Parametric Study on Environmetal Loads of Hindcast and Measured Full Scale Data

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***Abstract*—The reason of determining the probability of extreme occurrences of wind speed, wave height and current flow is due to the large impact these environmental loads have on the offshore facilities. These occurrences are difficult to predict and may happen once in many years. Several techniques can be used to extract and derive wind, wave and current information from the measured or measured full scale metocean data (PARAS). However, to rely on the measured metocean data alone may not be representative of the accurate sea conditions found locally. This requires correlating the measured metocean data to data derived from *Hindcast*.**

This research focuses on the parametric studies of two (2) types of data which are PARAS and hindcast. The hindcast model here is referred to as SEAMOS-South Fine Grid hindcast (SEAFINE) which is derived from a Joint Industry Project (JIP). The objectives of this research are to compare the statistical properties of measured full scale metocean data to the hindcast data through the correlation between winds, waves and currents of measured full scale metocean data and hindcast data in the basins off the coast of Malaysia and finally to validate with statistical certainty on the reliability of the hindcast data.

This paper demonstrates some of the previous hindcast studies that have been done in some other regions. The statistical analysis, time series of metocean data and its correlation results are presented here in.

Keywords-component; Hindcast, SEAFINE, Time Series, Wind, Wave and Current Correlation

I. INTRODUCTION

The environmental load conditions are the drivers on the design of structures, especially in engineering offshore platforms, as they provide important design criteria, which are normally based on code and standard not reflective of the region. There are numerous types of environmental loads. However, only wind, wave and current are focused in this study. These parameters must be carefully considered in order to operate offshore facilities in a safe and sustainable manner. Good knowledge and understanding of metocean conditions are necessary when the installations of offshore platforms are exposed. Accurate information on metocean conditions are required to optimize future construction of offshore platform.

Wind is the main factor to generate waves [3]. Wind energy will be transmitted to the sea surface and waves up the sea water. The erroneous data used in predicting wind speed has a large impact to forecast the uncertainties of wave field [1] [3]. Therefore, it is imperative that wind information must be exceedingly accurate. Consequently, forecasting of Meteorological and Oceanographic information is essential to facilitate development of future studies and to enhance understanding of coastal knowledge [12]. Nevertheless, effort on the forecasting and estimating of Meteorological and Oceanographic data may be considered as sensitive process and complicated. Recently, there are various approaches to acquire the Meteorological and Oceanographic information. In this research, the measurement of environmental loads is divided into two (2) different types of time series which are an measured full scale data and hindcast data.

Measured full scale data or PARAS can be obtained at the site under real circumstances. The PARAS consists of many parameters such as wind speed, wind directions, wave height, tidal wave and current information etc. Various techniques can be used to determine waves in any specific locations especially buoying which is floated in the sea at exact locations where the measurement is needed. The wave data is recorded by an internal data logger [10]. In some certain location, modern technologies such as sensors and weather radar are attached at the platform in order to get quality data.

Subsequently, new technology called Hindcast has been developed and most widely used in the industries nowadays [15]. It is considered as the most suitable technique to analyze the metocean data [8]. Hindcast can be applied to investigate the probability distribution of winds, waves, currents and storm surge to design loads affecting coastal and offshore facilities. It is a statistical model testing or database to estimate contributions of past events to see how well the outputs equivalent to the real measured results which may be different with forecasting. It is necessary to provide an inference about the future or some hypothetical situation based on known facts and observations of reliable sea state. Beside, hindcast model can be defined as a model testing system which uses to analyze metocean data based on historical real circumstances information and will not be obsolete since the model itself can be developed and standardized with contemporary data [5][9]. The representative wind fields of the meteorological data will be used as an input for wave predictions. These wave results have been regularly developed and concerned in only a single region or basin [10]. Therefore, to obtain the metocean data,

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hindcast model is used relatively frequent compared to the conventional data collection such as sensors or radar at the site.

SEAFINE or SEAMOS-South Fine Grid Hindcast is operated in this research. This model was initially generated in 1992 by Oceanweather Inc. It is designed to provide 50 years continuous and efficient Meteorological and Oceanographic data and find grid wind and wave hindcast in the general region of South China Sea and the immediate neighboring basins. The SEAFINE does not only present a new and updated meatocean information, it also demonstrates extremely high resolutions metocean hindcasts with fine mesh nested grid(s) covering the coastal development areas of interest to contributors of this project [17]. Nevertheless, the research is concerned on the basins off the coast of Malaysia to compare the statistical properties of the full scale metocean data with the hindcast data typically used in the offshore industries and ascertain the correlation of winds, waves and currents of full scale metocean data and hindcast data in the Malay basin.

II. Previous Investigations

Accurate information and operational of wind, waves and current data is required for the coastal or offshore engineering community and facilities [7]. However, there is no standard method in the world to determine and to predict wind, wave and currents at the moment. The prediction of wave height and wave period is developed by using a computer program called "Hindcast". Generally, hindcast is a model testing system and based only on input of historical data which are wind velocity, wind direction in degree, duration and storm wave database [9]. Its output will be presented both numerically and graphically and stored in the output files for further use. Additional information such as maximum wave height and peak period that may occur once in hundred or thousand years can be obtained from wind statistics and these parameters are very valuable in designing offshore structure [6][16]. Sufficient wave information can be forecasted for a return period of 10, 50 or 100 years by utilizing hindcast model.

The SEAFINE produce a fine grid(s), resulting in more precise information. The information is displayed on a 25 km grid with very high resolution of mesh nested grid of 6 km and focused only in the southern part of the South China Seas. SEAMOS or South East Asia Meteorological and Oceanographic Hindcast Study are generated to provide an efficient metocean data and its operational condition in order to facilitate the oil and gas operations, offshore studies and maintenance of offshore structures in this specific region. It produces wind, waves and current hindcasting ensure no significant events are missed which will be very valuable for future development. The SEAFINE covered 50 years of continuous (1956-2005) wind and waves and 20-50 years continuous current hindcast [17].

Hindcast is computer application uses to predict the occurrences of future events using a computer model based on wind-wave information of past events. It can be carried out only after real events have occurred. Within the past few years, several of hindcast studies have been revised due to the founding of many JIPs. Majority of new JIPs have been managed by Oceanweather Inc. for example GOMOS or GUMSHOE ad WINX for the Gulf of Mexico, NESS/NUG/NEXT for North Sea and Norwegian, WAX/WANE for West Africa, BORE for the Beaufort Sea of U.S., BAMS databases for the Pacific Coast of North America and etc. Majority of latest continuous information hindcasts by Oceanweather Inc. also include a 40 years unremitting hindcast data of the North Atlantic Basin or GROWFAB [11]. Most of JIP's works have been represented and acknowledged by engineering and scientific societies [6]. Moreover, several of marine metocean including current specification, ocean engineering and statistics of environmental data have also been performed by Oceanweather Inc. as a result of dedicating a lot of hindcast studies. It mostly covered every ocean basin in the world.

Wave Information Studies or WIS program of Engineering Research and Development Center (ERDC), United States provides a realistic database of metocean information for all coastlines of US and develops new numerical wave hindcast computer technology. WIS provides information of more than 20 years of continuous record of ocean wind and wave which essentially is originated in the Great Lakes in the mid 1970's and migrated to some other places. It uses the best available input wind fields with numerical wave hindcast models, output parameters and wave spectra of US coast and contiguous basin is obtainable. The accuracy of hindcasted wave spectra have been verified through comparison hindcast results to measured information from all available in-situ data. Further information is provided in WIS website: http://frf.usace.army.mil/ which contains of 20 years and above of available hindcast databases of Atlantic, Gulf of Mexico, Pacific region and Grate Lakes information such a plotting, summary table, wave spectra, diagram and etc [13].

Referring to [18] stated that the WIS is very significant to the Pacific coastal area due to all designs, projects and maintenances of US coastlines have to be reliant on its information. At the present time, WIS has already accomplished 23 years (1981-2004) of information of the Pacific Basin hindcast and used a new wave modeling technology which is a multi-grid third generation (3G) in interpreting wind information that able to handle multiple grid resolutions in a single run and energy is circulated in and out of every grid boundaries shows in the Figure 1. Figure 2 shows perfect agreement between measured and hindcast wind speed and wave heights.

The results of modeling were compared with available measured results to validate the numerical result shows in Table 1 and 2. Bias, Root Mean Square error (RMS), Scatter Index (SI), Skill Score (SS) and Correlation (Corr.) of two different measurements have been analyzed. The significant wave height of regional hindcast shows the degree of perfection compare to the basin hindcast, the wave period of both are parallel to each other and the mean wave period is almost the same.

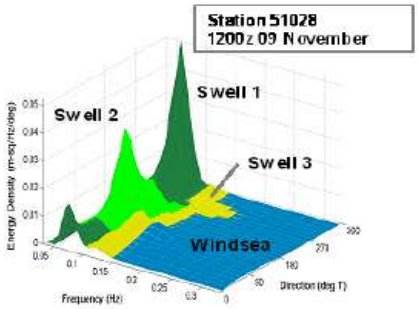

Figure 1. Multi-grid third generation (3G) shows three swell and windsea

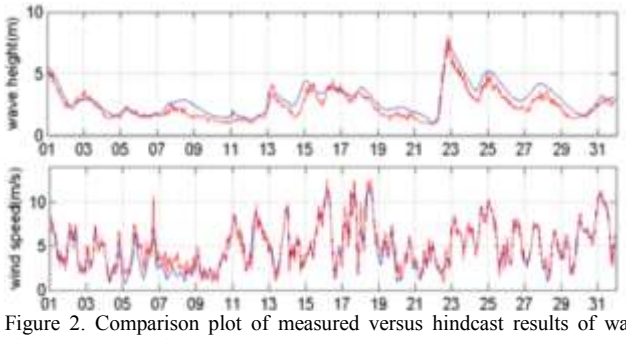

Figure 2. Comparison plot of measured versus hindcast results of wave height and wind speed

TABLE 1 RESULTS FROM STATISTICS FOR THE PACIFIC BASIN HINDCAST

	Bias	RMS	SI	SS	Corr.
WS	0.37	2.39	46	0.90	0.54
HS	0.61	0.52	21	0.93	0.91
TP	0.22	2.05	15	0.99	0.54
TM	-0.02	1.00	8	1.00	0.80

TABLE 2 RESULTS FROM STATISTICAL RESULTS FOR THE PACIFIC REGINAL HINDCAST FOR BUOY 46042

	Bias	RMS	SI	SS	Corr.
WS	-0.25	0.85	16	0.99	0.94
HS	0.41	0.44	18	0.97	0.93
TP	0.23	2.10	15	0.99	0.53
TM	0.23	0.93	8	1.00	0.82

In addition to the above, Horizon Marine is one of the founder in operational oceanography, cooperates with Accurate Environmental Forecasting (AFT) to provide services called Eddy Forecast service to the offshore industry around the world. AFT has been using new modeling technique to predict the situation of Hurricanes Katrina and Rita and has been validated by Eddy Ulysses and Eddy Vortex. From the deepwater hindcast of hurricane Rita research, the in-situ results was measured by NOAA buoy which is located at 25.17°N, 94.42° W in the Gulf and compared with the hindcast results. Figure 3 (a) and (b) show wind speed and significant wave height of NOAA buoy and hindcast. Plotting shows the hindcast results are extremely fit to in both timing and amplitude to the buoy measurements. Model provides a consequential skill all regions of Gulf of Mexico. This technique can be applied obtain similar quality of results in other tropical storm events [2].

From [4], Dutch Offshore Wind Energy Converter (DOWEC) project used NEXT/NESS database to investigate metocean condition. The objective of this study is to find out the wind, wave and current conditions of two fields located in Dutch coast which are NL3 and NL7. The NEXT/NESS database is formed of recorded hindcast data of 3 hours interval from October 1964 to March 1995. However, only 9 years of complete data are available, from 1977 to 1979 and 1989 to 1994. Figure 4 shows the total wind energy in the fitted Weibull distribution and the actual data is matched.

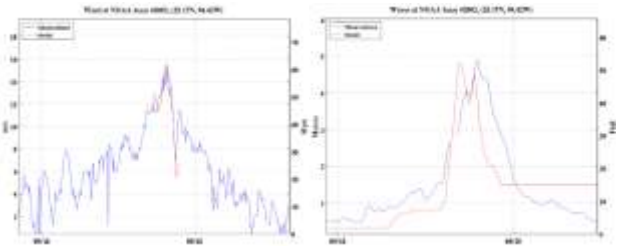
Figure 3. (a) Wind speed of hindcast results compared with in-situ results
(b) Significant wave height from hindcasting compared with in-situ results

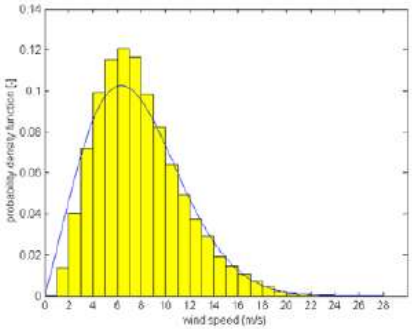

Figure 4. Probability density function versus wind speed

A study period of 9 years is not really long enough compared to some other studies which normally use a period of 30 years. The database of the Dutch KNMI was used to predict a long term situation (30 years) and the results of both were compared to each other.

Offshore wind climate has been measured at Light Isle Goeree station, the correlation of NEXT database, KNMI database and measuring post Noordwijk have been obtained. The correlation factor of those three modes is 0.98 shows a strong correlation to each other and 94% give good reason for the application of this correlation method [4]. Figure 5 shows the correlation of NEXT, KNMI and Noordwijk database.

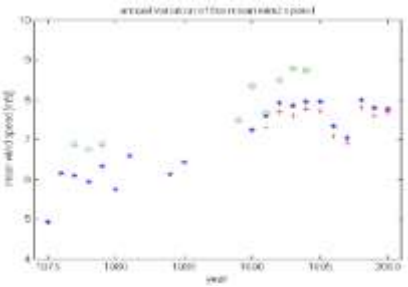
Figure 5. correlation of mean wind speed of NEXT, KNMI and Noordwijk database

As mentioned in [4], there is no typical method of an extreme value statistical analysis technique. However, only the preceding studies or literature can guide which method is the most suitable. Based on this study, the annual extremes for the period of 30 years from 1965-1994 from the NEXT database

has been chosen. The parameters of extreme value distribution are selected and assume that is a right decision making. The calculation of extreme values has been done using the Kolmogoroff-Smirnov test. NEXT database is suitable for designing and estimating metocean conditions.

According to the "*Test of Hindcast Model Results Against Measurements During Four Different Meteorological Systems*" by [10] has stressed that, in the past, non of wind, wave and current modeling performances has been implemented against real data under satisfactorily diverse condition such as hindcast. The study has evaluated the hindcast results of four (4) different circumstances and compared with the real wave conditions. Grid scheme and propagation method have been used to ensure the accuracy and better fit of both data. The four wave situations which were Hurricane scale meteorological systems in the Gulf of Mexico and several storms based on Ocean Data Gathering Program (ODGP) was able developed.

For the Gulf of Mexico, the comparisons of time series were made and verified that the modeling results were compared well to the actual measurements. The comparison proves characteristics that succeed with this model. However, the statistical curve of hindcast is slightly smooth compared to the measured results. Similar to the measurement during the hurricane Camille, the maximum spectrum of hindcast and real situation were measured as illustrated in Figure 6. The graph shows that the 90 percent confidence limits of hindcast spectral peak associated with measured results. At higher frequency, the hindcast values were more vigorous than the measured results [10][6].

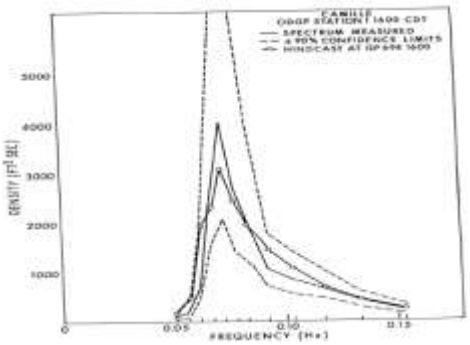

Figure 6. Hindcast and measured result during hurricane Camille

Additionally, throughout the tropical storm Delia at Buccaneer platform, the full directional spectral of hindcast was compared to measure results. The energy density of both had also been contrasted to each other. The model can provide a good prediction of directional character of the sea state. As well as for the U.S. East Coast, the measured and hindcast results agree well to each other in both timing and storm peak. Besides the Gulf of Alaska, the shape of the spectrum from hindcast is mostly the same as measured values. The peak in the time series of hindcast significant wave height and actual measurement is in agreement.

Figure 7 illustrates the time series of each storm in the South of California during March 9-14, 1977. Three storms were measured by using GAPS model. The time series of each storm was observed and reasonably accepted.

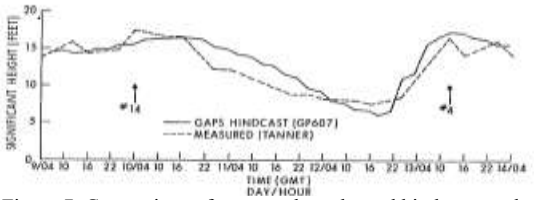

Figure 7. Comparison of measured results and hindcast results

The study had proved that the measured significant wave height and wave period of four (4) different locations were compared well to the hindcast model. Thereby, the difference between actual measurement and model significant wave height does not fluctuate significantly with the change in situation such as location and type of storm. The significant wave height and peak period are well predicted by the hindcast model.

The information from each of the four sites was summarized as shown in Figure 8(a) and (b). The mean and rms of significant wave height and wave period were expressed in Table 3(a) and (b). A positive bias designates hindcast is under predicted.

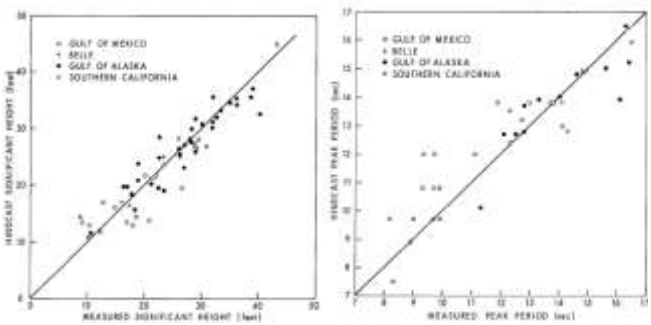

Figure 8. (a) Significant wave height comparison and (b) Peak spectral period comparison (Cardone and Reece, 1982)

Table 3(a) Mean and bias of significant wave height and (b) Mean and bias of peak period

ERRORS IN SIGNIFICANT HEIGHT

Error Type	All Data	Measured Waves Exceed 25 Feet
Bias (ft)	+ 0.47	+ 1.10
RMS (ft)	2.78	2.53

ERRORS IN SPECTRAL PEAK PERIOD

Error Type	Value in Seconds
Bias	-0.22
RMS	1.01

As mention in [6], the hindcast model is used to develop ultimate and reliable measured metocean information correlated with the Hurricane Lili (2002) in the Northern Gulf of Mexico (GOM). UNIWAVE high resolution hindcast was uesd and 3G version was selected to present the condition of its spectrum. Further information and details regarding 3G have been provided in [14]. The UNIWAVE model has been experimented against the measurement of buoy. As a consequence, good agreements of both data are accessed. For the current estimation, Hybrid Coordinate Ocean Model

(HYCOM) which was validated to the Hurricane Andrew in 1992 since there is no any current information of hurricane Lili in the GOM available. Figure 9 shows a comparison of time series of current speed during hurricane Andrew in the GOM. The plot indicates the response in the surface waters of GOM. Results show that hindcast curves are smoother compared to the measured current flow. From the validation of hurricane Andrew, the current hindcasts are more prejudiced compared to the wave hindcasts and the correlation between actual measurement and hindcast model is 0.95 [6].

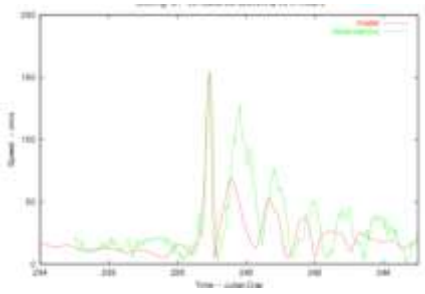

Figure 9. Model versus observed current speed at GOM

Likewise, the study of [8] has presented the result of wave hindcast model's performance versus the measured data at different circumstances as shown in the Figure 10. The comparison of real measurement and hindcast results of significant wave height in the Hurricanes Camille, Carla, Hilda, Betsy and Tropical storm Felice has been made. As consequences, the hindcast model is accomplished of determining metocean data that caused by historical hurricanes with acceptable accuracy. This verifies hindcast model provides precise wave information that can be utilized in statistics design problem.

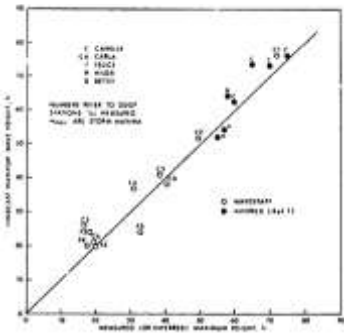

Figure 10. Hindcast and measured maximum wave height during Hurricanes Camille, Carla, Hilda, Betsy and Tropical storm Felice

III. DISCUSSION

Based on the literature review, there are numerous hindcast applications have been applied and developed in many regions in order to enhance its applications. The studies show that using hindcast as a tool in forecasting wind, wave and current information is sufficient and its results are also acceptable when compared to the measured full scale metocean data. Even though, the hindcast model gives acceptable wave climatology information for every concerned area as shown in previous studies. Specific hindcast model can be identified as regional sensitive result which can be used in specific region only leading to optimum design of offshore structure.

IV. CONCLUSION

This paper has presented on hindcast and its application. However, many works have been done to study on usability of hindcast. The literature review has been investigated regarding the existing hindcast model applied in several places.

The future works will be focus more on the detail on the comparison the statistical properties of the full scale metocean data with hindcast data typically used in the offshore industries and ascertaining the correlation of winds, waves and currents of both data in the basins off the coast of Malaysia. Finally the study will prove and validate the results with statistical certainty on the reliability of hindcast data. Moreover, the design domain parameter is expected to be done and can be implemented in the offshore industries.

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REFERENCES

[1] Abreu, M.P., Guedes Soares, C., and Teixeira, J.C. (1995). "Uncertainty of ocean wave hindcasts due to wind modeling", Journal of Offshore Mechanics and Arctic Engineering, Vol. 117, pp. 294-297.

[2] Accurante Environmental Forecasting, Inc. and Horizon Marine, Inc. (2006). "Deepwater Hindcast of Hurricane Rita." Retrieved from horizonmarine: http://www.horizonmarine.com/library/Hurricane_Rita_Report.pdf

[3] Alvarez, E., Carretero, J.C., Guedes Soares, C., and Weisse, R. (2002). A 40 years hindcast of wind, sea level and waves in European waters. *21th International Conference on Offshore Mechanics and Arctic Engineering.* Oslo, Norway: ASME.

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

[5] Borgman, L.E., Cardone, V.J. and Pierson, W.J. (1979). "Statistics of hurricane waves in the Gulf of Mexico" Journal of Petroleum Technology, Vol. 31, No. 5, pp. 632-642.

[6] 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

[7] Cardone, V. J., Cox, A. T., & Swail, V. R. (2001). On the use of In-Situ and Satellite Measurements for Evaluation of Wave Hindcasts.

[8] 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.

[9] Cardone, V.J., Pierson, W.J. and Ward, E.G. (1979). “Statistics of Hurricane Waves in the Gulf of Mexico” Journal of Petroleum Technology, Vol. 31, No.5, pp. 632-642

[10] Cardone, V. J., and Reece, A. M. (1982). Test of Wave Hindcast Model Results Against Measurements During Four Different Meteorological Systems. *Offshore Technology Conference*, (pp. 269-276). Houston.

[11] Cox, A. T., and Swail, V. R. (2000). “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).

[12] Friebel, H.C., Hanson, J.L., and Hathaway, K.K. (2009). “Coastal wave energy dissipation observations and STWAVE-FP performance.” Proc., 11th Int. *Symp. On Wave Hindcasting and Forecasting and 2nd Int. Symp. On Coastal Hazards, Canada.*

[13] Jensen, R. (2010). “Coastal field data collection program Wave Information Studies (WIS).” Coastal and Hydraulics Laboratory, ERDC, Vicksburg, MS 39180.

[14] Khandekar, M.L.,Lalbeharry, R., and Cardone, V.J., (1994) “The Preformance of the Canadian /spectral Ocean Wave Model (CSOWM) during the Grand Banks ERS-SAR Wave Spectra Validation Experiment.” *Atmosphere-Oceans*, 32, 31-60

[15] 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

[16] Lopatoukhin, L.J., Rozhkov, V.A., Ryabinin, V.E., Swail, V.R., Boukhanovsky, A.V., and Degtyarev, A.B., (2000) “Estimate of Extreme Wind Wave Height” JCOMM Technical Report No. 9. World Meteorological Organization Intergovernmental Oceanographic Commission (of UNESCO)

[17] Oceanweather Inc. (n.d.). Oceanweather *Inc: MetOcean Studies: SEAFINE*. Retrieved from Oceanweather Inc. Web Site: http://www.oceanweather.com/metocean/seafine/index.html

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