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# Analysis of Mesoscale Convective Complex during Madden Julian Oscillation Phase 4 (Case Study: Heavy rain in Cilacap on Sept 16-17, 2016)

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**Abstract.** This research aims to analyze the heavy rain which accompanied by severe winds, caused floods and landslides in several of sub-districts in Cilacap, Central Java on 16-17 September 2016 that coincides with the phase 4 of Madden Julian Oscillation (MJO) event. In the same time, also found a Mesoscale Convective Complex (MCC) in the around Central Java. MCCs were identified by infrared satellite imagery from Himawari 8 using an algorithm that combines criteria of cloud coverage, eccentricity, and cloud lifetime. The data used is a combination of observation data, satellite data and reanalysis data. This study results that there is an increase in vertical velocity accompanied by strong negative vorticity since the development of MCC until it reached its mature phase, then the vertical velocity decreases as the cloud systems disseminated. These results indicate there is the evolution of MCC convective cells from growth until dissipation. Throughout its lifetime the MCC system moves south-east into the Indian Ocean and is decapitated there. Based on GSMaP rainfall data it was observed that in Central Java area especially Cilacap area has extreme rainfall which caused by MCC activity. The influence of MCC on significant rainfall is also supported by the existence of MJO phase 4. The significant increase in rainfall when phase 4 active MJO is followed by the MCC. The value of rainfall intensity when MJO followed by the presence of MCC is greater than in the absence of MCC.

Keywords : MCC, MJO, IMC, GSMaP

## 1. Introduction

Ramage [1] have stated that Indonesian Maritime Continent (IMC) is one of the regions with the largest amount of rainfall, rainfall levels over the IMC are among the highest globally. Spatial and temporal variations in rainfall affect the global circulation through latent heat release, because of the IMC is composed of a large number of islands and surrounded by sea, both regional and temporal variations in rainfall may be quite complicated due to strong interactions between land and the adjacent sea. The precipitation organization mechanism over the IMC may involve several factors, such as the complex geographical variation mentioned above and the large-scale atmospheric circulation. Madden-Julian



Oscillation (MJO) is one of the dominant modes of tropical variability on the intraseasonal time scale [2] of the ocean-atmospheric pairing system which greatly influences atmospheric circulation throughout the global tropical including IMC. The influence of MJO on IMC is also very significant, especially in phase 4 where MJO is in the Maritime continent [3].

Besides MJO, Mesoscale Convective Complex (MCC) also has a considerable influence on rainfall in Indonesia. Trismidianto [4] has reported that the contribution of MCC to total rainfall in the Indonesia territory is between 18% -20% with the concentration of the most MCC formation region is in the coastal areas south of Sumatra, the sea of South China, Central Kalimantan, Central Sulawesi and the Indian Ocean, while the biggest influence of the MCC to the rainfall is in the region of Central Kalimantan which reaches 20%. Several studies regarding the interaction between deep convection and MJO global scale oscillation systems have been carried out. But previous research only focused on the interaction between MJO and deep convection in general such as MCS. Research that focuses on the interaction between MJO and MCC is still not much done that left many questions about the interaction between those systems. Therefore, this study aims to determine the interaction between the MCC and MJO, but is limited to phase 4 [3], so that the results of this study are expected to increase knowledge about interaction between the MCC and MJO and also help to improve forecast and early warning skills to the existence of a potential hydrometeorology disaster. This paper also discusses the evolution of cloud top temperature, precipitation cell evolution, environmental conditions around the occurrence of the MCC system and also thermodynamic conditions before the initiation of MCC, when the MCC initiate and mature also after the MCC dissipate which happened coincides with phase 4 of MJO.

## 2. Data and Method

Identification of the MCC system will be using Himawari 8 Infrared Channel (IR1/B13) satellite imagery data obtained from Kochi University which can be accessed freely at the website address <http://weather.is.kochi-u.ac.jp/sat/> in the form of portable gray map (.pgm) data and its calibration in the form of (.dat) format. The satellite data has a horizontal resolution of  $0.05^\circ \times 0.05^\circ$  and temporal resolution of 60 minutes. The MCC identification technique used Ismanto's [5] identification method. This method selected cloud shield (SA) and interior cloud (IA) temperature as Maddox [6] definition and Machado technique (least square) to determine the quasi-circular shape of the MCC system. Next is to do a selection of the system by eliminating system that can't last up to 6 hours. The resulting output is the time data (date and time of occurrence of the system) and MCC identification location (latitude, longitude, pixels). The strength of the convective activity that occurs during MCC will be analysed using Convective Index (CI) analysis. This analysis will separate between surface temperatures and high convective clouds through threshold based on to the research of Adler and Negri [7]. The temperature of 253 K as the warmest brightness temperature ( $T_{BB}$ ) to determine the clouds which allegedly result in the rain. The greater CI values, the stronger the convective activity occurs. If  $T_{BB}$  is smaller than threshold value so CI can be determined by reducing the threshold with the value of  $T_{BB}$  ( $T_{BB} < \text{threshold}$ ,  $CI = \text{threshold} - T_{BB}$ ) and if  $T_{BB}$  greater than or equal to the threshold value, CI is 0 ( $T_{BB} \geq \text{threshold}$ ,  $CI = 0$ ).

Based on the results of this identification, analysis of evolution and propagation analysis of TBB and the precipitation area of the MCC system will be performed. This paper adapted Cotton et al. [8] and Trismidianto et al. [9] technique, the analysis will be focus on 4 phases of life of MCC, that's in the initiation phase, mature phase, decay phase and dissipation phase. The MCC initiation phase is the phase of the MCC system where the cloud system meets the MCC requirements defined by Maddox [6] that's having  $T_{BB} \text{ IA} \leq -52^\circ\text{C}$ , with IA coverage of  $\geq 50,000 \text{ km}^2$  and  $T_{BB} \text{ SA} \leq -32^\circ\text{C}$ , with SA coverage  $\geq 100,000 \text{ km}^2$  and eccentricity  $\geq 0.7$ . While the pre-MCC phase is a phase that occurs 3 hours before MCC reaches the initiation phase. The decay phase is the phase where the system no longer qualifies as an MCC and begins to decay. Dissipation phase is the phase where the system has been dissipated.  $T_{BB}$  analysis will used Himawari 8 satellite channel IR1 data while rainfall analysis on the system is using Global Satellite Mapping of Precipitation (GSMaP) with a horizontal resolution of  $0.1^\circ \times 0.1^\circ$  and

temporal resolution of 60 minutes and rainfall observation data obtained from Cilacap Meteorological Station on September 16 to September 17, 2016.

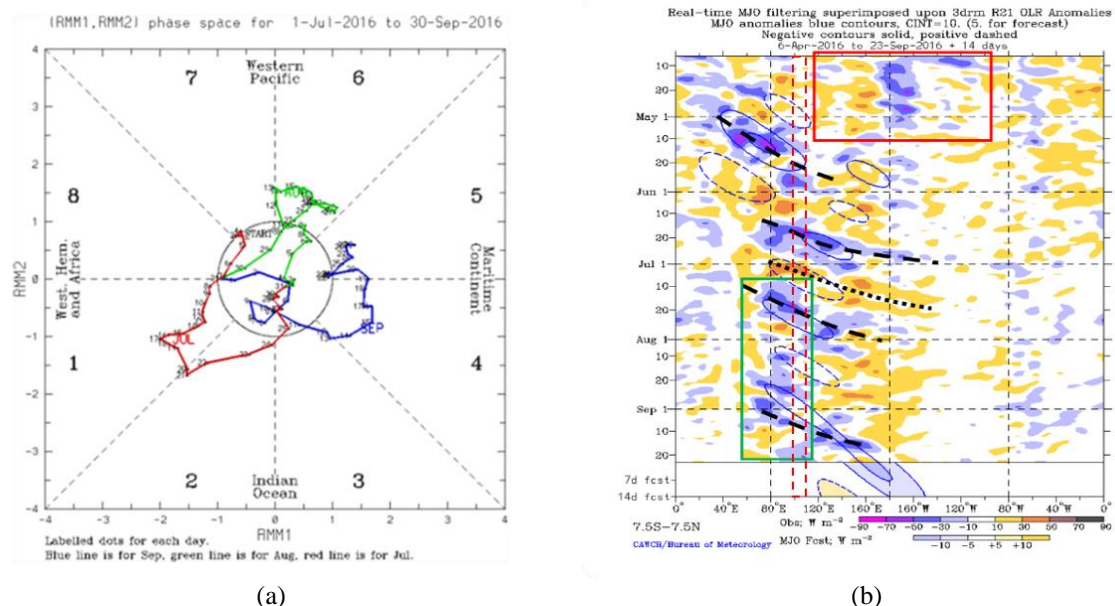
The thermodynamic analysis will be using upper air sounding observation data obtained from the Cilacap Meteorological Station on September 16 to September 17 at 0700 LT (Local Time) with LT is UTC + 7 and 1900 LT. In addition, to show the environmental conditions at the time of the MCC system, this study uses European Center for Medium-Range Weather Forecasts (ECMWF) data with a spatial resolution of  $0.125^\circ \times 0.125^\circ$  with parameters such as divergence, vertical velocity, u and v component of wind in the pressure level from 1000 mb to 100 mb. MJO monitoring data is obtained from Australian BoM which can be accessed through <http://www.bom.gov.au/climate/mjo/> in the form of RMM1 and RMM2 data.

### 3. Result and Discussion

#### 3.1. Analysis of the Evolution of MCC during MJO Phase 4

Heavy rains accompanied by strong winds that occurred in the Cilacap region on 16 - 17 September 2016 resulted in a number of losses, including the occurrence of flooding in some location of Sidareja District, such as Gunungreja, Sidareja, and Sidamulya. In addition, landslides also occurred in Bantar and Madura villages, Wanareja District [10]. Cilacap Meteorological Station recorded that the rain on 16 to 17 September 2016 reached 117.2 mm. The heaviest rainfall occurred on 17 September 2016 at 0300 LT until 17 September 2016 at 0700 LT. Based on the RMM MJO index shown in Figure 1 (a) and Figure 1 (b), the heavy rain was coincided with the MJO being active in phase 4. Many of the previous researchers has found that MJO has significant impact on generating heavy rain based on where it active [10, 11, 12].

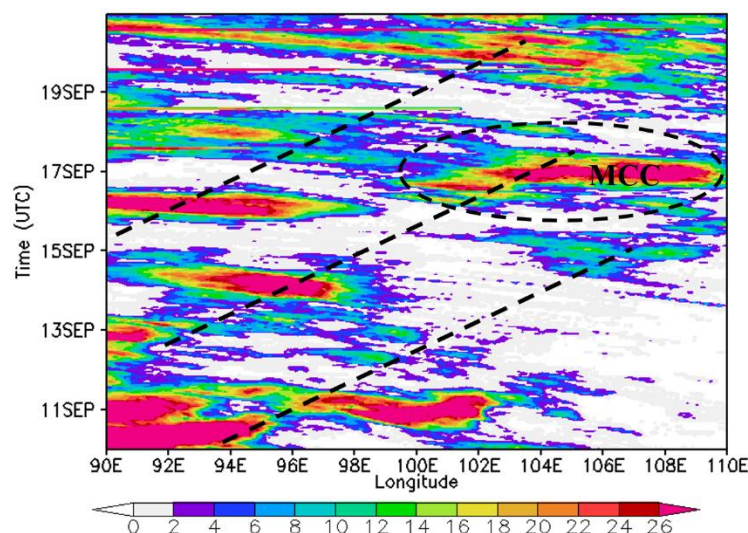
The axes (RMM1 and RMM2) represent the daily values of the principal components from the two leading modes. The triangular areas indicate the location of the enhanced phase of the MJO, counter-clockwise motion is indicative of eastward propagation. The RMM index indicates a recent strengthening of the signal over the Maritime Continent in Phase 4 of MJO over Indian Ocean on 16 - 17 September 2016.



**Figure 1.** (a) RMM MJO index (left) (source: <http://www.bom.gov.au/climate/mjo/#tabs=Time-longitude>) and (b) Outgoing Longwave Radiation (OLR) Anomalies ( $7.5^\circ\text{S} - 7.5^\circ\text{N}$ ) (source: <http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/foregfs.shtml>). The dashed red line is longitude of Cilacap.

Figure 1 (b) shows that the 2015-2016 El Niño background state is observed (red box) as a dipole of anomalous convection extending from the Maritime Continent to the East Pacific. The signal weakened steadily through boreal Spring. Several intra-seasonal events were observed during May through July, with other modes such as tropical cyclone activity also influence the pattern. A low-frequency state favoring enhanced convection over the eastern Indian Ocean has been evident since July (green box). This activity is likely related to a negative phase Indian Ocean Dipole event. During September, a fast-eastward moving envelope was evident, likely linked to intra-seasonal activity. More recently, the OLR pattern became increasingly incoherent. This reinforces that in September there was MJO phase 4, but it is interesting to see that from the beginning to mid-September there was significant convective activity. Satellite imagery shows that there is a convective system that last for more than 6 hours around Cilacap. Based on the identification, it is known that the system is the MCC system as shown in Figure 2.

Cotton et al. [8] have defined eight stages in the life cycle of an MCC: MCC-12 h, pre-MCC, initial, growth, mature, decay, dissipation, and post-MCC; however, the most important period for an MCC is from the initial to the dissipation stage. The MCC began to develop from the pre-MCC stage at 1800 LT on 16 September 2016. At that time, small-scale clouds were located over Java, as shown in Figure 1 (a). The system, which was initially monitored as a number of small convective cells, continues to develop into a system of large size and meets all criteria to be categorized as an MCC system before the system is finally dissipated. The MCC system initiated in the mainland at night local time. The system is at night, based on research conducted by Gray and Jacobson [13] in Laing and Fritsch [14] stated that the growth of the system at night is related to differences in solar radiative heating between the MCC system and the surrounding environment, which results in the subsidence of environmental peripherals and the convergence of the lower layers to the system. During the initial stage, deep convective seem over the Indian Ocean and several small clouds in the Java Island.

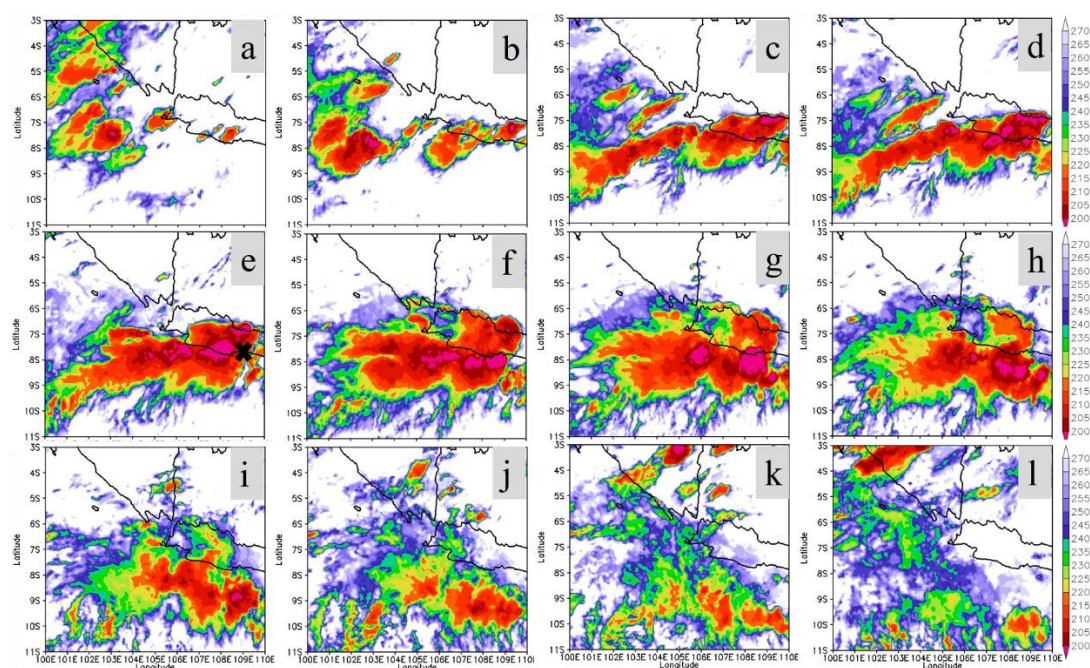


**Figure 2.** Time-Longitude cross section on convective index at 10 – 20 September 2016 during MJO phase 4 event and MCC system event.

During the growth stage of the MCC in the midnight, the sizes of the deep convective and small clouds had increased further, and they began merging with each other, such that the maximum extent of the MCC was attained at 0300 LT (Figure 3 (e)). At 0800 LT, during the decay stage in the morning, the MCC began to split and dissipated (Figure 3 (h)). During the dissipation stage in the late afternoon



(1400 LT) (Figure 3 (k)), the MCC had split into small-scale clouds that propagated southward toward the Indian Ocean near the Java Island. The system has been completely dissipated and in the surrounding environment, a new convective system begins to form. The MCC system has a long-life duration that's around 20 hours because the system has an extensive SA coverage area around 373,244 km<sup>2</sup> and the IA coverage area of the system is about 304,768.75 km<sup>2</sup>. When the system reaches mature phase and the dissipation phase it formed a new convective system around the Java Sea region and in the southern area of Indian Ocean near East Java. The system is formed due to cold pool activity [4, 5, 9]. Based on the results of the analysis of the time series evolution of MCC which was formed on September 16, 2017, this study supports the results of previous studies conducted by Laing and Fritsch [14] on the global population of MCC. The results of research conducted by Laing and Fritsch [14] showed that the MCC system formed on land with large cold cloud cover has a long-life duration.



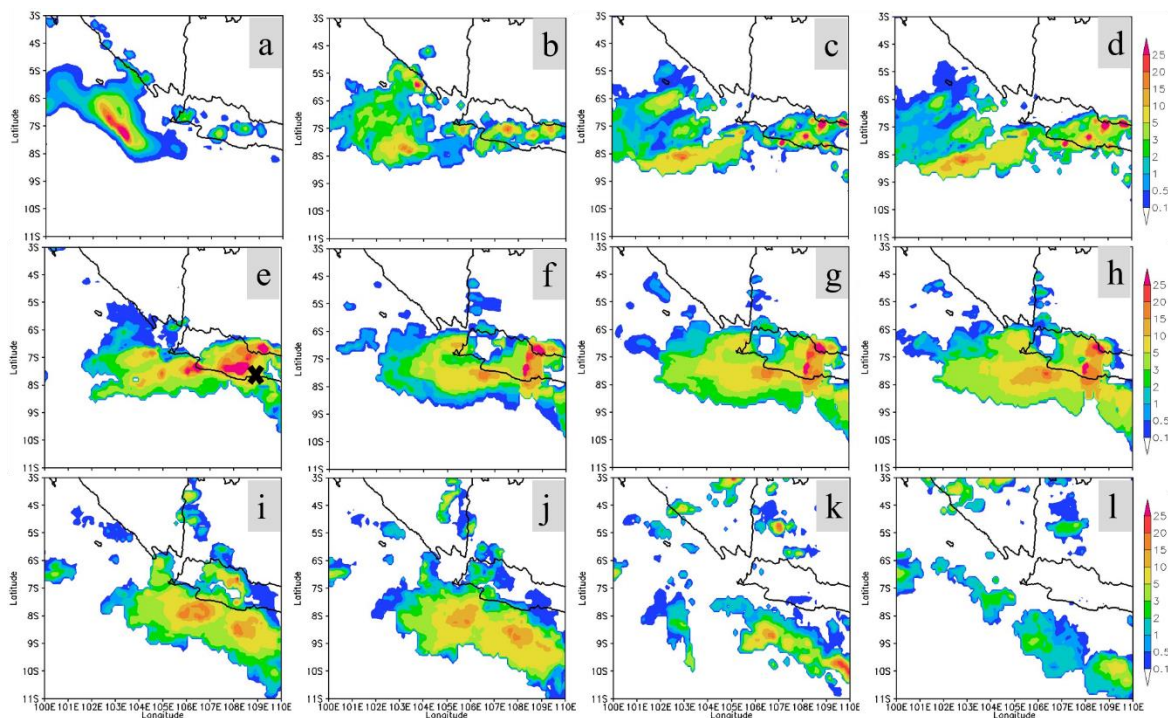
**Figure 3.** Horizontal distribution of  $T_{BB}$  for MCC criteria from infrared data obtained by Himawari 8 on 16 September 2016, (a) 1700 LT (initial phase), (b) 2100 LT, (c) 0000 LT, (d) 0100 LT, (e) 0300 LT (maximum phase), (f) 0600 LT, (g) 0700 LT, (h) 0800 LT (decay phase), (i) 1000 LT, (j) 1200 LT, (k) 1400 LT (dissipation phase), (l) 1700 LT. Unit for  $T_{BB}$  is kelvin. Black cross sign in Figure 3 (e) is representative to location of Cilacap Meteorology Station.

### 3.2. Influence of the MCC to the Rainfall

Figure 4 shows the horizontal distribution of rainfall during the studied MCC events. Previous research has been conducted on the impact of the MCC system on rainfall in the surrounding area. In Reynolds [15], based on Fritsch [16] research shows that the MCC system is the most productive rainfall generation system. The comparison between Hurricane Alicia and the three MCC systems that occurred earlier shows that the MCC system was able to produce twice as much rainfall as Hurricane Alicia. In the dry season, the occurrence of the MCC system often results in inaccurate quantitative predictions of rainfall. To better understand the effect of the MCC system on precipitation in the surrounding area, this section will explain the evolution of the MCC system precipitation region using GPM GSMaP data.

The result of analysis of evolution precipitation cell is that the system was identified as the first storm on September 16, 2016 at 0000 LT, the system precipitation area is limited. The system, which was originally centered in the Sundanese Strait region to the south of the island of Java as propagate to the northeast and continues to grow. Maximum rainfall recorded by Cilacap Meteorological Station is about 108 mm/3 hours from September 16 at 0500 until September 0700 LT. This is support previous research conducted by Kane [17] which states that the heaviest precipitation occurs in the first half of the life phase of the MCC convective system.

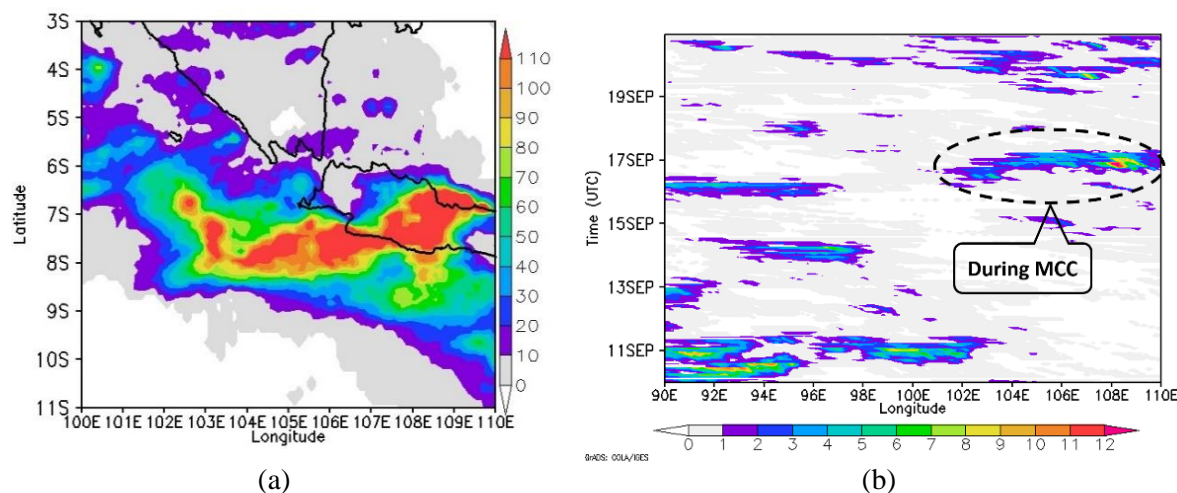
After reaching maximum precipitation activity, the MCC system began to be decay. The precipitation area will become narrow, the system begins to propagate to the southern area of Indian Ocean region in the central Java and finally dissipated around there. System dissipation occurred on September 17, 2016 at 1000 LT. After the decay phase, then the system will reach the dissipation phase. In this phase the system has been dissipated and the environment has formed a new convective system. This phase occurs on September 17, 2016 at 1900 LT. Analysis of time series evolution of MCC precipitation cell also provides information that as the MCC system develops and propagates towards the Indian Ocean region, formed new precipitation cell in the waters southern area of the Indian Ocean south of eastern Java. The formation of these new convective cells is related to the cold pool activity [4, 5].



**Figure 4.** Horizontal distribution of rainfall from GSMaP data obtained during MCC event on 16 September 2016, a) 1700 LT (initial phase) , (b) 2100 LT, (c) 0000 LT, (d) 0100 LT, (e) 0300 LT (maximum phase), (f) 0600 LT, (g) 0700 LT, (h) 0800 LT (decay phase), (i) 1000 LT, (j) 1200 LT, (k) 1400 LT (dissipation phase), (l) 1700 LT. Unit for rainfall is mm/hr. Black cross sign in Figure 4 (e) is representative to location of Cilacap Meteorology Station.

Figure 5 (a) shows the rainfall accumulation during the MCC events from the Pre-MCC stage until 6 hours after the post-MCC stage for all of the case study. The greatest rainfall accumulation is presented in the center of MCC system area for the oceanic, continental and coastal MCCs. It indicated that the significant influence of MCC to the rainfall is during MCC reached maximum extent in the mature stage. However, the high rainfall accumulation also appears in several regions near the MCC system area. It

indicated that the effect of MCCs are not only over the MCC system area but also influencing to the rainfall in the surrounding area of the MCC systems. In this research, the area in the surrounding of MCC systems that get affected by the MCC. The influence of MCC on significant rainfall is also supported by the existence of MJO phase 4. Figure 5 (b) shows that there is a significant increase in rainfall when phase 4 active MJO is followed by the MCC. The value of rainfall intensity when MJO followed by the presence of MCC is greater than in the absence of MCC.



**Figure 5.** (a) Rainfall accumulation during MJO event on 16 – 17 September 2016, and (b) Time-Longitude cross section on rainfall at 10 – 20 September 2016 during MJO phase 4 event and MCC system event. Unit for rainfall in Figure 5(a) is mm/2 day, while in Figure 5(b) is mm/11day.

### 3.3. Analysis of the Meteorological Condition during MCC

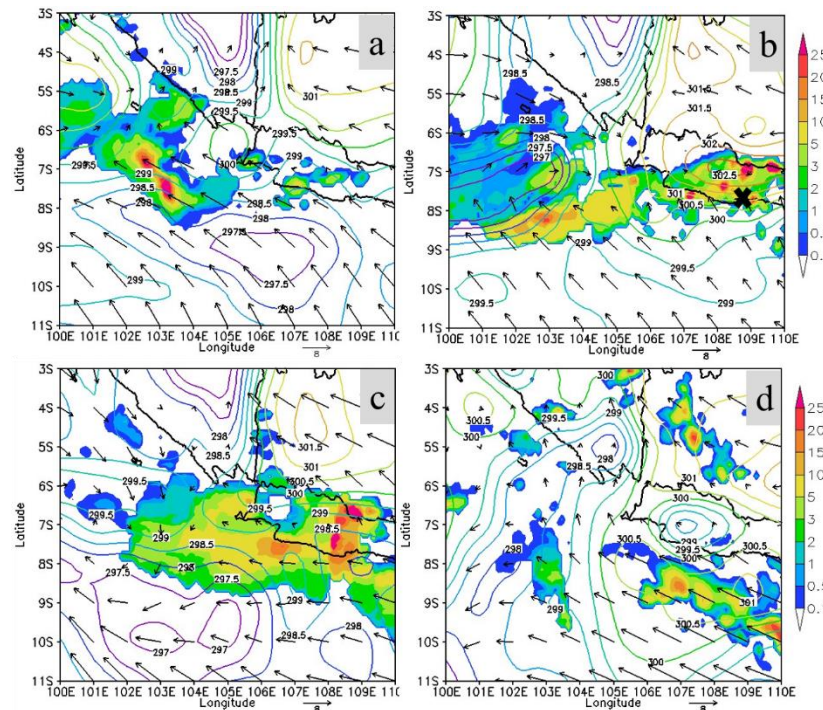
The development of MCC in Cilacap region can't be separated from the influence of the environmental conditions around the system where it was formed. The MCC was formed on September 17, 2016 at 0000 LT. The wind comes from several directions, that is western winds and northeasterly winds that originate from the Indian Ocean region and eastern winds originating from the Pacific Ocean, the wind was convergence around south western area of Cilacap. The MCC initiation phase is also characterized by an increase in potential temperature around the IA of MCC. These environmental conditions will support the MCC system convective process.

In the mature phase, there was occurred a shear line and convergence of wind (Figure 6 (b)). In the western area of the MCC system there is a weak divergence pattern and the potential temperature around the system has decreased. This is related to the formation of cold pools during the mature phase of MCC. Another mature phase characteristic that can be captured in the MCC case in Cilacap is that there is a large area of precipitation and the development of new convective system around the Java Sea region and the southern area of Indian Ocean of near East Java. The existence of this cold pool is in accordance with the research by Fritsch and Brown [18] and Trismidianto et al. [4].

When entering the decay phase at 1000 LT, the system has propagated to the Indian Ocean region (Figure 6 (c)). The potential temperature around the MCC system is lower than the surrounding environment. The wind convergence pattern is still formed, but the system that has propagated from the convergence region. Another thing that marks the decay phase of the MCC system is that the convective cloud begins to decay so that the area of precipitation becomes smaller and the formation of a new convective system due to cold pool activity. The system propagated from the convergence region causes the system lose water vapour supply from the lower layers and the stability of the air of the region is more stable [6] so the system cannot evolve anymore. The dissipation phase of the MCC system



occurred at 1900 LT on 17 September 2016. This phase is marked by the system that already dissipated and the convective system that is induced by cold pools starting to grow and propagate (Figure 6 (d)).



**Figure 6.** Horizontal distribution of rainfall from GSMaP data (mm/hr, shaded), potential temperature (K, contour), wind vector (m/s, vector) in the environment around MCC in each phase of life of the MCC system on September 16 - 17, 2016. (a) Initiation Phase (1900 LT) (b) Mature phase (0100 LT) (c) Decay phase (0700 LT) and (d) Dissipation phase (1300 LT). Black cross sign in Figure (e) is representative to the location of Cilacap Meteorology Station.

### 3.4. Thermodynamic Condition

In the research about convective cloud, knowing the condition of atmospheric stability is very important. Atmospheric stability conditions can provide information about the potential of thick and towering convective cloud formation. To find out more about the thermodynamic conditions at the time of the occurrence MCC, in this study will use upper air observations data from Cilacap Meteorological Station. Based on radiosonde observations dated September 16, 2016 and September 17 at 0700 LT and 1900 LT that resulted atmospheric stability index, some of them were listed below (Table 1).

The data shows the stability index value at the time of MCC occurring on September 16-17, 2016 at 0700 LT and 1900 LT, there is an increase in atmospheric lability from September 16 at 0700 LT until September 17, 2016 at 0700 LT. It can be seen by the increase of CAPE (Convective Available Potential Energy), SWEAT (Severe Weather Threat Index), and Total Totals Index and the decrease of Showalter Index, Lifted Index and CIN. This is also accompanied by the increase of possibility of Ts, that can be seen on the increase of K Index. When the MCC reach its mature stage upper air data can't get K Index data. On September 17, 2016 at 1900 LT it appeared that the value of atmospheric stability began to increase, it means that the atmosphere began to stabilize, that showed by the decrease of CAPE Index, SWEAT and Total Totals Index also the increase of Showalter Index, Lifted Index and CIN. Based on these data it can be seen that the most unstable condition of the atmosphere happened on September 16 at 1900 LT where the system is still in the form of a small convective cell. These atmospheric conditions support convective cell growth into a larger system. At 0700 UTC the

system begins to enter pre-MCC phase and at 1700 LT the system starts to begin to enter the initiation phase. On September 17 at 1900 LT the atmospheric stability index value showed that atmospheric conditions became more stable, at the same time the MCC system had been dissipated.

**Table 1.** Stability Index from Upper Air Sounding Cilacap Meteorological Station.

Stability Index	16 September 2016 (J/kg)		17 September 2016 (J/kg)	
	0700 LT	1900 LT	0700 LT	1900 LT
Showalter Index (SI)	-0.20 <sup>c</sup>	-1.59 <sup>c</sup>	-1.59 <sup>c</sup>	1.01 <sup>b</sup>
Lifted Index (LI)	-1.98 <sup>b</sup>	-2.85 <sup>c</sup>	-0.59 <sup>b</sup>	-0.04 <sup>b</sup>
SWEAT Index	196.5	221.9	255.4	218
K Index (KI)	32.60 <sup>c</sup>	34.70 <sup>c</sup>	-	21.90 <sup>b</sup>
Totals Total Index (TT)	44.10 <sup>b</sup>	45.70 <sup>b</sup>	45.80 <sup>b</sup>	42.00 <sup>a</sup>
CAPE	464.4	794.6	58.61	89.04
CIN	-0.13	-5.69	-40.1	-6.52

<sup>a</sup> Stable.

<sup>b</sup> Possible Thunderstorm (Ts), strong trigger needed

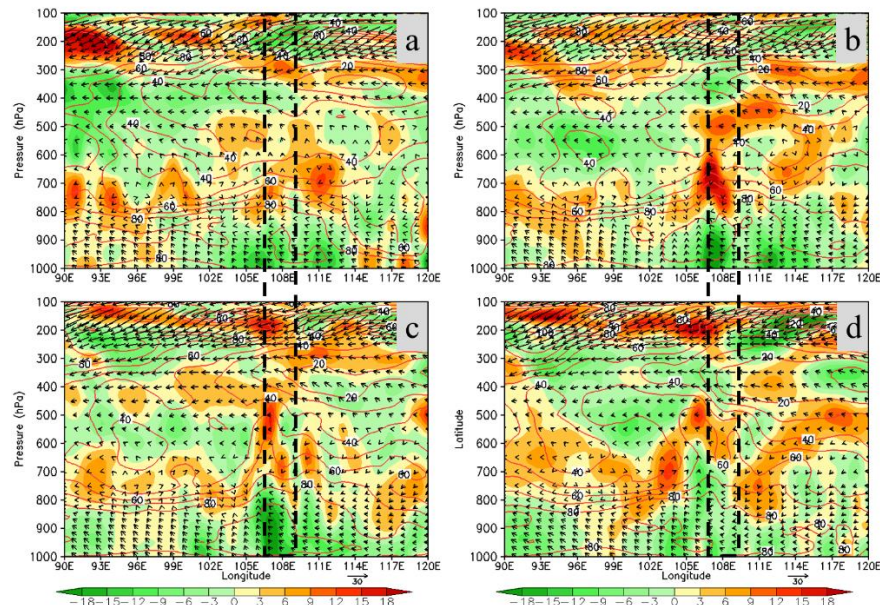
<sup>c</sup> Unstable, Ts probability

<sup>c</sup> Extremely Unstable.

In the initiation phase of the MCC system (Figure 7 (a)), shows that there is convergence in the lower layers of the troposphere, ie at layers of 1000 hPa to 800 hPa, convergence with strong intensity is found in layers 1000 hPa to 900 hPa. there is a divergence pattern in the middle layer between 800 hPa and 300 hPa layer, however, a strong divergence is split into two parts, that's on layers of 800 hPa to 700 hPa and layers of 350 hPa to 250 hPa. While in the upper layer there is strong convergence and divergence, strong convergence in the upper layer occurs in layers of 200 hPa to 100 hPa. While moisture shows a moist layer (RH 80%) from layers 1000 hPa to layer 925 hPa. Then RH decreases with increasing altitude, up to 300 mb the humidity is 40%. Above this layer, RH will increase again to the 100 hPa layer.

When the MCC system reaches the mature phase (Figure 7 (b)), the convergence of the lower layer becomes wider and stronger, namely between layers of 1000 hPa to 700 hPa. Strengthening the lower layer convergence is also followed by the increase of the lower layer of moisture. The RH layer 1000 hPa reaches 90% while the 850 hPa layer reaches 65%. While the layer above is 650 hPa to 100 hPa layer, the air is dominated by strong divergence. Strong divergence is in the 700 mb layer to 400 mb layer and in the high layer between 300 hPa to 100 hPa layer. In the divergence pattern, the humidity decreases to only 40%. While in the 700 hPa layer up to 500 hPa layer convergence is formed but not so strong.

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**Figure 7.** Pressure-Longitude cross section (by averaging latitude  $11^{\circ}\text{S} - 5^{\circ}\text{S}$ ) for divergence ( $10^{-5}\text{ s}^{-1}$ , shaded), relative humidity (% , contour) and wind direction (m/s, vector) in the environment around MCC in each phase of life of the MCC system on September 16 - 17, 2016. (a) Initiation Phase (1900 LT), (b) Mature phase (0100 LT), (c) Decay phase (0700 LT) and (d) Dissipation phase (1300 LT). Black dashed box is representative to the location of MCC Occurrence.

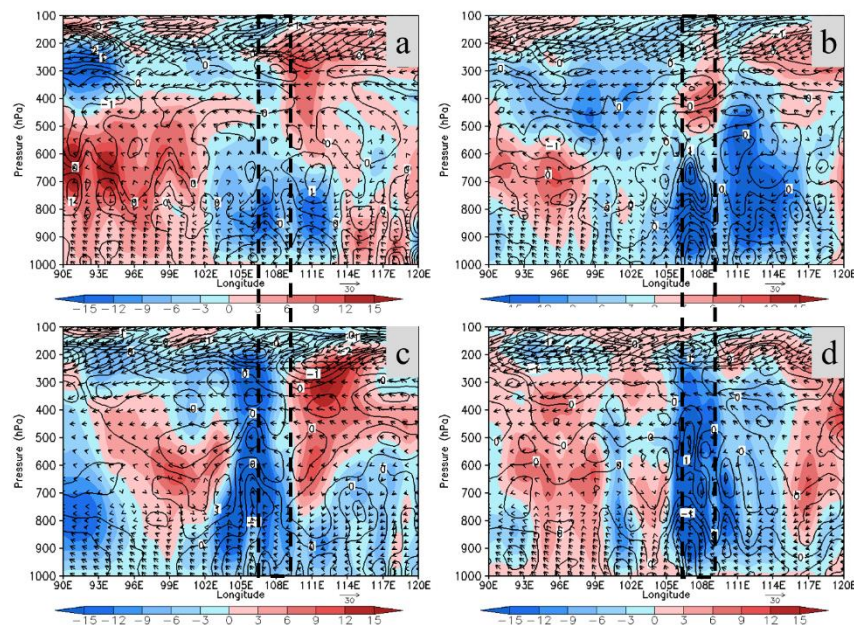
The system reaches dissipation phase (Figure 7 (d)), it appears that the lower to middle layers are still dominated by divergence. The bottom layer convergence is only formed from layers of 1000 hPa to 900 hPa. In the middle layer there is convergence from layers of 900 hPa to 500 hPa. The next layer is dominated by convergence, which is from the layer 500 hPa to 300 hPa. While in the upper layer, that is at the 250 hPa layer to 100 hPa layer there is a strong divergence. RH layer is 1000 hPa to 800 hPa layer moist, but in the 750 hPa layer to 500 hPa layer has a low RH that is 40%. In the next layer, layer 400 hPa to 100 hPa of moisture will increase to 80%.

The next discussion is about the pressure longitude cross-section between vertical velocity, divergence and wind direction in each phase of the MCC system life. The discussion needs to be done in order to obtain an overview of vertical air motion conditions, divergence and wind direction in each phase of the life of the MCC system. By this analysis, it will give us a better picture of the condition of the MCC system in each phase. In the initiation phase (Figure 8 (a)), it appears that the air around the central region of the formation of IA MCC is dominated by the presence of upward. The upward motion last from 1000 hPa to 100 hPa layer, the strongest upward vertical motion can be in the layer 1000 hPa to 700 hPa where the air convergence also occurs. At layers 600 hPa to 100 hPa, there is air divergence with the strongest downward motion in the 400 hPa to 200 hPa layer. Upward vertical motion and air downward help the development of the MCC to maintain the system.

The mature phase of MCC (Figure 8 (b)), is marked by expanding upward from layers 1000 hPa to 100 hPa layer. Widespread upward is in accordance with the strengthening of the lower layer convergence and the weakening of the divergence in the upper layer. In the mature phase, the MCC system is dominated by strong upward air motion. In the decay phase (Figure 8(c)), it appears that there is a downward layer in the middle layer, ie at layers of 800 hPa to 400 hPa. In addition, there is an increase in air divergence activity. Strong divergence occurs in layers of 200 hPa to 100 hPa. Upward still survives from 1000 hPa to 150 hPa. The increase in downward and divergence can help the MCC system decay process. In the dissipation phase of the MCC system (Figure 8(d)), the air is dominated



by the downward from 1000 hPa to 450 hPa. The strongest downward occurs in the middle layer, starting from 800 hPa to 450 hPa. Upward still occurs in the lower layer but occurs in very narrow layers, while in the upper layer between layers 400 hPa to 150 hPa occurs upward strong. Divergence in the lower layers and upper layers still occurs but in the middle layer, there is strong convergence.



**Figure 8.** Pressure-Longitude cross section (by averaging latitude  $11 - 5^\circ \text{S}$ ) between vertical velocity ( $10^{-2} \text{ Pa s}^{-1}$ , shaded), divergence ( $10^{-5} \text{ s}^{-1}$ , contour) and wind direction ( $\text{m/s}$ , vector) in the environment around MCC in each phase of life of the MCC system on September 16 - 17, 2016. (a) Initiation Phase (1900 LT) (b) Mature phase (0100 LT) (c) Decay phase (0700 LT) and (d) Dissipation phase (1300 LT). Black dashed box is representative to the location of MCC Occurrence.

#### 4. Conclusion

The formation of MCC in the Cilacap on September 16-17, 2016 impacted to the occurrence of heavy rain accompanied by strong winds and a number of other hydrometeorological disasters. Based on the analysis that has been done it is known that the system is a land system which then propagates to the Indian Ocean region in southern Java. The MCC system begins to enter the initiation phase on September 16 at 1500 LT and reaches the mature phase on September 17 at 0700 LT. The MCC system reaches the decay phase at 1000 LT and dissipated at 1900 LT. Overall the MCC system has a duration of life about 20 hours.

The suitable atmospheric condition will support the growth of convective cell into larger convective system. The initiation phase of the MCC system begins with the formation of one or more small convective systems that can continue to evolve into larger systems because they are supported by the surrounding environment including unstable atmospheric conditions and allowing Ts. There is a disturbance in the form of convergence patterns around the northwest of the Cilacap region. Based on the pressure longitude cross section it is known that in the pre-MCC phase until the initiation phase there is a strong convergence in the lower layer. In general, the convergence of the lower layer is in the layer 1000 hPa to 800 hPa. In the mature phase of the MCC system, there is still support from the surrounding environment and the wind convergence area is still formed. The results of the analysis of the pressure longitude cross section show that in the mature phase the convergence of the lower layer strengthens, namely between the layers of 1000 hPa to 700 hPa. When the system enters the decay phase, the system no longer receives support from the surrounding environment. This is indicated by the propagation of



the system towards the Indian Ocean region away from the convergence pattern with the stability of the atmosphere more stable.

The influence of MCC on significant rainfall is also supported by the existence of MJO phase 4. The significant increase in rainfall when phase 4 active MJO is followed by the MCC. The value of rainfall intensity when MJO followed by the presence of MCC is greater than in the absence of MCC. Environment conditions when the system begins to enter the decay phase is the formation of the lower layer divergence, that is at 1000 hPa to 800 hPa. In the upper layer, there is also a divergence between layers 300 hPa to 100 hPa. In this phase, it begins to form downward in the middle or lower layers. The last phase in MCC's life cycle is MCC dissipation phase. In this phase the MCC system has been dissipated and the environment has begun to form a new convective system. Pressure longitude cross-section analysis is known that in this phase around the location where the MCC system is formed, a lower layer convergence is formed. This convergence is able to withstand 1000 hPa to 900 hPa layers. Vertical velocity in this phase shows that there is still a downward vertical motion between layers 1000 mb to 450 hPa. Upward still occurs in the lower layer but occurs in very narrow layers, while in the upper layer between layers 400 hPa to 150 hPa occurs upward strong. Divergence in the lower layers and upper layers still occurs but in the middle layer there is strong convergence.

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