Variation in extreme rainfall in indonesia associated with four propagation types of madden-julian oscillation

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Abstract. The impact of the MJO on extreme daily rainfall ($x_{MJO} \geq x_c$), namely the 95th extreme, is known by quantifying the difference in probability of extreme daily rainfall during the MJO versus NDJFMA ($\triangle P_{MJO}$) events. MJO has four propagation characteristics. In this study, the differences in the 95th extreme probability is the impact of the characteristics of each type of MJO propagation which are different from each other. MJO identification is by using a band-pass filter frequency against the daily average Outgoing Longwave Radiation and certain criteria. MJO identified according to certain criteria from the band-pass filter will be grouped based on the similarity of propagation types using the k-mean clustering method. In addition, a regional probability matrix of the 95th extreme probability difference is created. The positive (negative) difference in daily rainfall and the probability of the 95th extreme follows the propagation of the active phase (inactive phases) of each MJO type. The regional probability of a positive 95th extreme probability difference or positive probability (negative probability) also has the same or follows the propagation of active phase (inactive phases) for each MJO type from west to east, just like the similarity of the pattern of bulk difference daily rainfall and 95th extreme probability.

1 Introduction

The Madden-Julian Oscillation (MJO) is the eastward propagation of cloud clusters and precipitation from the Indian Ocean to the Pacific Ocean [1]. The impact of the MJO on extreme weather is known by quantifying the probability of extreme weather caused by the MJO, which is the first step in forecasting. Quantifying the probability of extreme weather on a seasonal time scale prepares in weather forecasting better [2]. There have long been major obstacles to accurately simulating and predicting the MJO using sophisticated global weather forecasts and climate models. Therefore, understanding the MJO also becomes a challenge to explain this major obstacle. Apart from that, understanding the MJO also provides a better understanding of atmospheric circulation. Regarding weather models,

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Global Circulation Models (GCM) have useful skills in forecasting MJO phases for the next 2-3 weeks [3, 4] In addition, the reproduction of the Global Seasonal Forecasting System 5 (GloSea5) has adequate skills in quantifying the probability of extreme rainfall over the medium range.

The inter-annual variability of rainfall in Indonesia is dominated by ENSO [5-7] and the Indian Ocean Dipole (IOD) [6-8], seasonal by the Asian-Australian Monsoon [5, 7] and intraseasonally by the Madden-Julian Oscillation (MJO) [9-11], and Convectively Coupled Equatorial Waves (CCEWs) [12]. The MJO is the dominant mode of intraseasonal (20–90 days) variability in tropical regions [1, 9, 10, 13].

One way to quantify the impact of MJO on extreme weather is to quantify the probability of extreme rainfall in the Southeast Asia (SEA) region. The Southeast Asia region is a region with high vulnerability to extreme weather due to its high population, low-lying islands, and a variety of marine ecosystems [14]. During November-March (NDJFM) in SEA regarding daily rainfall, MJO phases 2-4 produce increased daily rainfall, while phases 6-8 produce decreased daily rainfall. Apart from that, regarding changes in the probability of extreme daily rainfall in SEA in the same period, changes in the probability of extreme daily rainfall during MJO phases 2-4 increased by 30-50%, while phases 6-8 decreased by 20-25% [2].

Understanding the impact of the MJO on the distribution of extreme rainfall in each different region in Indonesia is very important because each MJO has different characteristics and influences from each other on the distribution of extreme rainfall in each different region in Indonesia. During the northern hemisphere (BBU) winter regarding daily rainfall, MJO phases 2-4 increase daily rainfall by 5 mm/day in Indonesia, while phases 6-8 reduce daily rainfall by the same value in Indonesia [15]. Apart from that, regarding changes in the probability of extreme daily rainfall in the same region and the same period, spatially MJO increases the probability of extreme daily rainfall during phase 2 in Sumatra, phase 3 in Java and Papua, and phase 4 in Kalimantan and Sulawesi, while phase 6-8 reduce changes in the probability of extreme daily rainfall in almost all regions of Indonesia [16].

The MJO that formed in the Indian Ocean propagated eastward and passed through Indonesia and the Pacific Ocean [1]. Convection from the MJO that moves from the Indian Ocean towards the east but does not pass through the Pacific Ocean is called non-propagating MJO, while MJO that passes through the Pacific Ocean is called propagating MJO. The non-propagating MJO is divided into 2, namely stand and jump. Then, MJO propagation is also divided into 2, namely fast and slow. Each propagation of the MJO influences daily rainfall in the area it passes through, even causing extreme daily rainfall in that area [17]

The MJO with its phases is intraseasonal rainfall variability associated with daily rainfall [15] and daily extremes in Indonesia [16]. The MJO is the dominant component or mode of intraseasonal (30-90 day) rainfall variability in tropical regions [9, 10, 11, 13]. The dynamics of the MJO occur due to the structural features of the planetary scale atmospheric circulation and its interaction with mesoscale and oceanic convective activity [18-19]. Therefore, the impact of MJO on the distribution of extreme daily rainfall in Indonesia is still unclear and requires further investigation [16]

Recent research related to MJO propagation shows that the MJO formed in the Indian Ocean has 4 types of propagation (fast, slow, jump, and stand) [17]. The various types of MJO propagation have the potential to have different impacts on changes in the probability of extreme rainfall in each different region in Indonesia because each MJO has different characteristics and influences on the distribution of extreme rainfall in each different region in Indonesia.

2 Research methodology

MJO identification was conducted in the Indian Ocean region during the northern hemisphere winter (BBU), namely during November-April (NDJFMA) using a band-pass filter on the daily average OLR and certain criteria [17]. The MJOs that have been identified are grouped based on the similarity of propagation types using the k-mean clustering method.

The daily rainfall period used is the same as the daily average OLR period, namely during NDJFMA. The difference in daily rainfall for each MJO type and NDJFMA is calculated first. This calculation is useful for looking at the climatology of daily rainfall for each MJO (MJO-NDJFMA) in Indonesia. The method for analyzing extreme daily rainfall is the use of the Extreme Rainfall Index, namely the 95th percentile of daily rainfall. The 95th Extreme Index is calculated, then the index is used to calculate the probability of the 95th extreme during each phase of the MJO and NDJFMA. Next, quantification of changes in the 95th extreme probability is calculated according to the equation with probability differences between each type of MJO and NDJFMA [2].

2.1 Data

The data used in this research are daily rainfall observations from the Meteorology, Climatology, and Geophysics Agency (BMKG) and daily average OLR from NCEP. The period used in this research was during the northern hemisphere winter season (November-April) or NDJFMA from 1979-2013. Daily average OLR data are used to identify the MJO in the Indian Ocean (10°N-10°S and 60°-90°E) [17]. The data has a resolution of 2.5°×2.5°**.** Daily average OLR data are used to identify the MJO in the Indian Ocean (10°N-10°S and 60°-90°E) [17]. The data has a resolution of 2.5°×2.5°.

Table 1. Research data

	Outgoing Longwave Radiation	**Rainfall Observations**
Temporal resolution	daily average	daily
Spatial resolution	2,5°×2,5°	observation point
Source	NCEP	BMKG
Pressure level or altitude	850 & 200 hPa	Surface
Period	1979-2013	

The observation data used is data from each observation point which has data completeness >80%. There are 63% of observation points used from all observation point data in Indonesia. Before analyzing daily rainfall and changes in the probability of the 95th extreme, a climatological analysis of monthly rainfall is carried out in the form of a monthly rainfall cycle to determine the peak of monthly rainfall for all years at each observation point.

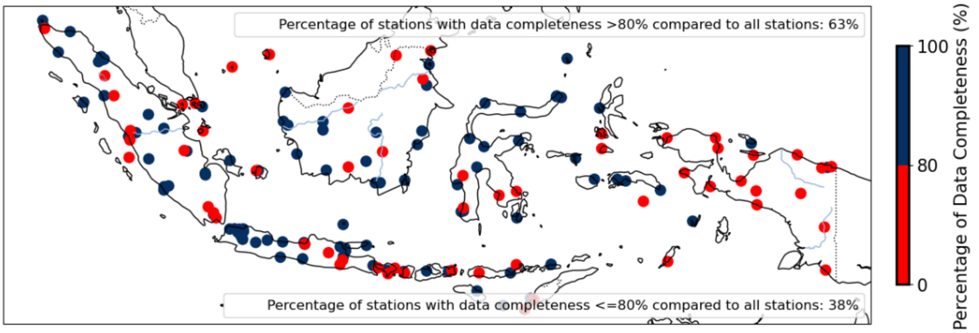

Fig. 1. Percentage of data completeness (%) for each daily rainfall observation point in Indonesia.

2.2 Method

The methods used in this research are band-pass filter, k-mean clustering, and Extreme Rainfall Index (95th percentile).

2.2.1 Band-pass filter against daily average OLR

Before performing the band-pass filter, the first three harmonics (365.25 days, 182.625 days, and 121.75 days) of the daily average OLR were filtered [20]. A band-pass filter is a filter to pass signals of a certain frequency, limiting it to a low cut-off frequency (f_{CL}) and a high cut-off frequency (f_{CH}), and attenuating signals that are below the low cut-off frequency and above the cut-off frequency. The difference between the high cut-off frequency and the low cut-off frequency is called the bandwidth value [21].

Identification of MJO according to the criteria. After going through the band-pass filter method, the daily average OLR anomaly is selected if it has a value lower than the standard deviation. One MJO event is an MJO that occurs for at least 5 consecutive days. An MJO event with a minimum daily average OLR anomaly is designated as day 0 (D0) of the MJO event.

On the other hand, MJO can be grouped into strong and weak MJO which are obtained using the amplitude of the real multivariate MJO indices equation (RMM1 and RMM2), namely $\sqrt{RMM1^2 + RMM2^2}$. If the amplitude is greater than 1, then the MJO is called strong [10], as used to identify the MJO with 8 phases in the previous studies about MJO phases [2, 15, 16].

2.2.2 Visualization of each MJO type and its dimensions

The MJO visualization is displayed in a Hovmoller diagram of daily average OLR anomalies. The daily average OLR data has the spatial dimensions of averaged latitude (average 10°S-10°N) and longitude (30-180°E) and the time dimension from D-25 to D+25. The longitude of the daily average OLR anomaly is from the Indian Ocean to the Pacific Ocean, namely 60-165°E. This is considered to see the movement of the active and inactive phases of the MJO starting from the Indian Ocean and passing through Indonesian territory. Daily average OLR anomaly values higher than $-5\ W/m^2$ and lower than $5\ W/m^2$ will be changed to zero.

2.2.3 Calculation of the difference in daily rainfall for each MJO with NDJFMA, 95th percentile of daily rainfall, and percentage change in 95th extreme probability for each MJO with NDJFMA

K-mean clustering is a method for grouping objects according to their characteristics. In this method, the number of groups (k) and the group center point (centroid) are required. Objects that have the same characteristics will be included in one group [22].

Objects with different characteristics will be grouped into another group together with objects with the same characteristics in that group [22]. The objects included in k-mean clustering are the daily average Hovmoller OLR anomalies which consist of values that have the spatial dimensions of averaged latitude (average 10°S-10°N) and longitude (30-180 °E) and time dimensions from D-25 to D+25.

2.2.4 K-mean clustering

Before carrying out calculations in the 95th extreme probability difference equation, it is best to first see how the distribution of rainfall for each MJO type is compared with NDJFMA. The difference in daily rainfall for each MJO type and NDJFMA is calculated first, this calculation is useful for looking at the climatology of daily rainfall for each MJO (MJO-NDJFMA) in Indonesia.

Next, the 90th (95th) extremes describes extreme events when daily rainfall is greater than the 90th (95th) percentile of daily rainfall during a certain period, for example November-March (NDJFM) [23-24]. The calculation of the percentage difference in the 95th extreme probability [2, 24] is:

$$\triangle P_{MJO} = \frac{P_{MJO}(x_{MJO} \geq x_c) - P_{NDJFMA}(x_{NDJFMA} \geq x_c)}{P_{NDJFMA}(x_{NDJFMA} \geq x_c)} \times 100\% \quad (1)$$

Explanation:

$\triangle P_{MJO}$: percentage difference between P_{MJO} and P_{NDJFMA}
P_{MJO} : probability during each type of MJO when x_{MJO} exceeds x_c
x_{MJO} : daily rainfall during each MJO type
x_c : 95th extreme threshold (95th percentile) of rainfall daily for one year
P_{NDJFMA} : probability during NDJFMA when x_{NDJFMA} exceeds x_c
x_{NDJFMA} : daily rainfall during the NDJFMA period

After getting the difference in daily rainfall (MJO-NDJFMA) and the difference in the 95th extreme probability for each MJO type, the next step is to divide Indonesian territory into 3 regions to create a matrix of the 95th extreme probability difference in each region for each MJO type, namely: west, middle, and east. The daily rainfall difference matrix (MJO-NDJFMA) has 3 categories, namely: the region with a positive daily rainfall difference (MJO-NDJFMA) is >1 mm, regions with a negative daily rainfall difference (MJO-NDJFMA) is <1 mm, and regions with the daily rainfall difference (MJO-NDJFMA) between >-1 mm and <1 mm. Meanwhile, the 95th extreme probability difference matrix has 3 categories, namely: the region with a positive 95th extreme probability difference is >15%, regions with a negative 95th extreme probability difference is <-15%, and regions with the 95th extreme probability difference between >-15% mm and <15%.

3 Results and discussion

The results in this research are results of identification of four types of Madden-Julian Oscillation and extreme daily rainfall change for each MJO type.

3.1 Results of identification of four types of madden-julian oscillation

The total occurrence of all types of MJO was 94 events. The period and propagation pattern of each type of MJO in the study are the same as previos study in 4 types of MJO propagation. The Hovmoller images below explain that there is similar pattern between this study and previos study in 4 types of MJO propagation [17] of each MJO type.

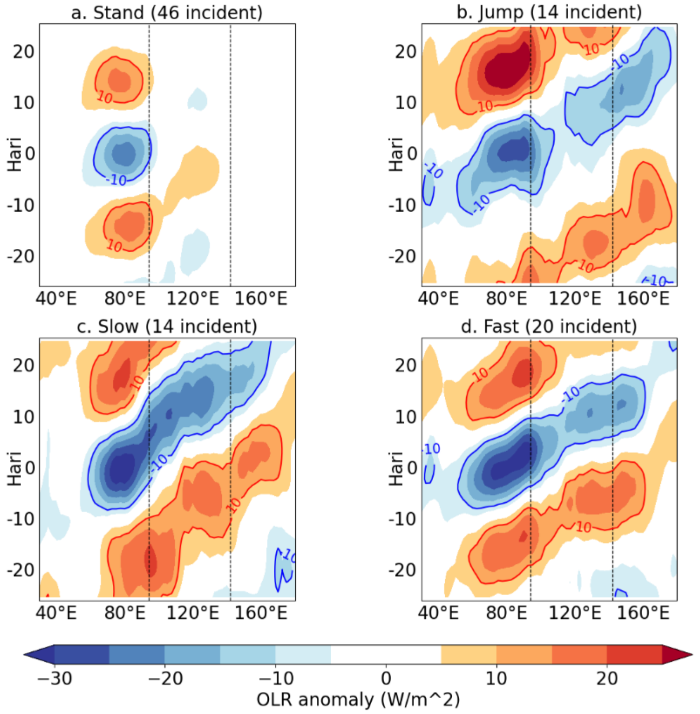

Fig. 2. Hovmoller results of processing daily average OLR anomaly (W/m^2). These anomalies come from all longitudes (30-180°E), while latitudes are averaged from 10°S - 10°N. The dotted vertical line (94-142°E) represents Indonesian territory. The dotted horizontal line is a division of MJO time during its stay in Indonesian territory with a time step of 5 days which is used for analysis of changes in extreme daily rainfall for the 95th in the next subchapter.

3.2 Extreme daily rainfall change for each MJO type

In this subchapter we will explain the differences in daily rainfall for each MJO type (MJO-NDJFMA) and the 95th extreme probability of each MJO type and a comparison of the pattern of differences in extreme daily rainfall for each MJO type in western, central, and eastern Indonesia.

3.2.1 Difference in daily rainfall and 95th extreme probability for each MJO type

The active phase and inactive phases of the stand-type MJO do not propagate through Indonesian territory, but its active phases (inactive phases) approaches Indonesian territory and cause an increase (decrease) in daily rainfall of 4 mm (-6 mm) and an increase (decrease) 95th extreme probability of 34-67% (-67 to -100%). The increase in daily rainfall difference and the 95th extreme probability starts from D-5 to D+20. When entering D+11, only the eastern part of Indonesia experienced an increase. During the inactive phases of the stand-type MJO, it causes a decrease in daily rainfall difference and the probability of the 95th extreme from D-20 to D-6.

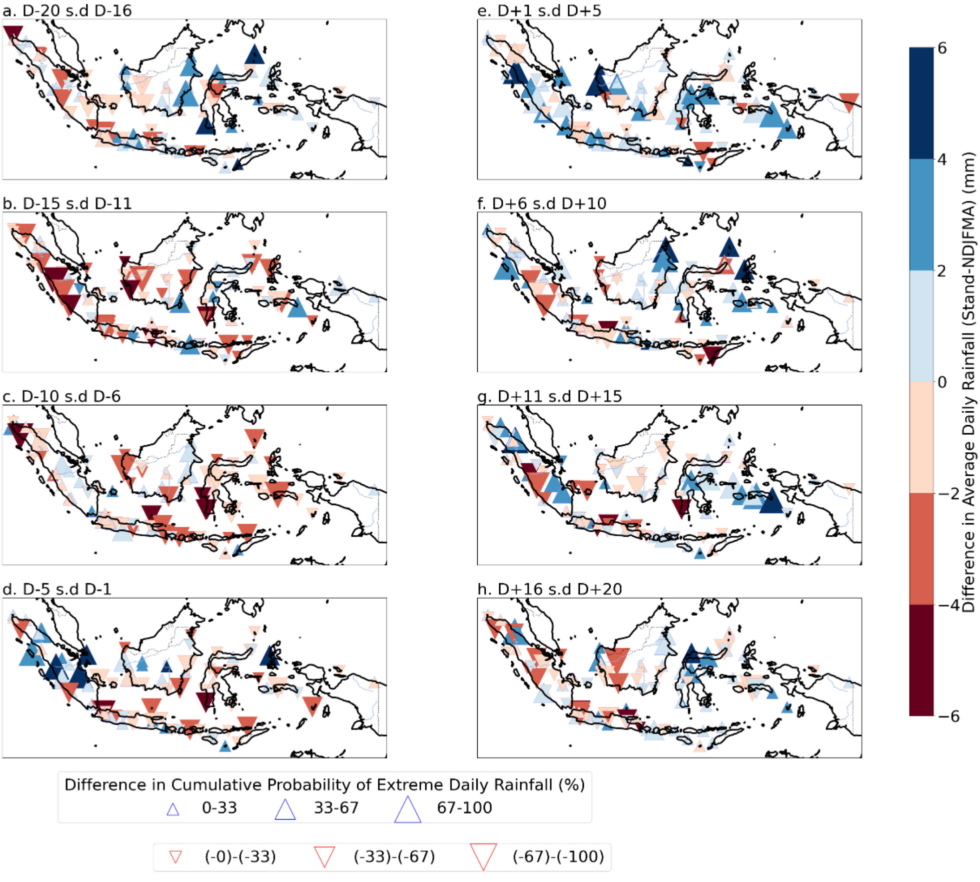

Fig. 3. Difference in probability of the 95th extreme during a stand type MJO relative to NDJFMA (%, difference in triangle size) and difference in average daily rainfall during that MJO versus NDJFMA (color, mm).

The highest difference in daily rainfall and the 95th extreme probability occur during the active phases of the stand type MJO, namely on the central part of Sumatra Island, the northern part of Kalimantan Island and the Maluku Islands. The lowest difference in daily rainfall and probability of the 95th extreme occur during the inactive phases, namely on central part of Sumatra Island, Sulawesi Island and the Nusa Tenggara Islands.

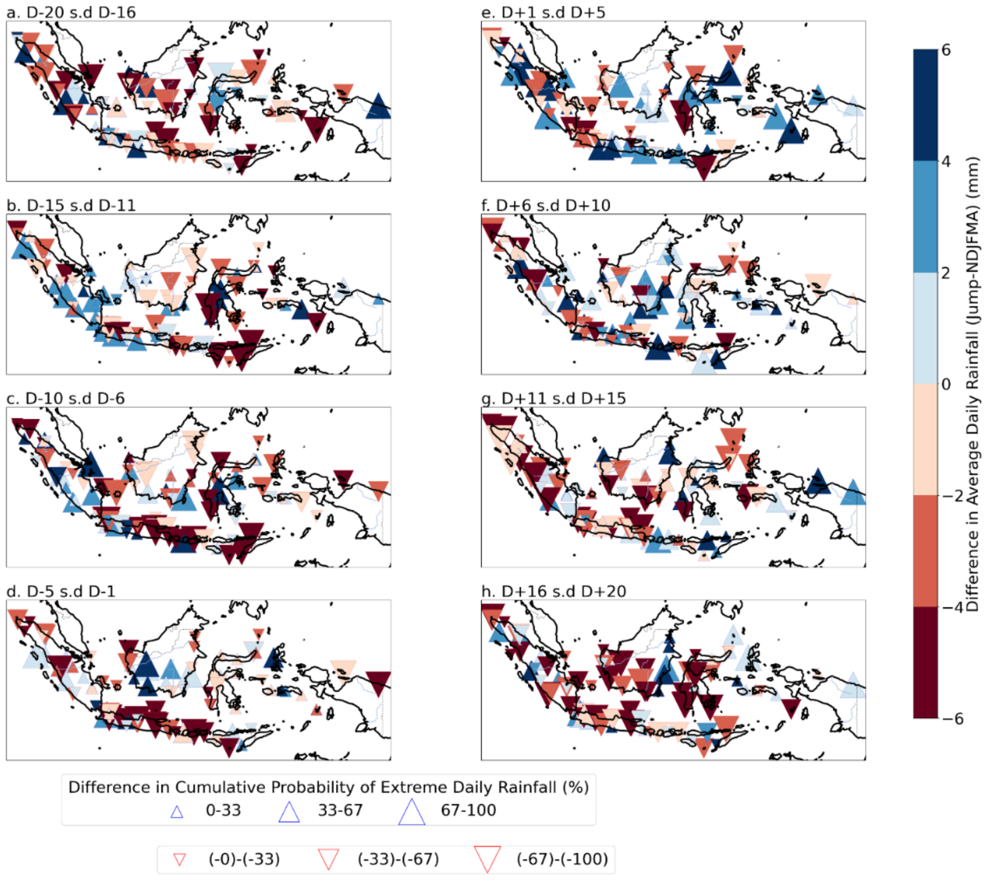

Fig. 4. Difference in probability of the 95th extreme during a jump type MJO relative to NDJFMA (%, difference in triangle size) and difference in average daily rainfall during that MJO versus NDJFMA (color, mm).

The active phases and inactive phases of the MJO jump and stand type do not propagate through Indonesian territory, but their active phases (inactive phases) approach Indonesian territory and cause an increase (decrease) in daily rainfall of 4 mm (-6 mm). Increase (decrease) in the 95th extreme probability of 34-67% (-67 to -100%).

Stand and jump have similarities, namely the type of MJO propagation that does not pass through Indonesian territory, both have slight simimilarities that namely the temporal and magnitude pattern of difference in daily rainfall and probability of the 95th extreme values. Apart from that, slow active phases and inactive phases only appear on the western border of Indonesia, while jumps appear in the western and eastern parts.

The increase in difference in daily rainfall and the probability of the 95th extreme of the MJO jump type starts from D-15 to D+10, the beginning comes from Sumatra Island or only western Indonesia from D-15 to D-1, the start was much faster than the stand type and entering D+6 only the central part of Indonesia experienced an increase, still almost the same as the stand type. This may be caused by the topography of the area [15].

The values of the difference in daily rainfall and the probability of the 95th extreme of the jump type MJO is much lower than the slow type. During the inactive phases of the jump type MJO, it cause a decrease in daily rainfall difference and the probability of the 95th extreme from D-20 to D-16.

The highest difference in daily rainfall and extreme probability of the 95th MJO jump type occur on southern Kalimantan Island, Sulawesi Island, and Bali Island, different from the stand type. The difference in daily rainfall and the probability of the 95th extreme is lowest during the inactive phases, namely in the same region.

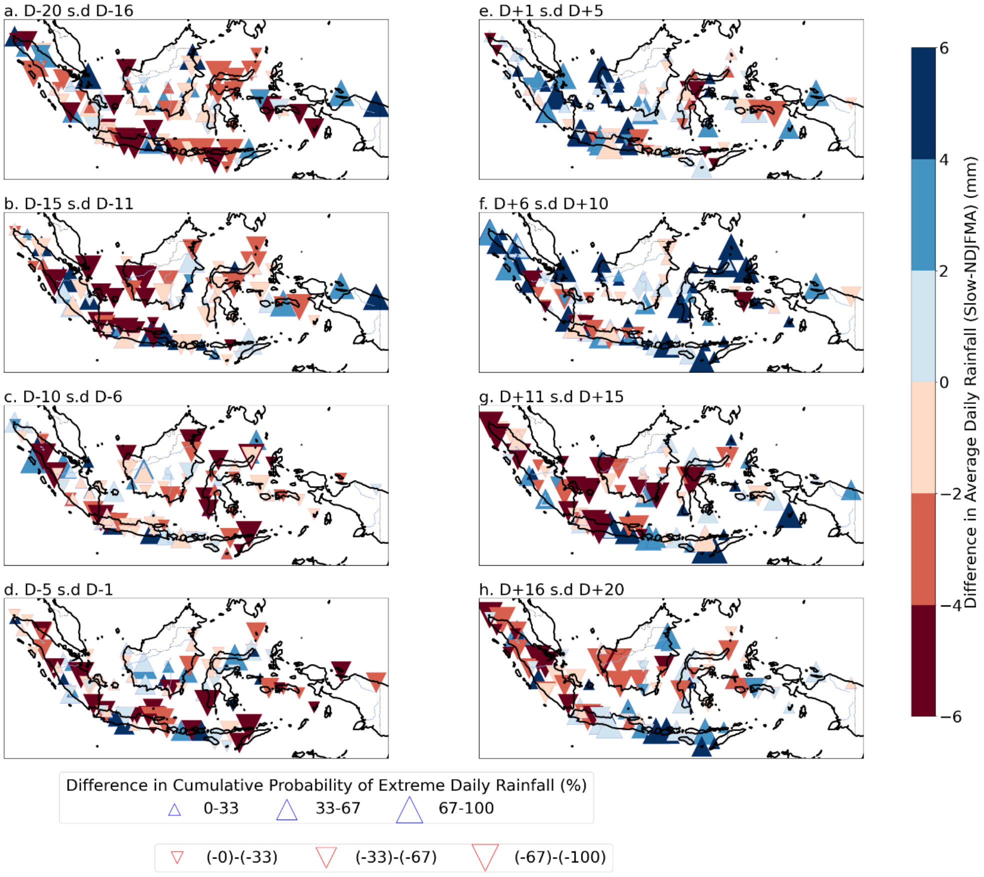

Fig. 5. Difference in probability of the 95th extreme during a slow type MJO relative to NDJFMA (%, difference in triangle size) and difference in average daily rainfall during that MJO versus NDJFMA (color, mm).

The MJO slow type active phases 2-4 from the Indian Ocean to Indonesian territory (inactive phases) are followed by an increase (decrease) in daily rainfall of 6 mm (-6 mm) and a probability of the 95th extreme of 67 to >100% (-67 to -100%). During the active phases, the MJO propagate through Indonesian territory causing an increase in daily rainfall difference and the probability of the 95th extreme starting from D+1 to D+20. When entering D+11, only the eastern part of Indonesia experienced an increase, still almost same as stand type. During the MJO slow type inactive phases, it cause a decrease in daily rainfall difference and the probability of the 95th extreme from D-20 to D-1.

The highest difference in daily rainfall and the 95th extreme probability occurs during the active phases of the slow type, namely on Sumatra Island, western Java Island, western Kalimantan Island, Nusa Tenggara Islands, Sulwaesi Island and Maluku Islands. The lowest difference in daily rainfall and probability of the 95th extreme occurs during the inactive phases, namely in the same area but not as far as Sulwaesi Island, the Nusa Tenggara Islands and the Maluku Islands.

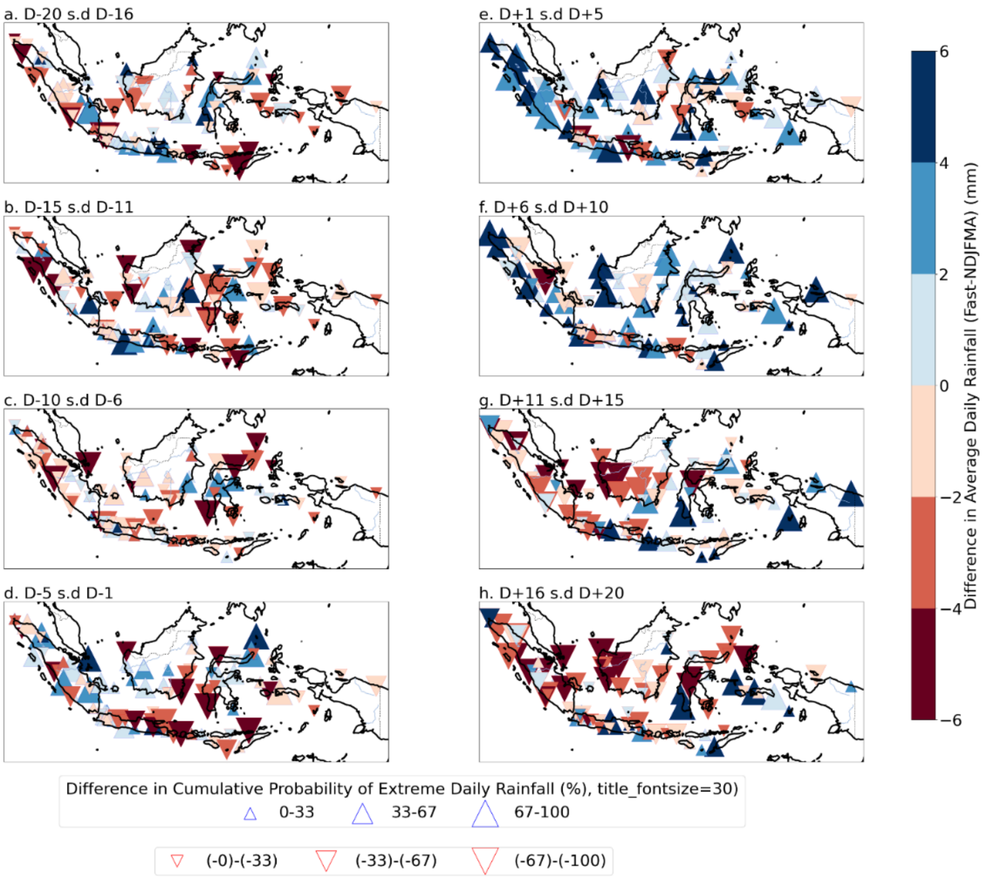

Fig. 6. Difference in probability of the 95th extreme during a fast type MJO relative to NDJFMA (%, difference in triangle size) and difference in average daily rainfall during that MJO versus NDJFMA (color, mm).

The increase in difference in daily rainfall and the probability of the 95th extreme of the fast type MJO starts from D-5 to D+20, the start was much faster than the slow type and entering D+11 only the eastern part of Indonesia experienced an increase, still almost the same as the stand and slow type. This may be because the fast type of MJO propagation requires less time to reach and pass through Indonesian territory.

The value of the difference in daily rainfall and the 95th extreme probability of the fast type MJO is slightly lower than the slow type, even though the two types of MJO have similar difference pattern. This is because fast type MJO propagation requires less time in Indonesia. During the inactive phases, it cause a decrease in daily rainfall differences and the probability of the 95th extreme from D-20 to D-6.

The highest difference in daily rainfall and the 95th extreme probability occurs during the active phases of the fast type, namely on Sumatra Island, western Java Island, western Kalimantan Island, Nusa Tenggara Islands, Sulwaesi Island and Maluku Islands, the same as the slow type. The difference in daily rainfall and the lowest probability of the 95th extreme occurs during the inactive phases, namely in the same area but not as far as Sulwaesi Island, the Nusa Tenggara Islands, and the Maluku Islands.

3.2.2 Comparison of difference in extreme daily rainfall patterns for each MJO type in western, central and eastern indonesia regions

The image below shows the opportunities for areas with difference in daily rainfall (MJO-NDJFMA) which are divided into 3 criteria, namely >1 mm (positive opportunity), <-1 mm (negative opportunity), and between >-1 mm and <1 mm (normal chance). The regional probability with positive daily rainfall difference (MJO-NDJFMA) or positive probability (negative probability) also has the same or follows the propagation of active phases (inactive phases) for each MJO type according to the criteria (stand, jump, slow, fast) from west to east, the same as the similarity in the pattern of difference in daily rainfall and the 95th extreme probability, in the previous subchapters. Meanwhile, normal opportunity is like condition when the MJO is not active or the daily average OLR anomaly shows a value close to zero (-5 to 5 $Watt/m^2$) in the Indonesian region.

The MJO slow and fast type cause positive opportunity almost evenly distributed throughout Indonesia, but the positive opportunity from the fast type MJO immediately disappears as soon as the active phases propagate towards the Pacific Ocean. Jump and stand do not propagate through Indonesia, each active phases (inactive phases) approaching Indonesian territory do not cause positive (negative) opportunity, both tend to have normal opportunity.

In western Indonesia, especially the island of Sumatra, there is a negative opportunity during the active phases of the jump type MJO. This may be caused by the topography of the area [15].

The slow type MJO has the highest and widest positive chance from western to eastern Indonesia compared to other types of MJO. This is because slow type MJO propagation takes longer in Indonesia.

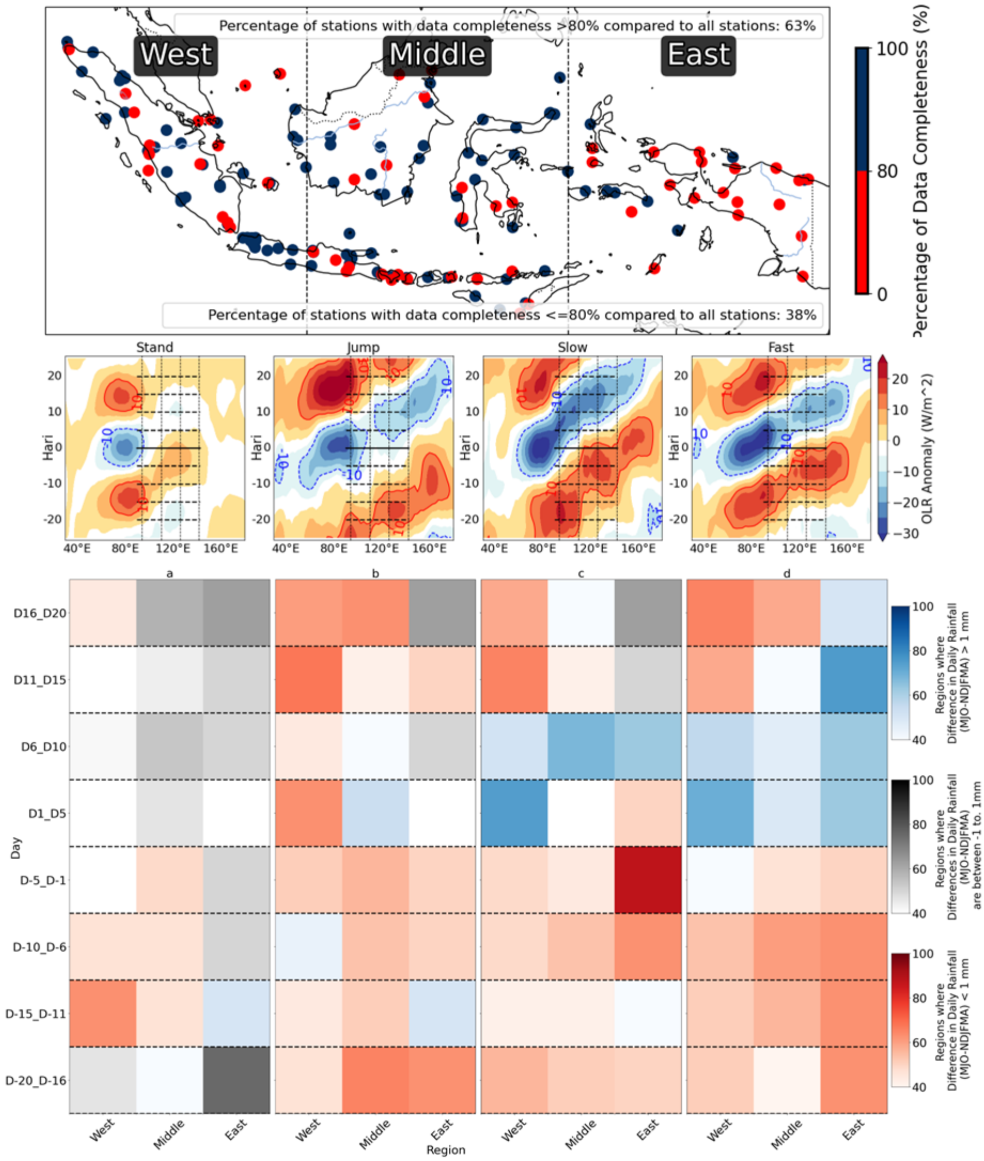

Fig. 7. Regional matrix with difference in daily rainfall (MJO-NDJFMA) (mm) when positive, normal, or negative for (a) stand, (b) jump, (c) slow, and (d) fast.

The image below shows the opportunities from areas with the 95th extreme probability difference which are divided into 3 criteria, namely >15% (positive chance), <-15% (negative chance), and between >-15% and <15% (normal chance). The regional probability of the positive 95th extreme probability difference or positive probability (negative probability) also has the same or follows the propagation of the active phases (inactive phases) for each MJO type according to the criteria (stand, jump, slow, fast) from west to east, the same as the similarity of the pattern of daily rainfall difference and the 95th extreme probability. This similar pattern follows the results of previous studies regarding the impact of MJO on the distribution of daily and daily extreme rainfall [2, 15] namely that each characteristic of MJO propagation during active phases 2-4 in the Indian Ocean and the Indonesian region (inactive phases 6-8) are followed by an increase (decrease) in the difference in daily rainfall with the climatology during NDJFM. Meanwhile, normal opportunity is similar to condition when the MJO is not active or the daily average OLR anomaly shows a value close to zero (-5 to 5 $Watt/m^2$) in the Indonesian region.

The slow and fast MJO types cause positive opportunity almost evenly distributed throughout Indonesia, but the positive opportunity from the fast type MJO immediately disappears as soon as the active phases propagate towards the Pacific Ocean. Jump and stand do not propagate through Indonesia, but each active phases (inactive phases) approache Indonesian territory, causing positive (negative) opportunity, in contrast to the pattern of difference in daily rainfall where both do not cause positive or negative opportunity. When the daily average OLR anomaly is close to 0 or the MJO is not active then the Indonesian region has a normal chance, the jump and stand type MJO have this pattern.

In western Indonesia, especially the island of Sumatra, there is a negative opportunity during the active phases of the jump type MJO. This may be caused by the topography of the area [15].

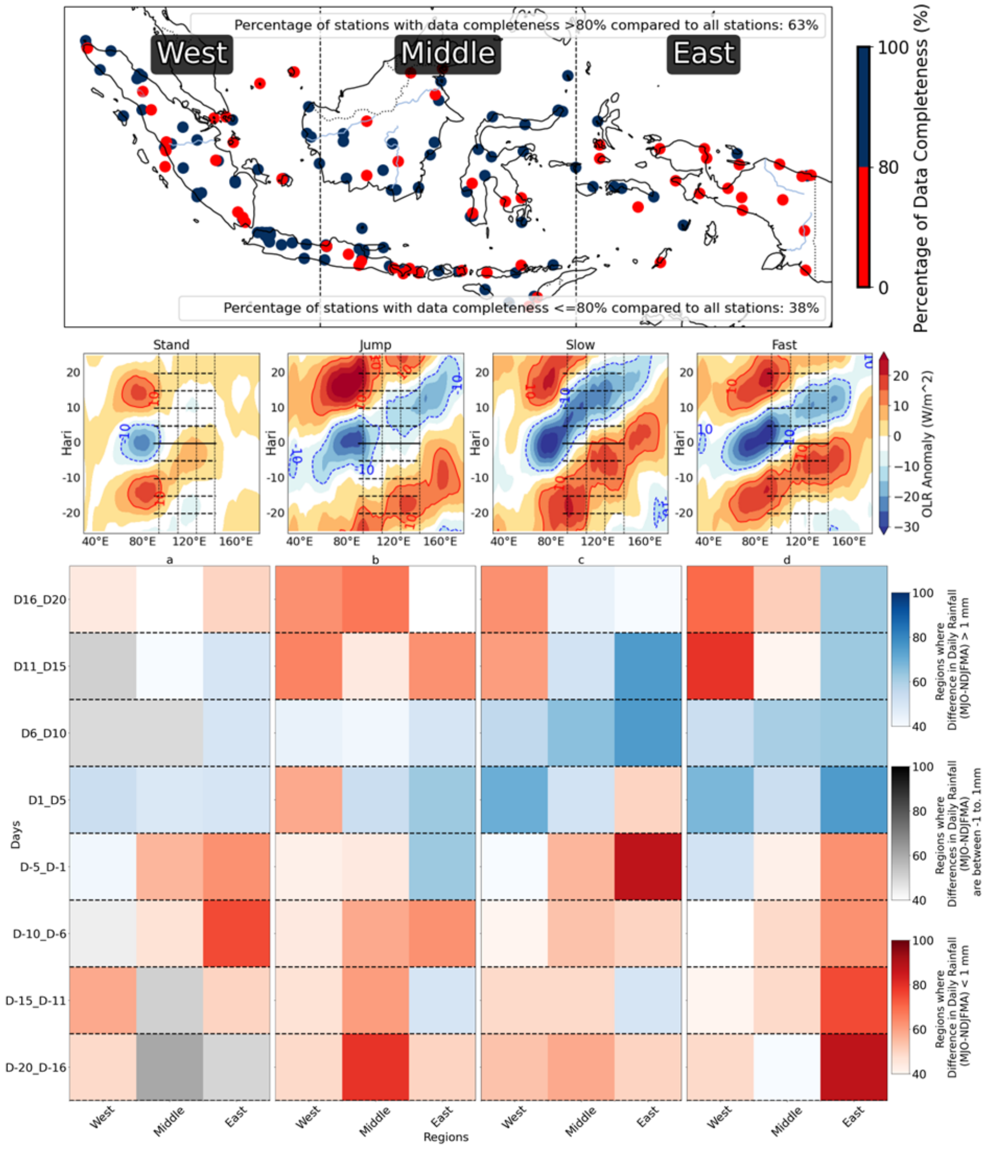

Fig. 8. Regional matrix with difference in daily rainfall (MJO-NDJFMA) (mm) when positive, normal, or negative for (a) stand, (b) jump, (c) slow, and (d) fast.

The slow type MJO has the highest and widest positive chance from western to eastern Indonesia compared to other types of MJO. This is because slow type MJO propagation takes longer in Indonesia. Parts of Indonesia during the stand and jump type MJO showed positive (negative) daily average OLR anomalies even though they were not included in the two MJO types, this caused the emergence of small positive opportunity (small negative opportunity).

4 Conclusion

Previous studies show that each characteristic of the MJO during its active phases (inactive phases) in the Indian Ocean to Indonesian territory are followed by an increase (decrease) in the difference in daily rainfall with its climatology during NDJFM [2, 15]. In this research, the following conclusions were obtained:

- Active phases 2-4 from slow and fast from the Indian Ocean to Indonesian territory (inactive phases 6-8) are followed by an increase (decrease) in daily rainfall of 6 mm (-6 mm) and an extreme probability of 95th amounting to 67 to >100% (-67 to -100%). The active phases and inactive phases of the jump and stand MJO types do not propagate through Indonesian territory, but their active phases (inactive phases) approach Indonesian territory and cause an increase (decrease) in daily rainfall of 4 mm (-6 mm) and increase (decrease) in the probability of the 95th extreme by 34-67% (-67 to -100%), the decrease in the probability of the 95th extreme has the same values between stand, jump, slow and fast, but the decrease in the difference in daily rainfall is much greater lower on stand and jump than slow and fast.
- MJO jump type increase in difference in daily rainfall and extreme probability of the 95th starting from D-15 to D+10, the beginning comes from Sumatra Island or only western Indonesia from D-15 to. H-1, the start was much faster than the stand type and entering D+6 only the central part of Indonesia experienced an increase, still almost the same as the stand type. This may be caused by the topography of the area [15].
- The regional chance of daily rainfall differences (MJO-NDJFMA) and the difference in positive 95th extreme probability or positive probability (negative probability) also have the same or follow the propagation of the active phases (inactive phases) for each MJO type according to the criteria (stand, jump, slow, fast) from western to eastern Indonesia, as well as similar pattern of difference in daily rainfall. The MJO slow type has the highest and widest positive chance from western to eastern Indonesia compared to other types of MJO. This is because the active phases of the MJO take longer to propagate in Indonesia. Meanwhile, the jump type of MJO has the lowest and narrowest positive opportunities in Indonesia.
- Jump and stand type do not propagate through Indonesia, but each active phases (inactive phases) approache Indonesian territory, causing positive (negative) opportunity, in contrast to the pattern of difference in daily rainfall where neither causes positive or negative opportunity.

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