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Patterns of Wind and Waves Along the Kenjeran Beach Tourism Areas in Surabaya, Indonesia

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ABSTRACT

Waves are movements of ups and downs of seawater that carry energy. This wave energy can erode the beach shore, including the Kenjeran Beach. The areas of eroded coast will depend on the magnitude of the energy of the waves. This research aimed to analyze wind and ocean waves for the management of coastal tourism areas, mainly related to visitor safety. This research used wind and wave data from BMKG obtained for ten years (2009–2018), and they were processed using Software ArcGis 9.3 and Software WRPOLT View 8.0.2. The statistical method used in this research was the Windrose method, which analyzed the wind direction and speed in a certain place and was the ratio of the wind blowing in each wind direction. The distribution of wind was intended to determine the significant wind speed and direction that have an effect in 10 years. The wind had an average speed of 5.31 m/s from 2009 to 2018. The variation in the dominant wind direction movement occurred in the range of 90° to 270°, but overall, the wind came from the East and Southeast. The highest ocean waves caused by wind in the Kenjeran tourism area were 0.8 m and occurred in 2014. It can be concluded that the wind and the ocean waves in the coastal tourism area of Kenjeran are relatively weak. Thus, in terms of security and safety for visitors, Kenjeran beach is very suitable for tourists.

Keywords: Beach tourism, ocean wave, wind rose

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INTRODUCTION

Kenjeran beach is a part of Surabaya's coast, designated as a tourism area. As a tourist area, weather and climate conditions need to be known in depth because they are an intrinsic component of the vacation experience and become a motivation for tourists, as Scotta and Lemieux (2010) stated. One of the most important climate components is wind. The wind can provide comfort and generate harmful waves to tourists and the environment. The Beaufort wind scale can be used as an indicator standard of wind and waves (Sandino et al., 2016).

Kenjeran beach is mostly a mangrove area and provides an interesting view. According to Mustain et al. (2015), the Integrated Beach Value Index (IBVI) of Kenjeran beach was high, which means that Kenjeran beach was considered good in terms of 36 indicators for ecological aspects in biophysical conditions. The indicators also included conditions of environmental problems.

Nevertheless, some places must be protected from damage caused by scouring by waves or currents, known as coastal abrasion. In addition to coastal abrasion, accretion also occurred in the area, i.e., increased land due to sedimentation. Accretion in Pamurbaya was more dominant than abrasion (Prasita et al., 2019; Herdianti et al., 2017; Prasita, 2015).

Mangrove areas are coastal areas that can be used to protect from abrasion from ocean waves as well as for spawning and calving areas for marine animals, such as fish and mangrove crabs. This area functions as a protector/conservation and is also used for tourism activities. The coastal dynamics in Pamurbaya need to be studied in more detail to maintain and manage this tourism area, especially related to wind and ocean waves.

Therefore, this study aimed to analyze wind and waves for the management of coastal tourism areas, mainly related to visitor safety.

MATERIALS AND METHODS

This research used wind data from BMKG for ten years (2009–2018). The research location was Surabaya Kenjeran Beach from 7° 11' 30" S to 7° 15' 10" S and from 112° 45' 00" E to 112° 50' 22" E. The research location is presented in Figure 1.

The tools and materials needed for this research were the following: Software ArcGis 9.3, Automatic Weather Station (AWS) in BMKG, and wind and wave data during 2009–2018 (BMKG, 2019). The data were needed over a long period because they were needed as a basic condition for future planning. The wind data were processed and analyzed using Software WRPOLT View 8.0.2. The overall data processing flowchart is shown in Figure 2.

Methods used in this data retrieval were based on BMKG data. The data were observed from synoptic observations of meteorological stations and the other meteorological observations, which were interpolated using a mesoscale numerical weather prediction (NWP) system designed for atmospheric research and operational forecasting applications.

It features two dynamical cores, a data assimilation system, and a software architecture supporting parallel computation and system extensibility. These products produce a model which serves a wide range of meteorological applications across scales from hundreds of meters to thousands of kilometers.

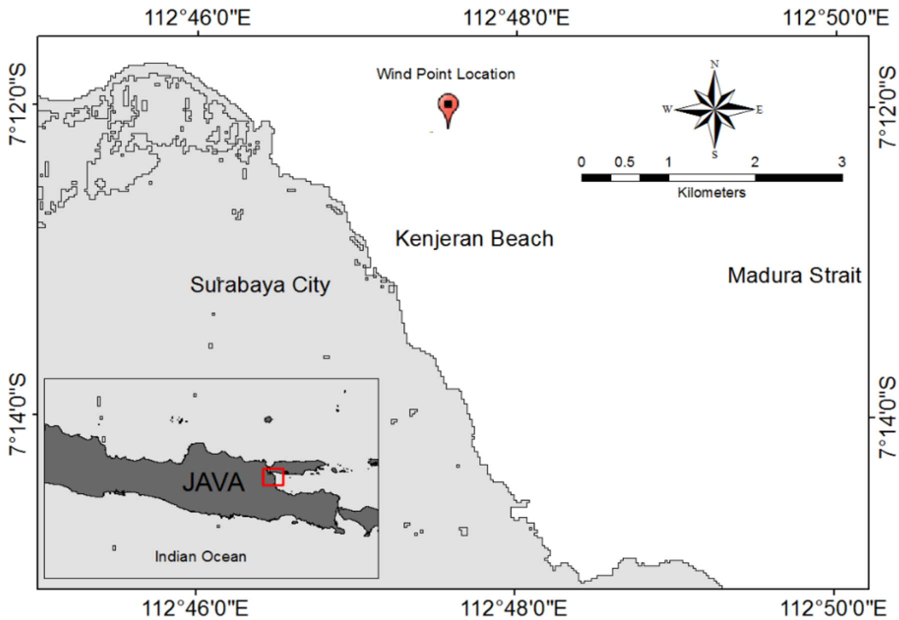

Figure 1. Research location in the Kenjeran Beach Surabaya

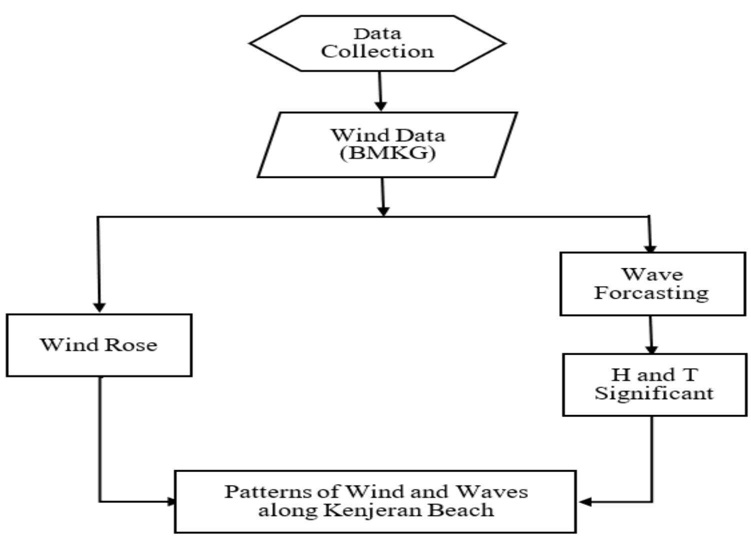

Figure 2. Flowchart of the research

The inputs of data are based on ideal situations where meteorological parameters were observed, while statistical calculations were used to determine probable past conditions. The data from this hindcast were stored in a server that could be accessed over websites using a *pythonic* script by inserting coordinates and *hindcast* dates. The accurations of its data based on verification and validation of BMKG monthly reports were about 70-85% based on its season, whereas transition season will result in lower accurations. The highest accurations are obtained in dry seasons.

The method for making windrose was as follows: (1) Preparing data from BMKG for format adjustment in the WR Plot process. This preparation was done by removing the parts that did not match and inserting a column for the separation of date, month, and year. The data were saved in Excel format; (2) Running WRPlot started importing the above excel file. At first, open and fill in the data according to the WRPlot format specification. The data entered were Year, Month, Day, Hour, Wind Direction, and Wind Speed. Then station, longitude, and latitude were entered. The result of this import file was saved in .sam file format, which was then processed with WRPlot; (3) Displaying Windrose in WRPlot. First, by changing the wind direction 8, Units knots, orientation direction blowing. Furthermore, the windrose was kept in A5 paper form for clear viewing. The WRPlot creation method was described in detail in the WRPlot view user guide (Jesse et al., 2016).

Wind data from BMKG were processed for windrose, wave forecasts, wave height, wave period, breaking waves and wave energy (Prasita et al., 2021). Correction of location effects was needed because wind data came from the ground stations not measured directly above sea level or on the coast. An existing chart was used to change the wind speed blowing on the water (Prasita et al., 2018; Engki & Viv, 2018). The relationship between sea breeze and the land wind is shown in Equation 1.

$$RL = U_W/U_L \qquad [1]$$

where U_L is land wind speed, U_W is sea breeze speed, and RL is the relationship between sea wind speed and land wind. After the location effect was corrected, the next step was to convert wind speed into a wind stress factor, as shown in Equation 2.

$$U_A = 0.71U^{1.23} \qquad [2]$$

where U_A is wind stress factor (m/s) and U is wind speed (m/s).

Wave forecasting through graphs (Prasita et al., 2018), if the fetch length (F), wind stress factor (U_A), and duration were known, then the height and significant wave period could be calculated. It was necessary to know the duration of sea wind speed, wind stress factor (U_A), and effective fetch to estimate the wave height. This estimation only applied to significant waves, namely the average of 33% of the highest waves of all waves that occurred in waters that had been predicted of high waves (Dauhan et al., 2013).

Effective fetch is a wave generator area with constant wind direction and direction. The effective fetch equation is shown in Equation 3.

$$F_{eff} = \frac{\sum X_i \cos\alpha}{\sum \cos\alpha} \qquad [3]$$

where F_{eff} is the effective average fetch, X_i is the length of the fetch segment measured from the wave observation point to the end of the fetch, α is the deviation on both sides of the wind direction, using an increase of 6° to an angle of 42° on both sides of the wind direction.

Estimating wave forecasting was done through graphs to obtain the period and height of the wind generation wave. Forecasting waves were done through graphs if fetch length (F), wind stress factor (U_A), and duration are known height, and significant wave period can be calculated. It was necessary to know the duration of sea wind speed, wind stress factor (U_A), and effective fetch to estimate the wave height. This estimation only applied to significant waves, namely the average of 33% of the highest waves, of all waves that occurred in waters that have been predicted of high waves (Dauhan et al., 2013).

The determination of the breaking wave was carried out using the graph (CERC, 1984). The graph stated the relationship between Ho/gT^2 and Hb/H'o. The H'o value is the height of the equivalent waveform, g is gravity, and T is the wave period. H'o was obtained from the calculation of the refraction coefficient and wave height that propagates from the deep sea, as presented in Equation 4.

$$H'o = Kr\ x\ Ho \qquad [4]$$

After obtaining a breaking wave height value (Hb), the depth of the breaking wave (db) is determined. Determination of the breaking wave depth was based on the calculated value of Hb/gT^2.

Wave energy was calculated using Equation 5, where ρ is the density of seawater with a value of 1,030 kg/ m^3, g is the earth's gravity with a value of 9.81 m/s^2, and H is the wave height at a certain depth. In this study, the calculated wave energy was wave energy at a depth of the breaking wave that occurred.

$$E = \frac{\rho g H^2}{8} \qquad [5]$$

This research was limited to the study of wind-generated waves and analyzed using windrose analysis. This method is used to analyze the wind direction and speed in a certain place and is the ratio of the winds blowing in each wind direction.

RESULTS AND DISCUSSIONS

The distribution of wind speed and direction in the District of Kenjeran for ten years analyzed on an annual basis is shown in Table 1. The distribution of wind was intended to determine the significant wind speed and direction that have an effect in ten years. The wind had an average speed of 5.31 m/s. This value occurred during the ten years, namely from 2009 to 2018. This relatively small value was included in the 3-scale value based on the Beaford scale, namely Gentle Wind (Sandino et al., 2016). The variation in the dominant wind direction movement occurred in the range of 90° to 270°. However, overall the wind that occurred came from the East and Southeast in accordance with the wind direction category based on Dauhan et al. (2013), namely Southeast Wind Direction Category if they have values of 112.5° to 157.5°. However, in 2018 there was a slight change in the dominant direction of the incoming wind, namely from the west (270°). The wind distribution patterns on the Kenjeran beach waters from 2009 to 2018 are explained below.

Table 1
Distribution of the dominant winds for 10 ten years

Year	Wind	
	Speed (m/s)	Direction (°)
2009	1.97	135
2010	2.07	135
2011	2.98	90
2012	3.31	135
2013	3.39	90
2014	3.51	90
2015	2.59	135
2016	2.04	90
2017	2.55	135
2018	2.87	270

The Wind Pattern of the Kenjeran Beach Water During 2009-2018

Wind speed and direction in 2009 are shown in Figure 3. During this period, the wind record shows that the wind spreads from all directions with a predominance of gusts from the southeast and east, about 25% and 20%, respectively. Winds are rarely found blowing from the north and northeast (<5%). Winds of 0-2 m/s and 2-4 m/s were the dominant winds (~44%), while winds of >8 m/s were also recorded, although with a frequency of

0.2%. Although the frequency was very small, the emergence of the strongest winds during 2009 needed to be watched out for considering the potential danger, especially since the patterns spread from many directions, especially from the west-northwest. It was a wind condition with a minimum dominant speed for the last ten years.

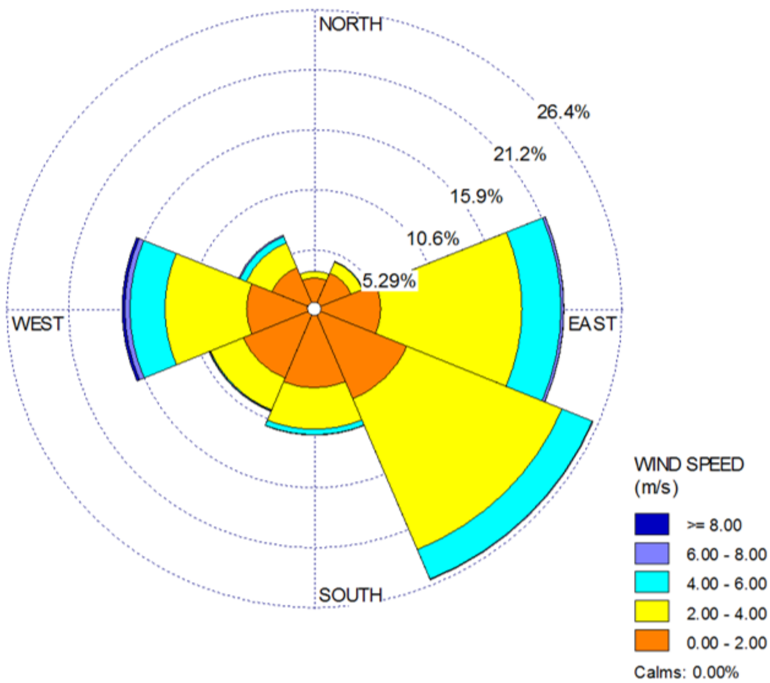

Figure 3. Distribution of wind speed and direction in 2009

The same wind pattern was still found a year later. The 2010 record showed the southeast and east winds were still dominant with a range of ~26.5% and ~17.5%, respectively, in Figure 4. The westerly wind decreased slightly in frequency, followed by a slight increase in the southwest wind. Wind speeds of 0-2 m/s and 2–4 m/s dominated in the range of 45% and 40%, followed by increasing wind speeds of 8 m/s (0.5%). The same pattern for the strongest wind speed >8 m/s also still confirmed the dominance of the strongest winds from the northwest-west sphere.

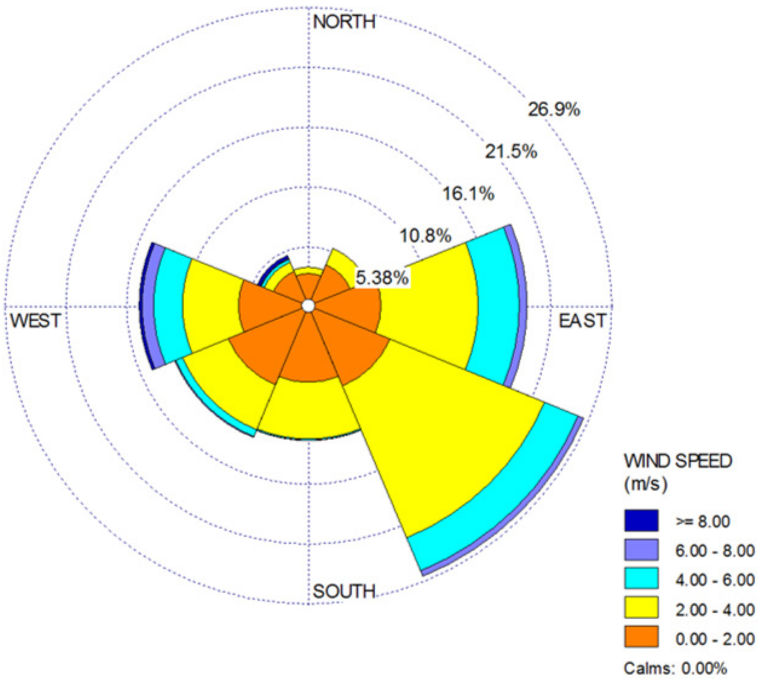

Figure 4. Distribution of wind speed and direction in 2010

The pattern of wind speed and direction in 2011 is shown in Figure 5. The wind pattern changes with the increasing dominance of the east wind in 30% of the frequency of occurrence. The southeast wind was reduced to <20%, almost matching the westerly wind. The south wind was also much reduced compared to the same wind in the two previous periods. The wind was blowing harder with the dominant wind speed of 2–4 m/s (35.4%) and 4-6 m/s (26.0%). This wind tightening was also reinforced by recorded winds of 6-8 m/s and 8.0 m/s, which became 9.4 m/s and 2.2 m/s. Slightly different from the previous strongest wind pattern, which was dominated by the northwest-west direction, in 2011, the strongest winds were blowing from the west-northwest. In addition, relatively dominant winds with a strength of > 8 m/s were recorded moving from the east during this period.

The wind speed and direction in 2012 are shown in Figure 6. In this period, the wind pattern returned to the same as in 2009 and 2010 with the strengthening of the east-southeast wind (~25%) and the dominant wind speed of 0-2 m/s (37.9 m/s) and 2-4 m/s (45, 5%). The wind blowing 8 m/s was also much reduced (0.6%). In this period, winds of >8 m/s from the east were no longer recorded. Winds blowing from this direction generally weakened from the previous year. The domination of the westerly wind, followed by the northwest wind in the previous periods, was happening again.

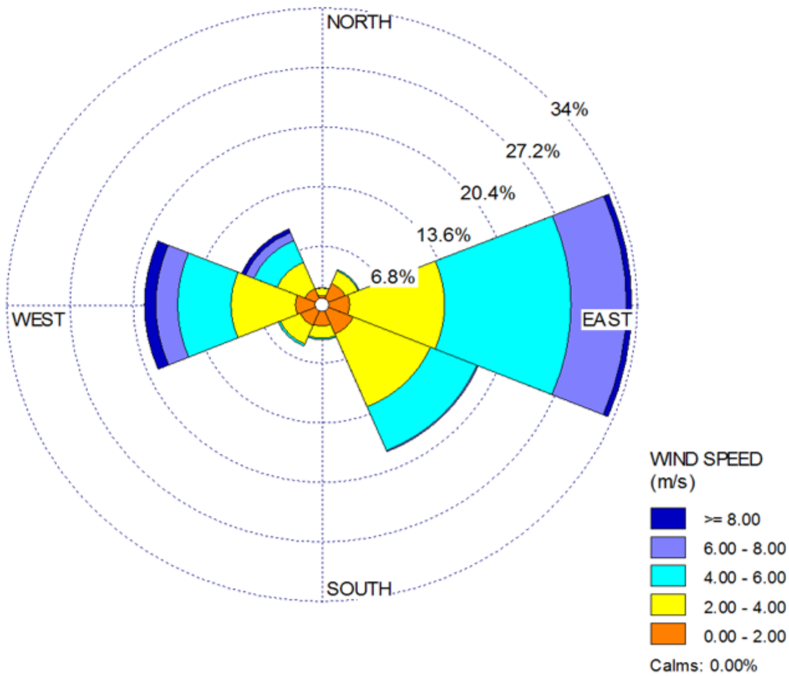

Figure 5. Distribution of wind speed and direction in 2011

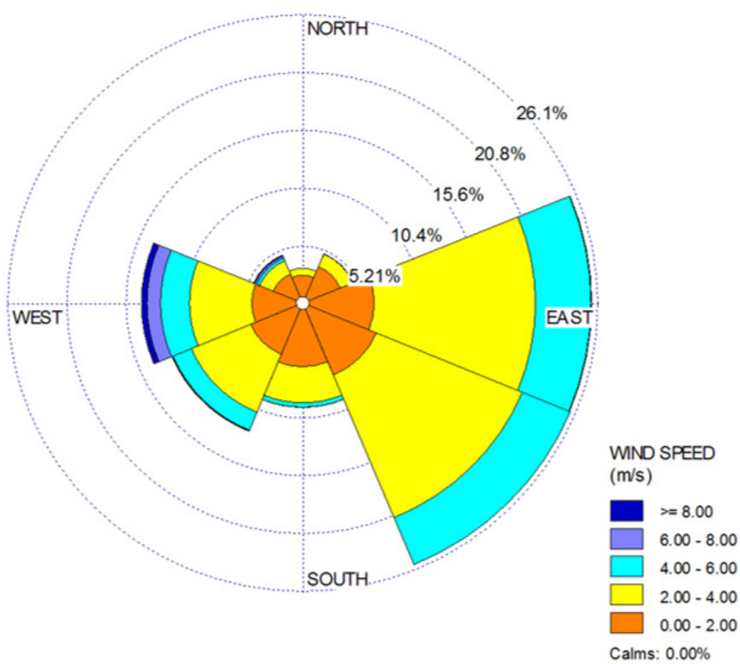

Figure 6. Distribution of wind speed and direction in 2012

The speed and direction of the wind in 2013 are illustrated in Figure 7. The domination of the east-southeast winds, respectively ~29% and ~20%, was still recorded, as were the westerly winds (~20%). The strongest winds (≥8.0%) were mostly found from the west out of a 6.4% frequency of occurrence. Wind speed of 6-8 m/s also increased by 10% from before and became 12.0%. In 2013 the strongest winds (>8 m/s) were still dominantly blowing from the west, followed by a weakening of the strongest winds from the northwest, followed by strengthening the frequency of gusts of similar speed winds from the east. The pattern that occurred this year resembled the wind pattern of the previous two years.

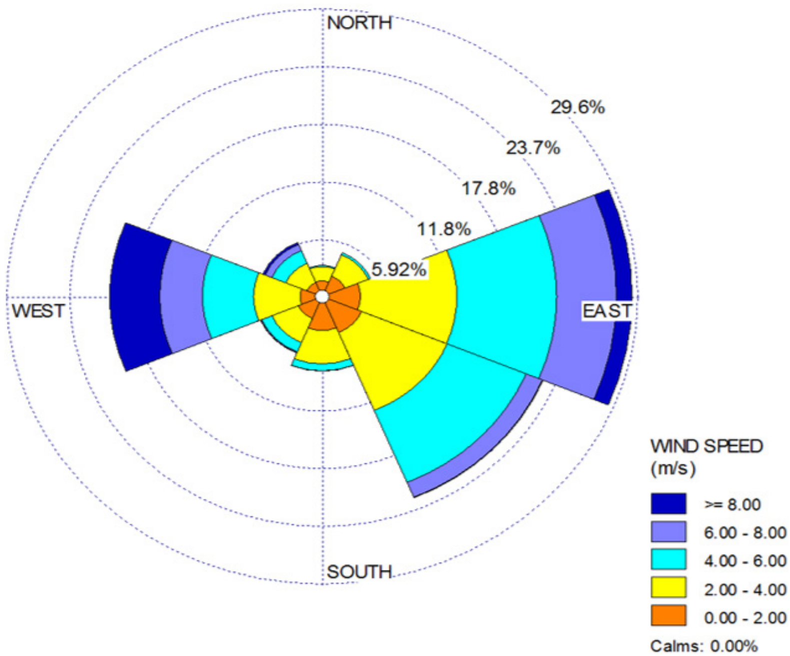

Figure 7. Distribution of wind speed and direction in 2013

The wind speed and direction in 2014 are shown in Figure 8. The wind patterns resembled the wind pattern of the previous year with slight variations in wind direction and speed. East winds still dominated with a slight increase in incidence (~30%), as did southeast winds (~25%). The slight increase in both wind directions was followed by weakening the westerly wind from a year earlier (~20% to ~15%). In 2014 the relative wind speed had the same pattern with a slight variation from the 2013 wind pattern, marked by a weakening of the wind speed of 2–4 m/s from 21.7% (2013) to 14.9%. The weakening wind speed of 0-2 m/s was accompanied by the strengthening of the wind speed of 4–6 m/s and 6-8 m/s, which are now 30.6% and 15.4%, respectively. The wind pattern of >8 m/s this year was still relatively the same as the wind pattern of the previous year, each of which was dominated by winds blowing from the west, east, and northwest.

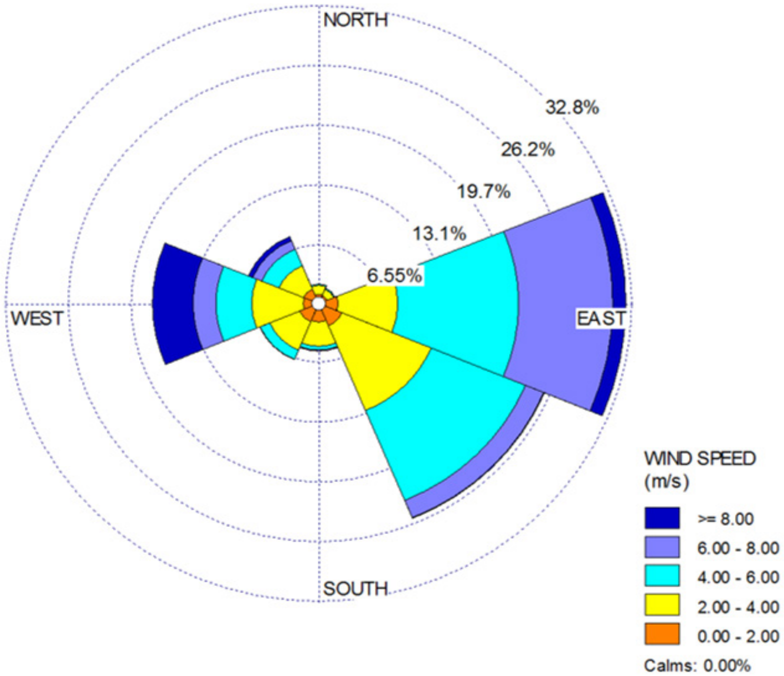

Figure 8. Distribution of wind speed and direction in 2014

The wind speed and direction in 2015 are shown in Figure 9. In 2015 the wind pattern was still relatively the same with variations in the direction of arrival and wind speed. The striking difference from the previous year was the dominant southeast wind (~28%) and the weaker east wind (~20%). This year was also marked by a weakening of wind power. Wind speeds of 6-8 m/s and 8 m/s were at 3.8% and 0.2%, respectively. West winds and east winds still dominated the arrival of the strongest winds during 2015. The strengthening of the southeast wind in this period was followed by a low frequency of strong winds with a strength of >8 m/s. The strongest wind dominance was recorded blowing from the west-northwest as in previous periods. Wind speed >8 m/s, which was previously recorded strikingly from the east, was no longer happening.

The speed and direction of the wind in 2016 are illustrated in Figure 10. The weakening of wind speed was increasing even though the wind speed of 2-4 m/s still dominated (53.1%), an increase of 13.7% from the previous year. Wind speed levels of 4-6 m/s, 6-8 m/s and 8 m/s were now also experiencing a decline of 19.4%, 2.5% and 0.1%, respectively. This period was also marked by strengthening the dominance of the east wind by ~20% from the previous, and the weakening of the dominance of the southeastern wind, which was ~15%. The dominance of the east wind in this period was followed by the lower frequency of the strongest winds with a speed of >8 m/s. Recorded data still showed that the strong winds were blowing from the west-northwest like the wind patterns of the previous periods.

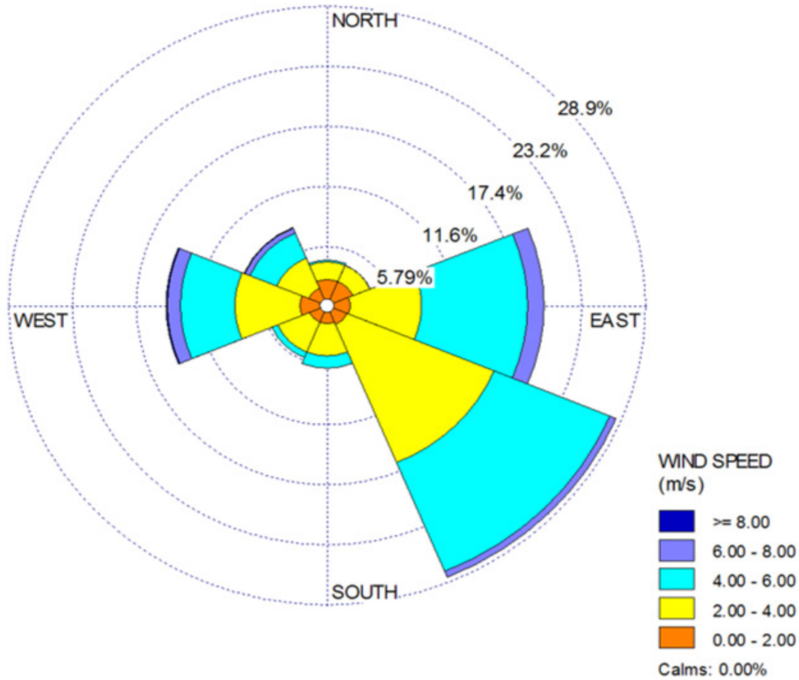

Figure 9. Distribution of wind speed and direction in 2015

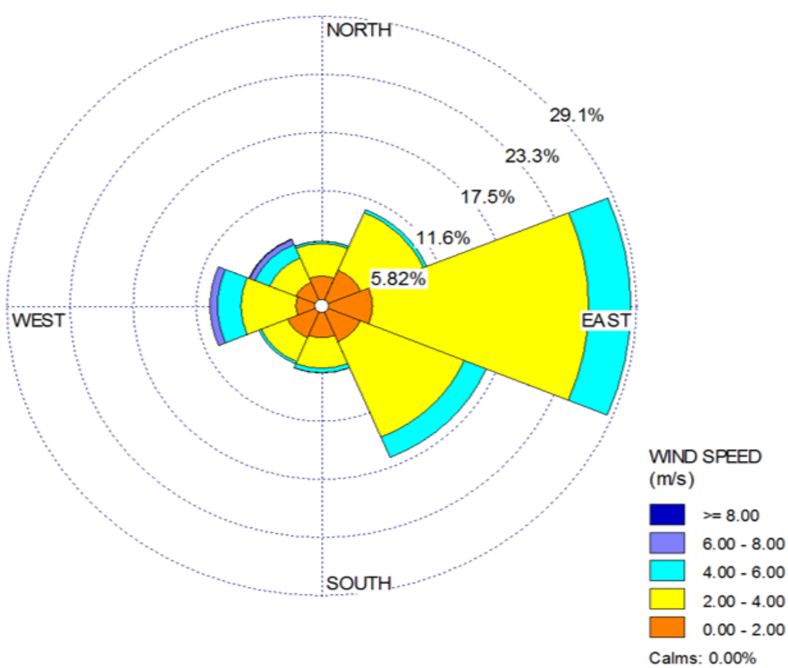

Figure 10. Distribution of wind speed and direction in 2016

The pattern of wind speed and direction on the coast in 2017 are shown in Figure 11. The wind continued to spread from all directions with various frequencies. However, there was the weakening of the east wind, which dominated the previous year (~29%) to (~12%), and the strengthening of the southeastern wind from ~11% to ~29%. Almost half (48.3%) of the winds that occurred this year moved at a speed of 2–4 m/s. In addition, during this period, the wind speed also experienced a slight strengthening. Wind speeds of 4-6 m/s, 6–8 m/s and 8 m/s were recorded at 23.7%, 5% and 0.6%, respectively. Wind speed >8 m/s weakened. In this period, the frequency of the wind was recorded as blowing from the northwest, without being followed by a northwest or east wind like in previous periods.

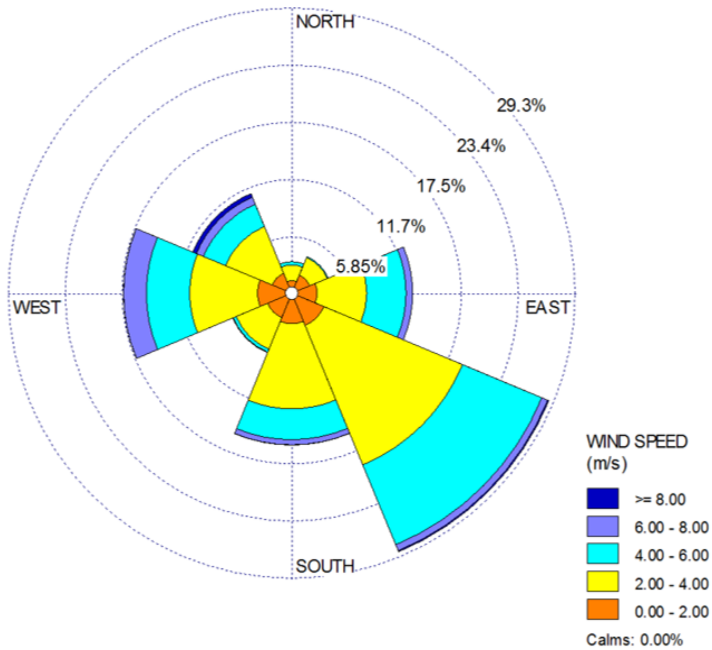

Figure 11. Distribution of wind speed and direction in 2017

The wind speed and direction in 2018 are shown in Figure 12. The wind pattern in this period was characterized by the weakening of the dominance of the southeast-east wind strength and the strengthening of the west wind. The strengthening of the westerly wind, which was the most dominant (~25%), although the frequency was almost the same as the southeast wind (~23%), marks a change in pattern from the previous wind pattern (2009-2017). The change in the domination of the wind direction indicated a strengthening of local-regional influence. The wind speed classification still had the same pattern as the previous year's pattern, although the values were different. Wind speeds of 2–4 m/s still dominated with 45.1%, followed by wind speeds of 4-6 m/s, 0–2 m/s, 6-8 m/s and 8 m/s, respectively 31 .2%, 13.5%, 9.2% and 1.0%. In 2018 winds of >8 m/s were recorded again blowing from the west-northwest as the strongest wind pattern in the previous periods in this region.

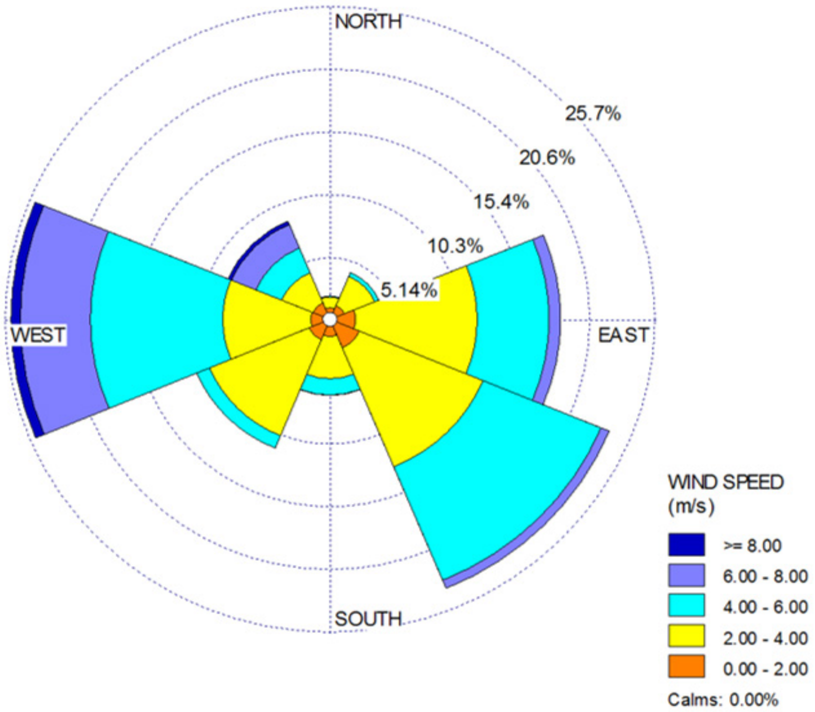

Figure 12. Distribution of wind speed and direction in 2018

The wind pattern in the waters of the Madura Strait around Kenjeran during the period 2009-2012 showed the relatively dominant east-southeast wind with a dominating speed of 2–4 m/s. A slight difference was shown by the wind pattern in 2011 when the wind experienced an increase in gusts from the east (~35%) without being followed by southeast domination. In that year, the wind speed was also recorded to strengthen with recorded wind speed data of 6-8 m/s reaching 9.4%, and wind speeds were exceeding 8 m/s as much as 2.2%. In the other three years, the speed >8 m/s the frequency distribution never exceeded 0.5%, except in 2012, which was recorded at 0.6%.

The wind pattern during the 2013–2016 period in the waters of the Madura Strait around Kenjeran confirmed the dominance of wind from the east. The exception occurred in 2015 when southeast winds predominated with a frequency of ~30%. Wind speed in the range of 2-4 m/s still dominated with a frequency range of 30-50%.

The dominance of the southeast wind was still recorded in 2017-2018 in the waters around Kenjeran Beach. Although winds of 8 m/s still occurred, the frequency of occurrence was relatively very small, at 0.6% and 1.0%, respectively. The wind blew from all directions with various distribution frequencies. An interesting phenomenon in the last two years of this research period was the strengthening of the westerly wind. The west wind in 2018 became the most dominant wind (~25%) of the series of air mass movements that crossed the research area, including the east-southeast wind (<20%), which during the eight years of the study relatively dominated.

In general, the typology of the wind direction pattern of Kenjeran coastal waters as part of the Madura Strait was characterized by the predominance of the southeast and/or east winds. The dominance of southeast and/or east winds indicated the influence of the condition of the Madura Strait, which was semi-closed: open in the east, which was much wider (~80 km at the eastern inlet) and narrows in a north-northwest direction (~25 km at the inlet from the north). In the waters of the Madura Strait, as part of the marine area of the Indonesian Archipelago, which was ideal for monsoons, the configuration of the shape of the strait can potentially affect the course of the wind that was blowing. This condition was allegedly forcing a much larger wind movement from the east-southeast side, especially in the east monsoon when regional winds moved from the Australian continent to the Asian continent. The wind strengthened as it moved into a narrower northwest side.

When the west monsoon takes place, the wind movement from the Asian continent to the Australian continent enters the Madura Strait through the Java Sea area on the north side. The strait inlet on the north side has a width of ~25 km (waters of Pangkah Kulon, Gresik) and then turns southeast to finally enter Kenjeran waters from the relatively narrow west side (~2.5 km in the waters of Kedung Cowek, Surabaya). When fluids, including wind, enter a narrower area, their speed will increase. Therefore, during certain periods, especially during 2012–2013 (5–6%), winds of 8 m/s were found blowing from this direction. In addition, the terrestrial bend in the form of the Madura Strait had the potential to weaken wind stability through the relatively large number of wind direction deviations at low speeds. It was recorded from the low frequency of wind events through the north to the southwest (as the main cardinal wedge to the west) throughout the year.

Therefore, the dominance of westerly winds over east-southeast winds in 2018 marked the interruption of the main wind pattern in the Kenjeran waters as part of the Madura Strait, indicating that other factors were at play. Local-regional phenomena occurring and strengthening, such as the Indian Ocean Dipole (IOD), are thought to contribute to the strengthening of the westerly wind. Positive IOD, as stated by Azuga et al. (2020), occurred in October 2018. The intensity of rainfall during the positive IOD phase was 157 mm/month and increased to 525 mm/month during the negative IOD phase. October was when the wind began to change direction, which marks the second transitional season ahead of the west monsoon. The strengthening of the westerly wind was thought to occur in these periods. Further research is needed to confirm whether the Indian Ocean heat transfer axis, which is on the west side of the research location, contributes to various levels in certain periods. The focus was directed at other meteorological factors besides rainfall, as has been done so far, including wind patterns.

Results of Effective Fetch Calculation

The drawing and calculation of the fetch were done to determine the region of wave formation caused by wind in an area. Fetch in the Kenjeran region is presented in Figure 13. Fetch occurred in the Southeast direction based on the dominant wind in the region with the calculated fetch value presented in Table 2, which was 73.87 km. The length of the fetch line at an angle of 6° to 42° with respect to the main direction line (0°) was blocked by land while the angle of -6° to -42° with respect to the line of 0° was unobstructed by land. The line that was unobstructed by the land had an infinite distance. However, the wind that blew on an infinite area would still have energy that was increasingly fading away and eventually disappear. If the fetch line had more than 200 km, the line was said to have a maximum fetch distance of 200 km (Yudhicara & Yossy, 2011).

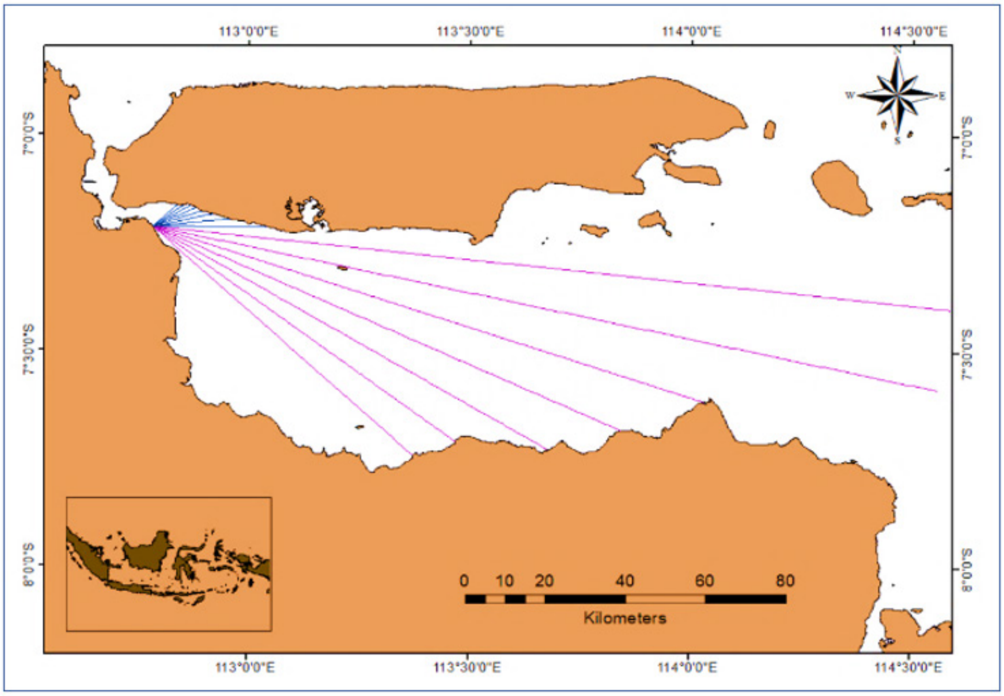

Figure 13. Fetch occurred in the East Coast region of Surabaya

Table 2

Calculation of fetch

No	Direction (α)	Fi (Km)	Cos α	Fi cos α	Fetch Effective (Km)
1	42	8.40	0.74	6.25	
2	36	9.40	0.81	7.60	
3	30	10.99	0.87	9.52	
4	24	11.85	0.91	10.83	
5	18	12.88	0.95	12.25	
6	12	15.55	0.98	15.21	
7	6	19.31	0.99	19.20	
8	0	28.37	1.00	28.37	73.87
9	6	200.15	0.99	199.05	
10	12	200.14	0.98	195.77	
11	18	144.61	0.95	137.54	
12	24	128.03	0.91	116.96	
13	30	114.61	0.87	98.73	
14	36	93.61	0.81	75.73	
15	42	87.49	0.74	65.02	
	Total		13.51	998.03	

Wind Wave

In forecasting waves before getting high values and wave periods required values of the wind stress factor (U_A) and the fetch length that occurred in the region. U_A and fetch values, as well as the results of forecasting height and wave periods each year, were presented in Table 3.

Patterns of wave fluctuations form non-repetitive curves. In the first four years of the study, wave heights had the same wave heights because U_A formed less than 5, while in the next two years, there was an increase, then there was a decrease in wave height in 2015 and again the same in 2015 to 2018 wave heights like the four preceding years. Increased wave height occurred in 2013 with a difference of 0.004 m from the mean wave height, while a decrease occurred in 2014 with a difference of 0.044 m from the average wave height. The wave height value each year was then searched for significant wave values that have occurred for ten years in the Kenjeran Districts. Significant wave results in 10 years found that the wave height occurred 0.77 m with a 4.64-second wave period. The direction of the waves was adjusted to the direction of the wind that forms them, originating from the Southeast.

Table 3
Calculation of forecasting waves

Year	Wind speed (m/s)	RL	U_W	U_A	Feff	Wave	
						H(m)	T(s)
2009	1.97	1.80	3.55	3.37	73.87	0.75	4.60
2010	2.07	1.75	3.63	3.47	73.87	0.75	4.60
2011	2.98	1.65	4.92	5.04	73.87	0.75	4.60
2012	3.31	1.60	5.30	5.52	73.87	0.75	4.60
2013	3.39	1.59	5.39	5.64	73.87	0.76	4.62
2014	3.51	1.58	5.54	5.84	73.87	0.80	4.70
2015	2.59	1.70	4.40	4.39	73.87	0.75	4.60
2016	2.04	1.75	3.57	3.40	73.87	0.75	4.60
2017	2.55	1.70	4.33	4.31	73.87	0.75	4.60
2018	2.87	1.65	4.73	4.80	73.87	0.75	4.60

Wind and Wave Condition in Kenjeran Beach for Tourist' Safety

From the wind and wave analysis results for the last ten years above, the dominant maximum wind speed of 3.51 m/s occurred in 2014. The wind speed was classified as weak according to the Beaufort wind scale (Sandino et al., 2016). Moreover, the maximum wave height at Kenjeran beach was 0.8 meters, so the wave height was categorized as a low wave (Table 4). Therefore, Kenjeran beach was classified as a safe and comfortable beach for traveling. This safety and comfort had also been studied by Mustain et al. (2015) by measuring the Integrated Beach Value Index (IBVI).

Table 4
Wave category

Wave Height (m)	
0.1 - 0.5	Calm (Tenang)
0.5 - 1.25	Low (Rendah)
1.25 - 2.50	Moderate (Sedang)
2.50 - 4.0	High (Tinggi)
4.0 - 6.0	Very High (Sangat Tinggi)
6.0 - 9.0	Extrem (Ekstrem)
9.0 - 14.0	Very Extrem (Sangat Ekstrem)

Sources: BMKG (2018)

CONCLUSION

The study concluded that the wind and the ocean waves in the coastal tourism area of Kenjeran were relatively small. The average wind speed was 5.31 m/s from 2009 to 2018, and the dominant wind direction was 90° to 270°. The highest wave height of 0.8 m occurred in 2014. Thus, based on the wind and the wave, in terms of the safety and security of visitors, the location of Kenjeran beach was very suitable for tourists. Further research needs to be conducted on conditions of currents, both currents caused by waves and tides, as well as soil/geological conditions for the development of underwater tourism.

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