INVESTIGATING THE IMPACT OF TROPICAL CYCLONES CEMPAKA AND DAHLIA ON ATMOSPHERIC CONDITIONS IN SOUTHERN INDONESIA

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ABSTRACT

At the end of 2017, the Jakarta Tropical Cyclone Warning Center (TCWC) observed the formation of two tropical cyclones in the southern waters of Indonesia, namely Cempaka and Dahlia, which triggered extreme weather and caused damage and casualties in several areas. This study aims to identify the stages of development of tropical cyclones Cempaka and Dahlia, from formation to dissipation, and to examine atmospheric conditions before, during, and after the cyclones. The method used is the Dvorak analysis technique based on Himawari-8 satellite infrared imagery to monitor cyclone intensity, supported by ECMWF reanalysis data to analyze atmospheric parameters in the cyclone growth region. The study results show that Cempaka and Dahlia reached Tropical Storm (TS) category on November 27 and December 1, 2017, respectively. At the mature stage, atmospheric conditions showed high relative humidity between 90% and 100%, the presence of strong cyclonic circulation with negative vorticity values ranging from $-10 \times 10^{-5}/s$ to $-50 \times 10^{-5}/s$, and convergence in the lower layer indicated by negative divergence values ranging from $-10 \times 10^{-5}/s$ to $-20 \times 10^{-5}/s$. These conditions support the formation of convective clouds and the intensification of the cyclonic system. These findings provide insight into the role of atmospheric dynamics in the growth of tropical cyclones in the vicinity of Indonesia.

Keywords: Cempaka, cyclone, Dahlia, Dvorak, Himawari

1. Introduction

Indonesia is located in the equatorial region so it has a tropical climate and high rainfall [1], [2], [3]. Tropical cyclones are low-pressure systems that grow over tropical and subtropical waters with warm sea surface temperatures (>26.5°C) [4], [5]. Most tropical cyclones grow in the northern hemisphere at latitudes of 10° to 20° from the equator [6], [7], so the Indonesian region rarely experiences tropical cyclone events, but because it is in the tropics, which is a cyclone track [8], [9], this makes Indonesia vulnerable to the impact of tropical cyclone phenomena [10].

In late November to early December 2017, the Jakarta Tropical Cyclone Warning Center (TCWC) observed two tropical cyclone systems forming in the southern region of Indonesia, namely Tropical Cyclone Cempaka and Tropical Cyclone Dahlia [11]. Tropical Cyclone Cempaka lasted from November 21 to 30, 2017, while Dahlia was active from November 26 to December 4, 2017 [12], [13]. Both systems caused extreme rains, floods, landslides, and infrastructure damage in several areas such as Central Java, Yogyakarta, and the southern coast of Java Island [14]. These events emphasize the importance of intensive monitoring of atmospheric dynamics and tropical cyclone activity, even though Indonesia is not located at latitudes where cyclone cores commonly form.

To monitor the development of tropical cyclones, one of the commonly used methods is the Dvorak technique [15], [16], [17]. This technique is a satellite image-based tropical cyclone intensity estimation method utilizing the infrared channel, to assess the cloud pattern and intensity of the cyclonic system based on cloud spiral structure, Central Dense Overcast (CDO) shape and cloud top temperature [18], [19], [20]. The T-Number values generated from the Dvorak technique allow estimation of the strength of tropical cyclone systems without the need for direct field observations [21], [22]. This technique is especially useful in open water areas that are difficult to reach by conventional measuring instruments, and has become an operational standard adopted by the world's meteorological agencies because it has been proven effective and efficient [22]. In this study, thermal imagery from the Himawari-8 satellite provides high quality data and sufficient temporal resolution to perform detailed and in-depth Dvorak analysis for more accurate monitoring of tropical cyclone dynamics [23], [24].

In addition to visual monitoring using satellites, dynamic atmospheric conditions also play an important role in supporting or inhibiting the growth of tropical cyclones. Several parameters such as relative humidity, vorticity, and wind divergence in the lower tropospheric layer are important indicators to assess convection potential and atmospheric stability [25]. By utilizing ECMWF (European Centre for Medium-Range Weather Forecasts) reanalysis data, particularly the ERA5 product, atmospheric conditions can be described spatially and temporally to support interpretation of the evolution of cyclonic systems.

Several studies have examined the impact of tropical cyclones on atmospheric conditions in southern Indonesia, especially during the Cempaka and Dahlia Tropical Cyclone events. Cyclone Cempaka is triggered by the Coriolis effect which is amplified by warm sea surface temperature (SST), increased wind speed, decreased air pressure, and negative vorticity that promotes air mass lifting. Meanwhile, the growth of Cyclone Dahlia was characterized by weak vertical windshear, maximum vorticity as the eye of the storm formed, changes in cloud structure, high humidity in the convergence belt, and increasingly patterned convergence until the system decayed [26]. Cyclone Dahlia persisted for 9 days, moving clockwise from the waters south of Bengkulu eastward to southern Java, then ended up moving away to southeast Indonesia [27].

Previous research by Saragih et al. (2018) used Himawari-8 satellite imagery to analyze the growth and life cycle of Tropical Cyclones Cempaka and Dahlia through the Dvorak technique and see its impact on rainfall distribution in the Maritime Continent. However, the study has not addressed atmospheric conditions before, during, and after the event due to time constraints [28]. Therefore, this study monitored both cyclones using Himawari-8 thermal imagery and ECMWF reanalysis data to assess atmospheric conditions before, during and after cyclone growth. By understanding these two aspects in an integrated manner, it is expected that the research results can contribute to the improvement of the early warning system as well as the understanding of tropical atmospheric dynamics in the Indonesian region.

2. Methods

This research was conducted with a case study in the southern waters of Indonesia, especially around the location of the growth and decay of Tropical Cyclones Cempaka and Dahlia, during November 14 to December 11, 2017. This research uses several data such as:

1. Thermal image of Himawari-8 satellites IR channel, which is used for intensity estimation and monitoring of tropical cyclone convective cloud structure by applying Dvorak Technique. This image has a spatial resolution of 2 km and a temporal resolution of 10 minutes obtained from BMKG Soekarno-Hatta.
2. European Center for Medium-Range Weather Forecast (ECMWF) reanalysis model data which includes atmospheric parameters such as relative humidity (%) at the 700 mb pressure level, vorticity (1/s), and wind divergence (s^{-1}) at the 850 mb pressure level. This data is used to analyze atmospheric conditions during the formation and development of Tropical Cyclones Cempaka and Dahlia obtained from https://www.ecmwf.int/en/forecasts/datasets.
3. Tropical cyclone data obtained from http://www.bom.gov.au/index includes data on the track coordinates of tropical cyclones Cempaka and Dahlia.

The spatial boundaries of the research area are coordinates 5.1°N - 17.7°N and 90.1°E - 114.0°E, covering the growth areas of both cyclones in southern Sumatra and Java. The research area boundaries to determine the atmospheric conditions are divided into two, namely at the coordinates of 9.4°S 110.7°BT which represents the atmospheric conditions in the growth area of tropical cyclone Cempaka and at the coordinates of 10.1°S 104.6°BT which represents the atmospheric conditions in the growth area of tropical cyclone Dahlia. Temporally, the study covers seven days before the growth, during the growth and seven days after the decay of tropical cyclones Cempaka and Dahlia.

The method used in this study is to use the Dvorak technique to determine the intensity of tropical cyclones based on the identification of convective cloud spiral patterns [17] and cloud top temperature to determine the T-number value, which is then converted into cyclone intensity categories [29]. The assessment is done visually through features such as the shape of the central dense overcast (CDO), spiral bands, and the presence and clarity of the cyclone eye [22], [30]. In this study, EIR images from Himawari-8 were processed using SATAID (Satellite Animation and Interactive Diagnosis) software [31]. Based on Dvorak Table (1982), T-number values between 2.5 to 4.0 indicate Tropical Storm category with maximum wind speed ranging from 34-63 knots. This value is used as an indicator of the intensity of Tropical Cyclones Cempaka and Dahlia at each stage of their life cycle (formation, immature, mature, and decay). To support the monitoring results of tropical cyclones Cempaka and Dahlia, an analysis of atmospheric conditions such as relative humidity (RH), vorticity, divergence was carried out using GrADS (Grid Analysis and Display System) software, with visualization of atmospheric parameter patterns at certain times and regions relevant to the development of each cyclone.

3. Result and Discussion

Monitoring the development of tropical cyclone Cempaka. Based on Australian Meteorological Agency data, Tropical Cyclone Cempaka began to orm in the southern waters of Java Island on November 21, 2017 at 07.00 LT (00 UTC), precisely at the coordinates of -10°S 112°E, with sea surface temperatures reaching 28.2°C. The results of Cempaka tropical cyclone monitoring based on Himawari-8 thermal images are used to determine the development pattern of Cempaka tropical cyclone from the growing stage to decay using Dvorak technique analysis and ECMWF (European Centre of Medium-range Weather Forecast) reanalysis data shown in Table 1.

Several time steps in Table 1 do not include minimum pressure values due to the unavailability of valid data during the early development phase and weakening of the cyclone. Only observation times with reliable data from ECMWF or JTWC are shown to ensure accuracy.

To support the observational data in Table 3.1, an example of monitoring results using the Dvorak technique based on Himawari-8 infrared imagery showing the spiral cloud band of Tropical Cyclone Cempaka on November 27, 2017, at 00:00 UTC is presented in Figure 1.

Table 1. Parameter Description of Cempaka Tropical Cyclone Monitoring Results

Date	Time (WIB)	Time (UTC)	Cloud Spiral Tape	T-Number	Category	Minimum Pressure (mb)
November 25, 2017	07:00	00:00	0,25	1,5	TD	
	19:00	12:00	0,3	2,0	TD	
November 26, 2017	07:00	00:00	0,3	2,0	TD	
	19:00	12:00	0,3	2,0	TD	
	01:00	18:00	0,4	2,5	TS	997
November 27, 2017	07:00	00:00	0,9	3,5	TS	984
	13:00	06:00	0,8	3,5	TS	984
	19:00	12:00	0,9	3,5	TS	984
	01:00	18:00	0,8	3,5	TS	984
November 28, 2017	07:00	00:00	0,4	2,5	TS	997
	13:00	06:00	0,2	1,0	TD	
	19:00	12:00	0,25	1,5	TD	
	01:00	18:00	0,2	1,0	TD	

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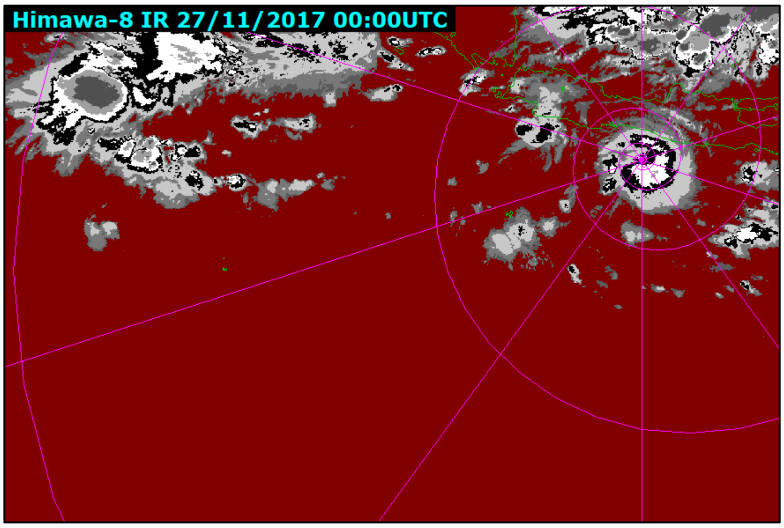

Figure1. Himawari-8 IR image (November 27, 2017, 00:00 UTC) showing the spiral band of Cyclone Cempaka, corresponding to the highest spiral tape value (0.9) in Table 3.1, made by SATAID software

November 25, 2017 at 07.00 LT (00 UTC) shows the intensity of tropical cyclone Cempaka in the Tropical Depression category with a maximum wind speed of 25 knots in the Strong breeze category. The tropical depression phase is characterized by a maximum wind speed of <34 knots [32]. The intensity of tropical depression in tropical cyclone Cempaka increased on November 25, 2017 at 19:00 LT (12 UTC) until November 26, 2017 at 19:00 LT (12 UTC) which is characterized by the number of spiral levels in the cloud band as much as 0.3 with a T-Number of 2.0 which indicates a minimum air pressure of 1000 mb and a maximum wind speed of 30 knots in the near gale category.

The tropical depression developed into a tropical storm on November 26, 2017 at 01.00 WIB (18 UTC) which was marked by the increasing intensity of the tropical cyclone, where the T-Number was 2.5 indicating the Tropical Storm (TS) category with a minimum air pressure of 997 mb and a maximum wind speed of 35 knots in the moderate gale category. On November 27, tropical cyclone Cempaka stabilized in the Tropical Storm (TS) category, but there was a decrease in minimum air pressure to 984 mb and an increase in maximum wind speed of 55 knots in the storm category, indicating that the tropical cyclone was in the mature stage.

November 28, 2017, tropical cyclone Cempaka underwent a decay stage characterized by the cloud belt slowly disappearing and the intensity of the tropical cyclone decreased to Tropical Despression (TD) category, where the minimum air pressure in the decay stage increased to 997 mb and there was a decrease in maximum wind speed to 35 knots of moderate wind category (Gale). Tropical cyclone Cempaka was detected extinct on November 29th, 2017 by moving southward away from the southern waters of Java.

Monitoring the development of tropical cyclone Dahlia. Based on the tracking data of the Australian Meteorological Agency, tropical cyclone Dahlia grew in the Southwest Waters of Sumatra Island on November 26, 2017 at 07.00 LT (00 UTC) at the coordinates of 6.2°S 93.1°E with a sea surface temperature of 29°C. The monitoring results of tropical cyclone Dahlia based on Himawari-8 thermal imagery are used to determine the development pattern of tropical cyclone Dahlia from the growing stage to decay using Dvorak technique analysis and ECMWF (European Center of Medium-range Weather Forecast) reanalysis data shown in Table 2.

Several time steps in Table 2 do not include minimum pressure values due to the unavailability of valid data during the early development phase and weakening of the cyclone. Only observation times with reliable data from ECMWF or JTWC are shown to ensure accuracy.

Table2. Parameter Description of Dahlia Tropical Cyclone Monitoring Results

Date	**Time (WIB)**	**Time (UTC)**	**Cloud Spiral Tape**	**T-Number**	**Category**	**Minimum Pressure (mb)**
November 29, 2017	13:00	06:00	0,2	2,0	TD	
	01:00	18:00	0,35	2,0	TD	
November 30, 2017	07:00	00:00	0,5	2,5	TS	997
	13:00	06:00	0,4	2,5	TS	997
	19:00	12:00	0,6	3,0	TS	991
	01:00	18:00	0,6	3,0	TS	991
December 1, 2017	07:00	00:00	1,0	3,5	TS	984
	13:00	06:00	1,0	3,5	TS	984
	19:00	12:00	0,9	3,5	TS	984
	01:00	18:00	1,0	3,5	TS	984
December 2, 2017	07:00	00:00	0,9	3,5	TS	984
	13:00	06:00	0,6	3,0	TS	991
	19:00	12:00	0,2	1,0	TD	
December 3, 2017	07:00	00:00	0,25	1,5	TD	
	13:00	06:00	0,25	1,5	TD	
	19:00	12:00	0,2	1,0	TD	
	01:00	18:00	0,2	1,0	TD	

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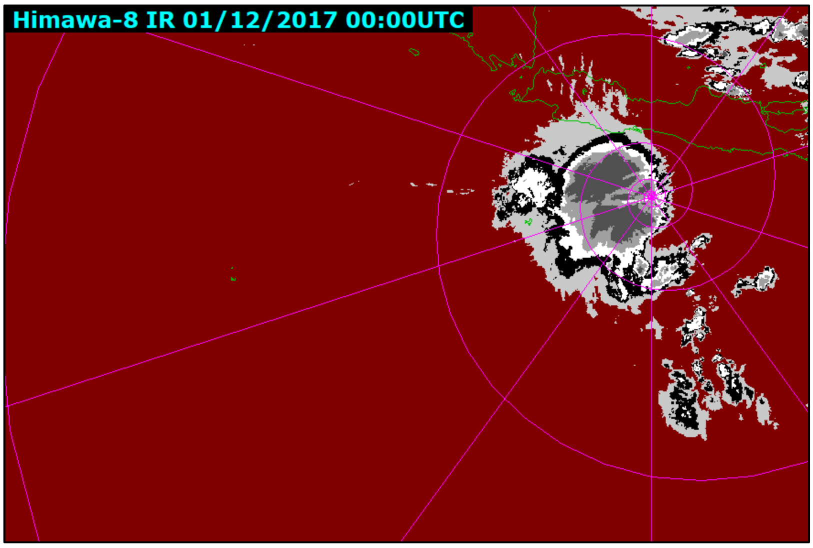


Figure 2. Himawari-8 IR image (December 1, 2017, 00:00 UTC) showing the spiral band of Cyclone Dahlia, corresponding to the highest spiral tape value (1.0) in Table 3.2, made by SATAID software

To support the observational data in Table 2, an example of monitoring results using the Dvorak technique based on Himawari-8 infrared imagery showing the spiral cloud band of Tropical Cyclone Dahlia on December 1, 2017, at 00:00 UTC is presented in Figure 2.

November 29, 2017 at 13:00 LT (06 UTC) shows the intensity of tropical cyclones in the Tropical Depression category with a maximum wind speed of 30 knots in the Near gale category. This phase is characterized by a maximum wind speed of <34 knots [32]. The intensity of tropical cyclone Dahlia on November 30, 2017 at 07:00 am (00 UTC) increased to Tropical Storm (TS) category with a minimum air pressure of 997 mb and a maximum wind speed of 35 knots of moderate gale category, then at 19:00 LT (12 UTC) the minimum air pressure decreased to 991 mb and the maximum wind speed increased to 45 knots of strong gale category.

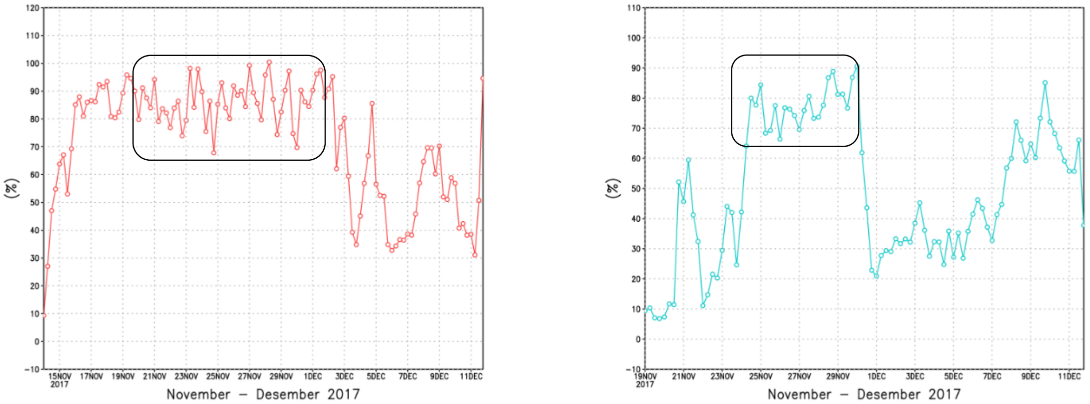
December 1, 2017 at 07.00 LT (00 UTC) shows a decrease in minimum air pressure to 984 mb and a maximum wind speed of 55 knots in the storm category. This condition indicates the mature stage of tropical cyclone Dahlia in the Tropical Storm (TS) category. The intensity of tropical cyclone Dahlia in the Tropical Storm (TS) category lasted for 24 hours until December 2, 2017 at 07.00 LT (00 UTC) before its intensity began to decrease on December 2, 2017 at 13.00 LT (06 UTC) indicated by the number of spirals in the cloud band decreased to 0.6 with a T-Number of 3.0 which indicated the minimum air pressure increased to 991 mb and the maximum wind speed decreased to 45 knots of strong gale category.
The intensity of tropical cyclone Dahlia on December 2, 2017 at 19:00 LT (12 UTC) until December 3, 2017 at 19:00 LT (12 UTC) decreased to the Tropical Depression (TD) category with a maximum wind speed of 25 knots in the Strong breeze category. This phase occurs at the beginning and end of tropical cyclones with wind speeds <34 km/h [24]. On December 3, 2017 at 19:00 LT (12 UTC), the maximum wind speed decreased to 23.4 knots of Strong breeze category and began to move away from the center of tropical cyclone Dahlia. Tropical cyclone Dahlia was detected extinct on December 4, 2017 with a southward movement away from the southern waters of Java.

Atmospheric conditions before, during, and after tropical cyclones Cempaka and Dahlia. The monitoring results of tropical cyclones Cempaka and Dahlia are supported by atmospheric conditions in their growth areas that includes relative humidity, wind speed, vorticity, and divergence before, during, and after tropical cyclones Cempaka and Dahlia.

Relative humidity reflects atmospheric conditions, whether wet or dry. One of the requirements for the formation of tropical cyclones is humid conditions with relative humidity (RH) > 70% at the 700 mb layer, which represents the middle layer of the troposphere. High relative humidity at the 700 mb layer can support the growth and maintenance of convective clouds by minimizing the influx of dry air. Therefore, RH at the 700 mb layer is often used in tropical cyclone studies as an indicator of environmental humidity conducive to the formation and strengthening of cyclones. Figure 3.3 shows the relative humidity in the growth areas of tropical cyclones Cempaka (a) and Dahlia (b) over time. In Figure 3.3(a), atmospheric conditions before the cyclone event (November 14 – 15, 2017) were classified as dry with RH 10% – 70%, then increased significantly to 80% – 95% on November 16 – 20, 2017. During the active period of the Cempaka cyclone (November 21 – 29, 2017), relative humidity remained high and stable above 80%, supporting the system's development. After the cyclone dissipated (November 30 – December 11, 2017), humidity decreased to 30% –70%, indicating that the atmosphere had returned to dry conditions and was no longer conducive to the formation of convective clouds.

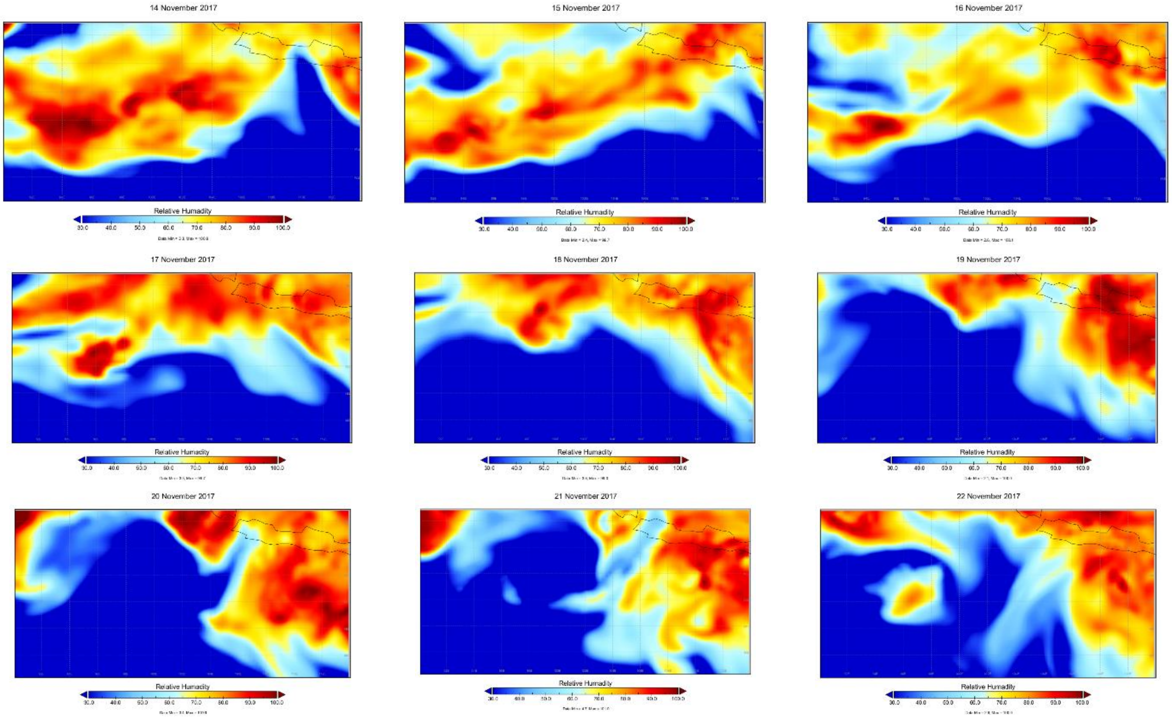
Figure 3 (b) shows that prior to the occurrence of tropical cyclone Dahlia (November 19–24, 2017), atmospheric conditions tended to be dry with RH ranging from 10% to 70%. Humidity increased significantly on November 25, 2017, reaching 85%. During the active period of the cyclone (November 26–30, 2017), relative humidity was high and stable at around 80%–90%, supporting the development of the system. A significant decrease occurred on December 1–4, 2017, to 20%–50%, as the cyclone moved away from the representative analysis point, so that the region was no longer under the direct influence of the system. As a result, the formation of convective clouds ceased due to the dry atmospheric conditions. Subsequently, humidity fluctuations from December 8–11, 2017, reflected local atmospheric dynamics with lower humidity values compared to the active phase of the cyclone.

To complement the temporal analysis shown in Figure 3, a spatial map of relative humidity at 700 mb has been included in Figure 4, which depicts the distribution of moist air around the cyclone center, particularly in the eye wall and rain zone regions. This humid region is very important for maintaining convection and supporting the intensification phase observed in both Cempaka and Dahlia.



(a) (b)

Figure 3. Relative humidity in the growth area of tropical cyclone Cempaka (a) and tropical cyclone Dahlia (b), made with GrADS software



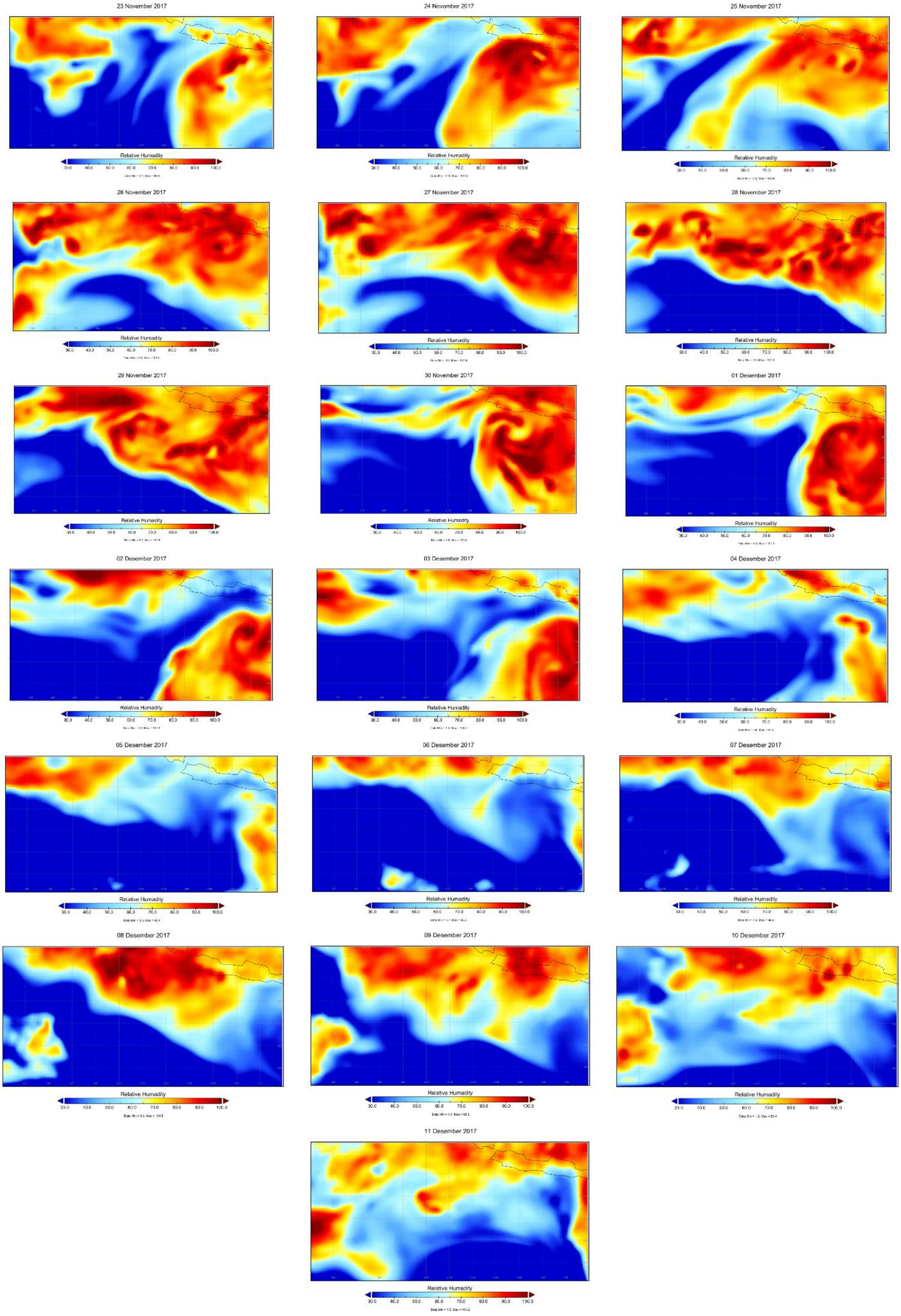
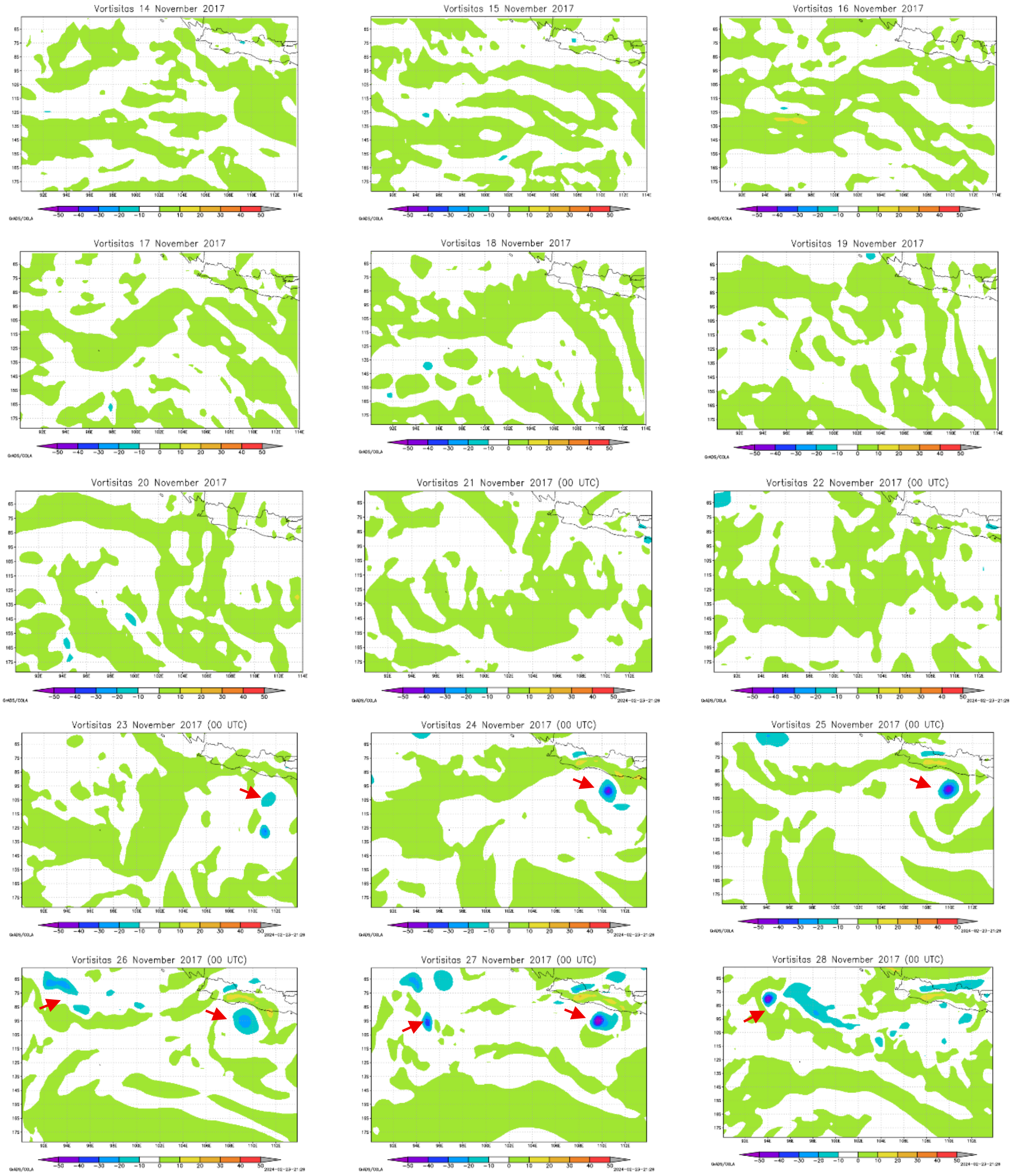


Figure 3. Spatial Distribution of Relative Humidity, made with Panoply software

In addition to humid atmospheric conditions, the formation of tropical cyclones is supported by negative vorticity which indicates an increase in air mass and forms a convection pattern that supports the growth of convective clouds. The development of tropical cyclones Cempaka and Dahlia can also be identified from the vorticity shown in Figure 3.2. On November 14 – 22, 2017 showed positive vorticity which indicated no cyclonic movement. On 23 November 2017, negative vorticity was detected which is shown in blue color in the southern waters of Java with values ranging from -10 x10-5/s to -20 x10-5/s and growing until it reached -50 x10-5/s on 27 November, 2017 which is marked with blue to purple color. These conditions support that tropical cyclone Cempaka was in its mature stage on November 27, 2017 with maximum vorticity values indicating strong cyclonic movement.



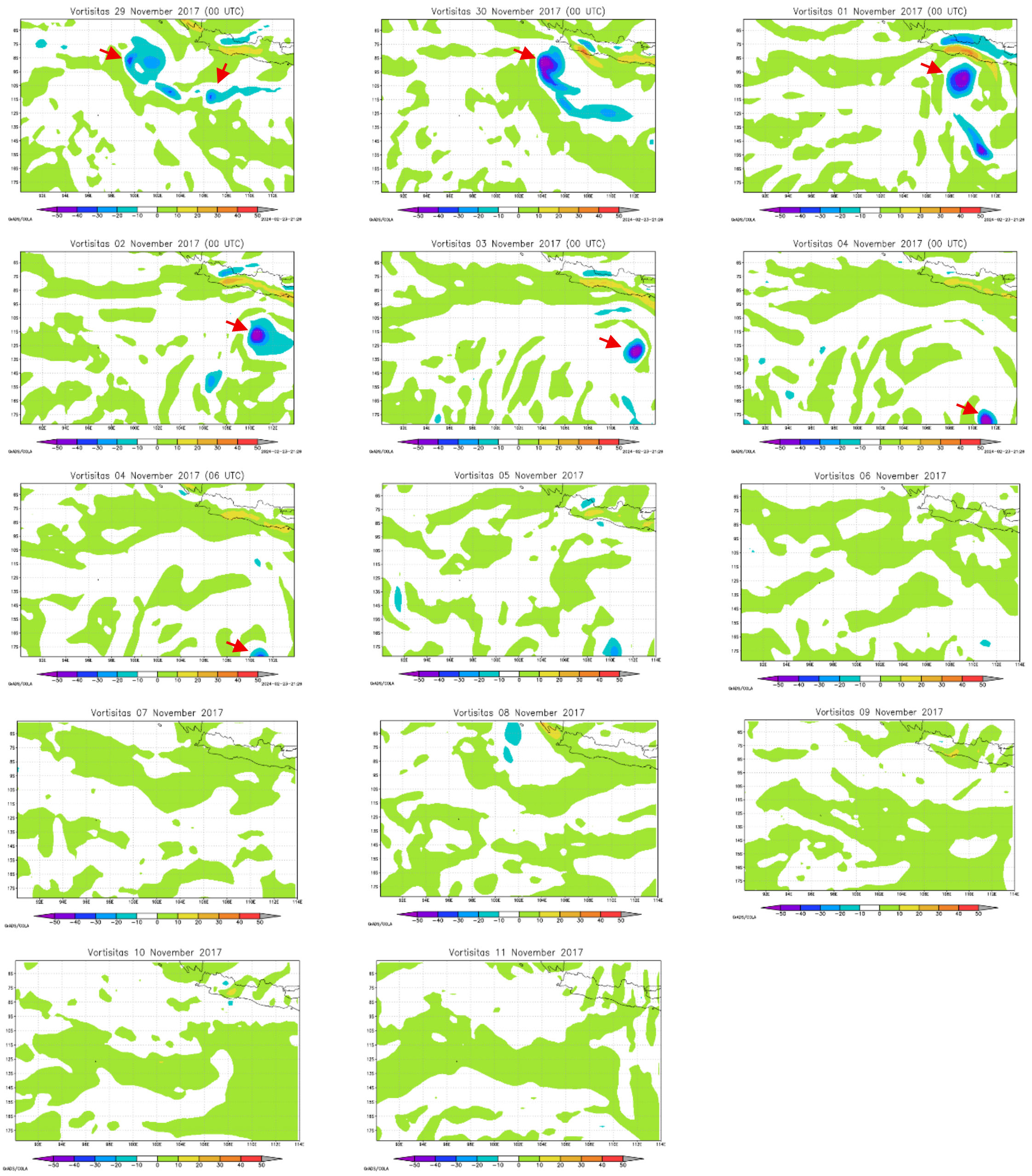
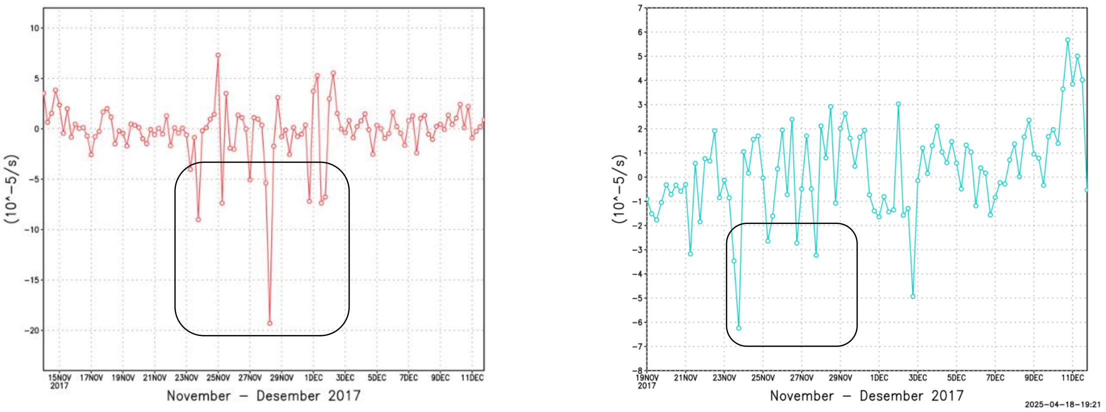


Figure 4. Development of tropical cyclones Cempaka and Dahlia based on vorticity, made with GrADS

Tropical cyclone Cempaka decayed on November 29, 2017 which was characterized by a cyclonic movement away from the southern waters of Java. At the same time, tropical cyclone Dahlia entered the southern waters of Java on November 30 - December 2, 2017 and began to move southward along with the decay of tropical cyclone Dahlia on December 3 – 4, 2017. Atmospheric conditions after the decay of both tropical cyclones returned to stable with positive vorticity indicating no increase in air mass and no cyclonic movement, thus not supporting the formation of convective clouds.

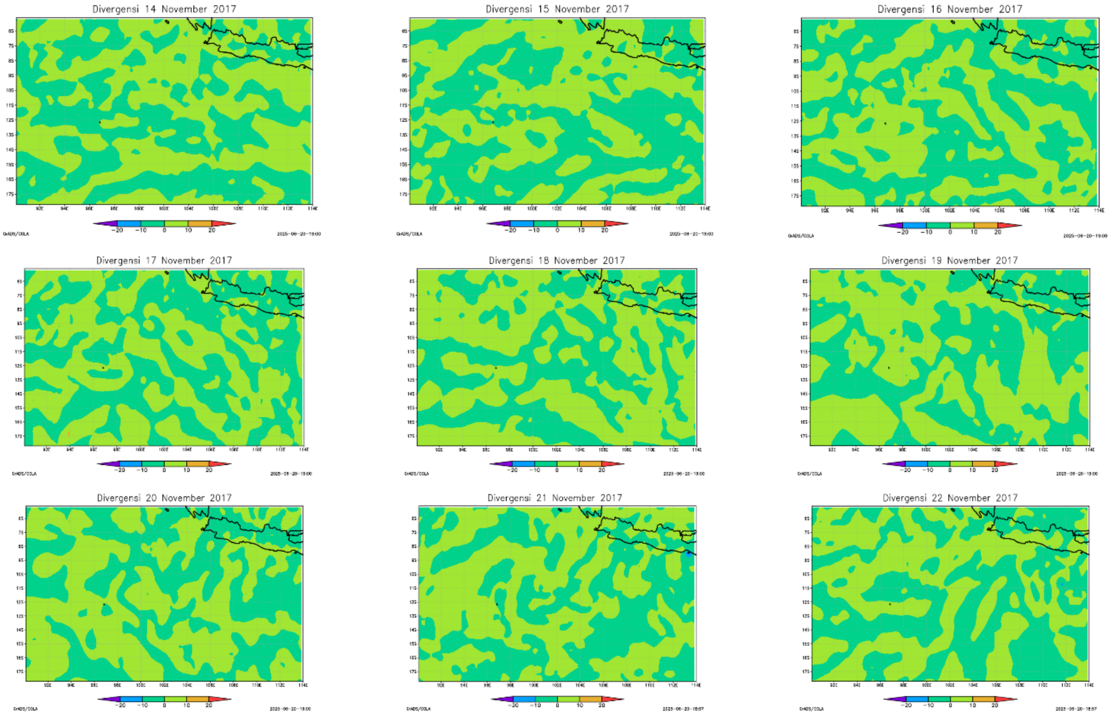
Vortices can cause air mass flows to converge or diverge. Divergence is a difference in air levels that spreads horizontally and is used to identify the spread or buildup of air masses, where negative divergence indicates convergence or buildup of air that will accelerate the growth of convective clouds and support the formation of tropical cyclones, where convergence at the surface can increase the layer of moist air [33]. The divergence data presented in this study were taken from the 850 mb pressure level, which represents the lower troposphere and is associated with the inflow or convergence area of tropical cyclones [34]. At this level, negative divergence (convergence) near the center of the system supports the accumulation of moist air and subsequent vertical convective development shown in Figure 5.

Figure 6 shows the spread of air mass before tropical cyclone Cempaka with positive divergence of 4 x10-5/s, then significantly decreased to around -5 x10-5/s to -20 x10-5/s on November 23 - December 1, 2017 which indicates the accumulation of air mass so as to accelerate the growth of convective clouds in the growth area of tropical cyclone Cempaka. While in the growth area of tropical cyclone Dahlia, there was weak convergence before tropical cyclone Dahlia on November 19, 2017 with divergence of -1 x10-5/s, then significantly decreased to around -3 x10-5/s to -6 x10-5/s on November 24 – 27, 2017. Tropical cyclone Dahlia began to enter the growth area of tropical cyclone Cempaka on November 30, 2017, this caused the divergence in the growth area of tropical cyclone Dahlia to increase to 3 x10-5/s which indicates the spread of air masses, so that convective cloud formation does not occur. After both cyclones decayed by moving southward away from the southern waters of Java, the atmospheric conditions in the growth areas of tropical cyclones Cempaka and Dahlia stabilized again with divergence increasing to 6 x10-5/s indicating no potential for convective cloud formation.



(a) (b)

Figure 5. Divergence in the growth region of tropical cyclone Cempaka (a) and tropical cyclone Dahlia (b), made with GrADS



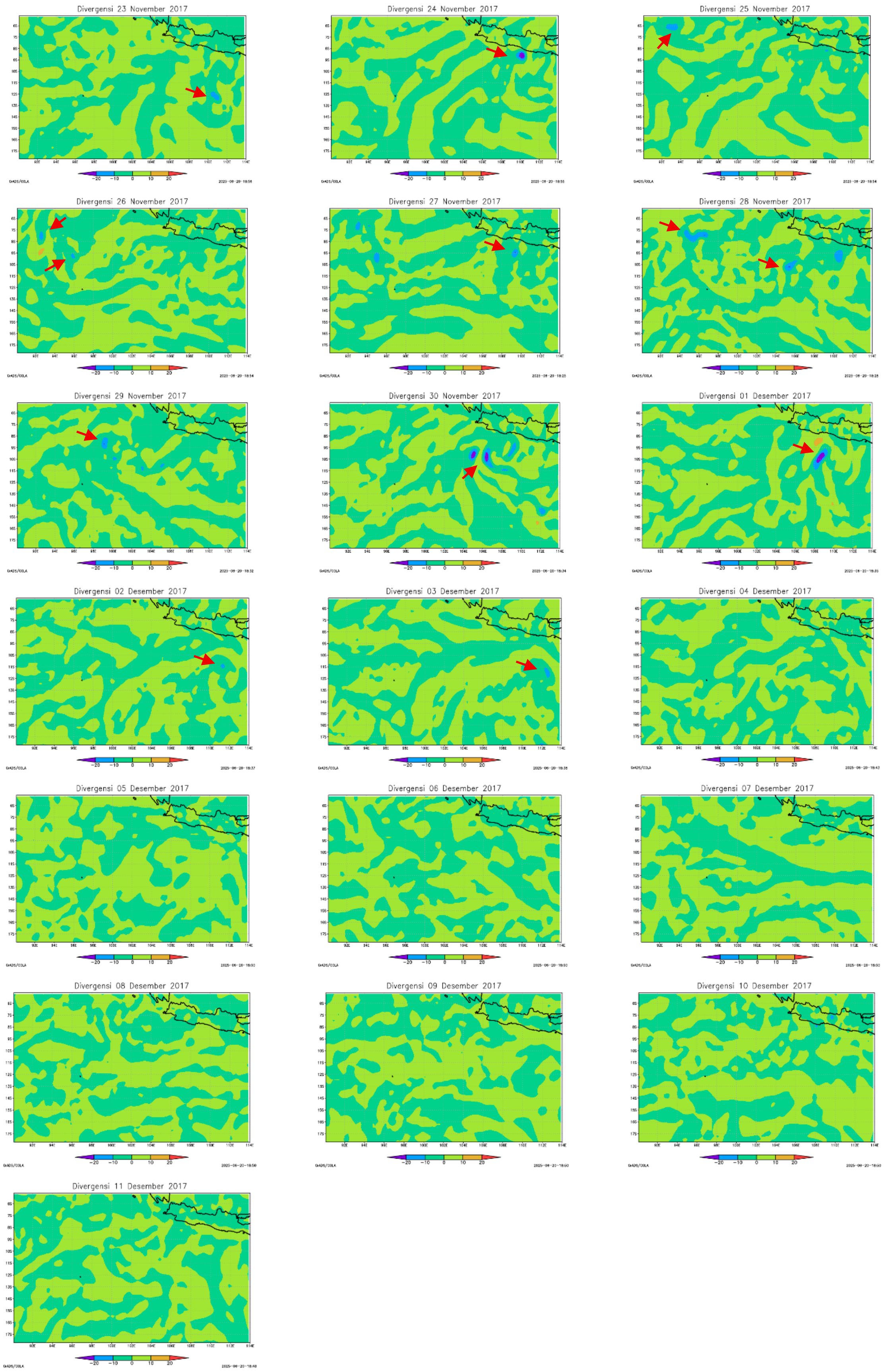


Figure 6. Spatial Distribution of Divergence, made with Panoply software

It is important to note that the atmospheric parameters analyzed in this study are based on fixed-point data representing the initial growth regions of each cyclone. As TC Dahlia moved eastward away from its original observation point, the intensity-related values (such as RH, vorticity, and divergence) at that location began to decrease, even though the cyclone was still active. Conversely, the increase in atmospheric values observed in the former TC Cempaka area after its decay is likely influenced by the presence and intensification of TC Dahlia.

We have included a spatial representation of the divergence at 850 mb pressure level (Figure 7), which clearly shows the convergence zone surrounding the center of the cyclone system.

Time series of cloud peak temperatures. Unstable atmospheric conditions can support the formation of convective clouds. Based on the data of relative humidity, vorticity, and divergence, the atmospheric conditions tend to be wet or humid during the development of tropical cyclones Cempaka and Dahlia, so it can support the formation of convective clouds and the growth of both tropical cyclones. Convective activity in an area whose growth can be monitored based on the temperature of the cloud tops, where in the growth stage the temperature ranges from -30°C to -50°C, in the mature stage ranges from -60°C to -80°C, and in the decay stage ranges from -50°C to -55°C [35], and is supported by unstable atmospheric conditions that can cause disturbances to the atmosphere and its surroundings [26]. This is evidenced by the time series of peak temperatures during the development of tropical cyclones Cempaka and Dahlia shown in Figure 8.

The cloud top temperature significantly increased during the mature stage of tropical cyclone Cempaka on November 27, 2017 with values ranging from -60°C to -80°C indicating the presence of mature deep convective clouds. On November 30th, 2017 in the Dahlia growth area there were mature deep convective clouds with values reaching around -80°C, then decreased very significantly to reach 20°C. This was caused by the movement of tropical cyclone Dahlia which began to enter the growth area of tropical cyclone Cempaka. This is evidenced by the time series of cloud top temperature in the Cempaka tropical cyclone growth region after the decay of Cempaka tropical cyclone on November 29, 2017.

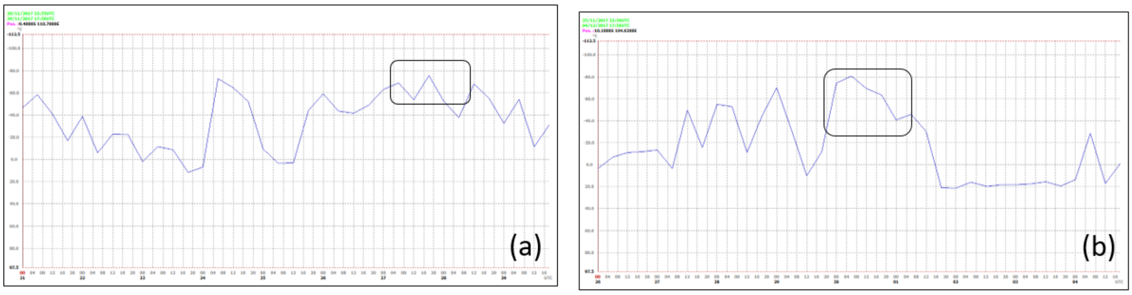


Figure 7. Time series of cloud top temperature in the growth region of tropical cyclone Cempaka (a) and tropical cyclone Dahlia (b), made with SATAID

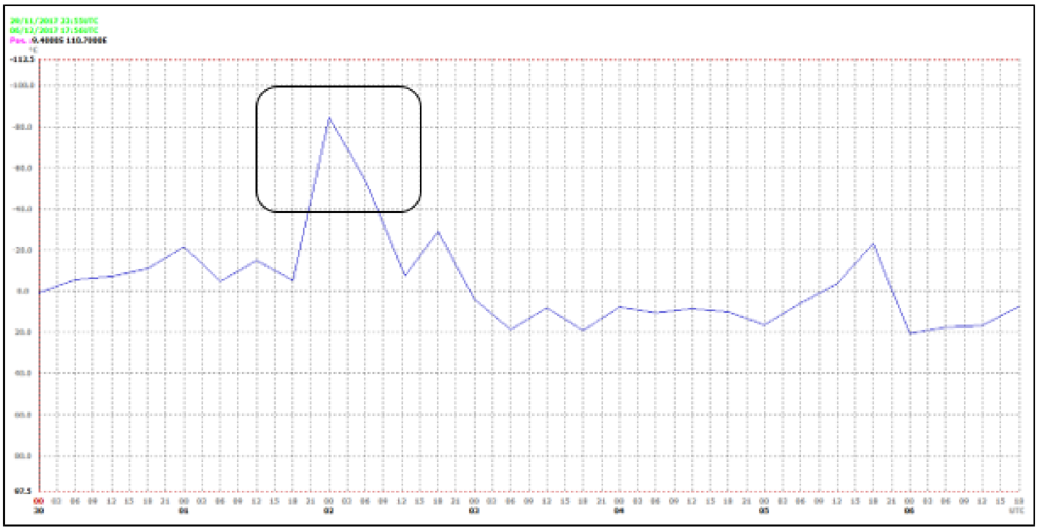


Figure 8. Time Series of cloud top temperature in the growth region of tropical cyclone Cempaka during the development of tropical cyclone Dahlia

Figure 9 shows a significant increase on December 1, 2017 with the cloud top temperature reaching -80°C due to the movement of tropical cyclone Dahlia which has entered the southern waters of Java and is in the mature stage. When tropical cyclones are in the mature stage, the cloud cover tends to be more organized and symmetrical with thick convective clouds at the eye wall of the cyclone. After both tropical cyclones decay, the atmospheric conditions stabilize again with the cloud top temperature decreasing to 20°C indicating that there is no potential for convective cloud formation.

4. Conclusion

This study successfully mapped the dynamics of tropical cyclones Cempaka and Dahlia using the Dvorak technique applied to Himawari-8 satellite thermal images, supported by ECMWF reanalysis data to comprehensively describe atmospheric conditions. Both cyclones were categorized as tropical storms (TS), with maximum intensities reaching 55 knots. The mature phase of both systems was marked by extremely low cloud top temperatures, ranging from –60°C to –80°C, and minimum central pressures of around 984 mb. Although both were classified as TS, the two cyclones exhibited different characteristics. TC Cempaka moved more slowly and remained near the southern coast of Java for a longer period, supported by consistently high relative humidity and stable convergence conditions. In contrast, TC Dahlia moved more quickly, with a more significant increase in vorticity (up to -48×10^{-5}/s) and wind speed, leading to stronger convective development in a shorter time. Additionally, after TC Cempaka dissipated, the re-intensification of atmospheric instability in the same region was influenced by the presence of TC Dahlia, as indicated by a sharp increase in vorticity (-35×10^{-5}/s) and wind speeds reaching the category of severe storm to hurricane. The development of both cyclones was also supported by favorable atmospheric conditions such as high relative humidity above 70% (at 700 mb), significant negative vorticity, and low-level convergence (at 850 mb), while reanalysis also confirmed that relative humidity, surface pressure, vorticity, and divergence were the most affected parameters during both cyclone events.

Suggestion

Future research is advised to expand the scope of analysis by incorporating additional parameters, including vertical wind shear, sea surface temperature anomalies, and the Madden-Julian Oscillation (MJO) phases, in order to achieve a more comprehensive understanding of the variability and development potential of tropical cyclones in the Indonesian region. It is also recommended to advance the utilization of satellite technologies and the assimilation of reanalysis data to further enhance the precision of tropical cyclone intensity estimations. Furthermore, the findings of this study are expected to serve as an important reference for the enhancement of early warning systems and the formulation of disaster risk reduction strategies, particularly in regions susceptible to the impacts of tropical cyclones.

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