Validating Hindcast Metocean Parameter with Measured Environmental Loads of Malaysian Water

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Abstract—**The forecasting of the Meteorological and Oceanographic (Metocean) conditions and its extreme occurrences is complicated since deciphering of the information obtained must be validate to produce reliable environmental loads based on specified return period of the design. These extreme events related to the environmental loads can have a detrimental effect to the offshore structures. Therefore, the metocean conditions become one of the most significant criteria in the oil and gas industries in designing, installation and running their operations in a safe and efficient manner.**

Various methods can be applied to acquire this information such as the actual standard measurement system obtained from instrumented buoy. However, it will be insufficient to completely depend on the measured data alone since the data might be regularly plagued by missing data or errors. Furthermore, measured data must be monitored for an extended period to minimize errors in estimating extreme values of the environmental loads. Hence, reliance on hindcast model is broadly used by the oil and gas majors to obtain the environmental loads derived from the metocean data because measured data are tedious, uneconomical, and requires constant monitoring to ensure the instrument is functioning all the time where possible. As such, to facilitate the efficient use of hindcast data which is regionally sensitive, a scientific approach is made to correlate the measured metocean data with the existing available hindcast. This is to ensure that the hindcast data can be used reliably and effectively for engineering purposes in the Malaysian water.

Keywords: Metocean, Hindcast, Environmental Loads, Correlation factors

I. Introduction

Environmental loads can be derived from two (2) different types of metocean time series: measured full scale data and hindcast data. Measured full scale data or actual data can be obtained at the selected position under actual sea-state conditions. It consists of many parameters such as wind speed, wind directions, wave height, wave directions, tidal wave, wave period, water elevation, current speed information and etc. Various techniques can be operated to obtain those parameters at any specific locations. The most reasonable technique is utilizing instrumented platform or moored buoys which are floated in the sea at exact locations where the measurement is required. The buoy stations will provide a variety of wind and wave situation in the sea. Other parameters such as wind speeds may use sensors such as anemometer. In addition, weather radar may be mounted to the platform in order to get quality data which has normally been done by the metocean engineer. Measured full scale data is typically expensive to maintain.

Hindcast had been developed and has become the most widely used tool in the oil and gas industries for design and operation purposes (Kim et al. 2011). It is considered as the most suitable technique to analyze the metocean information due to its ease of availability and typically the data is reasonably complete (Cardone et al. 1976). Hindcasting can be applied to investigate the probability distribution and densities of environmental loads such as wind speed, wind and wave directions, wave height, currents flow, storm surge and etc. which affect seacoast and offshore activities. There is however a lack of research on how accurate is the metocean data which is derived from the hindcast. It must be noted that the hindcast data are strictly regional based, and as such, the reliability of the hindcast data must be ascertained.

For this particular research presented herein, the reliability of SEAFINE or SEAMOS-South Fine Grid Hindcast is studied. This tool was initially generated in 1992 by an organization name Oceanweather Inc. It is designed to provide 50 years of continuous metocean data (from 1956-2005). This data operates on the basis of 6 km by 6 km grid where wind and wave hindcast data in the general region of South China Sea, immediately neighboring basin and

Makassar Straits may be obtained. The SEAFINE does not only present a new and updated meatocean information, it also demonstrates extremely high resolutions metocean hindcast with fine mesh nested grid(s) covering the coastal development areas of interest to contributors of this project i.e., Oceanweather Inc.

This paper is aimed at achieving the following objectives which are first to assess and validate the statistical properties of the measured full scale metocean data with hindcast data in the Malaysian water i.e., Malay basin, Sarawak Basin, and Sabah basin. Subsequently, the correlation factor of winds and wave of measured full scale metocean data with hindcast data through acceptable scientific and engineering method are analyzed.

II. Literature Review

Hindcast is application or tool used to forecast the phenominon of previous/pre-years metocean situations using a computer model based on historical events of wind-wave or atmospheric conditions. Therefore, it can be generated or modeled only after the real events have occurred. A few years past, several hindcast studies have been amended and developed due to the findings made by many initiatives in the joint industry projects or JIPs. These JIPs are principally supervised and controlled by Oceanweather Inc. such as GOMOS or Gulf of Mexico Oceanographic Study which is inclusive of hindcast study for the Gulf of Mexico made by Oceanweather. The data were modernized and changed to GOMOS08 in year 2009. GOMOS08 consist of 29 years of continuous from year 1980-2008 of metocean information (wind-wave) as stated in (http://Oceanweather.com/metocean/index/html). Also, the *NESS/NUG/NEXT* database that has been used in the DOWEC (Dutch Offshore Wind Energy Converter) project to investigate wind and wave conditions. This database comprises the hindcast data of wind and wave on a 30 km by 30 km grid of the North Sea. Based on the said study, DOWEC project indicated a correlation of 0.94 or higher is reasonable for the application and use of the hindcast. The model also show that the results of mean wind speed are slightly over predicted compared to the measured metocean results (Bierbooms, W. (2001)).

In the other region, WANE or West Africa Normals and Extremes is hindcast study of wind, wave and current for West Coast of Africa essentially which was modified from WAX/WAX2 study (West Africa Extremes). It is also under the JIPs project which has been done by Oceanweather Inc. WANE hindcast comprises of 15 years continuous metocean data (http://Oceanweather.com/metocean/index/html).

Likewise, for the Wave Information Studies (WIS), the US Army Corps of Engineers (USACE) provides a very practical database of metocean data in the coast of US. The accuracy of it has been verified through the comparison of hindcast results versus all available measured metocean data as mentioned in (http://frf.usace.army.wis2010). Tracy and Spindler (2008) deliberated and proved that the hindcast results show close resemblance compared to the actual measurement. Furthermore, Horizon Marine managed to predict the onset of Hurricanes Katrina and Rita utilizing hindcast results which are closely fit to the actual measurement which was used buoying system AEF, Inc. and HM, Inc. (2006).

In addition, there are many hindcast studies in other locations around the world such as BORE for the Beaufort Sea of U.S., BAMS databases for the Pacific Coast of North America and etc. The majority of the latest continuous hindcast information by Oceanweather Inc. also include 40 years of unremitting hindcast data of the North Atlantic Basin or GROWFAB Cox and Swail (2001). Most of these JIP works have been represented and acknowledged by many engineering and scientific societies (Cardone et al. 2004). The contributions made by Oceanweather Inc. have led to the consolidation of the hindcast studies.

Generally, past practices have strongly indicated that the hindcast data has been able to accurately predict measured data (due to high correlation factor), however, the application of hindcast data is regional based and therefore it is imperative that further studies are made to verify that hindcast shows a similar strong correlating factor with measured data.

III. Methodology

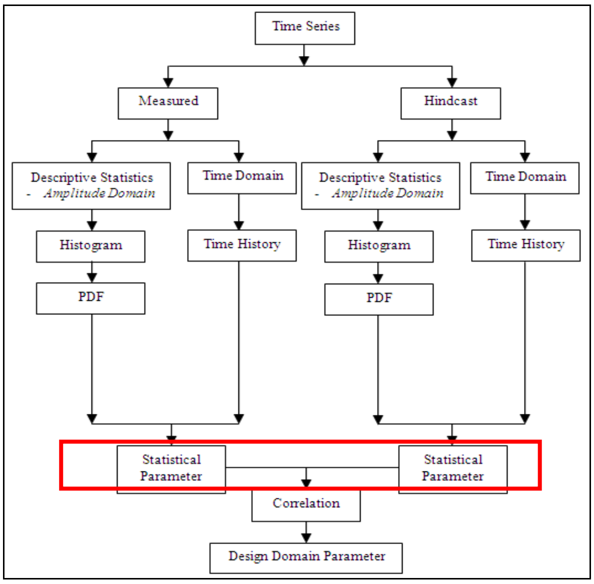

Figure 1. Work Flow Diagram

The methodology requires the initial design on descriptive statistics in the amplitude domain for both the measured metocean and hindcast data such as mean, variance, standard deviation, maximum, minimum and etc. to get the statistical parameters. The data on wind and wave will be analyzed for their respective probability density function (PDF). From the histogram, the PDF of measured and hindcast data can be estimated. At this stage, time domain analysis and time history plot need to be performed to observe how the time series of measured and hindcast data behave over time. This includes one to one mapping on the sampling time and the averaging time. Missing values will be validated for their reliability on the remaining data set for a particular month for example. The correlation of measured metocean and hindcast data can be determined based on the analyses of the statistical parameters for both data. Bivariate analyses will be made for the wind and wave to ascertain the correlation of the bivariates. Other consideration includes monsoon and non-monsoon sea-states in the Malay Basin, Sarawak Basin, and Sabah Basin. Figure 1 describes the overall work flow of this study.

IV. RESULTS AND DISCUSSION

A. Time Series Analysis

In this section presented herein, only sample results are discussed for reference. Figure 2 is a plot of significant wave height in June of 1999 for both measured and SEAFINE data during the non-monsoon season for C-station which located in Sarawak basin.

Figure 3 is a plot of significant wave height in December of 1999 for both measured and SEAFINE data during the monsoon season for C-station. Both plots show similarity on the trend between measured and SEAFINE data during monsoon and non-monsoon seasons with the SEAFINE data showing a smoother time series due to the longest averaging time as opposed to the measured data.

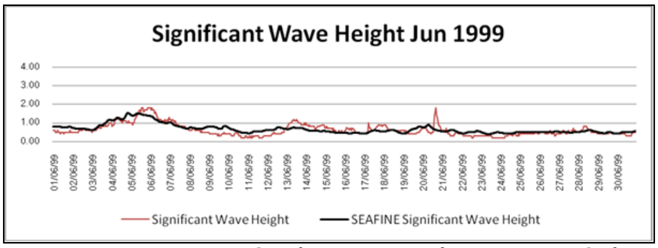

Figure 2. Time Series Plot of C-station Significant Wave Height for Measured and SEAFINE in June, 1999 (Non-Monsoon)

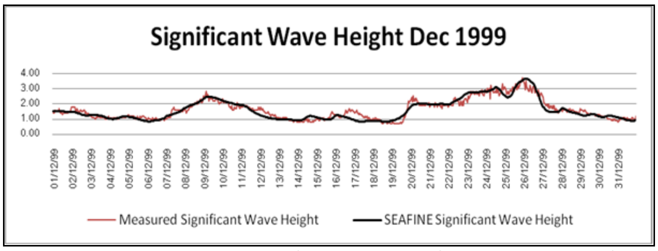

Figure 3. Time Series Plot of C-station Significant Wave Height for Measured and SEAFINE in December, 1999 (Monsoon)

Figure 4 is the plot of the wind speed at C-station in June, 1999, during the non-monsoon season for the measured and SEAFINE wind speed data. Similarly, Figure 5 is the plot of the wind speed at C-station in December, 1999, during the monsoon season for measured and SEAFINE wind speed data. The plots for measured and SEAFINE data during monsoon and non-monsoon seasons show some similarity although it can be seen that there is some variation in values between measured and SEAFINE wind speed data. It is further noted that the SEAFINE wind speed data is unable to track any short duration of extreme wind speed.

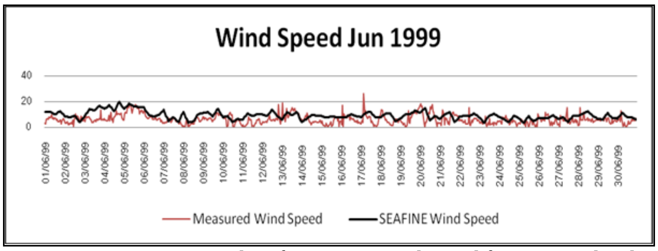

Figure 4 Time Series Plot of C-station Wind Speed for Measured and SEAFINE data in June, 1999 (Non-Monsoon)

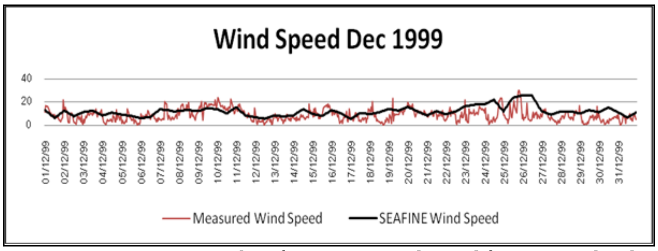

Figure 5 Time Series Plot of C-station Wind Speed for Measured and SEAFINE data in June, 1999 (Non-Monsoon)

Figure 6 is a plot of the average significant wave height for C-station in 1999 for both the measured and SEAFINE wave data. It can be seen that the average significant wave height for measured and SEAFINE data agrees well with one another. Figure 7 is a plot of the average wind speed for C-station field in 1999 for both the measured and SEAFINE wind speed data. It can be seen that the plot for both the measured and SEAFINE data is similar in trend and vary consistently on a monthly basis.

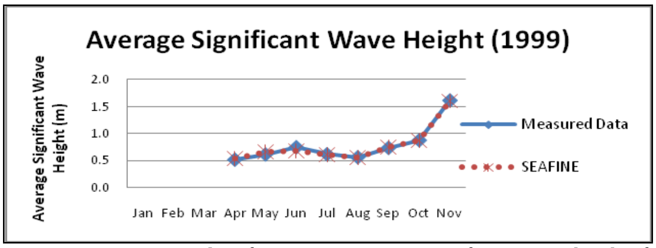

Figure 6 Time Series Plot of C-station Average Significant Wave heights for Measured and SEAFINE data in 1999

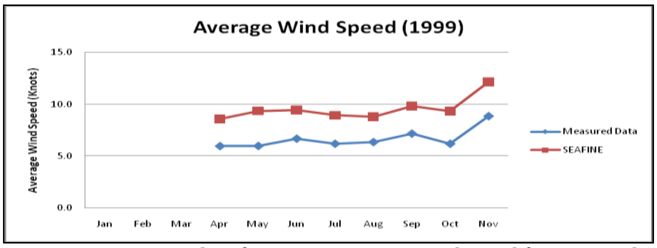

Figure 7 Time Series Plot of C-station Average Wind Speed for Measured and SEAFINE data in 1999

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B. Correlations

The correlations are ascertained through the plot on the spread of the bivariates plot. It can be seen in Figure 8 that the spread on the actual values of the bivariates plot is consistent for wind speed and significant wave height. In this figure, measured metocean and hindcast of average wind speed and average significant wave height are plotted against each other. The results from each month are plotted with different symbols. The graphs illustrate that the results of average wind speed for the measured metocean versus hindcast data is over forecasting. The results of average significant wave height results agree rather well.

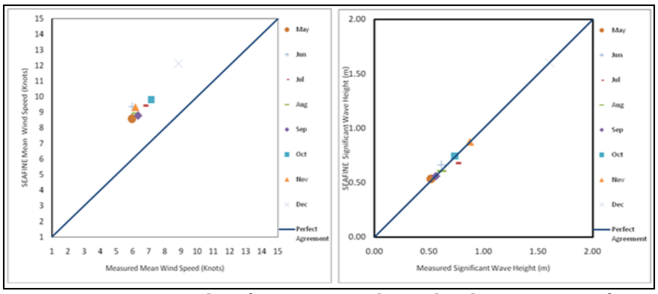

Figure 8 Bivariates Plot of Average Wind Speed and Average Significant Wave Height for the Measured versus SEAFINE data of C-station in 1999

Based on the results of average significant wave height and average wind speed for the measured metocean and hindcast data for the monsoon and the non-monsoon seasons of Malay basin, Sarawak basin, and Sabah basin, the results of correlations of significant wave height and wind speed are generated as shown in Table 1 and 2.

TABLE 1 CORRELATION OF SIGNIFICANT WAVE HEIGHT FOR MEASURED AND HINDCAST DATA

Year	A-Station (Malay Basin)		C-Station (Sarawak Basin)		F-Station (Sabah Basin)	
	Correlation (R)	*R-square* (R^2)	Correlation (R)	*R-square* (R^2)	Correlation (R)	*R-square* (R^2)
1999	0.999	0.997	0.996	0.991	0.994	0.987
2000	0.988	0.977	0.974	0.949	0.981	0.962
2001	0.996	0.992	0.984	0.967	0.873	0.763
2002	0.991	0.983	0.983	0.966	0.985	0.969
2003	0.960	0.921	0.911	0.981	0.964	0.929

TABLE 2 CORRELATION OF WIND SPEED FOR MEASURED AND HINDCAST DATA

Year	A-Station (Malay Basin)		C-Station (Sarawak Basin)		F-Station (Sabah Basin)	
	Correlation (R)	*R-square* (R^2)	Correlation (R)	*R-square* (R^2)	Correlation (R)	*R-square* (R^2)
1999	0.946	0.895	0.955	0.912	0.927	0.859
2000	0.648	0.420	0.983	0.967	0.843	0.710
2001	NA	NA	0.892	0.795	0.859	0.738
2002	NA	NA	0.971	0.943	0.957	0.915
2003	NA	NA	0.960	0.922	0.893	0.798

As a consequence, the measured metocean and SEAFINE significant wave height reveals a strong correlation which has a percentage error of less than one (1) percent. In the case of the wind speed measured data, adjustment must be made consistent with the atmospheric boundary layer wind, roughness coefficients, and averaging time. After adjustment was made, the correlation of the measured and the SEAFINE wind speed need to be done accordingly.

V. CONCLUSION

In conclusion, in using SEAFINE significant wave height data, no adjustment is recommended since a variation of one (1) percent is considered insignificant under operational conditions whereas adjustment up to 20 percent can be made based on longer mean return period. The estimation of extreme waves can be obtained using SEAFINE data. Measured data can also be used for design purposes and to estimate the extreme waves. However, to downgrade the wind speed derived from SEAFINE by 10 percent in using SEAFINE data for wind speed a correction factor must be made to get an accurate measured wind speed.

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REFERENCES

Accurate Environmental Forecasting, Inc. and Horizon Marine, Inc. (2006) "Deepwater Hindcast of Hurricane Rita" Retrived from Horizon Marine: http//www.horizonmarine.com/library/Hurricane_Rita_Report.pdf

Bierbooms, W. (2001). Determination of wind and wave designconditions based on the NEXT database. Offshore Energy-Special Topic Conference.

Cardone, V. J., and Cox, A. T., Oceanweather Inc; Lisaeter, K.A., Nansen Environmental and Remote Sensing Center; Szabo, D., and Ocean Numerics. (2004). "Hindcast of Winds, Waves, and Current in Northern Gulf of Mexico in Hurricane Lili (2002)" Offshore Technology Conferrence, Houston, Texsus

Cardone, V.J., Pierson, W.J. and Ward, E.G. (1976). Hindcasting the Directional Spectra of Hurricane-Generated Waves. Journal of Petroleum Technology, Vol. 28, No. 4, pp. 385-394

Cox, A. T., and Swail, V. R. (2001). "A Global Wave Hindcast over the Period 1958-1997: Validation and Climare Assessment." Journal of Geophysical Research, Vol. 106, No. C2, pp. 2313-2329. (Oceans).

Kim, G., Jeong, W.M., Lee, K.S., and Jun, K., (2011) "Assessment of Nearshore Wave Energy Resource using Offshore Hindcast data" International Offshore and Polar Engineering Conference, Hawaii, USA, 729.

Oceanweather Inc. (n.d.). Oceanweather *Inc: MetOcean Studies: SEAFINE*. Retrieved from Oceanweather Inc. Web

Site:http://www.oceanweather.com/metocean/SEAFINE/index .html

Tracy, B., and Spindler, D. (2008). Wave Information Studies (WIS) Pacific Regional Hindcast. IEEE Computer Society , 299-304.

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