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Correction Factors of Hindcast Wind and Wave for Malaysian Waters

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***Abstract*—Unreliability of measured meteorological and oceanographic (metocean) data happens due to missing data as a result of faulty measuring equipment during the measuring process. Therefore, SEAFINE hindcast model data is introduced as an alternative to measured data. SEAFINE is readily available, parametrically reliable and is able to provide long periods of historical metocean data. Therefore, SEAFINE becomes a common tool to assess metocean information at any locations especially in the South China Sea. However, SEAFINE is found to be not as accurate as measured data. The accuracy of the SEAFINE is improved and correction factors are recommended for three (3) operating regions located in Malaysian waters which are Peninsular Malaysian Operation, Serawak operation and Sabah Operation. The findings presented herein found that wind speeds determined from the SEAFINE are generally higher than measured ones. Wave height data obtained from the SEAFINE is found to agree well with that of measured data. The correction factors for both SEAFINE wind and wave data are recommended. The adjustment factor reflecting the 95% confidence intervals are adopted to interpret SEAFINE wind and wave data.**

***Keywords*—Metocean, Hindcast, SEAFINE, Environmental Loads, Correction Factors**

I. Introduction

Environmental load parameters such as wind, wave and storm surge have a major influence in the design of offshore structures. These parameters are directly related to safety issues during operations and will have financial implications especially for operating companies [1]. Therefore, it is essential to develop an accurate measurement system that will provide robust results with regards to environmental load conditions and extreme values.

Conventional metocean data collection is done by installing buoys and wave radars at the operation site to observe wave conditions such as wave height and wave directions. Anemometers are also installed on offshore platforms to measure wind speed and wind directions. This simple method is employed by various oil-and-gas companies, but it is unable to provide continual measurements and is prone to missing data as a result of malfunctioning instruments [2]. Nevertheless, such fragmented data must still be processed and analyzed. Hindcast model has become a major design tool for design and operation of offshore structures due to insufficient measured data. This model has been utilized by the coast and metocean engineers, and is applied in various coastal and offshore engineering studies today.

Hindcast metocean data is a form of historical data, and more than 50 years of such continuous data is available for most regions. The accuracy of such data, however, is disputed. It can only be applied to specific locations and regions because its data is meant for specific regions only. Therefore, measured data is very valuable to improve the reliability of hindcast data so that the lifespan of an offshore structure can be optimized.

Numerous studies have been carried out to develop the current approach to obtaining hindcast data. It can potentially replace the need for measured data if appropriate corrections are applied to reflect true sea state conditions. This paper focuses on SEAFINE hindcast metocean data. SEAFINE is capable of producing continuous wind and wave hindcast information for the southern region of South China Sea, Makassar Strait, Java Sea and other regions at immediate neighboring basins. These data are presented on high-resolution, fine-mesh nested grids. They are able to reflect extreme metocean conditions. More information on SEAFINE hindcast data is found in the reference [4].

The objective of this research is to validate and improve SEAFINE hindcast data by obtaining correction factors through measured full scale metocean data for wind and wave. The analysis is carried out for three regions in Malaysian waters, notably offshore Peninsular Malaysia, Sabah and Sarawak. The results presented in this paper are recent correction factors for each region.

II. Literature Review

Hindcasting is an approach to investigate the distribution of metocean conditions and is currently used by various organizations. Missing data resulting from faulty measuring equipment will result in discontinuity of measured data, which provides the motivation to look into hindcasting methods. Extensive hindcast studies have been done for several reasons. Loss of oceanographic information in the northern part of the United States, the Gulf of Mexico and Prince William Sound has prompted an investigation into the problem by employing artificial neural networks through the development of six buoy

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networks [2]. This was supposed to generate long-term oceanographic data completely. However, some of the data were missing, and breaking up available measured data has an effect on the statistical assessment of oceanographic and extreme condition design parameters for offshore platforms and other related applications. Missing metocean data is unavoidable. It may occur as a result of malfunctioning instruments. Repairing or reinstalling the instruments may involve intricate processes and the expenses for the monitoring system and other related costs to obtain measured data are significantly high. These issues resulted in a lengthy offshore design and operation timeline. Therefore, hindcasting is proposed considering lower costs and better consistency or availability as compared to measured data.

Several hindcast projects went through changes and improvements through joint industry projects (JIP). The Grow Reanalysis of Ocean Wave (GROW) project, primarily contributed and controlled by Oceanweather Inc., has produced various hindcast results, notably the GROW-Fine North Atlantic Basin (GROWFAB) hindcast, the GROW East Coast 28km hindcast, the GROW Fine Arctic hindcast and the GROW Fine Caribbean hindcast. Oceanweather Inc. also conducted hindcast studies for the Gulf of Mexico, known as GOMOS. In 2009, they developed GOMOS08 which consists of 29 years of continuous metocean data for wind and wave from 1980 to 2008. Then there is also the West Africa Normals and Extremes (WANE) hindcast study focusing on the west coast of Africa. WANE hindcast is able to simulate 80 individual storms in the west coast of Africa and consists of 15 years of continuous metocean data [4].

In 2001, the GROW and AEST40 hindcasts were studied and compared against in-situ data obtained from the buoy systems, platforms, ocean weather ships and satellite wave measurements to determine the bias and to obtain regional statistics. It was also meant to validate hindcast data. The results showed that GROW and AEST40 compared well with measured data – the hindcast results were consistent compared to actual measurements. However, some level of bias existed between AEST40 and measured data, and GROW showed some level of under-prediction of the highest sea states [5].

In the Dutch Offshore Wind Energy Converter (DOWEC) project, the NEXT/NESS (database) hindcast model was used to determine specific site conditions off the Dutch North Sea coast. It was found that the model overestimated the wind speeds compared to measured data. The NEXT database is highly appropriate to determine metocean design parameters [6]. In another study, the hindcast model used ECMWF wind data as the input to evaluate wave climates at the coast of Japan. Parameters such as significant wave height, mean wave directions and directional spectrum were compared between the model and measured data. The study concluded that the results of the hindcast model and measured data agree well with each other [7].

The use of wave hindcasting technique was also applied to the Gulf of Mexico region to estimate the extreme historical wave conditions caused by storms and hurricane wind fields which affected the offshore structures. Statistical analyses were conducted to evaluate the extreme wave conditions, storm events and hurricanes. The historical wind field data from hurricanes in this particular region were used as the input hindcast data. Hindcast data and measured maximum wave heights generated by hurricanes Camille, Carla, Hilda and Betsy and tropical storm Felice were compared. The results showed that the hindcast model is sufficient to forecast sea state conditions during hurricanes and provide reasonable accuracy [8].

The US Army Corps of Engineers, through the Wave Information Studies (WIS) programme, provided a metocean database for the United States coast. Its precision was demonstrated throughout the assessment of hindcast results versus measured metocean data. The database maintained by the WIS programme found that its data were in agreement with measured metocean data [9]. Horizon Marine also utilized hindcast metocean model to forecast the occurrence of hurricanes Katrina and Rita, with results showing that the model data fit closely to the measured metocean data obtained from buoys [10].

The contributions of JIPs have led to the consolidation of hindcast studies. Most of these works have been represented and acknowledged by various engineering and scientific societies [11]. Other hindcast studies for other regions include BORE (Beaufort Sea, USA), BOMOS (offshore Brazil) and CASMOS (Caspian Sea). GROWFAB, maintained by Oceanweather Inc., contains the longest continuous hindcast information spanning 40 years [12].

Past practices have indicated that hindcast data and measured metocean data are in agreement with one another. However, the application of hindcast data is regional-based. Therefore, it is necessary for additional studies to be made to substantiate that hindcast modelling shows a strong correlation to measured metocean data.

III. Methodology

A. *Metocean Data Collection*

Wind and wave data were recorded using measuring instruments at selected locations offshore Peninsular Malaysia (PMO), Sarawak (SKO) and Sabah (SBO) respectively. Sonic anemometers were installed to measure and record wind speed and wind directions, while wave radars were installed to obtain the mean sea level and wave elevation. Other applications of wave radars include structural monitoring, weather forecasting, sea state assessment for operations, water level observations and wind farm monitoring.

B. *Research Methodology*

The research requires preliminary assessment of statistical parameters using fundamental statistical analysis for both measured metocean and SEAFINE hindcast data. Missing value analysis of measured metocean data was done to validate the consistency of available measured metocean data. Wind and wave data were analyzed to obtain their respective probability density functions (PDF). Subsequently, analysis of wind speed and significant wave height for both hindcast and

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measured data was made through one-to-one mapping on the sampling time and averaging time to monitor the behavior of the data over time. The correction factors for SEAFINE hindcast data were proposed based on the analysis of statistical parameters for both measured and hindcast data. These factors were determined for offshore Peninsular Malaysia, Sabah and Sarawak regions.

Seasonal sea states were also considered to account for monsoon and non-monsoon conditions. After obtaining the correction factors, adjustments were made on the wind speed to reflect current codes and standards. SEAFINE hindcast data were adjusted using the Power Law given by Eq. (1). From the Eq. (1), U_1 is the original data of wind speed, U_2 is corrected wind speed, Z_1 is an original wind speed elevation, Z_2 is 10 meters elevation and α is 3 second gust-speed power law exponent which is based on exposure D or open terrain or typically found on the open sea.

$$U_2/U_1 = (Z_2/Z_1)^{1/\alpha} \quad (1)$$

Adjustments to the hindcast wave data were done by applying a 95-percent confidence interval, according to works prescribed in [13], [14], [15] and [16]. Figure 1 shows a schematic flow process of the research.

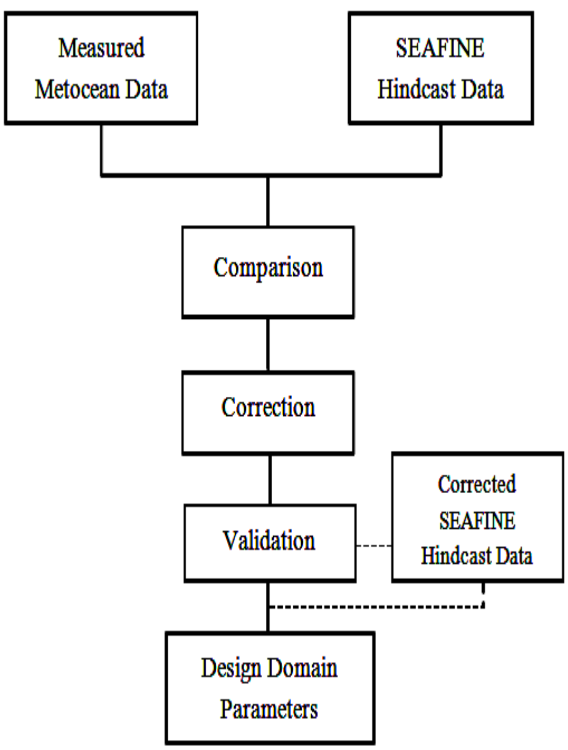

Figure 1. A schematic Flow Process of the Research

IV. Results and Discussion

A. *Wind Speed*

Values of SEAFINE wind speed data were observed to be slightly higher than those of measured data. Both data, however, share a similar trend and vary consistently on a monthly basis. It was found that SEAFINE hindcast model is unable to reflect short duration of extreme wind or gust events. This suggests that SEAFINE hindcast model cannot be applied directly in the design of structures subjected to environmental loads. In order to apply SEAFINE hindcast data in offshore engineering design, construction and operations, such data must be adjusted to reflect actual wind profiles and exposure conditions at 10 meters elevation using the Power Law.

The correction factors for offshore PMO, SKO and SBO regions are shown in Table I. The details of correction factors have been subjected to seasonal variation which are Northeast monsoon (NEM), Southwest Monsoon (SWM) and Inter-monsoon (InterM). The results indicate that the correction factors for all three regions are similar although the factors for offshore Peninsular Malaysia and Sabah are lower than that for offshore Sarawak during the NEM.

For the PMO, the difference between measured wind speed to SEAFINE hindcast during NEM is approximately 14 percent which present the highest percentage difference than the corrected factor during SWM and InterM. This might be influenced from agitated or heavy fluctuations of wind speed during NEM period. During SWM and InterM, the factors are 0.92 or 8 percent difference.

In the case of SKO and SBO, the corrected factors give higher value of a factor during the NEM which are close to 1. This means the measured and SEAFINE data are highly correlated. The percentage of difference is only about 1-2 percent. This will present small changes to the SEAFINE hindcast wind speed after applying these factors.

TABLE I. CORRECTION FACTORS OF WIND SPEED DURING NE, SW AND INTER MONSOON BASED ON 95% UCL

Region	SEAFINE Wind Speed Correction Factors					
	NEM	*95% UCL*	*SWM*	*95% UCL*	*InterM*	*95% UCL*
PMO	0.86	1.02	0.92	1.03	0.92	1.00
SKO	1.01	1.10	0.93	1.24	0.95	1.01
SBO	0.98	1.04	0.93	0.98	0.93	0.97

B. *Significant Wave Height*

Through time series and statistical analyses, SEAFINE wave data and measured wave data were found to agree well. This suggests that an adjustment of the SEAFINE wave data is unnecessary as the correction factors are close to unity, as shown in Table II. The results demonstrate that SEAFINE

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wave data can be utilized and employed as measured wave data in offshore PMO, SKO and SBO regions.

If true sea-state condition is needed, the correction factor is recommended to be applied in the design and assessment of significant wave height characteristics. A 95% upper confidence limit is recommended which will give the assurance to the metocean or design engineer in applying these correction factors in the real design practice [13], [14], [15] and [16]. Interval with 95% upper confidence limit (UCL) of wind wave are presented in Table II.

TABLE II. CORRECTION FACTORS OF SIGNIFICANT WAVE HEIGHT DURING NE, SW AND INTER MONSOON BASED ON 95% UCL

Region	SEAFINE Significant Wave Height Correction Factors					
	NEM	***95% UCL***	***SWM***	***95% UCL***	***InterM***	***95% UCL***
PMO	1.20	1.22	1.15	1.18	1.16	1.19
SKO	0.97	1.03	0.99	1.01	0.99	1.00
SBO	1.05	1.12	1.02	1.04	1.02	1.03

V. Conclusion

This study integrates the accuracy of measured data with the consistency of SEAFINE hindcast data. This paper presents the correction factors to be applied on SEAFINE hindcast data for offshore PMO, SKO and SBO regions. The correction is done to reflect values of measured metocean data. It is recommended that measured data of greater lengths be used to enhance the accuracy of the correction factors.

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