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Analysis of Cloud Growth Phases When Nocturnal Hail Occurs (Case Study: Sekadau, 22 August 2020)

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Abstract

On August 22 2020, hail was reported in Sekadau, West Kalimantan at 21:23 WIB. The phenomenon of hail does not usually occur at night. So, further research is needed to find out how the cloud growth phase and Cumulonimbus (Cb) cloud structure are in this phenomenon. This research utilizes remote sensing instruments in the form of a C-Band type weather radar for the Supadio Meteorological Station and the Himawari 8 Satellite, as well as a radiosonde instrument that is closest to the time and location of the hail events. The results of satellite imagery show that nocturnal hail occurs before the clouds reach the mature phase, with the cloud top temperature at the time of hail less than -60 °C. The maximum reflectivity detected by the radar using CMAX products shows a less significant value with an intensity of up to 52 dBZ. The VCUT product shows the maximum intensity altitude is at an altitude of 5 – 8 km. This shows that there is a process of ice condensation on the freezing level layer. The ZHAIL product image shows that there is a potential for hail in the Sekadau area with a probability of more than 80%. The occurrence of ice rain at Sekadau at night is caused by the presence of Cumulonimbus clouds with very cold peak temperatures and the mixing process above the freezing level which supports the formation of ice condensation in Cb clouds.

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INTRODUCTION

Cumulonimbus clouds are clouds that are vertically upward and have no clear cloud top boundaries and can produce showers, thunderstorms and even hail (Tjasyono, 2012). The existence of strong vertical convective currents causes cumulonimbus clouds to grow soaring that they even reach the tropopause layer. The formation of Cumulonimbus clouds accompanied by strong updrafts allows the formation of very large hail (Karmini, 2000; Houze, 1993. Precipitation can be in the form of rain (liquid water) and ice (solid water). Condensation occurs in the form of water. However, when the cloud passes the freezing level (a layer with a temperature < 0 ° C), the content in the cloud becomes a mixture of water and too cold drops. When the clouds begin to reach temperatures < 40 ° C, ice crystals begin to form from supercooled water drops that have frozen.

Indonesia as a tropical region gets a geographical bonus in the form of a surplus of solar radiation throughout the year. This causes the freezing level in the equatorial region to be higher than in the middle and high latitudes, so events such as hail should be rare. According to observational data in 1965-1966, in the tropics it is not only the wind that plays a dominant role in the formation of hail as in the middle latitudes. The phenomenon of hail in the tropics is more dominantly influenced by orographic factors, highlands, and other local factors (Frisby and Sansom, 1967).

On August 22, 2020, there was heavy rain accompanied by nocturnal hail in the Sekadau area, West Kalimantan. Although the phenomenon of hail does not cause any casualties, a method of identifying hail events in Sekadau District is needed to optimize mitigation efforts. This study aims to identify the phases of cloud growth and the probability of hail in the nocturnal hail phenomenon in Sekadau District, reviewed using remote sensing instruments in the form of radar and weather satellites.

METHOD

The research location is located in Sekadau Regency, West Kalimantan. While the time of research was on August 22 2020 with hail events at 14.23 UTC or 21.23 WIB based on reports on the website kalbar.bmkg.go.id. The location of the radar center used is in Pontianak City, West Kalimantan with coordinates 0.089750 South Latitude, 109.393288 East Longitude and an altitude of 26 meters above sea level, as shown in Figure 1.

Figure 1. The research location is in a 200 km radius of the Pontianak weather radar.

The method used in this study is a descriptive analysis method by identifying the diurnal dynamics of cloud top temperature and the maximum reflectivity of the cross section of the cloud to see the cloud growth phase and the ice condensation core (IKA) of the clouds that cause hail in Sekadau. Also, analysis of the probability of hail events in Sekadau. Weather radar uses the product to see cloud distribution patterns spatially, VCUT for cloud vertical structure analysis and ZHAIL to see hail probabilities. The Himawari-8 satellite uses time series analysis of cloud top temperature to see the growth cycle of Cb clouds in the observation area.

This research uses raw data from Pontianak brand EEC type C-band single polar radar obtained from (BMKG PCR) with extension (.vol), 10 minutes temporal resolution and 50m spatial resolution to see cloud distribution trajectories, cloud vertical structure and probability of hail. Then the Himawari–8 IR channel imagery data is sourced from JMA with *.z extension for analysis of cloud top temperature time series processed with SATAID software. The height of the freezing level was analyzed based on radiosonde data from the nearest available station, namely upper air data from Kuching Station, Malaysia, taken from the Wyoming University website.

The flow chart of this research is shown in Figure 2.

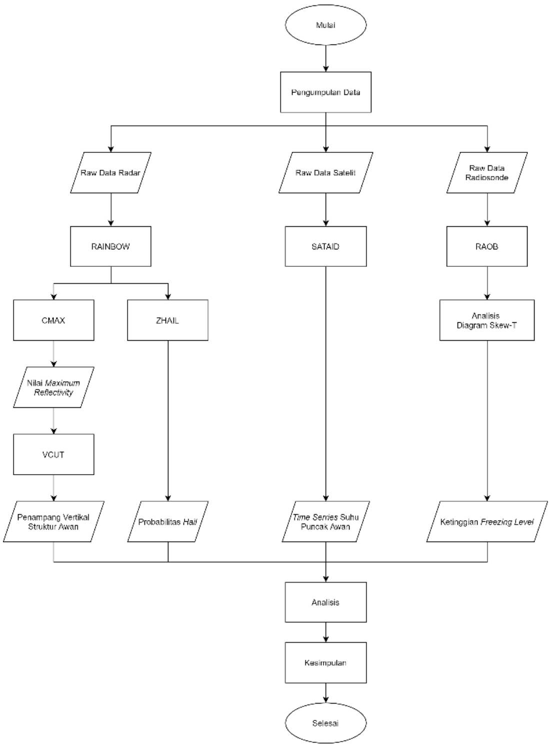

Figure 2. The research flowchart illustrates the processing of radar data using CMAX and VCUT products to view vertical cross-sections of clouds and ZHAIL products to view hail probability, satellite data processing for cloud top temperature time series analysis and radiosonde data processing for freezing level analysis.

RESULTS AND DISCUSSION

From the time series graph of cloud top temperature in Figure 3, it is known that the lowest cloud top temperature occurs at 16.00 UTC, which is -80 °C. Based on radar image analysis, hail occurred at 14:23 UTC, which occurred before the cloud top temperature reached its lowest point. In the period of hail in this case, the cloud top temperature reaches -80 °C which is marked with a red box. From the time series graph of the cloud top temperature it is known that there are convective cloud clusters (Cumulonimbus/CB clouds) which are the source of hail events with the growth phase shown in Figure 4. The cumulus phase of the CB cloud is expected to occur at around 12.00 UTC, reaching the mature phase at around at 16.00 UTC, and started to enter the dissipation phase (extinct) at around 19.00 UTC.

Figure 3. Cloud Top Temperature Time Series Graph. The minimum cloud temperature peak occurs at 16 UTC or 23 WIB, with values reaching -80 °C.

Radiosonde data is processed using RAOB software, by utilizing data at the time and location closest to the case. The data used is radiosonde data at the Kuching Meteorological Station on August 22, 2020 at 00 UTC, the freezing level value is obtained at an altitude of 4873 m (15987.5 ft). The freezing level is used to determine the height of the droplets in the cloud that are starting to freeze.

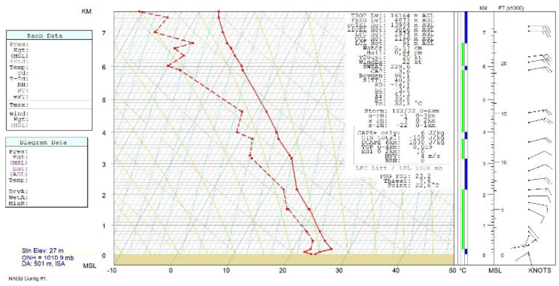

Figure 4. Skew-T diagram of the Kuching Meteorological Station August 22 2020 at 00 UTC, to see the freezing level (blue line).

For CMAX products, it is adjusted one hour before, during and 15 minutes after the hail event, i.e. from 13:24 - 14:39 UTC. CMAX product settings are set at an elevation range of 0.5 - 15 km to see the entire cloud structure. One hour before the hail incident, a cloud cell with a maximum reflectivity of 52 dBZ was detected in the Sekadau area, which is 165 km from the center of the Pontianak Weather Radar. The reflectivity value is 30 dBZ sensed by DWR (Doppler Weather Radar), indicating that there has been a convective initiation. (Roberts & Rutledge, 2003).

In analyzing the probability of hail, the simplest method is to look at the DWR reflectivity value. According to Geotis (1963), if the reflectivity value is more than 55 dBZ, then hail is indicated. In the case of Sekadau, the maximum reflectivity captured by the radar does not reach this value. This is probably caused by the distance from the incident location and the radar location which is too far away so that it experiences an attenuation effect or weakens the radar pulse energy received by the receiver on the weather radar system (Kosasih et al, 2021). The attenuation value that affects the raw data reflectivity (dBZ) of the radar will be greater if the wavelength used by the weather radar is shorter and the rain intensity is heavier. (Jacobi & Heistermann, 2016). However, according to (Waldvogel et al, 1979), a reflectivity value of more than 45 dBZ already indicates hail.

The VCUT product is a derivative product from CMAX so the data is adjusted one hour before, during and 15 minutes after the hail event, namely from 13:24 - 14:39 UTC. VCUT product settings are set at an elevation range of 0.5 - 15 km. One hour before the hail event, in the cloud cells, reflectivity of more than 50 dBZ was seen at an altitude of more than 6 km. At 30 minutes before the occurrence of hail, the height of its maximum reflectivity drops to an elevation of 5 km. 15 minutes later, the altitude rose again to above 8 km. This indicates that there is a strong updraft so that the ice condensation cores experience a process of ups and downs. There are two processes that initiate the formation of ice in clouds, namely the Bergeron-Findeisen process and Collision-Coalescence..

The Bergeron-Findeisen process occurs when liquid water vapor rapidly evaporates and combines with ice crystals above the freezing level of clouds (Rogers & Yau, 1989). Whereas the Collision-Coalescence process occurs due to impact/acretion, namely when ice crystals collide with other ice crystals or supercooled water droplets and aggregation/coalescence, namely the merging of ice crystals to form larger ice crystals (graupel) (Wallace and Hobbs, 2006). Based on this, the occurrence of ice rain in Sekadau was formed due to mixing in the layer above the freezing level which resulted in ice crystals growing and getting bigger until they fell at 14.23 UTC which was marked by the decrease in the maximum reflectivity value of the vertical cloud structure at 14:00: 24 UTC.

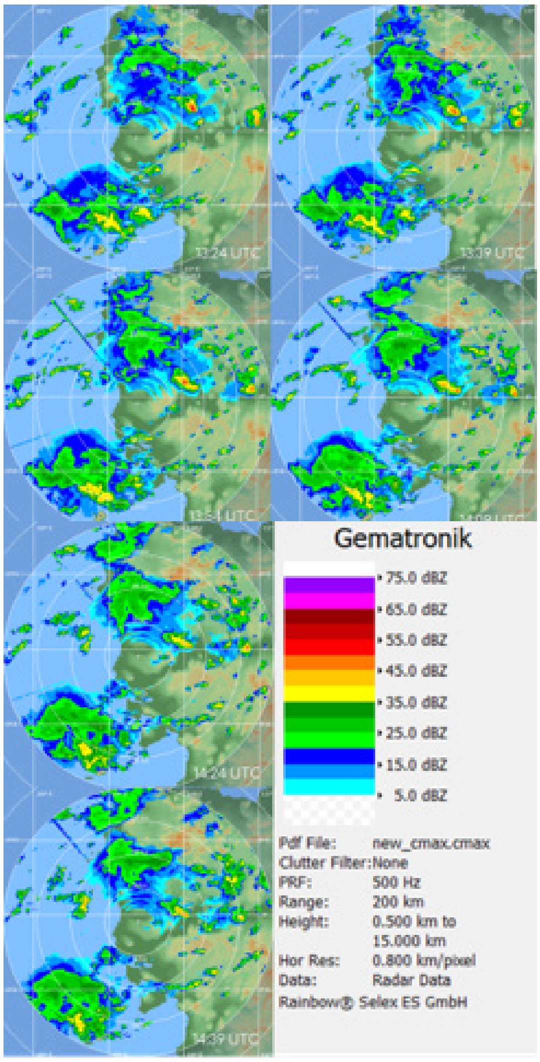

Figure 5. CMAX product radar image results at 13:24 - 14:39 UTC. Maximum reflectivity detected by Radar Pontianak, marked with a dark orange pattern, with a value of 52 dBZ.

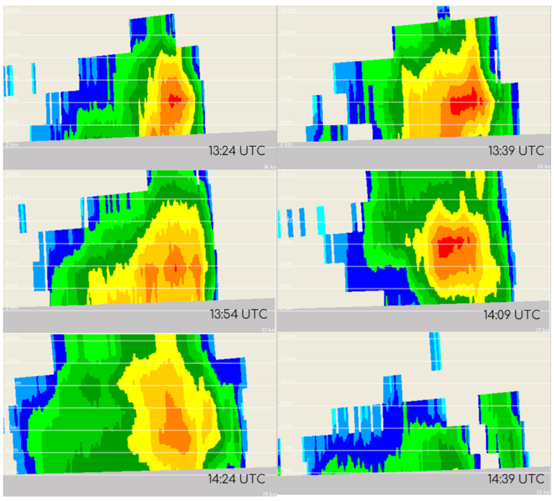

Figure 6. VCUT product radar image results at 13:24 - 14:39 UTC. The pattern of maximum reflectivity that fluctuates indicates strong updraft and downdraft patterns within the cloud.

For the ZHAIL product, it was adjusted at the time of the hail incident, which was around 14:23 UTC. Therefore, the data analyzed is the data closest to that time. ZHAIL product settings are set to default settings, according to Waldvogel's criteria (1979). At 14:19 UTC, hail was detected in the Sekadau area with a probability of more than 80%. Then, at 14:24 UTC, it shows the same probability in the Sekadau area with a value of more than 80%. There are indications of hail at location points in the Bengkayang-Landak area. However, there were no reports of hail in the area, so it is considered an overestimate of the ZHAIL product.

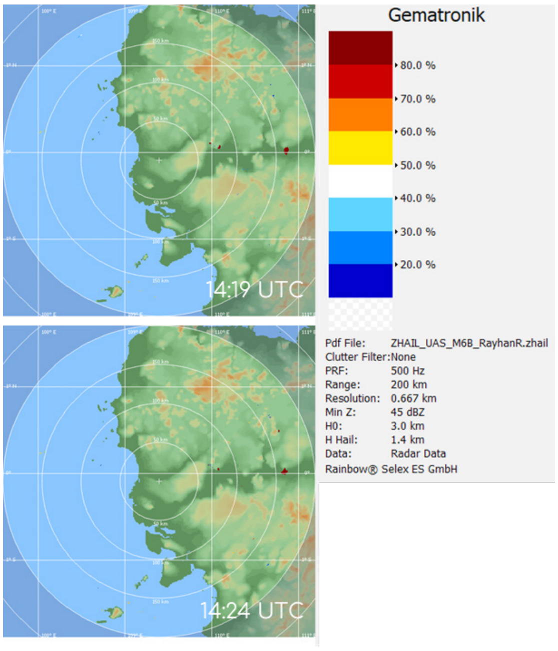

Figure 7. The results of the ZHAIL product radar at 14:19 - 14:24 UTC, show that the probability of hail in Sekadau is more than 80% which is marked with a dark red dot.

CONCLUSION

The results of time series analysis of cloud top temperatures and the RGB method from satellite data show that the nocturnal hail event on 22 August 2020 at 14:23 UTC in Sekadau occurred before the Cumulonimbus clouds entered the mature stage at 16:00 UTC. However, at the time of hail, the cloud top temperature reaches less than -60 °C. The results of the CMAX radar product show that the maximum reflectivity value reaches 52 dBZ which indicates that there is no indication of ice condensation in Cumulonimbus clouds. The reflectivity value is considered less significant due to the effect of the location of the radar center being too far from the location of the hail incident resulting in signal attenuation. Then from the results of the analysis of the cloud structure vertically, it shows that the maximum reflectivity height of the clouds fluctuates above the freezing level layer at an altitude of 5 – 8 km which supports the process of forming hail. From the ZHAIL product, the hail probability reached values of more than 80% at 14:19 UTC and 14:24 UTC. It can be concluded that the occurrence of hail at Sekadau occurred due to the mixing process above the freezing level layer which resulted in the formation of ice condensation nuclei in Cumulonimbus clouds.

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