International Journal of Research and Review
[Indexed, Peer-Reviewed Journal]
Volume 12; Issue: 2; February 2025
Website: www.ijrrjournal.com
E-ISSN: 2349-9788; P-ISSN: 2454-2237

Research Paper

Optimization Of Rainfall Correlation to Air Pressure, Wind Speed, and Air Humidity Of 2021 Seroja Cyclone Case Based on GPM-IMERG Data

Novandi Leonardo Marsada Sianturi[1], Rina Dwi Indriana[2], Rahmat Gernowo[3], Muhammad Fahmi[4]

[1]Under Graduate Student of Physics, Faculty of Sains and Mathematics, Diponegoro University, Indonesia.
[2]Physics Department. Faculty of Sains and Mathematics, Diponegoro University, Indonesia.
[3]Physics Department. Faculty of Sains and Mathematics, Diponegoro University, Indonesia.
[4]Physics Department. Faculty of Sains and Mathematics, Diponegoro University, Indonesia.

Corresponding Author: Rina Dwi Indriana

DOI: https://doi.org/10.52403/ijrr.20250242

ABSTRACT

Tropical storms are natural phenomena in the form of large cyclones with strong winds and heavy rainfall. The research aims to determine the influence of independent variables (air humidity, air pressure, and wind speed) on the dependent variable (rainfall). The research area is in Kupang City, West Nusa Tenggara, Indonesia. The rainfall data used is GPM-IMERG satellite data when tropical storm Cyclone Seroja occurred. The humidity, wind speed, and air pressure data used the European Centre for Medium-Range Weather Forecast (ECMWF) Reanalysis 5th Generation (ERA5) and GPM-IMERG data. Data processing used SPSS software to determine the percentage of the influence of the independent variable on the dependent variable. The results showed 85.3% of the influence of air humidity, 64.6% of the influence of air pressure, and 64.3% of the impact of wind speed on GPM-IMERG data-based rainfall. The factors of air humidity, air pressure, and wind speed contributed significantly to the occurrence of the Seroja cyclone.

Keywords: optimization, rainfall, air humidity, air pressure, wind speed, GPM-IMERG

INTRODUCTION

Indonesia's unique geographical location, between the Asian and Australian Continents and the Pacific and Indian Oceans, results in the convergence of two types of circulation: the meridional circulation (North-South), known as the Hadley Circulation, and the zonal circulation (East-West), known as the Walker Circulation. These circulations significantly shape Indonesia's tropical climate, with distinct rainy and dry seasons. The rainy season typically occurs between November and April, while the dry season spans from May to October. Interactions between the atmosphere and the ocean around Indonesia also affect rainfall in Indonesia, for example, the El Niño-Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD) (1-8).

ENSO is a recurring pattern of climate variability in the eastern Pacific Ocean as evidenced by sea surface temperature anomalies (warming of the sea surface representing La Niňa events) and sea level pressure anomalies (9-12). El Niño and La Niňa are two phenomena that can have several impacts on global weather and climate, including in Indonesia. The effects of the El Niño phenomenon include decreased rainfall in Indonesia, especially in areas such as Nusa Tenggara and Maluku, increased air and sea surface temperatures, and the potential for drought due to reduced rainfall. The impacts of the La Niňa phenomenon include increased rainfall in Indonesia, especially in western Indonesia, such as Sumatra, Java, and Kalimantan, increased frequency and intensity of typhoons in the Central and Eastern Pacific regions, and the potential for floods and landslides in areas affected by the La Niňa phenomenon (13).

The impacts of El Niño and La Niña are not only limited to Indonesia. Still, they can also have global-scale impacts such as increased sea surface temperatures, changes in rainfall patterns, and temperature anomalies in various parts of the world. Therefore, an understanding of El Niño and La Niña is essential to understanding the dynamics of climate on a global scale and its impact on human life and the environment. After completing verification and validation of disaster records that occurred during 2021 from all Regional Disaster Management Agencies of Indonesia, there were 5,402 natural disaster events, and a staggering 99.5% of these were hydrometeorological disasters. These figures underscore the urgent need for effective disaster management strategies in the region (14).

Cyclone Seroja is a tropical storm in the Indian Ocean in April 2021. The storm brought strong winds and high rainfall capable of causing flash floods and landslides in some areas in Indonesia (especially Kupang City) and Timor Leste. This disaster caused thousands of people to lose their homes, hundreds of people died, and many infrastructure and public facilities suffered severe damage (15). Cyclone Seroja first appeared on 3 April 2021 in the waters west of the Solomon Islands. It then became an increasingly powerful tropical storm moving towards the Southwest Indian Ocean. On 4 April 2021, the storm reached Indonesia and Timor Leste, resulting in flash floods, landslides, and tornadoes in areas such as East Nusa Tenggara, South Sulawesi, and North Maluku (16). The Cyclone Seroja disaster is one of the most significant natural disasters in the Indonesia and Timor Leste region in recent years.

Air pressure differences between regions result in an area of low pressure, which is a significant factor in the formation of cyclones. Historically, the La Niňa phenomenon occurred in the Pacific Ocean from 2020 to early 2021, affecting sea surface temperatures and winds in the Indian Ocean region. Significant changes in sea surface temperature, ocean currents, and wind patterns in the area can lead to the formation of tropical cyclones.

The research aims to delve deeper into other parameters that influence rainfall, specifically the effect of air humidity, air pressure, and wind speed before, during, and after the Seroja Cyclone phenomenon in Kupang City. This study utilizes the Global Precipitation Measuring (GPM-IMERG) satellite rainfall data, which offers higher accuracy than TRMM satellite rainfall data. Notably, this research on the Timor Seroja cyclone with GPM-IMERG data is a pioneering effort, opening up new avenues for future exploration.

The analysis is conducted using Global Precipitation Measuring (GPM-IMERG) satellite rainfall data, which will be processed using the correlation analysis method to find the relationship between air humidity, wind speed, and air pressure to the occurrence of the Seroja Cyclone phenomenon. The GPM-IMERG data was collected 30 days before and after the Seroja Cyclone phenomenon, which was visualized using Panoply software. The visualization depicts the condition of air humidity, air pressure, and wind speed before, during, and after the Seroja Cyclone phenomenon (17-19). Based on the phenomenon, the analysis obtained can be used to determine the cause of the cyclone and become a reference for mitigation efforts that can be done.

MATERIALS & METHODS

This research is significantly enriched by rainfall data, including satellite and secondary data. The secondary rainfall data, obtained from the Meteorological, Climatological, and Geophysical Agency (BMKG), is a key component of our study. The rainfall satellite data, using Global Precipitation Measurement—Integrated Multi-Satellite Retrieval for GPM (GPM-IMERG) data, plays a crucial role in our research. The inclusion of air humidity, wind speed, and air pressure data from the European Centre for Medium-Range Weather Forecast (ECMWF) Reanalysis 5th Generation (ERA5) and GPM-IMERG data further enhances the significance of our findings (20-23). Figure 1 is the research area. The cyclone path starts in East Nusa Tenggara to Australia.

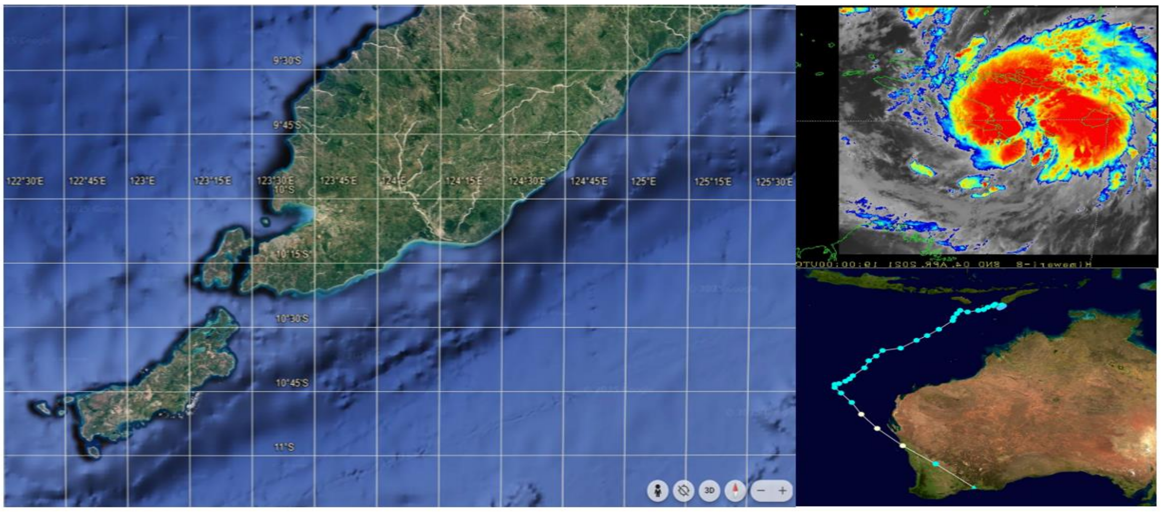


Figure 1. Seroja Cyclon area and Seroja Cyclone path

The research was conducted 30 days before and after Cyclone Seroja on April 5, 2021, in the southern part of Timor Island. The primary aim was to understand the cyclone's impact on weather variables, for which regression analysis was applied to air pressure, wind speed, and humidity data. The total amount of rainfall data, air humidity, wind speed, and air pressure as much as 61 days of data processed to be mapped and the values correlated. The relationship between variables was tested using the linear regression method. A high level of inter-variable correlation was obtained by using the linear regression test. The correlation value ranges from -1 to 1, and the maximum positive and negative values indicate a significant relationship, and vice versa (24-25). The linear regression equation is as follows:

$$r = \frac{n\sum x_i - (\sum x_i)(\sum y)}{\sqrt{(n\sum x_i^2 - (\sum x_i)(n\sum y^2 - (\sum y)^2)}}$$

where r is a correlation coefficient, n is a lot of data, *x* is an independent variable, and *y* is a dependent variable ( ).

Table 1. Correlation Level

Interval Coefficient		**Correlation level**
Positive	**Negative**	
0,800 s.d. 1,000	(-1,000) s.d (-0,800)	Significant/very strong
0,600 s.d. 0,799	(-0,799) s.d (-0,600)	Stong
0,400 s.d. 0,599	(-0,599) s.d (-0,400)	Moderate
0,200 s.d. 0,399	(-0,399) s.d (-0,200)	Weak
0,000 s.d. 0,199	(-0,199) s.d (-0,000)	Very Weak

RESULT

From 6 March 2021 to 5 May 2021, Kupang City’s humidity ranged from 70% to 90%. Figure 2 shows the air humidity before and after the Seroja cyclone event.

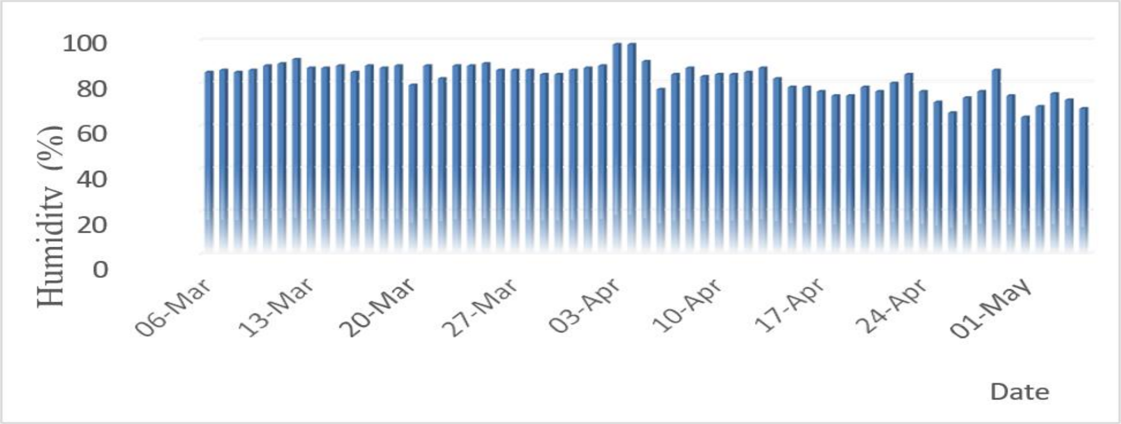


Figure 2. Air Humidity in the Kupang City

From 6 March 2021 to 5 May 2021, Kupang City's wind speed ranged from 1 m/s to 7 m/s. Figure 2 shows the wind speed before and after the Seroja cyclone event.

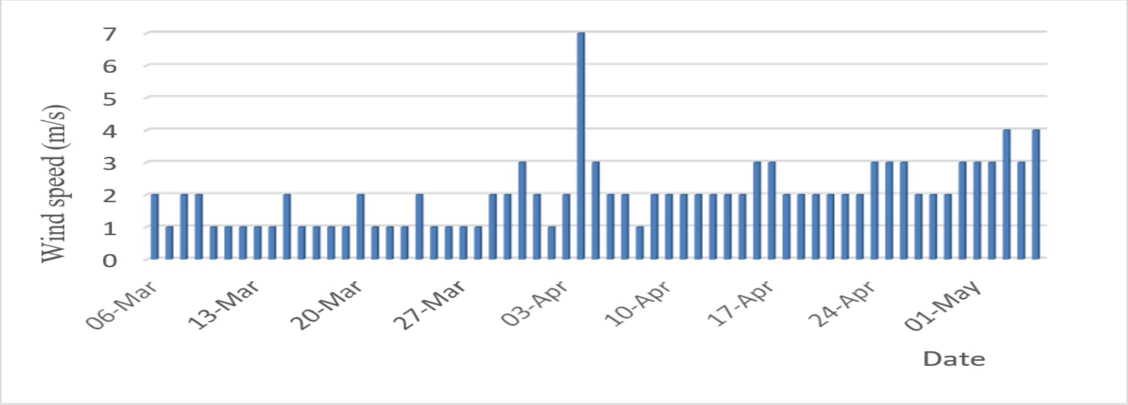


Figure 3. Wind Speed in the Kupang City

From 6 March 2021 to 5 May 2021, Kupang City's air pressure ranged from 98500 Pa to 100250 Pa across Indonesia. Figure 2 shows the air humidity before and after the Seroja cyclone event.

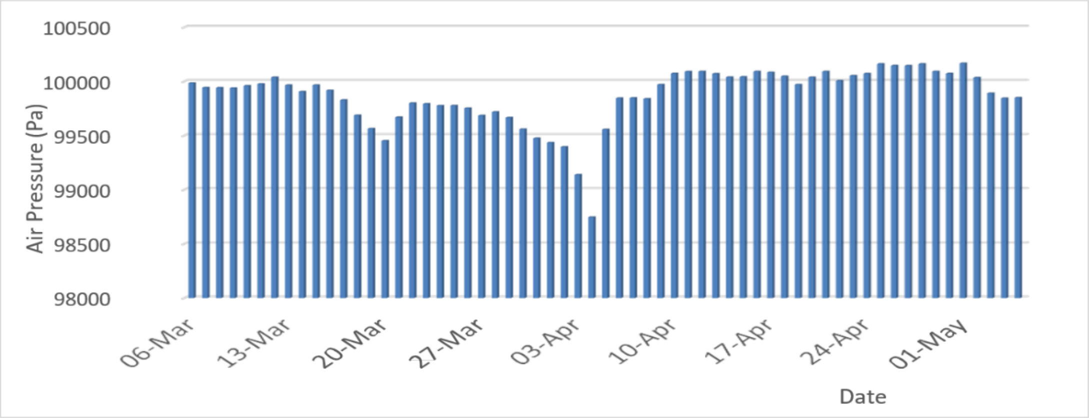


Figure 4. Air Pressure in Kupang City

Rainfall data for Kupang City, based on BMKG data, during the peak of tropical storm Cyclone Seroja, reached 250 mm/day to 300 mm/day (Figure 3).

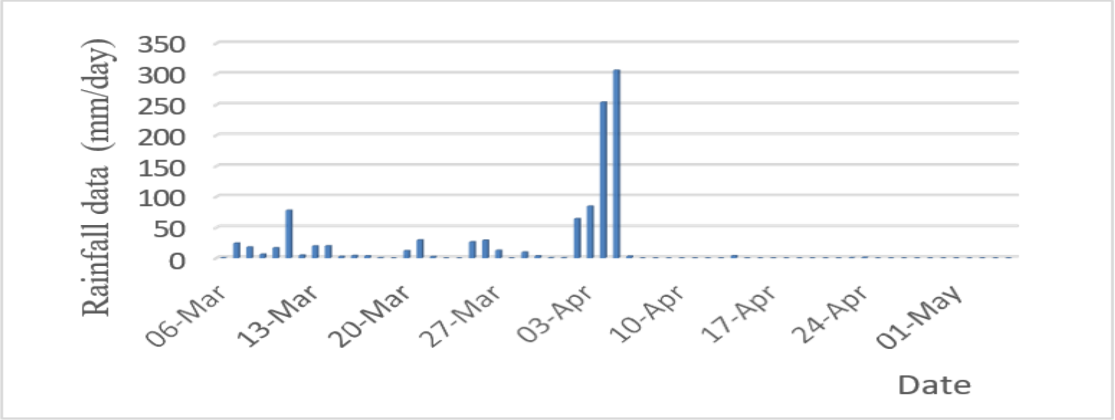


Figure 5. Rainfall data before and after Seroja Cyclon based on BMKG data in Kupang City

Figure 6 is a map of rainfall using GPM-IMERG satellite data showing the results of quite high rainfall before entering the East Nusa Tenggara region. Rainfall becomes very high when a storm occurs which is indicated by green to red colors.

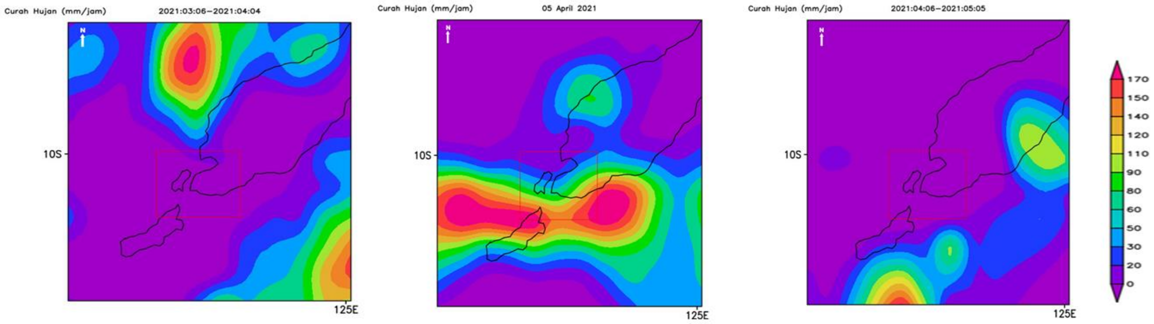
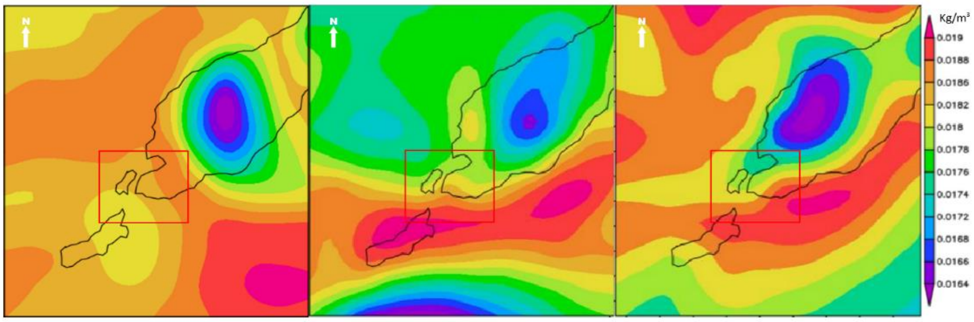


Figure 6. Rainfall level (a) before the event (b) on the event (c) after the event Seroja Cyclon based on GPM-IMERG

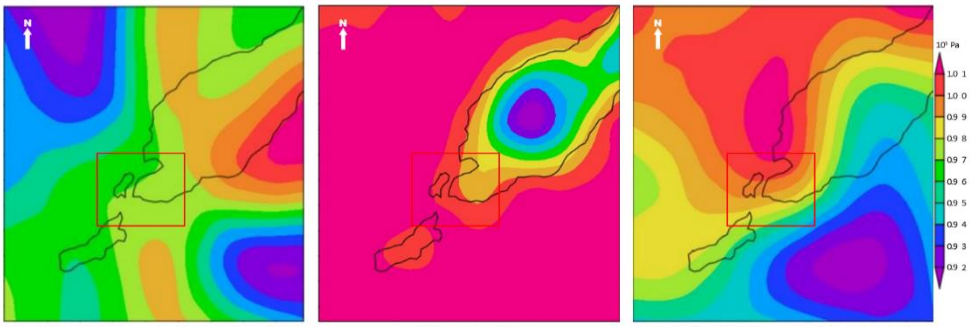
Figure 7 is a map of air humidity, showing increasing humidity during the cyclone event. Increasing air humidity, which is indicated by green to blue colors. The air humidity range is 0.0164 to 0.019 kg/m^3



06-03-2021 s.d. 04-04-2021 **(a)** **05-04-2021** **(b)** **06-04-2021 s.d. 05-05-2021** **(c)**

Figure 7. Air Humidify (a) before the event (b) on the event (c) after Seroja Cyclon 5 April 2021 based on GPM-IMERG

Figure 8 is a map of air pressure in East Nusa Tenggara region. The air pressure increased significantly during the Seroja cyclone event, which is indicated by red colors. The air pressure is 0.92 x 10^6 Pa – 1.01 x 10^6 Pa.



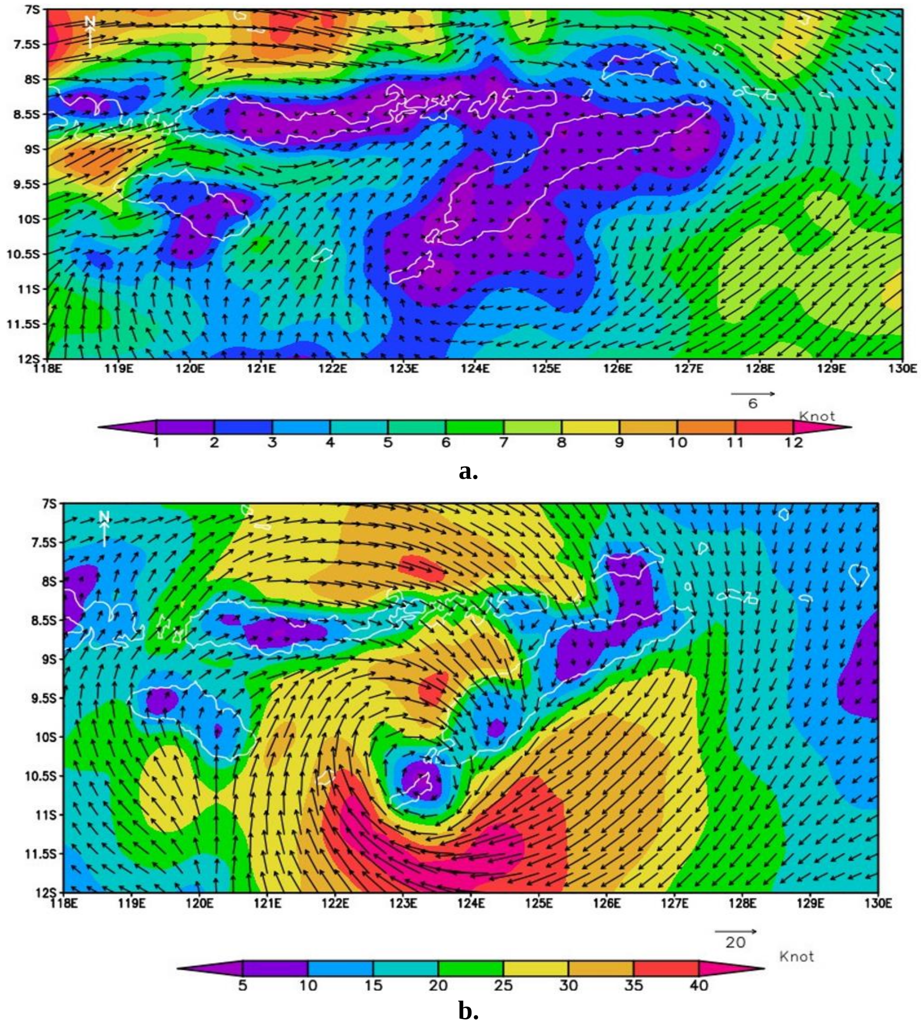
06-03-2021 s.d. 04-04-2021
(a)

05-04-2021
(b)

06-04-2021 s.d. 05-05-2021
(c)

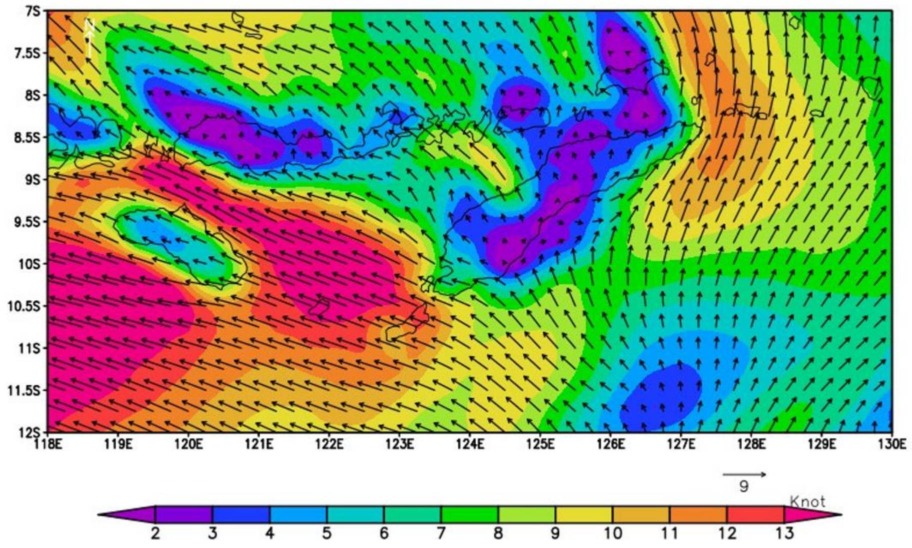
Figure 8. Air Pressure (a) before the event (b) on the event (c) after the Seroja Cyclon 5 April 2021 based on GPM -IMERG

Figure 9 is a map of wind speed, the map showing the results of increasing wind speed before entering the East Nusa Tenggara region. Wind speed is very high when a storm occurs which is indicated by red colors and the arrow have a circular path to be a cyclone. The wind speed is 2 Knot to 40 Knot.



a.

b.



c.

Figure 9. Wind speed periode a). 06 Maret 2021 – 13 Maret 2021 b). 05 April 2021 c). 25 April 2021 – 30 April 2021 based on GPM-IMERG

DISCUSSION

The humidity level in Kupang is often between 70% and 90% because Indonesia is known to have a tropical climate with high air humidity throughout the year. Figure 2 shows that air humidity from early March to mid-April is very high, with a peak in early April reaching 98% (the peak of tropical storm Cyclone Seroja). The percentage of air humidity slowly decreased after the peak of tropical storm Cyclone Seroja until early May.

The average wind speed in Indonesia varies depending on geographic location and time of day. Several factors influence wind speed in Indonesia, including climate, topography, and regional climate phenomena. Figure 3 shows that the average wind speed in Kupang City is a gust type of wind when assessed using the Beaufort scale, namely with a wind speed of 1.5 m/s to 3.3 m/s, except at the peak of the tropical storm cyclone Seroja, the wind speed in Kupang City reached 7 m/s which was in the moderate wind class, namely 5.5 m/s to 8 m/s. However, the wind speed after the storm's peak was more significant than before the peak of tropical storm Cyclone Seroja.

The altitude of a region significantly influences its air pressure, with higher altitudes typically experiencing lower air pressure due to the reduction in air molecules (16). Figure 4 provides a clear picture of this, showing the daily air pressure fluctuations in Kupang City. Before the peak of Cyclone Seroja, the air pressure steadily decreased, reaching its lowest point in 61 days at the storm's peak. This prolonged decrease in air pressure is a clear indication of the storm's lasting influence.

According to GPM-IMER satellite data, from March 6, 2021, to May 5, 2021, East Nusa Tenggara experienced high rainfall, exceeding 100mm/day in early April. Figure 6 illustrates a range of 10 mm/day to 30 mm/day, but after the tropical storm Cyclone Seroja, the rainfall significantly decreased to ≤ 2 mm/day. Notably, extreme rainfall was recorded during the tropical storm, reaching 170 mm/day. Two instances of extreme rainfall were observed on April 3, 2021, and April 4, 2021. Figure 5 depicts the rainfall data during the peak of tropical storm Cyclone Seroja, which reached 250 mm/day - 300 mm/day. Before the tropical storm, the rainfall was between 5 mm/day and 80 mm/day, but after the storm, the rainfall in Kupang City was minimal or non-existent. Figure 7, a rainfall distribution map in the East Nusa Tenggara region, shows the high rainfall per day before entering the Timor Island area, specifically Kupang City. High rainfall is indicated in red. Figure 7 shows that extreme rainfall moved south towards the Timor Sea and the Indian Ocean.

The regression test confirms a strong relationship between the GPM-IMERG satellite rainfall data and BMKG rainfall data, as indicated by the robust R-value of 0.895. The R-value, a measure of the strength and direction of a linear relationship between two variables, and the R2 value of 0.801, or 80.1%, represents the proportion of the variance for a dependent variable that's explained by an independent variable, both support a very strong correlation (25). Referring to the table of relationship levels based on the correlation coefficient intervals in Table 1, it's evident that the relationship between the two data sets is very strong, reinforcing the validity of the regression test.

The linear regression test of air humidity on rainfall data yields an R-value of 0.804, signifying a substantial correlation between air humidity and GPM-IMERG satellite rainfall. The R2 value of 0.646, or 64.6%, underscores the significant influence of air humidity on rain (24). This influence is particularly pronounced in the south of the study area, where high humidity increases during storms, thereby enhancing the potential for storm formation due to increased water vapor (13).

The linear regression test of the effect of air pressure on rainfall, with an R-value of 0.924, underscores the significant influence of air pressure on GPM satellite rainfall. The R2 value of 0.853 or 85.3% further confirms this strong correlation and the low significance level test value of 0.001 or 1% adds weight to the findings (24). A representation of air pressure in the southwest part of Timor Island is mapped in Figure 8, with the air pressure pattern following the storm's movement pattern, shown in the purple contour. It's crucial to note that air pressure is inversely proportional to the amount of rainfall, with higher rainfall values corresponding to lower air pressure (13).

The linear regression test for the effect of wind speed on rainfall is an R-value of 0.802, which means that wind speed and GPM satellite rainfall have a correlation coefficient of 0.802. The R2 value is 0.643, or as a percentage, it is 64.3%. The influence or relationship between the two data is also strengthened with a significance value of 0.001. The significant value of the simple linear regression results <0.05 indicates that variable X affects variable Y (25).

The three images representing wind speed data above, namely Figure 9, provide a clear visual representation of the changes in wind speed in the study area. The change in the position of the purple color to blue is that the area becomes minor from 06 March 2021 to 05 April 2021. Figure 9.b., the spiral pattern formed illustrates how the air flow gathers and rotates around the cyclone's center, known as the cyclone's eye. The wind speed increased from 2 Knot to 35 Knot. This visual representation enhances the clarity of the study. After the cyclone event, the spiral pattern changed direction and moved away from Kupang City towards the northwest, as in Figure 9.c.

CONCLUSION

The results of regression analysis of rainfall data based on Global Precipitation Measuring-Integrated Multi-Satellite Retrievals for GPM (GPM-IMERG) and the Meteorology, Climatology and Geophysics Agency (BMKG) before, during, and after tropical cyclone Seroja are the influence of air humidity by 64.6%, the impact of air pressure by 85.3%, and the influence of wind speed by 64.3%. The air humidity value in the East Nusa Tenggara area is 70% - 90%, wind speed is in the range of 1 Knot - 40 Knots, rainfall is in the range of 0 mm - 170 mm, and air pressure is 0.92 x 10^6 Pa, -1.01 x 10^6 Pa. The factors of air humidity, air pressure, and wind speed contributed significantly to the occurrence of the Seroja cyclone.

Declaration by Authors

Acknowledgement: None

Source of Funding: None

Conflict of Interest: The authors declare no conflict of interest.

REFERENCES

1. Ropelewski CF. and Halpert MS. Global and Regional Scale Precipitation Patterns Associated with the El Niño-Southern Oscillation. Monthly Weather Review. 1987. 115:1606-1626.
2. Fitria W. and Pratama MS. Pengaruh Fenomena El Niño 1997 dan La Niňa 1999 Terhadap Curah Hujan di Biak. Jurnal Meteorologi dan Geofisika. 2013.14(2): 65-74.
3. Dedi Kukuh. Cuaca dan Iklim Ekstrim di Indonesia. Jakarta. 2013.Puslitbang BMKG.
4. Aldrian E. and Susanto RD. Identification of Three Dominant Rainfall Regions Within Indonesia and Their Relationship to Sea Surface Temperature. Int.J. Climatol. 2003. 23: 1435-1452.
5. Hendon HH. Indonesian Rainfall Variability: impacts of ENSO and local air-sea interaction. Journal of Climate. 2003.16:1775-1790.
6. Saji NH and Yamagata T. Possible Impacts of Indian Ocean Dipole Mode Events on Global Climate. Climate Res. 2003. 25: 151-169.
7. Aldrian E, Gates LD, and Widodo FH. Seasonal Variability of Ondonesian Rainfall in ECHAM4 Simulations and The Reanalyses: The Role of ENSO. Theor. Appl. Climatol., 2007. 87: 41-59.
8. Irianto G. Implikasi Penyimpangan Iklim Terhadap Tataguna Lahan. Makalah Seminar Nasional Ilmu Tanah. KMIT Jurusan Tanah Fakultas Pertanian UGM. 2003.Yogyakarta.
9. Trenberth KE. The Definition of El Niño. Bull. Amer. Meteor. Soc. 1997. 78: 2771-2777.
10. Naylor LN, Falcon WP, Rochberg D, and Wada N, Using El Niño/Southern Oscillation Climate data to predict rice production in Indonesia. Climatic Change. 2001.50(3): 255-265.
11. Surface temperature anomaly in the Pacific and Indian Oceans on Indonesian Climate. Paper in the 11th CEReS International Symposium on Remote Sensing on 13 to 14 December 2005 at Chiba University. Chiba-Japan.
12. Yusuf M, Rahayu SW, and Rosmalina R. Flood risk mapping using geographic information system and remote sensing data in Medan City, Indonesia. IOP Conference Series: Earth and Environmental Science. 2021.891(1): 012044.
13. Dean R and Nur C. Analisa Karakteristik Kecepatan Angin dan Tinggi Gelombang Menggunakan Data Satelit Altimetri (Studi Kasus: Laut Jawa). GEOID Vol. 11 No. 01 Agustus 2015 (75-78).
14. Hurrell J, Kushnir WY, Ottersen G, and Visbeck M. The North Atlantic Oscillation: Climatic Significance and Environmental Impact. Geophysical Monograph Series. 2003Vol. 134, AGU, Washington, D.C., 279 pp.
15. Badan Meteorologi, Klimatologi, dan Geofisika. 2021. https://www.bmkg.go.id/press-release/?p=siaran-pers-update-perkembangan-siklon-tropis-seroja-dan-pertumbuhan-siklon-tropis-odette&tag=press-release&lang=ID.
16. Badan Nasional Penanggulangan Bencana. 2021. https://bnpb.go.id/berita/bnpb-verifikasi-5-402-kejadian-bencana-sepanjang-tahun-2021.
17. Irwin R, Karl MKTR, and Quayle RG. Trends in extreme humidity and temperature in the United States. Technical Report 99-01, National Climatic Data Center, Asheville. NC. 1999. 16 pp.
18. Thepaut JN, Dee DP, Engelen, R. and Pinty, B. 2018. The Coper-Nicus Programme and its Climate Change Service. Pp. 1591-1593 in IEEE International Geoscience and Remote Sensing Symposium. Valencia. Spain.
19. Wang C, and Tang W. Climate variability and change over the North Pacific and North America: Progress and challenges. Adv. Atmos. Sci., 2016. 33(3): 211-219.
20. The European Center for Medium-Range Weather Forecasting
21. WMO, Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8). 2018. Geneva: World Meteorological Organization.
22. Geospatial Interactive Online Visualization and Analysis Infrastructure Niňa and Interactions with the Tropical Indian Ocean. Journal of Climate. 20. 2872-2880. https://giovanni.gsfc.nasa.gov/giovanni/#.
23. National Oceanic and Atmospheric Administration (NOOA)

24. Singh VP. Generalized Linear And Nonlinear Regression Models For Hydrology. Water Resources Research. 1995. 31(2),251-263.
25. Neter J, Wasserman W, and Kutner MH. Applied linear regression models.1989.
26. Siswanti KY. Model Fungsi Transfer Multivariat dan Aplikasinya untuk Meramalkan Curah Hujan di Kota Yogyakarta. Skripsi. 2011.FMIPA UNY. Yogyakarta.

How to cite this article: Novandi Leonardo Marsada Sianturi, Rina Dwi Indriana, Rahmat Gernowo, Muhammad Fahmi. Optimization of rainfall correlation to air pressure, wind speed, and air humidity of 2021 Seroja cyclone case based on GPM-IMERG Data. *International Journal of Research and Review*. 2025; 12(2): 360-369. DOI: *10.52403/ijrr.20250242*

******