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Study of High Waves and Sea Level during Marian Tropical Cyclone in Southern Sea of Java

Kajian Kondisi Tinggi Gelombang dan Sea Level Saat Terjadinya Siklon Tropis Marian di Perairan Selatan Jawa

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Abstract

The southern coastal area of Java is an area directly bordering the Indian Ocean. This area often experiences high waves, which have an impact on community activities in coastal areas. High waves on the south coast of Java generally occur due to the impact of the Australian monsoon and tropical cyclones that form in the Indian Ocean. One of the tropical cyclones that emerged was Tropical Cyclone Marian, which occurred from February 27 to March 5, 2021. This research will use the Delft3D model, reanalysis, and observational data to determine these conditions. Based on the analysis results, the Delft3D Model can simulate tidal patterns and wave height conditions that occurred during the Mariana Tropical Cyclone in the Southern Java Waters region, supported by an RMSE correction of 0.2 to 0.4. The model results also show that in spatial conditions, there are fluctuations in sea level and wave height when cyclones occur, indicating that cyclones have sufficiently affected sea level and wave height conditions, which are supported by a comparison chart that shows sea level conditions tend to be higher than normal conditions and the model results. The wave height has fluctuations, indicating that the wave height corresponds to the cyclone period.

Keywords: Delft3D, Wave, Sea Level, Tropical Cyclone

Abstrak

Wilayah pesisir Selatan Jawa merupakan wilayah yang berbatasan langsung dengan Samudera Hindia. Wilayah ini seringkali mengalami gelombang tinggi yang berdampak pada aktivitas masyarakat di wilayah pesisir. Gelombang tinggi di pesisir Selatan Jawa umunya terjadi akibat dampak monsoon Australia dan siklon tropis yang terbentuk di Samudera Hindia. Salah satu siklon tropis yang muncul adalah siklon tropis Marian yang terjadi pada pada tanggal 27 Februari hingga 05 Maret 2021. Dalam penelitian ini akan digunakan Model Delft3D, Reanalysis, serta Data Pengamatan untuk mengetahui kondisi tersebut. Berdasarkan hasil analisis, Model Delft3D mampu untuk menyimulasikan pola pasang surut dan kondisi tinggi gelombang yang terjadi pada saat terjadinya Siklon Tropis Marian di wilayah Perairan Selatan Jawa didukung oleh koreksi RMSE yang bernilai 0,2 hingga 0,4. Hasil model juga menunjukkan bahwa pada kondisi spasial terlihat bahwa terjadi fluktuasi pada *sea level* dan tinggi gelombang saat terjadinya siklon menunjukkan bahwa siklon cukup memengaruhi kondisi *sea level* dan tinggi gelombang yang didukung oleh grafik perbandingan yang menunjukkan kondisi *sea level* cenderung lebih tinggi daripada kondisi normalnya serta model tinggi gelombang memiliki fluktuasi yang menunjukkan bahwa tinggi gelombang sesuai dengan periode siklon.

Kata Kunci : Delft3D, Gelombang Signifikan, Sea Level, Siklon Tropis

1. Introduction

Indonesia is often the site of many natural disasters which often cause a lot of material and immaterial losses to society. Weather phenomena are one of the main factors in several natural disasters in Indonesia. One type of disaster that often arises as a result of weather phenomena is a hydrometeorological disaster. One of the causes of hydrometeorological disasters is tropical cyclones. Tropical cyclones are atmospheric disturbances in the form of vortex circulation due to a low-pressure system (Habibie et al., 2018). The impact of a tropical cyclone itself can cause strong winds and high waves which can be accompanied by heavy rain. High waves or Storm Surge is an abnormal rise in water level caused by storm winds whose height can be measured during a storm compared to normal conditions (NOAA, 2021). Storm surges often occur in Indonesia, this is caused by the large number of cyclones that grow around Indonesian territory (Surinati and Kusuma, 2018). This is supported by several studies showing that there is a relationship between tropical cyclones and high waves. One method that is good enough to see the influence of tropical cyclones on wave height is to use the Delft3D model. Delft3D is generally good enough to simulate sea levels during Tropical Cyclone events (Burrahman et al., 2021). Besides that, DELFT3D is also quite good at mapping sea level anomalies as indicated by the relatively low RMSE values (Ariwibowo et al., 2021).

Delft3D is an application developed by Deltares which is quite good for mapping and simulating water conditions such as currents, waves, tides, density, tsunamis, transport of solutes, seawater intrusion, and pollutants (Deltares, 2016). From 22 February to 9 March 2021, the Marian Tropical Cyclone occurred in the Indian Ocean region in Western Australia. Reporting from several online media, the tropical cyclone Marian has caused high waves in several regions in Indonesia which has also caused several cases of hydrometeorological disasters due to high waves on the South Coast of Java. Based on this research background, it is very important to study the activity of Tropical Cyclone Marian on wave height conditions in the Southern part of Java Waters. This research is needed to provide risk information on the influence of tropical cyclones on wave height and sea level which can impact community activities in coastal areas.

2. Material and Method

This study uses the Delft3D application to simulate wave height and sea level during the Marian Tropical Cyclone period. The data used are tropical cyclone data from February 27 to March 5, 2021, FNL data for Delft3D input, IOC Wave Monitoring Data (Cilacap Station Area, Prigi Station, and Pangandaran Station), Coastline Data from NCEP NOAA, and Bathymetry Data. The research location is in the South Java Waters at coordinates7°07'05.5"S and 104°38'21.4"E to 9°06'58.3"S and 114°36'36.3". Which is shown in Figure 1. In addition, significant wave analysis is also used which is total waves or a combination of swells and sea waves (Dalphinet et al., 2022) when tropical cyclones occur in the study area. This data is sourced from data.marine. Copernicus.eu with a resolution of 1/12^{o}.

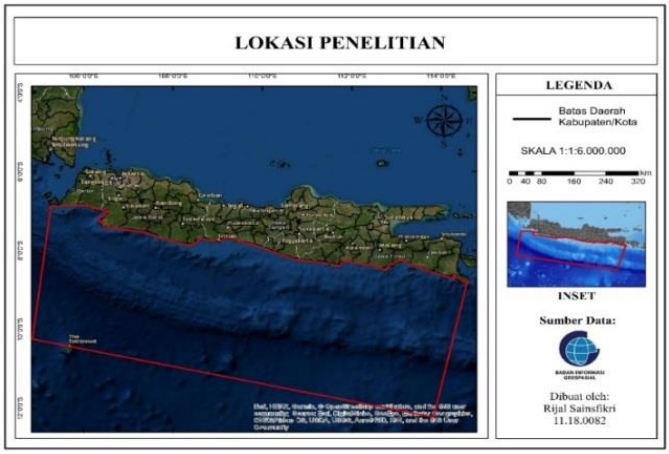

Figure 1. Research locations

3. Result and Discussion

3.1. Sea level conditions

Based on the results of a comparison of observational data, it can be seen that at the Cilacap station, there were tidal patterns that fluctuated during the case period. It can be seen from the Cilacap Station observation chart that on March 3, 2021, at 04.00 UTC which is a fairly high tide condition where the observed value shows 0.862 m which is the highest value during the case period. Meanwhile, March 1, 2021, is a low tide condition with a fairly low observation value reaching -0.992 m and is the lowest point during the observation period. In

the comparison chart, it can be seen that during the case period, there were several differences in values in the same moon phase and normal conditions. The difference in values is shown by a graphic pattern that slightly increases on several dates in the observation area.

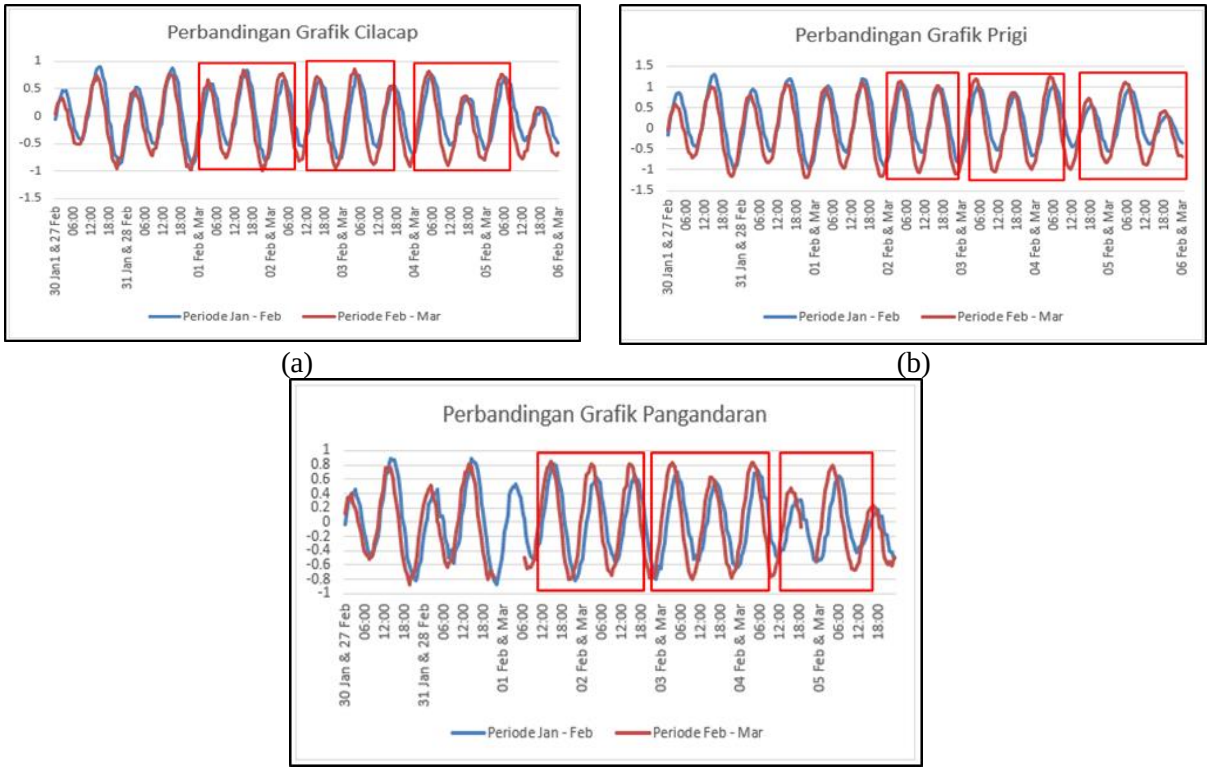

Figure 2.Graph of Tidal Comparison of Monitoring Stations a) Cilacap, b) Prigi, c) Pangandaran. The red box shows the period of the highest peak tide in the case of a tropical cyclone. The graph is a comparison of the ebb and flow before the cyclone in the same phase

At the Prigi tidal station, there are tidal patterns that fluctuate during the case period. It can be seen from the Prigi Station observation chart that on March 4 2021 at 05.00 UTC which is a high tide condition where the observed value shows 1.25 m which is the highest value during the case period. Meanwhile, on March 1, 2021, at 09.00 UTC is a low tide condition with a fairly low observation value reaching -0.925 m and is the lowest point during the case period. In the comparison chart, it can be seen that during the case period, there were several differences in values in the same moon phase and normal conditions. The difference in values is shown by a graphic pattern that slightly increases on several dates in the observation area.

In the results of the observation data, it can be seen that at the Pangandaran Wave Monitoring Station, there are tidal patterns that fluctuate during the case period. It can be seen in the observation chart of Pangandaran Station that on March 1 2021 at 15.00 UTC which is a high tide condition where the observed value shows 0.813 m which is the highest value during the case period. Meanwhile, on 27 February 2021 at 19.30 UTC was a low tide condition with a fairly low observation value reaching -0.866 m and was the lowest point during the case period. In the comparison chart, it can be seen that during the case period, there were several differences in values in the same moon phase and normal conditions. The difference in values is shown by a graphic pattern that slightly increases on several dates in the observation area.

In Figure 2, a comparison of sea level observation data was carried out when the Marian Tropical Cyclone occurred with conditions where a cyclone did not occur in the same moon phase. Comparisons were made to find out whether, during normal conditions and the cyclone period, there is a difference in the Sea Level data. Then, in the results of the comparison chart, it can be seen that at sea level conditions when the cyclone occurred there was a sea level pattern which showed an increase compared to the phase conditions before the cyclone occurred with the same phase on January 30 to February 5, 2021. This shows that during tropical cyclones sea level conditions tend to be higher than normal conditions caused by tropical cyclones.

Furthermore, the Delft3D model is used to see spatial changes at sea level in the research area related to the activity of the Marian tropical cyclone. But before doing the analysis, first, the output data from the model is compared with the observation results to see the model's ability to describe changes in sea level temporally. Based on the results of a comparison between the Delft3D model data of tidal observation station data, the results obtained at the three tidal stations were 0.98 with each RMSE value of 0.37 at Cilacap Station, 0.43 at Parigi tidal station and 0.23 at Pangandaran tidal station.

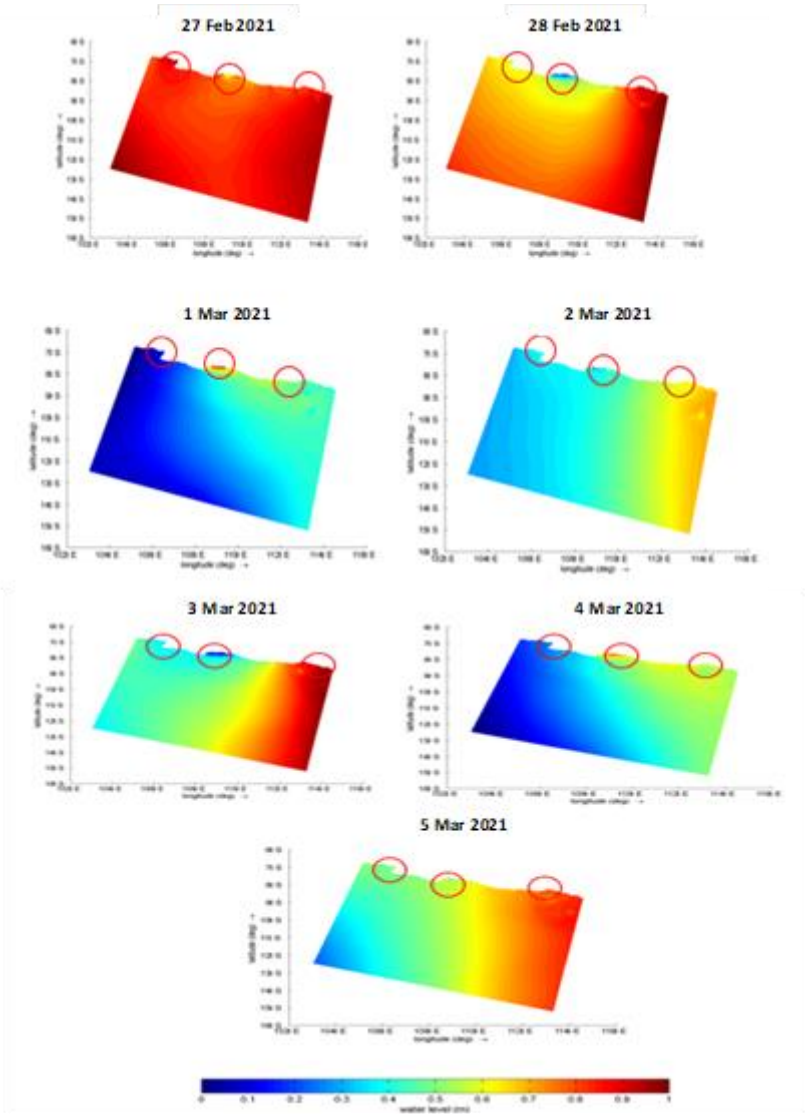

Figure 3. Sea Level conditions in the period 27 February - 5 March 2021 in the research area. The red circle indicates the observation station point

Spatially, sea level conditions in the study area can be seen in Figure 3, where during the period 28 February to 5 March 2021 there was an increase in sea level which in that period saw an increase of up to 1 meter on 27 February, 28 February and March 3, 2021 in the wave monitoring station area as shown by the red circle. It can be seen that in the Pangandaran Station area, Sea Level conditions tend to be high on 27 February and 28 February 2021 but then tend to decrease until 5 March 2021. At Cilacap Station, Sea Level conditions fluctuated where the highest values were seen on March 1 and March 4 2021 with a value reaching 1 meter despite the conditions of a decrease in height on March 2 and March 3 2021 as seen in the red circle. At Prigi Station, there is also an increase with the highest value on February 28, 2021. This fluctuation in value indicates that during a cyclone event, there is an increase in sea level in several station areas. This shows that during the cyclone period, it is enough to affect Sea Level conditions in the Southern Java Waters region. This fluctuation in value indicates that in the event of a cyclone, there is an increase in Sea Level in several station areas. This shows that during the cyclone period, it is enough to affect Sea Level conditions in the Southern Java Waters region. This fluctuation in value indicates that in the event of a cyclone, there is an increase in sea level in several station areas. This shows that during the cyclone period, it is enough to affect Sea Level conditions in the Southern Java Waters region.

3.2. Wave height conditions

Based on the processing of significant wave analysis data sourced from marine.copernicus.eu, it can be identified that the Marian tropical cyclone forms around 15o S and 95o E. This position is quite far from Indonesian territory, especially the island of Java, whose south coast is at latitude 7o – 8o LS. However, the significant waves that were formed due to tropical cyclones were strong enough to affect the increase in waves in the southern coastal areas of Java (Figure 4). When a cyclone forms in category 2 (BMKG, 2021) around

latitude 15° S on 27 February 2021, generally the wave height in the southern region of Java is recorded at 1.0 – 2.0 m. This condition increased when the cyclone entered the category 3 cyclone phase on 28 February - 2 March 2021 (BMKG, 2021) with significant wave heights ranging from 2.0 – 3.0 m along the southern coast of Java. As for March 3 - 5 2021, the cyclone category began to decline until it returned to being a low-pressure center on March 6, 2021. The waves on the south coast of Java again ranged from 1.0 - 2.0 m. When referring to the average waves in the southern Indian Ocean region of Java Island in March, generally significant waves have a height between 1.25 – 2.0 m (Kurniawan et al., 2011).

However, with the existence of cyclones that form in the Indian Ocean, the height increases beyond the average. The waves on the south coast of Java again ranged from 1.0 – 2.0 m. When referring to the average waves in the southern Indian Ocean region of Java Island in March, generally significant waves have a height between 1.25 – 2.0 m (Kurniawan et al., 2011). However, with the existence of cyclones that form in the Indian Ocean, the height increases beyond the average. The waves on the south coast of Java again ranged from 1.0 – 2.0 m. When referring to the average waves in the southern Indian Ocean region of Java Island in March, generally significant waves have a height between 1.25 – 2.0 m (Kurniawan et al., 2011). However, with the existence of cyclones that form in the Indian Ocean, the height increases beyond the average.

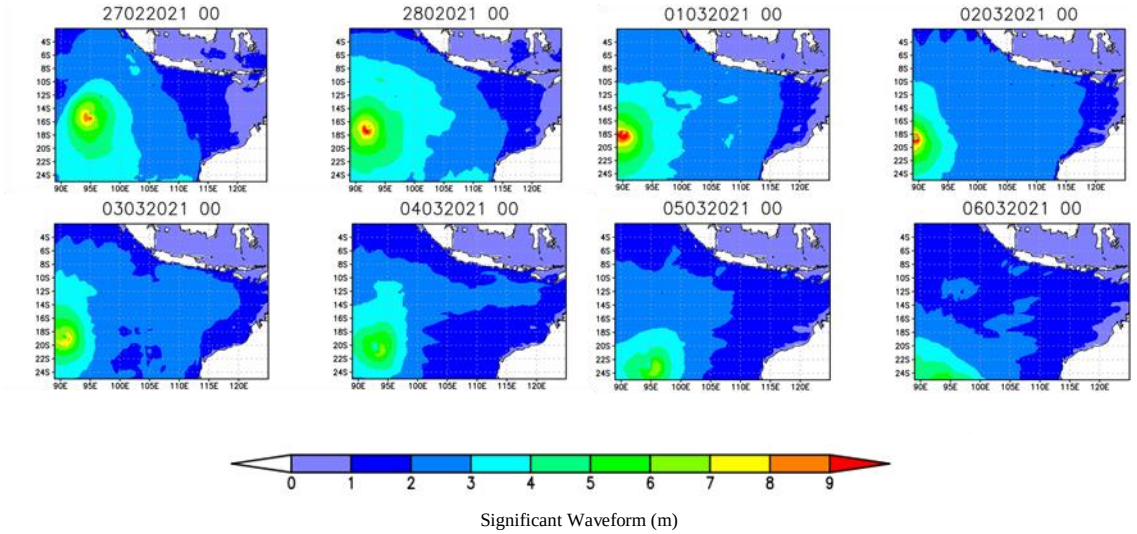

Figure 4. Mapsignificant waves (m) when the tropical cyclone Marian formed 27 February – 6 March 2021.

In the spatial results of the wave height model for the period of tropical cyclone occurrence from 27 February to 5 March 2021 using Delft3D (Figure 5) it can be seen that the wave height tends to be high so that it is in the range of 1 meter. Conditions with relatively high wave heights were seen in the waters around the Prigi area with a height of more than 1 m on 27 February to 2 March 2021 and then tended to decrease on 3 March 2021 to 5 March 2021 with a value range of 0.8 – 1.0 m. The locations with low wave heights occur in the waters around West Java with a value ranging from 0.4 to 0.8 m. The condition of the wave height in the picture shows that there was a decrease in wave height from March 3 to March 5 2021 with a range of values at 0.

Although in general, the Delft3D model has results that are still underestimated where the wave heights around the coast are recorded to only reach 1.0 m. However, the simulation results of the wave height model show that there were fluctuations in wave height when the Marian tropical cyclone occurred. The figure shows that wave heights tend to be high in the waters of Southern Java during the tropical cyclone period from 27 February to 5 March 2021. Conditions for high wave heights can be seen in the waters around the East Java region with visible heights reaching more than 1 meter. In the waters around West Java, wave height conditions tend to be lower with a range of 0.6 to 0.8 meters during cyclone periods. The condition of the wave heights in the picture shows that the wave height began to decrease from March 3 to March 5 2021 where on that date the cyclone also began to show a decay phase. The increase or decrease in wave height shows that cyclones have quite an effect on wave height conditions in the waters of Southern Java.

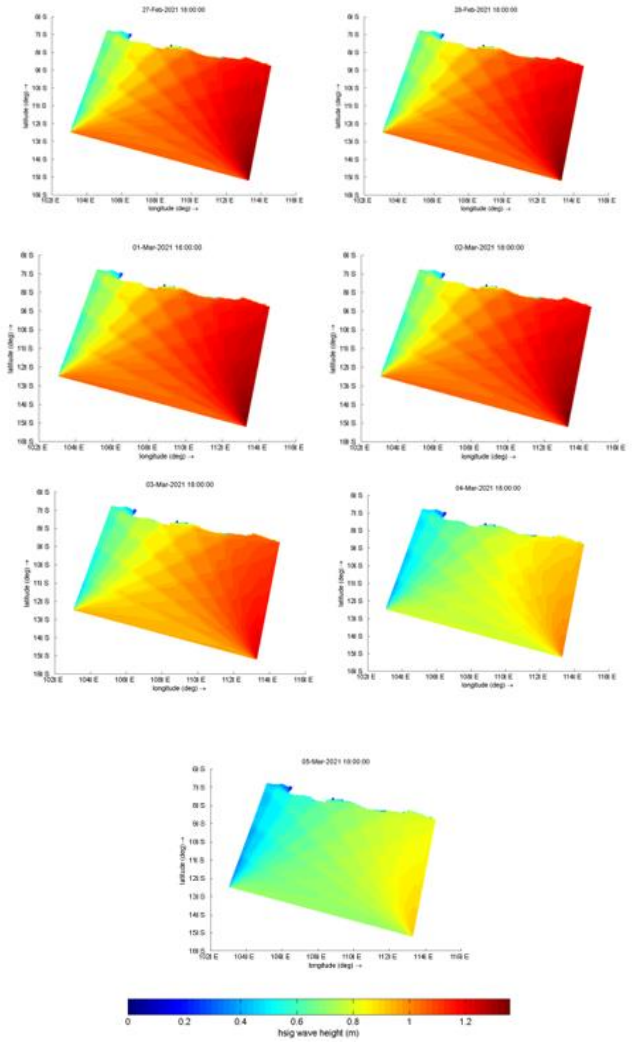

Figure 5.Wave Height Conditions in the period 27 February – 5 March 2021

4. Conclusions

Based on the model results, Delft3D adequately describes the Sea Level pattern. Although, in the Delft3D model parameter values there are differences that are smaller than the observed conditions which indicates that this model underestimates the observed conditions. Sea level conditions during the cyclone period tend to be higher than normal conditions which are supported by the results of the comparison chart. Based on the graphic results, it can be seen that sea levels tend to be higher during cyclonic periods compared to normal conditions with the highest values recorded on March 3, 2021, and March 4, 2021, with the highest values reaching 0.8 at Cilacap and Pangandaran Stations, and reaching a value of 1.2 at Primi Station.

Then, for the wave height model, the model simply describes the condition of the wave height. It can be seen that during the cyclone period it shows that there are fluctuations with the highest values being in the waters around the East Java region with a height reaching 1.2 m from 27 February to 2 March 2021 and gradually decreasing until 5 March 2021 according to the cyclone period.

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