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RESEARCH ARTICLE

Identifying the influence of El Nino Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) Phenomena on Rainfall in The Aceh Region, Indonesia

Miftahul Jannah[1,2], Nazli Ismail[1], Amir Asyqari[1], Fitriana N. Indahsari[2], Faisal Abdullah[1*]

[1]*Department of Physics, Faculty of Mathematics and Natural Sciences, University of Syiah Kuala, Aceh, Indonesia*
[2]*Indonesian Agency for Meteorology Climatology and Geophysics (BMKG), Jakarta, Indonesia*

* Corresponding author : faisal@usk.ac.id
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Abstract

The interaction process between the atmosphere and the ocean that occurs in the Pacific Ocean and the Indian Ocean has a major impact on climate and weather conditions in Indonesia. The phenomenon that arises due to this interaction is known as El Nino - Southern Oscillation (ENSO). In addition to ENSO, other mechanisms also impact weather and climate change in Indonesia, including the Indian Ocean Dipole (IOD). This study aimed to analyze the effect of ENSO and IOD on rainfall in the Aceh region. The data used were CHIRPS rainfall data with the locations of four meteorological stations and one climatology station in Aceh, IOD index data and ENSO index data. Data processing in this study was carried out using Grid Analysis and Display System (GrADS) software and Spreadsheet for CHIRPS rainfall data, followed by processing ENSO index data and IOD index using Spreadsheet software. The analysis showed that the ENSO phenomenon has a longer occurrence than the IOD phenomenon. ENSO has a greater influence on rainfall in the Aceh region than IOD, especially La Nina, which has a weak to moderate correlation. Negative IOD and El Nino phenomena influence several observation points, but some stations do not show a correlation between rainfall and the index. The positive IOD phenomenon is strongly negatively correlated with rainfall at the observation station, which shows that positive IOD does not influence the Aceh region.

Keywords: ENSO, IOD, rainfall, Aceh

1. Introduction

The interaction between the atmosphere and the ocean, occurring in the Pacific and Indian Oceans, exerts a significant influence on the climate and weather patterns observed in Indonesia (Julismin, 2013). The phenomenon that arises from this interaction is referred to as the El Niño–Southern Oscillation (ENSO). The interaction between the atmosphere and the ocean exerts a significant influence on changes in mean sea surface temperature, resulting in deviations from the normal (Sarachik, E.S. dan Cane, M.A., 2010). A positive anomaly indicates that sea surface temperatures are higher than normal, which is a prerequisite for the occurrence of El Niño. Conversely, the occurrence of negative anomalies indicates a reduction in sea surface temperatures below the norm, which is indicative of La Nina (Ariska, M., Akhsan, H., Muslim, M., Sudirman dan Kistiono, 2022). ENSO phenomenon has the potential to influence the amount of precipitation that occurs in certain regions of Indonesia (Firda, D. 2019). In addition to the ENSO, other mechanisms also exert an influence on weather and climate changes in Indonesia. One such mechanism is the Indian Ocean Dipole (IOD) (Estiningtyas, W., Susamti E., Syahbuddin H. dan Slaiman AA., 2018) (Saji, N. H., dan Yamagata, T., 2003).

The IOD is a phenomenon that occurs as a result of anomalous sea surface temperature disparities between the western and eastern Indian Ocean regions (Suwandi, Z., Y. dan Tjasyono, HK., B., 2014). The occurrence of IOD activity has been observed to result in a decrease or increase in rainfall in certain regions of Indonesia (Rahayu, N. D., Sasmito, B., dan Bashit, N., 2018), (Xiao, H.M., Lo, M.H. dan Yu, J.Y., 2022). The island of Sumatra is located close to the Indian Ocean and thus, fluctuations in sea surface temperature within this region have the potential to influence precipitation patterns (Schott, F.A., Xie, S.P. dan McCreary, J.P., 2009). The extreme positive IOD event of 2019 had a profound impact on rainfall patterns in Indonesia (Iskandar, I., Lestari, D.O., 2022). The rainfall deficit during 2019 resulted in drier conditions in Indonesia, which created optimal conditions for forest and peat fires, particularly in Sumatra (Ramadhanty, F. W., Muslim, Kunarso, Rochaddi, B., dan Ismunarti, D. H. 2021). Furthermore, the negative IOD that occurred in 2016 led to an increase in the average rainfall levels in the Sumatra region (Azuga, N. A., Galib, M., dan Elizal., 2020) (Hamada, J.I., Et al, 2012). The occurrence of El Niño and a positive IOD is associated with a reduction in sea surface temperature in Indonesian waters, which is subsequently accompanied by a decrease in precipitation (Millenia, Y.W., Helmi, M., dan Maslukah, L., 2022). The occurrence of La Niña and a negative IOD is associated with an increase in sea surface temperature (SST), which in turn is linked to an increase in precipitation (Yuniasih, B., Harahap, W.N., dan Wardana D.A.S., 2022).

In the past decade, Indonesia has experienced an increase in the frequency, duration, and intensity of El Niño and La Niña climate anomalies (Narulita, I., 2017). It is imperative to consider the potential consequences of this increase in order to prevent the occurrence of disasters,

such as an increase in rainfall, which could result in flooding in a particular region. Additionally, observations of ENSO and IOD play a crucial role in water resources management, as these phenomena significantly influence water availability (Fadholi, A. dan Adzani, R., 2018). In order to observe the climate relationship with the ENSO and IOD phenomena, it is necessary to utilize a multitude of supporting data sources, including satellite rainfall data, which can help to overcome the limitations of observational data when mapping potential flood areas (BPBA., 2023).

In accordance with data procured from the Aceh Disaster Management Agency (BPBA), the Aceh region is classified as highly susceptible to disasters resulting from extreme weather conditions (Husaini dan Ismail, M., 2022). Understanding the effects of ENSO and IOD on rainfall in the Aceh region is very important because this region is prone to natural disasters, especially floods and landslides. The objective of this study is to examine the pattern and periodicity of ENSO and IOD, as well as their impact on rainfall in the Aceh region. To obtain more optimal results, the data set utilized encompasses a comprehensive historical record extending from 2003 to 2022. The availability of data on rainfall patterns influenced by ENSO and IOD allows for the formulation of effective strategies to mitigate the impact of natural disasters resulting from climate change.

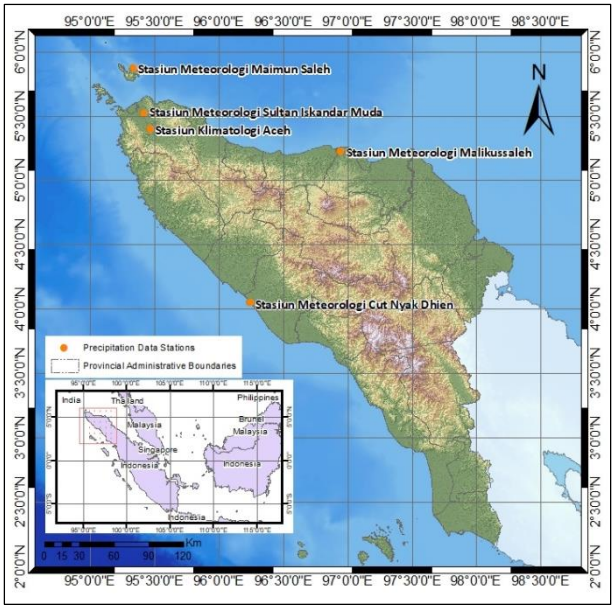

Fig 1. The following map of Aceh Province illustrates the distribution of analyzed rainfall data points

2. Data and Methods

In this study, the data utilized is satellite rainfall data for the period between 2003 and 2022 at the locations of the Sultan Iskandar Muda Meteorological Station, the Cut Ba'u Maimun Saleh Meteorological Station, the Aceh Besar Climatological Station, the Malikusaleh Meteorological Station, and the Tjut Nyak Dien Meulaboh Meteorological Station (Figure 1). Climate Hazards Group Infrared Precipitation with Station (CHIRPS) satellite rainfall data was obtained from the address https://data.chc.ucsb.edu/products/CHIRPS-2.0/global_month in millimeters (mm) with a data spatial resolution grid of 0.05 x 0.05°. In addition to rainfall data, Dipole Mode Index (DMI) and Nino Index data are also used. IOD or DMI index data is obtained from https://psl.noaa.gov/gcos/Timeseries/DMI/, while Nino index data is downloaded from https://psl.noaa.gov/gcos/Timeseries/.

In this study, data processing was conducted using the Grid Analysis and Display System (GrADS) and spreadsheet software. Rainfall data at the observation point location is processed using Spreadsheet software by summing the data for each month and averaging the rainfall data for 20 years (2003-2022) to obtain a graph of the amount of monthly rainfall. Additionally, the ENSO and IOD index data were processed using spreadsheet software to generate monthly index graphs. The processing of rainfall data is also conducted using the GrADS software, resulting in the acquisition of spatial monthly rainfall parameters. Rainfall data at the 5 observed rainfall sites were correlated with IOD and ENSO data to obtain the relationship between rainfall and the two indices. The data correlation process was subjected to analysis using the Pearson correlation equation. The equation is as follows:

$$r = \frac{\sum(x - \bar{x})(y - \bar{y})}{\sqrt{\sum(x - \bar{x})^2 \sum(y - \bar{y})^2}} \quad (1)$$

In this context, r represents the correlation coefficient, x denotes the value of the x variable to be correlated, $\bar{x}$ is the average value of all x variables, y signifies the value of the y variable as a comparison relationship, and $\bar{y}$ is the average value of all y variable values. Pearson correlation coefficient to measure the extent of the linear relationship between observed rainfall and satellite rainfall estimates. This coefficient ranges from -1 to 1. The classification of the correlation value range is as shown in Table 1.

Tabel 1. Classification of Pearson Correlation Values

No.	Correlation value	Criteria
1	0 – 0,25	Weak correlation
2	0,25 – 0,5	Moderate correlation
3	0,5 – 0,75	Strong correlation
4	0,75 – 0,99	Very strong correlation
5	1	Perfect correlation

Negative values have the same criteria as positive values, but refer to an oppositely strong relationship (Pribadi Y., 2012).

3. Results and Discussion

Rainfall data for 20 years (2003-2022) was analyzed spatially to determine the average rainfall pattern in the Aceh region. The spatial analysis of rainfall (Figure 2) provides information on the average rainfall per month for 20 years, with rainfall units in millimeters (mm).

The spatial pattern of average rainfall in Figure 2 clarifies the type of rainfall conditions in the Aceh region. Each month on the West Coast of Aceh, the average rainfall value is higher than in other areas. The average rainfall value for this area varies between 160 - 473 mm/month, which indicates that this area is likely to experience a longer rainy season than other areas. Meanwhile, the East Coast of Aceh has a lower average monthly rainfall value than other areas. The average rainfall value for this area varies between 20 - 250 mm/month, which indicates that this area is likely to experience a longer dry season than other areas. Meanwhile, the central region and a small part of the tip of Aceh experience dry season conditions at the beginning of the year with low average rainfall values and vice versa at the end of the year. Generally, the Aceh region's highest rainfall occurs in October, November, and December, while the lowest occurs in June, July, and August.

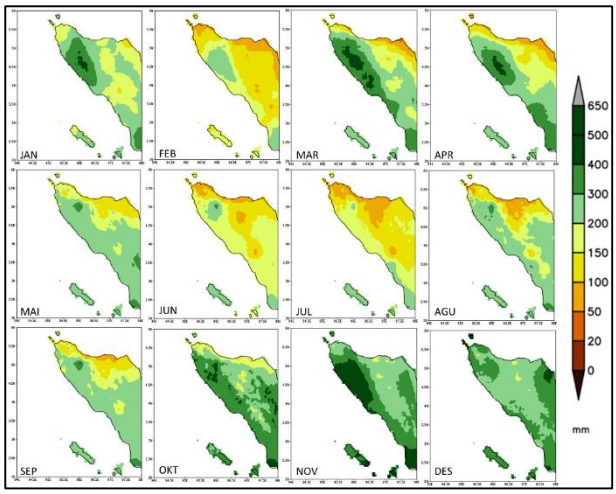

Fig 2. Average rainfall in Aceh Province for the period 2003 – 2022.

3.1 ENSO dan IOD Phenomena

The ENSO and IOD phenomena have quite a significant influence on changes in rainfall in Indonesia (Azuga, N. A., Galib, M., dan Elizal., 2020) (Xiao, H.M., Lo, M.H. dan Yu, J.Y., 2022) (Yuniasih, B., Harahap, W.N., dan Wardana D.A.S., 2022). To determine whether the ENSO and IOD phenomena are active, we can see the index value of each phenomenon. The ENSO index value explains the occurrence of the El Nino and La Nina phenomena. When the ENSO value is greater than 0.5°C, the sea surface temperature will be warmer than average, indicating El Nino conditions. Conversely, if the index value is lower than -0.5°C or colder than the average by 0.5°C, it indicates La Nina conditions. Meanwhile, the IOD also indicates warm or cold conditions in Indonesia. A positive IOD index value indicates that the sea surface temperature in the western Indian Ocean is warmer than in the eastern part. This condition causes a decrease in rainfall in Indonesia and southern Asia. Conversely, a negative IOD is characterized by warmer sea surface temperatures in the east and colder in the west. This negative IOD causes rainfall to increase in Indonesia.

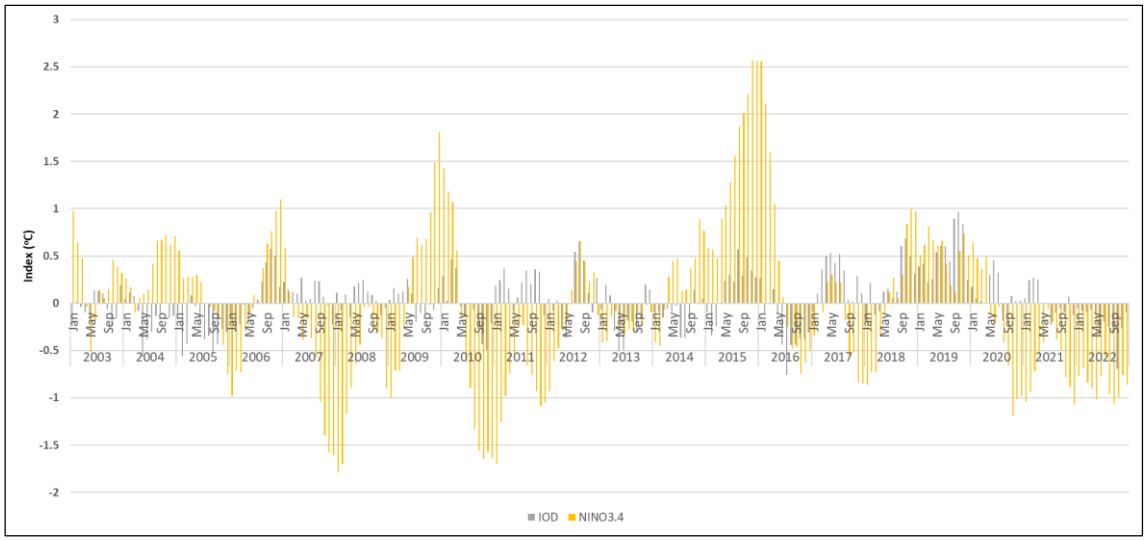

Fig. 3. IOD (Gray) and ENSO (Yellow) indices for the period 2003 – 2022.

Figure 3 shows the graph of the IOD and ENSO indices for 20 years, from 2003 - 2022. Based on the index results during the study period (2003 - 2022), there have been at least five El Nino events with the highest index value of +2.57 in 2015, six La Nina events with the strongest index of -1.79 in 2008, five positive IOD events with the highest index of 0.96 in 2019, and one negative IOD event with the strongest index value of -0.75 in 2016. El Nino events are seen based on the Nino 3.4 index value exceeding +0.5 for 5 months or more; then El Nino is active; conversely, for the La Nina phenomenon, it is active if the index is below -0.5. For the active IOD, if the IOD index for 3 months is greater than +0.4 for positive IOD, negative IOD is active if the index is -0.4 or less.

For further analysis, one event with the strongest index was selected for each phenomenon. The strongest El Nino event occurred in 2015, with a longer occurrence than other El Nino events, namely for 13 months. The longest La Nina period occurred in 2021, with a period of 16 months, but the strongest La Nina event occurred in 2008, with an event period of 10 months. The IOD phenomenon, both positive and negative, occurred in a relatively shorter period than the ENSO phenomena, namely 7 months in 2019 for positive IOD and 4 months for negative IOD in 2016.

Based on the index values in Figure 3, it can be seen that the occurrence of both ENSO and IOD peaked in September, October, and November (SON). Similar things are also seen in the studies (Hong, C. C., Lu, M. M. dan Kanamitsu, M., 2008), (Saji, N. H., Goswami, B. N., Vinayachandran, P. N. dan Yamagata, T., 1999), (Wang, H., Murtugudde, R., & Kumar, A., 2016), (Yang, Y., Xie, S. P., Wu, L., Kosaka, Y., Lau, N. C. dan Vecchi, G. A., 2015), where the phenomena of both IOD and ENSO in general began to occur in Sea Surface Temperature (SST) anomalies in June, July, and August (JJA) and reached their peak in the SON period.

3.2 The influence of the 2015-2016 El Nino event on rainfall

During the El Nino phase, sea surface temperatures in the eastern and central Pacific experience a decrease from

their average temperatures, which causes an increase in rainfall in the region. Conversely, areas such as Indonesia and parts of Southeast Asia will experience a decrease in rainfall, which causes drought. El Nino in 2015 lasted quite a long time, with a period of 13 months, which was previously also marked by warming sea surface temperature from April 2015 to April 2016. The El Nino phase peaked in November and December 2015 with the maximum and most significant index values, as seen in Figure 4.

Based on Figure 4, in November, the areas that experienced a decrease in rainfall were a small part of Aceh's central and northern regions. The area with the highest percentage decrease in rainfall occurred at Cut Ba'u Maimum Saleh Station by 33.98% from the average for November for 20 years (Figure 4E), then Sultan Iskandar Muda Station by 22.80%, Aceh Climatology Station by 13.10% and Malikussaleh Station by 11.93%. Meanwhile, Cut Nyak Dien Station had no significant decrease in rainfall. Then, rainfall significantly decreased in December on the North Coast and parts of Central Aceh. The highest decrease in rainfall occurred at Malikussaleh Station at 41.20%, then Cut Ba'u Maimum Saleh Station by 38%, and Sultan Iskandar Muda Station by 22.99%. For rainfall data, the Aceh Climatology Station experienced a 17.07% decrease in rainfall and the Cut Nyak Dien Meteorology Station was seen to have a 13.26% decrease in rainfall. Based on rainfall data, in general, the decrease in rainfall in the Aceh region during the 2015 El Nino was 16.92% for November and 26.51% for December from the average conditions of 20 years. Based on the variation in rainfall changes during the 2015-2016 El Nino period, there was a different correlation at each observation location point.

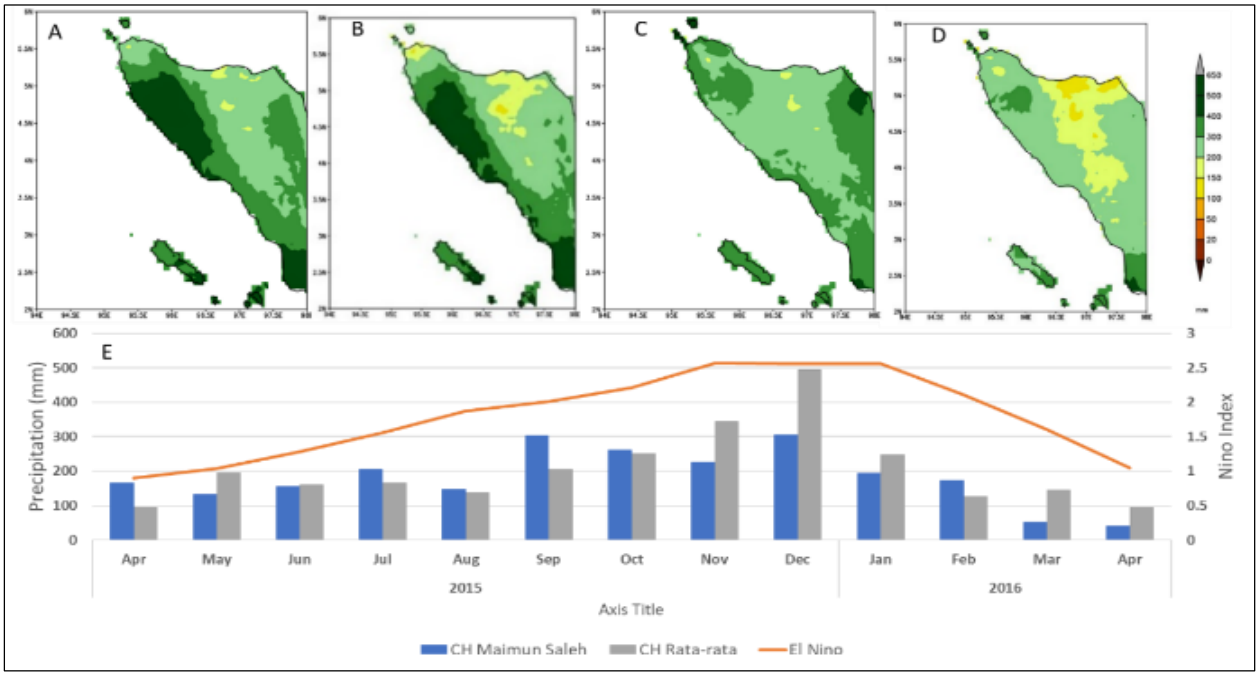

Fig. 4. Rainfall data during El Nino 2015-2016, (A) Contour of average rainfall data in November, (B) Contour of rainfall data in November 2015, (C) Contour of average rainfall data in December, (D) Contour of rainfall data in December 2015, (E) Comparison graph of rainfall and El Nino at Maimun Saleh Meteorological station.

The correlation between the El Nino phenomenon and rainfall at observation points in the Aceh region can be seen in Table 2. Based on Table 2, the relationship between the El Nino phenomenon in the period of occurrence from April 2015 to April 2016 with rainfall was analyzed based on the Pearson correlation, showing a linear correlation between -0.0133 - 0.4313. Based on a general study of the relationship between rainfall and the El Nino phase, when the phenomenon occurs, the surface temperature index will increase while the value of rainfall data will decrease. To obtain a linear relationship between the effects of El Nino and rainfall, the average rainfall data is subtracted from the rainfall data for the month of the El Nino event. This is done to obtain a large rainfall difference value when rainfall decreases dramatically compared to the average rainfall data.

Table 2. Pearson correlation of rainfall with El Nino index

No.	Location	Pearson Correlation (Rainfall and *El Nino*)
1	Aceh Climatology Station	-0.0133
2	Sultan Iskandar Muda Meteorological Station	0.2205
3	Cut Nyak Dien Meteorological Station	0.1888
4	Cut Ba'u Maimun Saleh Meteorological Station	0.3466
5	Malikussaleh Meteorological Station	0.4313

In the El Nino phase from April 2015 to April 2016, the largest correlation result was obtained at the Malikussaleh Meteorological Station, which was 0.4313. At the Aceh Climatology Station, a very small correlation value was obtained, indicating that the El Nino effect did not affect rainfall data. The correlation values obtained at all stations

were weak to moderate. Therefore, based on the correlation coefficient obtained, it can be concluded that the effect of El Nino on rainfall in the Aceh region is not significant enough. This discrepancy may also be caused by El Nio sometimes requiring time or a pause to influence the decrease in rainfall in a region. Regional differences also sometimes cause some regions to experience a decrease in rainfall in the western part of Indonesia but an increase in rainfall in the eastern part of Indonesia due to complex interactions with local-regional mechanisms (Kurniadi, A., Weller, E., Seungki, M. dan Mingyu, S., 2021). In addition, it is also possible that at the time of the incident, other phenomena affected the rainfall conditions of a region (Xing, Z., Yu, Z., Wei, J., Zhang, X., Ma, M., Peng, Y., Qin, J., Wang, J., Patrick, L., Kunstmann, H., 2022).

3.3 The influence of the 2007 – 2008 La Nina event on rainfall

The La Nina period in 2007-2008 was the longest, lasting from August 2007 to May 2008, or about 10 months. When the La Nina phenomenon occurs, the sea surface temperature in the Pacific is colder than the average value. This event causes an increase in rainfall in Indonesia and parts of Southeast Asia. The relationship between rainfall and La Nina is inversely proportional, with an increase in rainfall being associated with a decrease (negative) in the ENSO index. A similar thing happened in Aceh Province, when the ENSO index value showed the La Nina phenomenon, rainfall in the region increased (Figure 5).

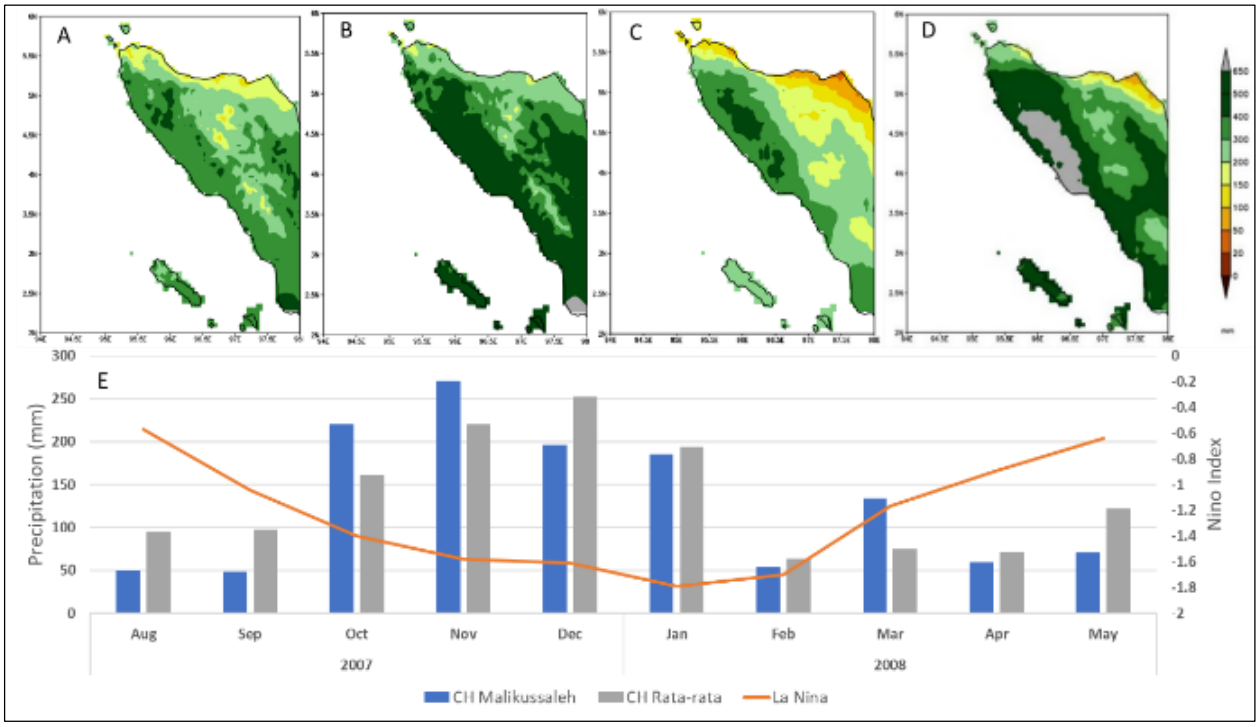

Fig. 5. Rainfall data during La Nina 2007-2008, (A) Contour of average rainfall data in October, (B) Contour of rainfall data in October 2007, (C) Contour of average rainfall data in March, (D) Contour of rainfall data in March 2008, (E) Comparison graph of rainfall and La Nina at Malikussaleh Meteorological Station.

Figure 5 shows that the influence of La Nina appears to have a more dominant impact on rainfall conditions in the Aceh region in March 2008. The increase in rainfall in the Aceh region during La Nina 2008 varied from 54.08 - 87.36%, with the highest percentage at the Cut Ba'u Malikussaleh Meteorological Station. Although the percentage increase in rainfall is very large, the East coast of Aceh tends to have the same rainfall level as the average (Figures 5C and 5D). Meanwhile, for October 2007, there was an increase in rainfall at all rainfall observation stations ranging from 0.28 - 39.5%. The percentage increase in rainfall was relatively lower when compared to March 2008. However, the increase in rainfall in October 2007 was evenly distributed throughout Aceh (Figures 5A and 5B).

As for changes in rainfall at Malikussaleh Meteorological Station (Figure 5E), it fluctuates, decreasing in August and September 2007 from the average rainfall for 20 years, then increasing in October and November 2007. Furthermore, from December 2007 to February 2008, rainfall decreased and increased again in March 2008. Although changes in rainfall fluctuate, the relationship between changes in rainfall and the ENSO index at this station is the most correlated. Then, the relationship between the La Nina index and rainfall in the Aceh region is available in Table 3.

Table 3. Pearson correlation of rainfall with La Nina index

No.	Location	Pearson Correlation (Rainfall and La Nina)
1	Aceh Climatology Station	0.0836
2	Sultan Iskandar Muda Meteorological Station	0.1959
3	Cut Nyak Dien Meteorological Station	0.0661
4	Cut Ba'u Maimun Saleh Meteorological Station	0.0205
5	Malikussaleh Meteorological Station	0.3621

The correlation between the La Nina index and CHIRPS rainfall data from August 2007 to May 2008 showed a weak to moderate correlation between 0.0205 - 0.3621. The correlated rainfall data is the difference between the average rainfall and the month of the event. The overall correlation between rainfall and the La Niña phenomenon is positive, indicating that rainfall at the station is influenced by the La Niña phenomenon. The suitability of this correlation is obtained from the results of the relationship between the index value and the difference between monthly rainfall and average rainfall. When rainfall exceeds the average, a negative difference is produced in accordance with the negative ENSO index. Based on the correlation value, the influence of La Nina on rainfall in the Aceh region is insignificant. However, rainfall data at each station shows a correlation at each observation station. The highest correlation value of the five observation points is seen at Malikussaleh Meteorological Station, with a correlation value 0.3621.

3.4 The influence of the 2016 Negative IOD on rainfall

Negative IOD in 2016 lasted 4 months, from June to September 2016 and began to weaken until December 2016. The average increase in rainfall caused by the negative IOD phenomenon in the Aceh region was 46.93% in August 2016 (Figure 6). All observation stations experienced an increase in rainfall between 29.52 - 64.48% in August, with the highest percentage increase at Cut Nyak Dien Meteorological Station. As seen in Figure 6C and Figure 6D, the negative IOD influence tends to occur at Cut Nyak Dien Meteorological Station in the Western Region of Aceh. In July 2016 (Figure 6A and Figure 6B), changes in rainfall in Aceh Province were minimal, and some areas even experienced a decrease in rainfall. The highest increase in rainfall occurred at Cut Ba'u Maimum Saleh Station by 4.37%; then Sultan Iskandar Muda Station experienced a less significant increase in rainfall of 0.21%.

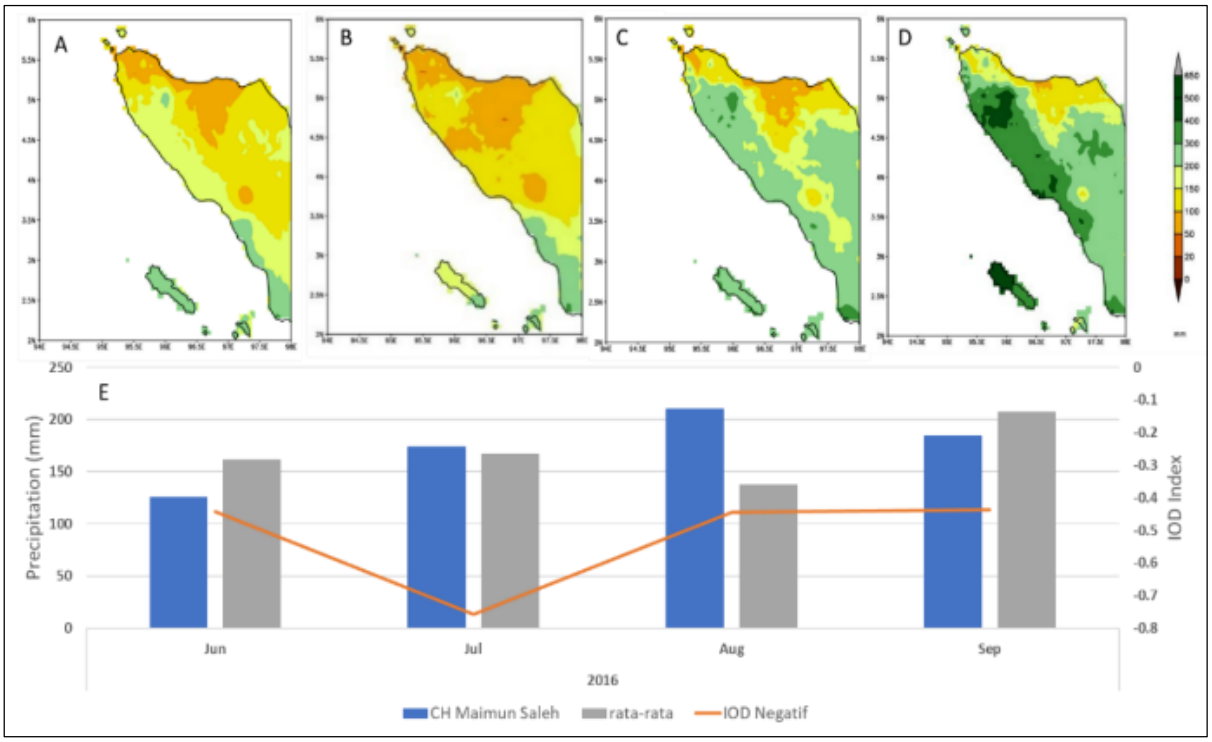

Fig. 6. Rainfall data during the negative IOD period in 2016, (A) Contours of average rainfall data in July, (B) Contours of rainfall data in July 2016, (C) Contours of average rainfall data in August, (D) Contours of rainfall data in August 2016, (E) Comparison graph of rainfall and negative IOD at Maimun Saleh Meteorological Station.

While other stations experienced a decrease in rainfall in the month, ranging from 3.66% - 41.02%. Changes in rainfall at Maimun Saleh Meteorological Station (Figure 6E) varied, namely experiencing a decrease in June, then increasing in July and August 2016, then falling again in September 2016 compared to the average rainfall for 20 years. To obtain the relationship between rainfall and negative IOD, a pearson correlation was also conducted between the rainfall difference variable and the IOD index at five observation points in the Aceh region (Table 4). Similar to the relationship between La Nina and rainfall, when the rainfall of the month of the Negative IOD phase increases from the average rainfall value, the rainfall difference value will be negative, which corresponds to the IOD index being negative. The correlation between the Negative IOD index and CHIRPS rainfall data during the 4 months of occurrence shows a negative correlation at two observation points, Cut Nyak Dien and Malikussaleh Stations, and a positive at other locations.

Table 4. Pearson correlation of rainfall with the Negative IOD index

No.	Location	Pearson Correlation (Rainfall and La Nina)
1	Aceh Climatology Station	0.2570
2	Sultan Iskandar Muda Meteorological Station	0.1100
3	Cut Nyak Dien Meteorological Station	-0.3864
4	Cut Ba'u Maimun Saleh Meteorological Station	0.0375
5	Malikussaleh Meteorological Station	-0.1760

The negative correlation shows that rainfall data that should have been high during the Negative IOD period decreased at these two stations. At other stations, a weak to moderate positive correlation is obtained between 0.0375 - 0.2570, indicating that rainfall increases when the IOD index is negative. However, the correlation value at the observation station obtained is relatively weak; only the Aceh Climatological Station has a moderate correlation category. This can conclude that the Negative IOD index only affects certain areas in Aceh with insignificant influence.

3.5 The influence of the 2019 Positive IOD on rainfall

The Positive IOD was observed from May to November 2019, with a duration of six months. Its intensity began to decline in December 2019. In 2019, it was also the most robust and prolonged positive IOD observed during the 2003–2022 period. The positive IOD in June 2019 (see Figures 7A and 7B) had a significant impact on the majority of Aceh's regions, particularly the eastern, central, and northern areas. The largest decrease in rainfall occurred at the Aceh Besar Climatology Station, namely 41.9% and the lowest decrease in rainfall of 27.7% occurred at Cut Ba'u Maimun Saleh Station. The decrease in average rainfall in the Aceh region is 33.059%. This percentage decrease in rainfall indicates that in June 2019, the Aceh region experienced warmer than normal conditions. In November 2019 (Figure 7C and Figure 7D), the decrease in average rainfall in the Aceh region caused by the positive IOD phenomenon in 2019 was 32,702%. This value is smaller than the rainfall decreases in June 2019. This is because the western part of Aceh did not experience a significant rainfall decrease in November 2019 (Figure 7C and Figure 7D).

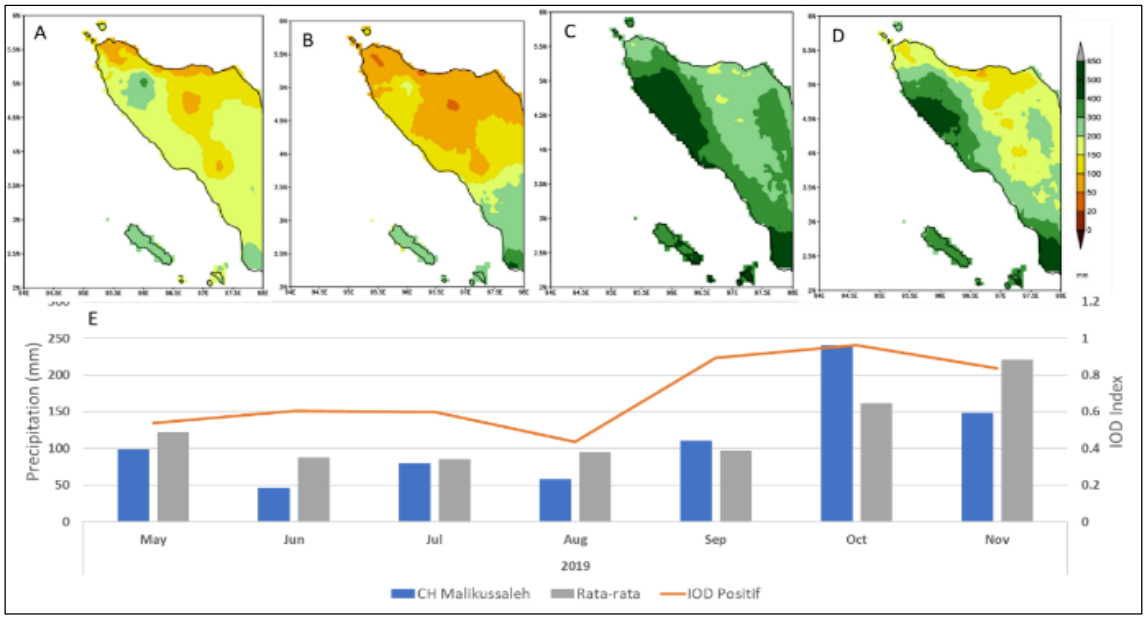

Fig 7. Rainfall data during the positive IOD period in 2019, (A) Contour of June average rainfall data, (B) Contour of June 2019 rainfall data, (C) Contour of November average rainfall data, (D) Contour of November 2019 rainfall data, (E) Comparison chart of rainfall and positive IOD at Malikussaleh Meteorological Station.

In November 2019, the Aceh region experienced a notable decrease in rainfall. This decline ranged from 13.17% to 42.63%, with the highest decrease occurring at the Malikussaleh Meteorological Station. Although a significant decrease in rainfall was observed in Aceh during the months of June and November, this trend was not universal. Indeed, during the positive IOD period in 2019, rainfall in other months exhibited either a low decline or even an increase.

This variability is one of the contributing factors influencing the correlation between rainfall and the positive IOD index. As evidenced in Table 5, the correlation between the positive IOD index and rainfall within the Aceh region has a positive value. The correlation results between the Positive IOD index and rainfall at 4 observation stations show a strong negative correlation between -0.5277 - 0.6541. The results of this correlation state that the Positive IOD phase does not influence rainfall at the 4 stations. The effect of positive IOD is only seen in the Aceh Climatological Station rainfall data but with a weak correlation of 0.1964.

Table 5. Pearson correlation of rainfall with IOD index Positive

No.	Location	Pearson Correlation (Rainfall and La Nina)
1	Aceh Climatology Station	0.1964
2	Sultan Iskandar Muda Meteorological Station	-0.6512
3	Cut Nyak Dien Meteorological Station	-0.6541
4	Cut Ba'u Maimun Saleh Meteorological Station	-0.5277
5	Malikussaleh Meteorological Station	-0.5346

Based on the results of this correlation, it can be said that the effect of Positive IOD on rainfall in the Aceh region is insignificant. The El Nino phenomenon could also influence the hot conditions in Aceh (October 2018 - June 2018), which occurred close to the Positive IOD event (May 2019 - November 2019).

4. Conclusion

The results of the percentage decrease and increase in monthly rainfall indicate a relationship between rainfall

and the ENSO and IOD indices. However, the correlation between rainfall and both indices show no significant relationship when observed during the ENSO and IOD phenomena. Pearson correlation between ENSO and IOD phenomena with rainfall at 5 observation points shows that La Nina has more influence on rainfall in the Aceh region than other phenomena. Negative IOD and El Nino phenomena influence some observation points, but some stations show no correlation between rainfall and indices. At the same time, the positive IOD phenomenon has a strong negative correlation with rainfall at the observation station, which indicates that positive IOD does not influence the Aceh region.

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