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Analysis of the Effects of the Indian Ocean Dipole (IOD) and the Madden-Julian Oscillation (MJO) on Rainfall During the Dry Season in Padang

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Abstract

Dry-season rainfall in Padang is highly variable and can reach extreme intensities; however, the influence of global atmospheric phenomena on rainfall variability during June–August (JJA) remains insufficiently understood. This study examined the relationships of the Madden–Julian Oscillation (MJO) and Indian Ocean Dipole (IOD) with dry-season rainfall variability in Padang. The analysis used daily MJO index data from the Bureau of Meteorology, monthly Dipole Mode Index data from JAMSTEC, and rainfall records from Minangkabau International Airport Station for 1991–2020 and Teluk Bayur Maritime Meteorological Station for 1994–2020. Pearson correlation and cross-correlation analyses were employed to determine the strength, significance, and temporal lag of the relationships between MJO and IOD activity and rainfall. MJO Phase 3 was positively and significantly correlated with JJA rainfall at Minangkabau International Airport Station ($r = .254$, $p = .003$) and Teluk Bayur Station ($r = .232$, $p = .006$), whereas MJO Phase 4 showed no significant relationship. Cross-correlation analysis identified a significant negative relationship at a lag of approximately 10–12 days, indicating that rainfall tends to decrease 10–12 days after the active MJO passes. By contrast, the negative IOD was not significantly associated with JJA rainfall in either the contemporaneous or lagged analyses. These findings demonstrate that MJO Phase 3 is more closely associated with dry-season rainfall variability in Padang than either MJO Phase 4 or the negative IOD. Monitoring MJO Phase 3 may therefore provide useful supplementary information for medium-range dry-season rainfall forecasting in the region.

Keywords: Dry-Season Rainfall; Indian Ocean Dipole; Lagged Response; Madden–Julian Oscillation; Padang

INTRODUCTION

Climate refers to the weather conditions or weather patterns that occur in a specific region throughout the year and from year to year. No two regions have exactly the same weather and climate characteristics. The climate of a region or area is determined by several key factors, including latitude, prevailing winds, landmasses or continents, ocean currents, and topography (Yuliana, 2020).

In general, Indonesia has two seasons: the rainy season and the dry season. The rainy season typically occurs from October through March, peaking from December through February, due to the Asian monsoon. The dry season, on the other hand, occurs from April through September, peaking from June through August, due to the Australian monsoon. A monsoon is a seasonal reversal of wind direction between summer and winter caused by differences in the thermal properties of land and sea (As-syakur et al., 2016). Although these two monsoon systems occur periodically, seasonal and inter-seasonal rainfall variability is not always the same every year. This is due to the global climate phenomenon known as the Indian Ocean Dipole Mode (IOD), which influences rainfall variability in Indonesia. In addition to the IOD, another global factor that influences rainfall in Indonesia is the Madden–Julian Oscillation (MJO). The MJO significantly influences rainfall patterns in Indonesia and the surrounding regions crossed by the equator (Pattipeilohy et al., 2019).

West Sumatra is a region with high rainfall variability. In fact, during certain periods, rainfall can reach very high intensities, even falling into the “extreme rainfall” category. The Minangkabau Meteorological Station of the BMKG recorded rainfall of 368.4 mm/day in March 2024. This high rainfall intensity indicates that atmospheric conditions in West Sumatra are highly dynamic and can lead to a significant increase in rainfall. This rainfall variability is believed to be influenced by global atmospheric phenomena such as the Indian

Ocean Dipole (IOD) and the Madden-Julian Oscillation (MJO), which affect cloud formation and rainfall distribution in western Indonesia (BMKG Minangkabau Meteorological Station, observation record).

The Indian Ocean Dipole Mode (IOD) is a pattern of internal variability characterized by low air temperature anomalies and high sea surface temperature anomalies in the western Indian Ocean. This phenomenon is caused by differences in temperature anomalies along the east coast of Africa and the west coast of Sumatra. The Indian Ocean Dipole Mode is considered to have a greater influence on rainfall in western Indonesia (Ismail et al., 2020). The ocean-atmosphere interaction driven by the IOD influences rainfall anomaly patterns in the tropics through the interaction between the ocean and the atmosphere. If sea surface temperature anomalies in the western tropical Indian Ocean are greater than in the eastern part, then atmospheric pressure along the western coast of Sumatra in the tropical Indian Ocean will be significantly lower than in the eastern part. Consequently, convection will be high in the western tropical Indian Ocean, leading to above-normal rainfall along the eastern coast of Africa and in the western Indian Ocean. Meanwhile, along the western coast of Sumatra, atmospheric pressure will be higher than normal, resulting in below-normal rainfall and causing drought (Narulita, 2017). According to Rahayu (2018), a positive IOD leads to a decrease in rainfall intensity, while a negative IOD leads to an increase in rainfall intensity. Meanwhile, the Madden–Julian Oscillation (MJO) is a phenomenon involving the eastward propagation of oscillatory waves with a recurrence period of 30–90 days. The effects of this oscillation are particularly strong in low-latitude regions near the equator; it originates in the Indian Ocean and moves eastward between 10° N and 10° S (Tallamma et al., 2016). According to Pattipeilohy (2019), in the Ngurah Rai region of Bali, positive rainfall anomalies predominantly occur when the MJO is in the Continental-Marine phase (phases 4–5), accounting for 36%, while negative anomalies predominate when the MJO is in the Indian Ocean phase (phases 2–3), accounting for 33%. However, this relationship was observed in the Bali region, whose topographic and geographic characteristics differ from those of West Sumatra; therefore, a similar pattern may not necessarily hold true in the city of Padang. This is consistent with the study by Lopez-Bravo et al. (2025) in Sumatra, which showed that significant contributions to land-based rainfall primarily occur during the active phases of the MJO, with phase 3 exhibiting a particularly prominent contribution. However, that study was conducted during the rainy season (DJF), so the results do not yet reflect the MJO's influence on rainfall in Sumatra during the dry season. Therefore, Phases 3 and 4 are important to examine further in assessing the MJO's influence on rainfall in the city of Padang.

Seasonal rainfall variability in West Sumatra indicates that rainfall during the dry season is not always within normal ranges. During certain periods, rainfall may decrease, leading to drier conditions, while during other periods it may increase due to the influence of global and regional atmospheric phenomena (Gara et al., 2019). Research by Muhammad et al. (2022) shows that Madden-Julian Oscillation (MJO) activity during the dry season (May–September) can increase the probability of extreme rainfall in western Indonesia by up to 80% during certain active phases. These conditions indicate that the dry season does not always occur under dry conditions, as significant increases in rainfall can still occur during certain periods. This variability in rainfall during the dry season is believed to be influenced by global atmospheric phenomena such as the Madden-Julian Oscillation (MJO). Phenomena such as the MJO and the Indian Ocean Dipole (IOD) can cause variations in rainfall across a region, leading to shifts in the dry and wet seasons with varying rainfall intensities from year to year, characterized by both decreases and increases in rainfall (Pattipeilohy, 2019). A short-term but intense increase in extreme rainfall during the dry season can cause flooding and affect the agricultural sector; conversely, a decrease in rainfall during the dry season can lead to drought and water crises, as well as trigger wildfires (Sumastuti, 2016).

The city of Padang, the capital of West Sumatra Province, is located on the western coast of Sumatra and directly faces the Indian Ocean; it is characterized by high and variable rainfall. This geographic location makes Padang vulnerable to the influence of global atmospheric phenomena such as the Indian Ocean Dipole (IOD) and the Madden-Julian Oscillation (MJO), which can affect rainfall distribution, including during the dry season.

This study focuses on the influence of the negative Indian Ocean Dipole (IOD) and the Madden-Julian Oscillation (MJO)—specifically phases 3 and 4—on rainfall in the city of Padang during the dry season. The negative IOD was chosen because it is associated with an increased supply of water vapor from the Indian Ocean to western Indonesia, which has the potential to increase rainfall in the city of Padang. Meanwhile, MJO phases 3 and 4 are of interest because their convective activity extends from the Indian Ocean to Indonesia's maritime region, potentially influencing atmospheric conditions and rainfall in West Sumatra. Therefore, this study aims to analyze the influence and relationship of the negative IOD and

MJO Phases 3 and 4 on rainfall in the city of Padang during the dry season, specifically in June, July, and August (JJA).

METHODS

This study is a quantitative study using a time-series analysis design to examine the relationship between the Indian Ocean Dipole (IOD) and the Madden-Julian Oscillation (MJO) and rainfall variability during the dry season in the city of Padang. The data used include daily MJO indices obtained from the Bureau of Meteorology (BoM) , the IOD index in the form of the Dipole Mode Index (DMI) obtained from JAMSTEC, as well as daily rainfall data from the BMKG Class II Minangkabau Padang Pariaman Meteorological Station for the period 1991–2020 (30 years) and the Teluk Bayur Maritime Meteorological Station for the period 1994–2020 (27 years). The IOD and MJO index data were used as climate variables, while the rainfall data from both observation stations were used as response variables. The analysis was conducted through the following steps: grouping of dry season (JJA) data; identification of negative IOD conditions and active MJO in phases 3 and 4; Pearson correlation analysis; and cross-correlation analysis to identify relationships across various time lags. This study relied entirely on secondary data, so no field observation was carried out by the authors. The MJO index was retrieved from the BoM website and the DMI from JAMSTEC, while the daily rainfall records were obtained from BMKG. Data collection, processing, and analysis were conducted over a period of thirty-six months, from September 2023 to August 2026.

Daily rainfall data from two BMKG stations—the Minangkabau International Airport (BIM) Station for the period 1991–2020 (30 years) and the Teluk Bayur Maritime Meteorological Station for the period 1994–2020 (27 years)—will be organized using Microsoft Excel by date, month, and year. The data will then be filtered to extract rainfall data for June, July, and August (JJA), which constitute the dry season. The JJA daily rainfall data will subsequently be organized into a time series based on the sequence of observation dates to illustrate rainfall variability during the study period. In addition, the daily rainfall data were processed into monthly rainfall data for June, July, and August (JJA), which were used in the analysis at the monthly scale. Daily MJO index data obtained from the Australian Bureau of Meteorology (BOM) will be filtered based on two criteria: MJO phases 3 and 4, and an amplitude value greater than 1. The selection of phases 3 and 4 is based on the position of the active MJO convection center, which is located in the central Indian Ocean extending to the Indonesian region, thereby exerting a direct influence on West Sumatra; meanwhile, an amplitude value greater than 1 indicates a significantly active MJO condition. The MJO amplitude is calculated using the following equation:

$$\textbf{Amplitude} = \sqrt{(\mathbf{RMM1^2 + RMM2^2})} \quad (1)$$

Monthly IOD index data, obtained in the form of the Dipole Mode Index (DMI), will be filtered based on negative IOD conditions that is, DMI values less than −0.4. The selection of negative IOD is based on sea surface temperatures in the eastern Indian Ocean being warmer than normal, which has the potential to increase rainfall in Indonesia during the dry season. Next, the Pearson correlation method is used to examine the relationship between the MJO and the IOD and dry-season rainfall; a cross-correlation analysis is then conducted to determine the optimal time lag between MJO and IOD activity and changes in dry-season rainfall in West Sumatra.

1. Pearson Correlation Analysis

Pearson correlation analysis is used to examine the direction and strength of the relationship between the MJO and the IOD and dry-season rainfall at both observation stations. Data on rainfall, the MJO, and the IOD will be analyzed using the following formula:

$$r = \frac{n \sum_{i=1}^{n} Xi\, Yi - \sum_{i=1}^{n} Xi \sum_{i=1}^{n} Yi}{\sqrt{n \sum_{i=1}^{n} Xi^2 - \sum_{i=1}^{n} Xi^2}\sqrt{n \sum_{i=1}^{n} Yi^2 - \sum_{i=1}^{n} Yi^2}} \quad (2)$$

r = Pearson correlation

n = number of data points

X = IOD index value / MJO amplitude value

Y = precipitation (daily/monthly)

The correlation coefficient (r) ranges from a minimum of -1 to a maximum of 1, or can also be expressed as ($-1 \le r \le 1$). If r = -1, this indicates a negative correlation (the closer the value is to -1, the stronger the relationship between X and Y, and the more inversely proportional the two variables are); r = 0 indicates that there is no linear relationship between variables X and Y, and r = 1 indicates a very strong positive correlation (the closer the value is to 1, the stronger the relationship between X and Y, and the two variables are directly proportional).

The strength of the correlation is interpreted using the following categories:

Table 1. Interpretation of Correlation Coefficient Strength

r-value	Category
0.00 - 0.19	Very Weak
0.20 - 0.39	Weak
0.40 - 0.59	Moderate
0.60 - 0.79	Strong
0.80 – 1.00	Very Strong

(Supardi,2017)

2. Cross-Correlation Analysis

A cross-correlation analysis was conducted to determine the relationship between Madden-Julian Oscillation (MJO) and Indian Ocean Dipole (IOD) activity and rainfall at various time lags. This analysis was used to determine whether changes in MJO and IOD activity are directly related to changes in rainfall or occur after a certain time lag.

A time lag is the time difference between two time series used to determine whether a variable is directly related to another variable or whether the relationship occurs after a certain time interval. In the analysis of the relationship between climate and precipitation, time lags are used to determine the response time of precipitation to changes in a climate index (Sağır et al., 2020).

Formula:

$$r_{xy}(k)=\frac{\frac{1}{n}\sum_{n-k}^{i=1}\ (x_i-\bar{x})(y_i+k-\bar{y})}{\sigma_x\sigma_y} \qquad (3)$$

x = data (DMI index and MJO amplitude)

y = precipitation anomalies

k = time lag

r_xy (k)= correlation coefficient between x and y at lag k

n = number of data points

$\bar{x}$, $\bar{y}$ = mean of each data set

σ_x, σ_y = standard deviation of each data set

(Sağır et al., 2020)

In cross-correlation analysis, the time lag is determined by testing the relationship between the MJO or IOD indices and precipitation at various time lags. Each lag value yields a cross-correlation coefficient ($r_{xy}(k)$). These coefficient values are then compared to determine the time lag that shows the strongest relationship. The optimal time lag is determined based on the largest absolute correlation coefficient among the lags in which the climate index leads rainfall, $|r_{xy}(k)|$, while also considering the sign of the coefficient to determine the direction of the relationship.

Because the MJO and IOD have different temporal resolutions, the time lag units used are also adjusted according to the type of data. For the MJO, since the MJO data used are daily, the cross correlation analysis is performed with time lags ranging from −30 to +30 days. In the series pair used in this study (rainfall anomaly with MJO index), k=0 indicates the relationship between the MJO and rainfall at the same time, a negative k indicates that the MJO index leads rainfall by k days, and a positive k indicates that rainfall leads the MJO index. Because only the lags in which the MJO leads rainfall are physically meaningful for this study, the optimal lag was selected from the negative range.

For the IOD, since the IOD data used are monthly, the analysis was conducted with time lags of −3 to +3 months. A value of k=0 indicates the relationship between the IOD and rainfall in the same month, while a negative k indicates that the DMI leads rainfall by k months. The cross-correlation values for each time lag were then compared to identify the time lag that showed the strongest relationship.

A time lag range of −30 to +30 days for the MJO was selected to evaluate the rainfall response within a time frame of up to one month following changes in MJO activity, while a range of −3 to +3 months for the IOD was used to evaluate the rainfall response up to three months after changes in the DMI.

RESULTS

1. Variability in Daily Rainfall During the Dry Season

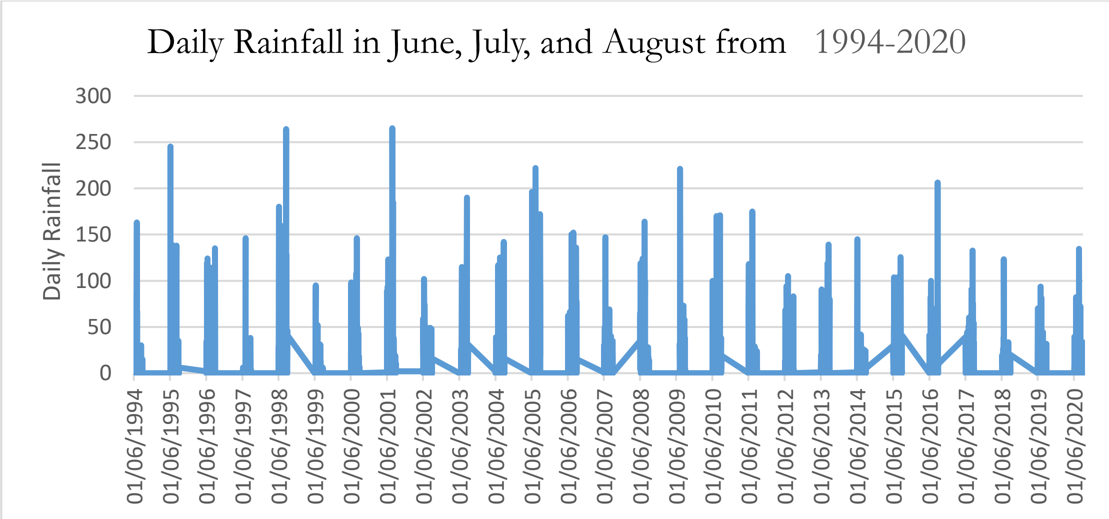

Figure 1. Graph of Daily Rainfall for June, July, and August, 1994–2020 at the Teluk Bayur Maritime Station

Figure 1 shows that the variability of daily rainfall during the dry season at the Teluk Bayur Maritime Station over the 1994–2020 period exhibits a consistent pattern. In general, most days during the dry season were characterized by no rain or very light rain, reflecting the typical characteristics of the dry season in the West Sumatra region. However, there were several sporadic episodes of heavy rainfall during this dry period, including a few extreme rainfall events exceeding 200 mm/day, with the highest recorded value reaching 265 mm/day during the observation period.

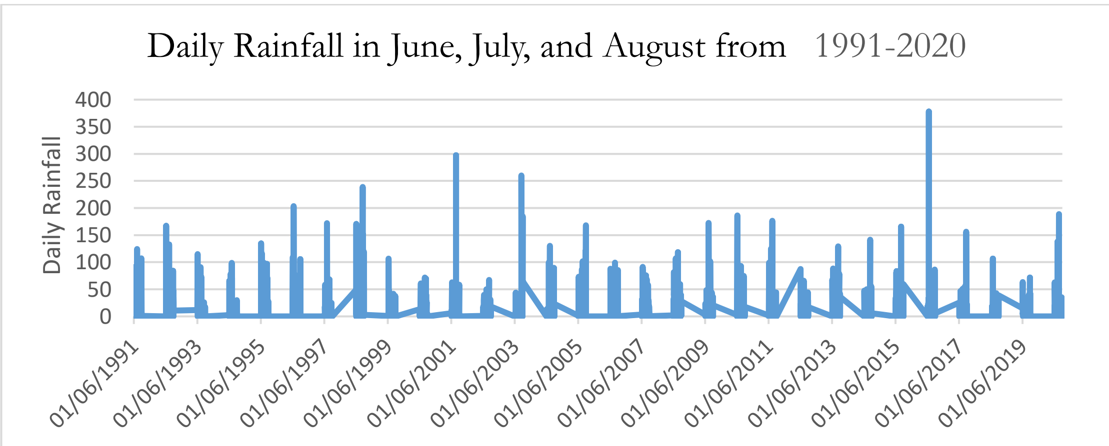

Figure 2. Graph of Daily Rainfall for June, July, and August, 1991–2020, at the Minangkabau Meteorological Station

Figure 2 shows the variability of daily rainfall during the dry season at the BIM Station over the period 1991–2020. In general, the pattern of daily rainfall variability at the BIM Station shows similarities to that at the Teluk Bayur Maritime Station, where most days during the dry season are characterized by no rain or very light rain, with sporadic occurrences of heavy to extreme rainfall. Although the variability patterns at the two stations are nearly identical, the BIM Station recorded higher extreme rainfall values than the Teluk Bayur Maritime Station, with the highest value reaching 378 mm/day during the observation period.

2. The Relationship between the MJO and the IOD and Rainfall

Table 2. Pearson correlation results between the MJO and rainfall

Station	MJO Phase	r	Sig.	N (Day)	Category	Significance
BIM	Phase 3	0.254	0.003	138	Weak	Yes
BIM	Phase 4	0.11	0.196	139	Very Weak	No
Teluk Bayur	Phase 3	0.232	0.006	139	Weak	Yes
Teluk Bayur	Phase 4	0.151	0.076	139	Very Weak	No

MJO Phase 3 showed a significant positive correlation with dry-season rainfall at both stations. At the BIM Station, a value of $r = 0.254$ was obtained with a significance level of 0.003, while the Teluk Bayur Station had a value of $r = 0.232$ with a significance level of 0.006. Both relationships fall into the weak but significant category at the 0.01 level, indicating that MJO Phase 3 activity tends to be followed by an increase in rainfall at both stations.

MJO Phase 4 showed a positive but insignificant correlation with rainfall. At the BIM Station, the correlation coefficient was $r = 0.110$ with a p-value of 0.196 (very weak category), while at the Teluk Bayur Station, it was $r = 0.151$ with a p-value of 0.076 (very weak category). Since the significance value is > 0.05, the relationship is not statistically significant; therefore, MJO Phase 4 has not yet shown a noticeable effect on dry-season rainfall at either station.

Table 3. Pearson correlation results between IOD and rainfall

Station	R	Sig.	N (Month)	Category	Significance
BIM	−0.085	0.730	19	Very Weak	No.
Teluk Bayur	0.029	0.910	18	Very Weak	No.

The results of the Pearson correlation analysis show that the negative IOD has no significant relationship with monthly rainfall during the dry season at both observation stations. At the BIM Station, a value of $r = -0.085$ was obtained with a significance level of

0.730, while at the Teluk Bayur Maritime Station, a value of r = 0.029 was obtained with a significance level of 0.910. Both significance levels are greater than 0.05, so statistically there is no significant relationship between the negative IOD and JJA rainfall in the study area.

Table 4. Time lag of the MJO

Station	Optimal Lag (Days)	r-Value	Standard error	Significance threshold (±2 SE)	Significant
BIM	-10	-0.073	0.019	0.038	Yes
Teluk Bayur	-12	-0.062	0.02	0.04	Yes

The results of the cross-correlation analysis between the MJO index and dry-season rainfall anomalies at the BIM Station showed the highest correlation value at a lag of −10 days, with r = −0.073 and a standard error of 0.019. This value exceeds the significance threshold of ±0.038 and is therefore significant at the 95% confidence level. The optimal time lag of −10 days at the BIM Station indicates that MJO activity in phases 3 and 4 influences dry-season rainfall with a 10-day time lag. The negative correlation of r = −0.073 suggests that when the active MJO passes over Indonesia, rainfall in the BIM region tends to decrease 10 days later. The correlation value at the BIM Station is stronger than that at the Teluk Bayur Maritime Station, indicating that the BIM area is more responsive to MJO activity.

At the Teluk Bayur Maritime Station, the same analysis produced the strongest relationship at a lag of −12 days, with r = −0.062 and a standard error of 0.020. This value also exceeds the significance threshold of ±0.040 and is therefore significant at the 95% confidence level. The pattern at the two stations is consistent: the correlation is positive at lag 0, in line with the Pearson results, and turns negative after a lag of roughly 10 to 12 days. This shift indicates that rainfall tends to increase while the active MJO is passing, then decrease about 10 to 12 days afterwards, when the convective center of the MJO has moved eastward and West Sumatra is situated in the suppressed phase of the oscillation.

Table 5. Time lag of the IOD

Station	Optimal Lag (Months)	r-Value	Standard error	Significance threshold (±2 SE)	Significant
BIM	−1	0.193	0.112	0.226	No
Teluk Bayur	0	0.182	0.105	0.214	No

The results of the cross-correlation analysis between the DMI IOD and monthly rainfall anomalies during the dry season showed no significant lag at either observation station. At the BIM Station, the highest correlation value was found at a lag of −1 month, with r = 0.193, but this was still below the significance threshold of ±0.226. At the Teluk Bayur Maritime Station, the highest correlation value was found at a lag of 0, with r = 0.182, but this was still below the significance threshold of ±0.214. The lack of significance in the IOD time lag results at both stations is consistent with the results of the negative Pearson correlation for the IOD, which was also not significant.

DISCUSSION

The results of the Pearson correlation analysis show that MJO Phase 3 has a positive and significant relationship with dry-season rainfall (JJA) at both observation stations. At the BIM Station, a value of r = 0.254 was obtained with a significance level of 0.003, while the Teluk Bayur Station had a value of r = 0.232 with a significance level of 0.006. Both relationships fall into the weak category but are significant at the 0.01 level. This indicates that MJO Phase 3 activity tends to be followed by an increase in rainfall in the study area. MJO Phase 3 is the phase when the active convection center is located in the central Indian Ocean and moves toward the Indonesian region, thereby increasing the supply of water vapor and supporting cloud formation in West Sumatra (Hidayat, 2016). These results are consistent with the study by Lopez-Bravo et al. (2025) in Sumatra, which showed that significant contributions to landfall rainfall primarily occur during the active phases of the MJO, with Phase 3 exhibiting a particularly prominent contribution. However, that study focused on the rainy season (DJF), whereas this study indicates that the influence of MJO Phase 3 is also significantly detected during the dry season (JJA) in the city of Padang. These findings suggest that the MJO's influence on rainfall does not occur exclusively during the rainy season but can also be detected during the dry season, particularly when the MJO is in Phase 3.

In contrast, MJO Phase 4 showed no significant correlation with rainfall at either station. The correlation coefficient at BIM was r = 0.110 with a p-value of 0.196, while at Teluk Bayur it was r = 0.151 with a p-value of 0.076. Although both showed a positive correlation, p-values > 0.05 indicate that the relationship is not yet statistically significant. This condition may be related to the dominance of the relatively dry Australian monsoon during the JJA period, thereby reducing the influence of MJO convection on rainfall in the West Sumatra region (Purwaningsih et al., 2020).

The difference in the responses of the two stations indicates that the influence of the MJO can also be affected by the local and geographic characteristics of the observation area. In addition to the MJO, dry-season rainfall in West Sumatra is influenced by various factors such as monsoon circulation, the topography of the Bukit Barisan mountain range, and other climatic phenomena. Therefore, the relatively weak correlation with the MJO suggests that the MJO is not the sole factor determining rainfall variability.

For the IOD, Pearson correlation results showed no significant relationship between negative IOD values and monthly rainfall during the JJA period. The BIM station yielded r = −0.085 with a significance level of 0.730, while Teluk Bayur yielded r = 0.029 with a significance level of 0.910. Cross-correlation results also indicated the absence of any significant time lags. The highest correlations were found at a lag of −1 month at BIM (r = 0.193) and at lag 0 at Teluk Bayur (r = 0.182), but both values remained below their respective significance thresholds. These results indicate that the influence of the IOD on JJA rainfall in the study area is relatively weak and not statistically detectable. This condition may be related to the spatially and seasonally varying response of the IOD, as well as the stronger influence of the IOD during specific periods in Indonesia (Nur'utami & Hidayat, 2016; Kurniadi et al., 2021). Amirudin et al. (2020) further reported that the isolated influence of the IOD on rainfall in Southeast Asia is expressed mainly through subsidence over the Maritime Continent, which suppresses convection and produces drier rather than wetter conditions during the JJA and SON seasons. This mechanism helps explain why the negative IOD did not translate into a detectable increase in dry season rainfall in the city of Padang.

Overall, MJO Phase 3 exhibits a more consistent relationship with dry-season rainfall compared to MJO Phase 4 and negative IOD. These findings suggest that monitoring MJO activity, particularly Phase 3, can serve as supporting information for understanding the variability and forecasting of dry-season rainfall in the city of Padang. However, this study is limited to two observation stations and the JJA period; therefore, future research could consider more stations, different seasonal periods, and incorporate other climatic factors such as ENSO and the monsoon to gain a more comprehensive understanding.

CONCLUSION

The results of the study show that MJO Phase 3 has a positive and significant relationship with dry-season rainfall (JJA) in Padang, with a correlation coefficient of r =

0.254 at the BIM Station and r = 0.232 at the Teluk Bayur Maritime Station, both significant at the 0.01 level. The cross correlation analysis further showed a significant negative relationship at a time lag of about 10 to 12 days, indicating that rainfall tends to decrease roughly 10 to 12 days after the active MJO passes, when the convective center has moved eastward and West Sumatra lies in the suppressed phase of the oscillation. Meanwhile, MJO Phase 4 did not show a significant relationship at either station. Negative IOD also did not show a significant relationship with dry-season rainfall, either in correlation or time-lag analysis. These results indicate that the MJO, particularly Phase 3, shows a more detectable relationship with dry-season rainfall variability in Padang than does the negative IOD.

These findings contribute to a better understanding of the relationship between the MJO and rainfall variability during the dry season in the Padang area, particularly that Phase 3 can serve as an indicator for understanding changes in rainfall while accounting for time lags. Future research is recommended to consider other climatic factors, such as ENSO, the monsoon, and local atmospheric conditions, as well as to use broader observation periods and regions to gain a more comprehensive understanding of dry-season rainfall variability.

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