IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

The Influence of ENSO and IOD During Mesoscale Convective Complex (MCC) to Rainfall in Indonesia

To cite this article: S Rustiana *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **303** 012006

View the article online for updates and enhancements.

This content was downloaded from IP address 120.234.63.196 on 08/11/2019 at 12:24

The Influence of ENSO and IOD During Mesoscale Convective Complex (MCC) to Rainfall in Indonesia

S Rustiana[1], Trismidianto[1] and H Satyawardhana[1]

[1]Center for Atmospheric Science and Technology, National Institute of Aeronautics and Space, Bandung, Indonesia

E-mail : shailla.rustiana@gmail.com

Abstract. Climate phenomena that significantly affect Indonesian rainfall to be lower (positive) and higher (negative) than normal conditions are ENSO and IOD. The other phenomenon with different time scale with ENSO and IOD is MCC that rainfall until causing storms. This study was conducted to determine the influence of ENSO and IOD during MCC to rainfall in Indonesia. The data used are monthly data of rainfall, Nino3.4-IOD index, and hourly MCC data derived from T_{BB} data of Himawari Satellite, year 2001-2015 observation. The study focused on 4 occurrence phenomena: Nino3.4 (+) IOD (+), Nino3.4 (-) IOD (-), Nino3.4 (+) IOD (-), and Nino3.4 (-) IOD (+) with the distribution of 3 longitude regions (90-105E, 106-125E, and 126-140E). The results showed that the distribution of rainfall during MCC were higher when the events of negative IOD compared to other events, especially in the western maritime of Sumatra until Kalimantan. While, in the Nusa Tenggara region there is no rainfall when positive Nino3.4 events due to positive ENSO influence from the Pacific Ocean. The MCC also give effect on interior cloud size and duration of life cycle when negative IOD events on 3 longitude regions. The effect includes the size of the interior of the cloud becomes larger and the duration of the life cycle is longer. Eccentricity interior is close to 1, means the contribution of MCC is high enough to Indonesian rainfall on negative IOD events.

Keywords : ENSO, IOD, MCC,rainfall.

1. Introduction

Indonesia's rainfall is various and dynamic mostly concentrated over the island [1]. The differences rainfall over Indonesia lies in apparent motion of the sun received in each region. Indonesia is one of the world's most convectively active regions [2]. Located between two continents (Asian and Australia) and between two oceans (Indian and the Pacific Ocean) [3] also situated at the core of the strongest monsoon region of the world, and its regional climate strongly influences both the Hadley and Walker circulations [1]. It plays an important role in the variability of the tropical and global climate system that caused climate phenomena occurred over there like El Nino/Southern Oscillation (ENSO), Indian Ocean Dipole (IOD), Madden-Julian Oscillation (MJO), Mesoscale Convective System (MCS), and Tropical Cyclone.

Rainfall in Indonesia closely related with ENSO in the Pacific Ocean. The previous study [4] said that during the early stages of 1997 El Nino, drought conditions developed across Indonesia and most of the Maritime Continent. Rainfall is normally occured over the western Pacific warm pool, whereas drier climate overall happening in the eastern and central equatorial Pacific and western Indian Ocean,

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

depending on the geophysical configuration of the Indo-Pacific coupled ocean-atmosphere system [5]. This region experiences higher (lower) rainfall during La Nina (El Nino) events in cased of 1997-98 [6]. The studies about the relationship between ENSO and IOD to Indonesia's rainfall have often been done. For the east Pacific El Nino type, a near-perfect linear correlation (r = 0.96) is detected between the El Niño intensity and the simultaneous IOD intensity [7]. This relatively high correlation is primarily due to the co-occurrence of the ENSO and the IOD events [8]. The occurrence of upwelling off of Java–Sumatra and the interplay of El Nino and the positive IOD generating rainfall anomalies in southwestern Western Australia [9] and certainly affected Indonesian's rainfall.

Beside ENSO and IOD, there is another phenomenon with shorter time scale (hourly) that also has an influence to rainfall distribution in Indonesia. Mesoscale Convective Complex (MCC) has an important role in the rainfall changes in the tropics, include Indonesia [10]. The contribution of MCC to total rainfall over Indonesia during fifteen years reached 20% [11]. Trismidianto [12] also reported that the largest frequency for occurrences of the MCC over Indonesia from total of 1028 MCCs during fifteen years (2001 – 2015), was found over the continental (42.32%). The previous study that conducted by Trismidiato and Satyawardhana [2], explained the influence of ENSO (El Nino and La Nina) condition reducing the number of MCC occurrences in Indonesia during June-July-August (JJA) season. Hence, the effect also reducing rainfall distribution in Indonesia. In this research, we also have seen the influence of IOD phenomenon to Indonesia's rainfall during MCC events. Because the ENSO+IOD phenomena have a strong effect to Indonesia's rainfall, so we need to determine how the ENSO+IOD phenomena influence to rainfall distribution in Indonesia during MCC occurrences.

2. Data and Methods

2.1. Data

This study utilized monthly data of Nino 3.4 from NOAA (http://www.cpc.ncep.noaa.gov/) and IOD index (DMI) data from JAMSTEC (www.jamstec.go.jp) [13] to identify ENSO and IOD phenomena during 2001 – 2015 (Figure 1). Four time occurrence of these two phenomena are chosen for comparison (Figure 2): Nino3.4(+) IOD(+), Nino3.4(-) IOD(-), Nino3.4(+) IOD(-), and Nino3.4(-) IOD(+). The selection of four occurrence phenomena based on time series data and the impact from the combination of those two phenomena (ENSO and IOD). The selected Nino 3.4 as observation data region, because based on Trenbeth's research [14], in this region ENSO events might be more precisely defined by a threshold of 0.3°C.

Analysis of spatial rainfall data provided by GSMaP data [15] from JAXA (http://sharaku.eorc.jaxa.jp/GSMaP/). The spatial distribution of rainfall from GSMaP has spatial and time resolutions 0.1º×0.1º and has time observation near real time. To identify the influence of MCC toward Indonesia's rainfall, this research utilized brightness temperature (T_{BB}) from Himawari geostationary satellites [16] that provided by the Japan Meteorological Agency (JMA) (http://weather.is.kochiu.ac.jp). In detail, the data consists of Himawari-5/GMS-5 for data from January 2001-April 2003, Pacific GOES/GOES-9 for data from May 2003-June 2005, Himawari-6/MTSAT-1R for data from July 2005 - June 2010, Himawari-7/MTSAT-2 for data from July 2010 - June 2015, and Himawari-8 for data from July 2015 - December 2015. This satellite data has spatial and time resolutions 0.05º×0.05º and one hour [2].

2.2. Methods

Identification of the four time combination of ENSO and IOD occurrences, conducted by sorting positive and negative data (Fig. 1) with a threshold of 0.3°C. Then grouped on 4 occurrences: Nino3.4(+) IOD(+), Nino3.4(-) IOD(-), Nino3.4(+) IOD(-), and Nino3.4(-) IOD(+) shown in Fig. 2. From the grouping occurrences, then we conducted the spatial analysis of rainfall distribution and becomes the reference to be associated with the MCC [2]. The MCC information used to explain the MCC characteristics over the 3 longitude regions (90-105E, 106-125E, and 126-140E) consisting of the area size interior, duration life cycle, and eccentricity interior of MCC.

3. Result and Discussion

3.1. Statistical Analysis

As mention from the previous section, to identify ENSO and IOD phenomena that influence to Indonesia's rainfall, we used Nino3.4 index and IOD index (Dipole Mode Index/DMI) data (Fig. 1). This figure explains that there are manytime when Nino3.4 index and DMI occurrence at the same time (positive on 2002, 2004, 2006, 2009, and 2015 and negative, partly in 2005, 2010, and 2013). There are also opposite conditions (Nino3.4(+) IOD(-) and Nino3.4(-) IOD(+)) at the same time, like the case on 2001, 2007, 2008, 2011, and 2013.

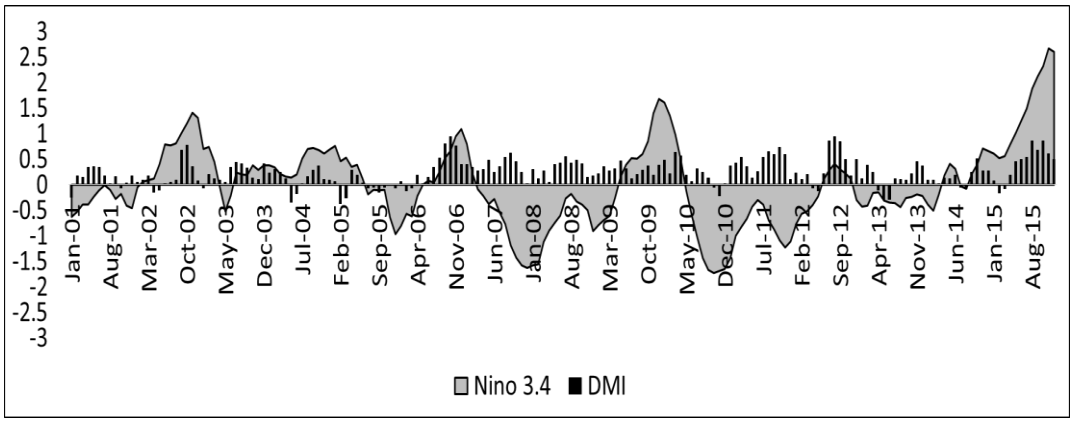

Figure 1. Time series of monthly ENSO and IOD occurrence on 2001 – 2015.

The high dataset of Nino3.4 and DMI on the boreal winter of 2014 until boreal winter of 2015 is strong El Nino phenomena that have a big impact to Indonesia's rainfall. On 2015, Indonesia has severely affected by El Nino, with marked rainfall deficits extending throughout the year. For the August-December 2015, rainfall indicates drier than average conditions over the country. On a longer perspective, Indonesia is clearly expected to experience drier than average conditions until 2016 [17].

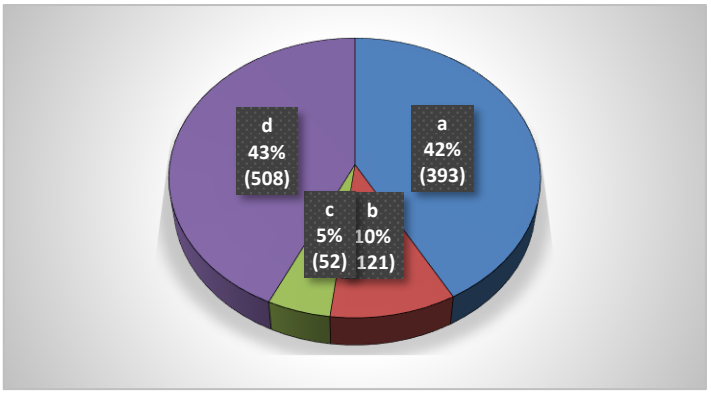

Figure 2. Percentage of ENSO and IOD combination for each time occurrence phenomena:

(a) Nino3.4(+) IOD(+),
(b) Nino3.4(-) IOD(-),
(c) Nino3.4(+) IOD(-), and
(d) Nino3.4(-) IOD(+).

The grouping 4 combinations of occurrence phenomena from the time series analysis (Figure 1) has a percentage as shown in Figure. 2. A combination of phenomena when an IOD(+) has a higher percentage than IOD (-), where a combination of Nino3.4(+) IOD(+) phenomena has 42% and a combination of Nino3.4(-) IOD(+) phenomena has 43%. Meanwhile, the combination of Nino3.4(-) IOD(-) phenomena has 5% and the combination of Nino3.4(+) IOD(-) phenomena has 10%. Hence, for

15 years of observations from the Nino3.4 and IOD index data, there are several phenomena when Nino3.4(+) and Nino3.4(-) occur with IOD(+) at the same time.

3.1.1. Analysis Area Size of MCC

To analyzed MCC occurrence more detail over Indonesia, we classify 3 region part of Indonesia from longitude large area. The western part region is 90 – 105 E, central part region is 106 – 125 E, and east part region is 126 – 140 E. For comparison, we also analyzed the total region of Indonesia (90 - 140 E) with 4 grouped combinations of occurrence phenomena.

Table 1. Interior Cloud Size Area of MCC (km^2) $x10^4$.

Longitude Regions	Occurrence Phenomena							
	Nino3.4(+) IOD(+)		Nino3.4(-) IOD(-)		Nino3.4(+) IOD(-)		Nino 3.4(-) IOD(+)	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
Total	15.64	11.93	14.87	11.84	15.59	13.02	14.00	9.30
90 – 105 E	19.93	15.43	19.38	15.30	19.87	17.22	17.77	11.95
106 – 125 E	12.96	7.19	10.29	3.63	13.08	9.18	12.27	7.43
126 – 140 E	12.06	7.88	13.40	9.63	11.33	4.41	11.78	5.75

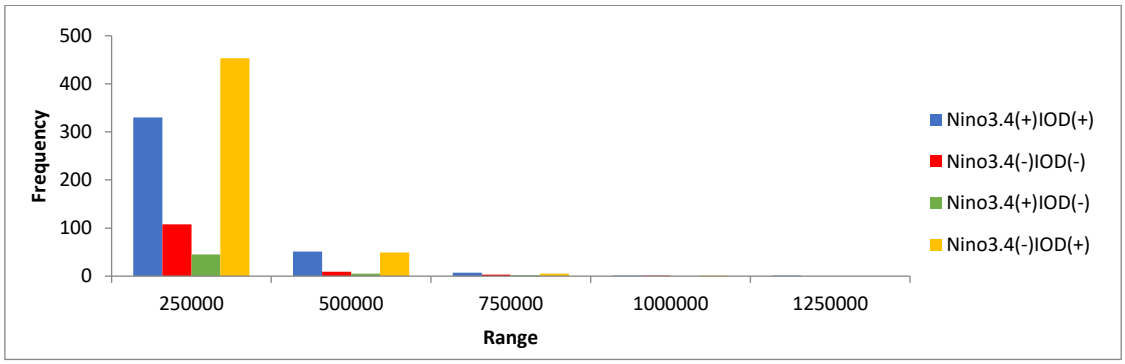

Figure 3. Histogram of Interior Cloud Size Area of MCC.

The number of MCC interior cloud size area in each group observation region and occurrence phenomena shown in Table 1. The western part region (90 -105 E) has a higher number of area sizes for each combination of occurrence phenomena than other regions. The same thing with the variation that evidenced by the higher standard deviation value than the other regions. The smallest value of standard deviation is 3.63 when Nino3.4(-) IOD(-) on 106 – 125 E region. That area makes it possible to have a lower variation of MCC because It is far from the Pacific Ocean as well as the Indian Ocean. The area size of MCC also larger when IOD(-) events both when the combination occurrence of Nino3.4(+) IOD(-) and Nino3.4(-) IOD(-) in total average around $15x10^4$ km^2 compared to IOD(+) events.

Based on histogram on Figure 3, the highest MCC distribution value is on the range of 0 – 2500000 km^2 (453 frequency) in the condition of Nino3.4 (+) IOD (-).

3.1.2. Analysis Duration Life Cycle of MCC

The duration life cycle of MCC in this study define as the duration between the time of initial stage and the time of dissipation stage. The distribution frequency of the MCC duration life cycle for each combinations of occurrence phenomena shown in Table 2. The average number of duration life cycle

shows around 11 hours for each region and occurrence phenomena. This number is close enough with analysis of MCC during El Nino, Neutral, and La Nina conditions over IMC that have done by a previous study [2].

Table 2. Duration Life Cycle of MCC (Hour).

Longitude Regions	Occurrence Phenomena							
	Nino3.4(+) IOD(+)		Nino3.4(-) IOD(-)		Nino3.4(+) IOD(-)		Nino 3.4(-) IOD(+)	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
Total	11.59	3.08	11.19	3.08	11.79	3.23	11.06	3.10
90 – 105 E	12.32	3.51	11.67	3.41	13.52	3.84	11.65	3.46
106 – 125 E	11.27	2.66	10.63	2.46	10.83	2.20	10.50	2.67
126 – 140 E	10.72	2.54	11.15	3.26	9.86	1.57	11.29	3.17

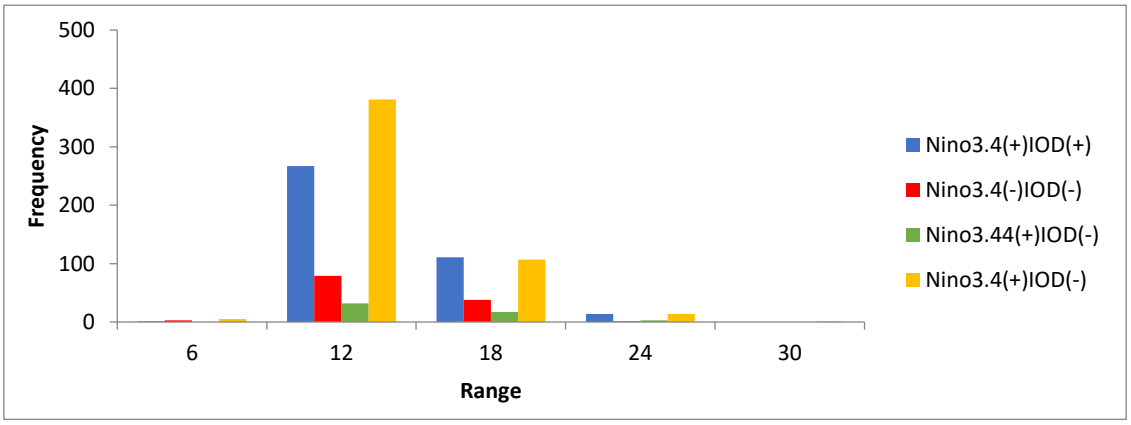

Figure 4. Histogram of Duration Life Cycle of MCC.

Same with case on Table 1 related to the interior cloud size area of MCC, the frequency of MCC duration life cycle longer in western part region (90 – 105E) than another region for each combinations occurrence phenomena, which is also proven by the magnitude of the variance of the standard deviation value. The average frequency of duration life cycle of MCC around 12 hours at this region. The combination occurrence phenomena with IOD(-) events also have longer duration life cycle than occurrence phenomena with IOD(+). Even though Lou et al. (2007) [18] said that negative IOD events do not appear to evolve into strong air-sea coupled processes in the Indian Ocean, in this study case IOD negative have strongly related with MCC occurrence. The effects of these phenomena will be explained in more detail in the next section (Figure 8). On the duration life cycle analysis, the highest MCC distribution value is on the range of 7 – 12 hour (381 frequency) shows in Figure 4. The extreme values of MCC characteristic also showed more on the Nino3.4(+) IOD(-) occurrence.

3.1.3. Analysis Eccentricity Interior of MCC

The previous study about MCS and MCC have measured the shape of the cloud-shield with calculated the eccentricity. This eccentricity is very important to distinguish the MCC with the other type of MCS. The eccentricity itself defined as the ratio of the minor axis to the major axis of the MCC best-fitting ellipse at the time of maximum extent [2]. The closer of eccentricity value to 1 means the contribution of MCC is quite high for this region and phenomenon.

Table 3. Eccentricity Interior of MCC.

Longitude Regions	Occurrence Phenomena							
	Nino3.4(+) IOD(+)		Nino3.4(-) IOD(-)		Nino3.4(+) IOD(-)		Nino 3.4(-) IOD(+)	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
Total	0.85	0.08	0.86	0.08	0.86	0.09	0.85	0.09
90 – 105 E	0.85	0.08	0.86	0.08	0.84	0.09	0.86	0.08
106 – 125 E	0.85	0.08	0.86	0.093	0.88	0.08	0.84	0.09
126 – 140 E	0.84	0.08	0.87	0.08	0.87	0.08	0.84	0.09

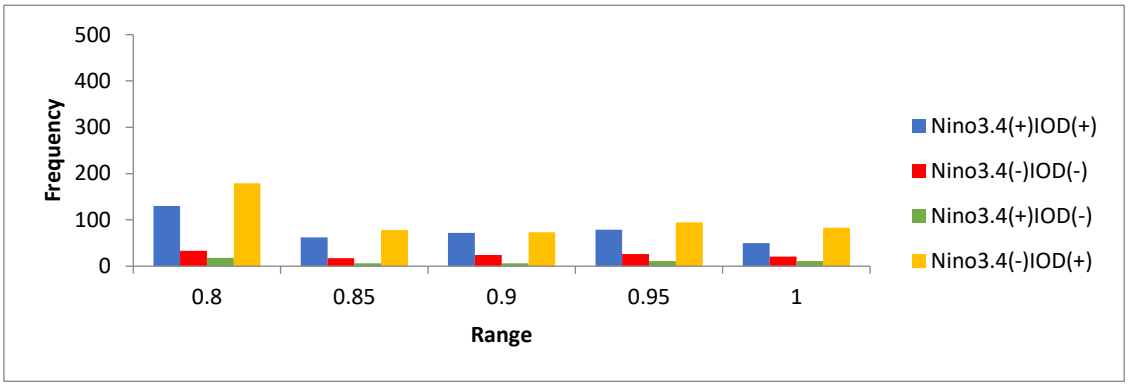

Figure 5. Histogram of Eccentricity Interior of MCC.

This study found the average eccentricity interior of MCC for all the observed regions was around 0.86, while the standard deviation value was around 0.08 (Table 3). Different from previous analysis, the analysis of this MCC eccentricity larger at central part region (106-125E). The higher value of eccentricity located around central of Kalimantan island (Figure 7), which means is located near equatorial regions. The development of the MCC near equatorial is possibly related to the ITCZ as a belt of low pressure which circles the earth generally near the equator, where the trade winds of the Northern and Southern Hemispheres come together. It is marked by convective activity which often generates strong thunderstorms over the large areas. It is most active over continental land masses by day and relatively less active over the oceans [19]. The extreme values of MCC characteristic on the eccentricity interior analysis also showed more in Nino3.4(+) IOD(-) occurrence. Based on histogram (Figure 6) analysis, the highest MCC distribution value is on the range of 0.7 – 0.8 (179) in the condition of Nino3.4(+) IOD(-).

3.2. ENSO and IOD Analysis during MCC Condition

Spatial analysis of Indonesia's rainfall for combination of ENSO+IOD occurrence phenomena (Figure 6) shows that Indonesia's rainfall is higher in Sumatra, Java, Kalimantan, and several Papua island for each occurrence phenomena. Distribution of Indonesia's rainfall when the combination of Nino3.4(-) IOD(-) occurrence phenomena is higher than other conditions. It shows with the color of rainfall distribution for all Indonesia region are green to yellow, with the average value 0.9 mm/hour near southern part of Sumatera and central part of Papua. Rainfall distribution when the combination of Nino3.4(+) IOD(-) occurrence phenomena is smaller than the other condition. The range of rainfall value is 0.1 to 0.6 mm/hour, this value smaller than combination of Nino3.4(+) IOD(+) and Nino3.4(-) IOD(+) that have average rainfall around 0.7 to 0.8 mm/hour.

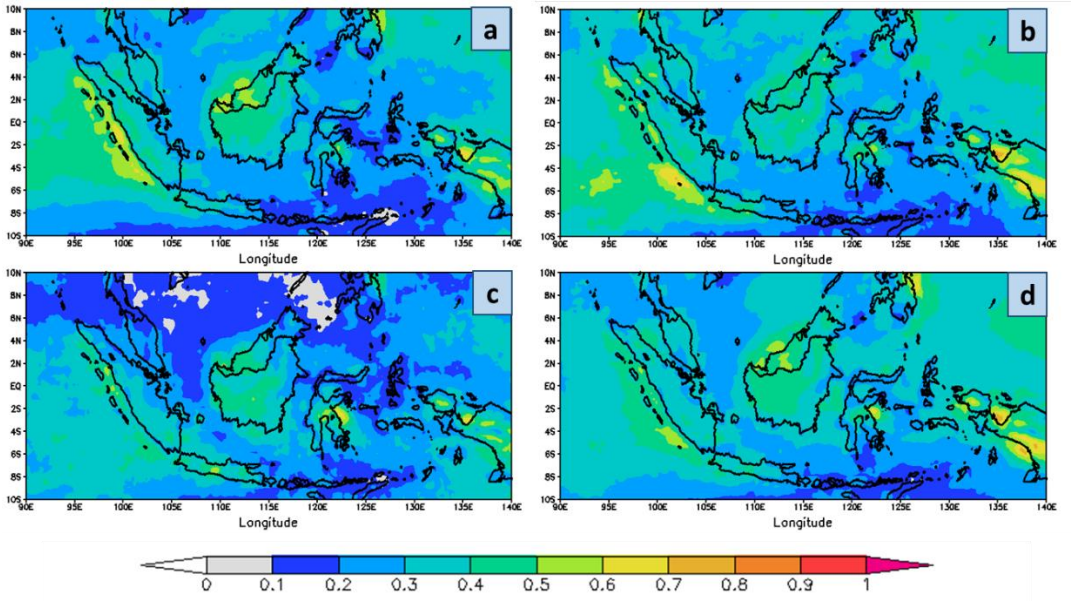

Figure 6. Rain rate distribution when ENSO and IOD event for each time occurrence phenomena : (a) Nino3.4(+) IOD(+), (b) Nino3.4(-) IOD(-), (c) Nino3.4(+) IOD(-), and (d) Nino3.4(-) IOD(+).

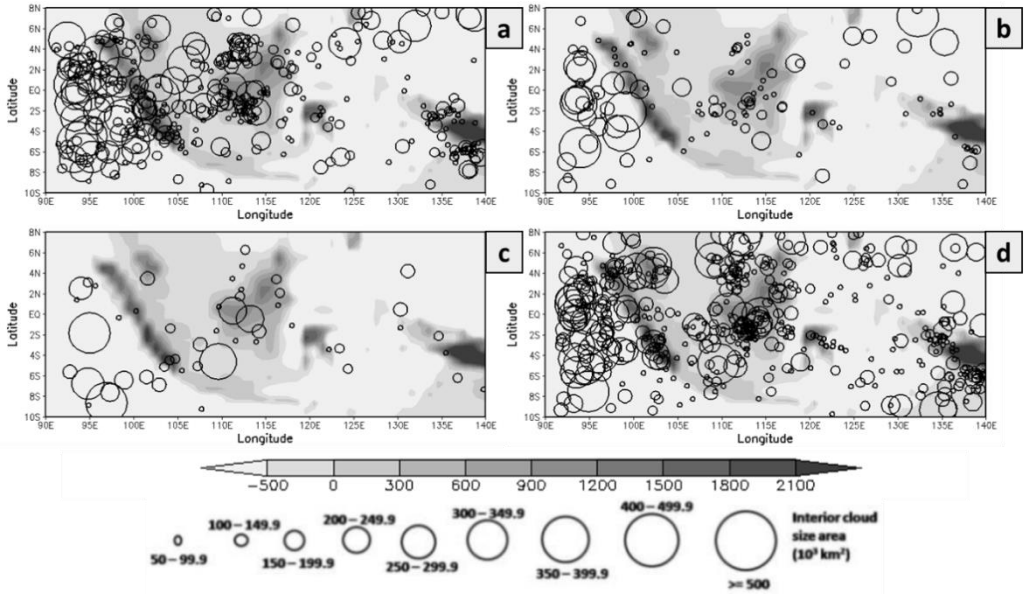

Figure 7. Frequency distribution of the MCC occurrences over Indonesia during 15 years from 2001 to 2015 when ENSO and IOD events for; (a) Nino3.4(+) IOD(+), (b) Nino3.4(-) IOD(-), (c) Nino3.4(+)IOD(-), and (d) Nino3.4(-) IOD(+). The circles shown the size and location of MCC when the mature stage at the time of the interior cloud size area of MCC reached the maximum extent (10^3 km^2). The color shaded refers to elevation which is the unit in meters (m).

Figure 7 shows the combination of ENSO and IOD phenomena influence to MCC events in Indonesia. When the combination of Nino3.4(+) IOD(+) occurrence phenomena, the MCC spread more in Sumatra and Kalimantan, while when the combination of Nino3.4(-) IOD(-), MCCs spread in the Indian Ocean and the Java Sea, and also some of MCC with small circle concentrated in Central Kalimantan. On the condition of Nino3.4(-) IOD(+), MCC spread averagely in the ocean near Sumatra

and Kalimantan, also several around Papua. Then, when the Nino3.4(-) IOD(+), MCC spread almost all over Indonesian both on ocean and land.

From Figure 7, there is a condition looks like the MCC occurrences directly proportional with the percentage of combination ENSO and IOD occurrence (Figure 2), indicated by the number of cloud size interior circles. Hence, the distribution of MCC larger in the combination occurrence phenomena with IOD(+) which have percentage over 40% than IOD(-) with the percentage less or equal to 10%. Meanwhile, the impact of these combination occurrence phenomena during MCC events to Indonesia's rainfall (Figure 8) more visible than the analysis of frequency distribution of MCC (Figure 7).

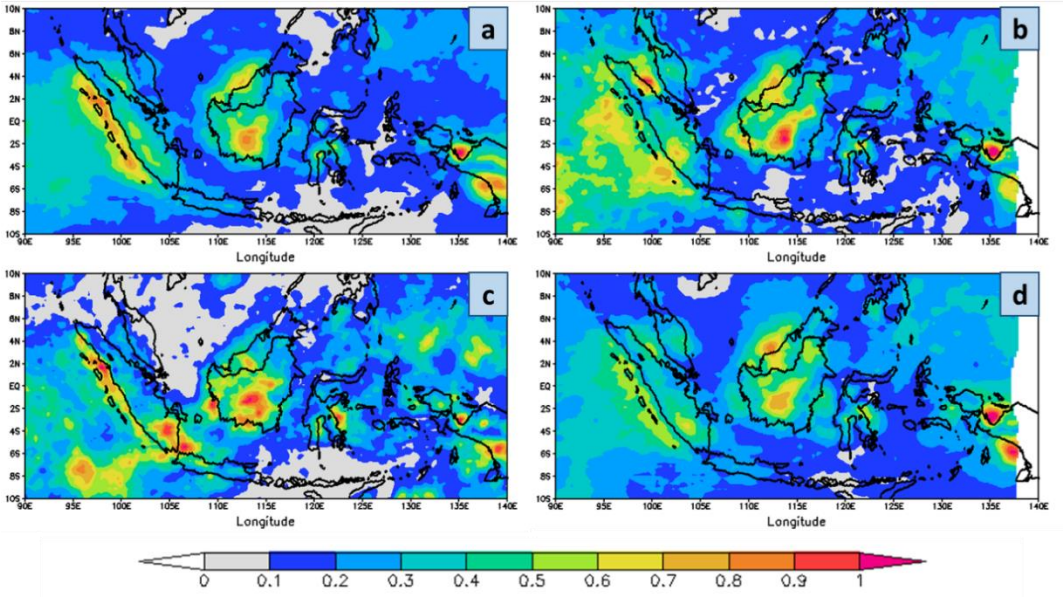

Figure 8. Rain rate distribution when ENSO IOD events during MCC for each time occurrence phenomena:(a) Nino3.4 (+) IOD (+), (b) Nino3.4 (-) IOD (-), (c) Nino3.4 (+) IOD (-), and (d) Nino3.4 (-) IOD (+).

Rainfall in Java during MCC events, not spread as much as Sumatra and Kalimantan region because the reduced of water vapor supply which become rain and producing convective clouds. As we know, the region which strongly affected by the climate phenomena in Indonesia is Java island, because it located between two continents (Asian and Australia) [1]. It appears that the largest MCCs at the time of Nino3.4(+) occurred in the southwest ocean of Sumatra (the eastern Indian Ocean), which is the most frequently formed area of large-scale MCC and the Pacific Pole (warm pole). MCC still spread both small and large in Sumatra and Kalimantan even though in the condition of Nino3.4(+), it is the same case with the previous study. The Walker's circulation shift at the condition of Nino3.4(+), possibly causing shifts and changes in the scale of MCCs further east. Hence, during the Nino3.4(-), MCCs spreads mostly in land and sea, otherwise, in Nino3.4(+), MCCs occur on land and several in the oceans [2].

4. Conclusion

Rainfall distribution during MCC event was higher when the occurrence phenomena with negative IOD (IOD(-)) compared to other phenomena, especially in the western maritime of Sumatra until Kalimantan. Meanwhile, Java, Bali, and Nusa Tenggara region there is no rainfall when positive Nino3.4 (Nino3.4(+)) occurrences, It is due to positive ENSO influence from the Pacific Ocean. The effect of MCC also seen on the larger interior cloud size area and longer duration life cycle when negative IOD events on 3 longitude regions, where the western part region (90-105E) has higher average value and

variance than the other regions. The eccentricity interior of MCC is close to 1, with the average around 0.86 and standard deviation around 0.08 also when negative IOD events and the larger in the central part region (106-110E). It also supported by the results of the 3 parameter analysis that shows the highest (extreme) value occurs when negative IOD events, It means the distribution of MCC is high enough to Indonesia's rainfall when negative IOD occurrence phenomena, The next study is required to determine the monthly and seasonal analysis on the influence of the ENSO+IOD occurrence phenomena combination with the strength level from those phenomena (strong, moderate, and weak) during the MCC events.

Acknowledgments
Thank you to Japan Meteorological Agency which provides Himawari data as the most important thing to this paper. NOAA and JAMSTEC which provides Nino 3.4 data and DMI data to analyse ENSO and IOD phenomena during 15 years. JAXA which provides GSMaP rainfall data, so the Indonesia's rainfall distribution could be analysed in this study. Thank you also for all author who works on the related fields which is cited in the references, so this paper can be finished. Lastly, the authors are grateful to the National Institute of Aeronautics and Space (LAPAN), which is the institution where the author works and also as the organizer committee to this international conference (ICTMAS).

References
[1] Qian J H 2007 Why Precipitation Is Mostly Concentrated over Island in the Maritime Continent *Journal of The Atmospheric Science* Vol **65**: 1428 -1440 doi: 10.1175/2007JAS2422.1
[2] Trismidianto and Satyawardhana H 2018 Mesoscale Convective Complexes (MCCs) over the Indonesian Maritime Continent during the ENSO events *IOP Conf. Ser.: Earth Environ Sci.* **149** 012025 p. 1 – 10 doi :10.1088/1755-1315/149/1/01202
[3] Ramage C S 1968 Role of A Tropical "Maritime Continent" in the Atmospheric Circulation *Monthly Weather Review* Vol **96** No. 6: 365 – 370
[4] Hendon H H 2003 Indonesian Rainfall Variability: Impacts of ENSO and Local Air–Sea Interaction *Journal of Climate* Vol **16**: 1775 – 1790
[5] Lee H S 2015 General Rainfall Patterns in Indonesia and the Potential Impacts of Local Seas on Rainfall Intensity *Water* **7**: 1751-1769 doi:10.12063390/w7041751
[6] Gutman G, Csiszar I, and Romanov P 2000 Using NOAA/AVHRR Products to Monitor El Nino Impacts: Focus on Indonesia in 1997-98 *Bulletin of the American Meteorological Society* Vol. **81**: 1189 – 1206
[7] Zhang W, Wang Y, Jin F F, Stuecker M F and Turner A G 2015 Impact of Different El Niño Types on the El Niño/IOD Relationship *AGU Geophisical Research Letters* p. 8570 – 8576 10.1002/2015GL065703
[8] Ashok K, Guan Z, and Yamagata T 2003 A Look at the Relationship between the ENSO and the Indian Ocean Dipole *Journal of the Meteorological Society of Japan* Vol. **81** No.1, pp. 41-56
[9] Meyers G, McIntosh P, Pigot L and M Pook 2007 The Years of El Niño, La Niña, and Interactions with the Tropical Indian Ocean *Journal of Climate* Vol **70** : 2872 – 2880 doi: 10.1175/JCLI4152.1
[10] Houze R A 1977 structure and Dynamics of a Tropical Squall-Line System *Monthly Weather Review* Vol. **105** : 1540 -1567
[11] Trismidianto, Yulihastin E, Satyawardhana H, Nugroho J T and S Ishida 2017 The Contribution of the Mesoscale Convective Complexes (MCCs) to total rainfall over Indonesian Maritime Continent *IOP Conf. Ser.: Earth Environ. Sci*. **54** 012027 p. 1 – 10 doi:10.1088/1755-1315/54/1/012027
[12] Trismidianto 2018 Characteristics of the oceanic MCC, continental MCC, and coastal MCC over the Indonesian maritime continent *IOP Conf. Ser.: Earth Environ. Sci.* **149** 012024 p. 1 – 12 doi :10.1088/1755-1315/149/1/012024
[13] Cahyarini S Y and Suharsono 2015 The Influence of ENSO/IOD on SST Signal in Kendari, Southeast Sulawesi Waters: 27-year-records of Sr/Ca from Porites corals *Indonesian Journal on Geoscience* Vol. **2** No. 1: 43-51
[14] Trenberth K E 1997 The Definition of El Niño *Bulletin of the American Meteorological Society* p. 2771 – 2777
[15] Setiawati M D and Miura F 2016 Evaluation of GSMaP Daily Rainfall Satellite Data for Flood Monitoring: Case Study—Kyushu Japan *Journal of Geoscience and Environment Protection* **4** : 101-117 ISSN Online: 2327-4344

[16] Min M, Bai C, Guo J, Sun F, Liu C, Wang F, Xu H, Tang S, Li B, Di D, Dong L and Li J 2018 Estimating Summertime Precipitation from Himawari-8 and Global Forecast System Based on Machine Learning IEEE Transactions on Geoscience and Remote Sensing p. 1 – 13, DOI: 10.1109/TGRS.2018.2874950
[17] Inter-Agency Regional Analysts Network 2015 2015/2016 El Nino Event *Global Report an ACF and IRIS initiative* p. 1 – 35
[18] Luo J J, Zhang R, Bahera S K, Masumoto Y, Jin F F, Lukas R, and Yamagata T 2009 Interaction between El Niñoand Extreme Indian Ocean Dipole *J. Climate* p. 1- 46
[19] Trismidianto 2018 The Global Population of Mesoscale Convective Complexes (MCCs) over Indonesian Maritime Continent during 15 Years *IOP Conf. Ser.: Earth Environ. Sci.* **166** 012040 p. 1 – 17 doi :10.1088/1755-1315/166/1/012040