

Physical Oceanography Condition in Eastern Karimata Strait: Pasir Mayang Beach West Kalimantan

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Abstract

Karimata strait is located in the western Indonesian, separate the Kalimantan and Belitung island, that has an important role for the distribution services. The information about its dynamics such as tidal behavior, and wave is the key to support the navigation activities in this area. This research describes the results of measurements of the physical oceanography parameter on the eastern side of the Karimata Strait, Pasir Mayang Beach. The tidal data were measured for 15 days in February 25th – March 12th, 2017 and sea current were observed for 24 hours on February 27-28th, 2017. The result showed that tidal type in this area is diurnal tide with amplitude of M₂, S₂, K₁, and O₁ respectively are 0.085 m, 0.086 m, 0.455 m, and 0.342 m. Significant wave's high is ranged from 0.12 – 0.31 m with significant period of 5.32-6.9 s. The wave direction is south western. The current velocity is ranged from 0.087- 0.112 m/s and average current velocity is 0.092 m/s. The tidal current direction is northeast at low tide and south western at high tide. This study also reveals important information that wave energy variability is not only affected by seasonal conditions but also influenced by tides. The tides have responsibility to change the propagation medium of wave that is originated dispersive to non-dispersive medium. This study opens a new study of correction of wave measurement procedures by including and taking into account the effects of tides.

Keywords: Karimata strait, parameters of physical oceanography, tides, waves

Kondisi Oseanografi Fisis di Sisi Timur Selat Karimata: Pantai Pasir Mayang Kalimantan Barat

Abstrak

Selat Karimata terletak di Indonesia Bagian Barat, memisahkan antara Pulau Kalimantan dan Pulau Belitung, memiliki peran penting dalam distribusi barang dan jasa. Informasi mengenai kondisi dinamik seperti pasang surut (pasut) dan gelombang sangat penting untuk mendukung kegiatan navigasi di wilayah ini. Penelitian ini memaparkan hasil pengukuran parameter oseanografi fisis tersebut di sisi timur Selat Karimata, Pantai Pasir Mayang. Data pasang surut diukur selama 15 hari, tanggal 25 Februari-12 Maret 2017 dengan interval 1 jam sedangkan pengukuran gelombang dilakukan selama 3 hari, tanggal 3-5 Maret 2017 dan arus laut diamati selama 24 jam, tanggal 27-28 Februari 2017. Hasil penelitian menunjukkan bahwa tipe pasang surut di daerah ini adalah harian tunggal (diurnal tide) dengan nilai amplitudo komponen M₂, S₂, K₁, dan O₁ adalah 0,085 m, 0,086 m, 0,455 m, dan 0,342 m. Tinggi gelombang signifikan rata-rata berkisar 0,12-0,31 m dengan periode signifikan rata-rata

5,32-6,9 s dan arah datang gelombang dominan barat daya. Kecepatan arus di lokasi penelitian berkisar antara 0,087-0,112 m/s dan kecepatan arus rata-rata sebesar 0,092 m/s. Pada saat kondisi pasang arah arus dominan ke arah timur laut sementara pada saat surut arah arus dominan ke arah barat - barat daya. Hasil penelitian juga memberikan informasi penting bahwa variabilitas energi gelombang tidak hanya dipengaruhi oleh musim namun juga dipengaruhi oleh pasang surut. Pasang surut berperan dalam mengubah media perambatan gelombang dari yang awalnya dispersif menjadi tak dispersif. Kajian ini membuka penelitian baru terkait koreksi prosedur pengukuran gelombang dengan memasukkan dan memperhitungkan pengaruh pasut.

Kata Kunci: selat Karimata, parameter oseanografi fisis, pasang surut, gelombang

PACS: 92.10.-c, 92.10.ah, 92.10.Hm

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I. INTRODUCTION

Karimata Strait is located in West Indonesia, Figure 1, which separates Kalimantan Island and Belitung Island. The length of the Karimata Strait is estimated to be ~ 150 kilometers and has a depth of ~ 30 meters [1]. This strait connects Natuna Sea and Java Sea so it has an important role in the distribution of goods and services. The role makes these waters a busy shipping lane that has access to the ASEAN, Asia-Pacific, Indonesia and Australia [2]. Therefore, information on dynamic conditions such as tides and waves is very important to support navigation activities in this region.

The tidal studies have been conducted in this area such as by Ray et al [3], Zu et al [4], and Heriati et al [5]. These three studies provide an overview of the tidal conditions in the Karimata Strait using the model. In general, both studies provide good spatial information, but do not have a verification point in the Karimata Strait. In fact, the most dynamic part of their result is located in the Karimata Strait. The void is then supplemented with measurements by Wei et al

in the project "The South China Sea-Indonesian seas Transport / Exchange (SITE) and Impacts on Seasonal Fish Migration" [1].

The study of ocean waves in the Karimata Strait has also been carried out with various empirical and numerical models. In 2012, Ramlan computed high-wave in the Karimata Strait and the Java Sea, using the Wilson IV method with *windwave-05* software [6]. Then in 2015, sea wave computation is also done by Mulyadi et al using the Munck Bretschneider Sverdrup method (SMB) [7]. In the same year, 2015, Wicaksana et al also modeled the wave height in the Karimata Strait and the Java Sea using the Wave-Wach III model [2]. The analysis of wave characteristics in these waters has also been studied by Rachmayani et al 2018 [8]. The four studies use monthly wind data as input models and generate high-wave field in the waters of the Karimata Strait and its surroundings.

All of these studies provide much information for coastal navigation and management activities around the west coast of Borneo, the east coast of Sumatra, and the

northern coast of Java. The above-mentioned tide models provide good results for describing conditions in the Karimata Strait. Ray et al and Zu et al in accordance with the results of field measurements issued by Wei et al. Nevertheless, model results have a disadvantage when the data is less than the model parameters that are resolved or under-determined [9] and applied to shallow waters such as near shore [10]. While all wave models result, as already mentioned, have not been verified by the measurement results in the study area. Therefore, out of these three outcomes, it is not known which one corresponds to the conditions of the Strait of Karimata and the Java Sea.

This research will describe the results of physical oceanographic parameter measurements on the East side of the Karimata Strait, precisely at the Pasir Mayang Beach. The results of this study are expected to complement the information and strengthen

the results of previous studies. This research can be used to find out which model, from the previous research, is closest to the field measurement results. After knowing this, the results of the previous review model can be used for activities such as navigation, recreation, development and rehabilitation around the Natuna Sea, the Karimata Strait and the Java Sea.

II. RESEARCH METHOD

Data and Research Locations

The data used in this study is data that obtained from field observations in February 2017 to March 2017 on the Pasir Mayang Beach, Pampang Harapan Village, Kayong Utara Regency, West Kalimantan.

Pasir Mayang Beach is located on the Eastern side of the Karimata Strait. The location of data capture can be seen in Figure 1.

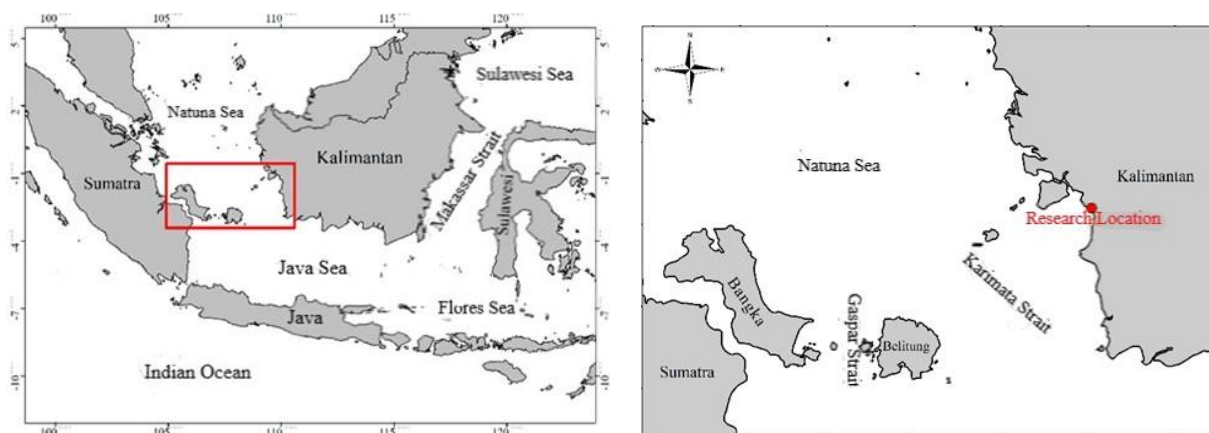


Figure 1. Research Location is Located on the East Coast of Karimata Strait (Left), at the Pasir Mayang Beach, North Kayong District (Red Point in the Right)

The measured parameters are tides, wave, and current. The tidal data is a daily observation data, starting from February 25 to March 12, 2017. The tidal data interval is 1 hour. The daily 15 days tidal data meets the minimum requirements required to obtain tidal main components such as O1, K1, M2, and S2. The wave data are observed for 3 days,

March 3-5, 2017. The hourly current data is the measurement data at spring tide, February 27-28, 2017, so that data can be show profile current maximum and minimum in one tidal period.

Data Collection Procedure

Tides

The installation of tidal palm was done in a relatively safe location. The zero number of the palm scale should always be submerged during low tide or low tide.

Waves

Observation of waves done during the day. The measurement of wave height was done by using tidal palm with crest and trough reading as much as 51 times crest and trough measurement. The wave period measurement was performed by using a stopwatch, which calculated the amount of time required during measurement of 51 crest data and 51 trough data. The direction of the arrived waves was determined by using the compass.

Current

Observation of current velocity and current direction was carried out for 1×24 hours. Drifter was used to measure current velocity. Current velocity measurements were made to calculate the travel time of the drifter until the predetermined distance. The current direction was determined by directing the geological compass in the direction of the drifter.

Data Analysis

Tides

Tidal analysis was done using the Least Square Method. Least Square method was used to perform harmonic analysis. Harmonic analysis is done to get the value of each tidal component that is O_1 , K_1 , M_2 , and S_2 . This analysis uses T_Tide software [11] with Matlab programming language, can be run using Oktav and Matlab programs. T_Tide is an open source program that can be downloaded at:

http://www.eos.ubc.ca/%7Erich/t_tide/t_tide_v1.1.zip

Wave

H_s is significant wave height. To obtain H_s , wave height data should be sorted from highest value to lowest value, then the average of 33% of the highest value is called significant wave height.

$$T = \frac{t}{n} \quad (1)$$

where :

T = wave period (sec)

t = time (seconds)

n = number of waves

Current

$$v = \frac{s}{t} \quad (2)$$

where:

v = current velocity (m / s)

s = distance (m)

t = time (seconds)

III. RESULTS AND DISCUSSION

Results

The results of the water level elevation measurement, on February 25 to March 12, 2017, are shown in Figure 2 as the red line. The observed data is a combination of several components of tidal wave. Harmonic analysis has been performed to obtain the amplitude and phase of each component as shown in Table 1. The dominant main components at this site are diurnal components such as K_1 and O_1 . Meanwhile, semi-diurnal components such as M_2 and S_2 have no significant effect. The amplitude and phase of each tidal component are then used to re-model the water level pattern on the same date. The results of the water elevation model are drawn as the blue lines in Figure 2. The difference of the observed data and the model results are drawn as the black line, Figure 2. The

correlation index value of the model results to the observed data is 0.90, meaning the amplitude and phase of the harmonic analysis

results have been representing tidal conditions at the study site. Mean sea level in the site is 1.18 meters.

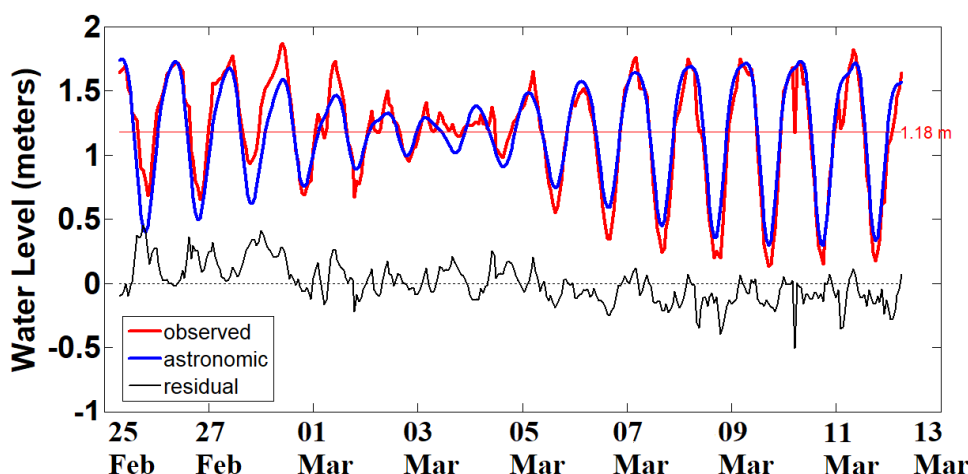


Figure 2. Results of Sea Level Measurement (Red Line) for 15 Days Compared with Model Data (Blue Line). Difference in the Measurement Results to the Model is Illustrated by a Black Line

Table 1. Amplitude and Phase of Main Component of Tide

Component of tide	A (m)	Fase (°)
M2	0.085	343.26
S2	0.086	349.24
K1	0.455	145.1
O1	0.342	34.04

The average value per session of the wave's height measurement results from March 3-5, 2017 is shown in Figure 3. The wave height is measured four times in a day, and the measurement is repeated on the second and third days. The highest wave occurred at 14:00 o'clock, local time, with a wave height of 0.31 m. Otherwise, the lowest wave occurred at 17:00 o'clock with wave height of 0.12 m. The average daily wave height is 0.24 m.

The results of the wave period measurements are shown in Figure 4. The measurements of the waves are done at the neap tide. Neap tide is a condition while the minor tidal effect and the change of water level in a small range. The largest period

occurred at 17:00 o'clock and the magnitude is 6.9 seconds. Otherwise, the smallest period occurs at 14:00 o'clock and the magnitude is 5.3 seconds. These results indicate that the wave period in this sited is inversely proportional to the wave height.

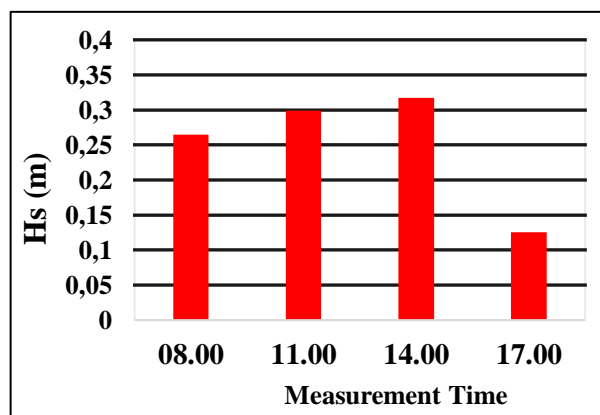


Figure 3. Significant Wave Height

The percentage of wave direction of the measurement is shown in Figure 5. Most of the waves come from the South-west. The orientation of the wave direction follows the direction of wind, the shore shape and the depth of the waters.

The percentage of the current direction

is shown in Figure 6. In general, the currents flow in the opposite directions, i.e. South-west and Northeast. The current from the Northeast is greater than the currents of the South-west. In addition to these two dominant directions, there is a minor current from the East. The maximum current velocity is 0.112 m / s and the minimum current velocity is 0.078 m / s.

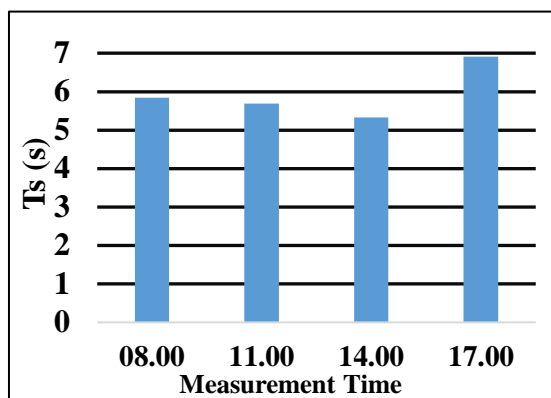


Figure 4. Wave Periods

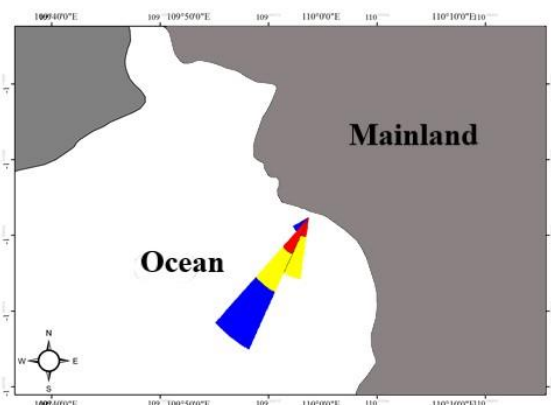


Figure 5. Wave Direction at the Study Site

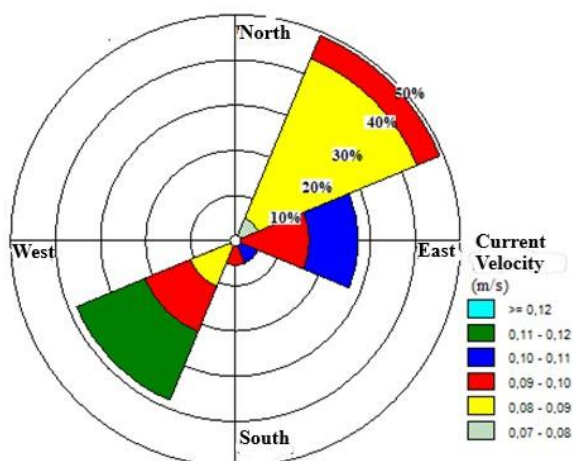


Figure 6. Current Direction

Discussion

The pattern of tides on the Pasir Mayang Beach is a diurnal. The pattern can be clearly observed from Figure 2, where it occurs once rise and once fall of the sea surface recedes in one day. Tidal patterns can also be determined based on the number of Formzahl (F) by calculating the ratio between the diurnal and semi-diurnal amplitude that shown in equation (3)[10]:

$$F = \frac{K_1 + O_1}{M_2 + S_2} \tag{3}$$

where K_1 and O_1 are diurnal component amplitudes, whereas M_2 and S_2 are the amplitude of semi-diurnal components. The value of Formzahl number (F) is 4.66. Based on this number, the tidal patterns at this site is diurnal.

The Diurnal component is almost five times larger than the semi-diurnal component. This is unusual condition where M_2 is usually the most dominant component in almost all the oceans except the Western Indonesia Sea [1, 3, 4, 12, 13, 14]. The diurnal influence is dominant in this site because large amount of M_2 energy lost while it enters the South China Sea and Java Sea [3, 4]. Besides the weakening of M_2 energy, strengthening of diurnal component energy causes also the role of this component to be more significant. the resonance and superposition of diurnal components in Java and South China Sea cause such strengthening of the diurnal component [4, 10, 11, 16]. Tidal wave resonance can occur when the frequency of tidal components is equal or close to the natural frequency of the basin.

The amplitude of each tidal component of the observed data is generally smaller than the study results by Wei et al [1] except M_2 , although both of the study location are close. This difference occurs because the tidal waves are generally dampened when entering the

shallow water area due to bottom friction [17, 18]. Especially for M2, the amplitude of M2 in the middle of the Karimata Strait is smaller than in the eastern part, near land, because the central part of the Karimata Strait is an amphidromic point of M2 and S2 [4]. The amplitude of the tidal wave at amphidromic point is very small indeed it can be zero.

The surface wave height, wave generated by wind, in the measurement period varies with time. As mentioned earlier, the highest wave occurs during 14.00 o'clock local time and the smallest wave occurs in the 17.00 o'clock. Although measurements are made during neap tide, but tidal influence can still be affected based on high variability and period of the waves. Neap tide is condition while the tidal influence in the seas is small, and sea level changes at this time are not significant. In this discussion, we first discuss the influence of the tide on the wave height due to the wind, and the second will discuss the influence of the tide on the wave period.

The tides cause the water level change in one day. High tides occur in the morning, local time. The water level is above the average sea level and the depth of the water is at its deepest level in a day. In this condition, the wave velocity is less affected by the bottom friction and the amplification of wave height due to shoaling affect [17, 20] does not occur. During the day, the sea level decreases and the water depth decreases. The wave feels the bottom friction and increases the wave height. While in the 14.00 o'clock, the water level fall to the lowest point, the water depth is reduced, and the waters become very shallow. Bottom friction affects greatly and reduces wave energy. As a result, the wave height is reduced and damped due loss of their energy.

Changes in water level and depth caused by tides and sea wave height affect the wave period. This change causes the wave velocity differs in one day.

The wave velocity c in shallow water is:

$$c = \sqrt{gd} \quad (4)$$

Where g is the gravitational acceleration and d is the water depth from the surface [17]. The value of d at high tide is greater than at low tide. Therefore, the waves will move towards the coast faster at high tide than at low tide. This means that the wave period will be shorter at high tide; otherwise, the wave period will be longer at low tide. The same condition is also happening on tidal waves, the tidal wave in the Java Sea, Karimata Strait and Natuna Sea have a short period compared to their periods in the Pacific and Indian Oceans [3, 4, 11, 12]. The period difference occurs because the depth in both oceans is greater than in these three seas.

Current at the study site is dominated by tidal currents. It can be seen in Figure 6. as opposite direction. We know that the characteristic of the tidal current direction in shallow and near-shore waters is two-way (opposite direction) [18, 19, 21]. The direction's percentage of the dominant current is coming from northeast or to the offshore and south-west or towards the coast. The current that going to beach is flood current and the current that going to the sea is ebb current. The ebb current that more dominant than flood current indicate that the flood time duration in this location is longer than the ebb duration. Maximum current at low tide is stronger than the maximum current at high tide. This current condition indicates that tidal currents play a role to shift coastal material toward offshore (abrasion).

The long-shore currents, Figure 7, is minor currents in these waters. Long-shore currents flow from east to west. Long-shore currents is caused by momentum flux due to breaking waves that form a certain angle to the coastline. The waves come from the south-

west and form an angle of 90° or perpendicular to the beach. Waves in perpendicular direction cannot cause long-shore currents. Based on previous studies [6, 7], the direction of waves that coming along the east coast of the Karimata Strait is from the South-west and the orientation of the shoreline is elongated from the north-south. Accordingly, it can be seen that the formed angle is estimated 45° to the coastline. The angle will cause long-shore current from south to north. At the observation site, the long-shore current flows from east to west.

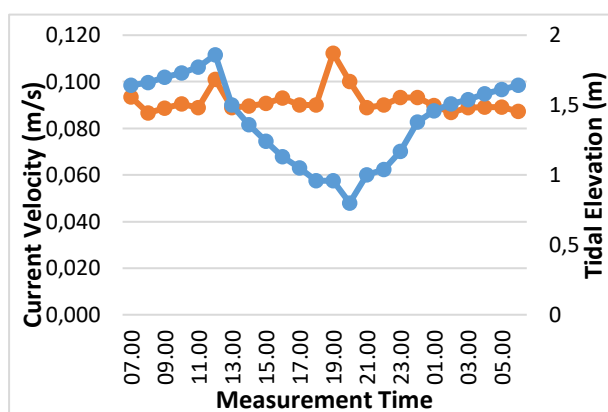


Figure 7. Current Profile and Tidal Elevation at Pasir Mayang Beach

The season's influence on the rise and fall of water level is usually very small in a year because the tides are generated by the gravitational interaction of the space objects especially the Moon and the Sun. Although the wave data does not represent all seasons, but tidal data may be considered to represent tidal conditions over a long period. On the other hand, waves are heavily influenced by the seasons because the waves are generated by the wind. Wind patterns in western Indonesia follow the pattern of monsoonal winds. The direction and intensity of the wind will change in a year [2, 6, 7, 8].

This study completes the knowledge of the physical oceanography conditions on the eastern side of the Karimata Strait. The results of this study can be used as reference to the

determination of initial values, boundary values, and validation materials for modeling studies that incorporate these waters into the model domain. In addition, these results can be used for consideration of various coastal activities such as tourism, construction, rehabilitation, and navigation. For construction and rehabilitation, the calculation of tidal currents and long-shore currents should be taken into account as it affects the sedimentation process. As for navigation, tidal information and significant wave height is an important parameter in supporting navigation safety.

This study cannot describe the variability of waves in the Karimata Strait East related to the seasonal pattern due to limited availability of measurement data. Nevertheless, based on this results study, we found important information that the tide has an important role in changing the wave energy near the coast. The changing of wave energy occurs in one day due to rising and falling sea levels. The tides play a role in changing the wave propagation medium where it originally is a dispersive medium into a non-dispersive medium. In dispersive medium, wave properties will be greatly influenced by length and wave period. In contrast to non-dispersive medium, the wave will be affected by the depth of the water. This study also implicitly explains that wave energy will vary every week. This can happen because spring tide and neap tide occur two times in a month.

IV. CONCLUSION

Investigation of physical oceanographic parameters such as tides, waves and currents has explained some physical processes on the east side of the Karimata Strait, Pasir Mayang Beach. The tides in these waters are diurnal tides, which is dominated by K_1 and O_1 . This change of sea level due to tidal also affects the high of waves coming to the shore. Significant wave heights will increase at high tide and

decrease at low tide. The current in these waters is dominated by tidal currents. The flood tide condition longer than ebb conditions. The ebb current is stronger than flood current driving the dominant erosion process on this beach. The long-shore current is a minority current at the study site.

This study has the limitations of not being able to give information on the variability of waves related to the seasonal pattern, but this research provides other important information. The obtained results indicate that ocean wave energy is strongly influenced by tidal conditions in these waters. The wave energy will increase and decrease due to the change of water depth due to tides. A follow-up study of wave energy changes induced by tides will be very useful for the study of coastline change, reclamation and coastal rehabilitation. In addition, such advanced studies may recommend wave measurement procedures regard to tidal conditions.

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