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Identification of Ocean Wave Measurement in Sungai Suci Beach by Using Drone and Ultrasonic Sensor

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Abstract: Measurement of wave height in the specify area of sea which has coral submarine topography and large waves is difficult if using an ocean wave instrument that still exist. This study conducted experiment of a new method to measure the height and period of a single wave in a region such those conditions. This measurement was performed using a drone that was connected with ultrasonic distance sensor. The data that were recorded in the sensor were the distance between the sensor to the sea level per second. The distance differences from time to time were an wave height. Signal analysis based on Fourier theorem was done to calculated superposition results from some waves. This measurement can be implemented in the specify area with low cost.

Key words: Ocean wave measurement, drone, ultrasonic sensor, Bengkulu, Indonesia, measurment

INTRODUCTION

Ocean surface waves are one of the most important maritime parameters that are frequently monitored for purposes of 20 coastal protection, shipping as well as ofshore industry operations. The information of waves has an important factor in the service of marine meteorological communication (Sugianto *et al*., 2017). Surface waves are typically measured by wave gauges from fixed platforms or moored buoys (Carrasco *et al*., 2017; Bretschneider, 1964; Brooke, 2003). Ocean wave measurements also can be done using satellite (Guymer, 1990; Fedor and Barrick, 1978). However, there are several drawbacks of some methods which are included using fixed platform or moored buoys. It is difficult to measure on the area which has full coral topography, shallow water and high waves. Besides those, using satellite data required high resolution (for costal survey) with expensive cost.

Some marine areas in Indonesia have coral seabed topography, shallow waters and high waves. It is impossible doing ocean waves measurement through sea route. One of the area such these condition was Sungai Suci Beach Bengkulu, Indonesia. This location has topography formed by cliffs (Alifdini *et al*., 2016) and swell waves because this location is directly facing Indian Ocean (Alifdini *et al*., 2016). Based on bathimetry study, bathimetry condition of Bengkulu's coastal waters was the shallow waters with depth ranging from 0-20 m. In the study of shallow water (near coastline), many encountered bulges in the bottom of sea until 12 m depth satellite (Fahmi *et al*., 2014; Herterich and Hasselmann, 1980). Those bulges and the shallow water depth make difficult to conducted ocean waves measurement.

We introduced a new method to measured ocean waves heights and periods with ultrasonic sensor which was connected to drone. The sensor that we used was HC-SR04 ultrasonic sensor that is an inexpensive and commercial sensors. The measurement with ultrasonic sensors was performed between an object and the sensor (Guerrero *et al*., 2015). HC-SR04 is the ultrasonic ranging module that has a resolution of 0.3 cm and the ranging distance from 2-500 cm. This sensor can measure up to 500 cm in some conditions. It operates from a $5V_{DC}$ supply. Its standby current <2 mA (Thomas *et al*., 2014).

MATERIALS AND METHODS

The method that we used in this research were experimental method.

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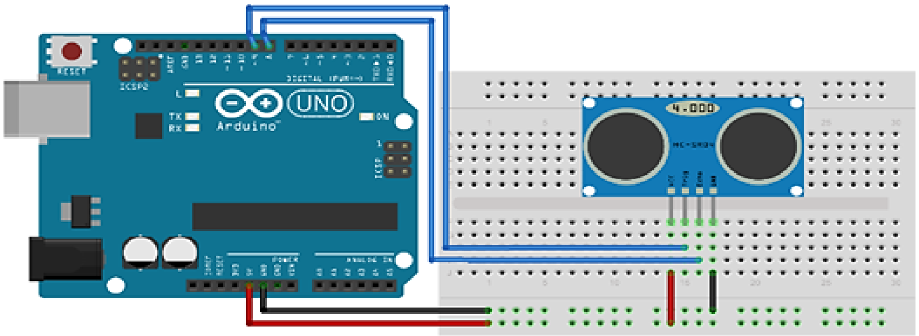


Fig. 1: Experimental circuit of ultrasonic sensor and Ardui Uno

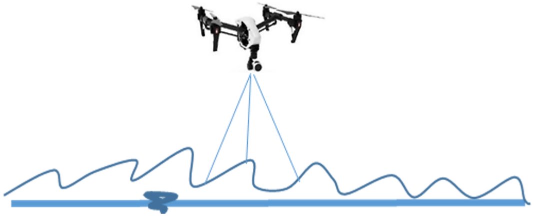


Fig. 2: Ilustration of ocean wave measurement by using a drone above the water surfaces

Ultrasonic sensor circuit: We connected ultrasonic sensor with Arduino Uno microcontroller. The script in Arduino Uno program was designed to measure the distance to object per second. The experimental circuit was shown in Fig. 1.

This sensor was tested to measure distance between sensor to water. We tested in a pool. Then, we compared the original distance which is measured with rool meter and the results of sensor recorded. Based on this comparison, calibration curve was made to correct data from the results of sensor recorded.

Field research method: This sensor which was connected with drone has been tested for measuring ocean waves in Sungai Suci Beach Bengkulu, Indonesia. The ilustration of measurement scheme is shown in Fig. 2. This research was conducted from September 27-29 2016. Each day, this measurement has been done during 5 h. Each hours, ocean wave data were recorded only for 15 min (based on maximum drone flight time). In September 27 2016, this measurement was begun from 7-11 am. In September 28 2016, this measurement was begun from 9 am-1 pm. In September 29 2016, this measurement was begun from 12-4 pm. Location coordinate of this measurement was-3.721163 LS and 102.235401 BT (200 m distance range from the coastline). Drone was flied in 10 m height from sea level. The conditions of ocean waves when measurement has been conducted are shown in Fig. 3 and 4.

Fig. 3: Ocean wave photo which was taken on September 27 2016 (11 am) with drone camera

Fig. 4: Ocean wave photo which was taken on September 29 2016 (4 pm) with drone camera\

Signal analysis based on Fourier theorem: The results of ultrasonic sensors recorded were the distance between the sensor to the sea level per second. These data were plotted in the graph as a function of time. The graph plots of the data formed a wave which are consisted of peaks and troughs. The wave heights from this data were the differences between peaks and troughs. Wave periods were the length of time between peaks or troughs. Wave data recorded were still a single waveform data which still had a wave superposition.

Fourier analysis is a common method for identifying periodic components in stationary time series of oceanographic data (Emery and Thomson, 1998; Constantin and Johnson, 2016). Fourier series is the sum of an infinite number consisting of sines and cosines functions as Taylor series formed from polynomial (Thyng, 2013; Abad *et al*., 2015; Colombo and Gantner, 2016). Implementation of Fouries Series on the waves, the angular Fourier coefficients are independent real functions of the number of ocean waves and provide same information as given by the roll of the waves (Lipa and Nyden , 2005; Hodgins, 1994). Signal analysis with Fourier's theorem were used to determined the result of the superposition of several waves. This analysis was done by clipping sensor recording data per 15 sec (assuming the maximum period of the wave was 15 sec).

Fourier's theorem expresses a function which has a space period that can be analyzed as the sum of harmonic functions where the wavelength is an sub-multiple integral of λ (λ, λ / 2, λ /λ 3, ...,). Fourier series can be expressed in the following equation:

$$f(x) = \frac{A_0}{2} + \sum_{m=1}^{\infty} A_m \cos mkx + \sum_{m=1}^{\infty} B_m \sin mkx$$

The process to determine the coefficients A_0, Am, and Bm for a specific periodic function f (x) is known as Fourier analysis. In this study, the value of m order was 5.

RESULTS AND DISCUSSION

Calibration curve: For the most accurate sensor readings is by making a calibration curve to compare the results between actual and sensor readings. The test results are written in Table 1. The results of the readings in Table 1 create a calibration curve (Fig. 5).

Regression values were obtained from the curve equal to 0.99, it means that if the value of R^2 closer to 1, thereis a significant correlation (strong) between the distance value of sensor and roll meter readings. Results of the calibrated sensor readings are shown in Fig. 6.

Signal analysis based on Fourier theorem: This analysis performe as amplitude value approach of several wave superpositions. Order m that used in this analysis is m = 5. Results of signal analysis are displayed in Fig. 7-9.

In Fourier analysis that had been done, there was a value of RMS error between the data before and after analysis. The RMS error are shown in Table 2. RMS error can be acceptable if the percentage <50%.

After calibration process and Fourier theorem analysis, we calculated the differences between peaks and troughs. The difference between the peaks and troughs is wave heights. Meanwhile, the length of time which is taken between the wave peak to the next wave peaks is wave periods. The result of wave height are shown in Table 3.

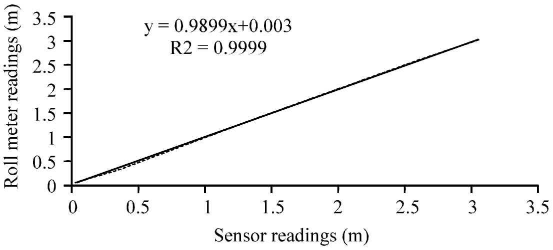


Fig. 5: Calibration curve of ultrasonic sensor HC-SR04

Table 1: Comparison between sensor and actual reading

Using roll meter (m)	Using ultrasonic sensor (m)
0.05	0.05
0.10	0.10
0.15	0.15
0.20	0.20
0.25	0.25
0.30	0.30
0.50	0.52
1.00	0.99
1.50	1.49
2.60	2.62
2.70	2.74
3.00	3.03

Table 2: RMS error of fourier analysis

Date	Time	RMSE (%)
9/27/2016	7 am	34.91
	8 am	3.81
	9 am	30.64
	10 am	29.46
	11 am	39.22
9/28/2016	9 am	40.91
	10 am	32.42
	11 am	33.45
	00 am	19.90
	1 pm	30.37
9/29/2016	00 pm	36.68
	1 pm	37.96
	2 pm	23.58
	3 pm	20.85
	4 pm	35.52

Table 3: The results of wave height

Wave height (m)	Frequency (amount of data)	Percentage
0-1	183	6.15
>1-2	106	16.36
>2-3	48	10.41
>3-4	20	14.27

The results in Table 3 are shown in the form of a histogram curve (Fig. 10) and performed as statistical analysis. Significant wave height value is 2.33 m.The average value of the wave height is 1.21 m. Skewness value is 0.872 which means that the data are more distributed to <1.21 m. The standard deviation is 0.938 with a number of data that we used is 357 data. Wave periods which generated are shown in Table 4.

The results in Table 4 are shown in a histogram curve (Fig. 11) and performed statistical analysis. Significant wave period is 8.55 sec. The average value of wave periods is 6.62 sec. Skewness value is 1.102 which means

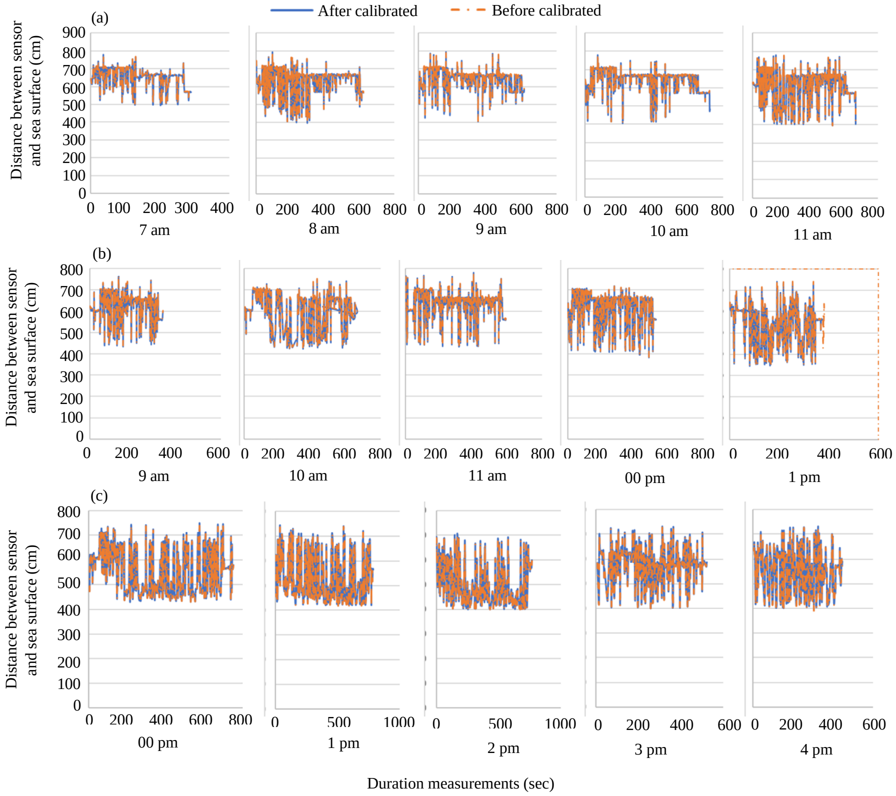


Fig. 6: Sensor reading comparison before and after calibrated from 27-29th September 2016; a) Graph of see waves measurment in 27th September 2016 Sungai Suci Bangkulu; b) Graph of see waves measurment in 28th September 2016 Sungai Suci Bangkulu and c) Graph of see waves measurment in 29th September 2016 Sungai Suci Bangkulu

Table 4: The result of wave periods

Periods (sec)	Frequency (amount of data)	Percentage
0-1	1	0.24
>1-2	2	0.49
>2-3	-	-
>3-4	3	0.75
>4-5	35	16.57
>5-6	112	20.39
>6-7	101	25.12
>7-8	104	25.87
>8-9	28	23.09
>9-10	16	3.98
>10	18	4.47

that the data are more distributed to <7 sec. A standard deviation is 1.76 with a number of wave data used is 357 data.

To know the error of data, we tried to compare the measurement data of sensor and satellite data (Gebhardt *et al*., 2016; Kubrayakov *et al*., 2016). The data from sensor measurement were compared with Sea Surface Height (SSH) data from Aviso^{+} by Jason-2 satellite altimetry, the average of wave heights from measurement with ultrasonic sensor is 1.21 m and the average of sea surface height from satellite data is 1.016 m. The details of satellite data are shown in Table 5.

Table 5: Sea Surface Height (SSH) data by Jason 2 satellite altimetry in september 2009-2016

Years	Date of measurement	Time	Corrected SSH (m)
2009	04/09/2009	11:57:22.624	1.01452
	14/09/2009	09:55:54.565	1.01448
	24/09/2009	07:54:26.391	1.01445
2010	06/09/2010	09:02:49.854	1.01448
	16/09/2010	07:01:21.397	1.01446
	26/09/2010	04:59:53.937	1.01464
2011	08/09/2011	06:08:13.736	1.01454
	18/09/2011	04:06:45.765	1.01453
	28/09/2011	02:05:17.340	1.01453
2012	09/09/2012	03:13:40.509	1.01450
	19/09/2012	01:12:11.833	1.01450
	28/09/2012	23:10:42.831	1.01450
2013	01/09/2013	02:20:36.625	1.01452
	20/09/2013	22:17:40.047	1.01446
	30/09/2013	20:16:13.573	1.01481
2014	02/09/2014	23:26:10.551	1.01479
	12/09/2014	21:24:39.885	1.01441
	22/09/2014	19:23:11.202	1.01442
2015	04/09/2015	20:31:35.647	1.01454
	14/09/2015	18:30:07.986	1.01452
	24/09/2015	16:28:40.650	1.01451
2016	05/09/2016	17:37:07.611	1.01454
	15/09/2016	15:35:40.610	1.01454

These data were compared by using Percentage Bias (PB) to validated data. Rate of

Percentage Bias (PB) between these data could be calculated with the following equation:

$$PB = \left| \frac{\sum D - \sum M}{\sum D} \right| \times 100\%$$

Where:

D = Wave data from sensor

M = SSH data from satellite

The results are considered as: excellent when PB<10 %, very good when 10% PB 20%, good when 20% PB 40% and poor when PB >40% (Huang *et al*., 2013; Rousseaux *et al*., 2016; Bonneton *et al*., 2016). Rate of Percentage Bias (PB) of wave height data equal to 16.53%, Therefore PB's wave height categorized as very good, so that, the measurement data of ocean waves sensor readings result are still acceptable.

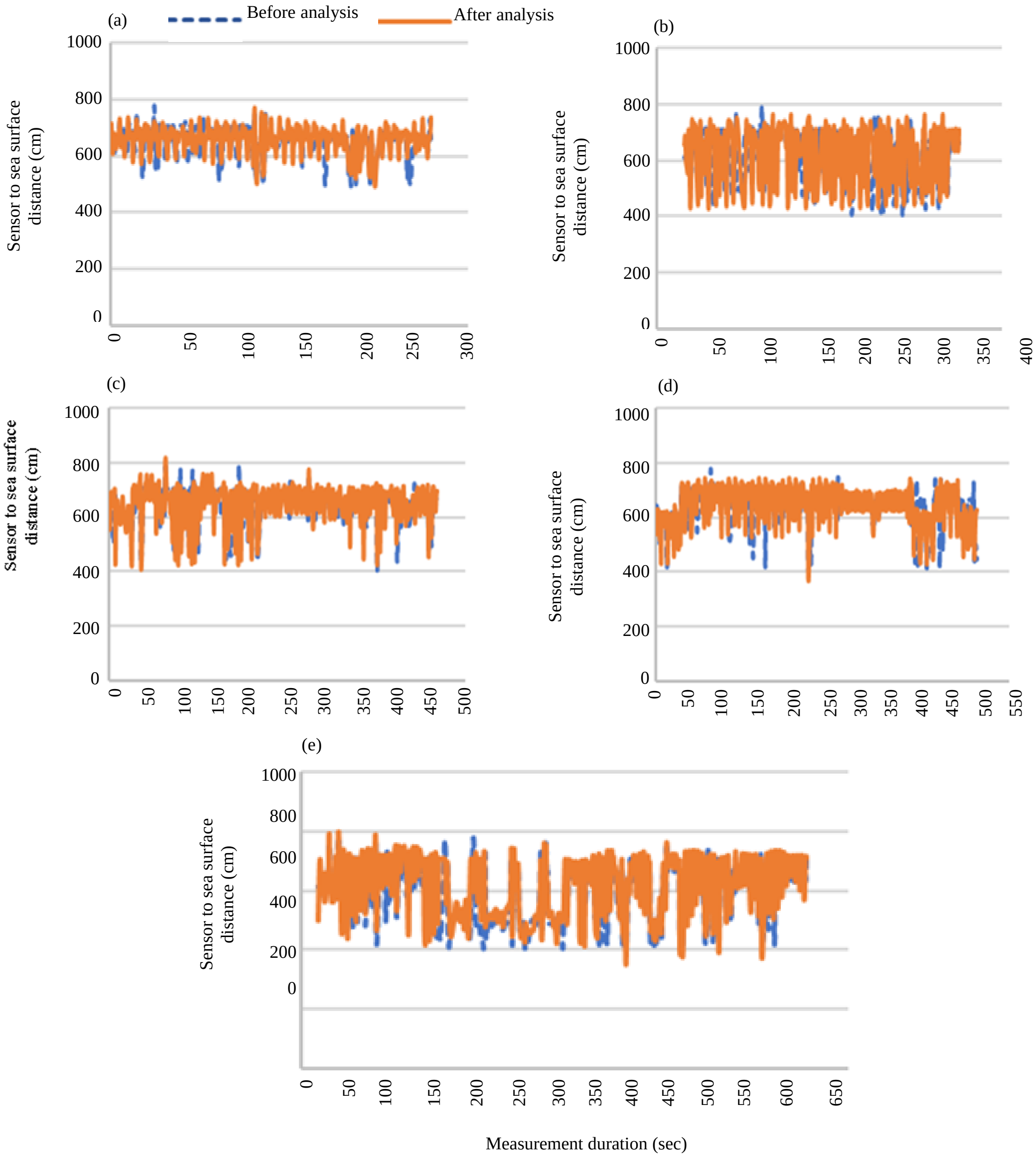


Fig. 7: Sensor reading comparison before and after Fourier analysis on September 27 2016 measurement from 7-11th am; a) Result of Fourier analysis in 7 am September 27 2016; b) Result of Fourier analysis in 8 am September 27 2016; c) Result of Fourier analysis in 9 am September 27 2016; d) Result of Fourier analysis in 10 am September 27 2016 and e) Result of Fourier analysis in 11 am September 27 2016

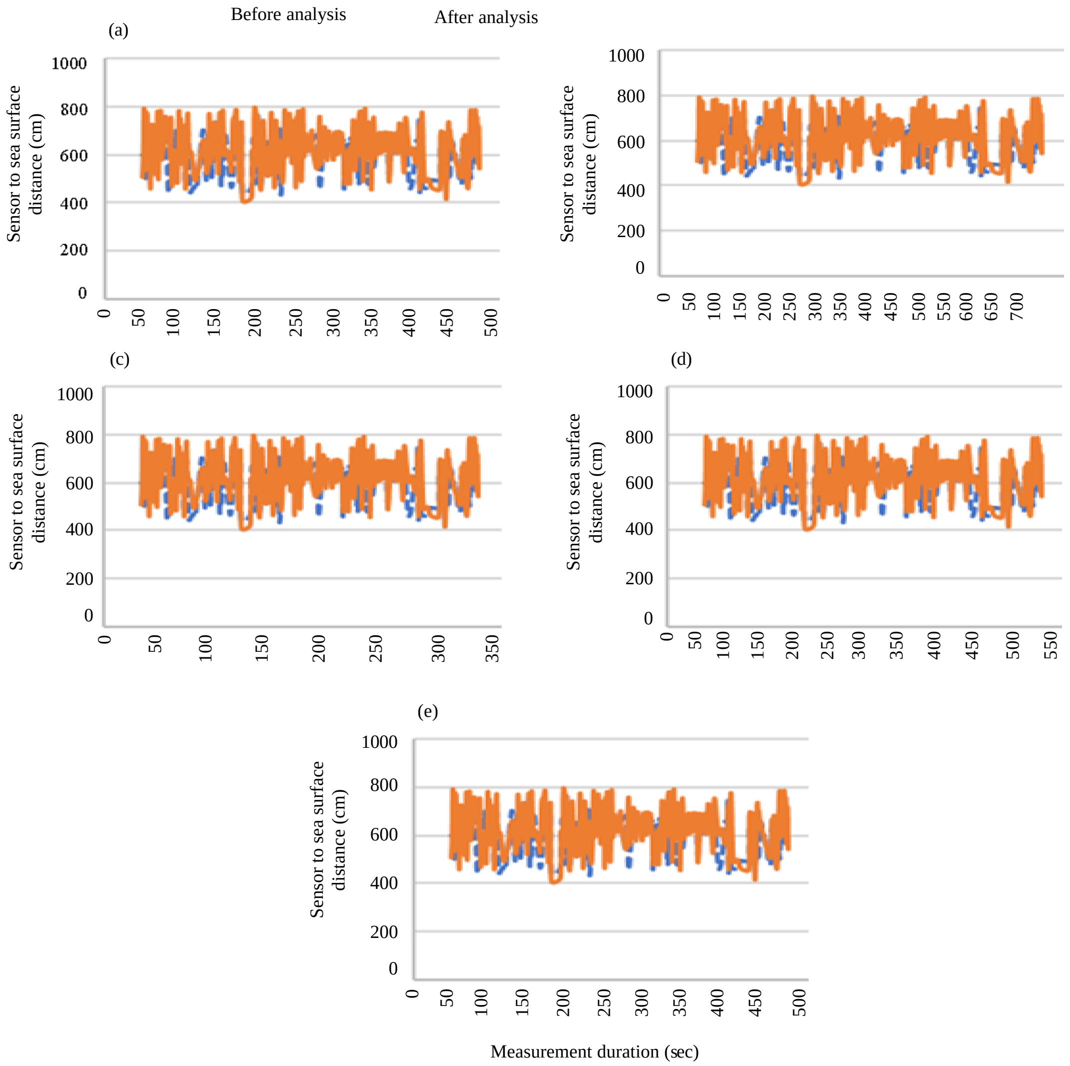


Fig. 8: Sensor reading comparison before and after Fourier analysis on September 28 2016 measurement from 9th am to 1 pm; a) Result of Fourier analysis in 00 am September 29 2016; b) Result of Fourier analysis in 9 am September 29 2016; c) Result of Fourier analysis in 10 am September 29 2016; d) Result of Fourier analysis in 00 pm September 29 2016 and e) Result of Fourier analysis in 1 pm September 29 2016

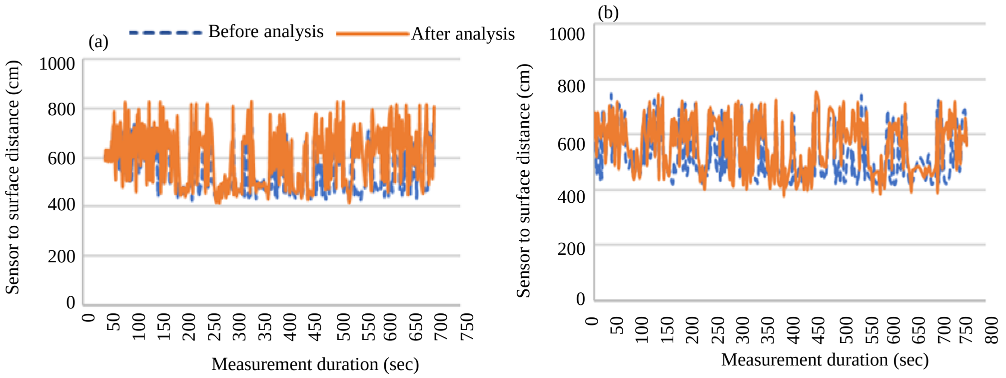


Fig. 9: Continue

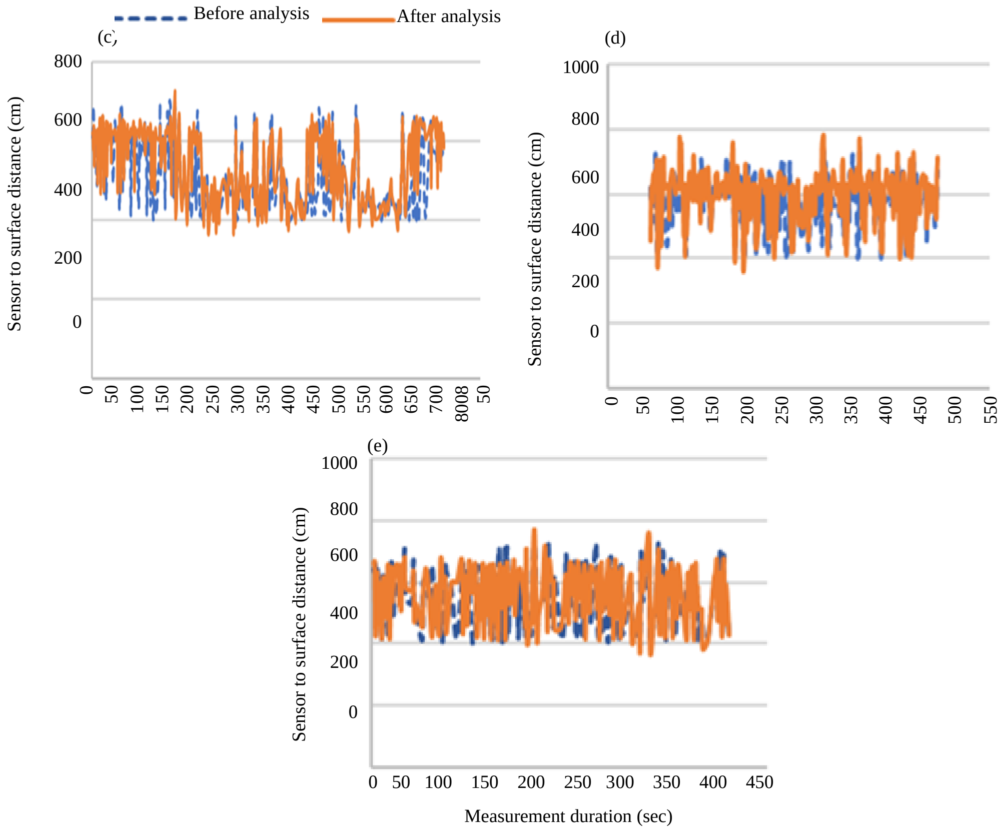
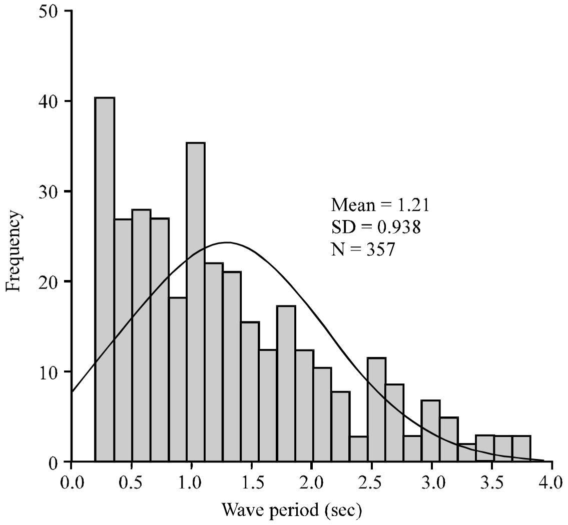


Fig. 9: Sensor reading comparison before and after Fourier analysis on September 29 2016 measurement from 00 to 4 pm; a) Result of Fourier analysis in 00 pm September 29 2016; b) Result of Fourier analysis in 1 pm September 29 2016; c) Result of Fourier analysis in 2 pm September 29 2016; d) Result of Fourier analysis in 3 pm September 29 2016 and Result of Fourier analysis in 4 pm September 29 2016



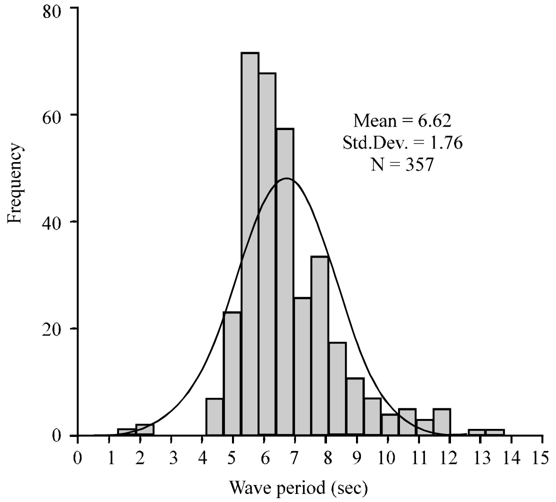


Fig. 10: Statistical distribution of ocean wave heights by ultrasonic sensor measurement

Fig. 11: Statistical distribution of ocean wave periods by ultrasonic sensor measurement

CONCLUSION

In this study, we find a new methods to measure ocean waves which can be measured in the specify area with low cost. Based on the results of the study, the significant wave height and period are 2.33 m and 8.55 seconds. Pb validation of this data are 16.53% if these data are compared with satellite data. It is means that the results of this measurement can be still acceptable.

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