PERFORMANCE ASSESSMENT OF DIFFERENT WAVE FORECASTING MODELS FOR DETECTING CRITICAL EVENTS IN MARINE CONSTRUCTION SITES ALONG JAPAN COASTS

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1. Introduction

Accurate forecast of the environmental parameters like wave and wind conditions are necessary to ensure safety and to assess the workability conditions in the marine construction site. This creates the necessity of a model that could assess and forecast the influencing environmental conditions. Though there are many forecasting models available, performance accuracy of each model varies depending on the site/area and therefore performance of the model should be good enough to avoid major forecasting errors. These errors can significantly increases the production costs, loss of energy and human resources. Hence, to measure the performance accuracy of each model along Japan coasts following steps have been implemented in this research work; (i) Wave forecasting models namely WAM Model by Wu, WAM Model by Janssen, WAVEWATCHIII, is verified with NOWPHAS Observational data and verification results have been summarized, (ii) Regions along Japan coasts is divided into four regions and performance assessment is carried out by inter comparing model verification results.

2. Study Site, Data Used, Study Period

In this study we use the forecasting results from WAM Model by Wu[1], WAM Model by Janssen[2], both developed at European Centre for Medium-Range Weather Forecasts, WAVEWATCHIII - a third generation numerical wave model by NOAA[3] (National Oceanic and Atmospheric Administration). The observational data was available from NOWPHAS from the Ministry to Ministry of Land, Infrastructure, Transport and Tourism website. To make a clear study on Japan Coasts, regions have been divided into four namely; Region1 East Pacific Ocean, Region2 West Pacific Ocean, Region3 East Sea of Japan, and Region4 West Sea of Japan. As shown in Figure1, three to six sites has been selected in each region based on the geographical locations of the Observational equipments. The data used in this study is for the year 2017, an hourly data for the period from 1st January 2017 to 31st December 2017.

Region1. East Pacific Ocean
■Kushiro ■Tokachi ■Mutsuogawara ■Hachinohe ■Onahama ■Hitachi-naka ■Kashima
Region2. West Pacific Ocean
■Shiyonomisaki ■Kochi ■Hososhima ■Nakagusuku
Region3. East Japan Sea
■Rumoi ■Sakata ■Washima
Region4. West Japan Sea
■Kanazawa ■Shibayama ■Genkainada ■Naha

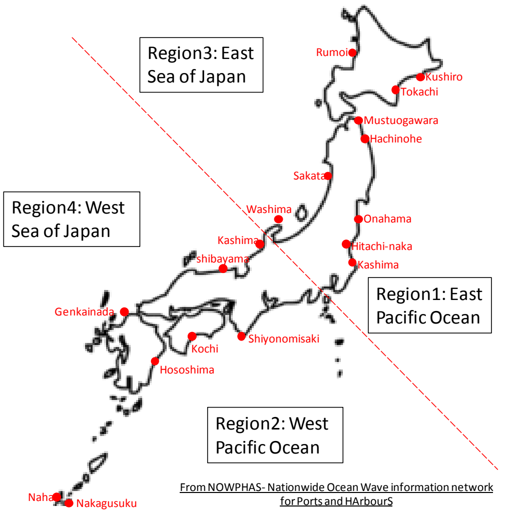

Figure1: Study Site

3. Performance Assessment Results

3.1 By Correlation factor:

Correlation, often measured as a correlation coefficient indicates the strength and direction of a linear relationship between two variables. The correlation between each forecasting model and observational data is calculated and compared in order to understand the strength of the linear relationship. The Figure2 shows the correlation of WAM(Wu), WAM(Janssen),WWIII with the observational data and thus the findings are as follows;

(1) In *Region1 East Pacific Ocean*, wave height is underestimated by WAM(Wu) model and overestimated by WAM(Janssen) model, whereas wave period is underestimated by both WAM(Wu) and WAM(Janssen) model. WWIII provides good correlation with the observations for both wave height and wave period.

(2) In *Region2 West Pacific Ocean*, wave height is overestimated by WAM(Janssen) model and underestimated by WAM(Wu) model, whereas wave period is underestimated by both WAM(Wu) and WAM(Janssen) model. WWIII provides good correlation with the observations for both wave height and wave period.

(3) In *Region3 East Sea of Japan and Region4 West Sea of Japan*, both wave height and wave period is underestimated by both WAM(Wu) and WAM(Janssen) model. While WWIII gives a comparatively better correlation approximation.

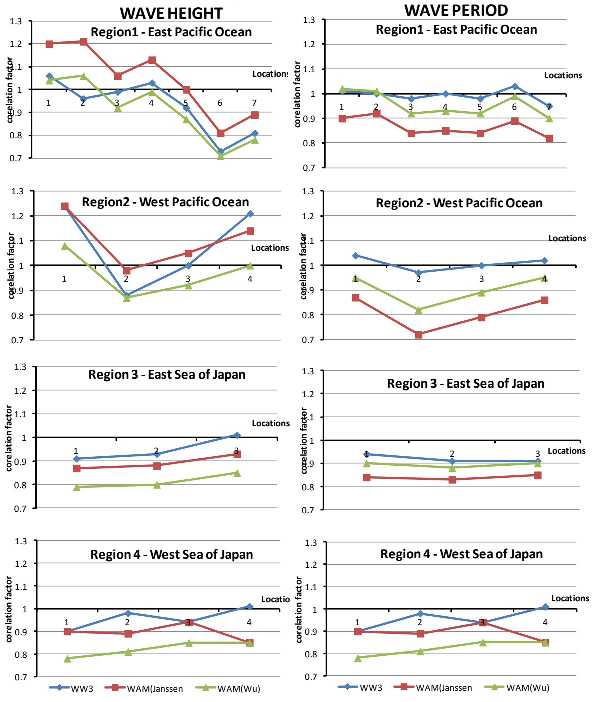

Figure2: Correlation of forecasting models with Observations

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3.2 By Confusion matrix

In this paper, the critical wave conditions in marine construction site are assumed to be 1m wave height and 8s wave period. So, a confusion matrix (error matrix) is calculated for all the places in each region. The following observations have been derived from the confusion matrix[4] *(1)Percent Correct (PC=(a+d)/n)* is percent of forecasts that are correct. PC ranges from zero for no correct forecasts to one when all forecasts are correct.

		Observation data		
		Yes	**No**	
Forecast Model	**Yes**	**TP (a)**	**FN (b)**	**a + b**
	No	**FP (c)**	**TN (d)**	**c + d**
		a + c	**b + d**	**n = a+b+c+d**

Figure3: Sample confusion matrix for forecasting

(2)Hit Rate (HR=a/(a+c)) is the fraction of observed events that is forecast correctly. It is also known as the Probability of Detection (POD). It ranges from zero at the poor end to one at the good end. *(3)False Alarm Ratio (FAR=b/(a+b))* is the fraction of "yes" forecasts that were wrong, i.e., those were false alarms. It ranges from zero at the good end to one at the poor end. *(4) Threat Score (TS = a/(a+b+c))* combines Hit Rate and False Alarm Ratio into one score for low frequency events. This score ranges from zero at the poor end to one at the good end. *(5) Bias (B= (a+b)/(a+c)* compares the number of times an event was forecast to the number of times an event was observed. If B=1 (unbiased), the event was forecast the same number of times that it was observed, if B>1 it implies over forecast and if B<1 implies under forecast.

3.2.1 Occurrence rates

Table1: Verification measures of the forecasting model at each region

	East Pacific Ocean			West Pacific Ocean			East Sea of Japan			West Sea of Japan		
Wave Height	**WWIII**	WAM(Wu)	WAM(Jan)	WWIII	**WAM(Wu)**	WAM(Jan)	**WWIII**	WAM(Wu)	WAM(Jan)	**WWIII**	WAM(Wu)	WAM(Jan)
Percent correct	0.863	0.818	0.716	0.718	0.753	0.632	0.902	0.859	0.885	0.927	0.886	0.908
Hit rate	0.95	0.911	0.972	0.946	0.872	0.94	0.901	0.708	0.792	0.937	0.767	0.852
False Alarm Ratio	0.262	0.319	0.443	0.42	0.373	0.49	0.125	0.050	0.071	0.099	0.032	0.064
Threat Score	0.71	0.639	0.548	0.561	0.575	0.494	0.798	0.683	0.747	0.85	0.748	0.805
Bias	1.287	1.337	1.744	1.63	1.39	1.844	1.03	0.746	0.853	1.04	0.792	0.91
Wave Period	**WWIII**	WAM(Wu)	WAM(Jan)	WWIII	WAM(Wu)	**WAM(Jan)**	WWIII	WAM(Wu)	**WAM(Jan)**	WWIII	WAM(Wu)	**WAM(Jan)**
Percent correct	0.796	0.76	0.784	0.826	0.86	0.875	0.976	0.976	0.978	0.91	0.915	0.948
Hit rate	0.813	0.435	0.623	0.767	0.375	0.56	0.42	0.41	0.651	0.375	0.404	0.67
False Alarm Ratio	0.301	0.133	0.233	0.427	0.054	0.194	0.16	0.147	0.28	0.032	0.026	0.056
Threat Score	0.602	0.408	0.524	0.488	0.367	0.493	0.389	0.383	0.519	0.37	0.4	0.644
Bias	1.163	0.502	0.812	1.337	0.397	0.695	0.5	0.481	0.904	0.387	0.415	0.71

For forecasting critical events (1) At *Region1 East Pacific Ocean*, WWIII forecast was correct 86.3% of the time for wave height and 79.6% of the time for the wave period. At the same time, Hit rate 95% for wave height and 81.3% for wave period is admirable, even though False Alarm Ratio is 26.2% and 30% respectively is high, because WWIII shows lesser FAR compared to other models. Though the bias of WWIII implies a tendency to over forecast, other models shows much larger extent of over forecasting.

(2) At *Region2 West Pacific Ocean*, for the wave height, WAM(Wu) forecast was correct 75.3% of the time. A hit rate of 87.2% gives good forecast, but the False alarm Ratio of 37% is observed to be greater. However WAM (Wu) produces a lesser FAR on comparison with WWIII and WAM (Janssen) with FAR of 42% and 49% respectively. In addition, the Bias of WAM(Wu) model also implies lesser tendency of over forecasting. On contrary, for the wave period, WAM(Janssen) was correct 87.5% of the time and hit rate is 56% with FAR of 19%. Although the bias of WAM(Janssen) implies under forecasting, WWIII and WAM(Wu) shows much larger extent of over forecasting and under forecasting respectively.

(3) At *Region3 East Sea of Japan*, for the wave height, WWIII forecast was correct 90.2% of the time. With higher hit rate of 90.1% and FAR of 12% and also WWIII model is unbiased. On contrary for the wave period, WAM(Janssen) model was correct 97.8% of the time. And the hit rate of 65.1% and FAR of 28%, the unbiased WAM(Janssen) model implies to be good forecasting model. While the other two models implies under forecasting to a larger extent.

(4) At *Region4*, *West Sea of Japan*, for the wave height, WWIII forecast was correct 92.7% of the time. With higher hit rate of 93.7% and lower FAR 9% and WWIII model is unbiased. On contrary for the wave period, WAM(Janssen) model was correct 94.8% of the time. And the hit rate of 67% and FAR of 0.5%, the unbiased WAM(Janssen) model implies to be good forecasting model. While the other two models implies under forecasting to a larger extent.

3.2.2 Skill Score

Table2: Skill Score for all forecasting models at each region

Place Name	Wave Height			Wave Period		
	WWIII	WAM(Wu)	WAM(Janssen)	WWIII	WAM(Wu)	WAM(Janssen)
Region1 (Hachinohe)	71.81	62.95	46.91	57.98	43.59	52.56
Region2 (Shiyonomisaki)	46.62	51.39	32.83	54.27	47.25	58.76
Region3 (Rumoi)	80.04	70.24	76.03	54.90	54.34	67.23
Region4 (Kanazawa)	85.20	76.36	81.26	50.14	53.30	75.49

Skill Score (SS) measures forecast accuracy relative to some set of control or reference forecast. It answers whether the forecast is better or worse than the control or reference forecast. **SS = [(A- A_{ref}) / (A_{pref} - A_{ref})]*100%** where A- measure of accuracy, A_{ref} – measure of accuracy of reference forecast, A_{pref} – measure of accuracy of perfect forecast. If A= A_{pref}, SS= 100% and if A= A_{ref}, SS=0 (no skill). As observed from Table2, at Region1, WWIII model has good forecast accuracy for both wave height and wave period. At Region2, WAM(Wu) shows good forecast accuracy for wave height and WAM(Janssen) for wave period. In Region3 and Region 4, WWIII shows good forecast accuracy for wave height and WAM(Janssen) model shows good forecast accuracy for wave period.

4. Conclusions

Thus the verification and performance assessment of different forecasting model at specific regions is carried out along Japan Coasts and the model that gives best forecasting results at each region has been investigated by calculating standard statistical parameters. Performance assessment of forecasting models of other important parameters like wind speed shall also be investigated in order to determine the workability assessment in marine construction site.

5. References

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