Jurnal Teknologi Perikanan dan Kelautan Vol. 16 No. 3 August 2025: 268-281 ISSN 2087-4871
DOI: https://doi.org/10.24319/jtpk.16.268-281 EISSN 2549-3841

APPLICATION OF INVERSE DISTANCE WEIGHTED (IDW) INTERPOLATION IN DETERMINING WAVE HEIGHT IN THE WATERS OF THE SUNDA STRAIT

PENERAPAN INTERPOLASI *INVERSE DISTANCE WEIGHTED* (IDW) DALAM MENENTUKAN TINGGI GELOMBANG LAUT DI PERAIRAN SELAT SUNDA

Willdan Aprizal Arifin[1*], Anton Daud[2], Ramzan Pradana Maulsyid[1], Raisa Maulidia[1], Lukman Handyanto[1], Rifki Andreana Sutrisno[1]
[1]Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No.229, Isola, Sukasari District, Bandung, West Java 40154, Indonesia
[2]Meteorology, Climatology, and Geophysics Agency (BMKG), Maritime Meteorological Station Class 1 Merak, Jl. Raya Taktakan No. 27, Taktakan District, Serang, Banten 42162, Indonesia
*Corresponding author: willdanarifin@upi.edu

(Received November 21, 2024; Revised July 2, 2025; Accepted July 7, 2025)

ABSTRACT

The Sunda Strait is one of the busiest transportation routes in Indonesia, which has great potential in the fields of shipping, fisheries, and tourism. In addition to its potential, the Sunda Strait is also faced with challenges in the form of high wave risks that can jeopardize safety and disrupt the smooth running of maritime activities. The availability of wave data is an important aspect in maintaining safety and maritime activities. This research aims to visualize Inverse Distance Weighted (IDW) interpolation of wave height to provide more accurate and detailed information in the waters of the Sunda Strait for the benefit of the maritime sector. In this study, the IDW method was applied to wind data at three Automatic Weather Stations (AWS) points around the Sunda Strait region. Before the application of IDW, the Delaunay Triangulation method was used to ensure the optimization of sample points used to perform interpolation. The results showed that the significant wave height tended to be higher in the southwest monsoon than in the northeast monsoon. During the observation period 2022-2024, the maximum significant wave height was recorded at 2.06 meters, and the minimum one was close to zero. The application of the IDW method successfully visualizes the spatial distribution of wave height in detail, thereby supporting decision-making in risk mitigation and shipping safety in the Sunda Strait.

Keywords: Inverse Distance Weighted, Sunda Strait, wave, wind

ABSTRAK

Selat Sunda merupakan salah satu jalur transportasi paling sibuk di Indonesia, sehingga memiliki potensi besar dalam bidang pelayaran, perikanan, serta pariwisata. Selain potensi yang dimiliki, Selat Sunda juga dihadapkan pada tantangan berupa risiko gelombang tinggi yang dapat membahayakan keselamatan dan mengganggu kelancaran aktivitas maritim. Ketersediaan data gelombang menjadi aspek penting dalam menjaga keselamatan dan aktivitas maritim. Penelitian ini bertujuan untuk memvisualisasikan interpolasi *Inverse Distance Weighted* (IDW) tinggi gelombang guna menyediakan informasi yang lebih akurat dan detail di perairan Selat Sunda serta berguna bagi sektor kemaritiman. Pada penelitian ini diterapkan metode IDW pada data angin di tiga titik *Automatic Weather Station* (AWS) di sekitar wilayah Selat Sunda. Sebelum penerapan IDW, metode *Delaunay Triangulation* digunakan untuk memastikan optimalisasi titik-titik sampel dalam menentukan interpolasi. Hasil penelitian menunjukkan bahwa tinggi gelombang signifikan cenderung lebih tinggi pada musim barat daya dibandingkan musim tenggara. Selama periode pengamatan 2022-2024, tinggi gelombang signifikan maksimum tercatat sebesar 2,06 meter dan minimum mendekati nol. Penerapan metode IDW berhasil memvisualisasikan distribusi spasial tinggi gelombang secara rinci, sehingga dapat mendukung pengambilan keputusan dalam mitigasi risiko dan keselamatan pelayaran di Selat Sunda.

Kata kunci: angin, gelombang, *Inverse Distance Weighted*, Selat Sunda

INTRODUCTION

The Sunda Strait is geographically located between Java Island and Sumatra Island, which also connects the Java Sea and the Indian Ocean (Nadira *et al.* 2023). The Sunda Strait is one of the busiest transportation routes in Indonesia, so it has great potential in the shipping, fisheries, and tourism (Parjito *et al.* 2022). In addition to its potential, the Sunda Strait also faces serious challenges in the form of wave risks that can threaten shipping safety (Setiawan *et al.* 2024). Based on research conducted by Avrian (2020), the wave height in the Sunda Strait in the period 2009-2018 ranged from 1.3 to 2.4 meters. The waves are formed due to wind blowing above sea level and partly influenced by tangential pressure on water particles (Putri *et al.* 2022). Natural factors play an important role in influencing shipping activities, especially related to weather conditions in the waters. Some of these factors include current speed, wind speed, wave height, and bad weather (Machdani *et al.* 2023). Therefore, wave height is a reference in carrying out all activities in the sea waters (Arifin *et al.* 2021).

The Meteorology, Climatology, and Geophysics Agency (BMKG) has an important role in efforts to improve preparedness for potential disasters (Samudra *et al.* 2024). As a Non-Departmental Government Institution (LPND), BMKG is tasked with carrying out government functions related to meteorology, climatology, and geophysics, as well as providing pre-disaster information through the Early Warning System (EWS) (Laili 2023). The system was developed by Purnomo *et al.* (2023), who focused on designing and developing a web interface to provide accurate weather information to support ship navigation in the BMKG Meteorology Surabaya area. The system focuses on increasing the effectiveness of early marine weather warnings, helping mitigate the risk of maritime disasters, and ensuring information is easily accessible to users.

In addition, BMKG has provided maritime weather information through the InaWIS website, which is an integrated numerical model-based weather prediction system that serves as support for the maritime sector (Prasetyo *et al.* 2022). The InaWIS system is linked to shipping navigation data from the Automatic Identification System (AIS), which enables the identification of risks of shipping activities to maritime weather conditions, such as currents, winds, and waves. InaWIS is also equipped with real-time weather observation data that can predict sea conditions up to 10 days ahead. Research conducted by Rifki *et al.* (2022) on mapping the distribution of nickel laterite and estimating resources using the IDW interpolation method produced accurate results with small RMSE values of 0.0911 and 0.19288. Therefore, the application of the IDW interpolation method can be updated by taking a smaller scope in the waters of the Sunda Strait so as to produce information coverage with a more detailed resolution.

The IDW analysis method was used to determine the value at an unknown point by combining the linear weights of a set of sample points (Supit and Prasetyo 2024; Rini *et al.* 2024). These sample points are points with known values and are spatially closest to the point whose value is to be estimated. Before applying IDW, the Delaunay Triangulation method was applied to optimally determine random points based on AWS data that form a triangle, thus avoiding overlap between nearby points (Suarmahajaya *et al.* 2023). Thus, IDW will serve as a method to fill in the gaps of data in the integrated water area from AWS. Therefore, this study aims to visualize IDW interpolation of wave height to provide more accurate and detailed information in the waters of the Sunda Strait, and will be useful in the maritime sector.

METHODS

Research location and time

The research was conducted at the Automatic Identification System (AIS) Laboratory, Indonesian Education University, Serang Campus. The waters of the Sunda Strait were chosen as the research location (Figure 1) because they play an important role in maritime activities and influence local weather conditions. This study used wind speed data obtained from AWS placed in three ports around the Sunda Strait, consisting of Merak Maritime, Ciwandan Maritime, and Bakauheni Maritime. It aims to analyze the pattern and variation of wind speed in the region. The study was carried out for 6 months, from March to September 2024, with data taken from 2022 to 2024. The selection of this period aims to provide sufficiently long and representative historical data so that monsoonal patterns, long-term trends, and periodic fluctuations in ocean wave data can be recognized by the model.

Research procedure

The stages of the research are shown in Figure 2. This research consists of 7 stages, including data collection, Delaunay triangulation, fetch, IDW interpolation of wind speed and direction, wave height calculation, IDW interpolation of wave height, and IDW interpolation map of wave height.

Data collection

The data used in this study was wind speed data sourced from the AWS tool owned by BMKG. This wind speed data was obtained from three AWS stations, namely Merak Maritime, Ciwandan Maritime, and Bakauheni Maritime, with a time span from 2022 to 2024. The AWS data included various atmospheric parameters such as wind speed and direction, temperature, humidity, air pressure, and solar radiation, as shown in Table 1. However, in this study, only wind speed and wind direction parameters were used because they are the main components in the calculation of significant wave height. The utilization of wind speed and wind direction data from these three stations was the main basis for the spatial interpolation process using the Delaunay Triangulation and IDW methods in the next stage of analysis.

The large amount of data, 1.3 million rows in 2022, 1.1 million rows in 2023, and 769 thousand rows in 2024, with time resolution per minute, ensured high temporal detail in the analysis. The Delaunay Triangulation and IDW methods were used to expand the coverage area and obtain a more even distribution of wind speed in the Sunda Strait. This method can also estimate wind speed at points where there is no direct data, so the results can be used as a basis for calculating significant wave height.

Data processing

Delaunay triangulation

The three main coordinate points used were the positions of the three AWS located around the Sunda Strait with latitude and longitude values of (-5.918889, 105.9853), (-5.869293, 105.755), and (-6.014822, 105.951525), respectively. After determining these points, the Delaunay Triangulation method was used to form a triangle connecting the three points. Then, 50 coordinates within the triangle were randomized to determine the random observation locations, using the 'random_points_in_triangle' function. This particular function ensured an even distribution of points within the triangle. The results of the coordinate randomization were then saved in a CSV file. The triangulation process that resulted in 50 new coordinate points is presented in Figure 3.

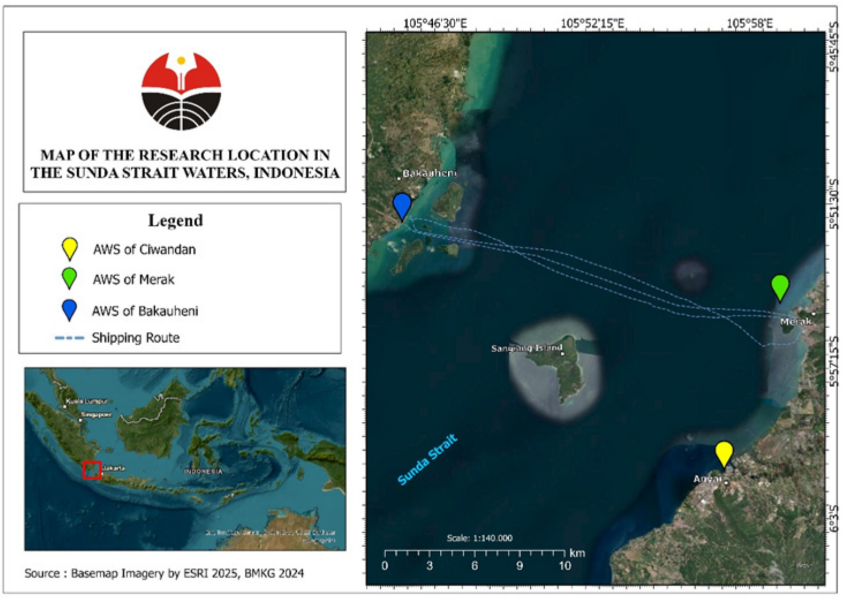

Figure 1. Research location in the waters of the Sunda Strait.

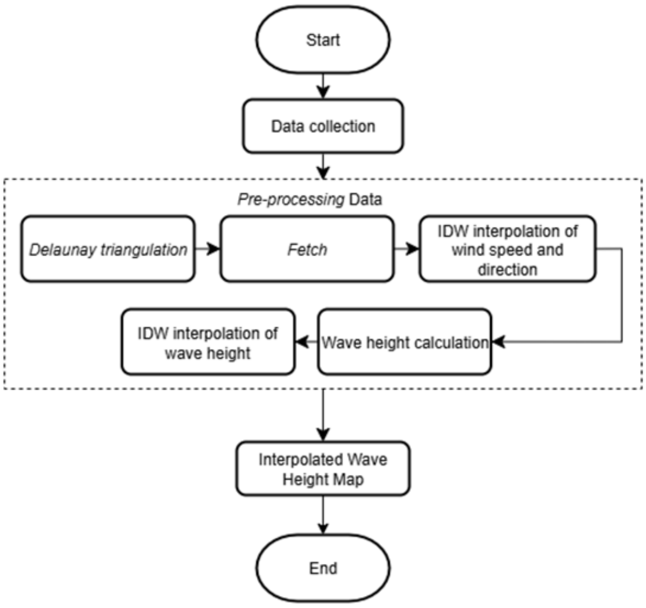

Figure 2. Flowchart of IDW interpolation research for wave height determination.

Table 1. Daily weather data from the Automatic Weather Station BMKG (wind speed, wind direction, temperature, etc.).

No	Time	WS (m/s)	Wind Dir (°)	Temp (°C)	RH (%)	Pressure (hPa)	Solrad (W/m²)	Water Temp (°C)	Water Level (m)	Lat	Lon
1	01/01/2022 00:00:00	0.90	262.00	26.90	85.01	1,010.80	201.00	29.50	5.000	-5.869293	105.755
2	01/01/2022 00:01:00	0.50	254.00	26.90	85.00	1,010.80	207.00	29.50	5.000	-5.869293	105.755
3	01/01/2022 00:02:00	1.40	286.00	26.90	84.00	1,010.90	215.00	29.50	5.000	-5.869293	105.755
...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...
491541	31/12/2022 23:57:00	0.00	308.00	26.70	80.00	1,011.90	37.00	28.40	2.856	-5.869293	105.755
491542	31/12/2022 23:58:00	1.60	307.00	26.70	80.00	1,011.90	37.00	28.40	2.868	-5.869293	105.755
491543	31/12/2022 23:59:00	0.90	314.00	26.80	80.00	1,012.00	37.00	28.40	2.867	-5.869293	105.755

Fetch

Fetch refers to the length of the area where the wind can blow with relatively constant speed and direction without any obstacles (Pasaribu *et al.* 2020). In wave formation at sea, the fetch is limited by the land surrounding the waters (Ma'sum 2021). According to Wijayanti (2023), the longer the fetch, the greater the energy that can be transferred from wind to water, resulting in the formation of larger and stronger waves. The fetch is limited by land or other geographical obstacles surrounding the waters, such as small islands or large land masses that can affect its effective length. The effective fetch length is determined using "Rupa Bumi Indonesia" (RBI) maps with the following steps: Starting from the initial point of wave generation in the deep sea, straight lines were drawn to the eight cardinal directions with an angle interval of 5° (Suhana *et al.* 2016).

Based on Figure 4, the fetch determination in this study was carried out using Python and several libraries such as pandas, geopandas, and geopy. The coordinate data of the measurement points were taken from a CSV file, while the land around the waters of the Sunda Strait was used in shapefile format from “Rupa Bumi”, Indonesia. Lines were drawn at various angles of 0° to 360° from each point to represent the wind direction. The fetch distance was calculated based on the distance from the starting point to the intersection point of the line with the nearest land, using the geodesic function. The effective fetch is calculated for the main directions, such as north, east, south, and west, taking into account the fetch distance contributions from various angles within the direction group. The fetch formula used in this study was expressed as follows (Arafat 2021):

$$F_{eff} = \frac{\sum Xi \cos \alpha}{\sum \cos \alpha}$$

Description:

Feff = Average effective fetch.

Xi = The length of the fetch segment is measured from the wave observation point to the end of the fetch.

α = Deviation on both sides of the wind direction is measured in 6° increments until it reaches 42° on each side of the wind direction.

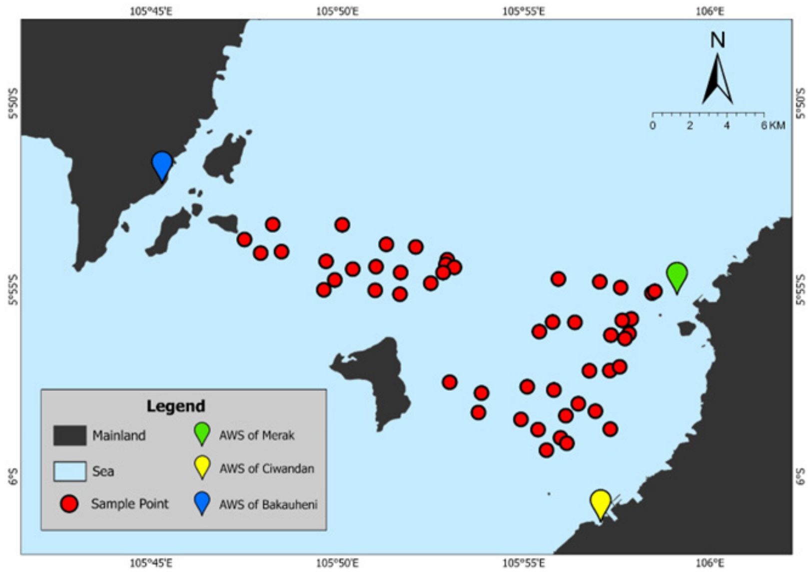

Figure 3. Coordinate distribution of random points after Delaunay triangulation.

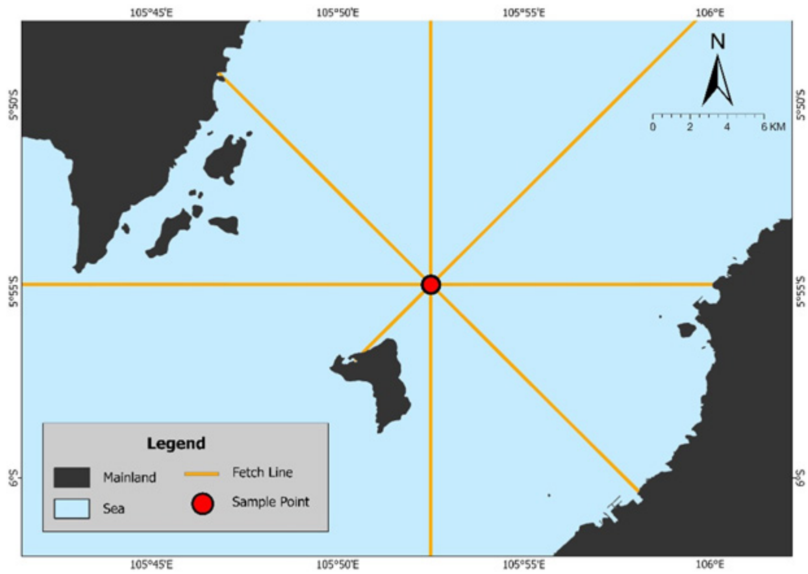

Figure 4. Example of fetch visualization at one of the sample points.

Fetch measurements were made at 50 points based on the results of Delaunay Triangulation spread across the Sunda Strait. In Table 2, the fetch measurement results are presented, which include the length of the area where the wind can blow with constant speed and direction, as well as its influence on wave formation in the waters. The length of the fetch line is measured until it reaches the nearest land. The fetch length results obtained are limited to 200 km only, this is because the wind speed will only remain consistent up to a distance of 200 km (Illona *et al*. 2018; Adji *et al*. 2020). The value 0 in the table indicates that at these points, the fetch length cannot be measured because it is blocked by land, so there is no distance available for the wind to blow unhindered.

IDW interpolation of wind speed and direction

According to Maleika (2024), the IDW interpolation method is used to calculate values at unknown points by utilizing weights based on the proximity of known measurement points. The distance between points can affect the determination of weights in the application of the IDW interpolation method (Sitorus *et al*. 2022). The closer the measurement points are, the greater the weight that is given (Sari *et al*. 2021). This allows IDW to produce accurate digital models by taking into account various parameters such as the density of measurement points. In the application of the IDW method, each wind speed data point from AWS in the waters of the Sunda Strait makes a greater contribution if the point is closer to the observation location, and vice versa, the contribution will be smaller if the distance is farther away. This process produced wind speed data at 50 new coordinates, which were estimated based on AWS data for the last three years.

This interpolation process was carried out using a Python program with the help of the scipy Interpolate library. At each timestamp, wind speed data from three AWSs were used as input for the interpolation process, which included observation time, wind speed, and latitude and longitude coordinates of each AWS. Wind speed data (wind data) and new point coordinates (coordinates_new data) were imported from CSV files by the Python program. The data contained wind speed at three AWS points (ws1, ws2, ws3), observation time, and AWS coordinates in the form of latitude (lat1, lat2, lat3) and longitude (lon1, lon2, lon3).

At each observation time, the wind speed at new coordinate points was calculated using the IDW method, so the contribution of each AWS was calculated based on its distance from closer points, contributing more. Although IDW is often used, in this context, the code was implemented using LinearNDInterpolator for interpolation. The coordinates of the three AWSs serve as input to calculate the wind speed at new, pre-randomized points. The interpolation results were stored in a DataFrame, with each column representing the wind speed at the new points. This interpolated data was then exported to a CSV file with the name (hasil_interpolasi.csv). The results of the IDW interpolation process of wind speed and direction are presented in Table 3.

Table 2. Fetch calculation data at each coordinate point.

No	Lat	Lon	North (m)	Northeast (m)	East (m)	Southeast (m)	South (m)	Southwest (m)	West (m)	Northwest (m)
1.	-5.957946098	105.8836512	5,849.999	558.094	4,558.901	13,671.103	14,281.284	14,557.921	13,550.758	10,072.262
2.	-5.935313294	105.9236991	4,789.166	434.577	5,038.093	12,978.404	17,358.020	14,968.925	13,157.810	9,441.612
3.	-5.959905389	105.9182852	5,006.052	854.693	5,030.433	13,710.016	14,890.450	12,742.255	12,600.164	9,375.457
...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...
48.	-5.951035958	105.9596448	4,067.332	1,107.067	4,170.375	13,752.017	16,656.248	9,355.043	11,342.207	8,505.867
49.	-5.916656203	105.8273377	5,479.144	0	4,032.117	11,842.168	15,099.678	12,926.618	15,518.469	11,579.296
50.	-5.918572485	105.8613816	5,890.583	0	4,574.712	11,943.894	16,709.255	10,945.542	14,793.460	10,900.022

Table 3. Wind speed and direction interpolation data.

No	Time	Lat	Lon	Winddir (°)	WS (m/s)
1	01/01/2023 00:08:00	-5.957946	105.883651	334.234714	5.626114
2	01/01/2023 00:08:00	-5.935313	105.923699	333.764855	3.947942
3	01/01/2023 00:08:00	-5.959905	105.918285	332.591661	5.151267
...		...	...		...
...		...	...		...
...		...	...		...
9.476.897	31/12/2023 23:59:00	-5.951036	105.959645	202.365957	2.922578
9.476.898	31/12/2023 23:59:00	-5.916656	105.827338	255.549464	2.177574
9.476.899	31/12/2023 23:59:00	-5.918572	105.861382	240.900725	2.303742

Table 3 presents the wind speed interpolation results, with each row representing the value for a particular coordinate point at a particular time. The 'time' column records the date and time of observation, the "Lat" and "Lon" columns record the geographical coordinates, and the 'winddir' column indicates the wind direction measured in degrees (°). The "WS" column contains the estimated wind speed values. A visualization of the interpolated wind speed and direction is presented in Figure 5.

Calculation of significant wave height

Significant wave height (Hs) is a key parameter in describing the overall state of marine waters (Wulandari and Aziz 2022). The significant wave height (Hs) represents the dominant wave height in a region over a certain period, so it is often used as a reference in various applications, such as maritime weather forecasting, shipping activity planning, and coastal risk assessment. The calculation of Hs in this study used the Sverdrup Munk Bretschneider (SMB) method, which has two approaches, namely for unlimited fetch and limited fetch conditions. The selection of the SMB method with a limited fetch approach is very suitable for this study. This is due to the geographical condition of the Sunda Strait, which is surrounded by small islands that limit the fetch length and affect the characteristics of wave formation. The formula used to calculate the significant wave height in the context of a limited fetch is stated as follows.

$$H = 0.283 \tanh [0.0125\, F^{0.42}]$$

Description:

$H = \frac{gH_s}{v^2}$

$F = \frac{gF}{v^2}$

IDW interpolation map of wave height

The final stage in the IDW interpolation is the visualization of the processed data on the wave height IDW map. The interpolation process was carried out using ArcGIS software with the default basemap. The wave height IDW interpolation data in CSV format was processed through a preprocessing stage to produce the visualization of the wave height IDW map.

RESULTS AND DISCUSSION

Calculation of significant wave height

The calculation of significant wave height in this study was carried out using wind data from 50 coordinate points of IDW interpolation results. The total data generated was 38,959,842, covering the period from January 2022 to May 2024. Some of the significant wave height calculation results are shown in Table 4 as a representation of the entire dataset.

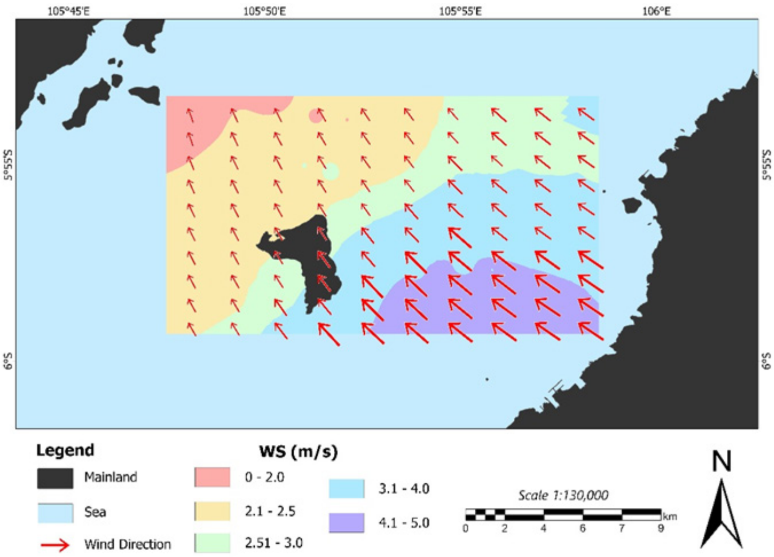

Figure 5. Interpolated map of wind speed and direction in the Sunda Strait.

Table 4. Calculated data of significant wave height based on wind speed from IDW interpolation.

No	Time	Lat	Lon	WS (m/s)	Hs (m)
0	01/01/2022 00:00:00	-5.957946	105.883651	3.784759	0.221199
1	01/01/2022 15:54:00	-5.957946	105.883651	5.278691	0.340359
2	01/01/2022 15:55:00	-5.957946	105.883651	5.720836	0.376605
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
38.959.840	31/05/2024 23:57:00	-5.918572	105.861382	1.144319	0.035470
38.959.841	31/05/2024 23:58:00	-5.918572	105.861382	0.971177	0.025317
38.959.842	31/05/2024 23:59:00	-5.918572	105.861382	0.845428	0.019657

Based on Table 4, it can be seen that the Hs value varies with the fluctuation of WS (wind speed), where the higher the WS value, the greater the Hs value. This indicates that there is a strong influence of wind speed and the formation of significant wave height. According to Satriadi and Prayogi (2017), the variability of wave height between monsoons is closely related to monsoonal wind patterns in Indonesian waters, where in the southwest monsoon, wind speeds can reach 8.8-11.1 m/s, while in the northeast monsoon, the highest speeds are in the lower range of 2.1-3.6 m/s. Globally, Zheng *et al.* (2022) proved that the increase in wind speed significantly drives the increase in wind-sea wave height, mixed wave height, and significant wave height regionally and monsoonally.

Trend and analysis of significant wave height

Data aggregation was carried out in the form of monthly averages to illustrate the temporal dynamics of high Hs during the period 2022 to 2024. Visualization of the data processing results is presented in Figure 6.

Analysis of data covering the last three-year period (2022-2024) revealed fluctuations in Hs in the study area. The results of data processing show that the maximum value is recorded at 2.06 meters on November 11, 2023, at 12:24 WIB at the geographical coordinates (-5.894181, 105.791842), which is in the western part of the Sunda Strait. This event coincides with the second transitional monsoon, which begins from September to November (Widianto and Pahlevi 2023). This finding is in line with information reported by Poskota (2023), that the Meteorology, Climatology, and Geophysics Agency (BMKG) on the same date issued a warning of potential waves up to 2.5 meters high in a number of Indonesian waters, including the western and southern Sunda Strait.

In contrast, the minimum significant wave height value is recorded close to zero, namely 0.0000000001 meters, which occurred at the coordinates (-5.916656, 105.827338) on June 17, 2022, at 16:41 WIB. The point is located in the central part of the Sunda Strait, and the event took place during the eastern monsoon, which starts from May to August (Widianto and Pahlevi 2023; Setiawan *et al.* 2024). Overall, the average significant wave height during the observation period reaches 0.1727 meters, reflecting monsoonal variability that is quite evident and important to note in the context of shipping safety and maritime activities in the Sunda Strait region.

Visualization of the significant wave height by the monsoon

The spatial visualization of wave height in this study is presented based on the spatial distribution of IDW interpolation results for certain months that represent the two main monsoons in the Indonesian region, namely the southwest monsoon and the northeast monsoon. The southwest monsoon is represented by January, while the northeast monsoon is represented by August. However, in 2024, the month of May was used instead of August due to limited data availability. The selection of these months is based on the climatological characteristics of the Indonesian region, where the southwest monsoon occurs from December to February, while the northeast monsoon occurs from May to August (Widianto and Pahlevi 2023; Setiawan *et al.* 2024). The visualized significant wave height values are monthly average results based on the representative months used for each monsoon each year. The visualization of the significant wave height by the monsoon in 2022 is shown in Figure 7.

The spatial distribution of Hs in the Sunda Strait during 2022 shows monsoonal dynamics (Figure 7). Based on the interpolation results using the IDW method, in the southwest monsoon, the distribution of Hs is quite varied, with a range between 0.11 and 0.225 meters, which is indicated by the color gradation of turquoise to yellow. The area with the highest Hs value is in the northeastern part of the study site. In contrast, during the eastern monsoon, the Hs distribution is dominated by dark blue and light blue colors with values less than 0.125 meters, indicating calmer ocean conditions. A similar monsoonal distribution in 2023 is presented in Figure 8 to illustrate the continuity of significant wave patterns between years.

Figure 8 shows the interpolated Hs in 2023 with greater variation than in previous years. In the southwest monsoon, the Hs distribution covers the full range of color classes, from dark blue (<0.05 meters), indicating very calm wave conditions in some areas, to orange and red (0.25-0.3 meters), indicating high waves, especially in the northeastern part of the study site. Meanwhile, the eastern monsoon is dominated by dark blue to light blue (<0.125 meters), indicating calmer wave conditions. Furthermore, the same distribution pattern was analyzed in 2024, as shown in Figure 9, to strengthen the consistency of the trend between years.

In 2024, the interpolated Hs results show a fairly even spatial distribution (Figure 9). In the southwest monsoon, the highest Hs values (0.251-0.275 meters) are shown by orange color gradations that dominate parts of the study area, while other areas show yellow to green colors (0.176-0.25 meters), indicating moderate waves. Meanwhile, the eastern monsoon is dominated by blue gradations (<0.125 meters), indicating calmer wave conditions. This pattern again confirms consistent monsoonal differences over the 2022-2024 period. To reinforce the results of the spatial visualization, Table 5 below presents the minimum, maximum, and average values of significant wave height for each monsoon during the 2022-2024 period.

Table 5 shows the minimum, maximum, and average significant wave height values for each monsoon in the period 2022 to 2024. In general, the southwest monsoon consistently shows higher mean values than the northeast monsoon in each year of observation. The highest mean significant wave height was recorded in the southwest monsoon in 2022 (at 0.1554 meters), while the lowest mean value was recorded in the northeast monsoon in 2023 (at 0.0553 meters). In 2024, the difference between the southwest monsoon (0.1079 meters) and the northeast monsoon (0.0743 meters) still reflects the same pattern, although the difference is not as large as the previous year. This trend indicates that wind conditions in the southwest monsoon tend to produce higher and more variable waves compared to the northeast monsoon.

This is in line with the findings of Aswad *et al.* (2021) in the western waters of Lampung Province, where this area is directly adjacent to the Sunda Strait. In the study, the highest significant wave height occurred in the southwest monsoon with a range of 1.25 to 2.975 meters, much higher than the northeast monsoon. In addition, research conducted by Pamungkas (2018) in Kelabat Bay and Sadai Strait (Bangka) showed significant wave heights in the southwest monsoon, with average wave heights higher than the northeast monsoon, ranging from 0.1 to 0.5 meters (in the north) and 0.1 to 0.3 meters (in the south). This consistency confirms that the influence of the southwest monsoon is a major factor shaping significant wave dynamics in western Indonesia, including the Sunda Strait, and is important to consider in the management of coastal areas and marine energy potential.

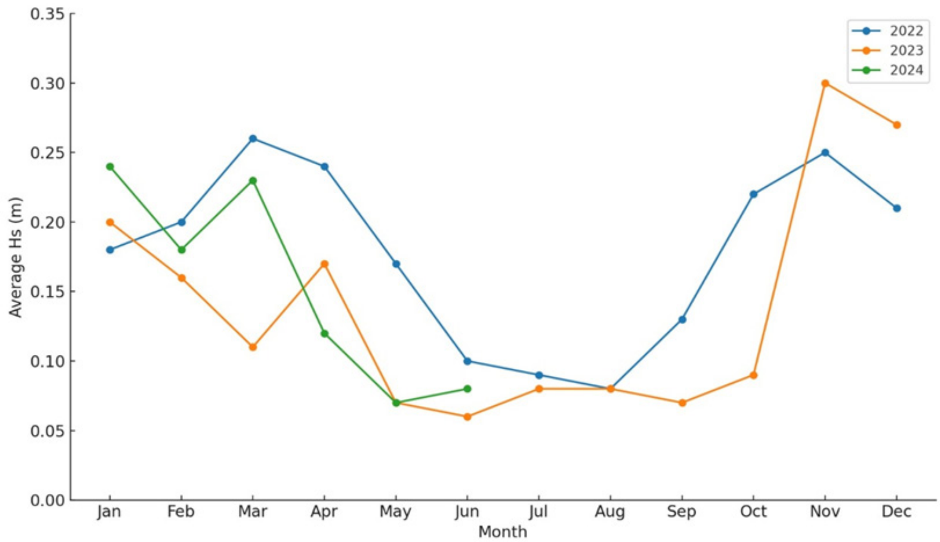

Figure 6. Average monthly significant wave height for 2022-2024.

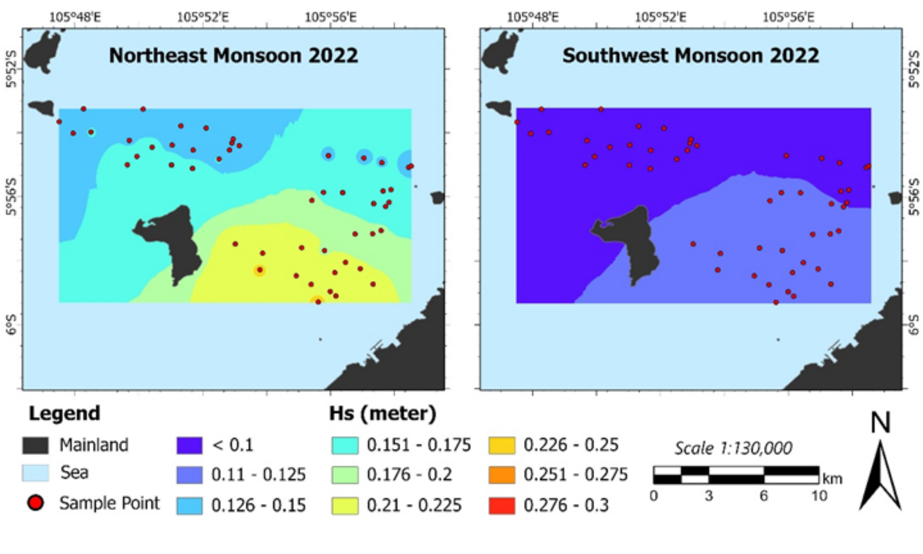

Figure 7. Visualization of significant wave height in 2022.

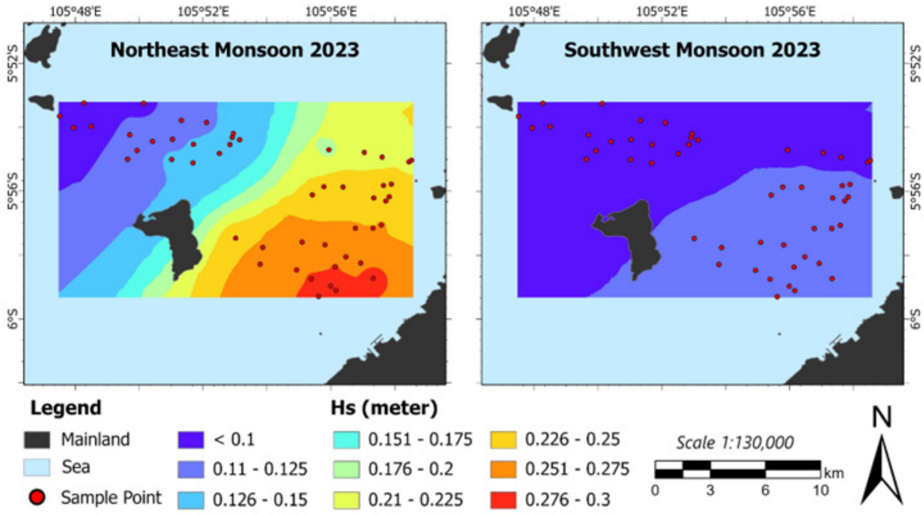

Figure 8. Visualization of significant wave height in 2023.

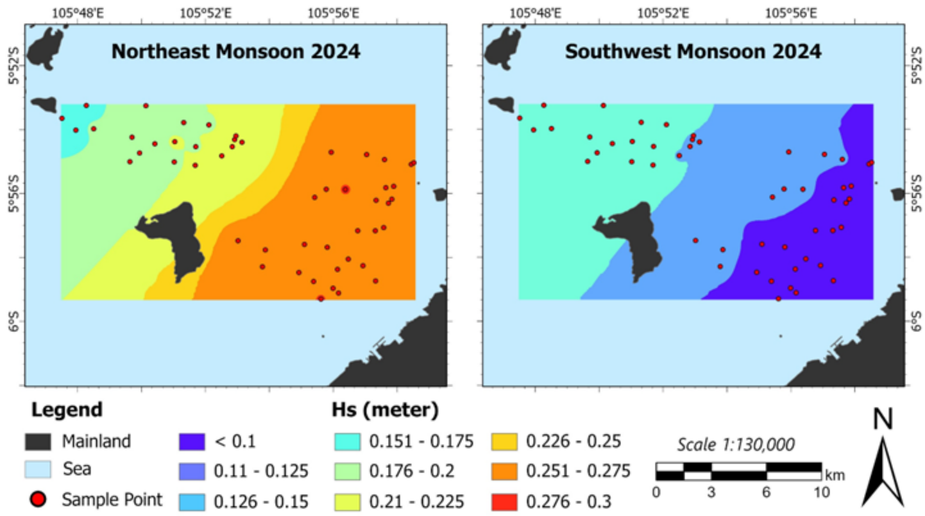

Figure 9. Visualization of significant wave height in 2024.

Table 5. Statistically significant wave height per monsoon in 2022-2024.

Year	Monsoon	Min (m)	Max (m)	Mean (m)
2022	Southwest	0.060197811	0.259840012	0.15538512
	Northeast	0.013669756	0.175009514	0.094480635
2023	Southwest	0.005298336	0.25963549	0.091279944
	Northeast	0.047111558	0.098649462	0.055340842
2024	Southwest	0.072844071	0.161744146	0.107902754
	Northeast	0.025261	0.148532	0.074254

CONCLUSION

This study successfully applied the IDW interpolation method to determine the wave height in the waters of the Sunda Strait using wind speed data from three AWS stations, namely Merak Maritime, Ciwandan Maritime, and Bakauheni Maritime. The interpolation results show that the significant wave height tends to be greater in the southwest monsoon than in the northeast monsoon. During the observation period 2022-2024, the maximum wave was recorded at 2.06 meters (in November 2023) during the monsoonal transition, while the minimum wave was close to zero, recorded in June 2022 during the eastern monsoon. The application of IDW successfully visualizes the wave height distribution well, providing a clear picture of the high-risk areas. This method is effective in filling data gaps, which can support decision-making in the maritime sector, especially for risk mitigation and improving operational safety in the Sunda Strait.

ACKNOWLEDGMENTS

The researcher would like to thank the Universitas Pendidikan Indonesia (UPI), the Marine Information System Study Program, BMKG Maritime Meteorological Station Class 1 Merak, and all parties who have contributed through material and moral support so that this research can take place smoothly and optimally.

REFERENCES

Adji SH, Putra RD, Suhana MP, Febrianto T, Koenawan CJ. 2020. Characteristics of Ocean Wave Southern Batam City Waters-Northern Lingga District Waters. *Journal of Applied Geospatial Information (JAGI)*. 4(2): 367-371. DOI: https://doi.org/10.30871/jagi.v4i2.1458.

Arafat AF. 2021. Analisis Kinerja Pelayanan Kapal di Terminal Multipurpose Dermaga 5 Pelabuhan Ciwandan [Thesis]. Yogyakarta (ID): Universitas Islam Indonesia.

Arifin WA, Ariawan I, Rosalia AA, Sasongko AS, Apriansyah MR, Satibi A. 2021. Model Prediksi Pasang Surut Air Laut pada Stasiun Pushidrosal Bakauheni Lampung Menggunakan Support Vector Regression. *Jurnal Kemaritiman: Indonesian Journal of Maritime*. 2(2): 139-148. DOI: https://doi.org/10.17509/ijom.v2i2.35149.

Aswad IAH, Armono HD, Rahmawati S, Ridlwan A, Ariefianto RM. 2021. Pemodelan Tinggi Gelombang untuk Kajian Energi Gelombang Laut di Perairan Barat Provinsi Lampung. *Wave: Jurnal Ilmiah Teknologi Maritim*. 15(2): 75-84. DOI: https://doi.org/10.29122/jurnalwave.v15i2.4958.

Avrian R. 2020. Analisis Karakteristik Gelombang Laut dengan Periode Ulang di Perairan Selat Sunda [Thesis]. Malang (ID): Universitas Brawijaya.

Illona DJ, Jaya YV, Koenawan CJ, Suhana MP. 2018. Global Warming dan Pengaruhnya terhadap Karakteristik Gelombang Laut di Pantai Timur Pulau Bintan yang Ditinjau dari Perspektif Klimatologi. *Dinamika Maritim*. 7(1): 20-26.

Laili AN. 2023. Analisis Optimalisasi Komunikasi Bencana BPBD Pamekasan dalam Penanggulangan Bencana Banjir Maret 2022 [Dissertation]. Madura (ID): Institut Agama Islam Negeri Madura.

Machdani S, Prihantoko KE, Suherman A. 2023. Tingkat Pemanfaatan Fasilitas Pelabuhan Perikanan (Studi Kasus: Pelabuhan Perikanan Pantai Lempasing). *Jurnal Perikanan Tangkap: Indonesian Journal of Capture Fisheries*. 7(2): 42-52.

Maleika W. 2024. The Effect of the Density of Measurement Points Collected from a Multibeam Echosounder on the Selection of IDW Interpolation Points in the Process of Creating Seabed Models. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*. 17: 7292-7304. DOI: https://doi.org/10.1109/JSTARS.2024.3378330.

Ma'sum DN. 2021. Analisis Karakteristik Gelombang Menggunakan Metode SPM dan Data Altimetri di Perairan Luwuk Sulawesi Tengah [Thesis]. Bandung (ID): Institut Teknologi Nasional.

Nadira AI, Ismanto A, Hakim AR, Ramdhani A. 2023. Tinjauan Pengaruh Pasang Surut terhadap Arus Permukaan Menggunakan Data HF Radar di Perairan Selat Sunda. *Indonesian Journal of Oceanography*. 5(4): 256-264. DOI: https://doi.org/10.14710/ijoce.v5i4.16834.

Pamungkas, A. 2018. Karakteristik Parameter Oseanografi (Pasang-Surut, Arus, dan Gelombang) di Perairan Utara dan Selatan Pulau Bangka. *Buletin Oseanografi Marina*. 7(1): 51-58. DOI: https://doi.org/10.14710/buloma.v7i1.19042.

Parjito P, Buchari H, Widiastuti EL, Bakri S. 2022. Analisis Alokasi Ruang

Laut dalam Rencana Zonasi Wilayah Pesisir dan Pulau-Pulau Kecil (RZWP3K) Provinsi Lampung. *Jurnal Sumberdaya Akuatik Indopasifik*. 6(1): 11-24. DOI: https://doi.org/10.46252/jsai-fpik-unipa.2022.Vol.6.No.1.186.

Pasaribu RP, Irwan A, Soeprijadi L, Pattirane C. 2020. Studi Alternatif Bangunan Pengaman Pantai di Pesisir Kabupaten Karawang. *PELAGICUS: Jurnal IPTEK Terapan Perikanan dan Kelautan*. 1(2): 83-95. DOI: http://dx.doi.org/10.15578/plgc.v1i2.8875.

Poskota. 2023. BMKG: Waspada Gelombang hingga 2,5 Meter di Sejumlah Perairan Indonesia. https://www.poskota.co.id/2023/11/11/bmkg-waspada-gelombang-hingga-25-meter-di-sejumlah-perairan-indonesia. [25 Juni 2025].

Prasetyo, E, Adi AP. Anwar S. 2022. Pengaruh Besar Pengetahuan Meteorologi Maritim dalam Kemenangan Pertempuran Normandia 1944. *Majalah Ilmiah METHODA*. 12(3): 269-281. DOI: https://doi.org/10.46880/methoda.Vol12No3.pp269-281.

Purnomo A, Sumanto AF, Holis MN. 2023. Desain Antarmuka Web Marine Weather EWS terhadap Jalur Pelayaran di Wilayah Pengamatan BMKG Meteorologi Surabaya. Laporan Praktik Kerja Lapang. Surabaya (ID): Universitas Pembangunan Nasional "Veteran" Jawa Timur.

Putri AAK, Diansyah G, Putri WAE. 2022. Analisis Tinggi Gelombang Signifikan Berdasarkan Model Wavewatch-III di Pantai Alau-Alau, Kalianda, Lampung Selatan. *Buletin Oseanografi Marina*. 11(2): 123-130. DOI: https://doi.org/10.14710/buloma.v11i2.39567.

Rifki M, Purnomo H, Sidiq H, Isjudarto A. 2022. Pemetaan Sebaran Nikel Laterit dan Estimasi Sumberdaya Menggunakan Metode *Inverse Distance Weighting* Berdasarkan Data *Test Pit* pada PT Wahyu Anggi Selaras Kecamatan Pomala Kabupaten Kolaka Sulawesi Tenggara. *Prosiding Seminar Nasional Rekayasa Teknologi Industri dan Informasi XVII Tahun 2022 (ReTII), 8 November 2022*. 105-111.

Rini SE, Harisuseno D, Suhartanto E. 2024. Pemodelan Peta Spasial Hujan Rancangan Metode Isohyet Interpolasi IDW pada Sub DAS Amprong. *Jurnal Teknologi dan Rekayasa Sumber Daya Air*. 4(02): 1361-1371. DOI: https://doi.org/10.21776/ub.jtresda.2024.004.02.138.

Samudra AA, Juhad M, Dewi MP. 2024. Mitigation Strategies and Policies Recommendation for the Economic Impact of the Sunda Strait Megathrust: Seismic Risk Probability Assessment and Cost Loss Estimates. *Journal of Infrastructure, Policy and Development*. 8(11): 9023. DOI: http://dx.doi.org/10.24294/jipd.v8i11.9023.

Sari M, Cahyaningtyas C, Prasetyo SYJ. 2021. Analysis of Landslide Prone Areas in Brebes Regency Using Landsat 8 Images with Inverse Distance Weighted (IDW) Method. *Journal of Information Technology*. 1(2): 1-6. DOI: https://doi.org/10.46229/jifotech.v1i2.276.

Satriadi A, Prayogi H. 2017. Peramalan Tinggi dan Periode Gelombang Signifikan di Perairan Dangkal (Studi Kasus Perairan Semarang). *Buletin Oseanografi Marina*. 6(1): 17-23. DOI: https://doi.org/10.14710/buloma.v6i1.15737.

Setiawan F, Malik K. 2024. Karakteristik Kecepatan Hanyut Gelombang dengan Menggunakan Data Model Global Periode 2022–2023 di Perairan Selat Sunda. *Journal Chart Datum*. 10(1): 11-22. DOI: https://doi.org/10.37875/chartdatum.v10i1.326.

Sitorus JH, Atmojo AT, Bachri S, Prayitno HS, Komarita I. 2022. Analisis Zona Potensi Penangkapan Ikan Berdasarkan SPL, Klorofil-a, dan Boat Detection Serta Mengkaji RZWP3K, Lampung. *Jurnal Teknologi Perikanan dan Kelautan*. 13(1): 89-102. DOI: https://doi.org/10.24319/jtpk.13.89-102.

Suarmahajaya IMS, Dwianto YB, Sasongko RA. 2023. Kajian Penggunaan LiDAR dan Kamera untuk Identifikasi Volume Limbah Tempat Pembuangan Akhir Menggunakan UAV. *Warta Penelitian Perhubungan*. 35(2): 126-134. DOI: https://doi.org/10.25104/warlit.v35i2.2309.

Suhana MP, Nurjaya IW, Natih NMN. 2016. Analisis Kerentanan Pantai Timur

Pulau Bintan Menggunakan *Digital Shoreline Analysis* dan *Coastal Vulnerability Index*. *Jurnal Teknologi Perikanan dan Kelautan*. 7(1): 21-38. DOI: https://doi.org/10.24319/jtpk.7.21-38.

Supit CE, Prasetyo SYJ. 2024. Analisis Potensi Bencana Tanah Longsor di Kabupaten Banjarnegara Menggunakan Interpolasi *Inverse Distance Weigthed* (IDW). *Building of Informatics, Technology, and Science (BITS)*. 6(1): 43-53. DOI: https://doi.org/10.47065/bits.v6i1.5187.

Widianto F, Pahlevi AR. 2023. Analisis Klimatologi Arus Laut Selat Sunda terhadap Situasi Penyeberangan Merak-Bakauheni. *Buletin Meteorologi, Klimatologi, dan Geofisika*. 3(2): 21-27.

Wijayanti MD. 2023. *Energi Gelombang*. Jakarta (ID): Bumi Aksara.

Wulandari ESP, Aziz RA. 2022. Model Prediksi dengan *Artificial Neural Network* untuk Kejadian Banjir Rob di Wilayah Pesisir Kota Bandar Lampung. *Prosiding Seminar Nasional Darmajaya*. 1: 77-84.

Zheng CW, Li XH, Cesar AM, Li CY, Wang Q, Xiao ZN, Yang SB, Chen X, Zhan C. 2022. Global Trends in Oceanic Wind Speed, Wind-Sea, Swell, and Mixed Wave Heights. *Applied Energy*. 321: 119327. DOI: https://doi.org/10.1016/j.apenergy.2022.119327.