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INFORMATION PAPER (IP/10)

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Agenda Item 6: Research, development and other initiatives

SATELLITE BASED ANALYSIS FOR IDENTIFYING, TRACKING AND FORECASTING THUNDERSTORMS; A CASE STUDY OVER THE IGI AIRPORT, NEW DELHI, INDIA

(Presented by India Meteorological Department)

SUMMARY

This information paper presents the development of an automated algorithm designed to detect, track, and forecast thunderstorms activity around the IGI Airport, New Delhi, India using satellite-based observations. The algorithm's performance was evaluated against METAR reports, showing a promising correlation of 0.98 between predicted and actual observations. This strong agreement highlights its potential for supporting timely and precise issuance of aerodrome warnings. Furthermore, the algorithm is adaptable for application at any desired location, provided the corresponding geographic coordinates are available.

1. INTRODUCTION

1.1 Thunderstorms and their associated hazards such as lightning, hail, icing, low visibility, reduced cloud ceiling, and intense vertical wind currents pose significant risks to the safety and efficiency of flight operations globally.

1.2. In India, Indira Gandhi International Airport (IGIA) in New Delhi, the country's busiest air hub handles millions of passengers annually. However, frequent thunderstorm occurrences in the region pose serious safety challenges and result in substantial economic losses for the aviation industry.

1.3 This study introduces an automated algorithm designed to detect and predict the movement of thunderstorms near the IGIA, utilizing data from the Indian National Satellite (INSAT-3D). The algorithm's performance was evaluated using METAR reports from the IGIA, demonstrating its reliability. By enabling timely and accurate issuance of aerodrome warnings, the algorithm offers a valuable tool for enhancing aviation safety. With appropriate geographic inputs, aviation weather forecasters can apply this method to any airport location.

2. DISCUSSION

Data and Methodology

2.1. In this study, thermal infrared brightness temperature (TIR BT) data with a spatial resolution of 4 km and a temporal resolution of 30 minutes were utilized. To validate the algorithm's performance, METAR observations recorded every 30 minutes at the IGIA were employed.

2.2 An automated thunderstorm detection and forecast algorithm is developed based on the INSAT-3D imager data. Thunderstorm near the IGIA is detected by applying a brightness temperature threshold of 243 K or lower. The nearest thunderstorm pixel is then determined using spatial distance calculations. Key details such as observation time, geographic coordinates, distance from the IGIA, brightness temperature, movement and direction are extracted for this pixel. Additionally, the thunderstorms translational speed is derived through linear polynomial analysis of satellite imagery data spanning the previous three hours. Using this analysis, the anticipated movement of the thunderstorm system is projected for the next two hours. Updated every 10 minutes, satellite geo-tiff images, forecast plots, and details of the nearest thunderstorm pixel are continuously produced.

Results

2.3 The present study was carried out on the thunderstorms event that occurred over the IGIA on May 23, 2022. The TIR BT data from 1200 UTC to 1630 UTC within a 200 km radius of the IGIA were retrieved using the developed algorithm applied to INSAT-3D imager observations which is depicted in [Figure 1 (a–j)].

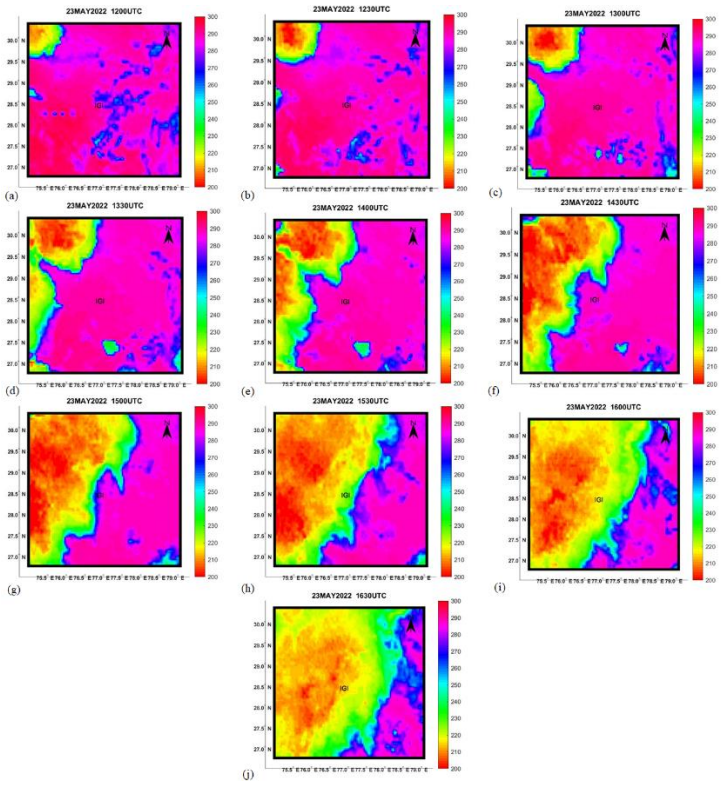

Figure 1 (a–j): Thermal Infrared Brightness Temperature (TIR BT) images generated between 1200 UTC and 1630 UTC on May 23, 2022 over the vicinity of the IGIA

2.4 Thunderstorm features like location, trajectory, and intensity are crucial for providing effective aviation weather support at the IGIA. Accordingly, data on the nearest thunderstorm pixel including latitude, longitude, brightness temperature, distance, and direction relative to the IGIIA were extracted for the period between 1200 UTC and 1430 UTC (refer to Table 1).

Time(UTC)	Latitude	Longitude	Distance (km)	BT (K)	Direction
1200	29.67	75.66	200.42	242.96	280.28
1230	29.67	76.08	166.65	231.03	279.01
1300	27.40	77.02	126.72	235.99	280.37
1330	29.24	76.45	103.84	230.29	297.15
1400	29.94	76.79	54.56	241.50	301.38
1430	28.91	77.13	39.27	239.99	265.86

Table 1: Details of the nearest thunderstorm pixel to the IGIA recorded between 1200 UTC and 1430 UTC on May 23, 2022.

2.5 At 1200 UTC, satellite imagery identified a thunderstorm system with its nearest pixel located 200.42 km from the IGIA, exhibiting a BT of 242.42 K and positioned at an angle of 280.28° from the northwest. By 1230 UTC, the system had advanced closer to the IGIA from the same direction, with the nearest pixel measured at 166.65 km away. This tracking continued through successive images, estimating the thunderstorms position, BT, and bearing at 30-minute intervals until 1430 UTC. The movement and speed of such thunderstorm systems are critical parameters in aviation weather forecasting, especially for enhancing decision-making during severe weather conditions. To support this, six consecutive satellite images were analysed to compute the translational speed of the thunderstorms and project its future proximity to the IGIA over the next two hours at half-hour intervals. Figure 2 presents an extrapolation plot created using the 1430 UTC data. The blue line illustrates the observed distances of the nearest thunderstorm pixel from IGIA, ranging from 200 km to 40 km between 1200 UTC and 1430 UTC. Using linear polynomial analysis, a red dotted line forecasts the system's progression from 1430 UTC to 1630 UTC, suggesting that the thunderstorm is likely to reach the IGIA around 1600 UTC.

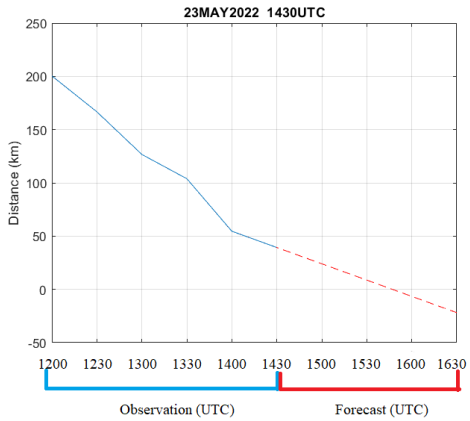

Figure 2: Observed (blue line) and forecasted (red dotted line) distances of the nearest thunderstorm pixel from IGIA, based on data analyzed at 1430 UTC on May 23, 2022.

2.6 The 1600 UTC METAR report confirmed the presence of Cumulonimbus (CB) clouds and strong surface winds in the vicinity of IGIA. In response, an aerodrome warning was released, and a thunderstorm trend forecast was incorporated into the METAR.

2.7 Figure 3 illustrates a strong correlation (r^2 = 0.98) between the observed and forecasted distances of the nearest thunderstorms pixel from the IGIA. Notably, the discrepancy between observed and predicted values was slightly higher during the early time steps (1200 and 1230 UTC) but progressively decreased from 1300 UTC onward. This initial variation is likely attributed to the inherent complexity of thunderstorms formation during its early development phase. By 1600 UTC, both observed and forecasted distances converged to nearly zero, indicating that the thunderstorms had reached the IGIA. The thunderstorm persisted over the region until approximately 1930 UTC. These findings highlight the high accuracy of the developed algorithm, particularly during the critical period when the thunderstorms impacted the study area.

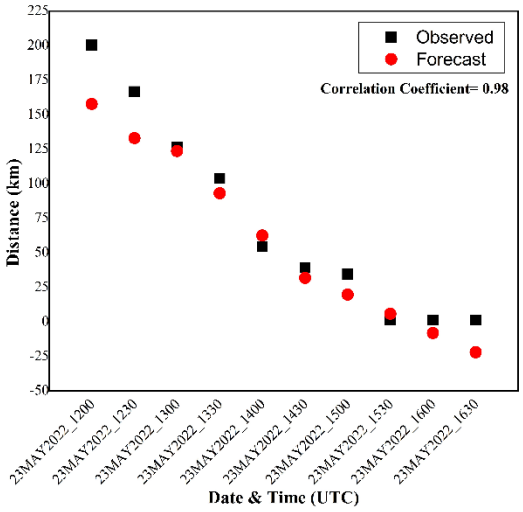

Figure 3: Scatter plot illustrating the relationship between forecasted and observed distances of the nearest thunderstorm pixel relative to the IGIA.

2.8 The proposed algorithm is adaptable for application at any specific geographic location, provided the necessary coordinate data is available. However, it is essential to evaluate and validate its performance for each chosen site to ensure reliability. Additionally, integrating this algorithm into aviation weather decision support systems could greatly enhance the precision and effectiveness of weather forecasting during thunderstorm events, thereby strengthening aviation safety.

3. ACTION BY THE MEETING

3.1 Note the information contained in this paper.

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