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Atmospheric Dynamics Analysis of Tropical Cyclone Cempaka

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Abstract

Tropical Cyclone (TC) is a cyclone which emerges, develops, and dissipates in the tropical waters. Indonesian waters where is located in the tropics as a maritime continent, becomes one of the region for emerging a TC in the world. The World Meteorological Organization (WMO) c.q. the Tropical Cyclone Committee (TCC) had already designated the Jakarta Tropical Cyclone Warning Center (TCWC) to monitor and report the activity of TCs in the area responsibility of 90° - 125° E 0° - 10° S. This Jakarta TCWC has started operating since 24 March 2008. In the end of November 2017, the TC named Cempaka developed. This TC Cempaka caused the appearance of extremee weather especially in Southern parts of Java Island coast. At least recorded some occurrences of extremeely heavy rainfalls in Pacitan Regency reaching up to 383 mm/day, floods, landslides, and strong winds of 41-53 knots in the surface.

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Domination of unstable atmospheric condition, strong convective lability, high potential thunderstorm occurrences, and strong convective condition are shown persistently during 27-29 November 2017. Cyclonic air masses over Southern part of Java Island have been detected since 23 November 2017. The monsoon activity seems to be weakened over this region in relation to the existence of this tropical disturbance. The thickness of wet air mass reaches up to 200 mb having a significant role to maintain supporting water vapor to the development of TC Cempaka. The Madden Julian Oscillation (MJO) has also contributed to support the emerging of TC Cempaka in this case.

Keywords: Tropical Cyclone.

1. Introduction

In the end of November 2017, people in Indonesia, have been shocked by the forming of a Tropical Cyclone (TC). This TC was so called as TC Cempaka and grew in Southern Hemisphere of Indonesian waters. This TC emerged, developed, and dissipated over the region of Indian Ocean. The location of TC forming was in the area of South-Southwestern direction from the Special Region of Yogyakarta Province, Indonesia. The impact of this TC Cempaka activity very deteriorated in Southern part of Java Island coast especially the region of Pacitan District, East Java Province, Indonesia. As reported, this TC Cempaka has caused 11 people death on the date of 28 November 2017 [1].

Several TCs have contribution to the extreme weather occurrences to some places within Indonesian Region. Two of them were TC Iggy and TC Saola in 2012. In the case of TC Iggy [2], the East Nusa Tenggara Province experienced heavy up to extreme daily rainfall record during 26 Januari 2012 up to 2 February 2012. The existences of shearline and convergence zone before the forming of TC Iggy and during the mature state of TC Iggy seem significantly having impact to increase the intensity of daily rainfall over the East Nusa Tenggara Province. Meanwhile, in the case of TC Saola [3], the Mollucca Island and its surrounding experinced heavy up to extreme daily rainfall record as well. In relation to the forming of TC Saola, the existence of Low Pressure Area (LPA) over Northern part of Papua Island and the shearlines causing of the forming of TC Saola have contribution to increase the daily rainfall intensity over Mollucca Island and its surrounding.

Hurricanes, tropical storms, and other intense rotating storms fall into a general category as so called cyclones [4]. There are two main types of cyclones: tropical and extratropical. Tropical Cyclones (TCs) are growing in the tropical waters and Extratropical Cyclones (ECs) are growing outside the tropical waters. The energy of the TCs come from warm tropical oceans. But the energy of the ECs are gotten from the jetstream, temperature difference between cold-dry air masses from higher latitudes, and moist air masses from lower latitudes.

As noted for its name as mentioned above, a TC is a cyclone where develops in the tropical region. But a TC has been characterized differently with commontly other ECs [5]. TCs have been included in the big scale disturbance weather systems. According to the definition [6], a TC represents to a system with low air pressure in its center and able to organize the air circulation itself which develope in tropical waters. The prosessing rotation system is able to organize cloudiness and thunderstorm especially in relation to the low level air circulations [7]. Mature TCs are also so called as hurricanes in Atlantic Ocean waters and typhoon in West Pacific ones [8, 9].

TCs are able to give impact up to 200 - 1000 kilometers of distance range. Even some of them can extend more than that, especially for the extraordinary TC activities. It's life time can commonly be hourly up to two weeks [10]. The characteristic of TCs can be shown of warm air availability in its center. They also have a big air pressure gardient. The availability of surface wind with high velocity surrounding in its center which direction of clockwise over Southern Hemisphere (counter clockwise over Northern Hemisphere), is as a sign of TC's air circulation [11].

TCs which develope over Eastern part of Indian Ocean waters, will generally impact the condition of oceanography parameters in Southern part of Java Island coast. The surface wind velocity condition and the maximum high wave will commonly increase along with the increasing in intensity of TCs activities [12].

The existance of TC Cempaka has caused extremeely weather condition especially in Southern parts of Java and Bali Islands coast. Heavy rainfall had triggered floods and landslides. Factually in Pacitan Regency, there were 2 people dead because of floods and other 9 people dead because of landslides. There were 13 villages taken from 3 subdistricts in Pacitan Regency had been affected by TC Cempaka activity. In the date of 28 November 2017, the center of TC Cempaka was available around 32 kilometers in the direction of South-Southeastern from Pacitan Regency. The surface wind velocity at that time was recorded reaching up to 65 kilometers per hour [1].

The forming and developing of a TC in the tropical waters such kind of Indonesian Region as a maritime continent, is factualy as a common things. Remembering that the natural characteristic of a TC will form dan develop in the warm waters surrounding the equator. The source of emerging TCs are in a quiet big opened ocean between latitude of 6° up to 15° [13]. But in this case, as the extra ordinary happening was the location of TC's forming. This TC was very near to the mainland of the Special Region of Yogyakarta Province especially Southern part of Java Island coast.

There was a surprise for Indonesian Meteorological Climatological and Geophysical Agency (BMKG) when the genesis of TC Cempaka had factually continued. BMKG has been designated by the Tropical Cyclone Committee (TCC) for the Regional Association (RA) V of the World Meteorological Organization (WMO) to become as one of the Tropical Cyclone Warning Center (TCWC) in the world since 2006 [13]. This TCWC has been installed in the head office of BMKG in Jakarta City. Further, this TCWC is more familiar to be called as the Jakarta-TCWC. The formal operation of the Jakarta-TCWC has been started on 24 March 2008. The Jakarta-TCWC has to take over the duty for reporting and monitoring TCs activities in the area of responsibility in region waters of 90° - 125°E, 0° - 10°S during the TC season in 2007/2008 until the present time.

The name of Cempaka has been taken from the ordinally list of TC's name in the area of responsibility of the Jakarta-TCWC [14].This TC Cempaka was as the fourth TC which has been emerged in the area of responsibility of the Jakarta-TCWC since operated in 2008. The name of TCs would be agreed with the need of every TCWC in each responsibility country. The United State of America gives the name of ladies for TCs such as Katia, Irma, Kathrina and so on. The Philippines gives the name of TCs in Tagalog Language such as Hayan, Rammasun, Bopha, Nepartak and many others [15]. Meanwhile, the Jakarta-TCWC gives the name of TCs consist of flowers and fruits in Bahasa Indonesia such as Anggrek (Orchid), Bakung (Lily), Cempaka (Manolia), Mangga (Mango), and so many others.

The existence locus of TC Cempaka has a similar characteristic with Sunda Strait up to Southern part of Java Island [16]. This region has been surrounded by a broadly ocean, namely Eastern part of Indian Ocean. This region is also becoming the extensive waters which is parallely with the equator. Further, this region becomes a part of the edge of Southern subtropical high pressure area. In a certain time, the air masses in this region is dominated by the characteristic of the South China Sea air masses which has moved to pass through many territories and also tropical air masses of Eastern part of Indian Ocean.

The development of a TC will be very easy if there are certain environment conditions which characterize such as follow:

Starting by the existence of a warm pool water near the equator. Recalling that the Sea Surface Temperature (SST) surrounding Indonesian waters is higher than other adjacent regions [17]. The SST of those a warm pool is at least reaching 27,0 °C up to the depth of 24 centimeters [6]. This warm pool becomes a source of water vapor for the atmospheric column where the TC is developed. The abundance supply of water vapor will be needed as fuel support for driving the development of a TC. The location of the mentioned warm pool above has a distance at least 500 kilometers out of the equator [5]. The closer to the equator will be the weaker of Coriolis Force in TC's development. The latitudes are decreasing toward the equator.

The wet condition of atmospheric humidity up to 4.900 meters above sea level and purely unstable atmospheric condition become clues to determine the location of the ongoing strong convective areas availability [5]. This situation has well relationship with easier lifting process vertically of water vapor as a source to support the development of a TC. The easier lifting process of water vapor causes easily development of convective clouds such as the Cumulonimbus. This cloud is commonly as a source of thunderstorm. The entraiment of dry air masses into the convective system will weaken the process of forming the thunderstorm clouds.

The availability of atmospheric disturbances near the surface level as forming of circle wind accompanied by the convergence air masses current are very important for a TC system. The air masses containing a lot of water vapor have to go into the TC system. The development process of TCs will be very fast, if there are available convergence in low level accompanied by divergence in high level with wet enough air masses column. As if a muffler of motor cycle, there should be an input mechanism (convergence) and an output ones (divergence) in order to maintain the wet air masses circulation into the TC system.

The changing condition of vertical wind shear between low level and height should not be significant. Commonly the nominal value of vertical windshear should be less than 37 km/hour between the surface and the upper troposphere ones [6]. This nominal value has relationship with the process of thunderstorm cloudiness development. If there are different wind condition significantly, both its direction and velocity, the process of thunderstorm cloudiness development would be disturbed.

The research goal described in this paper is to know better and understand generally the atmospheric dynamics characteristic of a TC in Indonesian Region. Especially the Southern Hemisphere's atmospheric dynamics of Indonesian region where the TC Cempaka had formed spatially and temporally. The analysis will be done starting from the emerging, developing, maturing, and dissipating of the TC Cempaka. Understanding factually many efects to the atmospheric parameters in situ caused by the existence of TC Cempaka will be described also, especially for spatial and temporal heavy rainfall and strong winds.

2. Data and Method

2.1. Data

Miscellaneous data have been used in this research for processing and analyzing, such as follow:

- Radiosond Data

Radiosond data have been taken from some meteorological stations in Java Island. Those stations were Cengkareng (Jakarta Meteorological Station), Juanda (Surabaya Meteorological Station), and Cilacap (Cilacap Meteorological Station). For further information, the range distance of each stations from Yogyakarta were 567 km (Cengkareng to Yogyakarta), 194 km (Cilacap to Yogyakarta), and 335 km (Juanda to Yogyakarta) [18]. The observed radiosond data taken twice a day observations of 00.00 UTC and 12.00 UTC have been utilized in data processing. These charts of radiosond data will also be shown further in this paper. The vertical atmospheric condition can be seen as well using these radiosond data.

- Model Data

The outputs of atmospheric dynamical model based on the data taken from European Center for Medium Range Weather Forecasts (ECMWF) as so called ECMWF ERA-Interim have also been included in the form of Relative Humidity (RH) maps, wind barbs, zonal wind fields, and relative vorticity fields as well especially for the date of 19 up to 30 November 2017.

- SST Data

The spatial of Sea Surface Temperature (SST) data within Indonesian Region were used as well. Those data have been taken from the ECMWF ERA-Interim data for the period of November 2017.

- Rainfall Data

The spatial and temporal of daily rainfall data for Indonesian Region have been utilized especially taken from the impacted locations based on in situ observation within the Special Region of Yogyakarta Province and its surrounding.

- Other Miscellaneous Data

The Himawari 8 meteorological satellite data have been used in order to detect the cloud formation and top cloud temperature. The occurrences of flood, flash flood, landslides, and strong winds data and information have been paid attention also in preparing this paper.

2.2. Methods

The processing and analyzing data based on sinoptical dynamics of atmospheric condition has been done in order to investigate the existence of TC Cempaka. The step of analysis has been started by seeing the global and regional atmospheric conditions since the date of 19 November 2017 up to 30 November 2017. These long enough range of time analysis has been used in order to know and understand better the life cycle of TC Cempaka.

The computation of some parameter values and indexes have been done using the data taken from radiosond observations [19, 20] and as well as the data model output. There were TC Tracking, Radiosond Plotting, Spatial and Temporal Rainfall Observation, Cloudiness Distribution, Sea Surface Temperature, MJO Phases Plotting, Mean Sea Level Pressure, Gradient Wind Analysis (Streamlines), Relative Humidity, Relative Vorticity Fields, Top Cloud Average Temperature, Australian Summer Monsoon Index, Convective Available Potential Energy (CAPE), Severe Weather Threat Index (SWEATI), Total-Total Index (TTI), and K Index (KI).

CAPE value could be used to compute the total amount of energy for a parcel of air if it lifted in a certain distance vertically through the atmosphere. Computing CAPE value may use this equation as follow [20, 21]:

$$CAPE = \int_{Zf}^{Ze} g\left(\frac{Tv_{parcel} - Tv_{env}}{Tv_{env}}\right) dz \qquad (1)$$

where: zf = the height of Free Convection Level (hPa), ze = the height of Equilibrium Level (hPa), g = the gravity force (ms-2), Tvparcel = the specific parcel virtual temperature (°C), and Tvenv = the environmental virtual temperature (°C).

Any value of CAPE greater than 0 J/kg indicates instability condition of the atmosphere. This means also an increasing possibility of thunderstorm and hail occurrences.

SWEAT index means a value to be used for detecting potentially atmospheric condition for severe weather occurences. To compute the value of SWEAT index can be used this equation below [20, 22]:

$$SWEATI = 12[Td_{850} + 20 * (TTI - 49) + 2f_{850} + f_{500} + 125 * \sin(D_{500} - D_{850}) + 0.2] \qquad (2)$$

SWEAT index where : Td850 = the 850 hPa dew point temperture (°C), TTI = the value of Total Totals Index, f850 = the wind speed of 850 hPa level, f500 = the wind speed of 500 hPa level, D500 = the wind direction of 500 hPa level, and D850 = the wind direction of 850 hPa level.

The SWEAT index over 300 means potential for severe thunderstorm occurences. Meanwhile, the SWEAT index over 400 means potential for tropical cyclone occurences.

KI means a value as a criterion to estimate potentially growing of thunderstorm cloud based on vertical lapse rate, wet air of lower level, and vertical extention of the layer of wet air. This KI can be compute using equation as follow [20, 22]:

$$KI = [(T_{850} - T_{500}) + Td_{850} - (T_{700} - Td_{700})] \qquad (3)$$

Where : T850 = temperature at 850 hPa level (°C), T500 = temperature at 500 hPa level (°C), Td850 = dew point temperature at 850 hPa level (°C), T700 = temperature at 700 hPa level (°C), and Td700 = dew point temperature at 700 hPa level (°C).

The KI less than 20 means no thunderstorm probability occurrences. KI of 20 up to 25 means isolated thunderstorm probability occurrences. KI of 26 up to 30 means widely scattered thunderstorm probability occurrences. KI of 31 up to 35 means scattered thunderstorm probability occurrences. KI above 35 means numerous thunderstorm probability occurrences. TTI means a value as a criterion of atmospheric lability which can be detected the atmospheric condition potentially for imerging severe weather. TTI can be computed using equation as follow [20, 22]:

$$TTI = [(T_{850} - T_{500}) + (Td_{850} - Td_{500})] \qquad (4)$$

where: T850 = temperature at 850 hPa level (°C), T500 = temperature at 500 hPa level (°C), Td850

= dew point temperature at 850 hPa level (°C), and Td500 = dew point temperature at 500 hPa level (°C).

The TTI of 45 up to 50 means thunderstorm possible occurrences. TTI of 51 up to 55 means thunderstorm more likely with possible severe occurrences. TTI of 56 up to 60 means severe thunderstorm most likely occurrences.

3. Discussions

The growing of TC Cempaka has been detected since a week prior by preceding the existence of Low Pressure Area (LPA) significantly to be seen at the sinoptical weather chart on 19 November 2017. The development detection of TC Cempaka origin has been known since 25 November 2017. The TC Cempaka emerged around a week later on 27 November 2017, 12.00 UTC, over the South - Southwestern part of the Special Region of Yogyakarta Province waters. This TC showed the closest distance to the Special Region of Yogyakarta Province on 28 November 2017 at 00.00 UTC. In relation to get more detail information of the TC Cempaka position to the Special Region of Yogyakarta Province coast, there can be seen the track of TC Cempaka seen on Figure 1. Data processing of vertically atmospheric observation using radiosond equipment at Cengkareng Meteorologi Station on 27 November 2017 up to 29 November 2017 can be seen on Figure 2. Especially on Figure 2(a), there seems the un-stable atmospheric condition domination. The mean computation of CAPE value reaches of 1210,67 J/Kg. This value showes that the existence of atmospheric convective stability in the scale of un-stable enough. The atmospheric condition indicates increasing possibility of thunderstorm and hail occurrences.

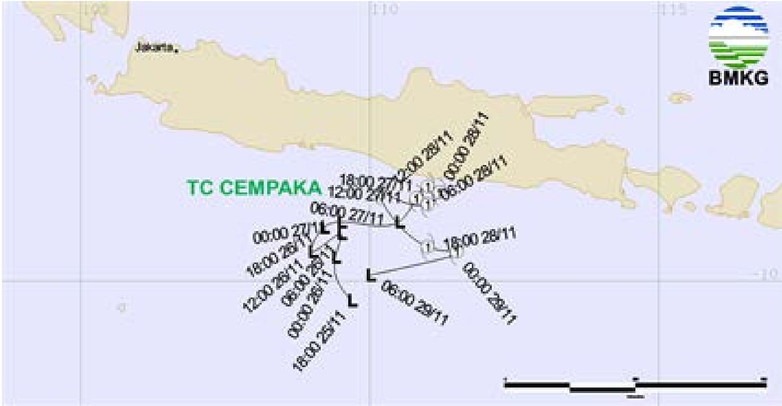
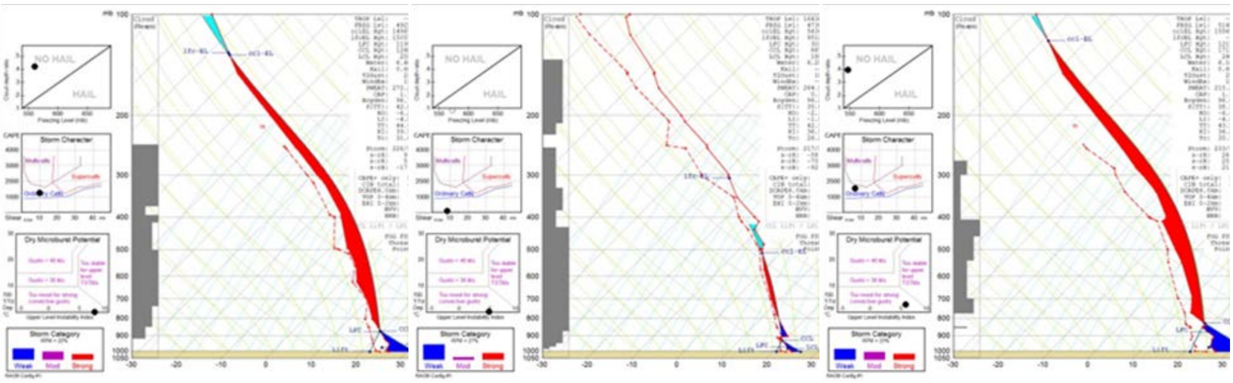


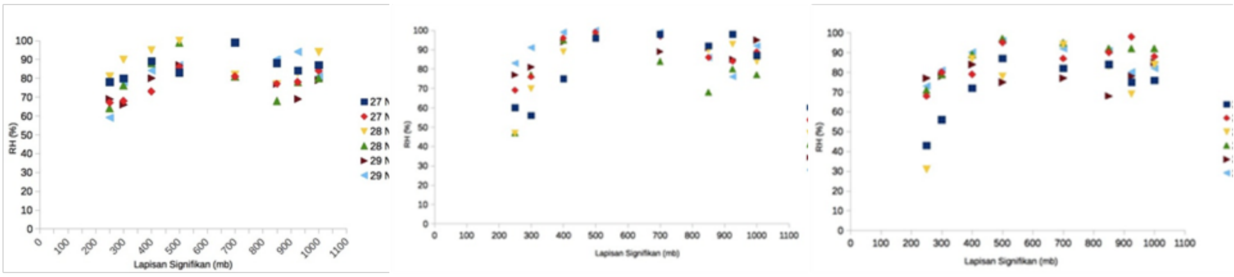
Figure 1: The TC Cempaka tracking. This TC development has been detected since 25 November 2017 [14]



(a) (b) ©

Figure 2: The vertical profile of the atmospheric condition on 27 November 2017 at 00.00 UTC taken from Cengkareng (a), Cilacap (b), and Juanda (c) Meteorological Stations. (Source: Data Processing 2017)

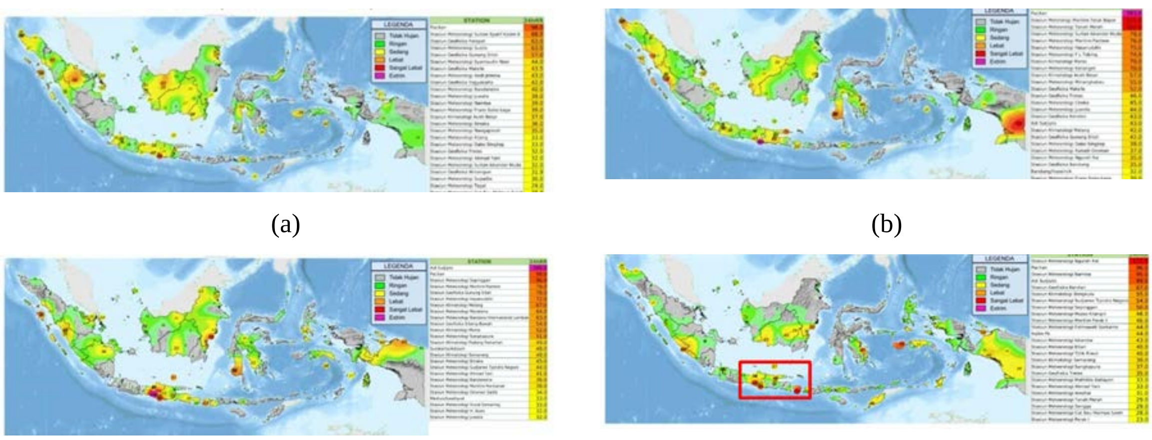
The vertical atmospheric condition at Juanda Meteorological Station during 27 - 29 November 2017 as seen on Figure 2(c) was dominated by un-stable scale. The mean CAPE value has been computed as 803.83 J/Kg. This value showes that the convective stability of the atmosphere seems to be weak. The mean KI value has pointed as 36.58 and the TT value showes 42.38. These values indicate that the potential atmospheric condition support the occurences of thunderstorm up to 80%. The mean SWEAT value has computed as 215.03. This value showes a weak convection process in the atmosphere during that time. Based on the radiosond data analisys at Juanda Meteorological Station, cloudiness availability are dominated by Altostatus and Altocumulus clouds. Among the three meteorological stations as stated above where the observation sounding data had been taken, the cloudiness were not dominated by the low convective clouds as a mark of the forming and developing of a TC. There were available for medium clouds (such as Altostratus, Altocumulus) and higher ones (Cirrus). These were cause by a long distances from every meteorological station to the location of TC. The convective cloudiness could be seen available in the location of TC and it's surrounding as seen on the Himawari 8 satellite imageries.



(a) (b) (c)

Figure 3: The vertival atmospheric Relative Humidity (RH) condition of 27 November 2017 at 00.00 UTC and 12.00 UTC over Cengkareng (a), Cilacap (b), and Juanda (c) Meteorological Stations. (Source: Data Processing 2017)

The vertical atmospheric condition of the Relative Humidity (RH) values taken from the three stations as mention above can be seen in Figure 3. At the level of 250 hPa, the average value of RH reaches 60%. This condition indicates that the wet layer of atmospheric condition is very thick, available from around 1000 hPa up to 250 hPa. Especially at the level of 850 hPa, the RH value of the atmosphere showes a little bit decreasing. But the value of RH tends to be increased again at the level of 500 hPa and decreases again in relation to the height. The mean values of Vertical Atmospheric Temperature (TT) taken from Cengkareng, Cilacap, and Juanda Meteorological Stations have pointed decreasingly to the height. The mean TT value at the level of 100 hPa reaches up to -85°C. The maximum wind velocity (VV) recorded on 29 November 2017 on 00.00 UTC at the Cengkareng Meteorological Station reaches up to 53 knots with the mean direction of 045°. Meanwhile, this condition has also been seen in the same date and time at Cilacap Meteorological Station. The maximum VV values showes up to 52 knots with direction of 045° as well. The maximum wind velocity is also seen at Juanda Meteorological Station at the same date and time. But the value of maximum VV exhibits a litle bit less than other meteorological stations. Here the maximum VV showes 41 knots with the direction of 070°.



(a) (b) (c) (d)

Figure 4: The daily spatial rainfall distribution in Indonesia region during the activity of TC Cempaka, 26 November 2017 (a), 27 November 2017 (b), 28 November 2017 (c), and 29 November 2017 (d). (Source: Data Processing 2017)

The daily rainfall distribution during the activity of TC Cempaka can be seen in Figure 4. The highest recorded of daily rainfall up to 96 mm/day occurred in Pacitan Regency, East Java Province. This regency is located at the Southern coast of Java Island and Eastern part of the Special Region of Yogyakarta Province. Meanwhile, the daily rainfall distribution in Central Java Province and the Special Region of Yogyakarta Provinces experienced 30 - 40 mm/day. Other region such as East Java Province experienced only less than 30 mm/day of daily rainfall.

On 27 November 2017, the maximum recorded of daily rainfall has reached 383 mm/day in Pacitan Regency once again. This daily rainfall record can be categorised as an extreme daily rainfall. Other regions experienced less than 30 mm/day in mostly Central Java Province. East Java Province commonly experienced 30 - 40 mm/day of daily rainfall.

The highest recorded daily rainfall of 28 November 2017 occurred at Adi Soetjipto International Airport, the Special Region of Yogyakarta Province. The record reaches 286 mm/day. This daily rainfall record can also be categorized as an extreme daily rainfall. During this time, Eastern part of Central Java Province and the Special Region of Yogyakarta Provinces commonly experienced of high daily rainfall. Western and Eastern parts of East Java Province experienced daily rainfall of 30 - 40 mm/day. Other regions have experienced less than 30 mm/day of daily rainfall.

The Pacitan Regency has experienced once again the highest recorded daily rainfall on 29 November 2017 reaching up to 96 mm/day. This record seems to be lesser than a day before but it seems to be significant. Most of the Special Region of Yogyakarta Province still experienced more than 40 mm/day daily rainfall at that time. Eastern part of Central Java Province experienced 30 - 40 mm/day of daily rainfall. Other region of Central Java Province experienced less than 30 mm/day of daily rainfall. East Java Province mostly experienced as well less than 30 mm/day of daily rainfall.

The daily rainfall monitoring in the scale of heavy up to extreme during the activity of TC Cempaka have been experienced by some regencies where have the closest distance to the central of the TC. This heavy up to extreme scale of daily rainfall happen in some places such as South-Southeastern part of Central Java Province (Purworejo, Kebumen, and Klaten Regencies), Southern part of the Special Region of Yogyakarta Province (Kulonprogo, Gunungkidul, and Bantul Regencies), and South-Southwestern part of East Java Province (Pacitan Regency).

The origin of a TC Cempaka has been monitored since 22 November 2017 as a LPA so called 95S. The position of 95S located in the region of Indian Ocean especially in the direction of Southern part of East Java Province coast. It has a coordinate of 111.3°E, 10.3°S. This origin TC has air pressure in its central of 1006 hPa with the wind velocity of around 20 knots. In order to show the location of 95S, the Himawari 8 satellite imagery of the last preceded 12 hours of 24 November 2017 can be seen in Figure 5. The persistence convective activity over Indian Ocean along Southern part of Java Island coast can be proved using this satellite imagery.

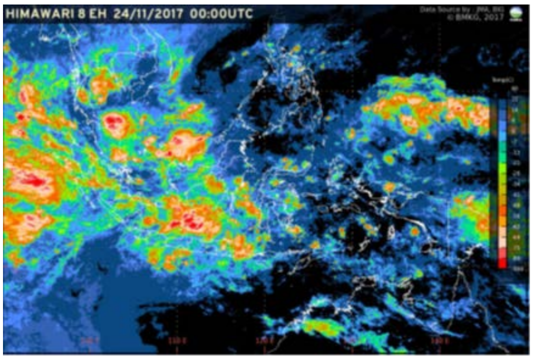


Figure 5: The cloudiness distribution has taken from Himawari 8 satellite imagery. Indicating the existence of 95S as a LPA which grows before changing to become TC Cempaka [14]

The condition of lower level wind fields (850 hPa) up to medium once (500 hPa) are able to show the availability of the cyclonal circulation. But this cyclonal circulation has not well centered yet. Vertical windshear is still weak up to medium scale. The wind velocity is about 5 - 25 knots. This condition is very good to support the growing the origin of a TC. Based on the NWP model outputs of Global Access of 24 - 48 hours ahead, the wind speed surrounding the TC origin is still not increasing. The cyclonal circulation system will remain existing up to 24 hours ahead. This system moves toward South - Southwestern part. The potency of TC developing from the origin TC during 24 - 48 hours ahead is still low.

The wind condition of upper level of 24 November 2017 taken from the three meteorological stations as used above and based on the observed radiosond data are still not showing the availability of TC developing. But the mean SST of Indian Ocean along Southern part of Java Island coast shows more than 26.0°C as seen on Figure 6 below. This value proves that the supporting water vapor to the potential developing of a TC is still high.

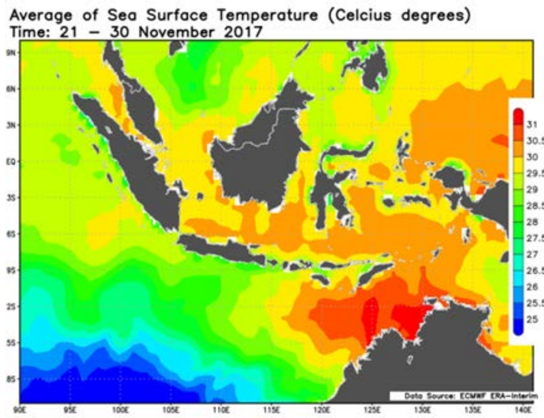


Figure 6: The average of SST (°C) surrounding of Indonesian region during 21 - 30 November 2017 [14]

In the meantime, the global and regional atmospheric conditions proved that the preceded time of TC Cempaka forming, during the date of 26 - 27 November 2017, there was a tropical wave disturbance so called MJO. This MJO was persistence in the fourth quadrant as seen in Figure 7. This condition caused increasingly the convection potential higher and higher. Based on data of MJO analysis from the BoM Australia [18], the intensity of MJO was increasing started from the date of 26 November 2017 up to the middle of December 2017.

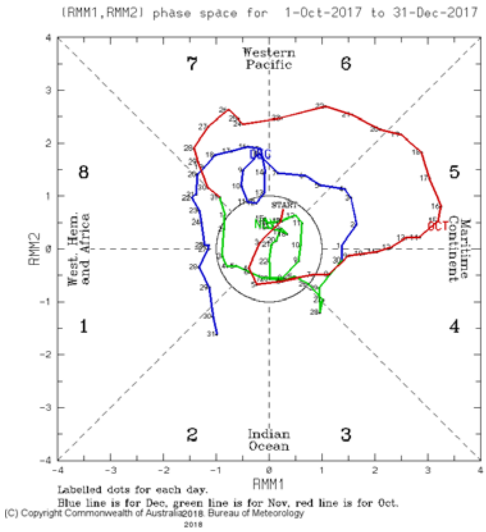


Figure 7: Plotting of the MJO phases during the months of October, November, and December 2017 [23]

The certained pattern could be seen also in relation to monitor of the MJO activity.

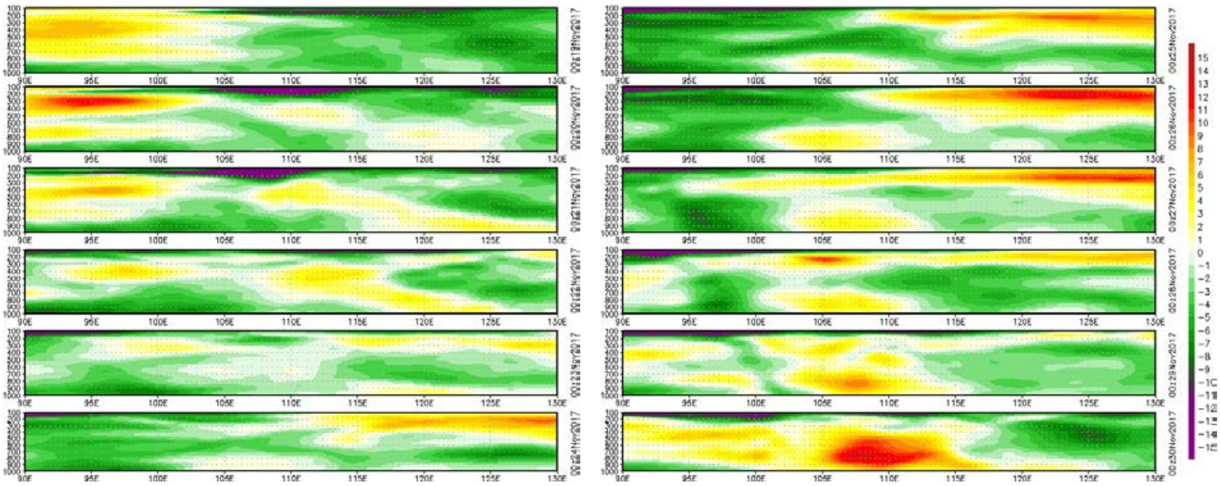
The zonal wind vertical profile of 90° - 150°E 7° - 12°S over Indian Ocean Southern part of Java Island coast during 19 - 30 November 2017 can be seen in Figure 8 completely.

Based on Figure 8(a), there was seen a system which moved from Western part toward Eastern part. This system was noted as the high speed of zonal wind velocity and had positive sign at the upper troposphere level near the tropopause around 200 hPa.

On 19 November 2017, there was seen the domination of the Westerly in the level of 850 hPa up to 100 hPa and the area of 90°E up to 105°E. In the following day of 20 November 2017, the Westerly of the 300 hPa seemed to strengthen significantly accompanied by weakening of it at the level of lower troposphere.

This condition was coincided with imerging the Westerly signal surrounding 110°E as the area of developing TC Cempaka at the level of 600 hPa up to 300 hPa. On the date of 22 November 2017, the Westerly of upper troposphere seemed to move eastward accompanied by the changing wind at the level of lower troposphere to become easterly. In the meantime, the Westerly surrounding 110°E tended stronger and stronger.

The Westerly surrounding the area of 110°E weakened once again on 23 November 2017. But there was also a new signal of the Westerly strengthened at the Eastern part of 110°E area. If one paid attention to this condition, there was a shift of Westerly from Western part to Eastern ones.



(a) (b)

Figure 8: The zonal wind profile cross-section in the area of 7° – 12°S,90° – 150°E, during19 – 24 November 2017 (a) and 25 – 30 November 2017 (b).The ordinate is the air pressure level (hPa) and the absis is longitude line (°). (Source: BoM 2018)

After the date of 23 November 2017, the Western part of 110°E area experienced the strengthened Easterly for all level. Over the 110°E area also happened the strengthened Westerly, started from lower troposphere. Westerly at the level of upper troposphere where had reached the Eastern part of 110°E area also strengthened once again and tended to shift toward Eastern part. These pattern movement of zonal wind system in the certain area indicated that the MJO activity happened coinciding with developing of TC Cempaka [23]. The Australian Summer Monsoon [24] during the period of middle up to last November 2017 tended increasingly and be more positive than its normal values. This condition indicated that the intensity of Australian Summer Monsoon during those periods was weaker than its climatology. The weakened Australian Summer Monsoon proved that there was available atmospheric disturbance at the level of 850 hPa over Southern Hemisphere of Indonesian Region, starting from Southern part of Central Java Province up to Eastern Nusa Tenggara Province since the middle of November 2017.

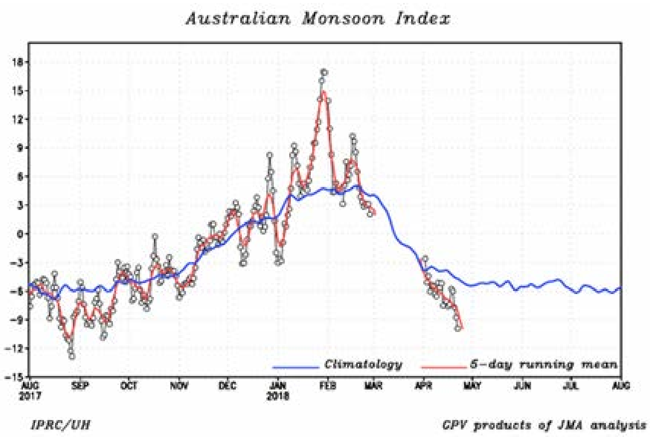


Figure 9: The Australia Summer Monsoon Indexes [24]

Based on the Mean Sea Level Pressure analysis chart [25] as seen on Figure 10, the LPA over Southern part of Indonesian region is available with mark of 1007 hPa. These LPA belt has been developed since 19 November 2017 along Indian Ocean (Southern part of Indian Peninsula), Southern part of Sumatera Island, Java Island, Bali Island, West Nusa Tenggara and East Nusa Tenggara Islands, West Papua Island up to Eastern part of Papua New Guinea. This condition has been triggered by the weakened of Australian Summer Monsoon since the middle of November 2017.

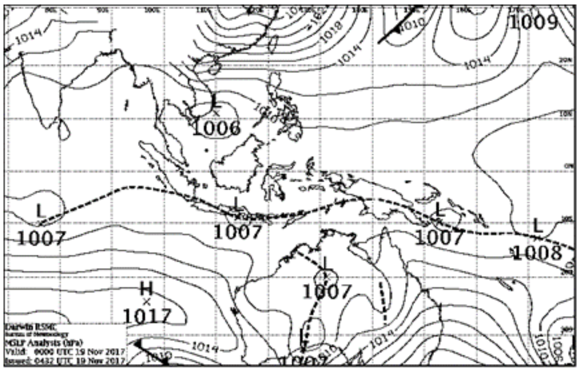


Figure 10: The Mean Sea Level Pressure analysis (hPa) on 19 November 2017 at 00.00 UTC [25]

Based on the wind gradient chart analysis of the level of 925 hPa on 19 November 2017, at 12.00 UTC, the cyclonic wind pattern has already formed over Eastern part of East Java Province and Bali Province as well. This pattern triggered the development of convergence zone over Southern part of Java Island coast. These atmospheric disturbances over East Java and Bali Provinces came up as LPA and cyclonic wind patterns. These patterns have continuously sustained up to 18.00 UTC on 23 November 2017. At last, the cyclonic wind pattern has formed over Southern part of the Special Region of Yogyakarta Province as seen in Figure 11.

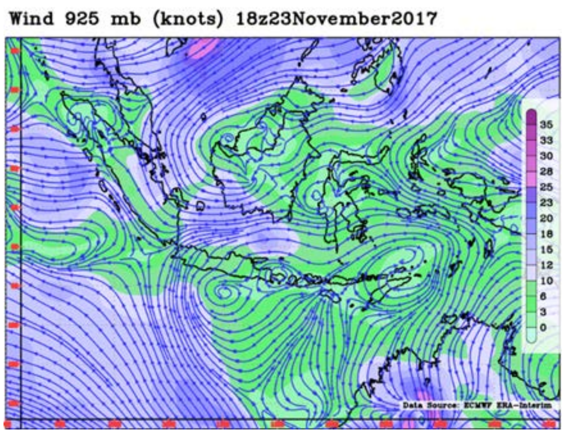


Figure 11: Wind gradient analysis at the level of 925 hPa on 23 November 2017 at 18.00 UTC (Source: Data Processing 2017).

The cyclonic wind pattern tended to be stationaire and even increased (decreased) in its intensity depend on the intensity of the system. The maximum wind velocity (red line color) increased and its minimum air pressure center (blue line color) decreased as seen in Figure 12. Starting from 27 November 2017, the system became a fully TC with the maximum wind speed of 35 knots and minimum air pressure at the center of 998 hPa.

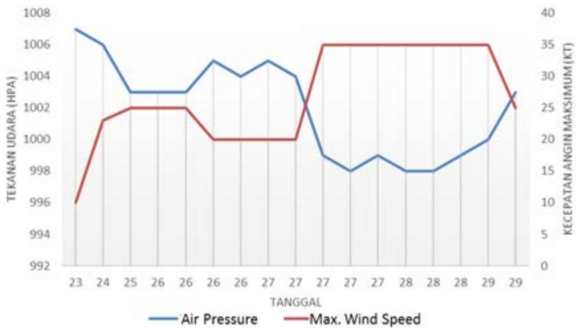
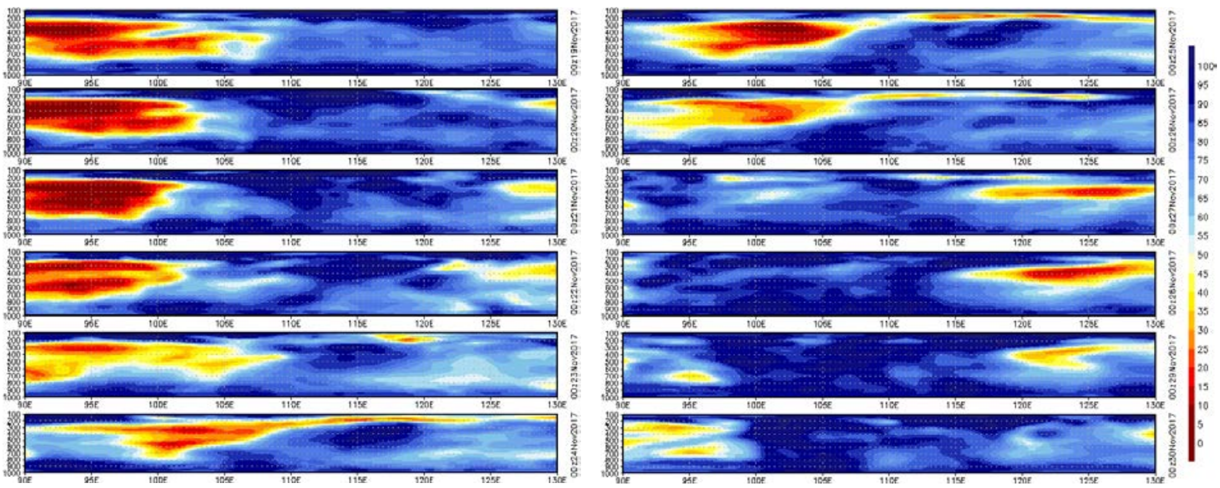


Figure 12: The minimum air pressure and maximum wind velocity chart over the area of LPA in Southern part of the Special Region of Yogyakarta Province during 23 - 29 November 2017. (Source: Data Processing 2017)

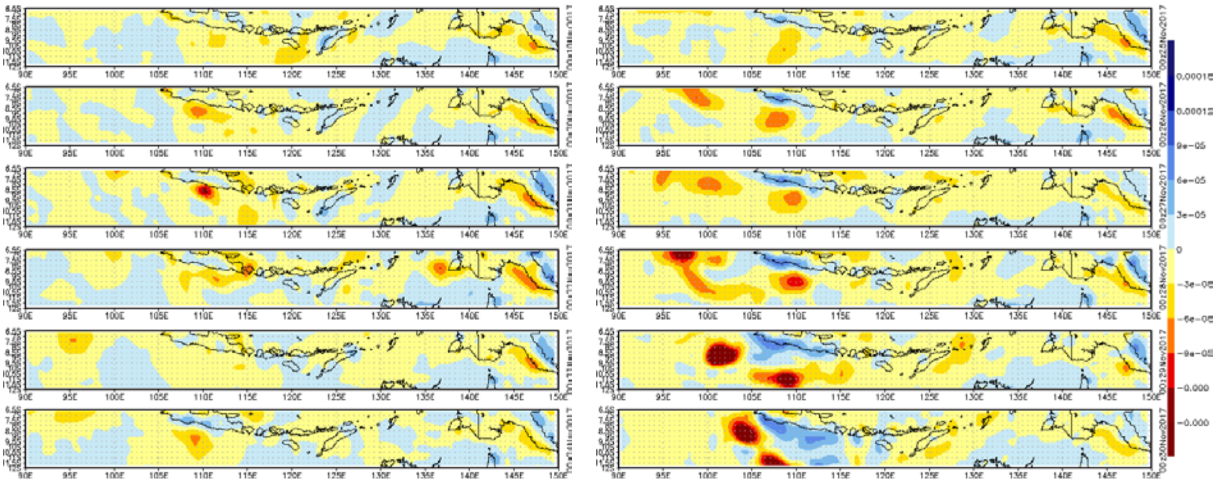
The vertical profile of Relative Humidity cross section is Figure 13 was also seen having a special pattern. During the date of 19 up to 22 November 2017, over the forming of TC Cempaka around the area of 110°E, the value of Relative Humidity showed very high than it's normal. Meanwhile, in the contrary this Relative Humidity seemed very dry over the Western part of TC Cempaka forming especially for below the level of 700 hPa.



(a) (b)

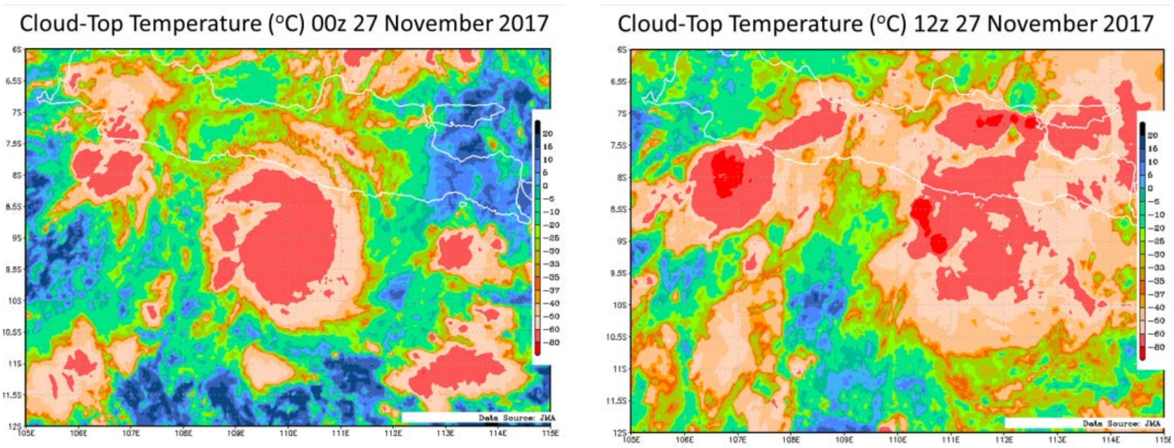
Figure 13: Relative Humidity cross-section profile over the area of 90°E – 150°E 7°S – 12°S during 19 – 24 November 2017 (a) and 25 – 30 November 2017 (b).The ordinate is air pressure level (hPa) and the absis is longitude (°) [14]

On the date of 23 November 2017, the dry air masses of upper level moved Eastward accompanied by increasing in Relative Humidity. In the meantime, air masses around the area of 110°E tended drier. This condition continuously sustained up to 26 November 2017. Furthermore on 27 November 2017, the dry air masses over Western part of 110°E longitude experienced increasingly in Relative Humidity and the wet air masses in the area of TC Cempaka forming increased once again. Referring to the explanation as mentioned above, the changing of the Relative Humidity values have an agreement with the gradient wind pattern. Based on the streamline as seen on the wind gradient pattern chart on 23 November 2017, the cyclonic wind pattern as the origin of TC Cempaka has already formed. Meanwhile, the vertical profile of Relative Humidity showed significantly changing of Relative Humidity values pattern as seen on Figure 13. The clue of potential existence of forming and developing of TC Cempaka has already seen on 19 November 2017 based on the Relative Vorticity chart. This chart can be seen on Figure 14. In this date, the signal of negative Relative Vorticity values has seemed over Southern part of the Special Region of Yogyakarta Province. This condition was still sustained up to 27 November 2017 when TC Cempaka was formed and declared.



(a) (b)

Figure 14: The Relative Vorticity profile on 19 – 24 November 2017 (a) and 25 – 30 November 2017 (b) [14]



(a) (b)

Figure 15: The spiral cloud system development of TC Cempaka as seen on Himawari 8 satellite imagery using IR canal on 27 November 2017 at 00.00 UTC (a) and 12.00 UTC (b) [14]

The negative Relative Vorticity signal over Southern part of the Special Region of Yogyakarta Province coast had still remained since 19 November 2017 up to 28 November 2017. The position coordinate of it had not moved relatively. This condition proved that the lifted potential of wet air masses over origin of TC Cempaka could be maintained persistently during relatively along time. The cloud pattern of TC Cempaka can be observed clearly using the Himawari 8 satellite imagery as a TC pattern. In this case, the IR canal output can be used. As seen on Figure 15, the spiral pattern of clouds can obviously be seen on 27 November 2017 at 00.00 UTC. But toward 12.00 UTC, this spiral pattern underwent disturbing so that the spiral pattern shape becoming not fully spiral. At 13.00 UTC, the convective cloud system of TC Cempaka strengthened again until reaching the lowest temperature of top cloud at 14.00 UTC. Observing the cloud system time series of TC Cempaka, it seemed weakening when TC Cempaka had been formed on 27 November 2017 at 12.00 UTC. But it strengthened again during 14.00 UTC up to 19.00 UTC as seen on Figure 16.

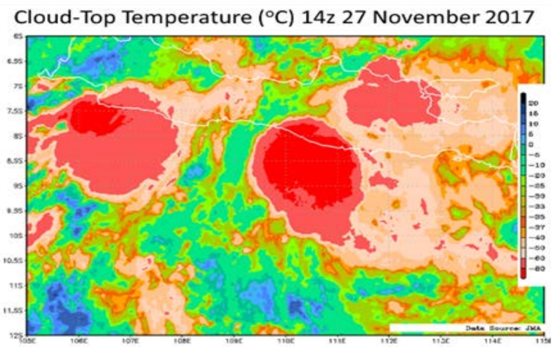


Figure 16: The strengthened cloud system of TC Cempaka on 27 November 2017 at 14.00 UTC taken from Himawari 8 satellite imagery using IR canal [14]

Using the top cloud average temperature time series chart over the area of TC Cempaka origin (see Figure 17), there can be seen that the increasing of top cloud average temperature happened during night time until early morning. Intensification of this cloud system during night time until early morning was as a characteristic of which can be usually seen on the forming of TC system and coincided with the activity of the MJO ones. Based on this condition, there was a special relationship between TC system and the MJO. In this case, the MJO has played a strong role to support the forming of TC Cempaka.

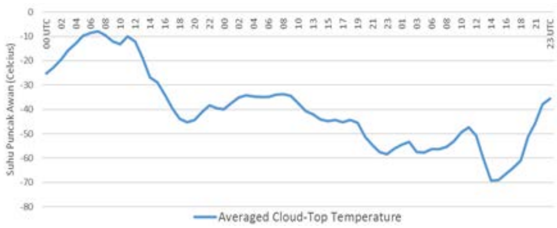


Figure 17: The top cloud average temperature timeseries over the area of TC Cempaka origin during 25 - 27 November 2017. (Source: Data Processing 2018)

4. Conclussion

Based on the analysis and descriptions as mentioned above, here can be concluded several points as follow:

- The signal of TC Cempaka formation could be detected during some couple days before the date of 27 November 2017, especially using the Mean Sea Level Pressure (isobar) chart, the relative vorticity field, the relative humidity chart, zonal wind field, and gradient wind pattern (streamlines) chart. The Tropical Depression (TD) has occurred on 27 November 2017 and followed quickly with the form of TC Cempaka in the same day.

- The Sea Surface Temperature over Southern part of the Special Region of Yogyakarta Province coast remained high enough. It has continuously produced and supported the wet air masses into the origin of TC Cempaka. Meanwhile, the MJO in the wet phase which was entering over the maritime continent of Indonesian Region, especially passing through the Southern part of the Special Region of Yogyakarta Province coast, has strongly triggered the forming of TC Cempaka by supporting abundant wet air masses into the TC system.

- The concentration of daily rainfall with high intensity from heavy up to extreme even to become a daily record, had already occurred over Southern part of the Special Region of Yogyakarta Province coast where was closely to the TC Cempaka origin. Some places had experienced daily rainfall record such as Pacitan Regency (383 mm/day) on 27 November 2017 and Adi Soetjipto International Airport (286 mm/day) on 28 November 2017. The impact of TC Cempaka happened over both places even causing some people dead in Pacitan Regency.

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