

STUDY OF SEA SURFACE TEMPERATURE IN INDONESIA ON MONTHLY RAINFALL PREDICTIONS ON AMBON ISLAND

Kajian Suhu Permukaan Laut Wilayah Indonesia Terhadap Prediksi Curah Hujan Bulanan di Pulau Ambon

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ABSTRACT

Ambon Island which is part of the territory of Indonesia has a unique rain pattern. When most parts of Indonesia experience the rainy season, Ambon Island actually experiences a dry season, and vice versa. This study aims to predict rainfall on Ambon Island using sea surface temperature predictors with high correlation. The study was conducted by observing rainfall (CH) data from the Pattimura Ambon Meteorological Station, SPL data with a spatial resolution of 0.25° x 0.25° covering the territory of Indonesia obtained from the European Union's Earth Observation Program (Copernicus) over a period of 30 years (January 1991-December 2020). The results show the Ambon CH Pattern showing Local Patterns and SPL conditions in Indonesia show that in the November-May period Indonesia tends to be dominated by SPL above 28.5°C, SPL warming occurs in southern Indonesia. Meanwhile, in the June-October period, there was a cold SPL movement from southern Indonesia, so that the northern part experienced SPL warming. The highest negative CH and SPL correlation values of 0.57 were in the 15° LS and 135.5° BT regions, while the highest positive correlation values of 0.50 were in the 14.5° LU and 121.25° BT regions. Based on the model built from SPL predictors, the best prediction result is the SPL(+) Model with an RMSE of 227.79.

Keywords: Ambon Island, Precipitation, Prediction, Sea Surface Temperature

ABSTRAK

Pulau Ambon yang merupakan bagian wilayah negara Indonesia memiliki keunikan pola hujan yang khas. Ketika sebagian besar wilayah Indonesia mengalami musim hujan, Pulau Ambon justru mengalami musim kemarau, begitupun sebaliknya. Penelitian ini bertujuan untuk memprediksi curah hujan di Pulau Ambon dengan menggunakan prediktor suhu permukaan laut dengan korelasi yang tinggi. Penelitian dilakukan dengan pengamatan data curah hujan (CH) dari Stasiun Meteorologi Pattimura Ambon, data SPL dengan resolusi spasial 0,25° x 0,25° yang meliputi wilayah Indonesia diperoleh dari *European Union's Earth Observation Programme* (Copernicus) selama periode 30 tahun (Januari 1991–Desember 2020). Hasil menunjukkan Pola CH Ambon menunjukkan Pola Lokal dan kondisi SPL wilayah Indonesia menunjukkan bahwa pada periode November–Mei Indonesia cenderung didominasi oleh SPL

di atas 28,5°C, penghangatan SPL terjadi pada selatan Indonesia. Sedangkan pada periode Juni–Oktober terlihat adanya pergerakan SPL yang dingin dari selatan Indonesia, sehingga bagian utara yang mengalami penghangatan SPL. Nilai korelasi CH Ambon dan SPL negatif tertinggi sebesar 0,57 berada pada wilayah 15° LS dan 135,5° BT, sedangkan nilai korelasi positif tertinggi sebesar 0,50 berada di wilayah 14,5° LU dan 121,25° BT. Berdasarkan model yang dibangun dari prediktor SPL, didapatkan hasil prediksi yang paling baik adalah Model SPL(+) dengan RMSE sebesar 227,79.

Kata Kunci: Curah Hujan, Prediksi, Pulau Ambon, Suhu Permukaan Laut

INTRODUCTION

Indonesia's territorial structure, consisting of islands dominated by oceans, plays a vital role in various aspects of life, including influencing its climate (Aldrian, 2008). The structure and orientation of the islands, the tropical region, and the equator make rainfall in Indonesia a highly diverse climate element (Swarinoto & Sugiyono 2011). Each region has its own distinct rainfall patterns and characteristics.

This unique rainfall pattern is evident on Ambon Island, where it differs from most other regions in Indonesia, which experience a monsoon rainfall pattern (Aldrian & Susanto, 2003). While most parts of Indonesia experience a rainy season, Ambon Island experiences a dry season, and vice versa. According to Aldrian (2001), the annual rainfall pattern on Ambon Island is considered an anomaly compared to other rainfall patterns in Indonesia, where the peak rainy season tends to occur in May-June-July (MJJ).

Ambon Island, with an area of only 803.9 km², is surrounded by ocean, bordered to the north by Piru Bay, to the south by the Banda Sea, to the east by the Haruku Strait, and to the west by the Banda Sea (BPS Kota Ambon 2021). This situation makes rainfall predictions on Ambon Island highly unstable, complex, and subject to significant variability, posing a challenge for forecasters in predicting climate conditions, particularly rainfall. According to Qu *et al.* (2005), one of the main factors driving rainfall variability in the Indonesian atmosphere, and even globally, is sea surface temperature.

Increased sea level rise tends to increase the evaporation rate (Ivatek-Sahdan *et al.*, 2018). According to Alfiandy *et al.* (2020), the greatest evaporation due to solar heating occurs over the ocean. This evaporation rate triggers the vertical transfer of water vapor from the ocean to the atmosphere (convection), which is essential for the dynamics of cloud and rain formation (Syaifullah, 2010).

The location of Ambon Island, which serves as a hub for various sectors, makes it highly vulnerable to weather and climate, particularly rainfall. To meet the need for information on future rainfall, a validated prediction model was developed using sea surface temperature as a predictor. The rainfall prediction model developed must be location-specific, suitable and highly accurate in one region, but may also be inaccurate in other locations (Estiningtyas *et al.*, 2008). Based on this background, this study aims to analyze the contribution of SST to predicting monthly rainfall on Ambon Island. This can be used as input to improve the accuracy of monthly rainfall prediction information provided to various sectors for policy-making on Ambon Island.

METHODS

Data and Location

This research took place on Ambon Island. The research area was covered by the Patimurra Ambon Meteorological Station (Figure 1). Ambon Island itself has two bays: Inner Ambon Bay and Outer Ambon Bay.

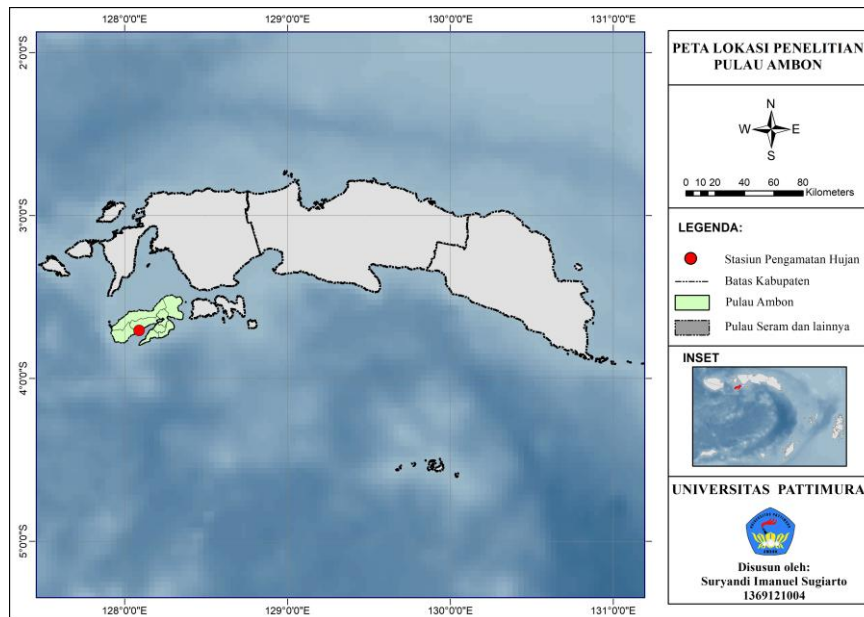


Figure 1. Rainfall Observation Points on Ambon Island

Direct observation data, consisting of monthly rainfall data for a 30-year period (January 1991–December 2020), was obtained from the Pattimura Ambon Meteorological Station. Sea surface temperature data with a spatial resolution of $0.25^\circ \times 0.25^\circ$, covering Indonesia (90° East - 150° East and 15° North - 15° South), was obtained from the European Union's Earth Observation Programme (Copernicus) at <https://cds.climate.copernicus.eu/>, which is remote sensing data (Figure 2).

Data Analysis

Correlation analysis was conducted to identify areas with a high correlation between SST and monthly rainfall on Ambon Island. Pearson correlation was used to determine the degree of closeness or strength of the relationship between one variable and another (for example, variable x and variable y), with data for both variables in interval or ratio form (Sugiyono, 2016). Pearson correlation can be formulated using the following equation.

$$r_{xy} = \frac{n \sum x_i y_i - (\sum x_i)(\sum y_i)}{\sqrt{(n \sum x_i^2 - (\sum x_i)^2)(n \sum y_i^2 - (\sum y_i)^2)}}$$

Where:

- r_{xy} = Pearson correlation coefficient r
- x_i = i -th value
- y_i = i -th value
- n = number of samples

The regression equation is used to predict how much the value of the dependent variable will change if the value of the independent variable changes or increases or decreases (Sugiyono, 2016). According to Wilks (2006), simple linear regression is the easiest regression to understand because it shows a linear relationship between two variables. The simple linear regression equation is expressed in the following formula:

$$Y = \alpha + bX$$

Where:

- Y = predicted rainfall
- α = constant coefficient
- b = regression coefficient

X = predictor variable (SST)

Multiple linear regression is an extension of the simple linear regression model. By extending the two- or three-variable linear regression model, a regression model with the dependent variable Y and k independent variables is created (Ruminta, 2009). This method is used to determine the direction, influence, and strength of the relationship between the independent variables and the dependent variable. The multiple linear regression equation is expressed in the following formula.

$$Y = \alpha + b_1X_1 + b_2X_2 + \varepsilon$$

Where:

- Y = rainfall prediction
- α = constant coefficient
- b_1, b_2, b_3 = regression coefficient
- X1 = Sea surface temperature (+)
- X2 = Sea surface temperature (-)
- ε = residual variable

Rainfall data processing uses spreadsheet software. GrADS software is used to extract and process the SST distribution. QGIS version 3.22.6 is used to analyze the spatial correlation distribution.

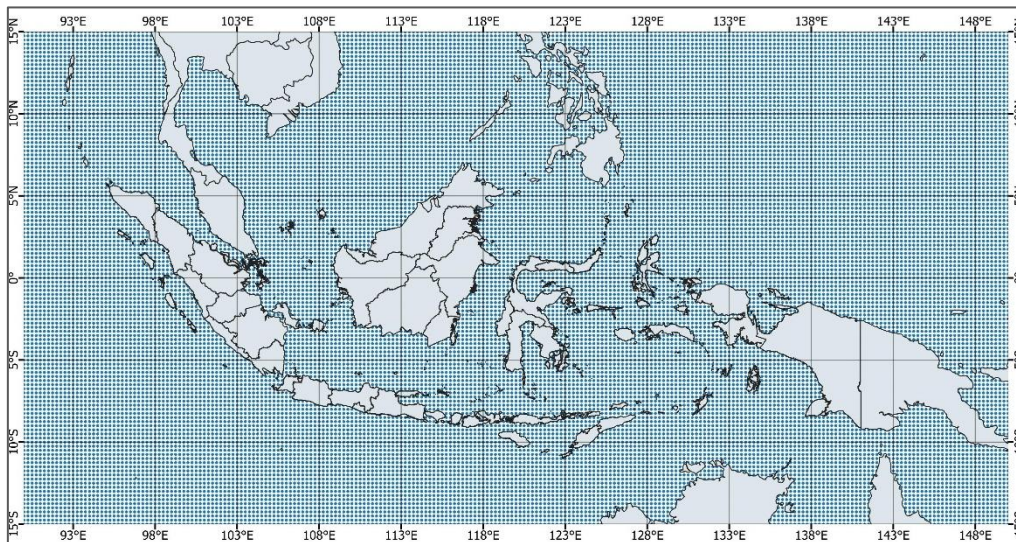


Figure 2. SST Location Points in Indonesia

RESULTS

Ambon Rainfall Patterns and SST Distribution in Indonesia

Figure 3, which shows rainfall patterns on Ambon Island (represented by the Pattimurra Ambon Meteorological Station), using observation data from 1991 to 2020, shows a local rainfall pattern. According to the Meteorology, Climatology, and Geophysics Agency (BMKG) (2022), this local rainfall pattern exhibits a period of peak rainfall intensity and a period of lowest rainfall intensity, with the peak occurring outside the Asian monsoon period. Peak rainfall on Ambon Island occurs in June, with 609 mm. The peak dry season on Ambon Island, indicated by the lowest rainfall, occurs in November, with 80 mm.

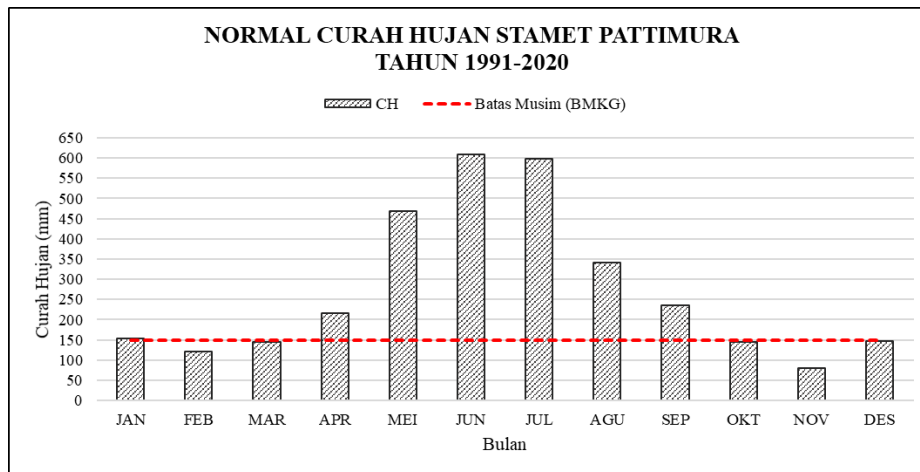


Figure 3. Graph of Normal Rainfall in Ambon 1991-2020

The SST distribution in Figure 4 shows monthly fluctuations throughout 1990–2020. In January, sea surface temperatures ranged from around 24.0°C to 30.8°C, with the greatest warming in the Arafura Sea and relative cooling in the South China Sea. February continued to show a similar pattern, although the range shifted slightly to 23.7°C to 30.7°C, with the Timor Sea recording the highest values and the South China Sea remaining the lowest. Entering March, temperatures ranged from around 24.6°C to 30.7°C, with the northern coast of Australia being the warmest zone, while the South China Sea again became the coolest.

From April to June, SSTs in Indonesia showed a gradual increase. In April, sea surface temperatures fluctuated between 26.0°C and 30.7°C, with the Strait of Malacca experiencing the warmest conditions and the South China Sea near the coast of Vietnam showing the lowest values. In May, the temperature range increased slightly to 26.1°C to 30.9°C, with the Gulf of Thailand reaching its maximum and southern Papua experiencing its minimum. June's conditions again placed the Strait of Malacca as the center of high temperatures (around 30.6°C), while the seas south of Papua recorded a low of around 23.9°C.

In the middle to the end of the year, there was a shift in the character of the SST. July saw the year's coldest point (around 22.6°C) in the waters south of Papua, while the warmer zone remained concentrated in the Strait of Malacca and the South China Sea north of Kalimantan (around 30.2°C). In August, a temperature range of 23.2°C–30.1°C maintained both regions as centers of warming, with southern Papua again being the coldest. September saw a range of 24.5°C–30.0°C, with the warm zone remaining unchanged but cooling extending to the Indian Ocean south of Java. Temperatures in October fluctuated between 25.6°C–30.1°C, with the Gulf of Tomini recording the peak warming, and the southern Papua–Indian Ocean region remaining the center of cooling. November saw the Timor Sea as the warmest location (around 30.8°C) and the southern Indian Ocean as the lowest, before December saw the annual maximum (around 31.0°C) in the Timor Sea with the South China Sea again at its lowest at around 24.9°C.

Relationship Between Ambon Island Rainfall and Indonesian Sea Surface Temperature

The correlation between Indonesian sea surface temperature and rainfall on Ambon Island, as shown in Figure 5, shows a relationship between the two parameters ranging from 0.50 to -0.57. Positive correlation values, indicated in blue on the map, are predominantly found in northern Indonesian waters, while negative correlations, indicated in red, tend to occur in southeastern Indonesian waters.

The highest negative correlation value is found at 15°S and 135.5°E in the waters east of Australia, while the highest positive correlation value is found at 14.5°N and 121.25°E in

Manila Bay. Furthermore, the two locations with the highest correlation values, both negative and positive, will be used as sea surface temperature predictors in subsequent processing. Therefore, the relationship patterns of these two locations will be specifically analyzed using scatter plots and monthly correlation values.

The relationship between rainfall on Ambon Island and sea surface temperature at the location with the highest negative correlation forms a linear relationship. A linear relationship is characterized by a data distribution that resembles a straight line. Based on the data distribution, when using sea surface temperature as a rainfall predictor, it is apparent that smaller deviations occur at sea surface temperatures in the range of 28°C to 32°C. Meanwhile, larger deviations occur at sea surface temperatures in the range of 20°C to 27°C using linear regression as the model (Figure 6a). Figure 6b shows the distribution of data between rainfall on Ambon Island with the highest positive correlation. It is evident that smaller deviations occur at sea surface temperatures in the range of 24°C to 27°C. Larger deviations occur at sea surface temperatures in the range of 28°C to 31°C.

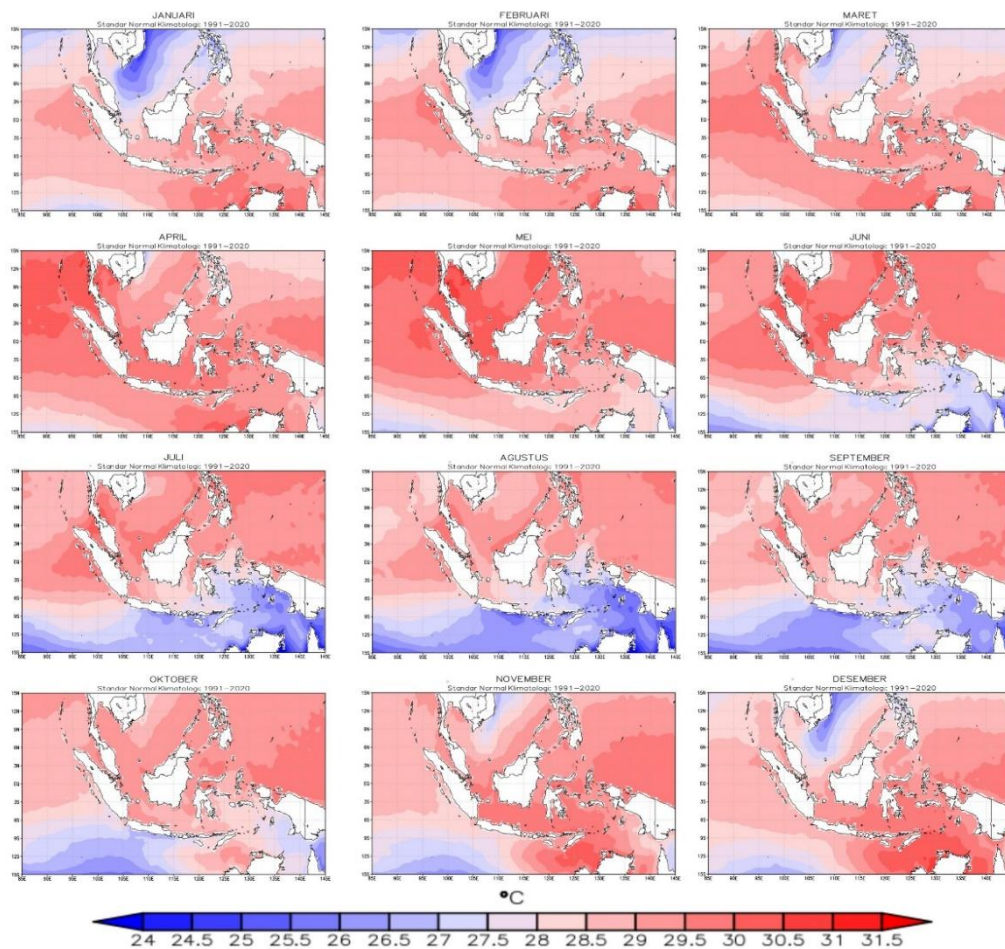


Figure 4. Distribution of Average Sea Surface Temperature in Indonesia

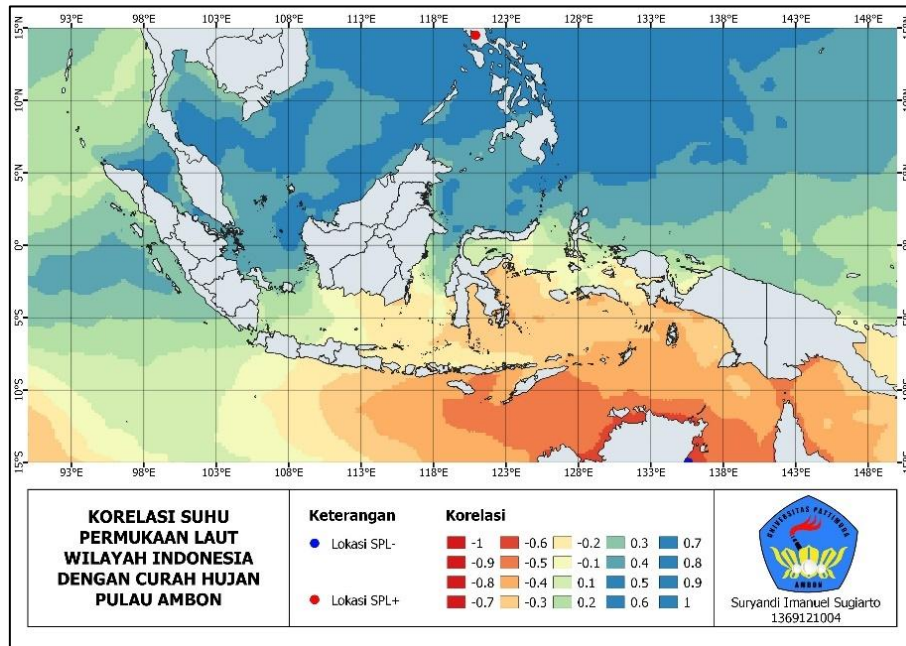


Figure 5. Correlation Between Rainfall on Ambon Island and Sea Surface Temperature in Indonesia

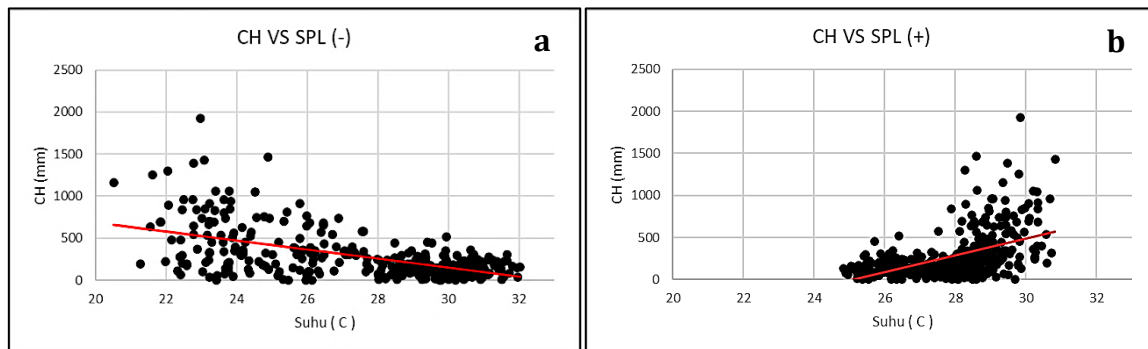


Figure 6. Scatter Plot of Rainfall and Sea Surface Temperature: Highest Negative Correlation (a) and Highest Positive Correlation (b)

The monthly correlation between rainfall on Ambon Island and sea surface temperature at the SST (-) predictor location in Table 1 shows that the highest correlation occurs in July, at 0.32. Strong correlations are observed in January, March, May, June, August, September, and October. Weak correlations occur in February, November, and December. The monthly correlation between rainfall on Ambon Island and sea surface temperature at the SST (+) predictor location in Table 2 shows the highest value in January, at 0.45. Strong correlations tend to occur in January, June, July, September, and October, while weak correlations occur in March and December.

Table 1. Correlation Between Rainfall and Sea Surface Temperature (-)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.20	0.17	0.09	-0.11	0.11	0.28	0.32	0.13	0.21	0.20	0.18	0.03

Table 2. Correlation Between Rainfall and Sea Surface Temperature (+)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.45	-0.02	-0.23	-0.19	-0.47	-0.65	0.12	-0.24	0.26	0.30	0.08	-0.07

Ambon Island Rainfall Prediction

Data from 1991 to 2015 will be used to develop a rainfall prediction model for Ambon Island. The resulting prediction method will then be used to predict rainfall for Ambon Island from 2016 to 2020. The positive correlation SST predictor (14.5° N and 121.25° E) is referred to as the SST(+) Model, the negative correlation SST predictor (15° S and 135.5° E) is referred to as the SST(-) Model, and the combined positive and negative correlation SST predictor is referred to as the SST Model. The simple and multiple regression equations for these three predictors are shown in Table 3.

Table 3. Linear Regression Equation for Ambon Island Rainfall Prediction

No.	Model	Regression Equation
1.	SST(+)	$CH = -2323.653 + 93.401(SST(+))$
2.	SST(-)	$CH = 1742.748 - 53.612(SST(-))$
3.	SST	$CH = 1122.798 + 16.562(SST(+)) - 47.768(SST(-))$

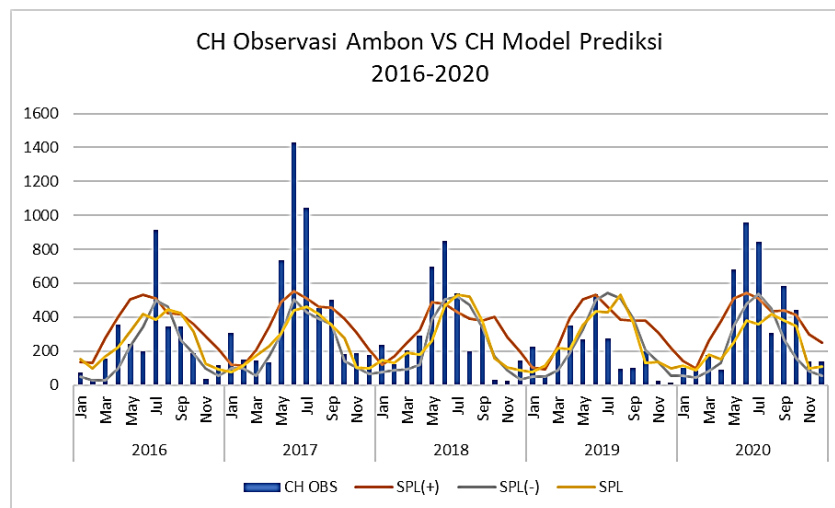


Figure 7. Graph of Rainfall Intensity (CH) Results from Prediction Models and Observations for 2016-2020

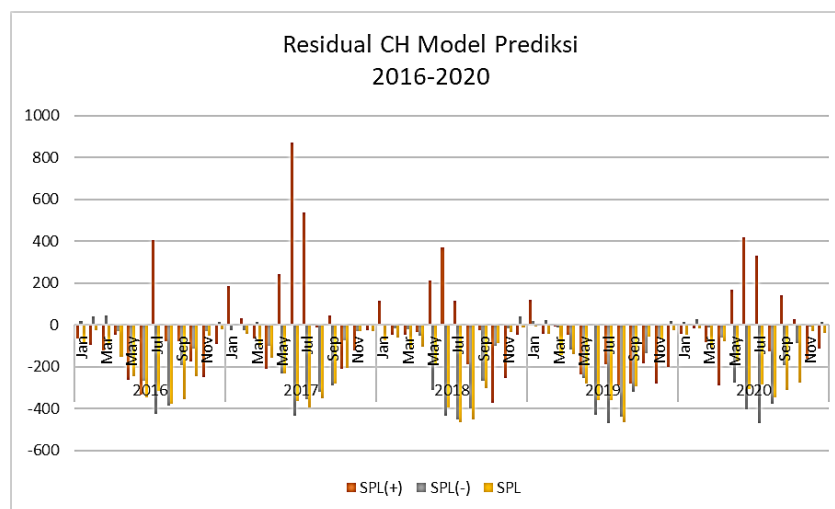


Figure 8. Graph of Residual (Error) Prediction Models Versus Observations for 2016-2020

Figure 7 shows that the monthly rainfall graph pattern generated by each prediction model tends to align with the observed CH value pattern on Ambon Island. As observed CH

increases, the rainfall value generated by the model also increases, and conversely, when observed CH decreases, the predicted CH value of the model also decreases. However, there are patterns of higher or lower CH in each model compared to observed rainfall in different periods. Furthermore, during extreme rainfall events, each model was unable to capture these rainfall values.

A comparison of the values generated by the models with observed rainfall values in Ambon generally shows that the largest residual (error) for each model occurs from May to October (Figure 8). These largest residuals tend to occur in the wet months when extreme rainfall is more likely.

The model considered the best predictor is the one with the smallest RMSE value. The best model with the lowest RMSE in 2016 was the SPL(-) model, and the worst with the highest RMSE was the SPL(-) model. In 2017, the best model was the SPL(-) model and the worst was the SPL(+) model. In 2018, the SPL(+) model was the best, while the SPL(-) model was the worst. Then, the SPL(+) model was the best and the SPL(-) model was the worst in 2019. The best model in 2020 was the SPL(+) model, and the SPL(-) model was the worst with the highest RMSE this year (Table 4).

Table 4. Root Mean Square Error (RMSE) Values for Each Model

Model	RMSE				
	2016	2017	2018	2019	2020
Model SST(+)	201.8411	324.0953	194.8244	188.0516	200.8438
Model SST(-)	200.8796	218.2940	247.1937	258.7601	232.9600
Model SST	232.4259	227.9515	248.7622	239.4114	208.3528

DISCUSSION

Research shows that rainfall patterns on Ambon Island are localized, with a peak rainy season and a dry season, differing from most other regions in Indonesia. The peak rainfall occurs in June, and the dry season occurs in November, as seen in data analysis from 1991–2020. This pattern aligns with the findings of Aldrian (2001), who stated that Ambon is within Indonesia's rainfall anomaly zone and does not follow the monsoon pattern. This weather difference is exacerbated by Ambon's geographic characteristics, which are surrounded by oceans, making it more strongly influenced by ocean dynamics than larger land areas (Swarinoto & Sugiyono, 2011).

The relationship between sea surface temperature (SST) and rainfall in Ambon was confirmed through spatial correlation analysis, with significant correlations ranging from strongly positive to strongly negative. The highest positive correlation was in Manila Bay (+0.50), while the highest negative correlation occurred in the waters east of Australia (-0.57). This correlation suggests that changes in sea temperature in specific regions can trigger increases or decreases in rainfall in Ambon. This pattern supports the statement of Qu *et al.* (2005) who stated that SST plays a dominant role in influencing the tropical atmospheric system, as well as research by Syaifullah (2010) and Alfiandy *et al.* (2020) who confirmed that ocean warming increases evaporation and water vapor content for rain formation.

The performance of SST-based prediction models shows that sea surface temperature can be a fairly reliable predictor of rainfall, particularly in the SST(+) model, which produces the smallest RMSE and the prediction pattern most closely follows the observed values. However, the model still fails to depict extreme rainfall events, as evidenced by the large discrepancy between observations and predictions during the wet months. This suggests that although SST contributes significantly to rainfall formation, other local atmospheric factors such as wind, cloud cover, and convection dynamics also play a role and are not yet accommodated in this

simple regression model, as explained by Estiningtyas *et al.* (2008) who argued that climate predictions in Indonesia must be location-specific, incorporating more than one determining variable.

CONCLUSION

Observations of rainfall from 1991 to 2020 on Ambon Island indicate a local rainfall pattern with one period of high rainfall and one period of low rainfall, with the peak rainy season in June and the peak dry season in November.

A high positive correlation value for SST was found in Manila Bay, with a value of 0.50, while a high negative correlation value of -0.57 was found in the waters east of Australia.

Based on the models built from SST predictors (simple and multiple linear regression), the best prediction results were obtained by the SST(+) Model with a RMSE of 227.79; the second best was the SST Model with a RMSE of 231.77; and the worst was the SST(-) Model with a RMSE of 232.52.

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REFERENCES

- Aldrian, E. (2001). Pembagian iklim Indonesia berdasarkan pola curah hujan dengan metoda "double correlation". *Jurnal Sains dan Teknologi Modifikasi Cuaca*, 2(1), 11–18.
- Aldrian, E. (2008). *Meteorologi laut Indonesia* (pp. 242–243). Badan Meteorologi dan Geofisika.
- Aldrian, E., & Susanto, R. D. (2003). Identification of three dominant rainfall regions within Indonesia and their relationship to sea surface temperature. *International Journal of Climatology*, 23(12), 1435–1452.
- Alfiandy, S., Hutauruk, R. C. H., & Permana, D. S. (2020). Peran dinamika laut dan topografi terhadap pola hujan tipe lokal di wilayah Kota Palu. *DEPIK Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan*, 9(2), 173–183.
- Badan Meteorologi Klimatologi dan Geofisika. (2022). *Pemutakhiran zona musim Indonesia periode 1991–2020*.
- Badan Pusat Statistik Kota Ambon. (2021). *Kota Ambon dalam angka 2021*.
- Estiningtyas, W., Surmaini, E., & Hariyanti, K. S. (2008). Penyusunan skenario masa tanam berdasarkan prakiraan curah hujan di sentra produksi pangan. *Jurnal Meteorologi dan Geofisika*, 9(1).
- Ivatek-Šahdan, S., Stanešić, A., Tudor, M., Plenković, I. O., & Janeković, I. (2018). Impact of SST on heavy rainfall events on Eastern Adriatic during SOP1 of HyMeX. *Atmospheric Research*, 200, 36–59.
- Qu, T., Dua, Y., Strachan, J., Meyers, G., & Slingo, J. (2005). Sea surface temperature and its variability. *Oceanography*, 18(4), 50.
- Ruminta. (2009). *Matriks persamaan linier dan pemrograman linier*. Rekayasa Sains.
- Sugiyono. (2016). *Statistika untuk penelitian*. Alfabeta.
- Swarinoto, Y. S., & Sugiyono, S. (2011). Pemanfaatan suhu udara dan kelembapan udara dalam persamaan regresi untuk simulasi prediksi total hujan bulanan di Bandar Lampung. *Jurnal Meteorologi dan Geofisika*, 12(3).
- Syaifullah, M. D. (2010). Analisis suhu muka laut selatan Jawa dan pengaruhnya terhadap curah hujan DAS Citarum. *Jurnal Sains dan Teknologi Modifikasi Cuaca*, 11(2), 11–19.
- Wilks, D. S. (2006). *Statistical methods in the atmospheric sciences* (2nd ed.). Elsevier Inc.