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Analysis of Atmospheric Conditions during the Occurrence of Mesoscale Convective Complex (MCC) in East Kalimantan and Surrounding Area (Case Study: December 26, 2021)

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Abstract

Mesoscale Convective Complex (MCC) was first introduced in 1980 through research on infrared (IR) satellite images by Maddox. The MCC phenomenon can caused rain with a long period of time. This study aims to determine the atmospheric conditions when MCC occurred in East Kalimantan and surroundings area on December 26, 2021. The research data used in this study is Himawari-8 satellite data to display cloud top temperatures and convective cloud distribution using the CCO method and image interpretation using RGB method. Analysis of atmospheric conditions was also carried out on air humidity, vertical velocity, and reflectivity in the atmosphere obtained from weather radar data from the Stasiun Meteorologi Sultan Aji Muhammad Sulaiman - Sepinggan. Based on the results of the analysis, MCC was identified as a mature phase on December 26, 2021 at 12.00 UTC. Airmass RGB analysis shows the presence of clouds which are known as Cb clouds through CCO analysis as well as warm air masses with high humidity in East Kalimantan. Negative value of vertical velocity also indicates an updraft of moist air masses and the maximum reflectivity value of the CMAX product, which is 53 dBz, indicates strong convection activity.

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INTRODUCTION

Geographically, Indonesia is located at 07° 20' N - 14° N and 92° - 141° E. Indonesia is one of the tropical countries, so that the most dominant type of precipitation that occurs is rain. Indonesia is one of the areas located in the equator with active convective clouds (Tjasyono, 2004). In addition, Indonesia receives heat continuously which results in high evaporation activity in the Indonesian region which in turn can cause the growth of convective clouds, such as Cumulunimbus (Cb).

Convective cloud growth can cause rain. If the growth is widespread, it can lead to extreme weather and phenomena such as the Mesoscale Convective System (MCS). MCS can be defined as a collection of Cb clouds that become one entity accompanied by precipitation covering a horizontal scale of thousands of kilometers (Houze, 2018). One of the largest types of MCS is the Mesoscale Convective Complex (MCC). MCC was first introduced in 1980 by Maddox through research on infrared (IR) satellite imagery. The MCC phenomenon is characterized as a cloud cover that resembles a circle with an eccentricity ≥ 0.7, a cloud blanket area $\geq 100{,}000$ km², a cloud core area of $\geq 50{,}000$ km² and an IR1 cloud top temperature $\leq$ -52 °C or 221 K. MCC has a life duration ≥ 6 hours (Maddox, 1980). The MCC phenomenon is a fairly frequent phenomenon in Indonesia that can cause rain with a long period of time. Previous research on MCC has been conducted by Septiadi & Septiadi (2020), Perdana, et al. (2019), and Wulandari, et al. (2019). Trismidianto (2018) suggested that there are 9 regions in Indonesia that are areas that often experience the MCC phenomenon, one of which is the East Kalimantan region.

Based on Himawari-8 satellite imagery, there was an MCC that entered the mature phase at 12:00 UTC December 26, 202 in the East Kalimantan region. This phenomenon caused measurable rain at Satsiun Meteorologi Sultan Aji Muhammad Sulaiman - Sepinggan of 33 mm/day and at Stasiun Meteorologi Aji Pangeran Tumenggung Pranoto - Samarinda of 49 mm/day. This study aims to determine the atmospheric conditions at the time of the MCC phenomenon in the East Kalimantan region on December 26, 2021. Information on the characteristics of MCC can be used as a consideration in analyzing severe weather events in the research area, as well as a source of literature in the development of further research related to the MCC phenomenon.

METHOD

This research took place in the East Kalimantan region and its surroundings with coordinates 2°N - 4°N and 113° - 120°E.

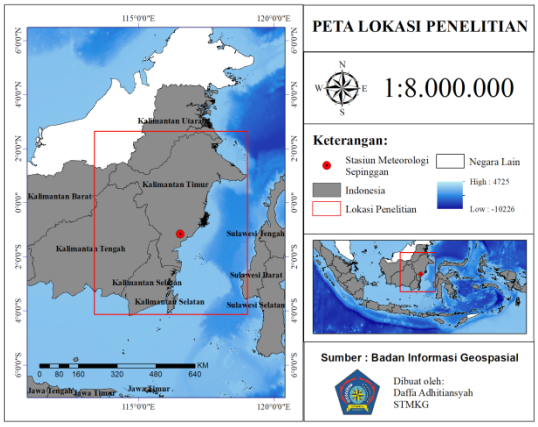

Figure 1. Research location map

The research data used in this study are as follows.

Himawari-8 satellite data for the period December 26, 2021 in .nc format and then processed using the MATLAB application to see the characteristics of the MCC. Then, this data is also processed with GrADS to display cloud top temperatures and display the distribution of convective clouds using the Cloud Convective Overlays (CCO) method.

Himawari-8 satellite data for the period December 26, 2021 in .z format to interpret the image with the Airmass RGB method which is processed using the SATAID application.

Vertical velocity and relative humidity (RH) data in .nc format for the December 26, 2021 time period obtained through the Copernicus website (https://cds.climate.copernicus.eu/cdsapp#!/home) and then processed using the GrADS application.

Weather radar data of Sultan Aji Muhammad Sulaiman Meteorological Station - Sepinggan CMAX product format (.png) for the time period December 26, 2021 to see the reflectivity of the situation in the atmosphere.

After the data is obtained and processed, it will be analyzed using a descriptive approach and conclusions will be drawn.

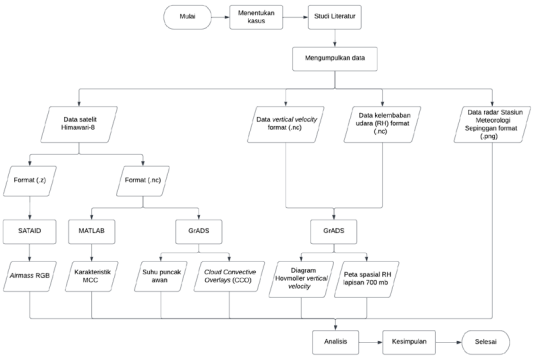

Figure 2. Research flowchart

RESULTS AND DISCUSSION

MCC Characteristics

Table 1 shows the results of satellite data processed using the MATLAB which identifies the growth of the MCC phenomenon in Kalimantan. East Kalimantan at 12.00 UTC with coordinates 0.5 °LU - 1.5 °LS and 116 - 117 °BT. MCC entered its mature phase characterized by cloud top temperature ≤ -52°C, eccentricity ≥ 0.7, cloud blanket area ≥ 100,000 km², and cloud core area of ≥ 50,000 km². The MCC lasted for 8 hours until 19:00 UTC. Based on Figure 3, which shows the changes in the cloud top temperature range, it can be seen that the temperature in the East Kalimantan region varies between 56 °C to < -80 °C in the cloud core (Figure 3 a). Furthermore, several cloud systems merged so that the MCC area continued to increase in area (Figures 3 b, c, and d). The MCC is seen moving northward Kalimantan Island as time passes. Figure 3 h shows that the MCC decreased in area and then entered the decay phase in the next hour.

Table 1. Results of satellite data processed using the MATLAB

Date	Hours	Eccentricity	MCC Core				MCC Cover			
			Pixel	Area (km²)	Lon	Lat	Pixel	Area (km²)	Lon	Lat
26	12	0.99982378	24637	121420.9	116.85	-1.570	106320	523987.4	116.45	-1.37
	13	0.981954084	28194	138951.31	116.08	-1.555	87138	429451	116.18	-1.256
	14	0.937930465	28799	141932.99	117.01	-1.324	87685	432146.7	117.21	-1.124
	15	0.923735801	30722	151410.30	116.34	-0.450	102693	506112.1	116.53	-0.13
	16	0.883606966	33723	166200.4	116.02	-0.410	110265	543430	116.61	-0.12
	17	0.958736338	31850	156969.5	116.64	-0.284	117134	577283.2	116.68	-0.184
	18	0.970066313	27503	135545.78	117.47	0.595	118488	583956.2	117.69	0.855
	19	0.84753491	21859	107729.89	117.76	0.569	116131	572340	117.57	0.879

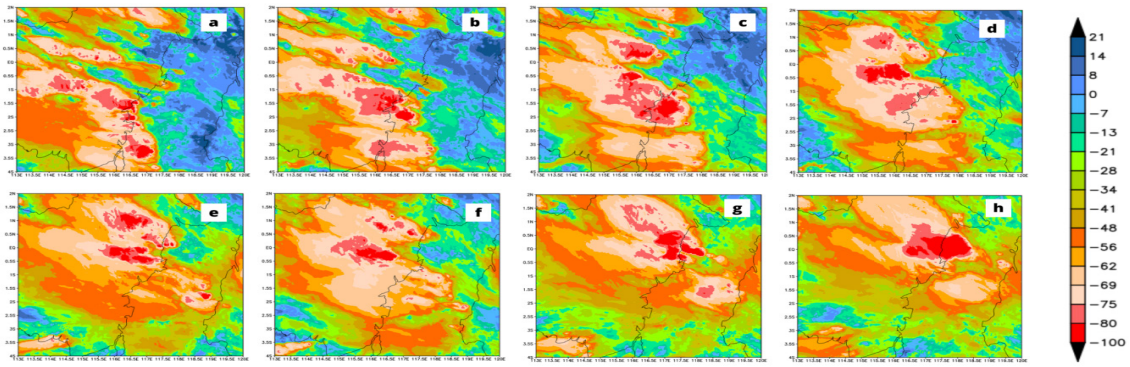

Figure 3. Change of cloud top temperature in (°C) during the mature phase of MCC for: (a) 12 UTC; (b) 13 UTC; (c) 14 UTC; (d) 15 UTC; (e) 16 UTC; (f) 17 UTC; (g) 18 UTC; (h) 19 UTC in East Kalimantan and surrounding areas

Cb Clouds Distribution Analysis

Based on the distribution of Cb clouds using the CCO method as shown in Figure 4, Cb clouds are seen to have been in the East Kalimantan region at 12.00 UTC The distribution of Cb clouds continues to expand over time and is seen moving towards the north of Kalimantan Island. The distribution and extent of Cb clouds were seen to decrease at 18:00 UTC (Figure 4 d).

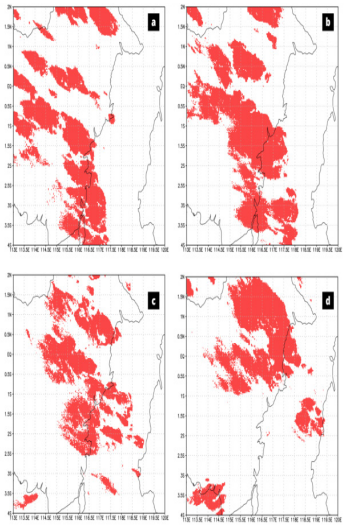

Figure 4. Map of Cb clouds distribution on December 26, 2021 at (a) 12 UTC; (b) 14 UTC; (c) 16 UTC; (d) 18 UTC

***Airmass* RGB Analysis**

Based on Figure 5, it can be seen that the Airmass RGB method can show the distribution of cloud characteristics quite well. Based on the criteria of the Japan Meteorological Agency (JMA) (2020) green colored images indicate the presence of warm air masses in the tropopause layer. It can be seen that there is a warm air mass with high humidity at the top of the tropopause around the East Kalimantan region which is marked with a dark green coloured area. This warm air mass is the source for convective cloud growth. Meanwhile, the white colored area indicates thick high clouds. It can be seen that the growth of high and thick clouds marked with white coloured areas is expanding due to the formation of MCC. These high and thick clouds are dominated by Cb clouds as shown in Figure 4.

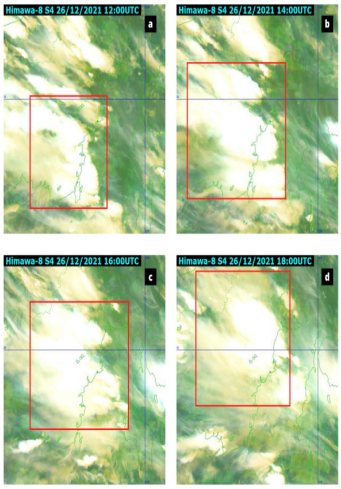

Figure 5. *Airmass* RGB on December 26, 2021 at (a) 12 UTC; (b) 14 UTC; (c) 16 UTC; (d) 18 UTC

Relative Humidity (RH) Analysis

Based on Figure 6 which shows the RH of the 700 mb layer, it can be seen that the RH value for East Kalimantan and its surroundings has a high value with RH values in most areas of East Kalimantan> 80% (Figure 6 a and b). The high RH value indicates that the layer is saturated and contains a lot of water vapor, thus supporting the growth process of convective clouds, such as Cb. Furthermore, RH began to decrease with varying values (Figure 6 c and d) when the MCC began to move towards the North Kalimantan region.

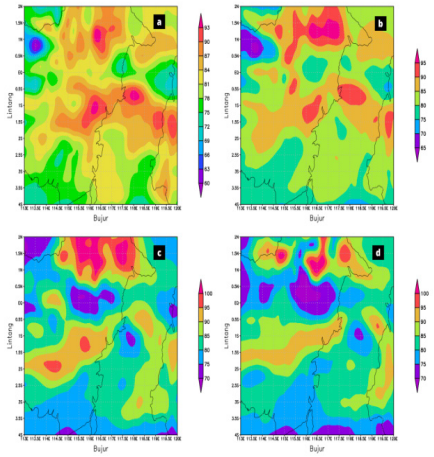

Figure 6. RH of the 700 mb layer on December 16, 2021 at (a) 12 UTC; (b) 14 UTC; (c) 16 UTC; (d) 18 UTC

Vertical Velocity Analysis

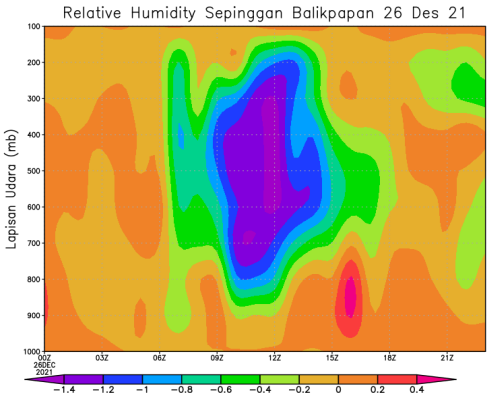

Figure 7. *Vertical velocity* at the Stasiun Meteorologi Sultan Aji Muhammad Sulaiman - Sepinggan December 26, 2021

Based on Figure 6 which shows the vertical velocity at the Stasiun Meteorologi Sultan Aji Muhammad Sulaiman - Sepinggan per air layer (1000 – 100 mb), it can be seen that on December 26, 2021 the vertical velocity value began to decrease at 06.00 UTC ranging from -0.4 to -0.6 Pa s^{-1}. Then, the value continues to decrease at 09.00 - 12.00 UTC in the 800 - 200 mb layer with its minimum value, namely -1.4 Pa s^{-1} which coincides with the start of MCC maturity as shown in Figure 3. Negative values indicate the movement of moist air masses that are lifted vertically into the atmosphere (updraft), where this air mass can support the growth of convective clouds in the upper layers in the area. The vertical velocity value increases to a positive value after MCC enters its decay phase on December 26, 2021 at 18.00 – 19.00 UTC. Positive values indicate the presence of air mass moving downward which can be indicated as the decay of a convective cloud.

CMAX Radar Analysis

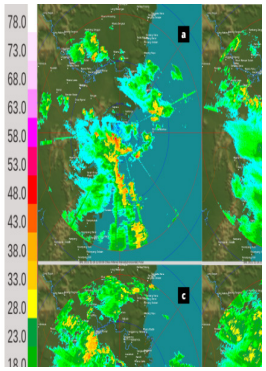

Figure 8. CMAX radar at the Stasiun Meteorologi Sultan Aji Muhammad Sulaiman - Sepinggan on December 26, 2021 at (a) 12 UTC; (b) 13 UTC; (c) 14 UTC; (d) 15 UTC

Figure 8 shows the development and movement of clouds during the MCC maturity period around the Stasiun Meteorologi Sultan Aji Muhammad Sulaiman - Sepinggan. The reflectivity value varies over time with the maximum value observed is 53 dBz which indicates the presence of convective cloud clusters that are quite strong Cb clouds in line with those shown in Figure 4. The clouds are seen moving northeast away from the radar location at 14 - 15 UTC (Figure 8 c and d).

CONCLUSIONS

Based on the results of the above analysis, it can be concluded that MCC entered its mature phase on December 16, 2021 at 12.00 UTC with the distribution of Cb clouds seen in East Kalimantan and its surroundings when MCC entered its mature phase. Airmass RGB shows the presence of thick high clouds and warm air masses with high humidity which is a source for convective cloud growth. RH in most areas of East Kalimantan > 80% and the minimum value of vertical velocity in the 800 - 200 mb layer, which is -1.4 Pa s-1 in the mature phase of MCC which can support the growth of convective clouds in the upper layers. The maximum reflectivity value of the observed CMAX product, which is 53 dBz, also indicates strong convection activity.

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