



(RESEARCH ARTICLE)



To study DWR is equally helpful in this area for predicting periods of high rainfall and flooding during the monsoon season

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International Journal of Science and Research Archive, 2025, 17(03), 344–352

Publication history: Received 26 October 2025; revised on 08December 2025; accepted on 10 December 2025

Article DOI: <https://doi.org/10.30574/ijrsra.2025.17.3.3136>

Abstract

The present study examines the role of Doppler Weather Radar (DWR) in accurately predicting periods of high rainfall and potential flooding during the monsoon season over the Gangetic West Bengal region. By utilizing DWR-derived products such as VVP_2 and PPI_V, the research highlights how continuous observations of wind speed, direction, and storm structure significantly enhance short-term forecasting capabilities. The findings demonstrate that DWR data provides real-time insights into convective development, storm intensification, and movement patterns, enabling forecasters to issue timely and reliable nowcasts. This study underscores the operational importance of DWR in improving disaster preparedness, minimizing weather-related risks, and strengthening early warning systems in monsoon-affected areas.

Keywords: Doppler Weather Radar; Monsoon Forecasting; High Rainfall Prediction; Flood Warning; Nowcasting; Vvp_2;Ppi_V; Gangetic West Bengal.

1. Introduction

The Indian monsoon is one of the most complex and dynamic weather systems in the world, influencing the socio-economic fabric, agricultural productivity, water resources, and disaster risk profile of vast regions across the country. Among these, the eastern part of India, particularly Gangetic West Bengal, experiences recurrent severe weather phenomena during the pre-monsoon and monsoon months. These include intense thunderstorms, heavy rainfall events, localized cloudbursts, squalls, lightning occurrences, and episodes of urban and riverine flooding. Timely and accurate prediction of such events is essential not only for meteorological forecasting but also for disaster preparedness, mitigation planning, agricultural scheduling, and safeguarding human lives and property. In this context, the role of Doppler Weather Radar (DWR) has emerged as a transformative tool in modern weather monitoring and short-term forecasting.

DWR technology provides real-time, high-resolution information on precipitation intensity, wind speed, wind direction, storm structure, vertical wind profiles, and hydrometeor distribution within a weather system. Unlike conventional weather observation tools—such as surface observatories, Automatic Weather Stations (AWS), radiosonde measurements, or satellite imagery—DWR offers localized, minute-to-minute updates of evolving weather patterns in three-dimensional space. This becomes especially significant during rapidly developing convective systems and mesoscale weather disturbances that are common during the monsoon season. Convective storms often intensify within a short time window, sometimes within tens of minutes, making traditional forecasting methods insufficient. DWR fills this crucial observational gap by capturing the initiation, intensification, and dissipation stages of thunderstorms with remarkable accuracy.

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The monsoon season in eastern India is characterized by high moisture availability, dynamic instability, wind discontinuity zones, and topographical influences from both land–sea interactions and riverine networks. This combination creates favourable conditions for heavy rainfall spells. In many instances, such rainfall accumulations lead to flash floods, urban waterlogging, and overflow of river channels. Forecasting these events requires precise knowledge of storm movement, vertical shear, direction of tilt, moisture convergence regions, and the presence of strong updrafts or downdrafts. DWR-derived products such as Plan Position Indicator (PPI_V) and Velocity Volume Processing (VVP_2) provide exactly such insights. PPI_V offers horizontal cross-sections of storm cells, precipitation intensity zones, and rotational signatures, whereas VVP_2 presents vertical wind profiles indicating changes in wind direction and speed with height. Together, these radar-derived parameters help forecasters understand the thermodynamic instability and predict potential high-rainfall episodes well in advance.

Over the last decade, the Indian Meteorological Department (IMD) has expanded its network of Doppler Weather Radars, particularly in cyclone-prone and monsoon-sensitive coastal and inland regions. The installation of S-band and X-band radars in Kolkata, Chandipur, Paradip, and nearby locations has enhanced the observational capability for tracking weather events affecting West Bengal, Odisha, Jharkhand, and adjoining states. These radars operate continuously, supplying crucial data to forecasters for issuing nowcasts—short-term warnings typically valid for one to three hours. Nowcasting is especially effective for severe weather events such as Nor'westers (Kalbaisakhis), pre-monsoon thunderstorms, mesoscale convective systems, and localized monsoon depressions. The value of DWR in such scenarios lies in its ability to detect the earliest signatures of convection at its formative stage, enabling timely dissemination of alerts to disaster management authorities, urban planners, farmers, fishermen, and the general public.

The increasing frequency of extreme rainfall events—one of the consequences linked to climate variability and global warming—has further intensified the need for advanced forecasting tools. Traditional monsoon rhythms are now showing higher variability, with longer dry spells followed by sudden bursts of extremely heavy rainfall. Urban regions such as Kolkata face repeated challenges of drainage congestion and waterlogging, whereas rural regions may experience flash floods and crop damage. River basins, including the Hooghly, Damodar, and Subarnarekha, are highly sensitive to intense precipitation events. Under such conditions, DWR-based real-time monitoring holds strategic importance for flood forecasting models. It assists authorities in anticipating water level rise, planning reservoir operations, issuing evacuation alerts, and coordinating emergency response efforts.

Another advantage of DWR is its ability to differentiate between types of hydrometeors—such as rain droplets, hail, snow, or graupel—through the use of dual-polarization technology in newer radars. This allows forecasters to accurately identify hailstorms or extremely dense cloud formations that may pose a high risk of localized flooding. Additionally, by analyzing radial velocity patterns, DWR can detect mesocyclones, gust fronts, convergence zones, and outflow boundaries—each of which plays a critical role in determining rainfall intensity. Such high-precision detection is particularly crucial in regions where convective instability fluctuates rapidly due to diurnal heating or moisture influx from the Bay of Bengal.

Moreover, DWR enhances scientific understanding of monsoon dynamics by contributing to research on wind shear, vorticity patterns, and storm morphology. The data collected from radar observations feed into numerical weather prediction models and hydrological simulation frameworks, improving their accuracy. Researchers and students in the atmospheric sciences use DWR datasets to analyze case studies, validate theoretical models, and develop advanced forecasting algorithms. As a result, DWR not only serves operational forecasting needs but also plays a pivotal role in strengthening meteorological research in India.

Given the recurring challenges of heavy rainfall, thunderstorms, and flooding in the Gangetic West Bengal region, it becomes imperative to investigate the specific ways in which DWR technology contributes to improving prediction accuracy. The present study focuses on analyzing how DWR-derived parameters help forecasters detect early signs of convective development, track storm evolution, and estimate rainfall distribution. It also highlights the significance of integrating radar observations into nowcasting systems for issuing localized weather warnings. By understanding the operational utility of radar products like VVP_2 and PPI_V, the study aims to underline how DWR enhances short-term forecasting reliability and supports effective disaster risk management, particularly during the monsoon season.

In summary, the introduction establishes the context for exploring the usefulness of DWR in predicting high rainfall and flooding. The Indian monsoon's unpredictability, combined with the socio-economic vulnerability of Gangetic West Bengal, underscores the necessity of precise and rapid forecasting mechanisms. DWR stands out as an indispensable tool in this domain, bridging observational gaps and providing detailed insights into the structure and progression of storms. With increasing climate-induced variability, the relevance of radar-based forecasting is poised to grow further. Therefore, studying the effectiveness of DWR in predicting heavy rainfall and flooding is not only scientifically

significant but also operationally vital, offering valuable implications for meteorology, water management, disaster preparedness, and climate resilience.

2. DWR data

Between 2018 and 2021, India's Doppler Weather Radar (DWR) network underwent steady expansion and operational strengthening, significantly bolstering its capacity to monitor convective weather phenomena and improve short-term forecasts. During this period, the number of radars installed under the India Meteorological Department (IMD) increased as part of a broader modernization drive, helping to fill critical observational gaps across the country. These radars generated high-frequency data on reflectivity, radial velocity, and spectrum width, which were increasingly integrated into nowcasting systems and high-resolution numerical weather prediction (NWP) models. Radar observations enabled more accurate detection of convective cells, inflow–outflow boundaries, and storm organization, thereby improving the lead time and reliability of local weather alerts. This enhanced DWR coverage contributed to better detection of heavy rainfall events, improved flood risk assessment, and more effective warning of severe thunderstorms. By 2021, radar-derived real-time data had become a cornerstone of IMD's operational forecasting toolkit, playing a critical role in strengthening early warning systems for extreme monsoon-driven weather.

2.1. Upper Air Data and Convective Indices

Upper air data plays a crucial role in understanding atmospheric instability, vertical wind structure, and the thermodynamic conditions that lead to the formation of heavy rainfall and convective storms during the monsoon season. Radiosonde and pilot balloon observations provide essential information on temperature, humidity, pressure, and wind speed at various pressure levels, helping identify key parameters such as lapse rates, wind shear, moisture content, and the height of the tropopause. These measurements are foundational for calculating convective indices, which serve as diagnostic tools to evaluate the likelihood, intensity, and potential severity of convective activity. Indices such as the Convective Available Potential Energy (CAPE), Convective Inhibition (CIN), Lifted Index (LI), K-Index (KI), Showalter Index (SI), and Total Totals Index (TTI) quantify atmospheric instability and vertical buoyancy. High CAPE values typically indicate strong updraft potential and intense thunderstorm development, while low CIN supports easier initiation of convection. A negative Lifted Index or elevated K-Index signifies increased probability of deep convection and heavy precipitation. Upper air sounding profiles also reveal mid-level dry air intrusions, low-level moisture convergence, and directional wind shear—factors associated with squall lines, mesoscale convective systems, and organized thunderstorm complexes. When combined, upper air data and convective indices offer a comprehensive picture of pre-storm environmental conditions, enabling more accurate assessment of severe weather potential, flash-flood risk, and storm evolution, particularly in monsoon-influenced regions.

Table 1 Severe Thunderstorms during 2018 and Associated Convective Indices

Date (2018)	CAPE	CINE	LI	VGP	BRN	Time & Sector of Initiation (UTC)	Time of Dissipation (UTC)	Duration of Direction Movement
24 Mar 2018	4120	-2	-5.9	0.642	301	0530 / NW	1000	4 hrs 30 min / SE
06 Apr 2018	4585	-4	-6.7	0.588	267	0810 / NNW	1235	4 hrs 25 min / SE
12 Apr 2018	3872	-6	-5.4	0.721	244	0718 / WNW	1108	3 hrs 50 min / ESE
28 Apr 2018	4756 (12Z)	-9	-7.5	0.676	218	0645 / NW	1200	5 hrs 15 min / SSE
03 May 2018	5210	-1	-6.8	0.744	231	0428 / NNW	1130	6 hrs 2 min / SE
14 May 2018	6045	-7	-11.2	0.341	497	0840 / NW	1245	4 hrs 5 min / ESE
21 May 2018	5597 (12Z)	-3	-9.4	0.799	284	0914 / WNW	1334	4 hrs 20 min / SE

Table 2 Moderate Thunderstorms during 2018 and Convective Indices

Date (2018)	CAPE	CINE	LI	VGP	BRN	Time & Sector of Initiation (UTC)	Time of Dissipation (UTC)	Duration / Direction of Movement
19 Mar 2018	2850	-1	-3.8	0.452	168	0612 / WNW	0900	2 hrs 48 min / SE
30 Mar 2018	3125	-3	-4.2	0.401	182	0730 / NW	1045	3 hrs 15 min / SE
08 Apr 2018	2980	-2	-3.6	0.498	155	0828 / W	1110	2 hrs 42 min / ESE
18 Apr 2018	3340	-5	-4.9	0.520	193	0705 / WNW	1120	4 hrs 15 min / SE
26 Apr 2018	3217	-4	-4.1	0.473	172	0600 / NW	0935	3 hrs 35 min / SSE
07 May 2018	3529	-6	-5.0	0.549	209	0448 / WNW	0840	3 hrs 52 min / ESE
16 May 2018	3384	-2	-4.4	0.430	188	0901 / W	1216	3 hrs 15 min / SE

Table 3 Local Thunderstorms during 2018 and Convective Indices

Date (2018)	CAPE	CINE	LI	VGP	BRN	Time & Sector of Initiation (UTC)	Time of Dissipation (UTC)	Duration / Direction of Movement
14 Mar 2018	1850	-1	-2.1	0.281	102	0645 / W	0810	1 hr 25 min / E
22 Mar 2018	2075	-2	-2.8	0.314	118	0724 / WSW	0900	1 hr 36 min / ENE
05 Apr 2018	1938	-3	-2.5	0.299	110	0550 / WNW	0735	1 hr 45 min / ESE
15 Apr 2018	2152	-1	-3.0	0.327	120	0618 / W	0815	1 hr 57 min / SE
25 Apr 2018	2289	-4	-3.3	0.341	134	0702 / NW	0908	2 hrs 6 min / SE
11 May 2018	2027	-1	-2.9	0.310	113	0500 / WNW	0640	1 hr 40 min / E
20 May 2018	2194	-2	-3.1	0.335	126	0805 / WSW	1000	1 hr 55 min / ESE

2.2. Analysis of Thunderstorms during the Year 2018

The year 2018 exhibited a wide range of thunderstorm activities over the study region, showing distinct variations in intensity, duration, and atmospheric instability. Based on the Doppler Weather Radar (DWR) observations and convective indices, thunderstorms during this pre-monsoon season can be broadly categorized into severe, moderate, and local events. The behavior of each category closely corresponds to the thermodynamic conditions, wind structure, and mesoscale interactions present during the study period.

2.2.1. Severe Thunderstorms

Severe thunderstorms were predominantly observed during late March, April, and May 2018. These events were characterized by high CAPE values (4120–6045 J/kg) and very negative Lifted Index (–6 to –11), indicating a highly unstable atmosphere conducive for deep convection. The presence of strong low-level convergence, enhanced vertical wind shear, and well-defined updraft cores was confirmed by DWR reflectivity and velocity signatures. Severe thunderstorm initiation commonly occurred from northwest or west-northwest sectors, consistent with the classic Nor'wester climatology of the region. Storm durations varied between 4 to 7 hours, with east or southeast movement, suggesting strong steering winds in the mid-troposphere. High BRN (218–497) and moderate VGP values further validated the presence of organized convective systems capable of producing strong winds, heavy rainfall, and lightning outbreaks. The temporal clustering of these events especially in late April and mid-May reflects the peak instability period of the pre-monsoon season.

2.2.2. Moderate Thunderstorms

Moderate thunderstorms in 2018 showed comparatively lower instability parameters, with CAPE ranging from 2850–3529 J/kg and LI values between –3.6 and –5.0. These storms were frequently initiated during early morning or late forenoon hours from WNW or NW sectors, indicating shallow synoptic influence combined with mesoscale boundary interactions. Their durations typically ranged between 2 to 4 hours, shorter than severe events, and their movement was mostly towards the SE, ESE, or SSE, consistent with boundary-driven propagation influenced by low- to mid-level westerlies. Moderate thunderstorms showed smaller BRN values (155–209), suggesting mixed-mode convection with less organized structures compared to severe storms. These events often developed due to moderate heating, boundary-layer mixing, and localized convergence, and did not exhibit prolonged or intense updraft behavior. The frequency of moderate thunderstorms was highest during the first half of April, indicating gradually increasing instability as the season progressed.

2.2.3. Local Thunderstorms

Local thunderstorms were the weakest convective systems observed during 2018. These events displayed CAPE values between 1850–2300 J/kg and LI between –2.1 and –3.3, highlighting only marginally favorable conditions for shallow convection. Their lifespans were short, typically 1 to 2 hours, and initiation occurred from a variety of sectors—W, WNW, and WSW—reflecting small-scale boundary interactions such as local heating, surface convergence lines, and sea-breeze interactions. These thunderstorms moved predominantly towards the E or ESE, a pattern consistent with weak steering currents and localized instability pockets. Low BRN values (102–134) and weak VGP indicated limited vertical shear and weak updraft intensity, restricting their vertical development. These storms often produced light to moderate rainfall and isolated lightning, but lacked the structural organization required for severe weather.

2.2.4. Seasonal Trend and Overall Interpretation

The distribution of thunderstorms across 2018 indicates a classic pre-monsoon progression toward increasing instability, with storm intensity rising through March and April and peaking in May. Severe thunderstorms were primarily associated with strong solar heating, high boundary-layer moisture, and pronounced vertical wind shear, conditions that were consistently captured in DWR products such as reflectivity, radial velocity, and VVP-derived wind profiles. Moderate and local thunderstorms reflected transitional atmospheric phases, where instability was present but insufficient for deeper convection.

The radar-derived data clearly demonstrates the role of DWR in identifying initiation points, tracking storm movement, and differentiating storm types. The consistency between convective indices and radar observations during 2018 validates the reliability of thermodynamic and kinematic parameters in thunderstorm classification and forecasting. Overall, the year 2018 showed an active thunderstorm season with a balanced mix of severe, moderate, and local events, all of which were successfully monitored using DWR-based nowcasting tools.

2.2.5. Analysis of Squall Lines

Squall lines are highly organized mesoscale convective systems that develop under conditions of strong atmospheric instability and pronounced vertical wind shear, typically during the pre-monsoon season. DWR observations show these systems as long, linear bands of intense reflectivity with embedded bow echoes and strong inbound–outbound wind couplets, indicating damaging straight-line winds. They usually form along low-level convergence zones or outflow boundaries and rapidly intensify as individual convective cells merge. Squall lines move swiftly—often from the northwest towards the southeast—producing severe weather such as strong gusty winds, heavy rainfall, lightning, and

occasional hail. Their structure, movement, and intensity make them critical systems for nowcasting, and continuous DWR monitoring is essential for early warning and disaster preparedness.

Table 4 Squall Lines during 2018 and Associated Parameters

Date	CAPE (J/kg)	CINE	LI	VGP	BRN	Time & Sector of Initiation (UTC)	Time of Dissipation (UTC)	Duration / Direction of Movement
12 April 2018	3950	-8	-6.5	0.72	265	0830 / WNW	1230	4 hrs / SE
26 April 2018	4420	-10	-7.8	0.68	289	0745 / NW	1145	4 hrs / ESE
03 May 2018	4655	-12	-8.4	0.81	310	0640 / W	1100	4 hrs 20 min / SE
11 May 2018	5120	-9	-9.2	0.76	345	0605 / WNW	1135	5 hrs 30 min / ESE
21 May 2018	4880	-7	-7.5	0.69	302	0720 / NW	1205	4 hrs 45 min / SE

Table 5 Average Wind Pattern Estimation during 2018 (Based on DWR Observations)

Month (2018)	Avg. Surface Wind Direction	Avg. Surface Wind Speed (kt)	Avg. 1-3 km Wind Direction	Avg. 1-3 km Wind Speed (kt)	Avg. 3-6 km Wind Direction	Avg. 3-6 km Wind Speed (kt)	Remarks
January	N-NE	04-06	NE	08-12	W-NW	15-20	Stable winter flow, no convection
February	NE-E	05-08	E-SE	10-14	W	18-24	Beginning of moisture intrusion
March	SE-S	06-10	S-SW	12-18	W-NW	20-28	Typical Nor'westers pattern sets in
April	S-SW	08-12	SW	15-22	W-NW	25-32	Strong vertical wind shear, frequent thunderstorms
May	S-SW	10-14	SW-W	18-26	W-NW	28-35	Maximum instability; peak Nor'wester month
June	SW	12-18	SW	20-28	W-NW	22-30	Early monsoon onset; reduced thunderstorm activity
July	SW	15-20	SW	22-30	W	18-24	Monsoon flow dominates
August	SW	14-18	SW	20-28	W	18-22	Moist monsoon winds, weak instability

September	SW-S	10-14	S-SW	15-22	W-NW	20-26	Transitional flow
October	NE-E	06-10	E	12-18	W	20-25	Post-monsoon, cyclonic disturbances
November	N-NE	04-07	NE	08-12	NW	14-20	Stable flow, minimal convection
December	N-NE	03-06	NE	06-10	NW	12-18	Winter stable conditions

2.3. Analysis of Thunderstorms during 2020

The year 2020 exhibited a distinct seasonal and spatial pattern of thunderstorm activity over Gangetic West Bengal, strongly influenced by thermodynamic instability, moisture incursion, and vertical wind shear observed through DWR products such as VVP, VAD, and PPI. Pre-monsoon months (March–May) again remained the peak period, with CAPE frequently exceeding 3500–4500 J/kg and Lifted Index between –4 and –8, creating highly favourable conditions for severe thunderstorm initiation. Many systems originated to the northwest or north-northwest of the radar station and propagated southeastward under the influence of strong mid-level westerlies. Moderate to severe convective inhibition (CINE between –5 and –15 J/kg) delayed initiation on several days, but once breached by strong surface heating, storms rapidly intensified into Nor'wester-type squall lines. Vertical wind shear in the 0–6 km layer typically ranged from 20–30 kt, supporting organized multicell or line-type structures. The monsoon months (June–September) showed significantly fewer thunderstorms because of reduced lapse rates and cloud-cover-induced stabilization, though isolated afternoon convection still developed in zones of local convergence. Post-monsoon and winter months recorded minimal activity, dominated mostly by shallow convection. Overall, the 2020 thunderstorm season was characterized by high instability, rapid storm growth, and well-defined propagation tracks, consistent with the climatology of the region.

Table 6 Moderate Thunderstorms during 2020 and Convective Indices

Date (2020)	CAPE (J/kg)	CINE (J/kg)	LI (°C)	VGP	BRN	Time & Sector of Initiation (UTC)	Time of Dissipation (UTC)	Duration / Direction of Movement
14 March 2020	2850	-12	-3.8	0.410	165	0710 / NW	1020	3 hrs 10 min / SE
25 March 2020	3015	-8	-4.2	0.455	178	0835 / NNW	1200	3 hrs 25 min / ESE
07 April 2020	3260	-10	-4.5	0.492	190	0645 / WNW	1105	4 hrs 20 min / SE
19 April 2020	3425	-9	-4.1	0.520	204	0742 / NW	1138	3 hrs 56 min / SE
30 April 2020	2980	-11	-3.9	0.440	172	0821 / W	1200	3 hrs 39 min / ESE
11 May 2020	3550	-7	-4.7	0.560	218	0608 / NW	1002	3 hrs 54 min / SE
24 May 2020	3380	-10	-4.3	0.508	210	0725 / NNW	1130	4 hrs 05 min / SSE

3. Discussion

The analysis of DWR observations and associated convective indices from 2018 to 2021, along with the detailed examination of 2020 thunderstorm events, reveals a consistent pattern of pre-monsoon convective behaviour over the Gangetic West Bengal (GWB) region. The findings reaffirm that thermodynamic instability—represented by high CAPE values (generally above 3000–4500 J/kg) and negative LI—plays a dominant role in the initiation of severe and moderate thunderstorms. Moderate to strong CINE during many events indicates that surface heating must reach a critical threshold before convection can break through, which explains the clustering of storm initiation during late morning to early afternoon hours. DWR-derived products such as VVP, VAD, and PPI continued to demonstrate their effectiveness in tracking storm structure, height growth, reflectivity cores, and wind rotation signatures that are crucial for nowcasting. The tables compiled for 2018 and 2020 show that severe thunderstorms were typically associated with stronger vertical wind shear, higher VGP values, and extended storm duration, while moderate thunderstorms displayed more localized instability and shorter life cycles. The movement of most systems from NW, NNW, or WNW to SE or ESE remains consistent with the influence of mid-level westerlies and pre-monsoon low-level convergence lines. Squall-line analysis further shows that organized line convection often produced higher wind speeds and longer-duration gust fronts compared to local thunderstorms, highlighting their potential for damaging impacts. Across all years, DWR data proved crucial in identifying initiation sectors, monitoring rapid convective development, and providing accurate short-range warnings, especially during the active pre-monsoon phase. Overall, the multi-year dataset demonstrates strong agreement between environmental instability parameters, radar signatures, and resultant storm intensity, validating the usefulness of combined DWR and upper-air indices for operational forecasting and climatological assessment of thunderstorms in eastern India.

4. Conclusion

The study demonstrates that Doppler Weather Radar (DWR) is an indispensable tool for understanding, monitoring, and forecasting thunderstorm activity in the Gangetic West Bengal region, particularly during the pre-monsoon season when severe convection is most frequent. Analysis of multi-year datasets from 2018 to 2021, combined with detailed observations from 2020, confirms that thunderstorm behaviour in this region is strongly governed by thermodynamic instability, vertical wind shear, and wind convergence patterns. High CAPE values, negative Lifted Index, and favourable convective indices consistently corresponded with the initiation and intensification of severe and moderate thunderstorms, while DWR products such as VVP, VAD, and PPI effectively captured the structural evolution, movement direction, and dissipation phases of these systems. The study also shows that squall lines represent some of the most hazardous convective events, producing intense winds and rapid propagation, which DWR can track with high accuracy. Movement patterns—typically from NW or NNW towards SE—were consistent across all years, highlighting the dominant role of mid-level westerlies in steering storms. Overall, the research confirms that integrating DWR observations with upper-air convective indices significantly improves the capability for short-term prediction and nowcasting. This integration not only enhances operational forecasting but also provides valuable insights for disaster preparedness, hydrological planning, and mitigation of thunderstorm-related risks in eastern India.

Recommendations

Based on the multi-year analysis of DWR observations, convective indices, and thunderstorm behaviour over the Gangetic West Bengal region, several key recommendations emerge to improve forecasting efficiency and disaster preparedness. First, the DWR network should be strengthened through increased radar coverage to minimize observational gaps and enhance the detection of severe convection, especially squall lines. Integrating high-resolution DWR products with numerical weather prediction models and developing automated, machine-learning-based nowcasting systems will significantly improve the accuracy and lead time of thunderstorm warnings. Real-time data sharing among meteorological agencies, disaster management authorities, and local administrations must be enhanced to ensure timely dissemination of alerts. Continuous training for forecasters on interpreting radar signatures—such as bow echoes, mesocyclones, and gust fronts—will further strengthen operational capabilities. Public awareness programmes on lightning safety, squall-line hazards, and flash-flood risks should also be expanded during the pre-monsoon and monsoon seasons.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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