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Design and Development of Ocean Monitoring System Based on Global Positioning System

Anuar Mohd Salleh[1,*], Mohd Effendi Daud [1], Mustaffa Anjang Ahmad[1], Saifullizan Mohd Bukari[1], Nursyahillah Nadzir[1]

[1]Faculty of Civil and Environmental Engineering,
Universiti Tun Hussein Onn Malaysia, Parit Raja 86400, Batu Pahat, Johor, Malaysia.

*Corresponding Author

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Abstract: Coastal zone of Malaysia has a vital role in socio-economic and environmental in pursuing the country development. However, it constantly faces a threat from coastal erosion. Hence, this study focused on developing the ocean monitoring system consists of a buoy with Global Positioning System (GPS) technology, reference station and data analysis techniques. Based on the verification with slider machine, this system has been able to provide high accuracy result less than 0.5 cm compared to the standard value of slider machine. This study presents the capabilities of GPS buoy to observe wave data at Strait of Malacca by using high precision kinematic positioning approach. The GPS buoy data obtained from this observation were processed through a precise, medium-range differential kinematic technique. The RMS error from data analysis technique is less than 0.0016 m. Validation with Department of Survey and Mapping Malaysia (JUPEM) automatic tide gauges have found both methods agreed on tidal pattern with small discrepancy of less than 10 cm. Encouraging results were also obtained when the tidal observations off coast Senggarang was done. The tidal pattern for each observation has successfully recorded with acceptable accuracy when compared with manual observation. The kinematic coordinates further used to calculate the magnitude of the Power Spectral Density (PSD). PSD analysis function able to shows the strength of the variations (energy) as a function of frequency. The tidal changes and monsoon wind have been found to greatly influence the wave energy as shown in the PSD analysis. From the test result, GPS buoy and data processing technique promises a total solution as a complete ocean wave monitoring solution.

Keywords: GPS buoy, kinematic positioning approach, power spectral density, ocean wave monitoring system

1. Introduction

Ocean is one of the earth's complex physical characteristics yet fully understood by man. The wave, tide and wind are dominant natural external forces in the ocean. A lot of study related to wave, tide and wind has been done to help understand its characteristics, which are advantages for human beings. Accurate forecasts of all these forces are the utmost importance for the individuals who live, work, or travel on or near the oceans [1]. The best decision in the economics or engineering can be made, when the sufficient information has been obtained. The coastal engineering is one of the examples of the necessity for prediction of wave. Also, observation data of wave and tide has given useful information to the monitoring of the rise in the sea level, caused by the global warming and mitigation programs for the damaged natural resources.

Ocean has a great influence on Malaysia because most of this country has been surrounded by the ocean, with a total of 4,675 kilometers of coastline, whereby the Peninsular Malaysia has 2068 kilometers, and East Malaysia has

*Corresponding author: anuarms@uthm.edu.my

2,607 kilometers of coastline. The South China Sea separate two distinct parts of Malaysia from each other. The western part of Peninsular Malaysia is also facing the Strait of Malacca. The coastal zone of Malaysia has a special socio-economic and environmental significance. More than 70% of the population lives within the coastal area and a lot of economic activities such as urbanization, agriculture, recreation and eco-tourism, fisheries, aquaculture and oil and gas exploration are situated in the area. Within these coastal areas, the industrialization and development demands had a great influence on the resources and coastline itself, with a large percentage of population living within 5 km from these areas. The zoning plans with multiple usages exist only in the framework of concrete management, i.e. the coastal and marine protected areas [2]. Generally, the coastal zone plays a vital role in the development of the country; however, it constantly faces a threat from erosion.

National coast erosion study reported that, 52% of the coastline in the east coast of Peninsular Malaysia is being eroded and in the west coast, 50% of the coastline is being eroded [3]. The recent study has revealed that about 29% of the total of 4,800 kilometers of Malaysia shoreline was subjected to varying degree of erosion [4].

Coastal erosion is a natural phenomenon resulting from the interactions between natural process and the system. The natural process is primarily responsible for coastal erosion and it is driven by waves. Ocean waves are capable of massive destruction and endless beauty. Unraveling the mysteries of their generation and predicting their height has been a pursuit of sea fairing people and coastal dwellers throughout history. There are many different kinds of open water waves; among them are wind waves, tides and tsunamis. Focus of this study are on wind waves and tidal waves.

It is really important to observe ocean wave to understand the factor influence the wave energy. By understanding these factors, early prevention can be taken to reduce coastal erosion. Therefore, various techniques have been employed for ocean wave observation such as the coastal water level gauges, bottom pressure gauge, satellite altimetry and wave buoy. This study will demonstrate the potential of Global Positioning System (GPS) buoy for ocean wave observation and PSD for ocean wave energy analysis.

2. Ocean Wave Monitoring System

2.1 Structure GPS Buoy Design and Fabrication

GPS buoy was designed by review some of the existing design and which are still actively used such as Datawell Directional Waverider [5], Fugro Tsunami buoy series Seawatch Deep Sea Module [6] and Deep Sea MKI-3 buoy by Envirtech [7]. Afterwards, the buoy was designed with suitable modifications and improvements. All parts of the buoy have been designed carefully by considering many aspects in order to facilitate the transportation of buoy to the observation site, can be deployed easily and capable of providing high-precision results.

The pole for the GPS receiver was mounted on the buoy; proximity to the water surface will cause frequent signal losses and cause the GPS antenna to be submerged during field observation in choppy waters. In addition, to prevent the occurrence of lost signals, it also designed to take into account the factor of buoy safety and civilians who also uses the waters where the buoy is anchored. By designed the pole to accommodate the beacon light with a height of 500 mm from the surface of the water. At night, the beacon light can be seen from a distance of 5 km, hence, assuring the safety of buoy and other public users.

The body parts of the buoy are composed of two conical shapes to ensure stability, as used in the Deep Sea MKI-3 by Envirtech. It is very challenging to make the buoy stand in a vertical position, due to the fact that these both cones are similar in size. Therefore, the concept of pendulum has been applied in the design of the buoy body, where the light weight equipment is placed on top of the buoy, while the heavy equipment was placed at the bottom of buoy. Such an arrangement will make the buoy always in vertical position and return back in its position when hit by big waves.

The fabrication process is divided into several stages such as material selection, fabrication of buoy, water proofing and anti-rust. The selection of appropriate material is crucial to assure that it can function well in various conditions of weather for a long period of observation. Thus, the factors which are necessarily considered in the process of material selection are mentioned as follows: ruggedness, sea water corrosion resistant, weight, flexible and cost.

After considering all the factors mentioned above, the steel sheets have been used as a material for this buoy. This selection was made because steel is more rugged in contrast with the other material. Although steel is easily corroded when immersed in salt water, this weakness is overcome by the process of galvanizing and painting using heavy duty undercoat of the buoy. Though steel is very heavy in weight compare to the aluminium, but by selecting the minimum thickness it is rugged enough to withstand the impact of heavy wave.

Then, the critical part is leak can occur on top cover and the acrylic window where the solar panel were installed. To keep buoy waterproof and prevent damage to equipment or worse sinking the buoy, the method of applying silicon glue on the buoy and rubber sheets has been used to make the window fully sealed. On the outer part of the buoy, a steel loop with float were install to shield the buoy impact from a boat or a drifting object. Without this barrier, the acrylic windows will break, thereby flooding the buoy. Mounted floats further enhance the stability and buoyancy of the buoy.

At the bottom part of the buoy, a ballast was attached. This ballast serves as a stabilizer to further maintain the buoy stability and reduce the rolling impact from the wave action. After the completion of the fabrication process, the next step is to run the test to make sure that the buoy was waterproof and also to analyze the buoy behavior in the water.

The fully assembled GPS buoy was tested in the calm waters of the UTHM lake. The tests which have been conducted include the buoyancy, waterproof and the buoy behavior. Test results have shown buoy designs have sufficient buoyancy to support the weight of all the equipment. During the test only 50% of the bouy's body submerged underwater. Ring with float attached to the buoy body has helped increase its buoyancy.

Water proofing test is the most important test because any leaks on the buoy can cause a short circuit and worse sink the buoy. This test was carried out in all parts of the buoy, especially at the window and opening on top of buoy. The test results show the buoy is fully water proof.

Apart from that, buoy behavior when hit by waves has also been test. Improvement on design by adding the ring with float and ballast has been able to reduce roll when buoy hit by wave. Combination of both design that has been improved has enhance the ability of buoy to follow the wave movement. Appropriate ballast weight also reduces the time taken by the buoy to less than 1 second to return to the vertical position if it falls hit by waves. Fig. 1 shows the field test that was done. The last process is hot dip galvanizing, heavy duty primer and painting to make the buoy corrosion resistant as shown in Fig. 2.

Fig. 1 - Performing the GPS buoy field test.

(a) (b)

Fig. 2 - (a) Buoy in heavy duty undercoat primer (b) painted buoy to safeguard the buoy against corrosion.

2.2 Control Station

The establishment of reference station has been divided into 5 stages, which are location of reference station, designing of reference station, material, fabrication and installation. The selection of the most suitable location is very critical, as it will have an influence on the precision of the data observed and contributed to the outcomes of this study. The rooftop of FKAAS South tower has been selected as the most appropriate location.

There are several factors that have influenced the decisions made in the selection of this reference station location. These factors including safety aspect of equipment during field observation and reference station protected from vandalism activities, stability of the location during natural disaster, provides a continuous direct power supply to ensure an uninterrupted field observation.

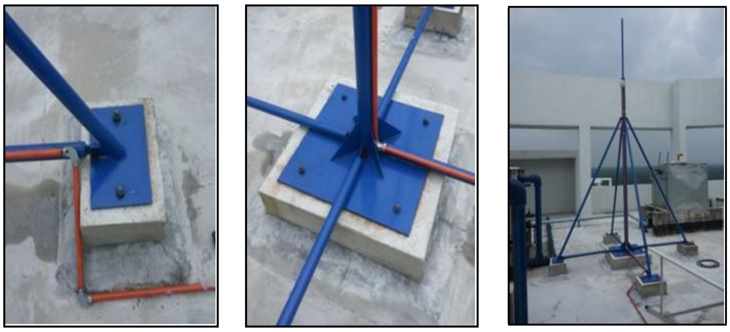
During the field observation, the possibility of GPS satellite signal being blocked by other building is not an issue. Based on a site visit to the roof of FKAAS south tower, it has been determined that this tower is the highest in the UTHM campus. Therefore, the GPS receiver can receive high quality of GPS satellite signals.

Reference station tower can be divided into three parts which were the concrete blocks, main pillar and receiver pole. The tower has four legs to support the main pillar and receiver pole is to facilitate the installation of the GPS receiver. The reference station was built to last for a long time and not restricted to the use of this study alone.

Therefore, the chosen material should be able to survive when exposed to all weather conditions for a long period. The steel has been chosen and to prevent from corrosion the steel has been painted with primer paint.

For the fourth stage of development reference station, it was decided to fabricate each part of the tower in the workshop before its installation on the rooftop. The main pillar, which provides the support to the receiver pole and leg, was made from the steel pipe according to the size that has been determined. The main pillars and supporting leg has been welded on the steel plates for getting it fitted on the concrete blocks easily.

Lastly, the installation process has been done by placing the concrete blocks to the specific location, as determined earlier. Then, the main pillar and supporting legs placed on the respective concrete block. The supporting legs were adjusted in such a manner that the main pillar is in vertical position. All concrete blocks were concreted to floor to ensure that the tower has been fixed permanently. Fig. 3 shows the installed reference station. The coordinates of this station are obtained based on International GNSS Service (IGS) Core Stations as a reference, due to its stability, high precision and are the closest reference station. The international code for this station is NTUS-01 and is situated in the Nanyang Technological University of Singapore.



(a) (b) (c)

Fig. 3 - (a) Supporting leg (b) main pillar (c) reference station.

2.3 Observation Technique and Data Processing Algorithm

The equipment used for field observation is Leica GS15 and software for data analysis is Bernese 5.0. In this study, the approach used in the measurement data is quite different where GPS antenna mounted on buoys to measure changes in sea surface level. This antenna records the signals from GPS satellite while buoy on the move with unpredicted movement patterns due to hit by sea waves. The antenna's ability to gather data in these situations is unknown. It can only be decided after the data observation in the same situation carried out. Therefore, a simulated wave observed in controlled conditions was conducted to get an overview of the capabilities of this equipment when observing data in real situations at sea.

In this study the field observation situation is different where the data observed by moving gps antenna in unpredictable patterns require different data analysis techniques. Thus, the observed wave simulation data that has been made in a controlled condition has been processed by this software is to get the parameters that are appropriate to remove the errors to get the high precision results. Observation waves in a controlled condition intended to verify the equipment and data analysis technique was carried out using a slider machine.

A slider machine that provides a constant wave motion was designed for this study and used to observe waves in controlled conditions to verify the equipment and perform data analysis. The main materials used to make these machines are steel for the machine frame, conveyer belt to move the antenna and wheels for smooth movement of the conveyer belt. The conveyer belt is driven by an electric powered motor. The GPS receiver has been mounted on the conveyer belt and this receiver driven back and forth by the electric motor during the observations were made. Fig. 4 demonstrates the movement of GPS antenna.

A field test was conducted at three sites situated at different distances from the UTHM control station: (i) Location 1 (1 km from reference station), (ii) Location 2 (10 km from reference station), and (iii) Location 3 (20 km from reference station). These observations were made in three different locations to test if the distance between observation stations have an effect on the accuracy and precision of the measurement results. Fig. 5 shows the change in the position (z axis) of the antenna at these stations. The “wave” heights at all stations ranged from 0.31 m to 0.35 m while the control value observed by slider machine is 0.32 m. The wave patterns were uniform in all locations and only the data from the third station were a bit unstable in comparison with the first observation station. These differences was contributed by the atmospheric and tropospheric variations during observation. The effect from these variations clearly shown by obvious different of root mean square (r.m.s.) values of each stations where rms for station 1 is 2.2 cm, station 2 is 2.9 cm and station 3 is 4.5 cm.

(a) (b) (c)

Fig. 4 - GPS antenna driven back and forth using slider machine.

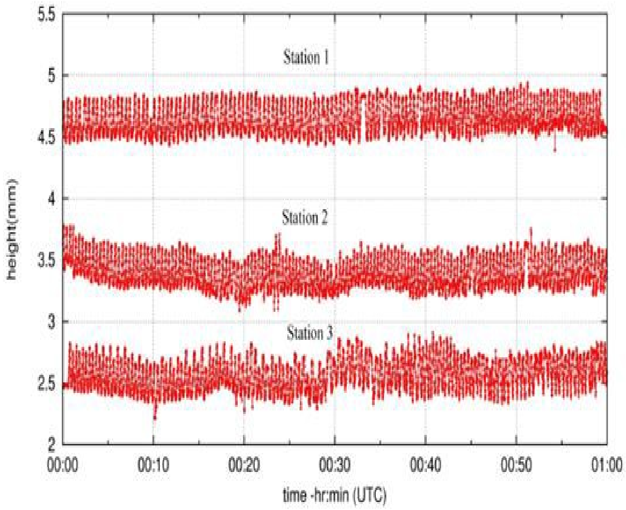


Fig. 5 - Wave heights at the three stations as observed with the slider machine.

This test has proven GPS receiver that was used to gather data able to measured high precision data even if the observations made in conditions that the GPS receiver was constantly moving. The accuracy obtained after comparisons were made with the actual value is very impressive showing this equipment suitable for use in actual observations at sea. The accuracy of the GPS receiver are also not affected by a significant difference between the location of the observations to a control station hence all wave height measured are almost the same as the control value of slider machine wave height. Based on the results and analysis carried out, the equipment and the algorithm that have been developed for the ocean wave monitoring system are ready for sea observation [8].

The first sea observation was done for "truth" comparison of sea level as measured by a digital tide gauge at a nearby buoy location. The digital tide was overseen by Geodesy Section Department of Survey and Mapping Malaysia (DSMM). DSMM is the government agency responsible for all survey works in Malaysia. The observation was conducted on March 13, 2014 at Kukup Port, Pontian, Johor. The GPS buoy was deployed about 500 m off the pier. The position of the GPS buoy was estimated relative to a fixed reference GPS receiver on the FKAAS control station, which was about 70 km away (Fig. 6). The GPS provided real-time 3D position relative to the reference station.

The local vertical component of the GPS solution was one of the sea level measures compared with the "truth" obtained through the tide gauge measurement. No comparable "truth" was available for the horizontal components of the GPS buoy. Based on the analysis, both methods were able to produce quite similar result. In sum, the ocean wave monitoring system demonstrates that the precise determination of sea surface height can be successfully achieved using the post-processing kinematic GPS technique. The centimeter-level agreement between the results of the two methods in ocean surface monitoring also suggests the future possibility of using this inexpensive and more flexible GPS buoy to improve (or even replace) tide gauge stations [9].

2.4 Field Campaign

The field observation was conducted off the shore of Senggarang, Batu Pahat, Johor on February, October 2014 and June 2015. A GPS buoy equipped was deployed approximately 4 km off the Senggarang Coast. The position of the GPS buoy was estimated relative to a fixed reference GPS receiver on the FKAAS control station, which was about 20 km away (Fig. 7). The observation has been done for 24 hours at high rate data logging (1Hz). During the observation the wind speed is moderate between 10 km/h to 20 km/h and the direction is keep changing. This is because of influence from inter monsoon season in month of March and October every year.

The data obtained from the fieldwork were processed by post-processing kinematic GPS positioning software based on the proposed methodology developed at the Astronomical Institute, University of Bern, Switzerland. Dual-frequency data must be obtained for linear ionosphere-free (Lc) resolution. Given that the program was designed for both post and real time data reduction, the GPS precise ephemeris technique was utilized by default to process data. The satellite elevation cutoff angle was set to 5°. Once phase ambiguities were successfully re-solved in the initialization procedure, L1 and L2 phase measurements were used to conduct continuous epoch by epoch kinematic positioning. When the number of continuously tracked satellites dropped below four, the program automatically reverts to the stage of ambiguity integer identification to determine the correct phase ambiguities [10-11].

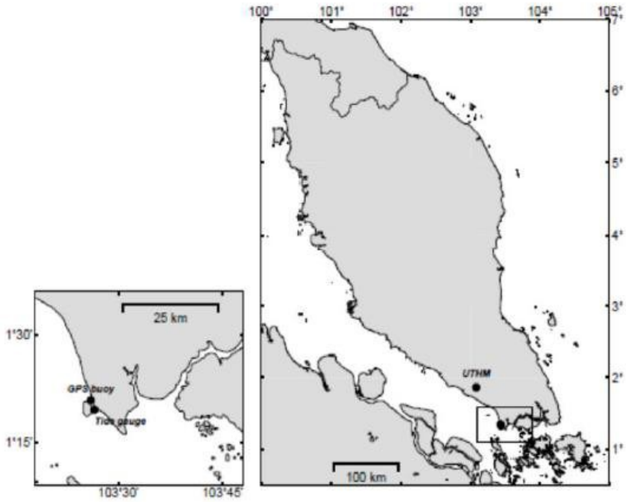


Fig. 6 - Location map of the GPS buoy, tide gauge, and reference GPS station.

Fig. 7 - Field campaign location.

Throughout the entire field campaign, the buoy constantly measured its location. The Cartesian co-ordinates (x, y, z) of the antenna reference point of the GPS buoy were readily converted into their corresponding geodetic quantities (φ, λ, h). The instantaneous water level was obtained after reducing the height component h from the antenna reference point to water level according to known antenna height information.

Then the GPS buoy position (x, y) is used to calculate the strength of the waves using PSD analysis. Input needed for PSD analysis is the magnitude of buoy. The magnitude values were calculated from the absolute difference of the buoy position (x, y) for every second. This is the value of buoy movement within one second period specified in unit of meters. PSD analysis was performed by using MATLAB software with special design toolbox for analyzing measured waves data. The results obtained from this analysis were shown in plotted graph of wave power and frequency of wave occurrence.

3. Results and Discussion

The wave observation data was analyze using kinematic method that involves three sets of observation data which each one represents a type of monsoon. The observation data are as: (i)17 February 2014 (Northeast monsoon), (ii) 14 October 2014 (Inter monsoon), and (iii) 9 June 2015 (Southwest monsoon). Although the data have been processed are from different dates of observation, but analysis were able to produce high accuracy result in range of 1 to 2 cm. The posteriori RMS is less than 1.3 mm for all processing results also prove that the observed data was high in quality and the processing has been made perfectly. Table 1 shows RMS error for each data processing.

Table 1 - RMS error for each data processing

N	Observation	RMS Error	Posteriori RMS Error	Standard Deviation
1	17 February 2014	0.017	0.00	0.0
2	14 October 2014	0.019	0.00	0.0
3	9 June 2015	0.013	0.00	0.0
			08	92

Fig. 8 clearly shows that the GPS buoy was observing the changes of tidal height for the duration of 24 hours. During this period, two high tides with a maximum height of 5 m were observed from 04:45 hour of observation to 10:00 hour of observation and from 17:00 hour of observation to 22:00 hour of observation. While two low tides with a minimum height of 2.5 m were observed from 00:00 hour of observation to 04:15 hour of observation and from 10:30 hour of observation to 16:30 hour of observation. The high tide and low tide during the day and evening is almost the same as fieldwork observations have been made during the tidal cycle is at spring tides. An increase in the wave height was also observed in first 7 hours of observation and also last 5 hours of observations. The increase of wave height during this period is in line with the increase winds speed around 10 km/h to 20 km/h.

Fig. 9 shows the tidal height for 24 hours on 14 October 2014. During this period, two high tides with a maximum height of 4.6 m were observed from 05:30 hour of observation to 11:00 hour of observation and from 17:15 hour of observation to 23:15 hour of observation. While two low tides with a minimum height of 2.8 m were observed from 00:00 hour of observation to 05:00 hour of observation and from 11:30 hour of observation to 16:45 hour of observation. There are significant differences between the observed values especially the high tides, it is because fieldwork observation was done during the cycle tides almost to neap tides on third quarter moon. The wind is also blowing around 10 km/h to 20 km/h, which results in almost a consistent wave height on the sea surface.

Fig. 10 shows the tidal for 24 hours on 9 June 2014. During this period, two high tides with a maximum height of 4.6 m were observed from 00:00 hour of observation to 04:00 hour of observation and from 11:45 hour of observation to 16:45 hour of observation. While two low tides with a minimum height of 2.7 m were observed from 04:30 hour of observation to 11:15 hour of observation and from 17:15 hour of observation to 24:00 hour of observation. The difference between high tide and low tide is still low due to the fieldwork observation was done two days after neap tides on the first quarter moon. Also, the high and low tide during the day is lower than the evening. During the observations, the wind speed increased up to 30 km/h, resulting in choppy sea conditions as recorded by the GPS buoy. The situation is most pronounced in the first 5 hours of observations and the observations made at the 10 to 13 hours of observation. As compared to the other observations, the wave height difference is obvious.

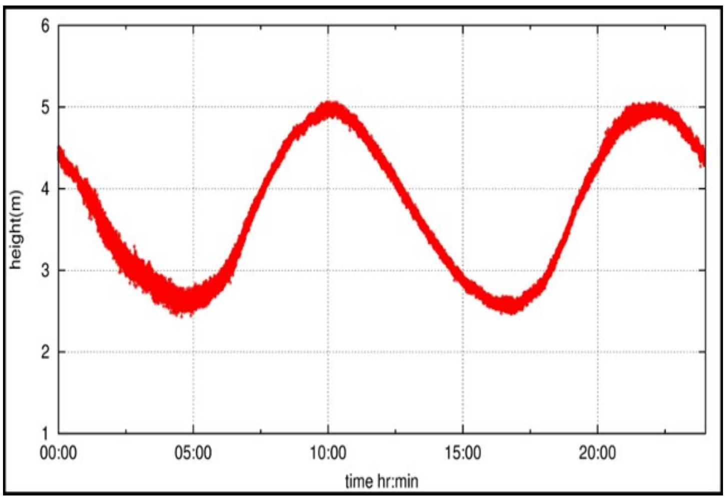


Fig. 8 - Tide observed by GPS buoy on 17 February 2014 at off coast Senggarang.

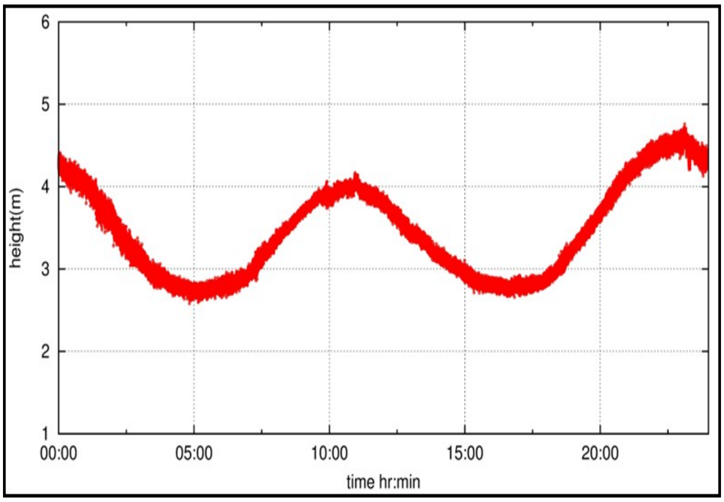


Fig. 9 - Tide observed by GPS buoy on 14 October 2014 at off coast Senggarang.

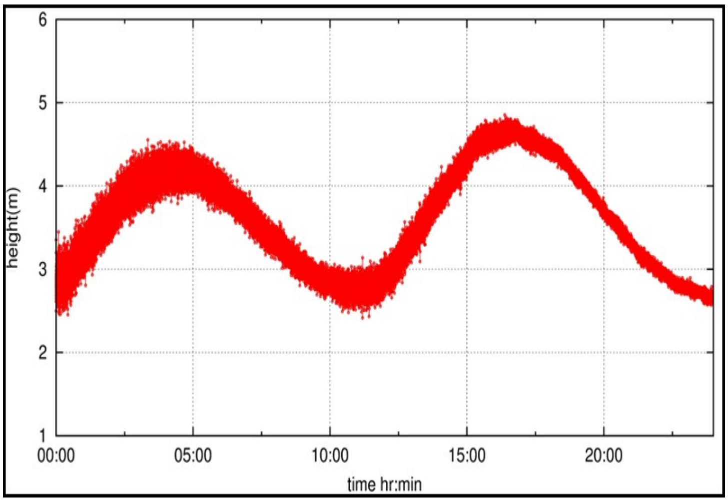


Fig. 10 - Tide observed by GPS buoy on 9 June 2015 at off coast Senggarang.

Aside tide height, the GPS buoy data has been further analyzed to understand the wave strength. The value obtained from the PSD analysis plotted on a graph PSD value against frequency with the value provided in the Log form. Unit for the PSD is expressed in the form of m²s [12-13]. The analysis of PSD values was related to the wind and monsoon season. Fig. 11 shows the PSD during the northeast monsoon (17 February 2014) is not significant because nearly 70% of the observed frequency has the uniformly increased PSD. The patterns of the PSD value for the whole observations did not reveal any dramatic changes. The only sharp changes in the PSD, as shown in the diagram marked by (A) caused by a tidal influence, rather than monsoon winds. The difference of high and low tide on that date may considered large, which indirectly led to the fast ocean currents during tidal changes. Apart from that, the low wind speeds of about 10-20 km/h and wind direction during the observations have also contributed to this situation. The effect of wind during the northeast monsoon is more significant to the states on the east coast of peninsular Malaysia as indicated by the lower PSD value. The highest values of the PSD has been recorded during the observations made is 130 m2s/Hz, which seems to occur at a frequency of 10-0.2. The minimum value of the PSD is observed to be 10 m2s/Hz, which has been recorded at a frequency of 10-0.4. The value of the difference between the maximum and minimum PSD was 120 m2s/Hz.

Fig. 12 shows the observations during the inter monsoon season (14 October 2014). Based on these figures, the PSD increased uniformly throughout almost 80% of the observed frequency. At the rest of the observed frequency, the changes of the PSD value are quite significant, whereas the maximum and minimum value difference is 195 m2s/Hz. The big difference of PSD values as shown in the figure marked by (B) caused by the tidal influence as on the date of the observations, the difference between the low and high tides are still large. Other than that, the winds have also contributed to an increase of wave height at the time of observations. The highest value of PSD during the observation is 210 m2s/Hz, which occurs at a frequency of 10-0.2. The minimum value of the PSD is 15 m2s/Hz, which was observed at a frequency of 10-0.55.

Fig. 13 shows the observations made during the southwest monsoon season (9 June 2015). Based on these figures, the PSD value does not show any increased at all observed frequency. Sudden changes of of PSD value as shown in figure marked by (C) is caused by tide changes. The difference in the maximum and minimum PSD value is 175 m2s/Hz is caused by small difference of tidal which has led to no significant current movement. However southwest monsoon winds have greatly influenced the value of PSD. The highest PSD value recorded during the observation made is 240 m2s/Hz, observed at a frequency of 10-0.1. The minimum PSD value is 65 m2s/Hz, recorded in the frequency of 10-1.5.

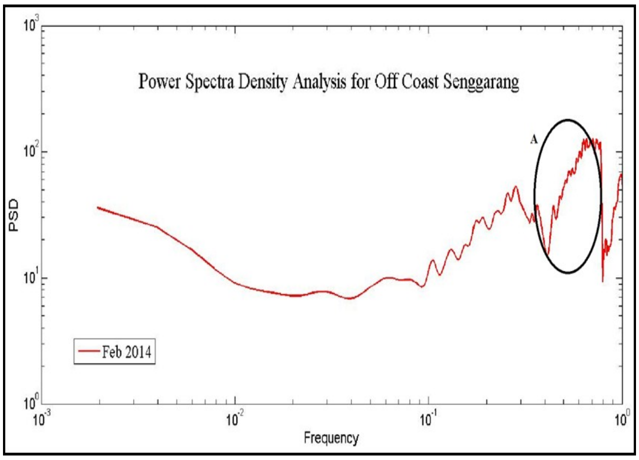


Fig. 11 - PSD analysis during northeast monsoon.

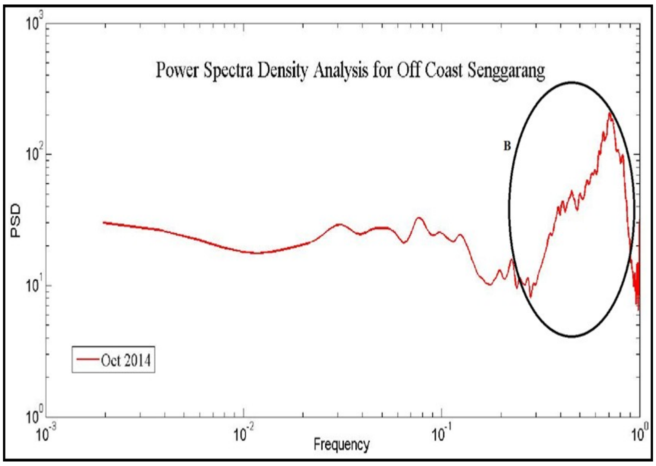


Fig. 12 - PSD analysis during inter monsoon.

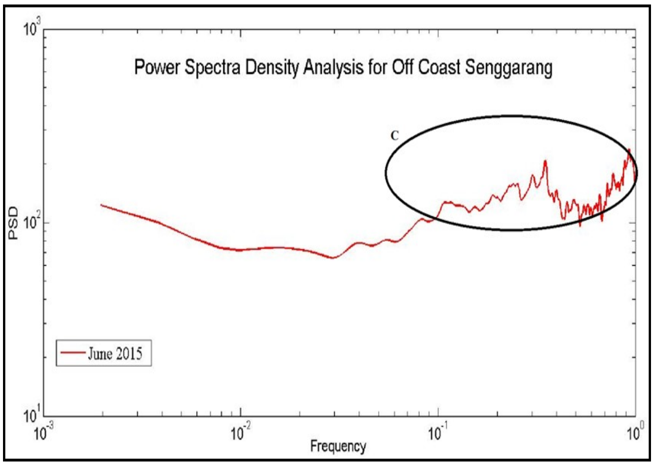


Fig. 13 - PSD analysis during southwest monsoon.

The difference of PSD value for every monsoon is shown in Fig. 14. The highest PSD value recorded during the southwest monsoon observation is 240 m2s, which is marked by (A1), the second highest is during the inter monsoon 210 m2s and is marked by (B1) and the lowest recorded during the northeast monsoon 130 m2s, as marked by (C1). The highest PSD value was recorded caused by the southwest monsoon winds from the Island of Sumatra that give significant impact on the states of the West Coast of Peninsular Malaysia as compared to the states of the East Coast of Peninsular Malaysia. The winds can reach to the speed of 30 km/h. The PSD is nearly uniform throughout the observations due to minimum tidal differences, which is 1.2 m. The small difference in tidal changes leads to the weak current, which is unable to influence the current direction from more dominant monsoon winds. It resulted in almost no change in the current direction during the observations made as indicated by the PSD value obtained. Thus, the high and uniform PSD value throughout the observations are due to the monsoon winds and minimum tidal difference.

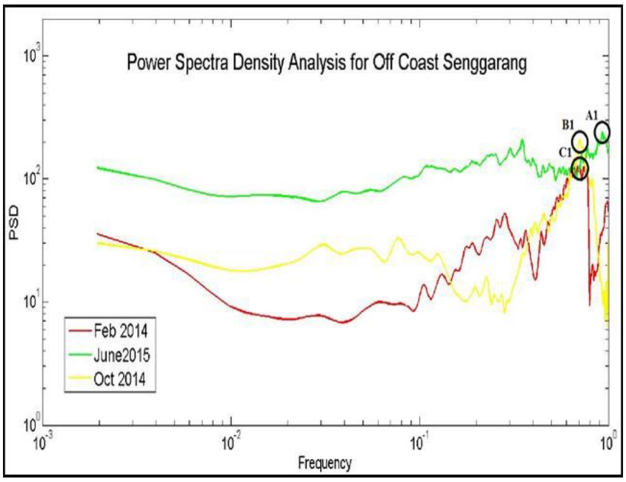


Fig. 14 - Comparison of PSD analysis during three different monsoon.

The observations made in February 2014 and October 2014 almost showed the same pattern of PSD. Both observations indicate a sharp increase of PSD value caused by the tidal changes. During the observation, the maximum tidal difference is 2.3 m and this value is still large for of coast off Senggarang. This difference results in the fast current during tidal changes that trigger a sharp increase in the PSD. Despite showing a sharp increase of PSD value, this value is much smaller as compared to the observations recorded in June 2015. These were caused by the monsoon type during the observations were made, which includes the northeast monsoon and inter monsoon.

The northeast monsoon gives an impact that is more significant to the states on the east coast than the west coast of Peninsular Malaysia. The winter winds of Siberia can reach up to 50 km/h, causing huge waves and heavy rains. This winds do not give much of an impact on the observations because the location of the observation is on the west coast of Peninsular Malaysia. This condition resulted in low value PSD during the observations carried out. While significant increase of PSD value can be seen when there is a change in tide movement.

Whereas during the inter monsoon, winds did not have a fixed direction and the speed keeps on changing. The effect of this wind can be seen on the inconsistency of PSD during the observations were made. Therefore, the PSD value recorded during these two observations made are influenced by large tidal differences and the weak monsoon wind at the observation site.

It can be concluded that the PSD obtained from observations in different monsoon did not show any dramatic changes, because the minimum PSD value is 130 m2s and the maximum value is 240 m2s. A study, in which has revealed that the power generated by wave in Straits of Malacca does not show any significant increase throughout the years of observation [14]. In addition, the comparison also shows that there is a sudden change of PSD value. This change was due to the phenomenon of ocean tidal that occurred during fieldwork conducted.

4. Summary

This study has successfully developed an ocean wave monitoring system that has high accuracy and suitable for use in Strait of Malacca. This has been proven by excellence result from the verification of equipment and data analysis techniques that have been carried out. The results have showed the combination of GPS receiver and data processing algorithms that has been developed able to provide high accuracy result when compared with standard value.

The "truth" comparison results of observations using the GPS buoy with the existing methods, in this case is automatic tide gauges also successfully done. The results of this comparison showed that the observed data using the GPS buoy has been able to provide almost the same results in terms of the tidal pattern observed. From the accuracy comparison, the GPS buoy observation was able to provide sufficient result compare with automatic tide gauge observation. While in terms of data observation frequency, the capabilities GPS buoy to is far superior to this observation method.

Apart from testing the accuracy and precision, GPS buoy observations results were analyzed using PSD to demonstrate the usefulness of this data. Based on this analysis, found out that the wave power off the coast of Senggarang is influenced by monsoon winds and tide difference. Although lack of field data, the system has shown great potential in the oceanography study in Malaysia especially in providing an alternative method for wave observation. For future studies, more field observations need to be conducted before firm conclusion can be made by considering the factor of difference monsoon and tidal changes.

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References

[1] Pinardi, N. & Woods, J. (2002). Ocean Forecasting Conceptual Basis and Applications. 1st ed., (New York, United State America: Springer).

[2] Agardy, M. T. (1993), Accommodating ecotourism in multiple use planning of coastal and marine protectedareas. Ocean & Coastal Management, 20, 219-239.

[3] Ghazali, N. H. M. (2006), Coastal erosion and reclamation in Malaysia. Aquatic Ecosystem Health & Management, 9, 237-246.

[4] Department of Irrigation and Drainage Malaysia. Coastal Management. (2013). Retrieved on August 24, 2014 from http://www.water.gov.my.

[5] Datawell. (2014). Datawell Waverider Reference Manual (WR-SG, DWR-MkIII, DWR-G). Retreived on November 18, 2014 from http://download.datawell.nl/.

[6] Oceanor. (2014). Oceanor Seawatch Deep Sea Module. Reterieved on January 18, 2015 from http://www.oceanor.no/seawatch/buoys-and-sensor/Seawatch-deep-sea-module.

[7] Envirtech (2014). Envirtech MKI-3: Directional – ODAS – MAWS. Retreived on November 18, 2014 from http://www.envirtech.hk/index.html.

[8] Salleh, M. A., & Daud, M. E. (2016). An observation technique and GPS buoy processing strategy for ocean surface monitoring. In D. K. Dong-Keon Kim, J. Jung & J. Seo (Ed.), Advances in Civil, Architectural, Structural and Constructional Engineering (London: Taylor & Francis Group), 347 -350.

[9] Salleh, M. A. & Daud, M. E. (2015), Development of a GPS Buoy for Ocean Surface Monitoring: Initial Results. Turkey International Scholarly and Scientific Research & Innovation, 6, 1579–1582.

[10] Colombo, O. (1996), Long-distance kinematic GPS. GPS for Geodesy (2nd edition) ed P J G Teunissen and A Kleusberg (London: Springer), Chapter 13, 537–567.

[11] Tsujii, T. Harigae, M. and Murata, M. (1997). The development of kinematic GPS software, KINGS, and its application to observations of the crustal movements in the Izu-islands area. J. Geod. Soc. Japan, 43, 91–105. [12] Karimpour, A. Oceanlyz. (2015). Ocean wave analyzing toolbox. MATLAB Toolbox Version 1.3: User manual. [13] Topper, M. B. R. (2013). Semantics of Spectral Density for Ocean Waves. Institute of Energy Systems Report (London: The University of Edinburgh).

[14] Chiang, E. P., Zainal, Z. A., Narayana, P. A. A., & Seetharamu, K. N. (2003). Potential of renewable wave and offshore wind energy sources in Malaysia, Proceedings of the International Symposium on Renewable Energy: Environment Protection & Energy Soilltion for Sustainable Development. Kuala Lumpur, Malaysia, 1-11.