VALIDATION OF ALTIMETER SIGNIFICANT WAVE HEIGHT USING WAVE GAUGE MEASUREMENT IN PACITAN COASTAL WATERS, EAST JAVA, INDONESIA

***Yati Muliati, **Andojo Wurjanto, *** Widodo S. Pranowo**

** Institut Teknologi Nasional*

Civil Engineering, Bandung, Indonesia

*** Institut Teknologi Bandung*

Ocean Engineering, Bandung, Indonesia

**** Ministry of Marine Affairs & Fisheries Republic of Indonesia*

R & D Center for Marine & Coastal Resources, Agency for Marine & Fisheries R & D

Jakarta, Indonesia

ABSTRACT

*Research in Indonesia Indonesia rarely utilizes altimetry technology related to significant wave height (Hs). This condition is partly due to the lack of Hs comparison between satellite altimetry results and field measurements in Indonesian waters. This study was conducted to validate satellite altimetry Hs measurement results on the results of field measurements in Pacitan, East Java waters. Altimetry Hs was generated by the three satellites acquisition, in which the file was in netCDF form, then the file was converted into ASCII and the extraction of data was into a series of time using specific computer software. Statistical methods were used for the calculation of daily average significant wave heights, and the amount of Hs altimetry deviation against Hs in field for Hs data on August 2010 - February 2011. The comparison showed the field Hs = 1.959 * altimetry Hs, with the pattern of the multiplier factor regression and each Hs followed the ordo 6 polynomial function. Especially in Des-Feb (west monsoon winds), the multiplier factor was quite good (1.05), where the wind was blowing and a lot of rain in Indonesia, so that the satellite measurements got closer to the field measurements. Multiplier factor 1.959 was a considerable value, so it could be considered that altimetry Hs data was less accurate. However, it would be better if there is revalidation at different locations in one full year.*

***Keywords**: validation, altimeter, significant wave height, wave gauge, Pacitan coastal waters,Indonesia*

INTRODUCTION

The determination of wave characteristics is actually based on the waveform data over all the water areas. However, this data is not easy to be achieved in connection with the limited data which is able to represent all over the waters. The data concerned is exactly the actual waveform data as a result of a quite long duration measurement at locations with different geographical conditions. The scarcity data is caused by the fact that there is no government agency being in charge of the continuously wave measurement at all over various locations. In addition, the cost for the measurement is relatively high, so the measurement is generally carried out at a location, except if will be built a coastal or offshore structures [1]. Design of marine structures is based on estimates of the maximum wave induced loads expected to occur during a given return period [2].

Considering the difficulty to obtain waveform measurement data in Indonesia, wind wave forecasting was often used in onshore and offshore building planning, although there is significant difference between measurement results and forecasting. Alternative in obtaining information of wave characteristics is utilizing altimetry data from satellites observations on sea level fluctuations, which also generates significant wave height (Hs).

The significant wave height is defined as average height of one third of highest waves, which equal to the wave height of visual observation [3]. The significant wave height is symbolized by parameter of H1/3 or Hs.

Researches in Indonesia are rarely utilizing the altimetry technology related to significant wave height. So far, the use of altimetry in Indonesia generally is for determination of sea surface topography, sea level variations, tidal harmonic analysis, and determination of tidal models. This condition is partly due to the lack of satellite altimetry comparison to field measurements in Indonesian waters, so that the users do not know whether altimetry Hs can be directly used for building planning of beach/sea in Indonesia. Therefore, in this paper, the significant wave height altimetry satellite measurement results will be validated against the results of field measurements in coastal waters of Pacitan, East Java, Indonesia.

LITERATURE SURVEY

Altimetry is a technique for measuring height. Satellite altimetry measures the time taken by a radar pulse to travel from the satellite antenna to the surface and back to the satellite receiver. Combined with precise satellite location data, altimetry measurements yield sea-surface heights [4].

Satellite altimetry system consists of a radar altimeter which is used to observe a satellite high above sea level and observe the tracking system that serves to determine the height of the satellite above the reference plane (ellipsoid), by using meticulous techniques orbit determination. The differences in height on both are referred to as Sea Surface Height, SSH [5]. Satellite emits a sharp signal to the surface of the sea to obtain the altimeter distance measurement. A circular area with a diameter of several kilometers on the temporary sea surface, called as footprint, is exposed by altimeter pulse. The receiver on the satellite records the signal reflected by sea surface. Sensitive chronometer records difference travel time (Δt) of transmitting and receiving signals. The altitude of satellite (ρ) above sea level is determined by specified result of recording time (Δt) and signal propagation velocity (c). Satellite altitude (ρ) can be approximated by equation 1 [6].

$$\rho = c\frac{\Delta t}{2} \quad (1)$$

The geometry relations of altimeter satellite measurements along with the necessary corrections are shown in Figure 1. By ignoring the applied corrections, basic equation of altimetry can be derived as follows [6]:

(IJAER) 2016, Vol. No. 12, Issue No. IV, October **e-ISSN: 2231-5152, p-ISSN: 2454-1796**

$$H = \rho + h = \rho + N + h_d \qquad (2)$$

Where H: satellite high, ρ: distance of altimeter, h: Sea Surface Height (SSH), N: undulations / geoid height, and hd: Sea Surface Topography (SST).

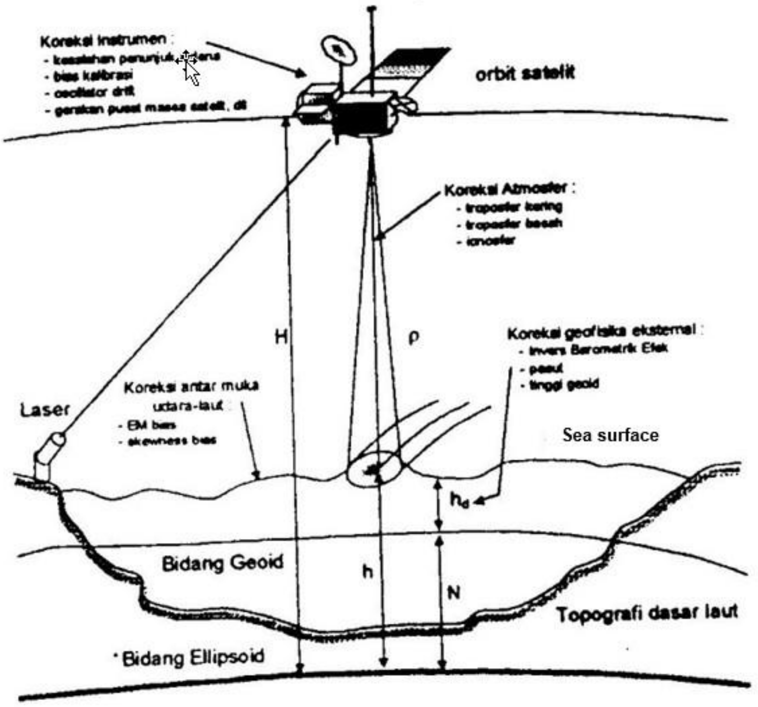


Figure 1. The basic concept of satellite altimetry measurements [7]

The sea surface is not flat, so that the first energy reflection begins when the foremost pulse reach the top of the wave, earlier than flat surface, but the reflected energy does not reach the maximum until the track record achieves the lowest wave. In this way, altimeter is able to average the effect of sea waves (Figure 2). This parameter is called as Significant Wave Height Average (Mean Significant Wave Height, MSWH). So, this parameter is obtained by analyzing the shape and intensity of the altimeter radar beam reflected from the sea surface (radar echo) [8].

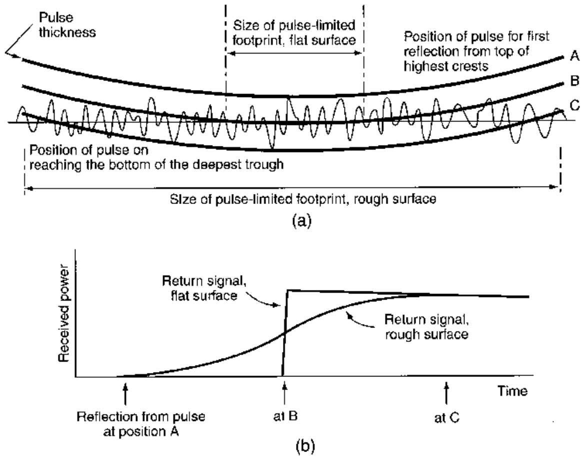


Figure 2. Ways of altimetry in making Mean Significant Wave Height

MATERIALS AND METHODS

The study begins with preparing altimetry data by changing altimetry Hs in form of netCDF into an ASCII file and subsequently extracting the data into a series of time using specific computer software. The field data processed by Setiyawan (2009) were in the form of hourly Hs which were changed into averaged daily Hs to correspond with the altimetry data. The methods used in performing the validation is a statistical method, which is calculated equivalency factor / multiplier by dividing the field Hs with altimetry Hs. Furthermore, the statistical calculation is continued by regression pattern that corresponds to the multiplier and each Hs.

A. *Hs Altimetry Data*

Distribution map of altimetry significant wave height (Hs) is obtained from the Development Research Center Marine and Coastal Resources (Research SDLP) Ministry of Maritime Affairs and Fisheries, which has been collecting data from AVISO (Archiving, Validation and Interpretation of Satellite Oceanographic).

The data is presented in the form netCDF file, where each grid express the X and Y values, with ordinate X is Longitude and abscissa Y is Latitude. The significant wave height data of satellites observations is validated and calibrated regularly to obtain observations result approaching the actual conditions in the field [9].

The location of the observation point in the territory of Indonesia are related to the track path traversed by the satellites with a spatial resolution of 40 km.

Validation of each satellite Jason-1, ERS-2 and Envisat have been done with the data obtained from the network buoy wave NDBC (National Data Buoy Centre) as a comparison, in the period of 1995 to 2011 [9]. From the comparison of the two values, it was obtained monthly refraction and standard deviation for each of the satellites. The observation shows satellites Jason-1 and 2 is 6 cm of refraction and 21 cm of standard deviation. As for the refraction of Envisat were in the range between 2 and 13 cm and standard deviation ranges between 14 and 27 cm [9].

For example, the map of significant wave height (Hs) distribution in meters which was created on February 14, 2011 showed the results of the acquisition of three satellites (satellite measurements, each corresponding to file name, ie 2 satellites on 14 February 2011 and 1 satellite on February 18, 2011). Furthermore, the data is are shown with the help of the Ncbrowse program as in Figure 3.

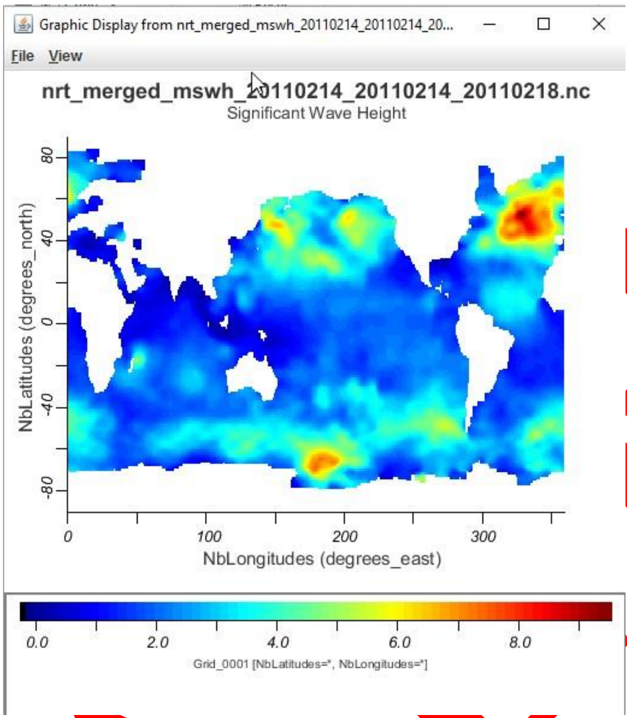
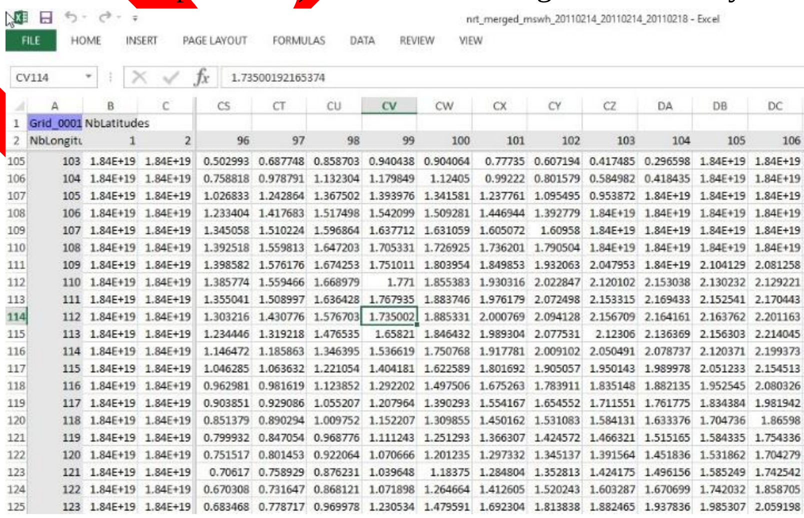


Figure 3. An example of Hs altimetry distribution map

The data file of significant wave height in the form of nc is converted with the help of NetCDF4Excel program into a xls form, with 5 sheets in each file, which contains the info file, the data in the form of a grid, Lat-Lon identity, the data Latitudes and Longitudes. Sheet contains data grid presented with 360 line format that shows Longitude (longitude 00 up to 3590), and 180 column showing Latitude (latitude -900 up to +890). This data shows grid intervals by 1 degree (Figure 4).



	A	B	C	CS	CT	CU	CV	CW	CX	CY	CZ	DA	DB	DC
1	Grid_0001	NbLatitudes												
2	NbLongitu	1	2	96	97	98	99	100	101	102	103	104	105	106
105	103	1.84E+19	1.84E+19	0.502993	0.687748	0.858703	0.940438	0.904064	0.77735	0.607194	0.417485	0.296598	1.84E+19	1.84E+19
106	104	1.84E+19	1.84E+19	0.758818	0.978791	1.132304	1.179849	1.12405	0.99222	0.801579	0.584982	0.418435	1.84E+19	1.84E+19
107	105	1.84E+19	1.84E+19	1.026833	1.242864	1.367502	1.393976	1.341581	1.237761	1.095495	0.953872	1.84E+19	1.84E+19	1.84E+19
108	106	1.84E+19	1.84E+19	1.233404	1.417683	1.517498	1.542099	1.509281	1.446944	1.392779	1.84E+19	1.84E+19	1.84E+19	1.84E+19
109	107	1.84E+19	1.84E+19	1.345058	1.510224	1.596864	1.637712	1.631059	1.605072	1.60958	1.84E+19	1.84E+19	1.84E+19	1.84E+19
110	108	1.84E+19	1.84E+19	1.392518	1.559813	1.647203	1.705331	1.726925	1.736201	1.790504	1.84E+19	1.84E+19	1.84E+19	1.84E+19
111	109	1.84E+19	1.84E+19	1.398582	1.576176	1.674253	1.751011	1.803954	1.849853	1.932063	2.047953	1.84E+19	2.104129	2.081258
112	110	1.84E+19	1.84E+19	1.385774	1.559466	1.668979	1.771	1.855383	1.930316	2.022847	2.120102	2.153038	2.130232	2.129221
113	111	1.84E+19	1.84E+19	1.355041	1.508997	1.636428	1.767935	1.883746	1.976179	2.072498	2.153315	2.169433	2.152541	2.170443
114	112	1.84E+19	1.84E+19	1.303216	1.430776	1.576703	1.735002	1.885331	2.000769	2.094128	2.156709	2.164161	2.163762	2.201163
115	113	1.84E+19	1.84E+19	1.234446	1.319218	1.476535	1.65821	1.846432	1.989304	2.077531	2.12306	2.136369	2.156303	2.214045
116	114	1.84E+19	1.84E+19	1.146472	1.185863	1.346395	1.536619	1.750768	1.917781	2.009102	2.050491	2.078737	2.120371	2.199373
117	115	1.84E+19	1.84E+19	1.046285	1.063632	1.221054	1.404181	1.622589	1.801692	1.905057	1.950143	1.989978	2.051233	2.154513
118	116	1.84E+19	1.84E+19	0.962981	0.981619	1.123852	1.292202	1.497506	1.675263	1.783911	1.835148	1.882135	1.952545	2.080326
119	117	1.84E+19	1.84E+19	0.903851	0.929086	1.055207	1.207964	1.390293	1.554167	1.654552	1.711551	1.761775	1.834384	1.981942
120	118	1.84E+19	1.84E+19	0.851379	0.890294	1.009752	1.152207	1.309855	1.450162	1.531083	1.584131	1.633376	1.704736	1.86598
121	119	1.84E+19	1.84E+19	0.799932	0.847054	0.968776	1.111243	1.251293	1.366307	1.424572	1.466321	1.515165	1.584335	1.754336
122	120	1.84E+19	1.84E+19	0.751517	0.801453	0.922064	1.070666	1.201235	1.297332	1.345137	1.391564	1.451836	1.531862	1.704279
123	121	1.84E+19	1.84E+19	0.70617	0.758929	0.876231	1.039648	1.18375	1.284804	1.352813	1.424175	1.496156	1.585249	1.742542
124	122	1.84E+19	1.84E+19	0.670308	0.731647	0.868121	1.071898	1.264664	1.412605	1.520243	1.603287	1.670699	1.742032	1.858705
125	123	1.84E+19	1.84E+19	0.683468	0.778717	0.969978	1.230534	1.479591	1.692304	1.813838	1.882465	1.937836	1.985307	2.059198

Figure 4. Example of Hs Altimetry Data Extraction Results

B. *Field Measurements of Hs Data*

Hs Data every hour was produced from field measurements obtained from Setiyawan (2009) for a period of time from 14 August 2010 - February 14, 2011. Hourly Hs was averaged into daily Hs.

The location of wave measurements on Pacitan coastal waters (Figure 5) is at a depth of 20 m, with the coordinates X = 540 750 and Y = 9085774 UTM (-8.270 South Latitude and 111.370 East Longitude). The measurements were made during the 12 months from February 2010 through January 2011 by Dongfang Electric Company (DEC) in cooperation with PT. Petrosol as a consultant survey and analysis of wave measurements for Coal-Fired Power Plant at the site, where PLN (Center) will build a Coal Fired Steam Power Plant [10].

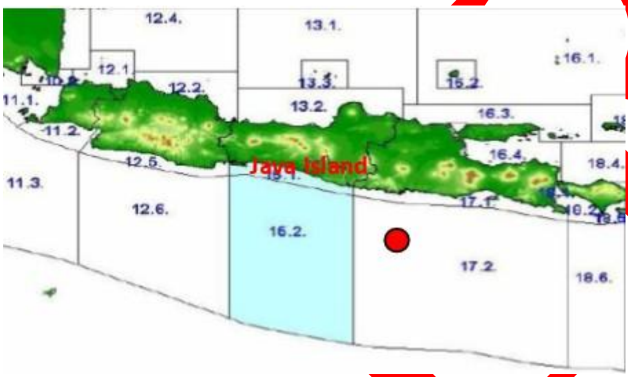


Figure 5. Locations of wave measurements [11]

RESULTS AND DISCUSSION

Furthermore, the both Hs daily data are presented in Figure 6. It appears altimetry Hs scale varies greatly, meanwhile the field Hs ranges from 1 to 2.50 meters. For 6 months of measurements, the average altimetry Hs was 1.52 m with a standard deviation of 0.93 m, while the average field Hs was 1.68 with a standard deviation of 0.34.

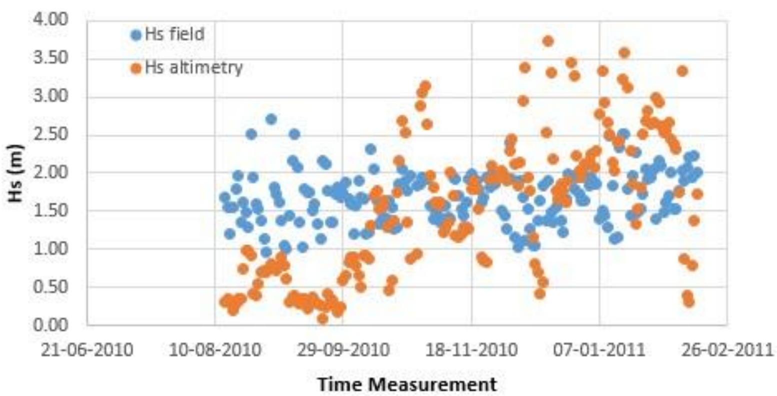


Figure 6. Plotting of Hs

The comparison between the Hs altimetry with Hs field for the data in August 2010 - February 2011 resulted in a multiplier factor = 1.959 or field Hs = 1.959 * altimetry Hs.

Specifically, in Des-Feb 2011 (west monsoon winds blows from the Asian continent to the continent of Australia) the multiplier factor is quite good (1.05), during the time where the wind was blowing and a lot of rain in Indonesia, so that the satellite measurements got closer to the field measurements.

This is consistent with the results of forecasting waves of wind data performed by R. Kurniawan, M.N. Habibie, and Suratno , which is average wave height during the west monsoon and east monsoon higher than the transitional period [12].

A multiplier for all daily Hs approached with different patterns of regression, and regression pattern that comes close is the order polynomial function of 6, is presented in Figure 7. Similarly for regression pattern field Hs and altimetry Hs, each follows the order of the polynomial function 6 (Figure 8 and Figure 9).

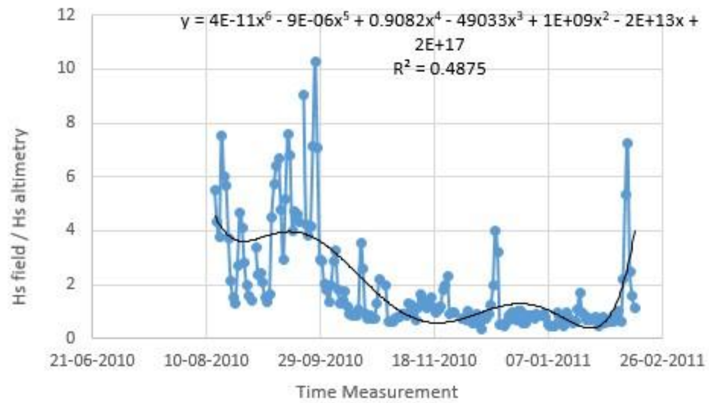


Figure 7. Regression type for Multiplication Factor

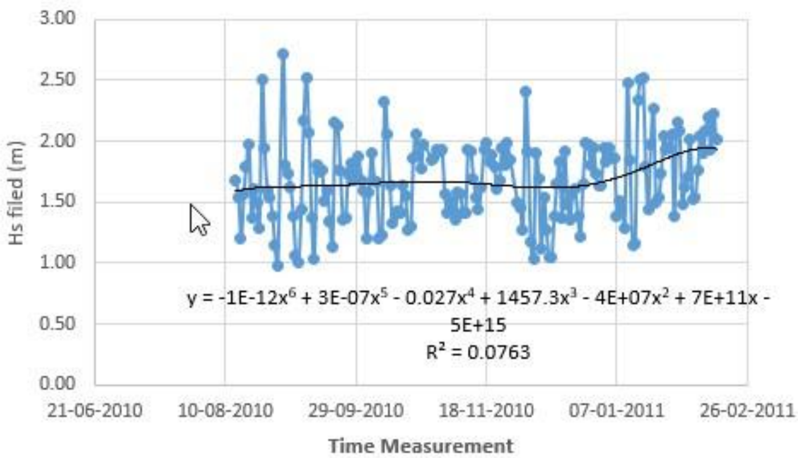


Figure 8. Regression type for Hs field

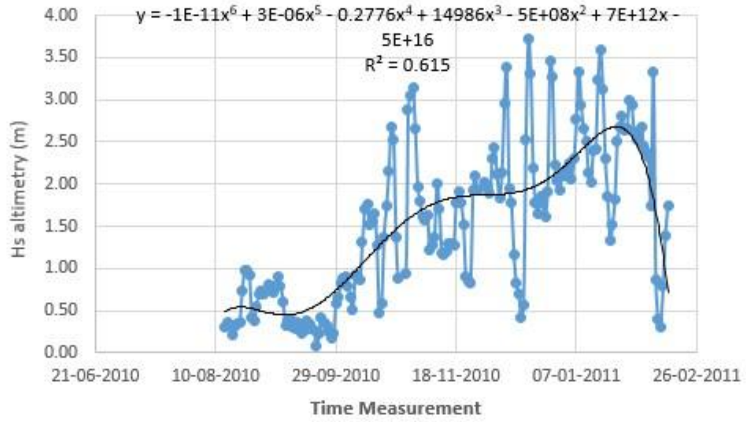


Figure 9. Regression type for Hs altimetry

CONCLUSIONS

The multiplier factor at 1.959 is a considerable value indicating that Hs altimetry data is less accurate for use. However, revalidation at different locations in one year period would be better to perform.

ACKNOWLEDGMENT

The author would like to thank Marine and Coastal Data Laboratory, Research and Development of Marine Fisheries (Agency for Marine & Fisheries R & D) and Mr. Setiyawan for provided the data.

Moreover, thanks are also dedicated to the Ministry of Research, Technology and Higher Education, which has funded this research through Doctoral Dissertation Research Grant scheme.

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