The activity of Borneo Vortex as a trigger for extreme rain in West Borneo (case study: 24th – 25th January 2017)

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Abstract. On January 24th – 25th, 2017, Borneo Vortex has occurred that started to form at 00.00 UTC and caused the extreme rain in some areas of West Borneo. It recorded 154.1 mm/day of heavy rain in the Ketapang regency, part of West Borneo region that indicated as the effect of Borneo Vortex. The objective of this study was to determine the activity of the Borneo Vortex phenomenon that triggers the extreme rain in some areas of West Borneo. Conducted data for this study obtained from ECMWF reanalysis data for some parameters such as vorticity, divergence, vertical velocity, and humidity transport. Those data used for providing an overview of atmospheric conditions during the Borneo Vortex. Rainfall data from six meteorological stations in West Borneo also used to identify the extreme rain. Regional and local scale analysis conducted to determine changes in atmospheric conditions that occur as triggers of extreme rain in the West Borneo region. The result showed that Borneo Vortex has a significant impact to the changing of atmospheric conditions at the area where close to the forming zone of Borneo Vortex and trigger to increase the convective cloud growing up which affects the increase of rainfall in some areas of West Borneo.

Keywords : ECMWF, Borneo Vortex, vorticity, extreme rain.

1. Introduction
Kalimantan Island (Borneo) is one of the islands directly adjacent to the South China Sea. In the northwestern coast of the Borneo Island to the south of South China Sea, in the Riau Islands region, there is a low-level cyclonic circulation characterized by the Asian monsoon [1]. The Previous study stated that when the Asian monsoon occurred around early November and ended at the end of February there was a vortex phenomenon over Indonesian waters [2]. This vortex circulation is formed continuously on the northwest coast of Borneo Island and called Borneo Vortex [1].

Monsoon is a pattern of wind circulation that blows periodically in a period (at least 3 months) and other periods, the pattern will change to the opposite direction [3]. Indonesia has two types of monsoon. They are the Asian monsoon and the Australian monsoon. In the Indonesian Maritime Continent (IMC), rainy season happened when the Asian monsoon active and dry season happens at the time of Australian monsoon occurred [4]. Borneo Vortex is one of the phenomena that occurs while Asia winter monsoon is active and occur in the northwest of the island of Borneo and often associated with heavy rain and flood disasters [7].
On January 24th – 25th, 2017, the Borneo Vortex phenomenon occurred in Borneo Island. This phenomenon has led to convective cloud growing up which had the effect of causing heavy rain and strong winds in some areas of West Borneo [1]. As a result, it recorded on January 24th and there was an increasing of the rainfall intensity in several regions of West Borneo. Some part of West Borneo regions such as Ketapang, Pontianak, Paloh, and Putusibau had a high rainfall intensity, and the highest rainfall happened in Ketapang region that reached up to 154.1 mm/day. When Borneo Vortex occurred, there was a significant change in atmospheric conditions in West Borneo and triggered extreme rain in several regions. Therefore, this research will analyse the activity of Borneo Vortex as a trigger for extreme precipitation in the West Borneo region [6].

2. Data and Method

The data used in this research were the daily data from Era Interim ECMWF (European Center for Medium-Range Weather Forecast) in netCDF file format at 00.00 Coordinated Universal Time with 0.125° x 0.125° spatial resolution [8]. The data include of wind component parameters U (east-west), wind component V (north-south), divergence, relative vorticity, vertical velocity, specific humidity, and daily rainfall data from BMKG Meteorological Station observations. The research area is in West Borneo which located in 2.46°N - 3.70°S and 108.03°E - 114.90°E (Figure 1).

![Figure 1. Research Area. Include identified area of Borneo Vortex on 2.5°S-7.5°N and 102.5°E-117.5°E [2].](image)

The composite method was used in this research. Borneo vortex was identified by seeing a counter-clockwise circulation in the 925hPa layer in the area of 2.50° S - 7.50° N and 102.50° - 117.50° E and at least one wind exceeds 2 ms-1 [2]. The interaction between Borneo Vortex and the selected parameter were described by using composite analysis. Then the atmospheric conditions when Borneo Vortex occurred were analyzed to identify the effect of Borneo Vortex to each parameter such as vorticity, vertical velocity, divergence, and humidity transport during the occurrence of Borneo Vortex.

3. Result and Discussion

3.1 Identification of The Borneo Vortex

Formation of Borneo vortex happened due to the vorticity which reproduced by wind shear and reinforced by the northeast monsoon wind convergence with the topography of the island of Borneo [11]. Figure 2 shows the streamline of wind in level 925hPa which can be used to identify the existence
of Borneo Vortex on January 24th and 25th, 2017 (green box). It observed wind vortex around West Borneo that has closed circulation and counter-clockwise direction. The wind speed at that vortex reaches 4 - 6 m/s⁻¹. This condition agrees with [2], as the Borneo Vortex has closed circulation and counter-clockwise direction at the level 925hPa which identified at 2.5°S - 7.5°N and 102.5°E – 117.5°E and there is at least one wind velocity exceeds 2 m/s. Also, the vortex seen to move to the southwest which on 24th was in the West Borneo region, and on the 25th was in the northern part of Borneo Island, as well as caused the formed of rain clouds in the region.

3.2 Regional Scale Analysis
3.2.1 Analysis of Sea Surface Temperature
Figure 3 explains the daily mean sea surface temperature around the West Borneo region. It is shown that sea surface temperature is high in the north and south of Borneo Island with a high anomaly value. While the cold sea surface temperature with a low anomaly in the southwest part of the island of Borneo, caused by the flow of cold air masses from the South China Sea [1]. It is the cause of the air flow from the South China Sea to Borneo. The Asian winter monsoon brings a lot of moisture from the Pacific Ocean through the South China Sea, and meets winds from the southeast in the northwest region of Borneo and then forms cyclonic circulation [4]. The warming sea surface temperatures caused by the influence of Borneo Vortex, can have an impact on increasing convection and increasing the intensity of rainfall in the region [12].
Figure 3. Daily Mean Sea Surface Temperature (A) and Sea Surface Temperature Anomaly (B) on January 24th and 25th 2017.

3.3 Local Scale Analysis
3.3.1 Surface Air Pressure Analysis
The result from observation showed there is a low surface air pressure in the northern part of Borneo Island reaches 920hPa (figure 4.). The low pressure increased from 24th until 25th of January 2017, indicating that the vortex formed caused a pressure drop in the Borneo Island region and supported the formation of rain clouds formation produced [12] and evenly distributed rain in the West Borneo region on 24th January, 2017.

Figure 4. Surface Air Pressure (hPa) on January 24th 2017 (A) and (B) 25th 2017

3.3.2 Atmosphere Parameter Analysis
3.3.2.1 Vorticity Analysis
The vorticity values (Figure 5) on January 24th and 25th 2017, has average vorticity value of 1.5 x 10-5 s\(^{-1}\) to 4.5 x 10-5 s\(^{-1}\) [6]. It shows the distribution of vortices value. High vortices showed in the Northwest of Borneo Island waters, the South China Sea to northern Borneo, western and southern West Borneo. The center of vorticity was identified on northwest Borneo Island waters and South China Sea.
then the area of vortex spread to the mainland of West Borneo. Propagations of vorticity are quite high from the South China Sea to the equator and concentrated in the northwest waters of Borneo Island and it is expanding into the South China Sea due to the influence of vortex [10]. Then it caused the formation of rain clouds in the West Borneo region affected by vortex and due to horizontal differences in wind speeds formed in that region but the wind speeds in the Vortex center has been decreased [5].

![Image](image1)

**Figure 5.** Vorticity (s\(^{-1}\)) on January (A) 24\(^{th}\) 2017 and (B) 25\(^{th}\) 2017.

3.3.2.2 Divergence Analysis

The divergence value (Figure 6) on January 24\(^{th}\) and 25\(^{th}\) 2017. Indicated that there is a negative or small divergence with an average value of -7.0 x 10-6 s\(^{-1}\) to -1.0 x 10-6 s\(^{-1}\) [6], with high values of areas that have high convergence appear and concentrated in almost all the South China Sea to the Java Sea, the east of waters Borneo Island to the northwest of Borneo Island. While in the west Borneo region the divergence looks more dominant which is characteristic by very high divergences that are almost throughout the West Borneo region reached value 7.0 x 10-6 s\(^{-1}\), except in the southern part of West Borneo, there is a convergence that causes the air mass gather and formed rain clouds in this area. On January 25\(^{th}\), 2017, it seems that convergence tends to spread from east to south of West Borneo. Wind speed turns slow in the north-western of Borneo Island’s waters and it causes cold air masses that is moving from the Pacific Ocean to the equator gathered on this region, which is influenced by high convergence values and the presence of Vortex vorticity.

![Image](image2)

**Figure 6.** Divergence (s\(^{-1}\)) on January (A) 24\(^{th}\) 2017 and (B) 25\(^{th}\) 2017.
3.3.2.3 Vertical Velocity Analysis

The vertical velocity value (Figure 7) on January 24th and 25th, 2017 shows that there is a negative divergence which means that there is an air mass that rises with an average value of -0.1 Pa s\(^{-1}\) to -0.06 Pa s\(^{-1}\). The areas with the highest vertical velocity are seen in the South China Sea to the Java Sea, and in the East to Northwest of Borneo waters, this indicates that there is an increase on air mass around Borneo islands and the South China Sea [6]. The atmosphere that is considered as a fluid and is considered (compressible) is very easily influenced by its environmental conditions [9], then the air masses this is strengthened by the cold air masses flows from the Pacific Ocean to the equator, so that the mass of air collects because the cold air masses tend to have a higher density so that it can push warmer air masses up and form rain clouds [12]. Then, the vertical velocity in the West Borneo region have value 0 Pa s\(^{-1}\), this happened because the influence of the cold air mass on the equator only affected the territorial waters of Indonesia, so that the West Borneo region did not experience an increase in air mass compared to the Riau Islands region [6]. The influence of the movement of the wind and the topography of the islands in IMC is a major factor in the formation of Borneo Vortex, due to the interaction between continents and oceans [11].

![Figure 7. Vertical Velocity (Pa s\(^{-1}\)) on January (A) 24th 2017 and (B) 25th 2017.](image)

3.3.2.4 Moisture Transport Analysis

Moisture transport value (Figure 8) on January 24th and 25th, 2017 shows that there is a movement of water vapor supply that enters to Indonesian waters that spread through the South China Sea into the waters of Bangka Belitung. It can be seen that the moisture transport value reaches an average value of 600 to 1400 kgms\(^{-1}\), but on January 25th 2017, it can be seen that the humidity transport value is decreased because there are weakening effect of the vortex, which is 600 to 1200 kgms\(^{-1}\). Indicates that the availability of moisture in on January 25th, 2017 is less than on January 24th, 2017. Showed the area that has high humidity transport moves from the Pacific Ocean to the equator and looks dominant in the South China Sea up to 2.5\(^{\circ}\)N. This high humidity transport values has caused by the influences of moisture vapor by Borneo Vortex formed in the Northwest waters of Borneo Island [6]. There is indicating that there sufficient supply of water vapor to make the air conditions in the region wet, moist, and can support the process of large convective clouds growth with high top clouds, so that the chance of rain with moderate to heavy intensity increase [7]. Wind velocity in the event of Borneo Vortex shows a strong influence to support the increase of wind movement from the Pacific Ocean to the equator carrying the supply of water vapor, later than the air mass is concentrated in the Northwest waters of Borneo Island due to the influence of the Vortex formed [10].
3.3.3 Rainfall Distribution Analysis

Rainfall distribution values (Figure 9) when Borneo Vortex occurred generally shows that there is a high distribution of rainfall in several research areas. It can be seen that there is a distribution of rainfall reaching a value of more than 27 mm/day on the South China Sea to the coast of Borneo Island, northwest of Borneo Island waters, and the western and southern parts of West Borneo. The distribution of rainfall indicates that there is a high rainfall concentration in the West Borneo region, the north, west, and south, marked by a large supply of water vapour on the coast of Borneo Island to the waters of the southern island of Borneo [6]. This confirms that heavy until very thick intensity rain in several areas of the research area has occurred. Then based on rainfall distribution shown at the time of the Borneo Vortex incident on January 24th 2017, indicated the tendency to have a higher distribution value more than caused on January 25th 2017 in all research locations. It shows that the most powerful influence of Borneo Vortex occurred on January 24th, 2017, because on January 24th was the strongest occurred of Borneo Vortex intensity.

Figure 8. Moisture Transport (kg ms$^{-1}$) on January (A) 24th 2017 and (B) 25th 2017.

Figure 9. Rainfall Distribution of TRMM (mm) on January (A) 24th 2017 and (B) 25th 2017.
Figure 10 shows the chart of rainfall observation values of each station. When Borneo Vortex occurred on 24 until 25 January 2017, the incident caused an increasing rainfall intensity on 24 January 2017, recorded in the region of West Borneo the highest rainfall was in the area of Paloh, Pontianak and Ketapang. It recorded rainfall ranged from 73.1 until 154.1 mm/day, where the region represents the northern, western and southern regions. The central and eastern regions have lower rainfall there are Sintang, Nangapinoh, and Putusibau regions ranging from 10.9 - 52.0 mm/day, it shows that the rainfall occurs in almost all regions with intensity range from slight to very heavy.

![Rainfall Observation Chart](image)

**Figure 10. Rainfall Observation Chart on Meteorological Station at January 24th until 25th, 2017 (Source: www.ogimet.com/synop report).**

4. Conclusion  
Based on regional scale analysis sea surface temperatures in the South China Sea cooler than the heat of around West Borneo. This causes air flowed from the Pacific Ocean travel through the South China Sea and convergence the winds from the southeast in the northwest region of Borneo Island, and then formed the cyclonic circulation. Based on a local scale analysis of atmospheric conditions during the Borneo Vortex event, there was a significant increase on surface pressure, vorticity, divergence, vertical velocity, and moisture transport. It was observed that in the event of Borneo vortex, the value of atmospheric parameters as the indicator of atmospheric conditions can change become higher than the normal value. Based on the results of the analysis of rainfall distribution during the Borneo Vortex on January 24th until 25th, 2017, the incidence of vortex triggered the increase of rainfall in several regions of West Borneo. Recorded on January 24th, 2017 in the West Borneo region the highest rainfall was affected Paloh, Pontianak, and Ketapang regions, which recorded rainfall ranges from 73.1 - 154.1 mm/day. This was significantly affected the region represents the northern, western, and southern regions of West Borneo, while the central and eastern regions have lower rainfall in Sintang, Nangapinoh and Putusibau regions ranging from 10.9 - 52.0 mm/day.

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