Atmospheric study of the impact of Borneo vortex and Madden-Julian oscillation over Western Indonesian maritime area

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Abstract. During the Asian winter Monsoon (November-March), the Indonesia Maritime Continent is an area of deep convection. In that period, there is a synoptic scale disturbance over Northwest of Borneo Island called Borneo vortex. In addition to the impact of Asian Winter Monsoon, Madden-Julian Oscillation (MJO) also have an impact on deep convection during an active period. This study aims to study the impact of interaction Borneo vortex and MJO (during MJO active period in phase 3, 4 and 5) and rainfall condition over the western part of Indonesia Maritime Continent using compositing technique in the period of November-March 2015/2016. The parameters used to identify the incidence of Borneo vortex, MJO, and its interaction is vertical velocity. When MJO is active, Borneo vortex occurs most often in phase 5 and at least in phase 3. However, Borneo vortex occurs most often when the MJO is inactive. The interaction between Borneo vortex and MJO seems may affect not so much rainfall occurrence in the western part of IMC.

1. Introduction

Indonesia is referred to as the Indonesian Maritime Continent (IMC) because Indonesia is an archipelago state located in the tropics. IMC located between two continent namely Asia and Australia, and two ocean namely Pacific and Indian. The impact of the geographical location is experiencing an Indonesia maritime continent seasonal wind blow from the continent of Asia (the Asian Monsoon) and the continent of Australia (the Australia Monsoon) which changed its direction periodically [1]. The air circulation in the influence by the motion of the Sun, all at a time when the position of the Sun in the northern hemisphere then high pressure will be in South hemisphere and Australia as well as the Monsoon occurs otherwise at the time the position of the Sun in the South (also known as with the boreal winter) is going to happen to the movement of air masses from Asia towards an Indonesia maritime continent which is called Monsoon Asia. The characteristics of air masses originating from the continent of Asia is both cold and dry. At the time of the air, masses interact with IMC's warm causes deep convection in that area.

During the period of the Asian Monsoon, the synoptic scale weather disruption, there is either a closed circulation of the cyclone in the western part of the island of Borneo known as the Borneo vortex[4]. The phenomenon of the Borneo vortex associated with the incidence of heavy rain around the region of Sumatera, Borneo, and Java [5]. The strength and position of the Borneo vortex are
sensitive to the presence of cold surge. The convection area around of the Borneo vortex will be strengthened when cold surge strengthens.

The IMC region also experienced the phenomenon in the form of a moving oscillation of the Indian Ocean towards the East in the area of Equator with a period of 30-60 days known as the Madden Julian Oscillation (MJO). According to Holton [8], the phenomenon of convection, thus reviving MJO effect on the increase in rainfall. The movement of the MJO is divided into 8 phases starting from the Indian Ocean to the Western Pacific and is in the region of Indonesian maritime continent on phase 4 and 5.

The phenomenon of the MJO and the Borneo vortex cause the IMC’s area become an active area of deep convection, but there have been no studies specifically observed the existence of this phenomenon at the same time. The purpose of this research is to see the influence of MJO activity against Borneo vortex and its impact on rainfall in the western part of the Indonesia maritime continent. In this journal will be discussed regarding the influence of activity of the Borneo vortex without the MJO and the interaction of the Borneo vortex with the MJO (in phase 3, 4, and 5).

2. Data and method

The data used in this study is an ECMWF (European Center for Medium-Range Weather Forecast) ERA-Interim reanalysis Interim data at 00.00 Universal Time Conversion (UTC) last November 2015 to March 2016 in the 925 hPa in the atmospheric layer with spatial resolution 2.5° x 2.5°. The parameters used are vertical velocity (vertical motion). Data of Madden Julian Oscillation (MJO) used are sourced from Bureau of Meteorological with data period is November 2015 until March 2016. Satellite data from TRMM (Tropical rain shower Measuring Mission) is used to view the distribution of precipitation.

The region became research area is in the West part of IMC (95°- 120° E 10° S 10° N) which includes the islands of Sumatera, Borneo, and Java (Figure 1).

![Figure 1. Western Indonesian maritime continent on 95°- 120° E 10° S 10° N, includes Sumatera island, Borneo island and Java island.](image)

Borneo vortex is identified with the way saw a counter-clockwise circulation in the 925 hPa layer in the area of 2.5° S-7.5° N and 102.5°-117.5° E and at least one wind exceeds 2 ms⁻¹ [3]. The phenomenon is observed when the MJO is in the Indonesia maritime continent, namely phases 4 and 5 (the maritime continent), as well as on phases 3 expansion when the MJO is starting to get to the West coast of Sumatera.
After identifying the incidence of Borneo vortex and the MJO, then performed in which the incidence of the Borneo vortex without the MJO and the interaction of the Borneo vortex with the MJO on phases 3, 4 and 5 and see its impact on rainfall in the western part of the IMC.

3. Result and Discussion

3.1 Identification of Borneo vortex

Formation of Borneo vortex happens due to the vorticity which is reproduced by wind shear and reinforced by the northeast monsoon wind convergence with the topography of the island of Borneo [11]. Figure 2 shows one Borneo vortex that is observed. During the period from November until March 2015/2016, there were 19 events of Borneo vortex, which mostly appears in November and March. Meanwhile, the Borneo vortex has the longest period in December (4 days) same with Chang [4].

![Figure 2. Winds at 925 hPa and identification area of Borneo vortex (green box).](image)

3.2 Identification of Madden-Julian Oscillation

MJO can be distinguished by 2 conditions, strong and weak/ inactive. Through the phase diagram of the MJO (figure 3), active MJO conditions identified by the position of the line outside the centre (circle), the farther from the centre of the circle the more strong intensity of the MJO. When MJO is active in phase 4, it signifies the MJO appear in the western IMC and in phase 5 appear in the eastern IMC.
Figure 3. MJO diagram phase period October - December 2015 (above) and January - March 2016 (below).
From figure 3 we can be observed the appearance of strong MJO on phase 3, 4 and 5. During November – December 2015, MJO phenomenon appeared for 33 days and longest occurred in November at phase 4. Meanwhile, in the period January to March 2016, MJO phenomena appear for 35 days with the longest period (9 days appear in phase 4 in February).

3.3 The Impact study of MJO and Borneo vortex

After analyzing the genesis of Borneo vortex and MJO, then the data displayed into a graph (figure 4).

**Figure 4.** Frequency of occurrences Borneo vortex (total), Borneo vortex during MJO phases 3, Borneo vortex during MJO phases 4, Borneo vortex during MJO phases 5 and Borneo vortex without MJO.

Based on figure 4, the Borneo vortex phenomenon most occur when the inactive MJO on all phase (phase 3, 4 and 5) of 42.10% of the total incidence of the Borneo vortex. The frequency of occurrence of the phenomenon of Borneo vortex at most at a time when strong MJO phase 5 as 6 events (31.57%) and there is a period of Borneo vortex is most long 4 events in December. In otherwise, when active MJO is in phase 3, there is one case of Borneo vortex (5.26%) and in phase 4 there are 4 cases (21.05%). According to Chang [4] the impact of the existence of the MJO is weaken the cold surge that influence to the formation of Borneo vortex so that the frequency of occurrence of Borneo vortex at the moment the MJO is in phase 3 and 4 (Western of IMC) is smaller than when the MJO is strong in phase 5.
Figure 5. Vertical velocity (ms\(^{-1}\)) during Borneo vortex without active MJO.

By knowing the value of vertical velocity parameters, the movement of air masses surrounding the region of the vortex can be known. The cyclonic flow on Borneo vortex system will make the air mass moves upward. The movement of air masses over and commensurate convection causes the convection that occurs. In figure 5, the region of Peninsula Malaysia, Karimata Strait to the South of the island of Borneo, there is a current of rising air masses that are strong enough (marked with colours increasingly blue). The smaller the value of vertical speed indicates the movement of air masses upward. The movement of air masses rise will be higher in the centre of the vortex.

When the Borneo vortex appeared in the period of active MJO, especially in phase 3 and 4, the value of vertical velocity does not indicate the existence of a mass movement of a strong upward air as in genesis Borneo vortex only. This indicates the intensity of the vortex that is not too strong. Unlike the MJO on phase 5, there is a rising air mass movement in the environment near the centre of the vortex (the South China Sea northern Borneo).
3.4 Rainfall study using TRMM

Based on the rainfall data from TRMM satellite during the occurrence of Borneo vortex without MJO (figure 7) can be known that rainfall at the time of occurrence of Borneo vortex without MJO recorded slightly to heavy rain near the vortex occurrence.
Figure 7. Rainfall intensity from TRMM’s data (mm) during Borneo vortex without MJO.

Generally, rainfall is recorded with the intensity of the slight to moderate rain (10 - 40 mm) which includes the western part of Indonesia (Western and southern parts of Kalimantan, Java Sea, the southern part of the Sumatra Island and the western part of Java Island). Recorded data of heavy rain (50 - 100 mm) around the waters of Riau Islands and Bangka Belitung. From figure 8, there was heavy rain in the Riau Islands and northern Borneo island to the amount of precipitation more than 110 mm.
Rainfall data recorded when the occurrence of Borneo vortex without MJO different with the amount of precipitation at the time of occurrence of Borneo vortex which appears simultaneously at the time of active MJO on phase 3. From figure 8 (a) can be known that rain occurred with slight rain (10 – 20 mm) with a wider area coverage of rain (West and South of the island of Borneo as a whole, Western Malaysia, Sumatra and the western part of Java island that extends to the Middle section). While the rainfall data recorded when the occurrence of Borneo vortex appeared concurrently with the active MJO on phase 4, rainfall increased to heavy intensity (10–90 mm) with a wider area of coverage again. However, the high intensity of rainfall does not occur in the western part of Borneo, but it occurs at the Java Sea and the western part of the island of Sumatra. While the coverage area in Sumatera’s trench narrows with the slight rain. The air mass from southwest of Sumatera met the air mass from northeastern Sumatera. The effect is high rainfall intensity over the southern area of IMC. At the time of occurrence of Borneo vortex appeared concurrently with the active MJO on phase 5, heavy rain recorded by region with the center of the vortex in South China Sea and precipitation recorded over 110 mm, while in the West area of IMC, the rainfall intensity vary from 20-50 mm, which located in the central of the Java Sea.

4. Conclusion
From this research study can be summarized as follows the highest frequency occurrence of Borneo vortex was during inactive MJO phases 3, 4 or 5. MJO may decrease the frequency of Borneo vortex especially during MJO phases 3 and 4. When MJO at phases 5, frequency Borneo Vortex may
increasing. Meanwhile, the interaction between MJO and Borneo vortex may enhance the indication of vertical motion as part of the convective process. Based on this study, tell us that the interaction between MJO (in phases 3 and 5) and Borneo vortex may affect the rainfall intensity over western IMC but not so much. The interaction between MJO phases 4 and Borneo vortex may increase rainfall intensity over western IMC.

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