

Analysis of the Effect of ENSO and IOD on High to Very High Rainfall in South Sumatra for the Period 2000–2024

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Abstract

High to very high rainfall variability in South Sumatra was a hydroclimatological phenomenon influenced by interactions between atmospheric and oceanic dynamics at various temporal scales. El Niño–Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) were two global climate phenomena that played important roles in influencing rainfall distribution in Indonesia. This study aimed to analyze the influence of ENSO and IOD variability on high to very high rainfall events in South Sumatra during the period 2000–2024. The study applied a quantitative approach based on climatological statistical analysis using monthly time-series data. Rainfall data were obtained from the Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG), while the Niño 3.4 index representing ENSO and Dipole Mode Index (DMI) representing IOD were obtained from the National Oceanic and Atmospheric Administration (NOAA). The relationships between variables were analyzed using Pearson correlation, simple linear regression, and multiple linear regression to determine the partial and simultaneous relationships between ENSO, IOD, and rainfall variability. The results showed that ENSO and IOD exhibited negative relationships with rainfall variability in South Sumatra. Simultaneously, ENSO and IOD influenced rainfall variation, although their contribution was relatively small compared with other atmospheric factors.

Keywords: ENSO, IOD, high and very high rainfall, South Sumatra.

INTRODUCTION

Global climate change has resulted in an increase in the Earth's average surface temperature due to the rising concentration of greenhouse gases in the atmosphere. This temperature increase affects the atmosphere's capacity to store water vapor, potentially enhancing the intensity and frequency of extreme rainfall events in various regions of the world (Fowler et al., 2021; Mikhaylov et al., 2020). Furthermore, climate change also influences global atmospheric circulation patterns and the spatial and temporal distribution of rainfall, leading to increased regional rainfall variability (Masson-Delmotte et al., 2021).

Indonesia, as a maritime tropical region, has highly active atmospheric characteristics with convective processes occurring throughout the year. These

conditions cause rainfall variability in Indonesia to be strongly influenced by interactions between the atmosphere and ocean across various time scales, ranging from local to global scales (Hartmann, 2016). The increasing occurrence of high-intensity rainfall events has become an important issue because it is associated with a higher risk of hydrometeorological disasters, such as floods and inundation, particularly in regions with complex hydrological systems.

Rainfall variability in Indonesia is influenced by the Asian–Australian monsoon system and various global climate phenomena, particularly the El Niño–Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) (McBride et al., 2003). ENSO is an ocean–atmosphere interaction phenomenon characterized by changes in sea surface

temperature in the tropical Pacific Ocean and influences the Walker circulation and tropical convective activity (Philander, 1990). The El Niño phase generally causes reduced rainfall in Indonesia due to weakened convective activity, whereas the La Niña phase increases the likelihood of rainfall occurrence due to enhanced moisture supply and convective activity over Indonesia (Hanifa & Wiratmo, 2024).

In addition to ENSO, the IOD phenomenon plays an important role in controlling rainfall variability, particularly in western Indonesia. IOD is a sea surface temperature anomaly phenomenon in the Indian Ocean that causes changes in the distribution of heat and atmospheric moisture. The positive IOD phase causes cooling of sea surface temperatures around Indonesia, thereby reducing convective activity and rainfall, whereas the negative IOD phase increases moisture supply that supports convective cloud formation and enhanced rainfall (Srivastava et al., 2023).

South Sumatra is an important region for investigating high to very high rainfall variability because of its geographical and hydroclimatic characteristics. The region includes extensive lowland areas and major river systems, particularly the Musi River Basin, and is located within the influence of atmospheric and oceanic processes associated with both the Indian and Pacific Oceans. These characteristics may contribute to complex rainfall responses to large-scale climate variability and make the region particularly relevant for examining the relationship between climate phenomena and high-intensity rainfall events. Understanding this relationship is important because variations in rainfall intensity may have implications for flood risk, water-resource management, and other hydroclimatic conditions in the region.

Several previous studies have investigated the influence of ENSO and IOD on rainfall variability in Indonesia (Hidayat & Ando, 2014; Kasihairani et al., 2014). These studies have demonstrated the relevance of large-scale climate phenomena in explaining variations in rainfall patterns across Indonesia. However, previous research has generally focused on overall or seasonal rainfall variability, whereas studies specifically examining the relationship between ENSO and IOD and high to very high rainfall events in South Sumatra using long-term monthly time-series data remain relatively limited.

Despite the established relevance of ENSO and IOD to rainfall variability across Indonesia, a notable research gap remains in understanding their specific relationship with high to very high rainfall events in South Sumatra. In particular, the occurrence of high to very high monthly rainfall events has received less focused attention than general rainfall variability. Moreover, the individual and combined relationships between ENSO and IOD and long-term monthly rainfall variability in South Sumatra remain insufficiently explored. Addressing this gap is essential for advancing the understanding of how large-scale climate variability is associated with high-intensity rainfall conditions in the region.

The novelty of this study lies in its specific focus on high to very high monthly rainfall events in South Sumatra and its examination of the individual and combined relationships between ENSO and IOD and rainfall variability using a 25-year monthly time series covering 2000–2024.

Accordingly, this study aims to examine the relationship between ENSO and IOD variability and high to very high rainfall events in South Sumatra during the 2000–2024 period. The findings are expected to enhance understanding of

the contribution of large-scale climate phenomena to high-intensity rainfall variability and to support hydrometeorological risk mitigation efforts in South Sumatra.

MATERIALS AND METHODS

This study was conducted in South Sumatra, Indonesia, using monthly rainfall data covering a 25-year period from January 2000 to December 2024. The dataset consists of 300 monthly observations. Monthly rainfall data were used as the primary dependent variable, while the Niño 3.4 index was used to represent ENSO variability and the Dipole Mode Index (DMI) was used to represent IOD variability. The rainfall data were obtained from the meteorological observation dataset used in this study, while the Niño 3.4 and DMI indices were obtained from the corresponding climate-index datasets described in the data sources section.

Monthly rainfall data were obtained from the Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG). The Niño 3.4 index as an indicator of ENSO and the Dipole Mode Index (DMI) as an indicator of IOD were obtained from the National Oceanic and Atmospheric Administration (NOAA). All datasets were arranged into monthly time series with the same observation period to ensure consistency among variables during the analysis process.

Before statistical analysis, the rainfall and climate-index datasets underwent quality control procedures to ensure data completeness, consistency, and reliability. The quality control process included checking the completeness of the monthly time series, identifying missing observations, examining anomalous values, and verifying the temporal consistency of the datasets. The datasets were also checked to ensure that the rainfall observations

and climate indices corresponded to the same monthly observation periods before statistical analysis was conducted.

The identification of high to very high rainfall events was conducted based on the monthly rainfall classification established by the Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG), where the high rainfall category is defined as monthly rainfall accumulation reaching ≥ 300 mm/month, while the very high rainfall category is defined as monthly rainfall accumulation reaching ≥ 500 mm/month. This classification was used to determine the characteristics of high to very high rainfall events during the study period.

The relationship between ENSO, IOD, and rainfall was analyzed using Pearson correlation to determine the direction and strength of the relationship among variables. Furthermore, simple linear regression was applied to determine the partial influence of each climate variable on rainfall variations. The simultaneous influence of ENSO and IOD was analyzed using multiple linear regression, with rainfall as the dependent variable and ENSO and IOD as independent variables. The statistical analysis results were then visualized through time series graphs, scatter plots, and statistical tables to support the interpretation of research findings.

RESULTS AND DISCUSSION

Variability of High to Very High Rainfall in South Sumatra during the Period of 2000–2024

Rainfall variability in South Sumatra during the period of 2000–2024 exhibited complex temporal variations, with fluctuations occurring on both monthly and annual scales. Based on the analysis of 300 monthly rainfall datasets, the rainfall pattern showed seasonal characteristics influenced by the Asian–Australian monsoon system as well as

regional and global atmospheric–oceanic dynamics.

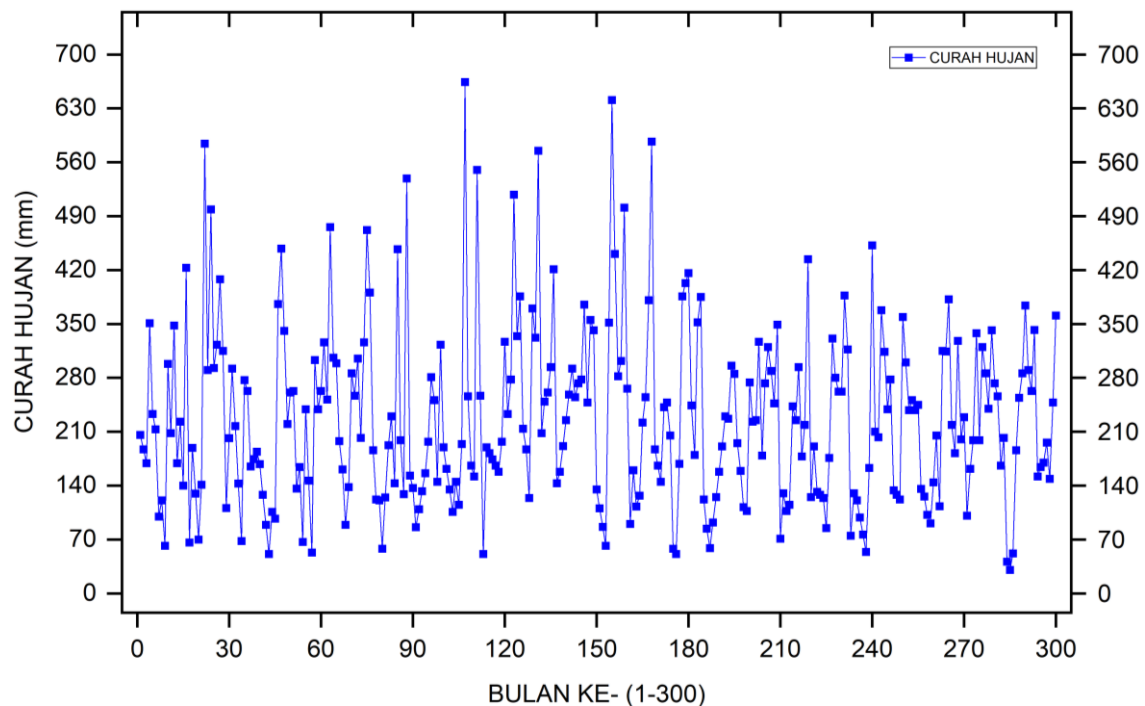


Figure 1. Monthly rainfall variation in South Sumatra during the period of 2000–2024

Figure 1 shows that rainfall in South Sumatra experienced significant fluctuations during the study period. Monthly rainfall values exhibited a wide range of variations, with several periods experiencing increased intensity that reached the high and very high rainfall categories. Based on the identification results, there were 68 high to very high rainfall events, accounting for approximately 22.7% of the total observation period.

These high to very high rainfall events did not occur continuously but appeared during certain periods associated with atmospheric conditions that supported enhanced convective activity. This condition indicates that rainfall variability in South Sumatra is not only controlled by local factors but is also influenced by broader-scale climate dynamics.

According to Aldrian & Susanto (2003), rainfall patterns in Indonesia are generally influenced by the Asian–Australian monsoon system, which

causes seasonal changes in rainfall distribution. However, variations between periods can be intensified or weakened by global climate phenomena such as ENSO and IOD, which modify sea surface temperature distribution and atmospheric convective activity (McBride et al., 2003; Saji et al., 1999).

The ENSO phenomenon plays a role in controlling changes in the Walker circulation, which affects moisture transport toward Indonesia. During La Niña conditions, increased convective activity over the Indonesian maritime region can enhance the probability of high rainfall events, whereas El Niño generally causes reduced rainfall due to decreased convective activity (McPhaden et al., 2006; Philander, 1990). In addition, IOD also contributes to regulating moisture supply from the Indian Ocean toward western Indonesia. The negative IOD phase generally enhances convective activity due to increased sea surface temperatures around Indonesia, while the positive IOD

phase leads to reduced convective activity (Ashok et al., 2001; Saji et al., 1999).

These characteristics indicate that high to very high rainfall events in South Sumatra are associated with global climate conditions occurring during certain periods. Therefore, further analysis of the relationship between ENSO and IOD with high to very high rainfall events is required to understand the contribution of each phenomenon to rainfall variability in the study area.

The Relationship between ENSO and High to Very High Rainfall in South Sumatra

ENSO is one of the global climate variability phenomena that plays an important role in controlling rainfall changes in tropical regions, including Indonesia. Changes in sea surface temperature anomalies in the Niño 3.4

region can influence the Walker circulation and cause variations in convective activity over Indonesia (McPhaden et al., 2006; Philander, 1990). During El Niño conditions, the center of convection tends to shift toward the central and eastern Pacific Ocean, resulting in reduced convective activity over Indonesia. Conversely, La Niña conditions enhance convective activity due to increased moisture supply toward the Indonesian maritime region (Hendon et al., 2017; Lindsey, 2016).

Based on Figures 2 and 3, the relationship between the ENSO index and rainfall in South Sumatra shows a negative correlation pattern. This indicates that an increase in the ENSO index, representing El Niño conditions, tends to be followed by a decrease in rainfall, whereas La Niña conditions characterized by negative ENSO values tend to increase the likelihood of higher rainfall occurrences.

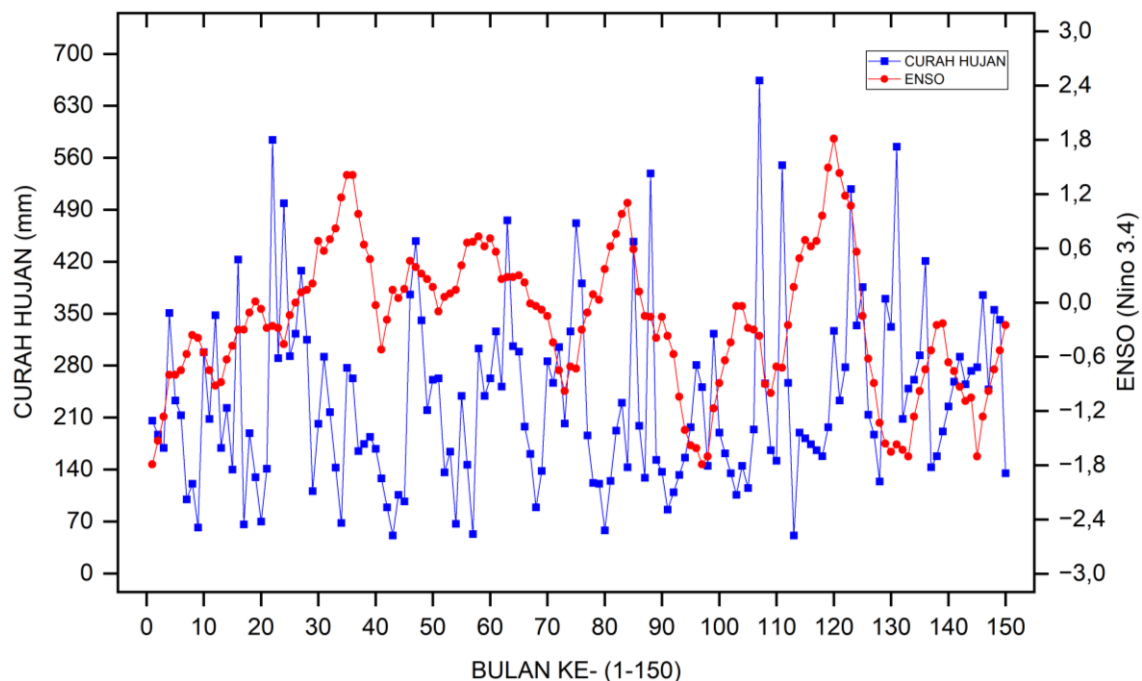


Figure 2. Relationship between ENSO (Niño 3.4) and monthly rainfall in South Sumatra during the period of 2000–2024 (Months 1–150)

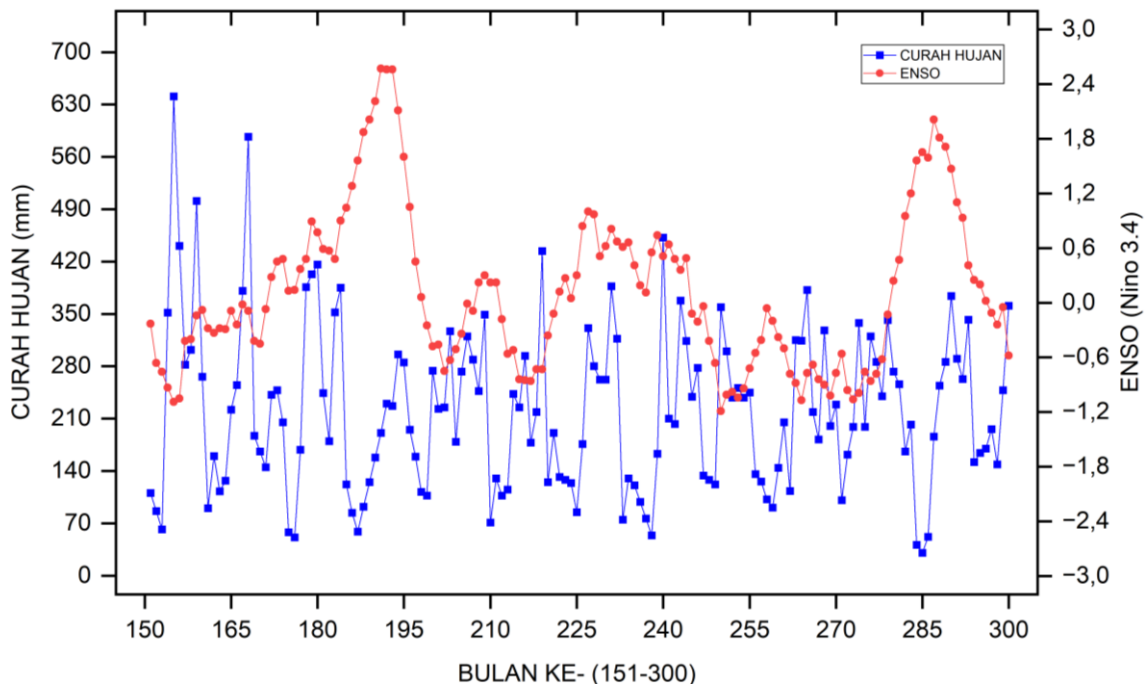


Figure 3. Relationship between ENSO (Niño 3.4) and monthly rainfall in South Sumatra during the period of 2000–2024 (Months 151–300)

The Pearson correlation analysis results show that ENSO has a negative relationship with rainfall, with a correlation coefficient of $r = -0.122$. This value indicates that the relationship between ENSO and rainfall is

categorized as weak, although the direction of the relationship is consistent with the physical mechanism of ENSO's influence on atmospheric convective systems over Indonesia.

Table 1. Results of ENSO Linear Regression Analysis on Rainfall in South Sumatra

Parameter	Value
Intercept	226,99
Koefisien regresi	-16,92
R^2	0,015
p-value	0,033
r (Korelasi Pearson)	-0,122

Based on Table 1, the regression model shows that each one-unit increase in the ENSO index results in a decrease in rainfall of 16.92 mm/month. The coefficient of determination value ($R^2 = 0.015$) indicates that ENSO explains only approximately 1.5% of the variation in monthly rainfall in South Sumatra, while most of the rainfall variability is influenced by other factors outside the model.

Although the contribution of ENSO is relatively small, the statistical test results show that this relationship is significant with a p-value of 0.033 (<0.05). This indicates that ENSO still influences rainfall variability in South Sumatra, particularly through global-scale atmospheric changes that affect moisture transport and convective activity.

The results of this study are consistent with Hidayat & Ando (2014), who demonstrated that ENSO influences rainfall patterns in Indonesia, particularly through changes in regional atmospheric circulation. During El Niño events, Indonesia generally experiences reduced rainfall due to weakened convective activity, whereas La Niña conditions can increase the probability of higher-intensity rainfall events due to enhanced moisture supply (McBride et al., 2003).

However, the weak correlation value between ENSO and rainfall in South Sumatra indicates that ENSO is not the only controlling factor for high to very high rainfall events. South Sumatra has complex atmospheric characteristics influenced by regional factors such as the Asian–Australian monsoon, surrounding sea surface temperature conditions, and interactions with other climate phenomena. According to Aldrian & Susanto (2003), the response of Indonesian rainfall to ENSO may vary between regions due to differences in geographical characteristics and local circulation patterns.

Therefore, ENSO acts as one of the global-scale controlling factors of rainfall variability in South Sumatra; however, its influence on high to very high rainfall events remains relatively limited when analyzed individually.

The Relationship between IOD and High to Very High Rainfall in South Sumatra

In addition to ENSO, another global climate phenomenon that influences rainfall variability in Indonesia is the Indian Ocean Dipole (IOD). IOD is an ocean–atmosphere interaction phenomenon occurring in the

tropical Indian Ocean, characterized by differences in sea surface temperature anomalies between the western and eastern parts of the Indian Ocean (Saji et al., 1999). These changes can affect atmospheric moisture distribution and convective activity, particularly in western Indonesia, including South Sumatra.

During the positive IOD phase, sea surface temperatures in the western Indian Ocean become warmer, while the eastern region near Indonesia experiences cooling. This condition reduces evaporation and moisture supply toward Indonesia, resulting in decreased convective cloud formation activity (Ashok et al., 2001). Conversely, the negative IOD phase causes increased sea surface temperatures around Indonesian waters, enhancing moisture supply and convective activity, which may increase rainfall (Saji et al., 1999).

Based on Figures 4 and 5, the relationship between the IOD index and rainfall in South Sumatra shows a negative correlation pattern. This pattern indicates that an increase in the DMI value, representing positive IOD conditions, tends to cause a decrease in rainfall, whereas negative IOD conditions are generally associated with increased rainfall.

The Pearson correlation analysis results show that IOD has a negative relationship with rainfall in South Sumatra, with a correlation coefficient value of $r = -0.142$. This correlation value indicates that the relationship between IOD and rainfall is categorized as weak; however, the direction of the relationship is consistent with the physical mechanism of IOD in influencing convective activity over western Indonesia.

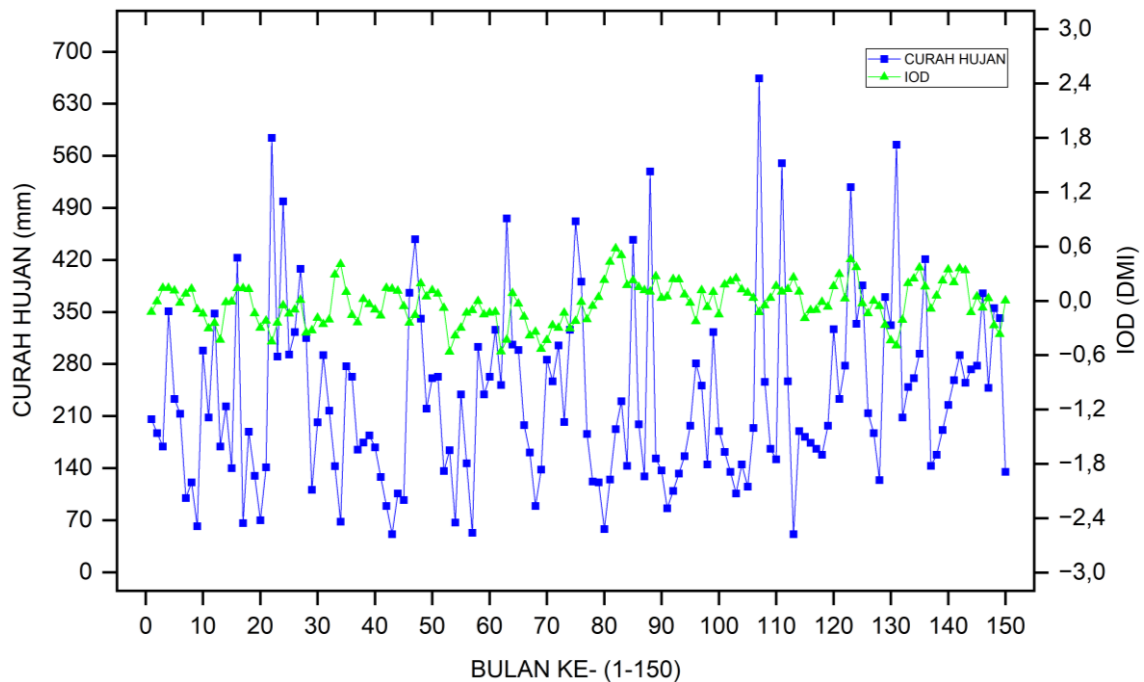


Figure 4. Relationship between Dipole Mode Index (DMI) and monthly rainfall in South Sumatra during the period of 2000–2024 (Months 1–150)

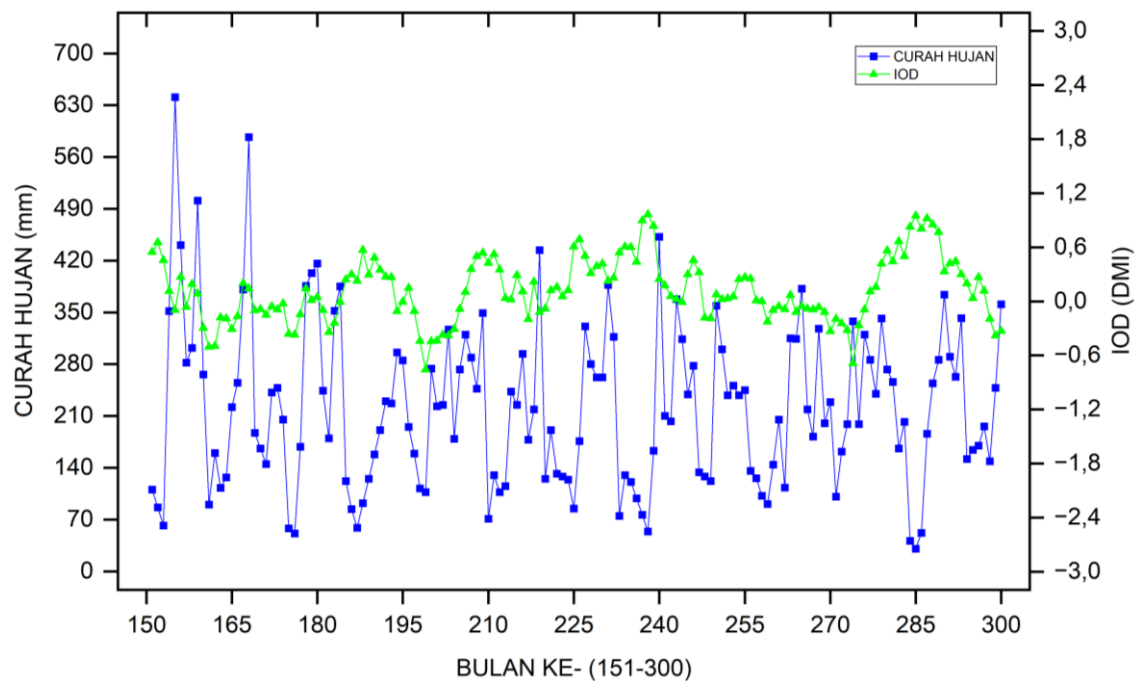


Figure 5. Relationship between Dipole Mode Index (DMI) and monthly rainfall in South Sumatra during the period of 2000–2024 (Months 151–300)

Table 2. Results of IOD Linear Regression Analysis on Rainfall in South Sumatra

Parameter	Value
Intercept	230,29
Koefisien regresi	-54,28
R ²	0,020
p-value	0,013
r (Korelasi <i>Pearson</i>)	-0,142

Based on Table 2, the regression results show that an increase of one unit in the IOD index causes a decrease in rainfall of 54.28 mm/month. The coefficient of determination value ($R^2 = 0.020$) indicates that IOD explains approximately 2.0% of the variation in monthly rainfall in South Sumatra, while the remaining variation is influenced by other atmospheric and oceanographic factors.

The statistical test results show that the relationship between IOD and rainfall has a significance value of $p = 0.013$ (<0.05), indicating that IOD has a statistically significant influence on rainfall variability in South Sumatra. Although its contribution is relatively small, the negative relationship indicates that changes in Indian Ocean conditions can affect the probability of high to very high rainfall occurrences.

The results of this study are consistent with (Saji et al., 1999), who explained that changes in sea surface temperature gradients between the western and eastern Indian Ocean can influence tropical atmospheric convection patterns. During negative IOD events, increased sea surface temperatures around Indonesia enhance evaporation and moisture transport, thereby supporting rainfall cloud formation. These conditions can increase the potential for high-intensity rainfall events in western Indonesia (Ashok et al., 2001).

Previous studies have also shown that the influence of IOD on Indonesian rainfall varies spatially depending on regional characteristics. According to (Millenia et al., 2023), western Indonesia

has relatively high sensitivity to changes in IOD phases due to its proximity to the center of sea surface temperature anomalies in the eastern Indian Ocean. This explains why variations in the IOD index can generate responses in rainfall variability over South Sumatra.

However, the relatively low correlation value indicates that IOD is not the sole factor determining high to very high rainfall events in South Sumatra. The relatively weak linear relationship also suggests that the statistical contribution of IOD should not be interpreted as evidence that IOD independently controls rainfall variability in the region. Regional rainfall variability is likely influenced by interactions among multiple processes operating at different spatial and temporal scales, including the Asian–Australian monsoon system, regional atmospheric conditions, and other climate phenomena. Therefore, the influence of IOD should be interpreted within the broader context of these interacting processes to obtain a more comprehensive understanding of rainfall variability in South Sumatra.

Simultaneous Influence of ENSO and IOD on High to Very High Rainfall in South Sumatra

ENSO and IOD are two global climate phenomena that play important roles in controlling rainfall variability in Indonesia through mechanisms involving sea surface temperature changes, atmospheric circulation, and moisture transport. ENSO, which develops in the tropical Pacific Ocean, influences

convective activity through changes in the Walker circulation, while IOD in the Indian Ocean affects atmospheric

moisture distribution, particularly over western Indonesia (Philander, 1990).

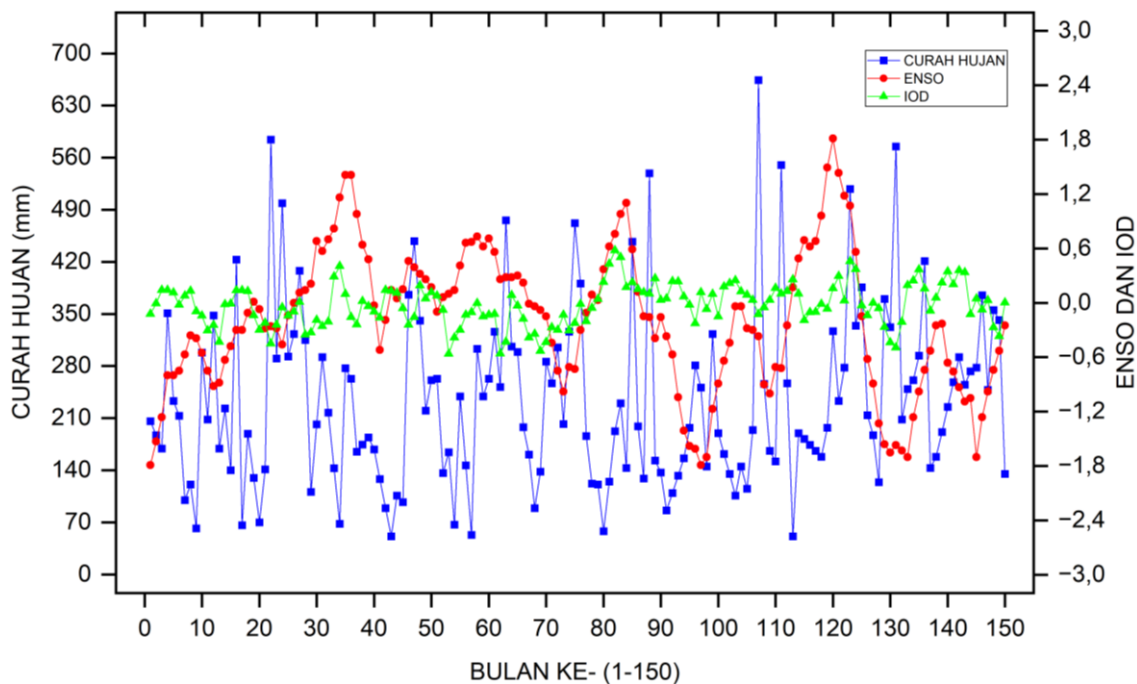


Figure 6. Temporal variations of rainfall, ENSO, and IOD in South Sumatra during the period of 2000–2024 (Months 1–150)

Based on Figures 6 and 7, rainfall variability in South Sumatra exhibited fluctuating patterns during the period of 2000–2024. Monthly rainfall showed considerable variations, with several periods experiencing increased rainfall that reached the high to very high categories according to the BMKG classification. These rainfall increases occurred during certain periods when ENSO and IOD conditions were in phases that supported enhanced convective activity.

During the early observation period, several high rainfall events occurred when the ENSO index was in negative conditions, indicating the La Niña phase. This condition was observed when ENSO values decreased to negative levels while rainfall increased. This phenomenon is consistent with the La Niña mechanism, which enhances convective activity over Indonesia due to increased moisture supply from the western Pacific Ocean

toward the Indonesian maritime region (Hendon et al., 2017).

Conversely, when ENSO is in a positive condition representing the El Niño phase, several periods show a tendency toward decreased rainfall. This condition is particularly evident during periods when ENSO values increase significantly, causing weakened convective activity over Indonesia due to the displacement of the convection center toward the central and eastern Pacific Ocean (Cai et al., 2020).

In addition to ENSO, variations in the IOD index also show a relationship with rainfall variability in South Sumatra. Under positive IOD conditions, when the IOD index increases, several periods exhibit a tendency toward reduced rainfall. This is associated with decreased moisture supply due to cooling of sea surface temperatures in the eastern Indian Ocean near Indonesia (Ashok et al., 2003). Conversely, during negative IOD conditions, enhanced convective activity

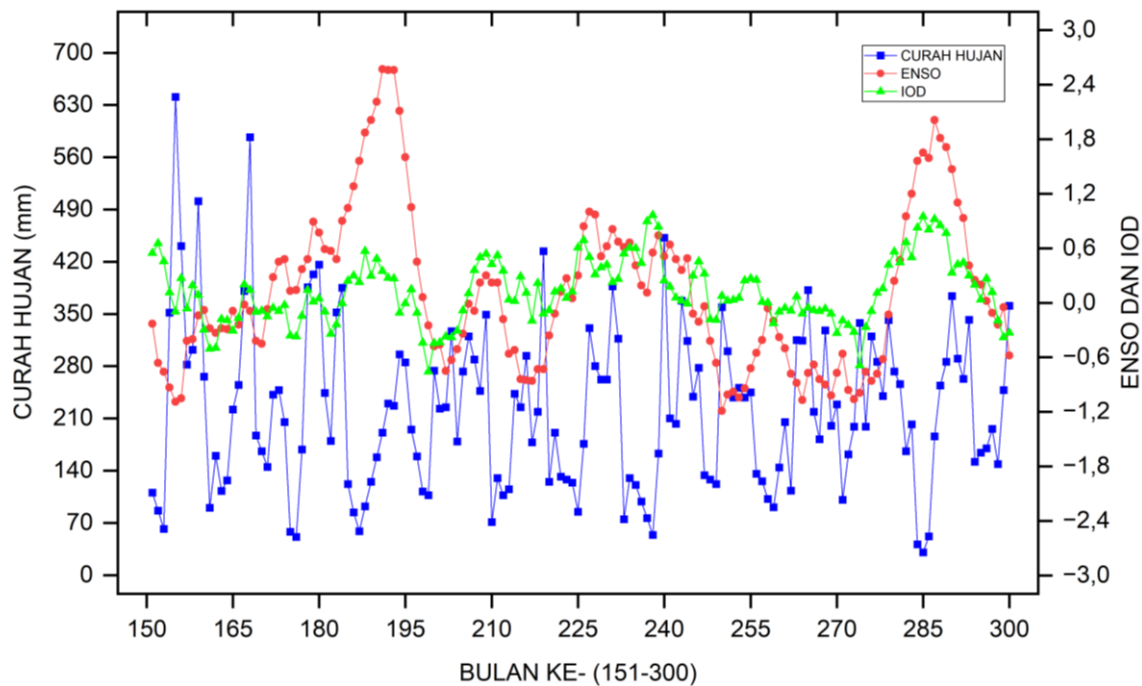


Figure 7. Temporal variations of rainfall, ENSO, and IOD in South Sumatra during the period of 2000–2024 (Months 151–300)

may occur due to increased evaporation and moisture availability around the Indonesian region (Sudirman et al., 2024).

However, based on the temporal patterns shown in both figures, the relationship between ENSO, IOD, and rainfall does not always show direct consistency during every period. This indicates that rainfall in South Sumatra is not controlled by a single global climate phenomenon but results from interactions among various atmospheric and oceanographic factors. Variability in the Asian–Australian monsoon, regional ocean conditions, and intraseasonal phenomena can produce different rainfall responses even when ENSO and IOD are in certain phases (Suhadi et al., 2024).

To determine the simultaneous influence of ENSO and IOD on rainfall in South Sumatra, multiple linear regression analysis was performed using the following equation:

$$Y = 229.266 - 11.018 \text{ ENSO} - 42.659 \text{ IOD} \quad (1)$$

The equation indicates that the constant value of 229.266 represents the estimated rainfall value when the ENSO and IOD indices are equal to zero. The ENSO regression coefficient of -11.018 indicates that every one-unit increase in the ENSO index causes a decrease in rainfall of 11.018 mm/month, assuming the IOD variable remains constant. Meanwhile, the IOD regression coefficient of -42.659 indicates that every one-unit increase in the IOD index causes a decrease in rainfall of 42.659 mm/month, assuming the ENSO variable remains constant.

Based on Table 3, the multiple linear regression model produces an R^2 value of 0.026 and an Adjusted R^2 value of 0.019. These values indicate that the combination of ENSO and IOD can only explain approximately 2.6% of the variation in monthly rainfall in South Sumatra, while the remaining 97.4% of the variation is influenced by other factors not included in the model

Table 3. Results of Multiple Linear Regression Analysis of ENSO and IOD on Rainfall in South Sumatra

Variable	Regression Coefficient	t-statistic	Significance (p)
Constant	229.266	34.066	0.000
ENSO	-11.018	-1.291	0.198
IOD	-42.659	-1.811	0.071

The simultaneous test results show an F-statistic value of 3.943 with a significance value of $p = 0.020$ (<0.05). This indicates that ENSO and IOD together have a significant influence on rainfall variability in South Sumatra. However, based on the partial significance test, ENSO has a significance value of $p = 0.198$, while IOD has a significance value of $p = 0.071$, indicating that both variables do not show a statistically significant individual influence within the simultaneous model.

These results indicate that ENSO and IOD jointly contribute to rainfall variability in South Sumatra, although neither variable shows a statistically significant individual contribution within the multiple regression model. The significant F-test indicates that the predictors considered together provide a statistically detectable relationship with rainfall variability, whereas the non-significant partial tests indicate that the individual contribution of each predictor cannot be clearly distinguished when the effects of the other predictor are controlled. This result highlights the importance of considering the combined influence of large-scale climate phenomena rather than interpreting ENSO or IOD independently. At the same time, the relatively low R^2 value indicates that most of the observed rainfall variability remains unexplained by ENSO and IOD, emphasizing the role of other atmospheric and oceanographic processes in controlling rainfall variability in South Sumatra.

The negative coefficients of ENSO and IOD indicate that the relationship

patterns are consistent with the physical mechanisms of both phenomena. An increase in the ENSO index toward El Niño conditions leads to reduced convective activity over Indonesia due to weakened atmospheric moisture supply (Hanifa & Wiratmo, 2024). Similarly, an increase in the IOD index toward the positive phase causes decreased sea surface temperatures around Indonesia, resulting in reduced evaporation and rainfall cloud formation (Millenia et al., 2023).

The results of this study demonstrate that ENSO and IOD cannot fully explain the variation in high to very high rainfall events in South Sumatra. The low explanatory power of the regression model suggests that rainfall variability in the region is controlled by multiple processes operating across different spatial and temporal scales. In addition to ENSO and IOD, these processes include the Asian–Australian monsoon system, regional sea surface temperature variability, local atmospheric conditions, and intraseasonal phenomena (Hanifa & Wiratmo, 2024). These factors may influence moisture availability, atmospheric convection, and the timing and intensity of rainfall events. Consequently, the occurrence of high to very high rainfall events may not always coincide directly with a particular ENSO or IOD phase, which helps explain the relatively weak statistical relationship observed in this study.

Previous studies have also shown that the influence of ENSO and IOD on Indonesian rainfall can vary depending on regional characteristics and the phase

interactions between both phenomena. Akhsan et al., (2023) explained that ENSO and IOD interactions can strengthen or weaken their impacts on regional rainfall, particularly in western Indonesia. Therefore, this study confirms that ENSO and IOD act as large-scale controlling factors of rainfall variability in South Sumatra, but they are not the only determining factors for high to very high rainfall events.

CONCLUSION

This study show that high to very high rainfall variability in South Sumatra during 2000–2024 is influenced by global climate drivers, particularly ENSO and IOD. Statistical results show a negative correlation between ENSO and rainfall ($r = -0.122$; $R^2 = 0.015$; $p = 0.033$), indicating that El Niño events tend to suppress moisture supply and reduce rainfall intensity, whereas La Niña phases increase the likelihood of heavy rainfall. A similar pattern is observed for the IOD, which also exhibits a negative correlation ($r = -0.142$; $R^2 = 0.020$; $p = 0.013$). Positive IOD phases are associated with reduced rainfall, while negative IOD phases enhance convection and moisture availability.

Although both relationships are statistically significant, their explanatory power is relatively small. Multiple linear regression analysis shows that ENSO and IOD together account for only 2.6% of rainfall variability ($R^2 = 0.026$; $p = 0.0204$). This finding highlights that other atmospheric and oceanographic factors—such as the Madden–Julian Oscillation (MJO), the Asian–Australian monsoon system, and regional sea surface temperature anomalies—play a more substantial role in controlling extreme rainfall events in South Sumatra. This aligns with previous studies emphasizing that while ENSO and IOD are relevant indicators, the intensity and frequency of extreme rainfall in the region are largely shaped by the complex interplay of tropical climate systems.

From a scientific perspective, this study contributes by reaffirming the relevance of ENSO and IOD as climatological signals, while clarifying that they are not the dominant drivers of rainfall extremes in South Sumatra. The results underscore the importance of integrating multiple climate indices into regional hydro-meteorological assessments, thereby strengthening predictive capacity and supporting more comprehensive disaster risk management strategies.

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