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AEROSOL DISTRIBUTION AND SEVERE STORM DYNAMICS IN NORTHERN THAILAND DURING THE PRE-MONSOON SEASON

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1. INTRODUCTION

Severe pre-monsoon thunderstorms in tropical regions pose significant threats to human life and property. The advent of meteorological radar has revolutionized hail storm research, enabling precise analyses of storm tracks and the spatial distribution of hailfall. Numerous studies have employed radar observations to elucidate the formation and structure of hailstorms. In Thailand, Chantraket (2015) utilized S-band weather radar data from Northern Thailand to investigate the relationship between hail occurrences and atmospheric instability within pre-monsoon thunderstorms in 2012. Building upon this research, Mahavik (2023) further advanced our understanding by employing dual-polarization weather radar data to analyze severe thunderstorms that occurred on April 23, 2020, in Chiang Rai Province, northern Thailand. It is well-established that hail formation exhibits a pronounced sensitivity to aerosol concentrations under specific atmospheric conditions (Andreae & Rosenfeld, 2008; Rosenfeld & Woodley, 2000). From a cloud microphysics perspective, comprehending this sensitivity and predicting the response of hail formation to anticipated future aerosol changes constitute significant scientific challenges. This study investigates the vertical distribution of aerosols from May 7 to May 10, 2024, to enhance our understanding of these critical issues and develop more effective mitigation strategies. By comparing the observed vertical aerosol distribution with concurrent radar and balloon-sounding data, this research aims to contribute valuable insights into the dynamics of hailstorm formation and improve our ability to mitigate their impacts.

2. CASE DESCRIPTION AND OBSERVATIONS

2.1 Study Area and Hail Records

This study focused on collecting location data of reported hail incidents within the northern region of Thailand, specifically within the measurement areas of the Rong-Kwang and Omkoi radar stations, as illustrated in Figure 1 .

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According to the Thai Meteorological Department (TMD), the study area experienced the confluence of southeasterly and southerly winds during the period from May 7 to May 10, 2024. These prevailing winds, coupled with hot to very hot weather conditions in the upper regions of the country, created an environment conducive to the development of summer storms. The TMD forecast predicted the possibility of thunderstorms, gusty winds, hail, and lightning strikes in the upper regions. A total of 20 hail events (cells) were recorded during this four-day period. Data on these hail events were obtained from reports submitted by volunteer observers and information gathered from social media posts. The locations of these recorded hail events are also depicted in Figure 1.

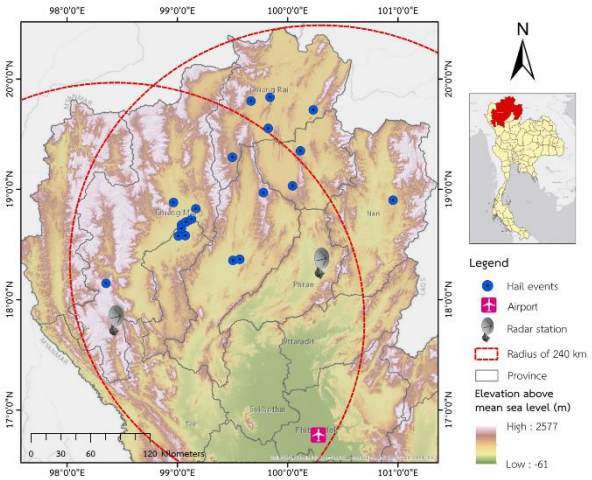


Figure 1 Study area, Rong-Kwang and Omkoi radar station over the northern Thailand and the location of hail observation during 7 to 10, May 2024.

2.2 Airborne Measurement

Airborne measurements of aerosol and cloud condensation nuclei (CCN) were conducted using the Super King Air 350 aircraft, operated by the Department of Royal Rainmaking and Agricultural Aviation (DRRAA). The instruments onboard included the Ultra-High Sensitivity Aerosol Spectrometer (UHSAS, 0.06 to 1.0 μm), the Passive Cavity Aerosol Spectrometer Probe (PCASP, 0.1 to 3.0 μm), and the Fast Forwarding Scattering Spectrometer Probe (FFSSP, 1 to 50 μm). These instruments measured the concentration and size

of aerosol particles ranging from 0.02 to 50 μm in diameter. Additionally, a Cloud Condensation Nuclei Counter was used to measure the concentration of CCN in the range of 0.75 to 10 μm. All airborne measurements were collected data from minimum allowable altitude through the altitude lower than 3500 m MSL.

2.3 Upper-Air Sounding

The sounding data are taken from Rong-Kwang meteorological station, Phrae province. The observed elements included stability indices Convective available potential energy (CAPE), Lifted Index (LI), Showalter Index (SI), K Index (KI) and Total of Totals Index (TTI) for each day. The indices and essential parameters were determined for the 00UTC sounding.

2.4 Weather Radar

The reflectivity data in the study area were measured using S–band weather radars operated by DRRAA at the Rong-Kwang and Omkoi stations, Phrae and Chiang-Mai provinces (18°19'21.5"N 100°18'07.4"E), as shown in Figure 1. These data originated from the radar volume coverage pattern 11 (VCP11) every 6-minute interval. The radar characteristics are shown in Table 1. The radar reflectivity data used in this study were collected during May 7 to 10, 2024.

Detail of radar	Description
Type of radar	Doppler weather radar
Radar band	S-band
Radar frequency (MHz)	5600
Wavelength (cm)	5.3
Beam width (degree)	0.95
Pulse length (μs)	0.8
Gate width (m)	500
Maximum transmission power (kW)	350
Maximum range (km)	240
Operation elevation angles (degree)	0.5°, 1.5°, 2.4°, 3.4°, 4.3°, 5.3°, 6.2°, 7.5°, 8.7°, 10.0°, 12.0°, 14.0°, 16.7° and 19.5°
Operation time	24 hours

Table 1 Radar characteristics of Rong-Kwang and Omkoi stations

3. RESULTS AND DISCUSSION

3.1 Distribution of Aerosol Size

Figure 2 presents the aerosol size spectra obtained from the USHAS, PCASP, and FFSSP measurements conducted from May 7 to May 10, 2024. It is clear that the aerosol size distribution over these four days showed a significant fine mode, with maximum number concentrations observed in the range of 0.1 to 0.3 μm. The concentration rapidly decreases as particle size approaches 1.0 μm. These findings align with observations made by Chantraket (2013). Additionally, a strong southwest wind associated with the onset of the monsoon in early May influenced the aerosol sources. Figure 3 illustrates the vertical distribution of aerosol and CCN (cloud condensation nuclei) concentrations from May 7 to May 10, 2024. Aerosols were primarily concentrated near the surface, extending up to approximately 1500 m, while CCN concentrations were predominantly found at higher altitudes, between 1500 and 3000 m. Balloon sounding data indicated that the average cloud base altitude (CCL) is around 1500 m. These results suggest that during this period, there was a notable increase in aerosol counts at lower altitudes, as well as an increase in the CCN activation ratio as altitude increased above the cloud base.

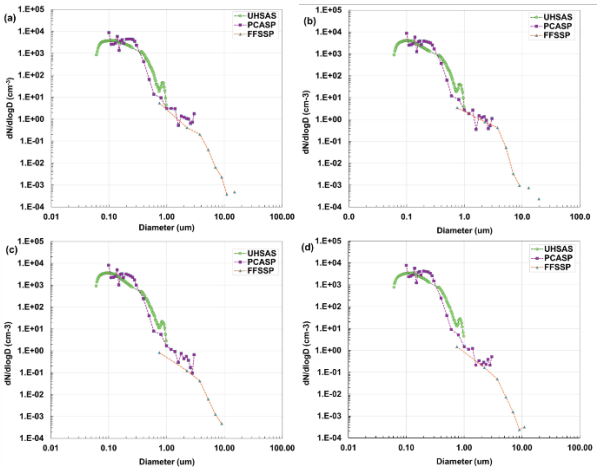


Figure 2 The aerosol size spectra from the USHAS, PCASP and FFSSP measurements of (a) May 7, (b) May 8, (c) May 9 and (d) May 10, 2024.

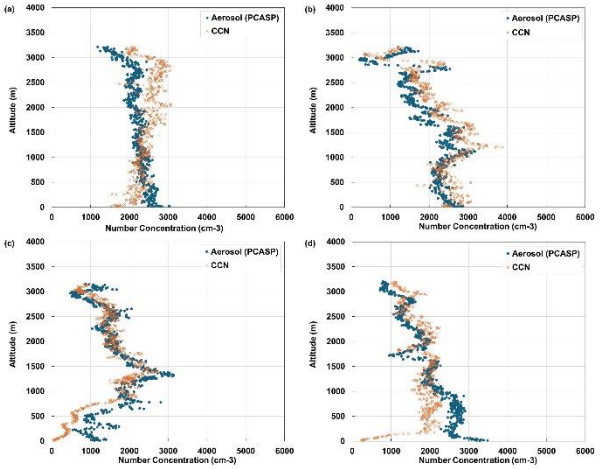


Figure 3 The vertical distributions of aerosol and CCN concentrations for (a) May 7, (b) May 8, (c) May 9 and (d) May 10, 2024.

3.2 Meteorological situation and hailstorm properties

arizes significant parameters derived from radiosonde data collected between May 7 and May 10, 2024. Five parameters were recorded from 00UTC sounding at the Rong-Kwang station. The thermodynamic analysis indicated instability. On May 7 and 9, a total of 16 hail events were reported, with high CAPE (Convective Available Potential Energy) values exceeding 2500 J/kg, indicating extreme instability. The Lifted Index (LI) played a more critical role than the Showalter Index (SI) on both

days. Further studies incorporating the K-index (KI), Total Totals Index (TTI), and other indices such as Convective Inhibition (CIN) and Severe Weather Threat (SWEAT) are necessary for further investigation. The four properties of the hailstorms, including (1) maximum reflectivity, (2) Vertical Integrated Liquid (VIL), (3) height of maximum reflectivity, and (4) cloud top, were analyzed using the TITAN algorithm. Figure 4 displays the results of the radar data analysis. The maximum reflectivity for all hail events ranged from 57 to 69 dBZ, with an average of 64 dBZ. The VIL values varied from 24 to 159 kg/m², averaging 83 kg/m². The height of maximum reflectivity ranged from 5 to 9 km, with an average height of 6.5 km, which is above the freezing level of 5 km based on radiosonde analysis. The cloud tops for all hail events were found between 9 and 16 km, with an average of 12 km.

Parameter	7 May	8 May	9 May	10 May
CAPE(J/kg)	2862	651	2610	1508
LI(C)	-4.0	-1.3	-4.8	-3.1
SI	-2.3	-2.0	-3.2	-2.5
KI(C)	36.2	36.0	38.8	34.8
TTI(C)	46.2	45.8	47.4	45.6
Hail Event	6	2	10	2

Table 2 Atmospheric instability indices

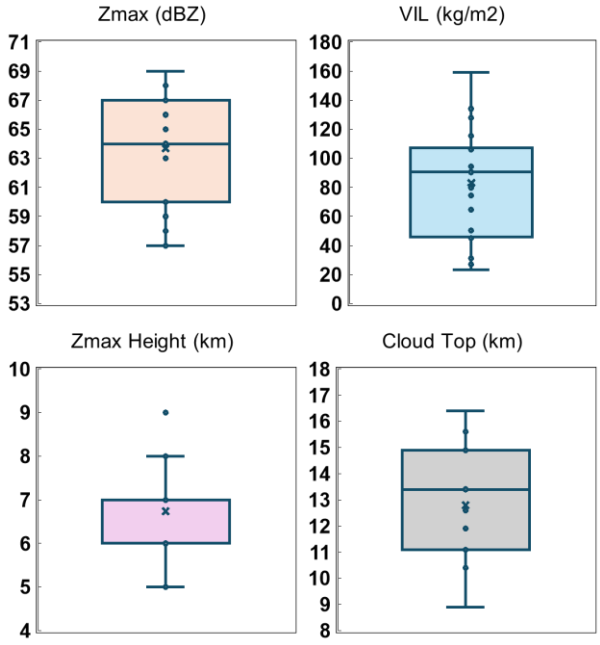


Figure 4 Box and whisker plot of (a) maximum reflectivity, (b) Vertical Integrated Liquid (VIL), (c) height of maximum reflectivity and (d) cloud top.

4. ACKNOWLEDGMENTS

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