The Modulation of Currents and Waves near the Korean Marginal seas computed by using MM5/KMA and WAVEWATHC-III model

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We have analyzed the characteristics of the sea surface winds and wind waves near the Korean marginal seas on the basis of prediction results of the sea surface winds from MM5/KMA model, which is being used for the operation system at the Korea Meteorological Administration and the third generation wave model, WAVEWATCH-III, which takes the sea surface winds derived from MM5/KMA model as the initial data. Statistical comparisons have been applied with the marine meteorological observation buoy data to verify the model results during Typhoon events. The correlation coefficients between the models and observation data reach up to about 95%, supporting that these models satisfactorily simulate the sea surface winds and wave heights even at the coastal regions. Based on these verification results, we have carried out numerical experiments about the wave modulation. When there exist an opposite strong current for the propagation direction of the waves or wind direction, wave height and length gets higher and shorter, and vice versa. It is proved that these modulations of wave parameters are well generated when wind speed is relatively week.

Key words: Sea surface winds, Wind waves, MM5/KMA, WAVEWATCH-III, Correlation. Modulation.

1. Introduction

Atmosphere and ocean interact in the form of exchanging of heat, material, and energy at sea surface each other. In the ocean, there exist surface current and wind wave due to energy source from atmosphere, and atmosphere generates climate change as it gets heat and other material source from sea surface.

Among the phenomena arisen in sea surface, wave motion is most noticeable parameter to people, therefore it has been carried that the study about the generation, growth, and dissipation of wave[4), 5), 7), 8)]. Since the pioneering paper[3)], many numerical wave prediction models have been formulate and developed through the project like JONSWAP[6)], SWAMP[9)] SWIM[10)] and so on.

In this study, it is carried out that the validation of WAVEWATCH-III(WWIII) model which consider the variation of sea surface wind on time and space and interaction among the nonlinear resonant wave and currents.

We consider the case of typhoons (the 12th PRAPIROON and 14th SAOMAI) in 2000, and verify the concordance between the associated prediction wind and wave fields and diagnose the stability of this model with steep gradient of topography and maximum wind speed in East Asian marginal sea using the third generation wave model.

Many kinds of numerical wave models also neglect the effects of tide and current on wave parameters, though its portion of modulation is small. In this study, it is carried out numerical experiments about the wave modulation near the East Asian marginal seas

2. Model Description

This model accounts for wave generation by adapting the Challikov and Belevich(1993)[2)] formulation. Also wave dissipation is simulated by whitecapping and bottom fraction effects[13)]. It employs a third order finite difference method by utilizing a split-mode scheme with a total variance diminishing limiter to solve wave

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propagation. These facts are the most different points compared to WAM[14]. To simulate and predict wave propagation and dissipation in the East Asian marginal sea, the first domain of this model has a spatial resolution of 0.5 by 0.5 in longitude and latitude ranging from 20N to 50N and from 115E to 145E and the second domain has a spatial resolution of 0.1 by 0.1 from 36N to 39N and from 127.5E to 132.5E.

WWIII model makes a distinction between four different time steps. We calculate wave propagation per 900 seconds for global time step and 300 seconds for CFL and another two minimum time step[12], respectively. Total integrated period is from 20 August to 20 September at major typhoon events in 2000 year.

Using the notation[11], bottom friction source term is defined by empirical constant($0.067m^2/s^3$) and ETOP5 global data is used for bottom topography information. The minimum bottom depth is limited at 2.5m depth.

Since wind waves have a direct effect of the wind blowing over the sea, any error in the input wind field is reflected in an error in the computation of the wave condition. So, first, we carry out the verification of wind data compared to buoy recorders operated by Japan Meteorological Agency(JMA) and Korea Meteorological Administration(KMA).

Wind fields at 10m to force this model are obtained from the lowest levels of the operational version of mesoscale model(MM5) which is developed by PSU/NCAR originally.

3. Model Validation

We consider the case of a typhoon in the East Asian marginal sea from 20 August to 20 September 2000, and the description of the time series of winds compared to wave buoy data. These periods include two major typhoon, one has become known as severe wind speed to west coast of Korea(the 12th PRAPIROON) and the other penetrate the central part of the Korean peninsula(the 14th SAOMAI). As going to higher latitude and land, typhoon forfeits its strength since it does not get energy source form sea surface, however PRAPIROON and SAOMAI do not get weaker because of abnormal warm sea surface temperature.

The comparison between the measured wind speed at the four buoy data and 12-hour forecasting data by the MM5 model is accomplished.

There is a quite remarkable fit as a whole. And the result at the buoy operating by JMA in East China Sea shows fitter than that of other three points located in coastal area in Korea. Since sea surface winds contain many regional effects with mesoscale dimension(2-2000km), especially in coastal area, it is difficult that resolve all local effects with 0.5 degree resolution in this model domain. We expect that diminish root mean square error(RMSE) with find grid model[1]. Nevertheless the whole fluctuation trends of forecasting wind speeds are similar to those of observed ones.

It is found that MM5 model can predict maximum wind speed more than 25m/s more reliably, and it is possible to improve the wave model results by acting as initial condition. This predicted sea surface winds enable us to forecast wave motion.

The wave model results coincide with the tracks of the typhoons if we concatenate the region showing maximum significant height in accordance with time(not shown). As for the right side of center in typhoon, there exist higher than left side since the direction of both wind speed and typhoon pass acts as resonance. The contour of significant wave height deflects to right side of the center in typhoon direction, these results well match with the common phenomenon as mention above.

The predicted results clearly demonstrate high correlation between wave parameters calculated by WWIII and those provided by buoy records. Fig.1 shows the result in buoy22001, which are located in East China Sea shelf break. This buoy is operated by JMA and its data is recorded per 6 hour and the unit of measurement is 50cm. We select 00UTC and 12UTC for validation during typhoon events.

Simple correlation coefficient is calculated about 95.18% and linear regression slope is exactly one. Judging from statistics results, WWIII model can predict as well wind wave or swell during period that shows unstable change of wind speed and sea surface pressure like typhoon event.

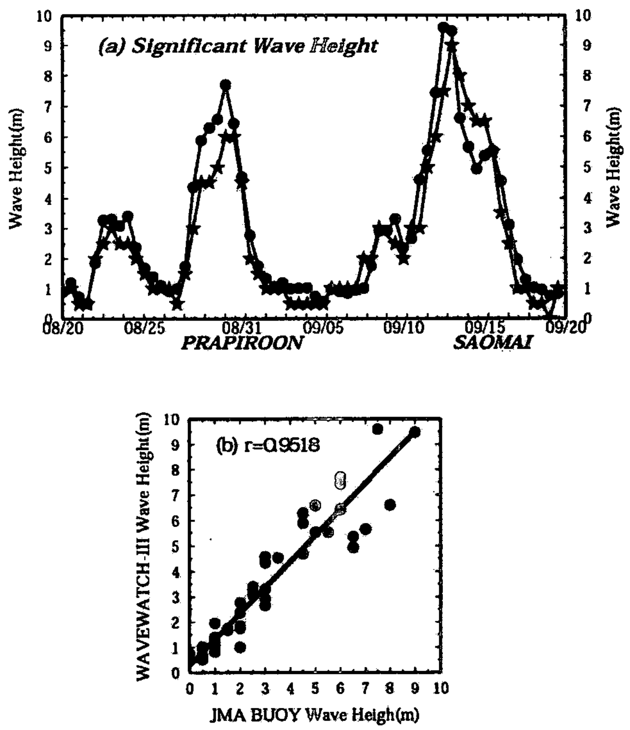

Fig. 1. (a) Comparison between observed data(star) of buoy at East China Sea and calculated significant wave height(circle) calculated by WWIII model during typhoon event. (b) Scatter plot between above two results, and linear regression line.

Table. 1. Statistics for the simulated significant wave height at the buoy positions.

	Correlation	Bias(m)	RMSE(m)	Regression Slope	SI
East China Sea	0.952	0.337	0.798	1.00	0.28
Chilbal island	0.834	0.290	0.612	0.97	0.49
Dukjok island	0.739	0.340	0.613	1.12	0.85
Gojae island	0.845	0.466	0.466	1.17	0.53

Up to now, because of buoy position in coastal region, many wave models cannot simulate coastal wave motion compared to KMA buoy. Consequently, it has been considered that the utilization of buoy data as the indicator of general oceanic condition produces limitation. However, wave parameters including wave height, wave direction and wave frequency that are calculated by WWIII show high correlation with buoy records.

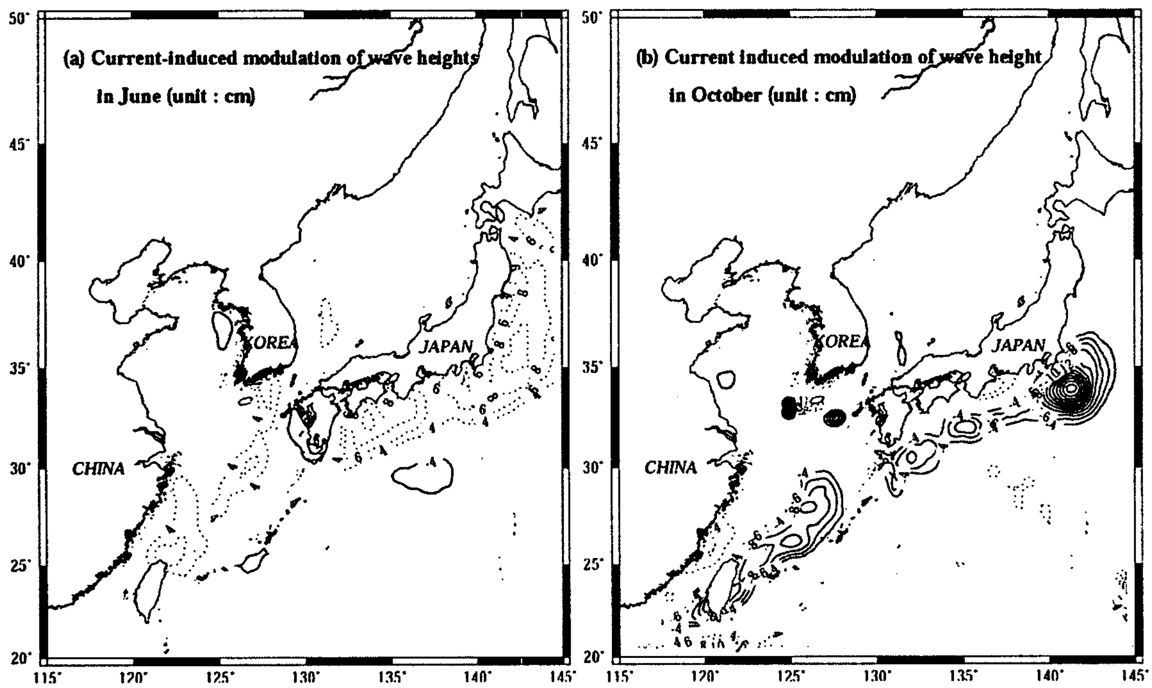

Fig. 2. The horizontal distribution of the current induced modulation of significant wave height in (a)June and (b) October.

Table. 2. Modulation of significant wave height depends on wind and current speeds.

Wind Speed(m/s)	Current Speed(m/s)	Maximum of Significant Wave Height(cm)	Modulation of Significant Wave Height(cm)	Modulation of Significant Wave Height(%)
5	3	112	60	53.6
5	2	112	49	43.8
5	1	112	43	38.4
5	0.5	112	39	34.8
10	0.5	307	40	13.0
15	0.5	564	22	3.9

KMA buoy data is recorded per one hour, we compared to it at same time. As for significant wave height, though simple correlation coefficients are 83.38%, 73.87%, 84.53% that is a little lower than that of East China buoy, bias and RMSE are within significance level. The calculated significant wave heights are some higher than those of observed data about 30 to 40cm. The overall statics for the wave results are given in table 1.

4. Wave Modulation

It has been known that when waves propagate on a variable current and tide, several mutual interactions occur. However, little evidences of observation about this possible interaction have been published. Many kinds of numerical wave models also neglect the effects of tide and current on wave parameters, though its portion of modulation is small.

In this study, it is carried out the numerical experiments by adding the current fields as another initial condition.

If there exist an opposite strong current for the propagation direction of the waves or wind direction, wave height and length gets higher and shorter, and vice versa(Fig. 2). It is proved that these modulations of wave parameters are well generated when wind speed is relatively week. We have calculated values of wave modulation by applying ideal current and wind fields, respectively (Table 2).

5. Discussion and Conclusions

We have always felt the need to develop prediction information about sea states in order to not only safeguard fishing and carrying trade but also defense nation in the sea around East Asian marginal seas especially during typhoon event.

To validate of sea surface prediction model(MM5) and wave model(WWIII) which is initialized by MM5, it is carried out that comparison with buoy data located in East China Sea, Chilbal, Dukjok, and Gojae island.

The third generation wave model shows stability with steep gradient of topography and maximum wind speed during typhoon periods in East Asian marginal sea and represents the energy dissipation by wave breaking like whitecap and interaction with current and bottom friction very well. The point outputs clearly demonstrate high correlation between wave parameters calculated by WWIII and provided by buoy records.

We conclude that the capacity of this wave model is well suitable for operational system for wave prediction. We are supposed to construct wave prediction system using fine grid less than 5km, therefore it enable us to provide precise information about wave motion around East Asian marginal seas.

We expect improvement of this model if we use fine resolution and add boundary condition of current and tide parameters by coupling with ocean circulation model.

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