Asian Journal of Aquatic Sciences, April 2024. Vol 7, Issue (1) 33-43
e-issn: 2716-4608
p-issn: 2655-366X

THE RELATIONSHIP OF THE DISTRIBUTION OF SEA SURFACE TEMPERATURE WITH RAINFALL AND WIND IN THE WATERS OF WEST SUMATRA

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ABSTRACT

This research was carried out in February-March 2023 in the West Sumatra waters. It aimed to determine the variability of sea surface temperature, rainfall intensity, wind direction, and speed in the West Sumatra waters. Sea surface temperatures were taken from three stations, namely: in the coastal waters of Pariaman City, Padang-Pariaman Regency, and Bungus, Padang. The survey method was used, which was directly observed in the field. The results showed that the Sea Surface Temperature of the study areas ranged from 29.25^{o}C-30.28^{o}C, while the rainfall went from 211.97-499.89 mm, and the dominant speed was between 0.50-2.10 m/s. The correlation analysis between rainfall and sea surface temperatures in Station 1 yielded an "r" value of 0.871, a powerful correlation category, and the determination coefficient (R^2) was 0.579 or 57.9% during the western season. In the east season, the "r" value was 0.321, in the moderate correlation category, and the determination coefficient was 0.103 or 10.3%. At Station 2, the correlation coefficient (r) was 0.788, a powerful correlation category, and the determination coefficient (R^2) was 0.622 or 62.2% during the western season. In the east season, the "r" value was 0.699, a strong correlation category, and the determination coefficient was 0.488 or 48.8%. At Station 3, the "r" value was 0.688, a strong correlation category, and the determination coefficient was 0.477 or 47.7% during the western season. In the east season, the "r" value was 0.743, a strong correlation category, and the determination coefficient was 0.579 or 57.9%.

Keywords: Sea surface temperature, Rainfall, Wind speed, West Sumatra

1. INTRODUCTION

Geographically, the waters of West Sumatra are in the Indian Ocean. The monsoon winds also influence the Indian Ocean. The change in direction of the monsoon winds twice a year causes the circulation of water masses to change. Oceanographic activities in the Indian Ocean, such as seasonal water mass movements, also influence the distribution of SST (sea surface temperature) in the waters of West Sumatra[1].

Sea surface temperature (SPL) is a physical quantity ranging from 2^{o}C to 35^{o}C. Temperatures in tropical oceans are generally higher than in mid-latitude and polar waters. Water movements, such as ocean currents and turbulence, cause the sea's heat to spread. In tropical areas, the amount of solar radiation received per unit area (insolation) is more significant than in other areas[2]. Sea surface temperature is an essential factor for the life of organisms in the ocean because temperature can affect the metabolism and reproduction of marine organisms. Sea surface temperature is critical to know because the distribution of sea surface temperature can provide information about upwelling, currents, weather, climate, and fish catchment areas[3].

According to Mulyono[4], rainfall is the height of rainwater that falls on a flat place with the assumption that it does not evaporate, seep, or flow. Hermawan & Komalaningsih[5] explains that rainfall in Indonesia is influenced by the monsoon,

Received : 17 January 2024
Accepted : 5 March 2024

which is driven by the presence of high-pressure and low-pressure cells on the continents of Asia and Australia alternately. This is due to the location of Indonesia's territory between two continents, Asia and Australia, and two seas, the Indian and Pacific. Monsoons are winds or air circulation systems that reverse direction seasonally caused by differences in thermal properties between continents and oceans. The most extensive monsoon circulation in the world occurs in the tropical region of Asia.

The sun's apparent motion causes differences in air pressure in the Northern Hemisphere (BBU) and the Southern Hemisphere (BBS). In Indonesia, located on the equator, air movement passes due to differences in air pressure in the two hemispheres. This air movement is known as the monsoon wind. Monsoon winds alternately move across Indonesia for six months: April to September (eastern monsoon) and October to March (west monsoon)[6].

Research on sea surface temperature has been carried out by Alfajri et al.[1] in West Sumatra. However, this study did not discuss the relationship between sea surface temperature and other parameters, such as rainfall and wind. Therefore, researchers are interested in researching the relationship between sea surface temperature, precipitation, and wind. Considering that sea surface temperature has implications for various aspects related to weather and climate, researchers feel that this research is essential to carry out.

This research aims to determine the distribution and fluctuation of monthly sea surface temperatures in the waters of West Sumatra, the intensity of rainfall and wind speed in West Sumatra, and the relationship between sea surface temperatures and seasonal rainfall in West Sumatra.

2. RESEARCH METHOD

Time and Place

This research was carried out in February-March 2023 in West Sumatra. Determining the coordinates of the research station was carried out using GPS. The location of the research stations is divided into three stations, namely, Station 1 Kasiak Island (Pariaman City), Station 2 Muara (Padang-Pariaman District), and Station 3 Bungus (Padang City) (Figure 1).

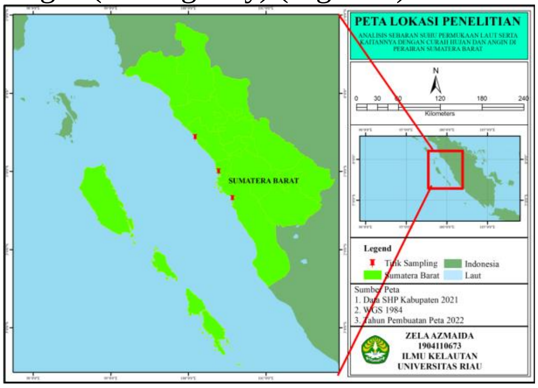


Figure 1. Map of Locations

Determination of Observation Locations

The method for determining the location for observing water conditions and collecting sea surface temperature data is to use a purposive sampling method, namely, taking carefully selected samples. Hence, they are relevant to the research structure with specific considerations. Collect data on sea surface temperature in West Sumatra waters, there are three stations, Station 1 is Pariaman Waters (Kasiak Island waters with coordinates 00°35'47" South Latitude and 100°04'29" East Longitude), Station 2 is Padang Regency Waters Pariaman (Muara with coordinates -0°44'35"N 100°13'48"E), Bungus Water Station 3, Padang (Bungus Bay with coordinates 00.54-1.80 South Latitude and 100°34 East Longitude).

Data Collection

Data collection consists of primary data and secondary data. Preliminary data was obtained from measurements of sea surface temperature in the field using a thermometer carried out in the waters of West Sumatra. Measurements were carried out in three repetitions at three predetermined station points: morning, afternoon, and evening.

Meanwhile, the secondary data used are NOAA daily SST data, NASA POWER rainfall data, and water wind data obtained from Copernicus, which was also taken at 3 station points. These data are obtained in FormatNC-file, which is then read using additional applications, namely Ocean Data View, processed and tabulated in graphs and maps, and then analyzed using time series analysis.

Data Analysis

NOAA daily reanalysis data is daily sea surface temperature reanalysis data in NetCDF (NC) format, which contains 365 or 366 data. The final form is an SPL distribution map for one month. It is necessary to convert the daily SPL data into monthly SPL data. The daily data obtained is then processed using Microsoft Excel to get the maximum and minimum values for the monthly data.

After data validation, the sea surface temperature data correlated with rainfall data for each season in the west and east seasons. Then, regression analysis was carried out using the SPSS 24.0 software. The formula for using Pearson regression for average distribution data[7]:

$$r_{xy} = \frac{n\Sigma XY - \Sigma X \Sigma Y}{\sqrt{[n\Sigma X^2 - (\Sigma X)^2][n\Sigma Y^2 - (\Sigma Y)^2]}} \quad \text{.. (1)}$$

Meanwhile, for data that is not normally distributed, use Spearman correlation[7]:

$$r_s = \frac{1 - 6\Sigma d^2}{n(n^2 - 1)} \quad \text{... (2)}$$

The relationship between sea surface temperature and rainfall was analyzed using a linear regression model based on latitude (x) and longitude (y). Coordinate transformation and spatial resolution of sea surface wind data are carried out. The regression formula used to analyze the relationship between rainfall and sea surface temperature is

$$Y = a + bX$$

Information:

Y = Rainfall
X = Sea Surface Temperature
a = Constant
b = Regression coefficient

The correlated data is secondary data in the form of daily sea surface temperature and rainfall data. Daily data on sea surface temperature with rainfall in the West Season (October-March) and daily data on sea surface temperature with rains in the East Season (April-September) have a total of 180-183 data for each season. Through the linear regression test, the coefficient of determination (R2), correlation coefficient (r), and standard error (SE) were used to determine the level of accuracy of the reanalysis data used. The closeness of the relationship between the dependent variable and the variables is determined based on the r-value. To see the interpretation of the correlation between two variables, the following are the criteria for the calculation results, citing Sarwono[8,] namely:

0	:	There is no correlation between the two variables.
>0 – 0,25	:	Very weak correlation
>0,25 – 0,5	:	Sufficient correlation
>0,5 – 0,75	:	Strong correlation
>0,75–0,99	:	Very strong correlation
1	:	The correlation is perfectly positive.
-1	:	Perfect relationship correlation is negative.

3. RESULT AND DISCUSSION

General Conditions of Research Locations

Kasiak Island is one of several islands located in the Pariaman Waters, West Sumatra, and the distance is more than 3 km or only about 45 minutes by boat from Padang Pariaman City to the island. Kasiak Island is approximately 54 km or closer to the earthquake's epicenter than Padang Pariaman. Kasiak Island is located right in front of the sea of Pariaman City. A coral reef ecosystem surrounds Kasiak Island, which is a protected area[9].

The city of Padang is located on the west coast of the island of Sumatra, with a

e-issn: 2716-4608
p-issn: 2655-366X

total area of 694.96 km² or equivalent to 1.65% of the area of West Sumatra province. Padang City is the largest city on the west coast of Sumatra Island and the capital of West Sumatra province, Indonesia. Padang City is one of Indonesia's coastal cities with tourist and recreational activities on the beach. Taplau Beach in the center of Padang City is one of the western beaches of Sumatra, which has a long coastline[10].

The Bungus Bay area is located in the southern part of Padang City - West Sumatra. It plays a vital role in West Sumatra and the island of Sumatra. The capture fishing industry is one of the mainstays in this region, with the value of pelagic fish catches continuing to increase from year to year. Apart from that, this area is an essential point in the fuel distribution network for Sumatra Island, which acts as a transit depot for Pertamina[11].

Data Validation

Data validation tests were carried out to determine the level of accuracy between field sea surface temperature values and NOAA sea surface temperature data. This level of accuracy is a benchmark for whether the recorded image data can represent the sea surface temperature value in the waters. The following is a comparison graph between field sea surface temperature and NOAA data.

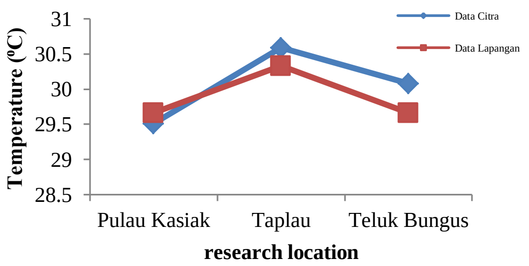
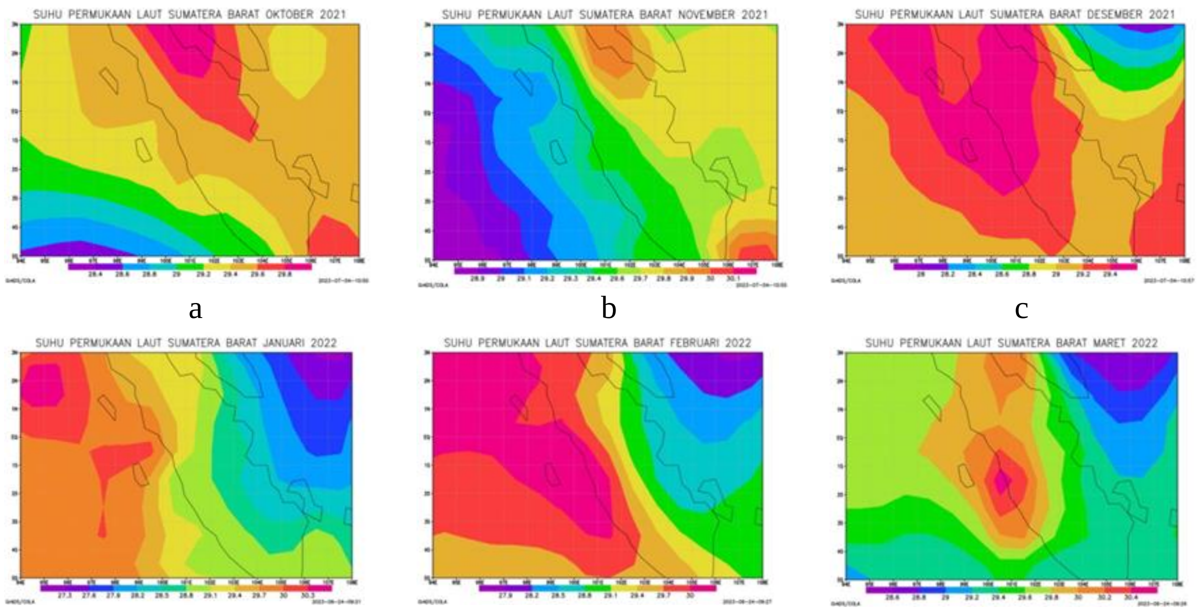


Figure 2. Field Temperature Data Validation Graph with NOAA Data

From the results of the graphic processing above (Figure 2), daily sea surface temperature data, both from field measurements and NOAA satellite recordings, ranges from 29.5-30,6^{O}C. It can be concluded that the level of accuracy of sea surface temperature data from field measurements with NOAA image recording data has a relatively high level of accuracy.

Sea Surface Temperature

Mapping the distribution of sea surface temperatures in the waters of West Sumatra was recorded from NOAA satellites using the GRADS software. The visualization results of this data can be seen in Figure 3.



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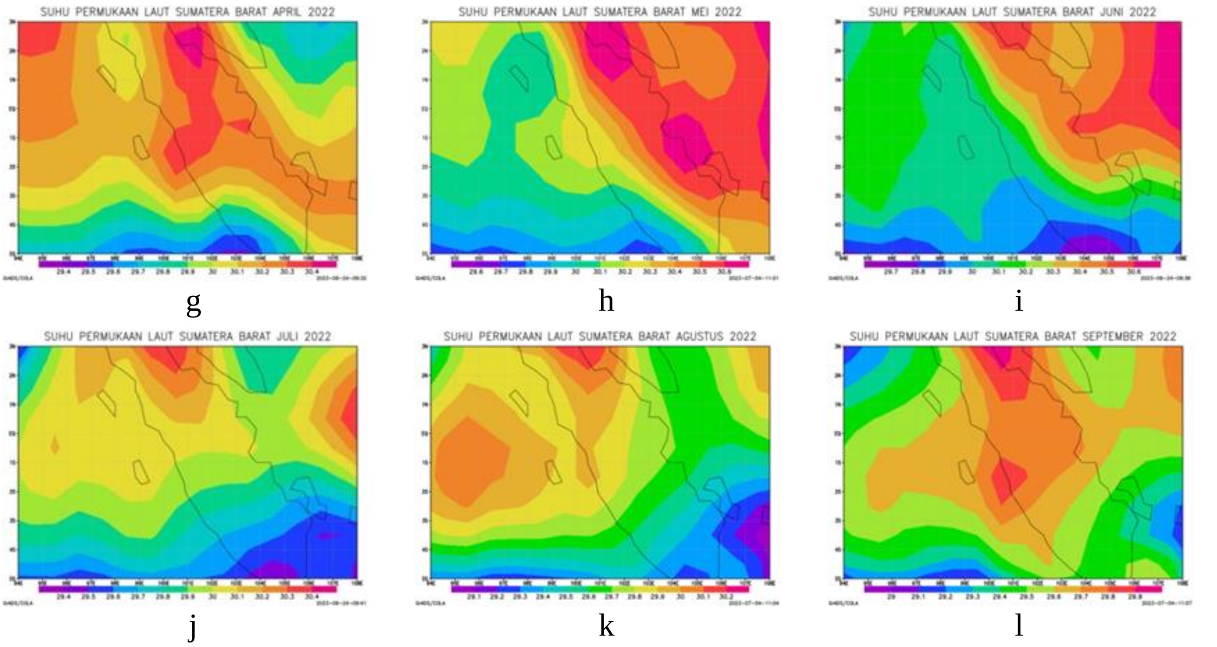


Figure 3. Distribution of Sea Surface Temperature in West Sumatra in (a) October 2021, (b) November 2021, (c) December 2021, (d) January 2022, (e) February 2022, (f) March 2022, (g) April 2022, (h) May 2022, (i) June 2022, (j) July 2022, (k) August 2022, (l) September 2022

Based on the map of the distribution of sea surface temperatures, it can be seen from October to March that the distribution of sea surface temperatures in the waters of West Sumatra in the western season shows that the temperature dominates between the range of 29.2-29.6^{o}C. At the exact location in October (Figure 3a) towards November (Figure 3b), the temperature decreased between 29 and 29.2^{o}C. The decrease in sea surface temperature is caused by high rainfall and wind movement, reducing sea surface temperature. According to Athoillah et al.[12], in 2016, there was a La Nina (weak) phenomenon where positive anomalies tended to occur, which supported more cloud growth with the potential for rain. This phenomenon results from climate deviations that have resulted in increased rainfall in several regions of Indonesia.

In December (Figure 3c), the sea surface temperature began to increase from 29.4 to 29.8^{O}C in the west season, which is usually the season where rainfall and wind speed tend to be high, causing sea surface temperatures in that season to grow to be low because high rainfall can cause waters to receive less light intensity, relatively quiet and high wind speed causes the sea surface to be bumpy and reducing the penetration of heat into seawater so that the sea reaches a minimum temperature.

Meanwhile, from April to September, temperatures dominate between 29.2-30.6^{O}C The increase in sea surface temperature in the east season is due to the low intensity of rainfall, which causes the high intensity of radiation and the sea surface to be calmer, which causes the absorption of temperature into sea waters to be higher so that the sea reaches its maximum temperature. Looking at April (Figure 3g), sea surface temperatures in April still tend to be warm. This is thought to be due to the low wind speed[13].

Wind speed affects the penetration of light into the waters, and decreasing evaporation levels will result in higher sea surface temperatures. The high sea surface temperature in that month is also thought to be influenced by the El Nino phenomenon, so the sea surface temperature in that month is high.

The high sea surface temperature in May decreased in June, allegedly because the El Niño phenomenon decreased and the movement of seawater masses in the study area. The decreasing sea surface temperature phenomenon is strengthened by research by Tristianto et al.[13]; entering May, sea surface temperatures decrease and increase in upwelling intensity. The decline in sea surface temperatures continues in June, July and August.

From the visualization results of the distribution of sea surface temperatures, it can be seen that sea temperatures in coastal areas tend to be warmer than in the open sea. This is caused by the movement of this water mass, which can generate heat due to friction between water molecules, so seawater temperature in waters near the coast is warmer than in offshore waters[14]. The high movement of water masses is caused by several factors, namely depth, brightness, waves, height above sea level, and human activity around the waters.

Rainfall

The intensity of rain depends on its duration and size. The longer the rain lasts, the higher the intensity, and vice versa. The shorter the duration, the lower the intensity[15]. The results of rainfall recording carried out by NASA satellites, which are daily rainfall data, are then accumulated into monthly data and tabulated in graphical form, which can be seen in Figure 4.

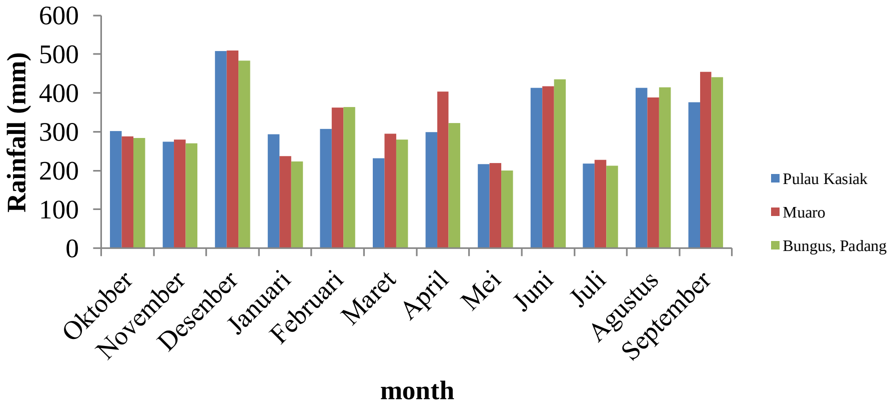


Figure 4. West Sumatra Rainfall

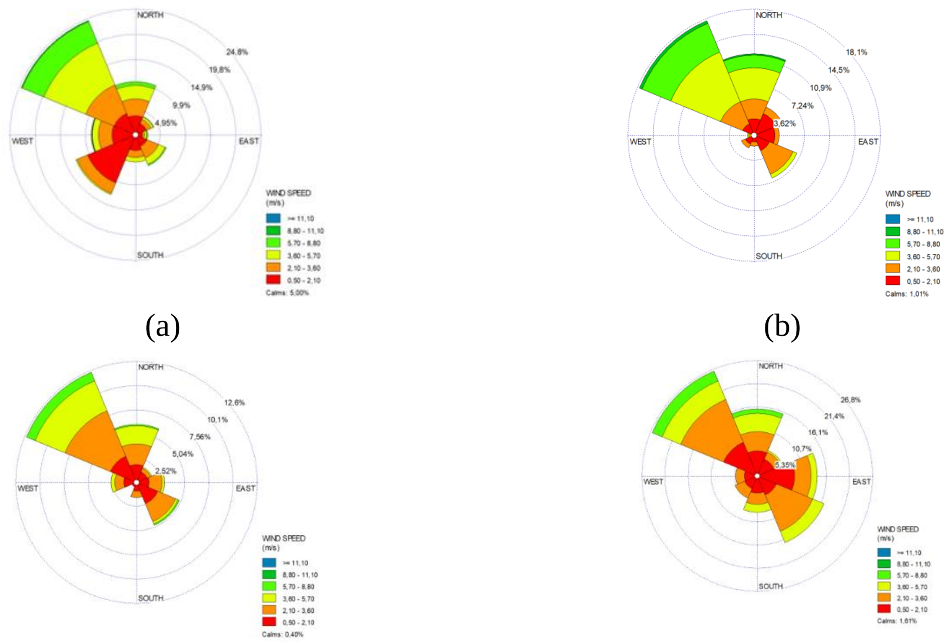
Based on the results of data processing from measurements from the NASA POWER satellite in Figure 4, it can be seen that the rainfall on Kasiak Island (Kota Pariaman) during one period, namely: in October, the total rainfall was 302.24 mm, in November 273.77 mm, in December 507 mm, January 293.79 mm, February 307.79 mm, March 231.49 mm, April 298.88 mm, May 216.84 mm, June 412.87 mm, July 218, 67 mm, in August 412.5 mm, in September 376.22. The highest rainfall occurred in the Kasiak Island area, namely in December, with a total rainfall of 507.37 mm.

Rainfall in Muaro (Padang-Pariaman Regency) during one period, namely: October total rainfall 288.55 mm, November 279.37 mm, December 509.73 mm, January 237.45 mm, February 361, 89 mm, March 294.97 mm, April 403.22 mm, May 218.82 mm, June 417.05 mm, July 227.42 mm, August 388.75 mm, September 453.7 mmm. The lowest rainfall was at Muara Beach (Taplau) in May, totaling 216.84 mm. The highest rainfall occurred at Muara Beach in December, with a total rainfall of 509.73 mm.

Rainfall in Bungus Bay, Padang (Padang City) during one period, namely: October total rainfall 283.65 mm, November 270.33 mm, December 482.57 mm, January 223.1 mm, February 363 .36 mm, March 279.36 mm, April 322.96 mm, May 200.26 mm, June 435.53 mm, July 212.61 mm, August 415.05 mm, September 440.17 mm. The lowest rainfall was in May, with a total of 218.82 mm. The highest rainfall occurred in the Bungus Bay area, namely in December, with a total rainfall of 487.52 mm, while the lowest rainfall was in May, with a total of 200.26 mm.

From Figure 4, West Sumatra's rainfall differs from region to region. This is due to the topography of the West Sumatra region. The highest rainfall predominantly occurs in areas directly facing the open sea, such as Pariaman City and Padang Pariaman Regency. Several factors that cause the high rainfall intensity in this area include wind direction. The average is higher, which makes it easier for clouds to move for rain, and the sea surface temperature is also dominantly higher. Sea surface temperature has a unidirectional relationship, which means that if the sea surface temperature is high, rainfall will also be higher, and vice versa. If sea surface temperature is low, rainfall will also be low. This is also associated with evaporation and the absence of hills because the hills that line an area can affect rainfall. These hills block the clouds so that the clouds cannot rain in the area behind the mountains.

SST changes are known to have a significant influence on rainfall variability. This is suspected to be related to spatial and temporal changes in the SST anomaly pattern. Several research results show a reasonably clear link between the SST phenomenon and rain events in an area[16].



(a) (b) (c) (d)

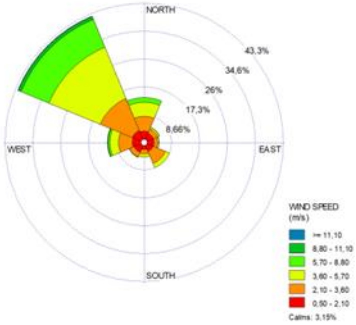
Figure 5. Comparison of Windrose Seasonal Winds on Kasiak Island, (A) West Season, (B) Wet to Dry Transition Season, (C) East Season, (D) Dry to Wet Transition Season

High rainfall has a significant impact on activities that occur at sea, such as tourism, crossings, and fishing. This is reinforced by Sultan's research in Sari & Wiyono[17], which states that if rainfall and the number of rainy days are high, fishing trip activity will decrease, impacting fish production. High rainfall can cause high sea tides and affect the lack of sea-related tourist activities such as surfing, diving, etc. Continuous high rainfall at sea, accompanied by strong winds, also results in storms, disrupting transportation activities in sea waters.

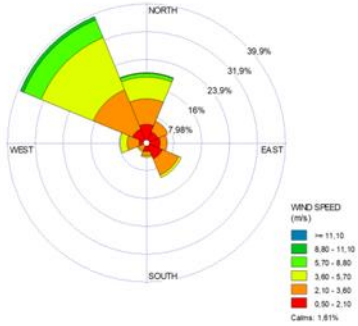
Wind Speed and Direction

The wind data used in this research is data from Copernicus. Program Copernicus is a program of the European Commission that aims to achieve an operational, autonomous, multi-level Earth observation capacity. Data Copernicus I took ERA5, the

5th generation ECMWF, ieERA hourly data on single levels from 1979 to the present. Data was obtained from Copernicus in NC file format. An Ocean Data View (ODV) application is needed to read this data. Figure 5 shows that the wind direction in each season at Station 1 comes from the North West, and the dominant wind speed is 0.5-2.10 (m/s).



(a)



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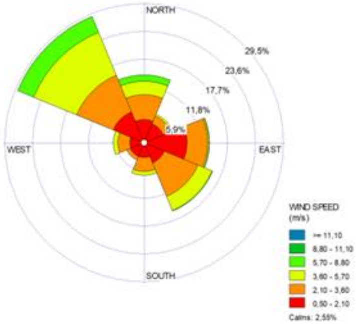

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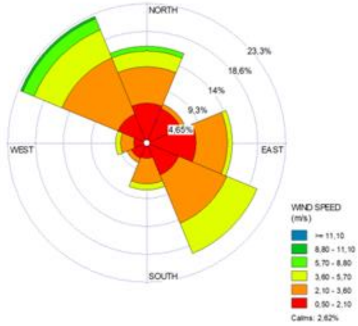
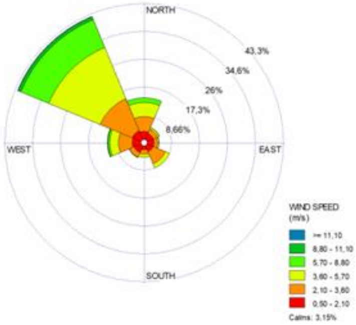


(d)

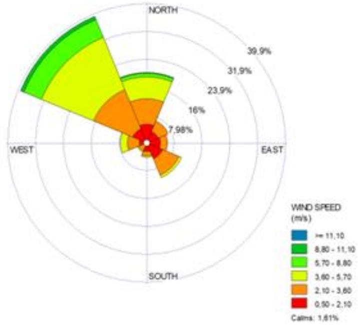
Figure 6. Comparison of Windrose Seasonal Winds in Muaro, (A) West Season, (B) Wet to Dry Transition Season, (C) East Season, (D) Dry to Wet Transition Season

Figure 6 shows that the wind in each season originates from the North West, the wind speed in the West Season and the Dry Transition Season is dominated by a speed range of 2.10-3.60 (m/s), while in the East Season and The Dry to Wet Transition Season is dominated by a speed range of 0.5-2.10 (m/s) each season at Station 2.

The wind in each season comes from the North West, the wind speed in the West Season and the Dry Transition Season is dominated by a speed range of 2.10-3.60 (m/s), while in the East Season and The Dry to Wet Transition Season is dominated by a speed range of 0.5-2.10 (m/s) (Figure 7).



(a)



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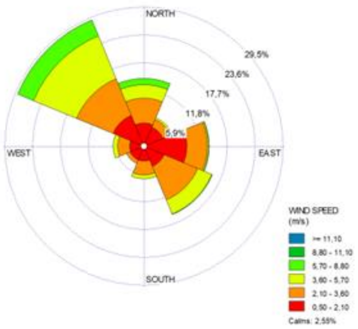

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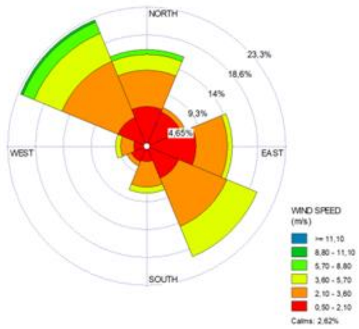

(d)

Figure 7. Comparison of Windrose Seasonal Winds in Muaro, (A) West Season, (B) Wet to Dry Transition Season, (C) East Season, (D) Dry to Wet Transition Season

Wind is one of the factors that causes sea surface temperature variability. High chlorophyll-a concentration values occur when wind speed increases, and low sea surface temperatures occur when wind speed is high. On the other hand, chlorophyll-α concentrations decrease, and sea surface temperatures increase when wind speed decreases[18]. Winds blowing over the ocean surface can cause thermal mixing. Wind changes the hot surface layers of the ocean with deeper layers that may be cooler. This can cause the spread of heat from the upper layers to deeper layers, which affects sea surface temperatures.

Wind can carry hot or cold air over the ocean surface depending on its direction. Land breezes (blowing from land to sea) usually have hot air and can increase sea surface temperatures, while sea breezes (blowing from sea to land) can bring cooler air and lower surface temperatures.

Correlation of Sea Surface Temperature with Seasonal Rainfall

The correlation between sea surface temperature and rainfall was analyzed using linear regression. Linear regression is a statistical method that forms a pattern or relationship between 1 or more independent X and Y response variables[19].

The correlation between sea surface temperature and rainfall at Station 1 of Kasiak Island can be seen in Table 1.

Table 1. Correlation of Sea Surface Temperature with Rainfall on Kasiak Island

Moon	r	R^2
Western Season (October 2021- March 2022)	0.871	0.597
Eastern Season (April-November 2022)	0.321	0.103

From the processing results, Table 4 shows that in the season (October 2021-March 2022), the r-value is 0.871, which means that the correlation between sea surface temperature and rainfall is in the powerful correlation category and the determination value or R^2 was obtained at 0.579 which explains that sea surface temperature has a 59.7% influence on rainfall variability and other factors influence 40.3%. In the East Season (April – September 2022), the r-value is 0.321, which means that the correlation between Sea Surface Temperature, Rainfall, and wind is in the sufficient correlation category. The determination value or *R Square* was obtained at 0.103, explaining that sea surface temperature has a 10.3% influence on rainfall variability and other factors influence 89.7%. The results of the correlation between sea surface temperature and rainfall at Station 2 on the Muara Padang Waterfront (Taplau) can be seen in Table 2.

Table 2. Correlation of Sea Surface Temperature with Rainfall in Muaro

Moon	r	R^2
Western Season (October 2021- March 2022)	0.788	0.622
Eastern Season (April-November 2022)	0.699	0.488

Table 2, in the West Season (October 2021- March 2022), the correlation coefficient (r) value is 0.788, which means that the correlation between sea surface temperature and rainfall is in the powerful correlation category and the value of determination or R^2 was obtained at 0.622, which explains that sea surface temperature has a 62.2% influence on rainfall variability and other factors influence 37.8%. In the East Season (April – September 2022), the r-value is 0.699, which means that the correlation between sea surface temperature and rainfall falls into the category of solid correlation. The determination value or R^2 was obtained at 0.488, which explains that sea surface temperature has a 48.8% influence on rainfall temperature variability and other factors influence 51.2%. The correlation between sea surface temperature and rainfall at Station 3 can be seen in Table 3.

Table 3. Correlation of Sea Surface Temperature with Rainfall in Bungus Bay

Moon	r	R^2
Western Season Oktober 2021- Maret 2022)	0,688	0,477
Eastern Seasons (April-November 2022)	0,743	0,552

Table 3, it is known that in the West Season (November 2021- March 2022), the r-value is 0.688, which means that the correlation relationship between Sea Surface Temperature, Rainfall, and wind is in the strong correlation category and the value of determination or R^2 was obtained at 0.477 which explains that sea surface temperature has a 47.7% influence on rainfall variability and other factors influence 52.3%. In the East Season (April – September 2022), the r-value is 0.743, which means that the correlation between sea surface temperature and rainfall falls into the category of solid correlation and determination value or $R^2$was obtained at 0.579, which explains that sea surface temperature has a 59.7% influence on rainfall temperature variability and is 40.3% influenced by other factors.

4. CONCLUSION

Based on research that has been conducted, the sea surface temperature of West Sumatra waters ranges between 28-31^{O}C. The sea surface temperature of West Sumatra always increases in the west season and decreases in the east season. The highest sea surface temperature in West Sumatra waters is in February and April, while the lowest in West Sumatra is in November. Meanwhile, yearly rainfall in West Sumatra ranges from 211.97 to 499.89 mm. Meanwhile, wind speed in West Sumatra waters is dominated by the range 0.50-2.10 (m/s) and the northwest wind direction. The correlation between sea surface temperature and rainfall in West Sumatra waters has a weak to solid relationship level, ranging from 0.321-0.871.

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