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A Study of Oceanographic Conditions During the Tropical Cyclone Anggrek in the Coastal Area of Bengkulu

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ABSTRACT

This research has not been discussed previously, especially in the waters of Bengkulu, which has a strategic position in relation to the formation and movement of tropical cyclones in the eastern Indian Ocean. The lack of research in this region has resulted in limited information on the direct impact of cyclones on oceanographic parameters. This study aims to identify the impact of tropical cyclone Anggrek on oceanographic parameters in Bengkulu waters during and after the occurrence of tropical cyclone Anggrek. This study is limited to the waters of Bengkulu with a focus on the period from January 15 to February 13, 2024. Reanalysis data from the Marine Copernicus numerical model was used and analyzed temporally with a quantitative descriptive approach, followed by a t-test: Paired Two Sample for Means. The results of the oceanographic parameter analysis showed significant changes due to the influence of Tropical Cyclone Anggrek in the waters of Bengkulu. Based on the results of the paired t-test, all main parameters showed significant differences ($p < 0.05$) between normal conditions and cyclone conditions. Sea surface temperature decreased during the cyclone due to vertical mixing processes, then increased again after the cyclone moved away. Salinity values also showed significant differences. Wave height and current velocity experienced noticeable fluctuations, and wind speed conditions during Tropical Cyclone Anggrek generally increased. The results of this study provide updates to BMKG predictions and support the strengthening of early warning systems in the western coastal region of Sumatra, particularly in the waters of Bengkulu, by understanding changes in sea and atmospheric conditions after the cyclone.

KEYWORDS: Tropical storm Anggrek; Temporal approach; Oceanographic parameters

INTRODUCTION

Tropical cyclones are atmospheric storm systems that form vortices over warm waters in tropical and subtropical regions. This phenomenon has several key characteristics, including a low-pressure center, neatly arranged convective clouds, and strong rotating wind circulation. These conditions cause the formation of a cyclonic low-pressure center, moving counterclockwise in the Northern Hemisphere (NH) and clockwise in the Southern Hemisphere (SH) (Selkofa. M et al. 2024).

Although Indonesia is not located in the path of tropical cyclones, the presence of tropical cyclones around Indonesia, especially those formed around the Indian Ocean and around Australia, will affect weather patterns in Indonesia, which in turn will have an indirect impact on oceanographic conditions (Kurniati et al., 2024; Prasetyaningrum et al., (2025). Maulida et al., (2025) states that several cases of tropical cyclones that occur indirectly also have an impact on Indonesia, such as causing flash floods, tornadoes, and other extreme weather conditions (Maulida et al., 2025).

Previous studies have discussed the impact of tropical cyclones such as Dahlia, Cempaka, and Seroja on oceanographic parameters in other parts of Indonesia. However, there has been no study that specifically analyzes the

temporal response of oceanographic parameters in western Sumatra, particularly Bengkulu, which faces the Indian Ocean and is located in the direct path of cyclones from the south. The Bengkulu region was chosen because it is geographically directly facing the Indian Ocean, just north of the formation and passage route of tropical cyclones from the southern waters of Indonesia. This position makes Bengkulu one of the areas most vulnerable to the indirect influence of tropical cyclones that form in the southern waters of Java and western Sumatra. In addition, to date, there has been no research focusing on the temporal response of oceanographic parameters in the Bengkulu region due to tropical cyclones.

The impact of this event is not only felt directly on land, but also has implications for sea surface temperature, salinity, currents, winds, wave heights, and marine life in the surrounding area. In coastal waters, tropical cyclones can alter physical conditions by increasing sea waves and currents, which can cause damage to coastal ecosystems. Tropical cyclones are also one of the factors that trigger vertical mixing and upwelling, which can increase water fertility (Insan et al., 2024 ; Sulistiyono & Fadlilah, 2024). Unstable atmospheric conditions, a humid atmosphere, the formation of low-pressure areas, sudden atmospheric disturbances, increased nutrients through upwelling mechanisms, and increased extreme waves all directly affect marine ecosystems (Sulistiyono and Fadlilah, 2024). In addition, the radius of a tropical cyclone that is close enough to a region can cause significant meteorological and oceanographic impacts. One of these impacts is an increase in intense rainfall in the affected area (Widyani et al., 2024). This high rainfall contributes to changes in water salinity, as the increased volume of fresh water from precipitation causes a decrease in salt content in the surface layer of the sea.

In addition to changes in salinity, ocean currents are also greatly influenced by wind activity, which intensifies due to cyclones. According to Ginanjar (2020), currents are one of the oceanographic parameters that are sensitive to changes in wind patterns and speeds, so when a tropical cyclone occurs, current patterns in the waters will deviate from their normal conditions. Ocean current velocity is generally generated by maximum wind friction at the sea surface and decreases exponentially towards deeper layers, reflecting the diminishing influence of wind at certain depths. In addition to currents, ocean waves also experience a significant increase during tropical cyclones. Strong winds blowing over the ocean surface transfer their energy to the water column, producing waves with greater amplitude and period than normal conditions (Widyani et al., 2024).

This study aims to analyze temporal changes in sea surface temperature, salinity, ocean currents, wind speed, and wave height during and after cyclones, so that the results can support the development of mitigation and adaptation strategies to the impacts of climate change in these waters. Understanding the changes in oceanographic parameters caused by tropical cyclones is crucial for the development of marine extreme weather prediction models and the mitigation of climate change impacts in Indonesia's coastal areas.

RESEARCH METHOD

This study is limited to the waters of Bengkulu, which are geographically directly adjacent to the Indian Ocean. The study area is bounded by spatial coordinates $3° - 5°$ South Latitude and $101° - 104°$ East Longitude, covering the coastal waters to the open sea of Bengkulu. The data collection period was from January 15 to February 13, 2024, covering the time during and after the Anggrek Tropical Cyclone to identify the dynamics of oceanographic changes. The research location is shown in Figure 1, which shows the geographical position of six observation points in the waters of Bengkulu that directly face the Indian Ocean. The six observation points used in this study are located at the following coordinates: point $1 = 3.2\,S - 101.4\,E$, point $2 = 4\,S - 101.4\,E$, Point $3 = 4.8°S - 101.4°E$, Point $4 = 4.8°S - 102°E$, Point $5 = 4.8°S - 102.9°E$, Point $6 = 4°S - 102°E$.

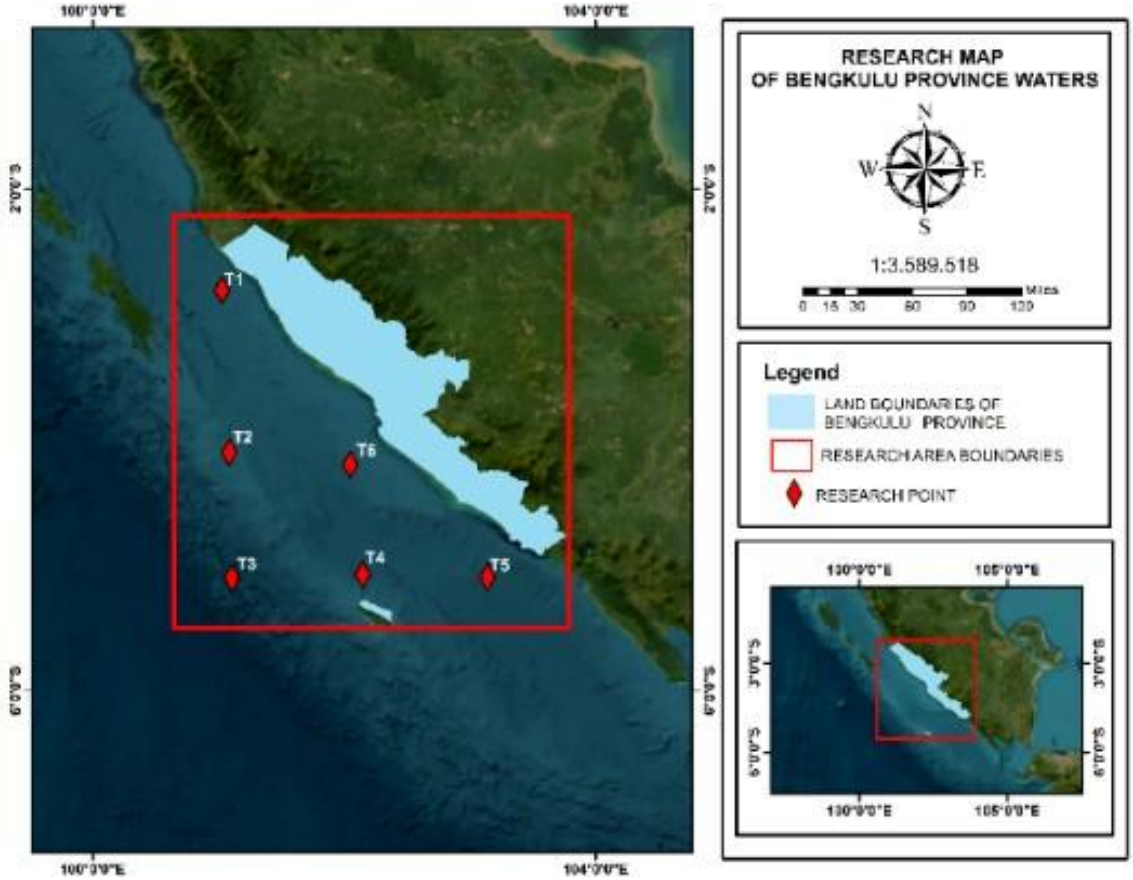

Figure 1. Map of the research location showing six observation points in the waters of Bengkulu (3°–5° S, 101°–104° E). The figure was created directly using ArcGIS

Tropical Cyclone Anggrek formed northwest of the Cocos (Keeling) Islands on January 15, 2024, near the border between the areas of responsibility of the Jakarta TCWC and the Australian Bureau of Meteorology (BoM). The cyclone then underwent a phase of intensification and reached its peak strength in the Indian Ocean before finally dissipating on February 2, 2024. Information on the intensity development of Tropical Cyclone Anggrek was obtained from satellite observation data from the Zoom Earth platform, which provides daily minimum air pressure and maximum wind speed parameters. Table 1 is compiled informatively to provide a chronological overview of the cyclone's intensity changes during its active period.

Materials and Tools

Oceanographic parameter data obtained from Marine Copernicus at https:// marine.copernicus.eu, specifically from the marine data store that provides global oceanographic products based on numerical model reanalysis and satellite observation data. The five main oceanographic parameters used in this study include: sea surface temperature (SST), currents, salinity, wind speed, and wave height. Sea surface temperature (SST), currents, and salinity were obtained from the Global Ocean Physics Reanalysis product with a spatial resolution of 0.083° × 0.083°. For sea surface temperature, salinity, and current data, the depth range was 0.5 m from the sea surface, with daily temporal resolution. Sea surface wind speed and direction are obtained from the Global Ocean Hourly Reprocessed Sea Surface Wind and Stress from Scatterometer and Model product, which provides hourly Eastward wind and Northward wind data with a spatial resolution of 0.125° × 0.125° at a height of 10 m above the surface. Significant wave height comes from the Global Ocean Waves Reanalysis product. This product provides wave height information with a temporal resolution of up to 3 hours and a spatial resolution of 0.2° × 0.2°.

Table 1. Presents chronological data on the movement and intensity of Tropical Cyclone Anggrek

Date	Time UTC+7	Latitude	Longitude	Maximum Wind Speed	Type
15 January 2024	13.00	9.6 S	93.6 E	65 km/h	Category 1 Tropical Cyclone
16 January 2024	07.00	9.5 S	93.9 E	70 km/h	Category 1 Tropical Cyclone
17 January 2024	07.00	9.8 S	94.0 E	70 km/h	Category 1 Tropical Cyclone
18 January 2024	07.00	10.8 S	93.9 E	85 km/h	Category 1 Tropical Cyclone
19 January 2024	07.00	12.4 S	92.8 E	95 km/h	Category 2 Tropical Cyclone
20 January 2024	07.00	12.4 S	92.8 E	120 km/h	Category 2 Tropical Cyclone
21 January 2024	07.00	12.0 S	92.3 E	120 km/h	Category 1 Tropical Cyclone
22 January 2024	07.00	12.6 S	91.8 E	85 km/h	Category 1 Tropical Cyclone
23 January 2024	07.00	12.7 S	91.4 E	70 km/h	Category 1 Tropical Cyclone
24 January 2024	07.00	13.8 S	91.3 E	100 km/h	Category 2 Tropical Cyclone
25 January 2024	07.00	14.7 S	90.8 E	150 km/h	Category 3 Tropical Cyclone
26 January 2024	07.00	16.6 S	87.5 E	195 km/h	Intense Tropical Cyclone
27 January 2024	07.00	18.7 S	83.2 E	185 km/h	Intense Tropical Cyclone
28 January 2024	07.00	20.0 S	77.9 E	185 km/h	Intense Tropical Cyclone
29 January 2024	07.00	22.7 S	71.9 E	200 km/h	Intense Tropical Cyclone
30 January 2024	07.00	27.9 S	71.8 E	170 km/h	Tropical Cyclone
31 January 2024	07.00	31.6 S	79.0 E	150 km/h	Tropical Cyclone
01 Februari 2024	07.00	36.2 S	90.8 E	200 km/h	Extratropical Cyclone

The tools required for data processing are: one laptop, Panoply software to open and extract data in NetCDF format into numerical data, and Microsoft Excel to create graphs for visualizing oceanographic parameters.

Data Analysis

The analysis was conducted only temporally using a descriptive approach to identify the dynamics of changes in oceanographic parameters during and after the tropical cyclone event in the waters around Bengkulu. Furthermore, a t-test: Paired Two Sample for Means was conducted to compare normal conditions with conditions during the cyclone to assess whether the differences were statistically significant or not.

RESULT AND DISCUSSION

Wind Speed

Sea surface winds are a parameter that has a significant impact due to tropical cyclones (Kusumawardani *et al*., 2021). Wind speeds in the waters off Bengkulu generally increased during Tropical Cyclone Anggrek. The highest wind speeds occurred on January 25, 2024, at several points except point 3. On that date, Tropical Cyclone Anggrek was a Category 3 tropical cyclone. The tropical cyclone produced a very strong atmospheric pressure gradient in the eastern Indian Ocean. This pressure gradient not only affected the core area of the cyclone but also drove the formation of strong wind patterns along the outer part of the cyclone, reaching the west coast of Sumatra, including the Bengkulu Waters. On January 23, the wind speed was not too strong, so it did not have much impact on other oceanographic parameters. This is also in line with the announcement issued by the BMKG regarding Tropical Cyclone Anggrek, stating that on January 23, 2024, the cyclone did not have an impact on weather conditions and oceanographic parameters.

Wind speeds at most locations generally decreased after Tropical Cyclone Anggrek. This decrease occurred gradually over a period of seven days after the event. After decreasing, wind speeds at all locations suddenly increased again on February 12, 2024, before stabilizing or decreasing slightly on February 13, 2024. This sudden increase in wind speed was temporary, as it was immediately followed by a decrease

and stabilization of wind speed on February 13, 2024. This indicates that the atmospheric system returned to a quasi-stable condition, where wind speed is determined by regional factors such as monsoon circulation patterns and surface air pressure, rather than by cyclonic disturbances.

T-test results: Paired Two Sample for Means between normal conditions and during Tropical Cyclone Anggrek show a significant difference in wind speed. The average wind speed under normal conditions was 4.59 m/s, while during the cyclone it was 2.85 m/s. Based on the calculation results, $t_{count} = 9.81$ was greater than $t_{critical} = 2.57$ with a p-value = $0.000187 (< 0.05)$. This indicates that there is a significant difference between normal conditions and cyclone conditions, where wind speeds in the Bengkulu Waters tend to decrease when Tropical Cyclone Anggrek occurs. This decrease shows that the research location only receives indirect impacts from the cyclone system centered in the Indian Ocean.

Sea Surface Temperature (SST)

Tropical cyclones affect ocean parameters such as sea surface temperature (SST) during the growth, occurrence, and dissipation phases of tropical cyclones (Sinaga et al., 2024). From the results of the visualisation graph of sea surface temperature parameters, the graph shows a decrease in sea surface temperature during tropical cyclones, with a decrease in temperature values before January 25, 2025, and an increase after that date. On January 19,

Figure 2. Wind speed conditions at each observation point during and after the tropical cyclone

2024, there was a decrease in sea surface temperature during a tropical cyclone category 2 cyclone, and the cyclone was not too far from the area under study. Thus, wind speed produces strong friction on the sea surface, causing vertical mixing in the water column. This process lifts water from the lower layers (which are colder and denser) to the surface and sinks warm surface water to the bottom. As a result, sea surface temperature (SST) decreases at that time. This is in line with the findings Tang et al. (2025) and He et al. (2020), which explain that the cooling of sea surface temperature is caused by a vertical mixing mechanism due to increased wind stress and upwelling in the surface layer. Then the surface temperature increased significantly after January 25, 2024, because the tropical cyclone moved away from the waters of Bengkulu, so that the influence of the cyclone on the surface temperature decreased or did not affect the condition of the waters. In general, tropical cyclones that occur in the Indian Ocean will move towards Australia (if formed south of Java) and towards Africa (if formed south of Sumatra) (Widyani et al., 2024).

After the cyclone disappeared, temperatures rose significantly at all observation points because when the wind weakened, friction on the sea surface

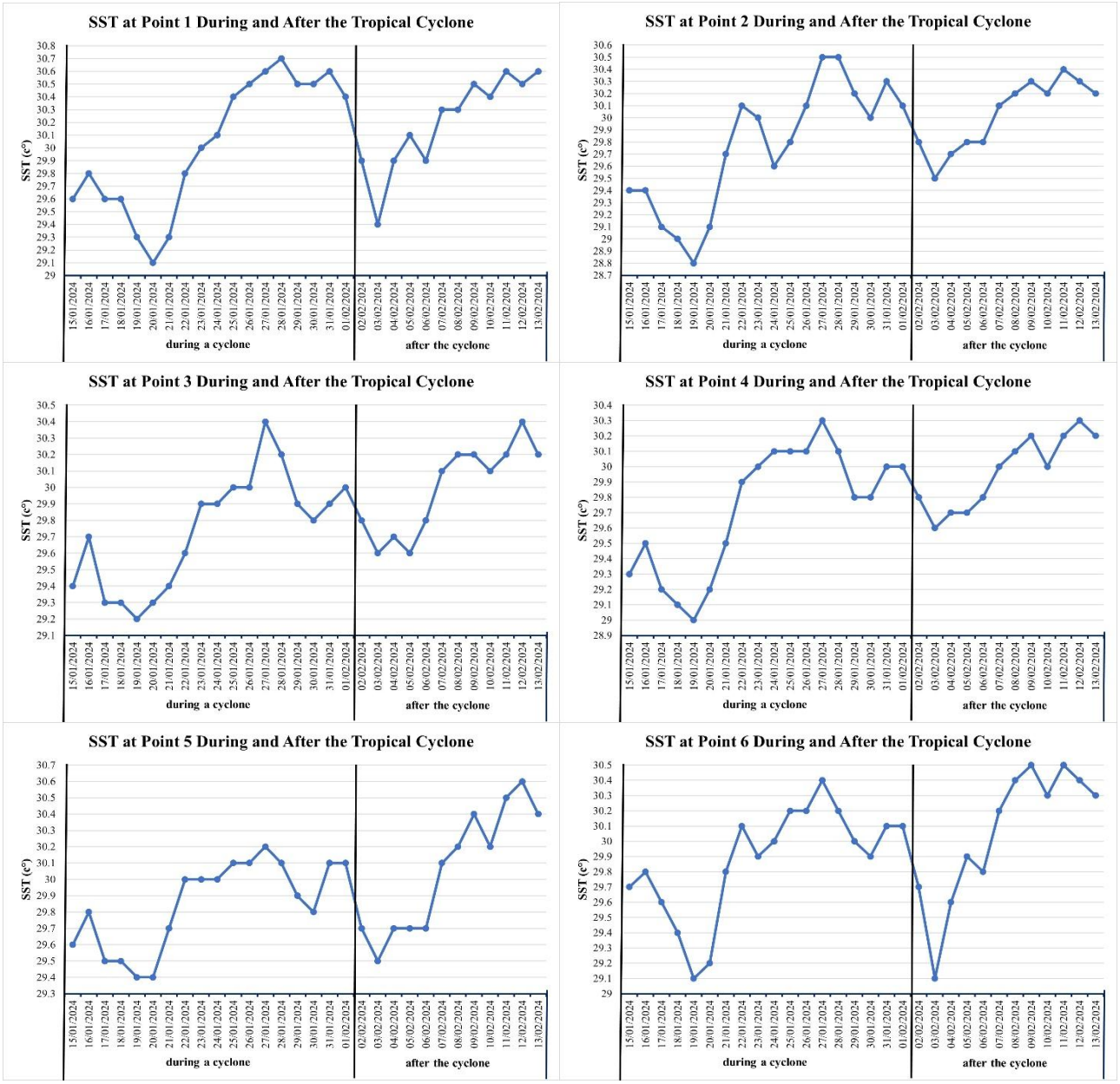

Figure 3. Sea Surface Temperature (SST) conditions at each observation point during and after the tropical cyclone

decreased. This caused the sea surface layer to return to thermal stability (restratification), where warm water remained on the surface and did not mix with the cold water below. This process accelerated the increase in temperature in the upper layer of the sea.

The results of the paired t-test between normal conditions and during Tropical Cyclone Anggrek show a significant difference in sea surface temperature in the waters of Bengkulu. The average temperature under normal conditions was $29.26°C$, while during the cyclone it increased to $29.83°C$. The calculated t-value was -16.41, which was much greater than the critical t-value of 2.57, with a two-tailed p-value of $1.53 \times 10^{-5} (< 0.05)$. These results indicate that the null hypothesis (H_0) is rejected and the alternative hypothesis (H_1) is accepted, meaning that there is a significant difference between sea temperatures under normal conditions and during cyclones. This increase in sea surface temperature is thought to be related to the advection of warm water masses from the Indian Ocean and changes in wind and current patterns due to cyclonic activity around the study area.

Salinity

Based on the salinity graph during tropical cyclones, salinity conditions in Bengkulu waters generally decreased by $0.4 - 1.4\ PSU$, except at point 2, where there was an increase of $0.4\ PSU$ at the onset of the cyclone. These changes in salinity conditions indicate a sequential response that illustrates the energy cycle between the atmosphere and the ocean. The cooling and salinity decrease phases are not only influenced by wind intensity, but also by the relative location to the cyclone center and the seabed topography that regulates local current dynamics. Suhardi (2020) research also explains that the decrease in salinity during tropical cyclones is caused by intense rainfall in a short period of time in a certain area, and that tropical cyclones also cause drought in other areas. From this explanation, it can be concluded why the graph results vary in terms of salinity values at all points.

After the cyclone disappeared, salinity conditions in the Bengkulu Waters generally increased, peaking at $33.8\ PSU$ at point 3, located west of the Bengkulu Waters after Tropical Cyclone Anggrek. Salinity conditions at several points generally experienced a significant increase, except at point 5, which experienced a decrease in salinity. The increase in salinity after the cyclone moved away occurred because solar radiation increased, accompanied by a decrease in rainfall. This caused an increase in the process of evaporation from the sea surface. Because the evaporated water only carried water vapor without salt, the remaining water on the surface became saltier, causing salinity to increase. The decrease in salinity at point 5 after the cyclone is because it is located closer to the coastal area, so after the cyclone, there is likely to be a flow of fresh water from the land due to residual rainfall runoff. This condition causes a decrease in local salinity compared to other points.

Based on the results of a paired t-test between normal conditions and during Tropical Cyclone Anggrek, it was found that there was a significant difference in salinity values in the waters of Bengkulu. The average salinity under normal conditions was $33.2\ PSU$, while during the cyclone it decreased to $32.09\ PSU$. The test results showed a t-value of 12.45, which was much greater than the critical t-value of 2.57, with a p-value (two-tailed) of $5.93 \times 10^{-5} (< 0.05)$. Thus, the null hypothesis (H_0) is rejected and the alternative hypothesis (H_1) is accepted, which means that there is a significant difference between normal conditions and cyclone conditions. The decrease in salinity indicates that Tropical Cyclone Anggrek has a significant effect on the waters of Bengkulu, particularly through increased rainfall, freshwater runoff, and vertical mixing due to the stirring of water masses by strong winds. Physically, this illustrates the ocean's response to major atmospheric disturbances, where the supply of fresh water from precipitation and turbulence in the surface layer causes a decrease in salt content in the water column during the cyclone period.

Current Speed

Observations show that ocean current speeds in the waters off Bengkulu increased significantly at the beginning of Tropical Cyclone Anggrek, then gradually decreased until weakening at the end of the cyclone period. At the beginning of the cyclone's formation and movement, wind speeds above the sea surface increased sharply due to a large air pressure gradient between the cyclone center and its surroundings. This condition produced strong surface friction, triggering the movement of seawater masses in the upper layer known as surface currents. In his research, Han *et al*. (2024) explain that surface currents strengthen local cyclonic vortices and accelerate water mass transport. However, when the cyclone began to move away from the waters of Bengkulu, as occurred on January 29 – 30, In 2024, wind intensity decreased, and the air pressure system returned to stability. Under these conditions, the energy source driving the currents weakens. As a result, ocean currents begin to slow down and eventually reach a near-calm state ($0\,m/s$). This phenomenon indicates that the direct influence of the cyclone on current dynamics in the Bengkulu region has ended, and the ocean is entering a recovery phase.

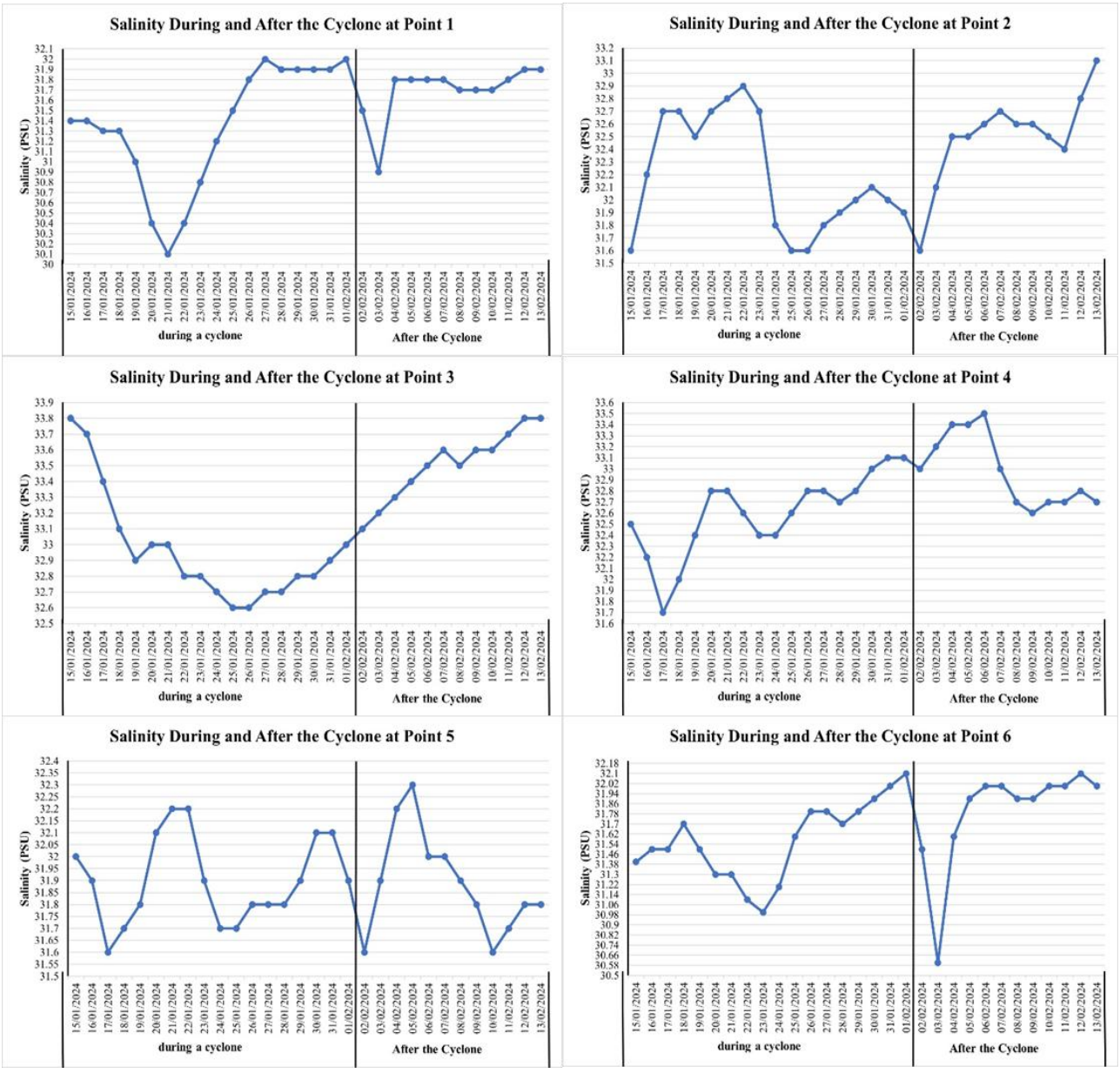

Figure 4. Salinity conditions at each observation point during and after the tropical cyclone

Based on the current velocity graph after the cyclone occurred, sea current conditions in Bengkulu waters generally varied, with a peak of 0.60 m/s at point 5, located on the southern coast of Bengkulu waters after Tropical Cyclone Angrek. The decrease in current velocity at the observation points indicates that the sea is entering a phase of energy stabilization, where the influence of the cyclone is weakening and local factors such as coastal topography and regional wind patterns become the main controlling factors. In their research, Khaldun (2025) explains that the movement of cyclonic vectors formed in the southern waters of Java creates a convergence zone that moves from west to east until it disappears when it reaches high latitudes. This condition causes calmer waters after the cyclone and marks the beginning of the monsoon transition phase. The results of the paired t-test between normal conditions and during Tropical Cyclone Anggrek show a significant difference in current velocity in the waters of Bengkulu. The average current velocity under normal conditions was 0.28 m/s, while during the cyclone it increased to

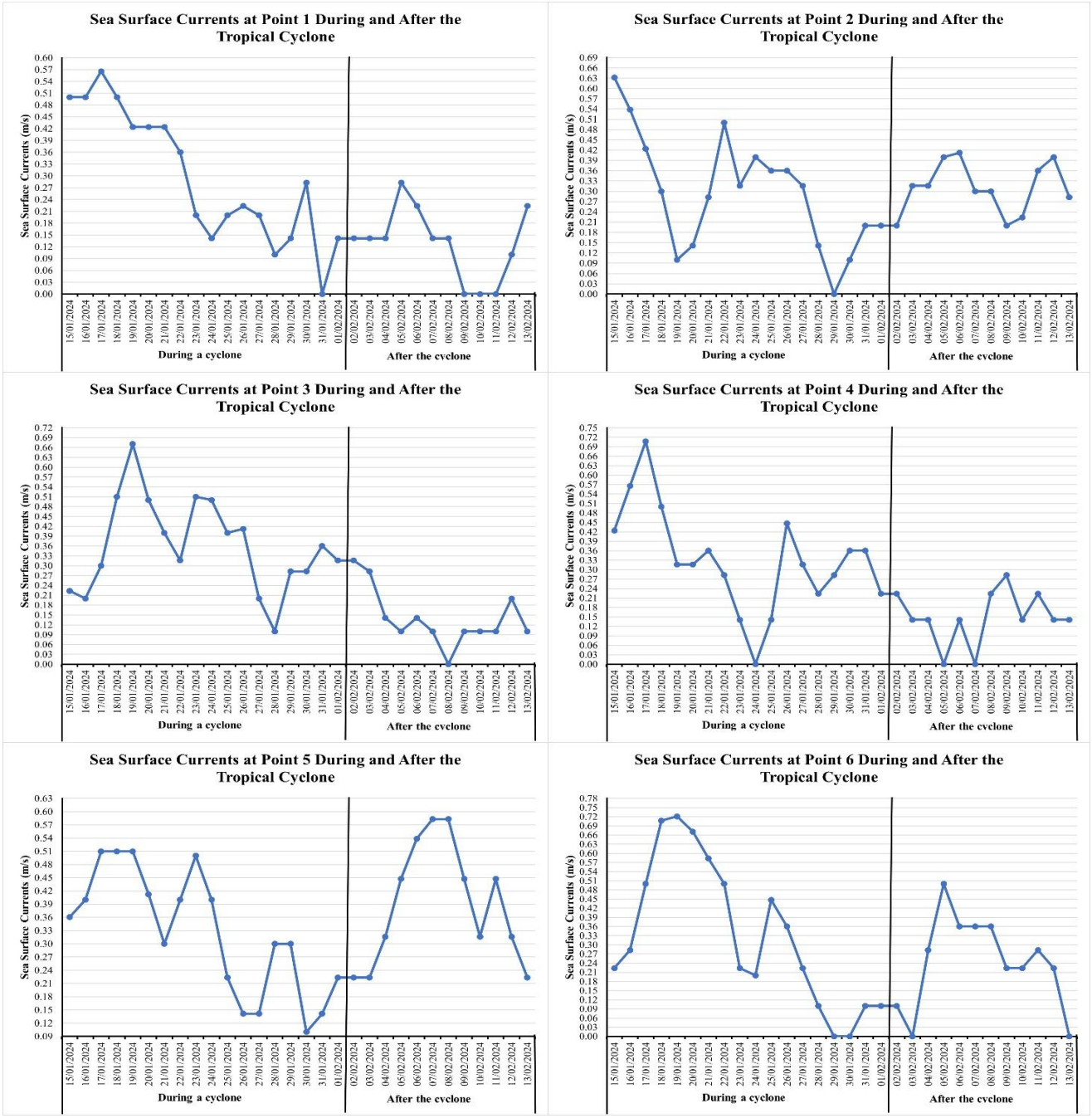

Figure 5. Conditions for current speed at each observation point during and after the tropical cyclone

$0.32\ m/s$. The calculation results show that t count $= -2.76$, which is greater in absolute terms than t critical= 2.57, with a p-value (two-tail)= 0.0398 (< 0.05). Thus, the null hypothesis (H_0) is rejected and the alternative hypothesis (H_1) is accepted, which means that there is a significant difference between normal conditions and during the cyclone. The increase in current velocity during a cyclone indicates a direct influence of tropical cyclone activity on ocean current dynamics in Bengkulu. Physically, this is caused by an increase in surface wind pressure and changes in atmospheric pressure gradients, which strengthen wind friction against the sea surface and produce stronger currents with varying propagation directions during the cyclone period.

Sea wave height

Observations show that wave heights in the Bengkulu Sea increased significantly at all observation points during the period of Tropical Cyclone Anggrek. The peak increase in wave heights occurred during two main periods, namely January $16-17$, 2024, and January $27-28$, 2024. During the first period

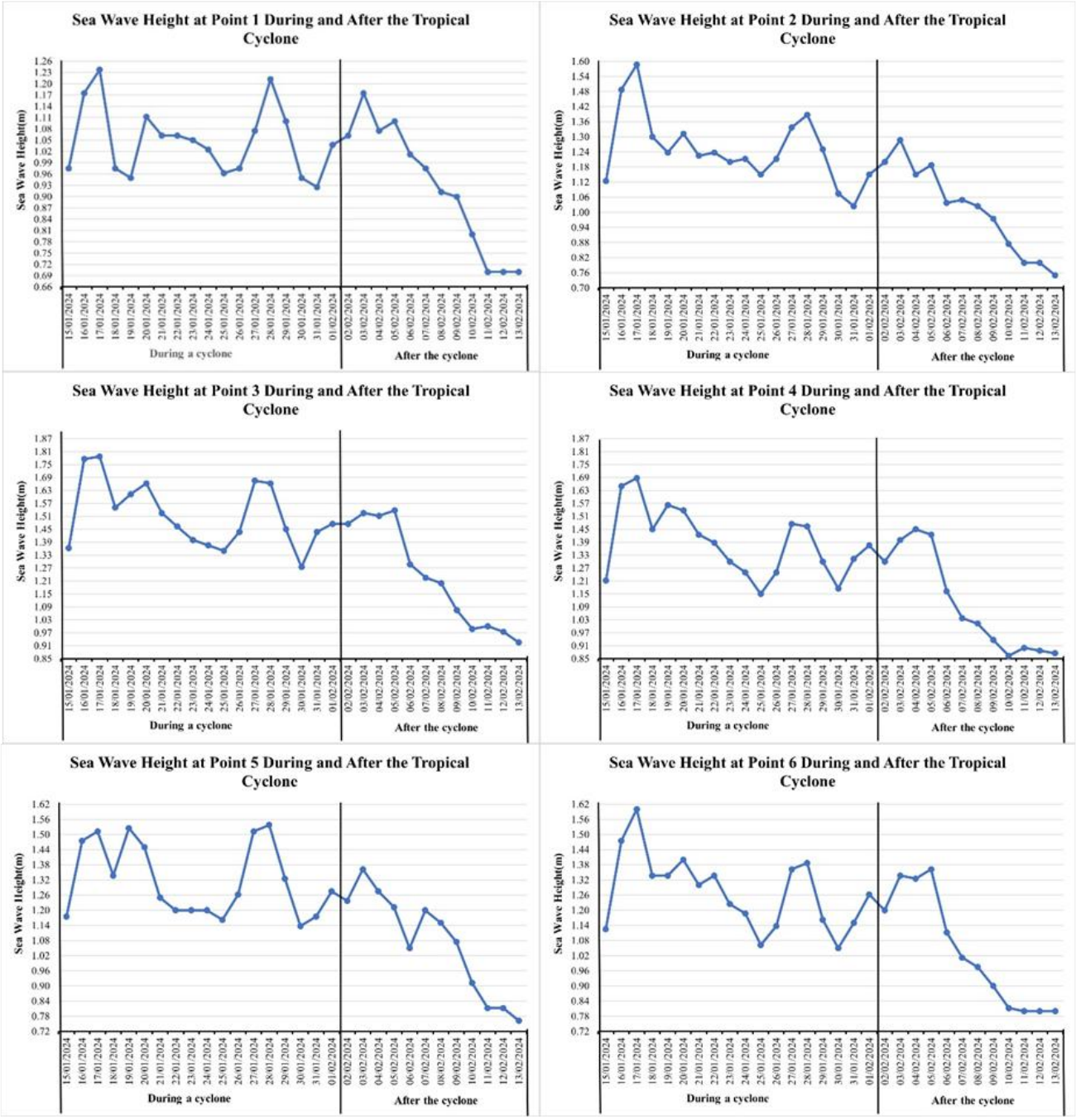

Figure 6. Sea wave height conditions at each observation point during and after the tropical cyclone

(January $16-17$), the cyclone was still in the Tropical Cyclone Category 1 phase with the center of the cyclone relatively close to the research location. These conditions caused an increase in wind speed around the observation area, resulting in intense local wind waves due to high sea surface friction. Meanwhile, during the period of January $27-28$, 2024, the cyclone had entered the Intense Tropical Cyclone phase with wind speeds reaching 195 km/h (54.17 m/s). Although the center of the cyclone had moved quite far from the research location, the observations showed that the wave height in the waters of Bengkulu was still relatively high. Based on research by Widyani *et al*. (2024), after the cyclone moved away, various oceanographic parameters, including wave height, were generally directly influenced by wind conditions above the sea surface. Thus, the phenomenon of increased wave height when the cyclone had moved away was not solely caused by local wind activity, but could also be linked to several other oceanographic mechanisms.

Based on the visualization graph, wave conditions in the Bengkulu waters showed a gradual decline after Tropical Cyclone Anggrek. Within approximately seven days after the event, wave heights at most observation points showed a consistent downward trend, despite initially reaching high values in the early post-cyclone period. This phenomenon illustrates the natural process of ocean energy dissipation that occurs after the primary energy source—strong winds from the cyclone system—weakens and moves away from the observation area.

Based on the results of the paired t-test between normal conditions and during Tropical Cyclone Anggrek, it was found that there was a significant difference in the parameters observed. The average value under normal conditions was 1.49 m/s, while during the cyclone it decreased to 1.30 m/s. The test results showed a t-value of 10.71, which was much greater than the critical t-value of 2.57, with a p-value (two-tailed) of 0.00012 (< 0.05). Thus, the null hypothesis (H_0) is rejected and the alternative hypothesis (H_1) is accepted, which means that there is a significant difference between normal conditions and cyclone conditions. This decrease in the average value indicates that Tropical Cyclone Anggrek has a real effect on the decrease in this parameter. Physically, these results indicate that when the cyclone center is located in the Indian Ocean, the pressure gradient and regional wind patterns undergo significant changes, causing a weakening of the intensity of the parameters in the Bengkulu coastal region. This phenomenon illustrates the indirect impact of tropical cyclones on atmospheric and ocean dynamics in areas located at the edge of the cyclonic system.

CONCLUSION

The results of this study indicate that Tropical Cyclone Anggrek in January 2024 had a significant effect on oceanographic parameters in the waters of Bengkulu, including sea surface temperature, salinity, current velocity, wind speed, and wave height. Based on the Paired Two Sample for Means statistical test, all parameters showed a significant difference ($p < 0.05$) between normal conditions and cyclone conditions, thus accepting the research hypothesis. These results answer the research question that the presence of tropical cyclones significantly modifies physical sea conditions through the mechanism of energy transfer from the atmosphere to the sea, which triggers vertical mixing, a decrease in salinity due to high rainfall, and an increase in currents and waves. Academically, this study strengthens the understanding of the direct and indirect impacts of cyclones on ocean dynamics. Practically, the results are important for the development of early warning systems, coastal disaster mitigation, and shipping safety.

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REFERENCES

Ginanjar, S., Syach, M. F, & Wulandari, S., (2020). Kajian Pengaruh Siklon Tropis Mangga Terhadap Curah Hujan, Transpor Ekman, Viskositas Eddy Dan Tinggi Gelombang Di Perairan Selatan Jawa Pada 20-25 Mei 2020. *Jurnal Meteorologi Klimatologi Dan Geofisika*, *7*(2), 15–23.

Han, C., Bowen, M., & Sutton, P. (2024). The Response of the Upper Ocean to Tropical Cyclones in the South Pacific. *Journal of Geophysical Research: Oceans*, *129*(4). https://doi.org/10.1029/2023JC020627

He, Q., Zhan, H., & Cai, S. (2020). Anticyclonic Eddies Enhance the Winter Barrier Layer and Surface Cooling in the Bay of Bengal. *Journal of Geophysical Research: Oceans*, *125*(10). https://doi.org/10.1029/2020JC016524

Insan, K., Patty, W., Manembu, I. S., & Sumilat, D. (2024). Dampak Siklon Tropis Rai Terhadap Kondisi Oseanografi di Perairan Kepulauan Talaud. *Prosiding Seminar Nasional Sains Dan Terapan*, *2*(1), 26–36.

Khaldun, M. H. I., Lestariningsih, W. A., Santika, L., & Heltria, S. (2025). Respon Perairan Terhadap Siklon Tropis Cempaka-Dahlia Di Perairan Selatan Jawa. *Indonesian Journal of Oceanography (IJOCE)*, *07*(01), 1–14. https://doi.org/10.14710/ijoce.v7i1.25924

Kurniati, R., Sagita, N., & Hanggoro, W. (2024). *Improvement Seroja Tropical Cyclone Prediction Improvement Seroja Tropical Cyclone Prediction Using Satellite Radiance Data Assiilition. Jurnal Meteorologi Dan Geofisiska, 25(1)*, 17–24. https://doi.org/10.31172/jmg.v25i1.932

Kusumawardani, N., Azani, A. A., & Iklima, C. (2021). Impact of Typhoon Surigae on Oceanographic Parameters in Sangihe-Talaud Waters. *Indonesian Association of Geologists Journal (IAGI Journal)*, *1*(3), 143–152. https://doi.org/10.51835/iagij.2021.1.3.376

Prasetyaningrum, N., Rahardjo, A. P., & Sujono, J. (2025). Evaluasi Pengaruh Siklon Tropis terhadap Curah Hujan Penyebab Banjir Bandang. *Jurnal Simposium Nasional Teknologi Infrastruktur*, *3*, 1–8.

Maulida, P., Anwar, S., Siregar, L.R., Mahdi, S. (2025). Pengaruh Perubahan Iklim terhadap Siklus Kejadian Siklon Tropis di Pasifik Selatan dan Utara. *Jurnal Lingkungan dan Bencana Geologi*, *15*(1), 122-137.

Selkofa. M, W. A., Wirasatriya, A., & Kunarso, K. (2024). Studi Pengaruh Siklon Tropis Flamboyan Terhadap Suhu Permukaan Laut Dan Klorofil-a Di Perairan Samudra Hindia Barat Daya Sumatra. *Indonesian Journal of Oceanography*, *6*(3), 266–274. https://doi.org/10.14710/ijoce.v6i3.18989

Sinaga, B. C., Wirasatriya, A., & Helmi, M. (2024). Analisis Variabilitas Klorofil-a Dan Suhu Permukaan Laut Pada Saat Kejadian Siklon Tropis Lili Di Laut Timor Dan Sekitarnya. *Jurnal Buletin Oseanografi Marina*, *13*(3), 475–489.

Suhardi, B., Adiputra, A., & Avrian, R. (2020). Kajian Dampak Cuaca Ekstrem Saat Siklon Tropis Cempaka dan Dahlia di Wilayah Jawa Barat. *Jurnal Geografi, Edukasi Dan Lingkungan (JGEL)*, *4*(2), 61–67. https://doi.org/10.29405/jgel.v4i2.4354

Sulistiyono, W., & Fadlilah, A. (2024). Analisis pertumbuhan dan perkembangan siklon tropis teratai pada periode 30 november – 2 desember. *JurnalMaterial dan Energi Indonesia*, *14*(02), 57–67.

Tang, H., Wang, D., Shu, Y., Yu, X., Shang, X., Qiu, C., Yu, J., & Chen, J. (2025). Vigorous Forced Submesoscale Instability Within an Anticyclonic Eddy During Tropical Cyclone "Haitang" From Glider Array Observations. *Journal of Geophysical Research: Oceans*, *130*(1), 1-22. https://doi.org/10.1029/2024JC021396

Widyani, A. P., Amalya, A., Adiprabowo, S. R., Suwignyo, T., Ismanto, A., & Maslukah, L. (2024). Pengaruh Siklon Tropis Dahlia Terhadap Karakteristik Gelombang Laut di Pesisir Selatan Banten Menggunakan Pemodelan SWAN. Jurnal Buletin Oseanografi Marina, *13*(3), 327–340. https://doi.org/10.14710/buloma.v13i3.58022