regions and representing a connected mountain-to-plain hazard.


SUMMARY (2001–2025)

Month	Jammu & Kashmir	Ladakh	Himachal Pradesh	Uttarakhand	Total
June	1	0	0	2	3
July	4	1	6	7	18
August	0	3	3	3	9
September	1	0	0	1	2
TOTAL EVENTS	6	4	9	13	32

Fig. 2: Month-wise major and disastrous cloudburst events across the Northwest Himalayan Region (2001–2025)

The vulnerability of Himalayan regions is not only theoretical as several devastating cloudburst events in recent decades have demonstrated how quickly extreme rainfall can transform into major disasters that are as follows. While the Himalayas witness numerous cloudburst events every year, the one that turned into catastrophic disasters that left a lasting mark on India's disaster history (Singh *et al*., 2026). The events mentioned in Table 1 are among those that gained widespread attention because of their immense destruction, loss of lives and far-reaching impacts.

Table1: Month-wise major and disastrous cloudburst events across the Northwest Himalayan Region (2001–2025)

Month	Year	Place
June	2011	Jammu & Kashmir
	2013	Uttarakhand
	2016	Uttarakhand
July	2003	Himachal Pradesh
	2004	Uttarakhand
	2005	Leh Ladakh
	2011	Himachal Pradesh
	2014	Jammu & Kashmir
	2015	Jammu & Kashmir
	2015	Himachal Pradesh
	2017	Uttrakhand
	2017	Jammu & Kashmir
	2021	Uttrakhand
	2022	Jammu & Kashmir
August	2001	Uttrakhand
	2006	Leh Ladakh
	2007	Himachal Pradesh
	2008	Leh Ladakh
	2009	Uttrakhand
	2010	Leh Ladakh
	2024	Himachal Pradesh
September	2010	Uttrakhand
	2010	Jammu & Kashmir

These events demonstrate how intense localized rainfall, combined with fragile mountain terrain and increasing human exposure, can rapidly develop into major disasters. During the 2025 monsoon, extreme rainfall and cloudburst-associated events in Himachal Pradesh and adjoining Himalayan catchments increased river inflows in the Ravi, Beas and Sutlej, causing severe flooding in Punjab's Majha and adjoining regions. The event highlighted the interconnected nature of mountain and plain-region hazards, where rainfall in upper catchments can trigger large-scale downstream impacts.

Changing extreme weather patterns in Northwest plains

Climate change is influencing temperature patterns, atmospheric moisture availability and precipitation variability. A warmer atmosphere can retain more moisture, increasing the potential for intense short-duration rainfall events. The combined effects of atmospheric instability, land-use changes and urban expansion are increasing the vulnerability of northwestern plains, including Punjab, Haryana and Delhi, to extreme rainfall and flooding.

Punjab, where such events were historically less frequent, has experienced increasing flood risks, agricultural losses, and infrastructure damage. The 400 mm rainfall event in Ludhiana (12 August 2011) and recent extreme rainfall episodes in districts such as Tarn Taran, Gurdaspur, Hoshiarpur, Rupnagar, and Patiala highlight the growing vulnerability of the plains. Furthermore, the occurrence of unusual snowfall events in traditionally non-snowfall regions reflects the increasing variability of weather patterns under a changing climate. Recent episodes in the northwestern plains highlight shifts in temperature patterns, moisture transport and atmospheric behaviour. In January 2011, parts of Pathankot and Hoshiarpur in Punjab, experienced snowfall after several decades due to the influence of strong western disturbances and favourable atmospheric conditions. Similarly, in January 2019, unusual snowfall was also reported in parts of Sangrur district.

Cloudburst Prediction and its challenges

The highly localized nature of cloudbursts makes it difficult to accurately predict their exact location, timing, and intensity. Current forecasting relies on short-range nowcasting using Doppler Weather Radars (DWR), satellites, automatic weather stations and numerical weather prediction models to identify favourable conditions such as moisture accumulation, atmospheric instability and convective cloud development.

Advanced approaches such as Multi-Radar Multi-Sensor (MRMS) systems integrate radar observations, weather models, rain gauges and additional sensors to improve monitoring and forecasting. India's meteorological infrastructure has expanded significantly, with the DWR network increasing from 16–17 radars to around 50 operational radars, with further expansion planned under Mission Mausam. The installation of radar facilities at Patiala and expansion towards Amritsar will enhance extreme rainfall detection across northwestern plains. Additionally, AI and ML are improving the analysis of complex weather data, enabling better early detection and timely warnings.

Safety measures during cloudburst events

- Follow official meteorological advisories and early warning alerts, especially during the monsoon season, for timely preparedness.
- Avoid vulnerable locations such as river channels, streams, steep slopes and flood-prone areas during July and August month.
- Develop emergency response plans, including evacuation strategies and essential supplies, for high-risk communities.
- Restrict construction activities in unstable slopes and flood-prone zones to reduce disaster risks.
- Promote community awareness and coordinated response systems to enhance resilience and minimize loss of life and property.

REFERENCES

Dar, T. and Aziz, K. 2025. Assessment and management of flash floods in the India Himalayas: challenges, strategies and solutions. *Water Resources Management in Mountain Regions*, 301-317.

Dimri, A. P., Chevuturi, A., Niyogi, D., Thayyen, R. J., Ray, K., Tripathi, S. N. and Mohanty, U. C. (2017). Cloudbursts in Indian Himalayas: a review. *Earth-Science Reviews*, *168*, 1-23.

Singh, S., Singh, V. K. and Jain, M. (2026). Decoding cloudburst formation: meteorological factors and advanced forecasting approaches: *Journal of Earth System Science*, *135*(2), 66.