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IMPACT PROFILE OF ENSO AND DIPOLE MODE ON RAINFALL AS ANTICIPATION OF HYDROMETEOROLOGICAL DISASTERS IN THE PROVINCE OF SOUTH SUMATRA

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ABSTRACT

El Niño Southern Oscillation (ENSO) is a weather phenomenon in the Pacific Ocean. At the same time, Dipole Mode (DM) is an ocean-atmosphere interaction phenomenon in the Indian Ocean. The area of South Sumatra Province, which is in the Monsunal area, makes the influence of ENSO and DM very instrumental in determining the length of the rainy season and throughout the year. The South Sumatra region is very vulnerable to forest and land fire disasters due to the condition of the area in the form of swamps and peatlands, which are very easy to burn if the dry season occurs in the South Sumatra area. In this study, an analysis of the effect of ENSO and DM on rainfall in the South Sumatra Region from 1981 to 2020 was carried out using a simple linear regression method and the correlation coefficient using Niño 3.4 index data and Dipole Mode with rainfall data and consecutive rainy days data. Consecutive Wet Day (CWD). The purpose of this study was to determine the effect of Enso and Dipole Mode on rainfall and CWD in the South Sumatra Region. The results show that the correlation between ENSO and rainfall is 0.0017-0.002573, DM and rainfall is 0.05972, and ENSO and CWD is -0.068. The correlation between DMI and CWD is 0.513. So it can be said that ENSO and DMI have no effect on rainfall in the South Sumatra Province. Still, the amount of CWD in South Sumatra Province is significantly determined by the Dipole Mode Index (DMI) at a moderate level. The number of consecutive rainy days in South Sumatra Province is influenced by the dynamics of the ocean and atmosphere of the Indian Ocean, which is characterized by the presence of positive IOD and negative IOD phenomena.

Keywords: dipole mode, El Niño, ENSO, La Niña, rainfall

INTRODUCTION

Rainfall is one of the weather elements that are very influential on human activities. Several weather phenomena affect rainfall conditions in Indonesia. ENSO is a weather phenomenon that occurs in the Pacific Ocean region. Generally, ENSO events repeat between two to seven years [1, 2]. ENSO has two phases, namely the El Niño phase and the La Niña phase. El Niño is a hot phase of the central and eastern equatorial Pacific Ocean, which is characterized by warming sea surface temperatures in the eastern Equatorial Pacific or positive sea surface temperature anomalies in the area [3, 4]. In contrast, La Niña is the cold phase of the central and eastern equatorial Pacific Ocean, which is the opposite of El Niño, characterized by an anomaly of sea surface temperature in the negative equatorial Pacific [5]. A Consecutive Wet Day (CWD) is the opposite of a Consecutive Dry Day (CDD), where the number of consecutive days has more than 1 mm of rain. In contrast to CDD, CWD is the number of consecutive wet days but has the same pattern as CDD, namely a decrease but not too significant, namely -0.245 days/year with a maximum value of 21 days [6].

Dipole Mode (DM) is an atmospheric and marine phenomenon characterized by differences in sea surface temperature anomalies in Indonesian waters around Sumatra and Java with east coast waters [7, 8]. DM has two periods, namely positive DM and negative DM. Positive DM is a period where the sea surface temperature on the east coast of Africa is hotter than the sea surface temperature on the west coast of Sumatra. In comparison, negative DM is the opposite phenomenon with positive DM conditions. Negative DM occurs when the sea surface temperature in the waters of west Sumatra is warmer than the coastal areas of East Africa [9]. Research has been carried out by Yuggotomo and Ihwan (2014), which explains that the effect of ENSO and DM on rainfall in Ketapang Regency is smaller than the effect of the monsoon wind cycle [10]. During the El Niño phase, the rainfall in Ketapang Regency tends to be low. However, when DM is positive, rainfall in Ketapang Regency tends not to be low.

Meanwhile, during the La Niña phase or negative DM, the rainfall in Ketapang Regency tends to be high [11, 12]. A previous study reported that ENSO and Dipole Mode had no effect on rainfall in Ketapang with a correlation value of Niño 3.4 index data on rainfall of -0.18, while the correlation value of Dipole Mode Index data was - 0.12 [13, 14]. The effect of ENSO and DM patterns on rainfall shows that the El Niño phase tends to be low. However, during the positive DM phase, rainfall in Ketapang Regency tends to be high. Meanwhile, rainfall tends to increase when the La Niña and DM phases are negative. Considering the magnitude of the influence of ENSO as a global phenomenon that can affect the weather, it is necessary to conduct a study related to the occurrence of the El Niño and La Niña phenomena in the West Kalimantan region which has an equatorial rainfall pattern, to see how much influence the ENSO phenomenon has so that it can complement previous research [15].

The Indian Ocean Dipole (IOD) is a global phenomenon that occurs along the equator of the Indian Ocean (the ocean to the west of Indonesia that separates Indonesia from the African continent) [16, 17]. Like El Niño/ La Niña, this phenomenon is divided into two, namely the positive and negative phases. In contrast to El Niño, which peaks around November to January, IOD reaches its peak around September to November and begins around May or 1-2 months earlier. The Indian Ocean near Indonesia is often referred to as the East Indies and those near the African continent are often referred to as the West Indies [18, 19].

The parameter used to see the incidence of IOD is the difference in SST changes in the West Indian Ocean and those in the East Indian Sea [20, 21]. If the SST change in the West Indian sea is higher than that in the East Indian sea, it means that the West Indian sea is warmer than that in the East Indian sea and there is a positive IOD phase. In the positive phase of IOD, rainfall will shift towards the west away from Indonesia and cause Indonesia to experience drought in the dry season [22]. In the negative phase of IOD, the opposite occurs, namely the change in SST in the East Indian Ocean will be warmer than the West Indian Ocean and as a result, Indonesia experiences higher rainfall in the dry season. This SST change in the West Indies and East Indies oscillates every year but none of them is IOD phenomenon, because the difference in SST changes in the West and East Indies must also exceed a certain value (usually around 0.4 degrees) for at least 3 consecutive months [23-25].

As for what will be done in this study is to analyze how the influence of ENSO and DM phenomena on rainfall in the Province of South Sumatra. The results of this study are expected to help anticipate the impact of the ENSO and DM phenomena on rainfall and CWD, which is the maximum number of consecutive days per time period with a minimum daily rainfall of 1 mm in the South Sumatra Region.

METHOD

The data used in this study are Niño 3.4 index data, DM index, and rainfall data from 1981 to 2020. Niño 3.4 index data and DM index data are obtained from the website www.bom.gov.au, while rainfall data in the Region South Sumatra Province is obtained from the site http://dataonline.bmkg.go.id. Palembang Climatology Station (SK Palembang) and Sultan Mahmud Badaruddin II Meteorological Station (SM SMB II) are the stations taken for rainfall data and CWD data. The method used in this study is a simple linear regression method. The causal factor is generally denoted by X (Niño 3.4 index data, and DM index data, while the effect variable is denoted by Y (rainfall data and CWD). The general equation of simple linear regression is defined as in EQUATION 1 [26].

$$Y = a + bX \quad (1)$$

Where Y is the dependent variable, X is the independent variable, a is a constant and b is the regression coefficient parameter. Analysis of the relationship (correlation) to determine the relationship between two variables and the form of their relationship with quantitative results. Two variables are correlated if there is a change in the other variable regularly in the same direction (positive correlation) or opposite (negative correlation). For the strength of the relationship, the correlation value is between -1 to 1, while the direction is expressed in positive and negative forms. If the correlation is close to positive one, it means that the relationship between the two variables is very strong and has a positive value. If the correlation is close to -1, it means that the relationship between the two variables is very strong and has a negative value [27]. If the correlation is close to 0.5 or -0.5, it means that the relationship between X as an estimator and Y as an estimator is considered strong enough. On the other hand, if the correlation is smaller than 0.5, or greater than -0.5, it means that the relationship between the two variables is considered weak. The correlation equation (R) is like EQUATION 2 [28, 29].

$$R = \frac{n\sum_{i=1}^{n} x_i y_i - (\sum_{i=1}^{n} x_i)(\sum_{i=1}^{n} y_i)}{\sqrt{\left[n\sum_{i=1}^{n} x_i^2 - (\sum_{i=1}^{n} x_i)^2\right]\left[n\sum_{i=1}^{n} y_i^2 - (\sum_{i=1}^{n} y_i)^2\right]}} \tag{2}$$

Where X is the independent variable, and Y is the dependent variable. The coefficient of determination is a number that states or is used to determine the contribution or contribution given by the variable or X (the independent variable) to the Y variable (the dependent variable). Determine the magnitude of the Coefficient of Determination using EQUATION 3 [30, 31].

$$KD = R^2 x\ 100\% \tag{3}$$

Where R is the correlation value.

The research flow FIGURE 1 begins with a literature study from various sources regarding the theme of this research and prepares rainfall and CWD data in the South Sumatra Region, Niño 3.4 index data and Dipole Mode index data from 1981 to 2020. Then by using a simple linear regression method, the correlation and relationship between the occurrence of ENSO, Dipole Mode, Rainfall and CWD in South Sumatra Province can be determined. To describe the closeness between rainfall and the occurrence of ENSO and DM, the rainfall and CWD data were correlated with the Niño 3.4 index data and the DM index [32, 33].

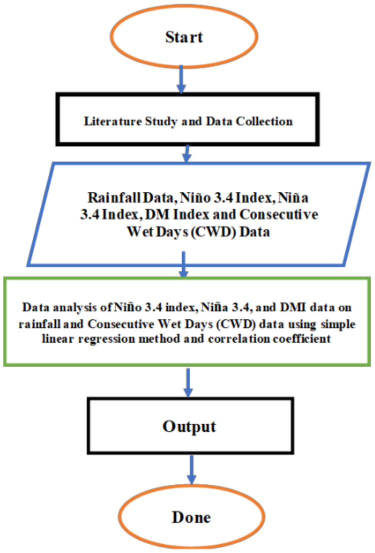

FIGURE 1. Research Scheme

RESULT AND DISCUSSION

The data processing results for the Niño 3.4 and Niña 3.4 indexes using the simple linear regression method are presented in FIGURE 2. The correlation results show a comparable relationship of 0.0017 and 0.002573 that occurs between the Niño 3.4 index and rainfall. This shows that the effect of the Niño Index 3.4 does not significantly affect changes in rainfall in the South Sumatra Region for 40 years.

In FIGURE 2 it can be observed that in 1982, 1986, 1987, 1991, 1994, 1997, 2002 and 2009, 2015 and 2018 there have been El Niño recorded both weak El Niño, Moderate and Strong El Niño. FIGURE 2 also shows that during El Niño rainfall tends to be high. In 2007 the correlation between the Niño 3.4 index and rainfall El Niño events was quite strong at -0.56, meaning the same as the previous year. Likewise, in 2010 and 2012 the correlation value was -0.59 and -0.63 where in that year La Niña occurred, resulting in a high rainfall value in that year.

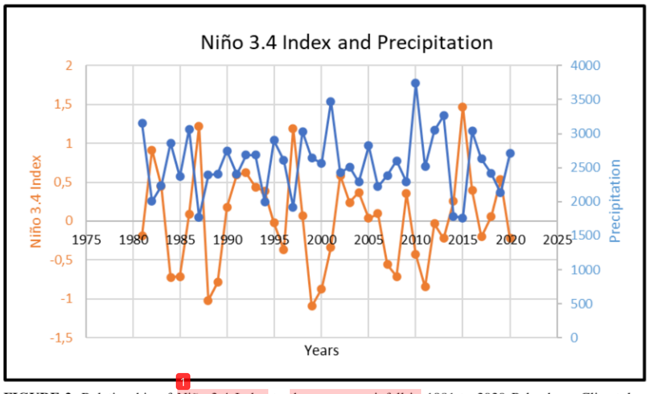

FIGURE 2. Relationship of Niño 3.4 Index to the average rainfall in 1981 to 2020 Palembang Climatology Station and SMB II Meteorological Station.

This shows that the relationship between rainfall in the South Sumatra Region is not very influential with ENSO either on the Niño 3.4 Index. The results of processing data on the Niño 3.4 index of rainfall using a simple linear regression method (FIGURE 2) show that the ENSO event repeats itself between two to seven years. In 1988, 1999, 2007, 2009 and 2011, the rainfall value for the Province of South Sumatra was high because the rainfall conditions were lower than the average rainfall in 2009 and 2011. The low rainfall in that year coincided with the occurrence of The El Niño phenomenon.

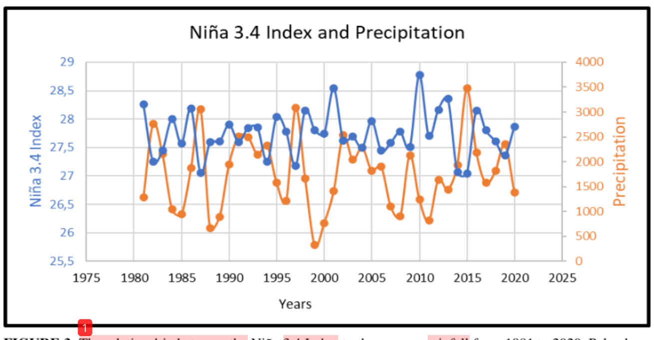

FIGURE 3. The relationship between the Niña 3.4 Index to the average rainfall from 1981 to 2020, Palembang Climatology Station and SMB II Meteorological Station.

Likewise, the results of the correlation between the DMI Index and Rainfall obtained the results of 0.05972. The results of this analysis show that the correlation value between Dipole Mode and rainfall from 1981 to 2020 data is shown in FIGURE 4. For the correlation with a very low level of relationship. FIGURE 2 and FIGURE 3 show that in 1981, 1994, 1998-2002, 2005-2006, 2007-2008, 2008-2009, 2010-2012, 2016, 2017-2018, and 2020. In the years the phenomenon occurred La Niña, rainfall has increased significantly. A strong correlation between this La Niña event occurred in 1994 at -0.45, a decrease followed by rainfall in the value of the Dipole Mode, and the level of a strong relationship occurred in 1998-2002 of 0.59 rainfall followed by an increase in the value of the Dipole Mode. The results of this analysis can be seen in the following graphic image.

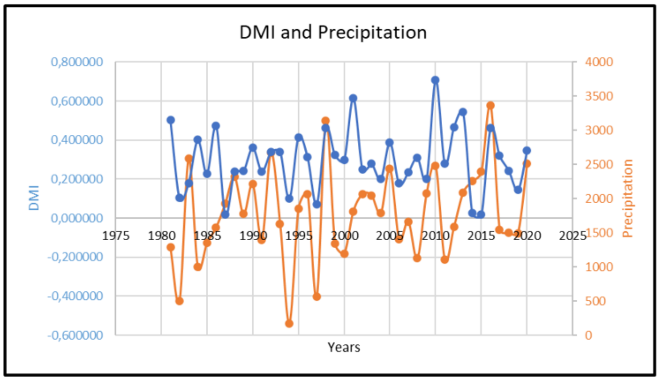

FIGURE 4. Relationship of DMI to average rainfall in 1981 to 2020 Palembang Climatology Station and SMB II Meteorological Station.

However, there are several conditions where rainfall should have increased or decreased during the ENSO and DM phenomena. Still, the results of the analysis showed that the rainfall remained in normal conditions. This is because the intensity of ENSO and DM depends on the magnitude of the deviation of sea surface temperature so that during the positive DM phase, rainfall in the South Sumatra Province decreases and is even relatively cold, and during the negative DM phase, rainfall tends to increase. Positive DM occurred in 1998, 2010 and 2019, and negative DM occurred in 1994 and 1998.

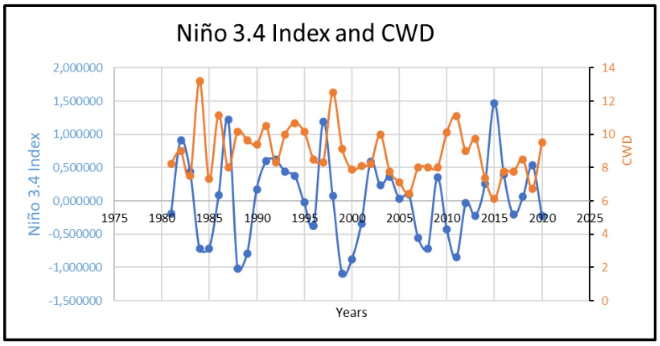

FIGURE 5. Relationship of Niño 3.4 Index to CWD 1981 to 2020 Palembang Climatology Station and SMB II Meteorological Station.

In FIGURE 5, it can be observed that 1986, 1987, 1991, 1994, 1997, 2002 and 2009, 2015, and 2018 there have been El Niño recorded as both weak El Niño, Moderate, and Strong El Niño. FIGURE 2 also shows that during El Niño, a lot of CWD is happening at that time. In 1998 the correlation between the Niño 3.4 index and CWD was quite significant, and the occurrence of El Niño events was quite strong that year. The relationship between CWD data for the South Sumatra Region does not have much effect on ENSO, both for the Niño 3.4 index and the Niña 3.4 index.

The results of processing Niño 3.4 and Niña 3.4 index data on CWD data using a simple linear regression method are presented in FIGURE 5-FIGURE 7. The correlation results show an inverse relationship of -0.068 that occurs between the Niño 3.4 index and the Niña 3.4 index and CWD. This shows that the effect of Niño 3.4 and Niña 3.4 indexes is not significant on CWD in the South Sumatra Region for 40 years.

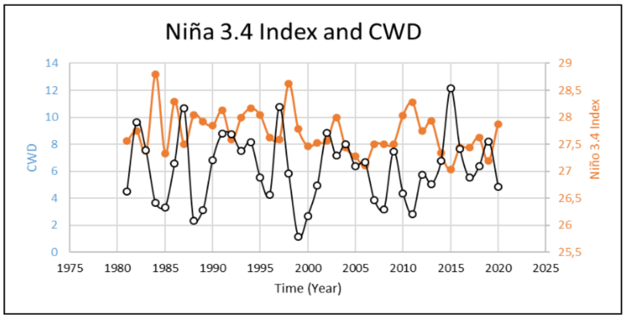

FIGURE 6. Relationship of Niña 3.4 Index to CWD 1981 to 2020 Palembang Climatology Station and SMB II Meteorological Station.

Different things are shown based on the results of the analysis of the correlation between DMI and CWD index data. The results of the analysis showed different results with other climate index correlations. There is a significant positive relationship between CWD and DMI data with a correlation value of 0.513. This shows that the number of wet days throughout the year is influenced by the DMI index, which is a phenomenon of interaction between the atmosphere and the ocean that causes inter-annual climate variability in the Indian Ocean and affects the climate of the area around the Indian Ocean, also known as Indian Niño, which is characterized by an anomaly of sea surface temperature in the Indian Ocean.

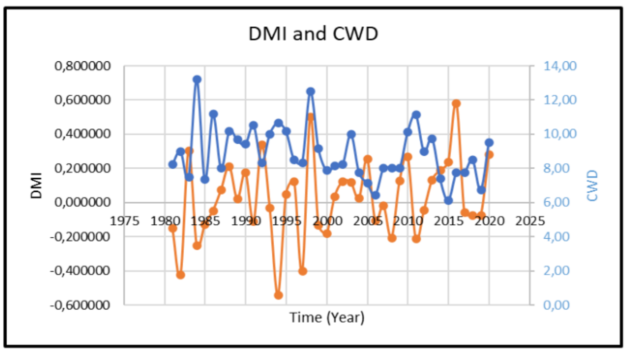

FIGURE 7. Relationship of DMI Index to CWD in 1981 to 2020 Palembang Climatology Station and SMB II Meteorological Station.

Based on the analysis, the results show that observations in the South Sulawesi and West Sumatra regions stated that The ENSO phenomenon has no influence on the rainfall in the region [34-36]. Based on the calculations stating the correlation between the Niño index of 3.4 and SOI on rainfall from 1995 to 2014, it can be concluded that rainfall in West Kalimantan is almost not influenced by the ENSO phenomenon [37-39]. Rainfall in West Kalimantan is not affected during the El Niño phase. The increase in rainfall during the La Niña phenomenon can be expected because West Kalimantan is located in the equatorial area with a double maximum rainfall distribution. This study also found that there was a significant relationship between DMI and CWD data that occurred within a year. This is thought to be due to the temperature difference between the western Indian Ocean and the West Coast of Sumatra Island. If the DMI is positive, it is called Positive IOD because the western part of the Indian Ocean is warm and the west coast of Sumatra is cold, so the wind is easterly (eastern), while the circulation of the ocean west of the island of Sumatra is upwelling. Meanwhile, if the DMI is negative, it is called a Negative IOD. Negative IOD occurs when the area to the west of the Indian Ocean is very cold while the west of Sumatra Island is warm, so the wind that occurs is a westerly (westerly) wind. Several positive IOD events can be seen in FIGURE 6, namely, in 2006, 2008, 2012, and 2015 with el Niño, and in 2019 there was a very strong positive IOD. In contrast, negative IOD occurred in 2005, 2010, and 2018.

CONCLUSION

From the calculation of the correlation between the Niño 3.4 index and the Niña 3.4 index on rainfall from 1981 to 2020, it can be concluded that rainfall in the southern Sumatra region is almost not influenced by the ENSO phenomenon. While the correlation between DMI and CWD is reasonably strong, this is thought to be due to the high difference between ocean temperature or sea surface temperature to the west of the Indian Ocean and the West Coast of Sumatra Island. So that when the DMI is positive, the sea surface temperature on the west coast of Sumatra will be warmer than the Indian Ocean. This resulted in reasonably high evaporation in the Sumatra area, resulting in high rainfall that occurred in the Sumatra area, especially the southern Sumatra region, and vice versa. Rainfall in the South Sumatra region is not affected by the El Niño phase. The increase in rainfall during the La Niña phenomenon can be expected because the location of the South Sumatra region is in the Monsunal area with a single rainfall distribution (one peak of the rainy season).

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