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Atmospheric Study of the Impact of Cold Surges and Borneo Vortex over Western Indonesia Maritime Continent Area

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Abstract

Cold surges and Borneo Vortex are the synoptic scale disturbances during the Asian Winter Monsoon period (November-March). These disturbances have closely linked with the growth of strong convective clouds and heavy rains in the western part of the Maritime Continent.

This study is subjected to study impact of cold surges and Borneo Vortex to the against atmospheric and rainfall conditions over the western part of the Maritime Continent using compositing technique these parameters for the period of November-March 2004/02-2014/15. The highest frequency of cold surge events occurs in January, while the incidence of Borneo Vortex alone and their interaction occurs in December. The atmospheric parameters of vortices, divergence, and moisture transport indicate that the incidence of cold surge, Borneo Vortex and their interaction having different influences. Region of South China Sea is mostly affected by the most significant of the other regions. Cold surge has the impact of increasing rainfall in all regions except Central Borneo/Kalimantan Island, Borneo Vortex while increasing rainfall throughout the region except Java, and the interaction of both resulted in increased throughout the study area.

This is preliminary study and it would be triggering further study, it was due to the lack study over Indonesia.

Keywords: Cold surge; Borneo vortex; Maritime continent; Atmospheric parameters

Introduction

Indonesia Maritime Continent area comprises from series big and small islands which separates the waters (sea and ocean), this condition mentioned as Maritime Continent Area [1]. As Aldrian [2] study, Indonesia area lies over 2 continents and 2 oceans. So that over this region has interesting weather phenomena to be studied. Indonesia Maritime Continent (IMC) is affected by regional wind of monsoonal wind to be due to the contrast between ocean and continent as well as lad/sea breeze circulation in synoptic scale point of view.

Zakir et al. [3] mentioned the monsoonal wind to be wind circulation pattern which are blowing periodically wind blowing in the consecutive direction and in another period in opposite direction. Tjasyono [4] studied monsoon that reversal on the wind direction on the consecutive monsoon period and differentiation of the seasonal condition in terms cloudy, rainfall and surface temperature. Where Indonesia Maritime Continent (IMC) is affected by Asian and Australian Monsoon.

During the active winter monsoon frequently occurs cold air advection from highland of Siberia of Northern Asian Continent of the so called cold surge. Yihui [5] defined “cold surge” as surging the Asian cold air to the South China Sea area. This Cold surge is the one weather disturbance to cause annual rainfall pattern especially over northwest IMC area the so called formation Monsoonal Asian Winter cycle [6]. Hattori et al. [7] studied that cold surge activity may cause increasing the rainfall over Java sea, western Borneo and eastern part of the Philippines area. Takahashi et al. [8] study showed that heavy rainfall to be occurred over west Malaysia area last end of December 2006, it was due to the cold surge activity.

Beside cold surge disturbance, during active period of Asia Winter Monsoon, there is another weather disturbance of the so called Borneo Vortex. It has been occurred over Northwest of Borneo Island which has linked with heavy rainfall activities to cause flooding area [9-12]. This weather disturbance is unusual disturbance because one of vortex occurs near the equator.

Asian Winter Monsoon has frequent been linked with occurrences of both weather disturbances of cold surge and Borneo Vortex disturbances. Main factor linked with the interaction of the strong wind occurrence with topographical condition over western Malaysia and IMC areas [13]. Both cold surge and Borneo Vortex strongly affects extreme weather conditions over western and middle IMC region [14].

From these weather disturbances, they are very interesting to be studied where the three aspect will be designed in this paper e.g., Cold Surge activity itself without Borneo Vortex activity, reversal Borneo Vortex without Borneo Vortex and the last both Borneo Vortex and Sold Surge activities. So that three options will be further studied in this paper.

Data and Method

The data might be used in this study to be Reanalysis ERA Interim ECMWF (European Centre for Medium-Range Weather Forecast) data

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at 00.00 Universal Time Conversion (UTC) in atmospheric layers from 925-300 hecto Pascal (h.Pa.) with spatial resolution 2.5° × 2.5° in terms of wind components of u and v; vorticity field; divergence field and moisture transport. Rainfall study used daily rainfall data from n TRMM (Tropical Rainfall Measuring Mission) and rainfall measurement from Meteorological Stations of Indonesia Meteorological and Geophysical Agency of the so called BMKG.

Used vorticity parameter is subjected to measure vertical microscopic circulation from every study option; meanwhile the divergence parameter to study area convergence/divergence of air mass and moisture transport will be used measure surging/advection the water vapour. The simple formula to use as follows,

$$Bq = \int_0^{300} qVdz \qquad (1)$$

Moisture transport quantity is counted using formula (1). Where level of 300 hecto Pascal will be used as above boundary with small moisture so it obeyed.

Location of the study will be over western IMC area, with 26 points of rainfall station and it will divided into 6 group (Figure 1) as follows,

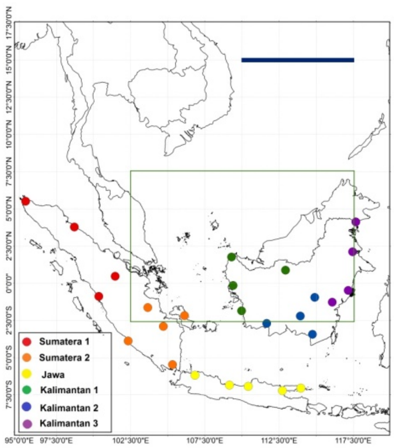

Figure 1: Colouring dots are rainfall stations and grouping divisions and squared box area is impact area from Cold Surge.

Cold Surge Index processing will be computed using Chang's et al. where computations mean meridional wind over 110°E latitude–117.5°E latitude along 15°North longitude. Used Index in this paper having assumption that impact from Cold Surge has not break time more than one day. This study obeys arising Cold Surge intensity.

Occurrence Borneo Vortex will be studied by observing closed counter-clock circulation on the layer 925 h.Pa. at 2.5° South–7.5° North and 102.5° East–117.5° East and at least having one wind component not more than 2 ms^{-1} [10]. Existing monsoonal wind interaction and Borneo topography presented at (Figure 2) such that causing occurrence of Borneo Vortex.

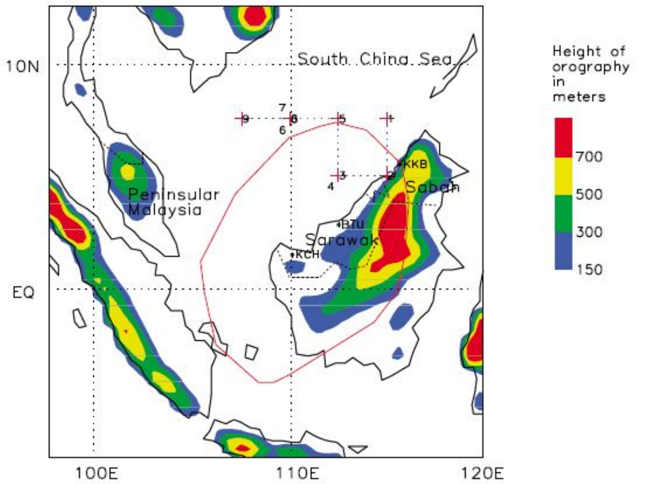

Figure 2: Western IMC topography [15].

After identification of the cold surge and Borneo Vortex occurrences, then they were classified their probability of their occurrences such as normal occurrences (without cold surge and Borneo Vortex occurrences), cold surge occurrence itself without Borneo Vortex, Borneo Vortex occurrence without cold surge, and coincident cold surge and Borneo Vortex occurrences (Figure 3).

Result and Discussion

Identification Borneo vortex

Borneo Vortex occurred; it was due to the shear Westerly wind in the southern area with Northeast Winter Monsoon from North Asia continent, such that those winds interact with Northwest Borneo topography (Figure 3).

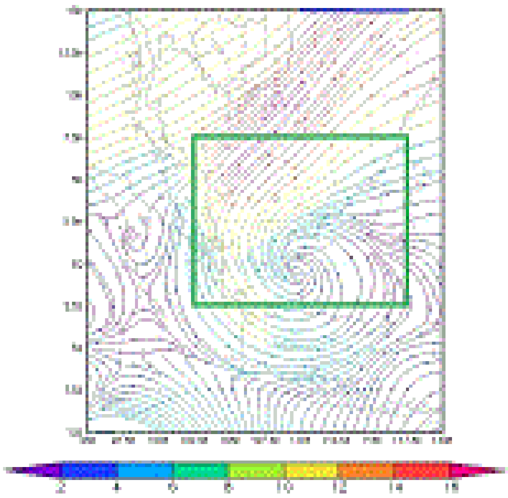

Figure 3: Winds at 925 h.Pa. level (ms^{-1}).

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Based on the Figure 4, December is the month having more weather disturbances. If looking from comparison frequency occurrences of Borneo Vortex, it was known that on month of December to have high frequency of occurrences which indicated that this month having more active of Borneo Vortex occurrence [10,11,13,16,17].

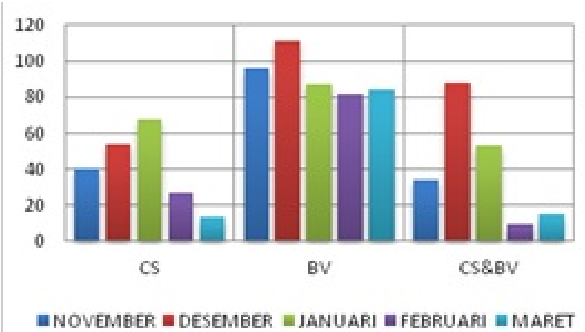

Figure 4: Frequency of occurrences Cold Surge and Borneo Vortex.

Anip and Lupo [10] stated that from November-February vortex centre may shift toward southeast approaching equator line. Vortex has longest life time in December, which indicated that Asian Winter Monsoon was more active during period November–February. More actively of occurrences of Borneo Vortex on December linked with existing strongest southeast trade wind on that month [13]. High frequency of occurrence of Cold Surge itself occurred on January. But, if looking daily occurrence of Cold Surge; so that December is the month more active of this disturbance [6,13].

Cold surge and Borneo Vortex may interact together with highest frequency on December. This occurrence has lowest frequency from another occurrence. Formation this occurrence required wind force from Southeast trade wind to encourage strong wind development from North direction as impact from Cold Surge to form Borneo Vortex. Becoming stronger from the north wind, it was required from strong Southeast trade wind to generate Borneo Vortex.

Impact study

From Compositing of the voracity parameter on the occurrences of the Cold surge, Borneo Vortex, and both Cold surge and Borneo Vortex give the significant result (Figure 5). There was transport high values vorticity advection from South China Sea toward the equator and centralized Northwest of Borneo (Kalimantan) island. It was same study by Wibianto [17] with his study during the period of Cold surge with high vorticity values movement southward. Centralized high vorticity values in Northwest Borneo/Kalimantan coincide with Borneo Vortex occurrence. These conditions may indicate strong counter clockwise circulation during the Borneo vortex occurrence. It indicated that there was increasing Borneo Vortex intensity over Northwest Borneo island. Increasing intensity of Borneo Vortex coincide with the Cold surge. High values of vorticity during Cold surge and Borneo Vortex occurrence reached value of $3 \times 10^{-5-3}$, $5 \times 10^{-5}\ s^{-1}$ and this condition might be higher values comparing with others. The strong winds pushed and encourage speed of circulation of Borneo Vortex.

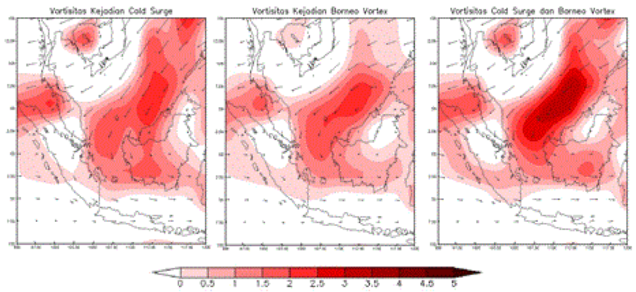

Figure 5: Compositing Vorticity ($10^{-5}\ s^{-1}$) during cold surge, Borneo Vortex occurrences also cold surge & Borneo Vortex occurred together on the months of NDJFM for the period 2004/05–2014/15.

Vortex is the main caused of increasing vorticity parameter over the waters Northwest Borneo/Kalimantan. From compositing technique of divergence parameter (Figure 6) produce negative divergence (convergence) in the South China Sea from Equator line reaching the divergence value-$6 \times 10^{-6}\ s^{-1}$ until -$7 \times 10^{-6}\ s^{-1}$.

It was due to the deceleration of wind speed toward equator, such that there store air mass over South China Sea up to equator line. When Borneo Vortex case found the convergence area over Northwest Borneo/Kalimantan Island with the value $5 \times 10^{-6}\ s^{-1}$ until $6 \times 10^{-6}\ s^{-1}$.

Different occurrence with cold surge activity, convergence area was due to the existing Borneo Vortex with exception of deceleration of air mass motion; it will be cyclonic motion such that converging of the air mass. Converging area occurred when cold surge and Borneo Vortex occurred together, divergence value not more that -$10 \times 10^{-6} s^{-1}$ (Figure 7).

Big divergence value was due to the increasing power from Borneo Vortex and cold surge so that they form circulation to be stronger from atmospheric condition without cold surge activity.

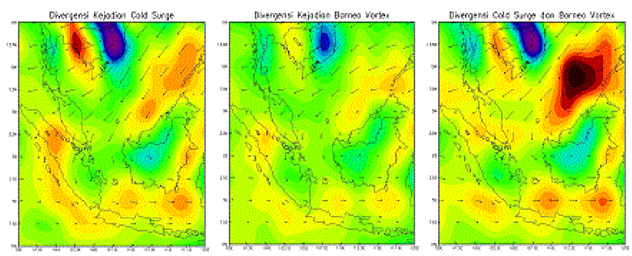

Figure 6: Compositing Divergence ($10^{-6}\ s^{-1}$) during cold surge, Borneo Vortex occurrences also cold surge & Borneo Vortex occurred together on the months of NDJFM for the period 2004/05–2014/15.

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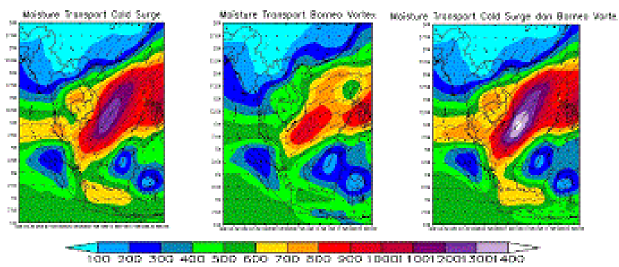

Figure 7: Compositing moisture transport (kg. ms^{-1}) during the cold surge (left), Borneo Vortex (middle), and cold surge & Borneo Vortex together (right) on the months of NDJFM 2004/05–2014/15.

Lowest values (negative) divergence were North Sumatera island with the range values 4 × 10^{-6} s^{-1}-7 × 10^{-6} s^{-1}, it was due to the converging air mass from Indian ocean on the western and Asian winter monsoon on the eastern sides. In spite, there was a high negative value over the Java Sea; it was due to the convergence area of Southeast Trade wind on the southern side and Asian and Asian winter on the northern sides. These lowest values of divergence encourage convective cloud development having potency of heavy rainfall occurrences. From compositing study of moisture transport (Figure 8) showed that Cold surge activity having moisture transport values ranging 1200-1300 kg ms^{-1}. These total moisture were due to the strong wind from the Cold surge such that transporting the moisture toward the equator. Different case with Borneo Vortex occurrence, it has moisture transport value ranging from 900-1000 kg ms^{-1}, to lower value comparing during Cold surge occurrence; because the North wind speed was not so strong such as during Cold surge occurrence. High moisture transport values were identified from coincide Cold surge and Borneo Vortex occurrence ranging from 1400-1500 kg ms^{-1}. High moisture transport values were due to pulling impact moisture by the Borneo Vortex such that to store many of the moistures.

In general over Maritime Continent area, incoming moisture transport came from South China Sea, the Pacific Ocean and Indian Ocean [14]. Most of the total moistures were toward the equator having support to the strong potential cloud development of convective cloudy type, if there were support from atmospheric condition. Based upon this finding, the moisture transport study might have important parameter to the developing the weather system over Maritime Continent area.

Rainfall Study using TRMM

Compositing technique of the monthly rainfall on the months NDJFM (November, December, January, February, March) 2004/05–2014/15 from each occurrence (Figure 9) give the different result significantly. During the Cold surge occurrence having high rainfall over South China Sea area ranging 7–15 mm. There was highest rainfall over small area in Western Borneo/Kalimantan and along East coast of North Sumatra. Besides, there were also high rainfall areas (15–21 mm) over the Java Sea. In general, high rainfall occurrences over Western Borneo/Kalimantan, along coastal North Sumatra and Java sea areas, they came from cold advection from Winter Season over North hemisphere toward equator area in the southern part. The movement of cold air mass southward direction may converge with warm air mass in the equator area in the lower troposphere. These may encourage huge convective cloud development over the tropical area.

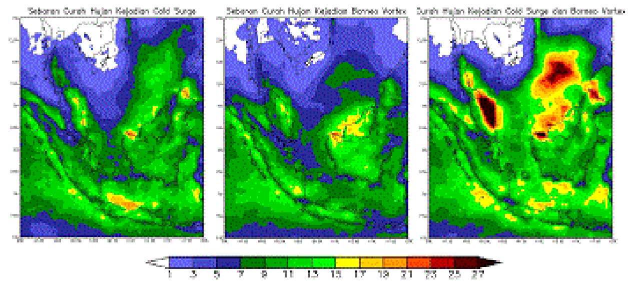

Figure 8: Compositing Rainfall from TRMM's data (mm) during Cold surge (left), Borneo Vortex (middle), and Cold surge & Borneo Vortex together (right) during months of NDJFM 2004/05–2014/15.

Borneo Vortex may encourage the rainfall occurrences over islands of Borneo/Kalimantan (7–23 mm.) and Southern Sumatera (7–17 mm.), but there was decreasing rainfall occurrences over Java island. It was due to deceleration air mass transported by the Asia winter monsoon wind with existing Borneo Vortex such that southern area (Java Island) receiving less of the rainfall.

When cold surge and Borneo Vortex occur coincidently, it might encourage high rainfall occurrences over South China Sea and almost the whole Borneo/Kalimantan Island reaching more than 27 mm. The high rainfall expanded also over some areas Sumatera and Java islands. During Cold surge and Borneo Vortex occurrence (Figure 9) showed that high rainfall occurred over western coast Southern Sumatera Island. This condition was caused by incoming air mass movement from Indian Ocean through Sumatera island. When Borneo Vortex occurred and it was caused from pushing the strong wind came from the Cold surge, so the size of the vortex expanded the area wider area if it occurred without Cold surge occurrence, such that expansion of the high rainfall occurrence over west Maritime Continent area.

Study of the rainfall observation

Processing of the rainfall observation from the meteorological station was done with the compositing technique from every occurrence. Computation of the rainfall was done using classification rainfall observing station followed rainfall distribution areas (Figure 8). From this figure areas were classified into 6 areas/regions (Figure 1).

From the result, there were increasing and decreasing areas of the rainfall over some part areas. Figure 2 presented that impact Cold surge and Borneo Vortex may cause increasing numbers of the rainfall over most the research areas except over area Borneo 2. It was due that area Borneo 2 was in the back of the mountainous area in Borneo/Kalimantan Island such that the developing of the cloud was less. Only Cold Surge occurrence itself may cause the decreasing the rainfall over Borneo 2 area around 6.9% and then additional number of rainfall occurred in area Sumatera 1 (2.7%), Sumatera 2 (1.1%), Borneo 1 (13%), Borneo 3 (25.8%) and area Java (21.9%). Increasing rainfall was caused cold advection process from cold air mass transported by the cold surge converged with warm air mass lying over the equator area. Serious impact the cold surge was over area Borneo 3 (25.8%). Because area Borneo 3 was over font area of the mountainous region of

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incoming strong wind flow coincides with cold surge activity, these areas were initial area when surge arrived.

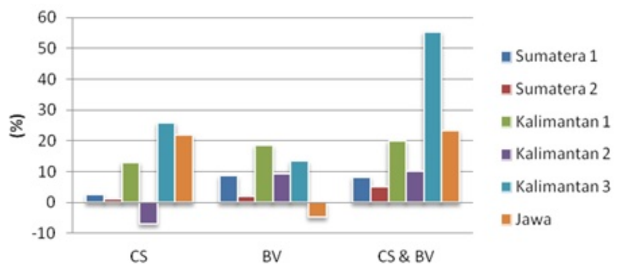

Figure 9: Rainfall Anomaly (mm) during occurrence of Cold surge & Borneo Vortex occurrences, and their interaction from compositing rainfall percentages on the months of NDJFM period 2004/05–2014/15.

Only Borneo Vortex occurrence might cause increasing number of the total rainfall overall impact locations, except over Java Island. When active Borneo Vortex occurrence had trend the air motion centralized in the center of the vortex. Their impact may be increasing rainfall over locations of Sumatera 1 (8.6%), Sumatera 2 (1.9%), Borneo 1 (18.5%), Borneo 2 (9.3%) and Borneo 3 (13.4%). It was reversal with rainfall occurrence over Java Island to decrease of the amount 4.8%. Most of the increasing total number of rainfall was over area nearest the central vortex (Locations of Sumatera 1 and over Borneo). Increasing rainfall over location Sumatera 2 where was away from central vortex, it was due to the wind convergence of Asia Winter Monsoonal wind and Southeast trade wind. This convergence zone extended from Indian Ocean, location Sumatera 2 and Java Sea. Decreasing of the rainfall in Java Island was due to blocking air mass in central vortex, such that it caused over some part Java Island not receiving these moist air mass to support the convective cloud development. Increasing the total highest rainfall was over Borneo location because this location was closed with central vortex. Beside the location Borneo 3 received the highest number rainfall, this location was convergence zone before the wet air mass centralized to form cyclonic pattern (Figure 7).

When Cold surge and Borneo Vortex occurred together, it might cause the increasing of the rainfall overall the study areas. It was due to the mixing process of the mechanical and thermal processes. Increasing of rainfall percentages as follows: Sumatera 1 area, 8.3%; Sumatera 2 area 4.9%; Borneo 1 area 19.9%; Borneo 2 area 10%, Borneo 3 area 55.2%, and Java area 23.3%. During Cold surge and Borneo Vortex occurred together, moisture transport didn't fully store in the vortex center. There was part of moisture transport during Cold Surge occurrence expanded southward direction. Increasing rainfall over Java Island was higher than rainfall causing from only Cold Surge occurrence itself. It was due the migrating convergence zone southward direction because it came from strong pushing cold surge activity from the Northern hemisphere. Meanwhile, over Sumatera 1 area there was increasing rainfall higher than rainfall occurrence over Sumatera 2 area, because position Sumatera 1 area was closed with vortex center. Observation over Borneo Island indicates the same condition when it was closed with vortex center, so that more closely with this center, they caused increasing their rainfall. But it might be different with Borneo 3 area which had own local topography to support increasing the highest rainfall than others areas.

Summary and Conclusion

From this research study can be summarized as follows:

A highest frequency occurrence of the only cold surge was in January, meanwhile only Borneo Vortex in December.

There was a significant parameters change such as vortices, divergence, moisture transport and rainfall; it was due to the Cold surge and Borneo Vortex activities. The areas were having significant changes to be over South China Sea and most Island over Western Indonesia area.

Most of the Cold surge activities to support the development of Borneo Vortex.

Impact of the twin activities of Cold surge and Borneo Vortex might cause increasing rainfall overall observation areas, meanwhile Cold surge activity causing increasing rainfall overall station except Borneo 2 area and only Borneo Vortex activity causing rainfall overall areas except over Java Island.

The highest increasing of the rainfall occurred over Borneo 1 area, it came from only Borneo Vortex activity; increasing rainfall over Borneo 3, it came from both only Cold surge activity and both twin Cold surge and Borneo Vortex activities.

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