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NUMERICAL SIMULATION OF TYPHOON WAVE UNDER THE INFLUENCE OF WINNIE (NO. 9711)

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Abstract: In this paper, the wind field provided by a meso-scale atmospheric model is employed. When main physical processes, including wave-current interactions, are considered, the latest version of the third generation wave model SWAN is applied to simulate the typhoon wave generated by Typhoon Winnie. The model results are compared with the TOPEX/POSEIDON and ERS-2 satellite altimeter data and analyzed in details. Then the distribution of wave fields are analyzed, with the results showing that applying SWAN to simulate large-scale domain can also fairly reproduce the observed features of waves and realistically reflect the distribution of typhoon waves.

Key words: typhoon waves; SWAN; Winnie; meso-scale numerical model

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1 INTRODUCTION

In the current numerical study on typhoon waves, the main models are WAM, WAVEWATCH and SWAN. Being a sea wave model for shallow water in the first place, SWAN can now be used for all scales varying from shallow water to open ocean, especially to greater effect when it is applied to simulate waves in shallow waters, thanks to a new numerical method by Rogers et al[1]. Desirable simulations have been made with SWAN for the estuary of the Yangtze River[2] and the Zhangjiang Port[3, 4] and open ocean[5, 6], verifying that it simulates well for open ocean as well as shallow water.

Taking the typhoon waves caused by Typhoon Winnie as the object of interest, the development of sea waves and distribution of typhoon waves are studied. SWAN is the model used to simulate the East China Sea that has complicated topography and geomorphology, for it takes into account physical processes comprehensively.

2 DESIGN OF THE NUMERICAL EXPERIMENT

The determination of the typhoon wind field is very important for the forecast of typhoon waves. As shown in our recent study, the wind field simulated with mesoscale atmospheric models has better simulation of typhoon waves than the popular, empirical conceptual wind field. In this study, a wind field 10 m above the sea surface at the interval of 30 minutes got from a simulation of Winnie using MM5v3[7] is used as the wind field of the SWAN model. During the period of simulation, the mean distance error is 54.5 km between the 6-h simulated position and the observed one, resulting in successful simulation of the change in sea surface wind field with the movement of Winnie[8 – 10].

The simulation starts from 06:00 Aug.17 to 18:00 Aug.19. The initial sea state starts from 06:00 Aug.17, which is simulated with POM. The model initialization is based on the JONSWAP spectra that have the initial input of a limited wind field. A non-static model is used that is depicted with the spherical coordinate system, with 135×165 gridpoints and the horizontal resolution is about 8 km. For the discretized wave spectrum at each of the gridpoints, the directional resolution is six degrees, or, 60 directions. The frequency resolution is

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over 25 sections of the frequency, from 0.0418 to 0.5. The time step is 15 minutes.

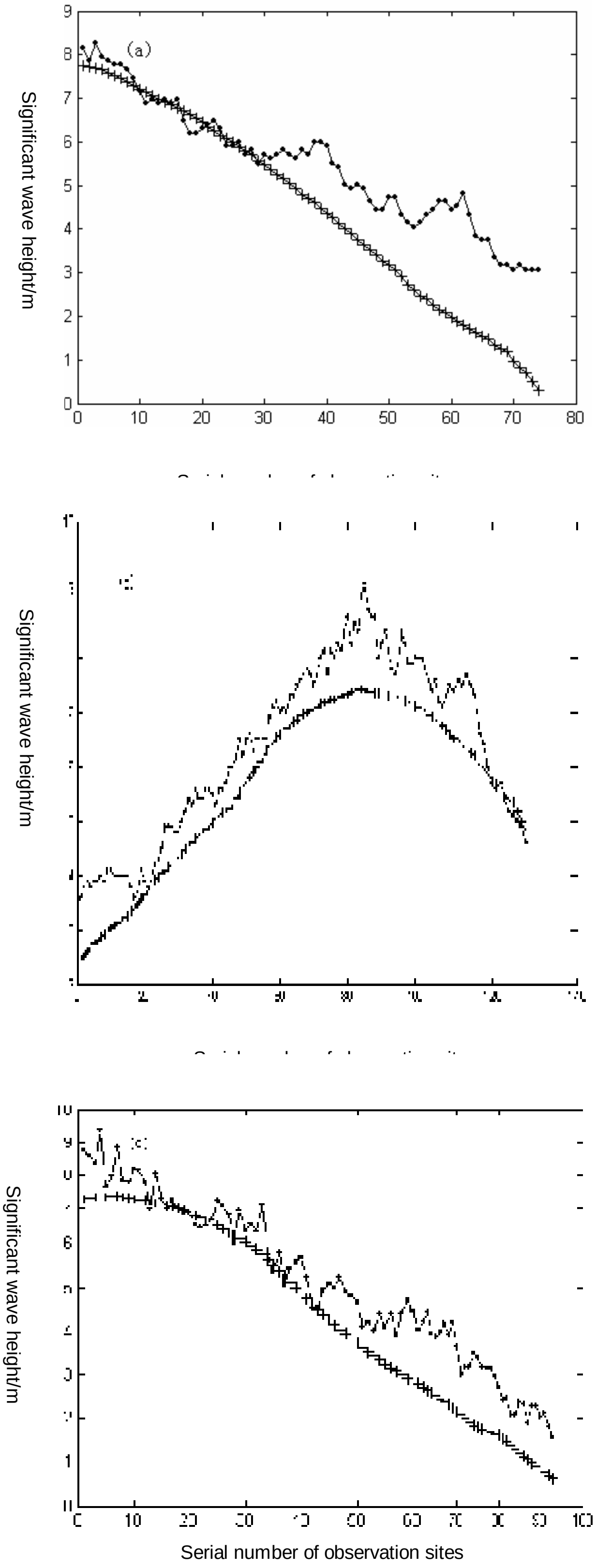


Fig.1 Comparison between significant wave height as observed with the significant wave height observed on Channel 127 (a) and Channel 138(b) of the T/P satellite and Channel 559 (c) of ERS-2 and the simulated one. •: the observation; +: the simulation.

3 ANALYSIS AND DISCUSSIONS OF THE RESULTS

The observations taken with the T/P and ER-2 satellite altimeters are compared with the simulated significant wave height. It is known from Fig.1a that the variation of the latter tends to be consistent with the observations. Most of them are a little smaller than the observation, especially so for the sites after the serial number of 40 where the simulated significant wave height differs much from that of the T/P dataset. Fig.1b shows that the simulated significant wave height is close to the observation, with the maximum error at 1.69 m and the minimum at 0.04 m, though most of the former is a little smaller than the latter. Fig.1c shows good agreement between the simulated significant wave height with the ERS-2 observation.

Fig.2 gives the distribution of the wind speed and significant wave height simulated for 22:00 Aug. 17. It can be seen that some of the distribution characteristics of the wave height are well reproduced. It is also known from the distribution of simultaneous wind field that the distribution of significant wave height is directly linked with that of wind speed. It results in asymmetric distribution of the wave height relative to the typhoon center. The maximum wave height of typhoon waves is generally to the right of the typhoon center and moves with it. Additionally, as the main factors affecting the distribution of significant wave height are wind speed and topographic features, the significant wave height is not completely consistent with the wind speed as far as the distribution is concerned. It is especially true in offshore areas where the latter affects the former substantially. Wave height can decreases rapidly due to the frictional effect of seabed.

The distribution of typhoon wind field is also affecting that of wave direction. As shown in Fig.3a and 3b, sea wave has been under persistent force of high wind speed to the right of the typhoon center over the open ocean to cause strong wind wave, which moves in the direction of the typhoon track that agrees generally well with the wind direction. To the left of the typhoon center, however, the smaller wind speed leads to larger portion of swell that results from a resonant mechanism. The directions of wind wave and swell jointly determine that of wave and the sea wave moves in directions that is different from the wind, with large included angles or even in reversed angles. After landfall (Fig.3d), the wind wave takes up the dominant role over sea surface so that the wind has basically the same direction as the wave. Over the offshore waters, due to large topographic effect on the direction of wave,

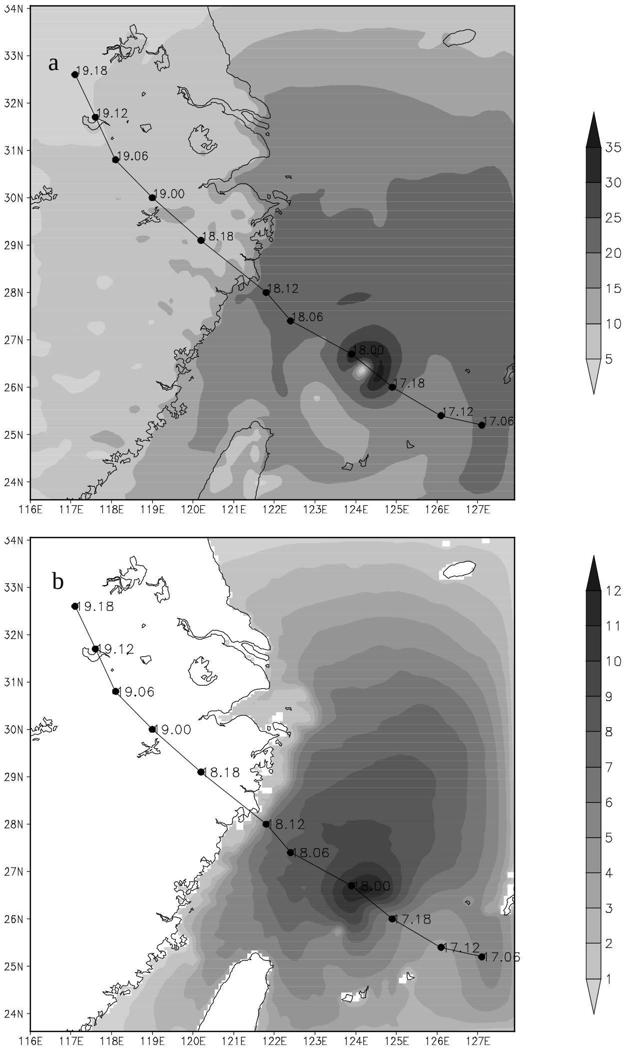


Fig.2 Distribution of wind speed (a) and simulated significant wave height (b) for 22:00 Aug. 17.

the typhoon wave is transported offshore in a way that is different from that over the open ocean. Whether it is before the landfall (Fig.3a & 3b), during it (Fig.3c) or after it (Fig.3d), there are swell and wind wave coming from the ocean, the direction of which is chiefly determined by wind direction and topographic features. The latter causes inconsistent offshore wave direction with the wind direction.

For analyses of other aspects, refer to the Chinese edition of the journal.

4 CONCLUSIONS

Applying the latest version of SWAN model, the current work simulates the process of typhoon wave caused by Typhoon Winnie (9711). The simulated significant wave height has been compared in detail with the data of T/P satellite altimeter. The results have shown that they are good agreement though with values slightly lower than the observation.

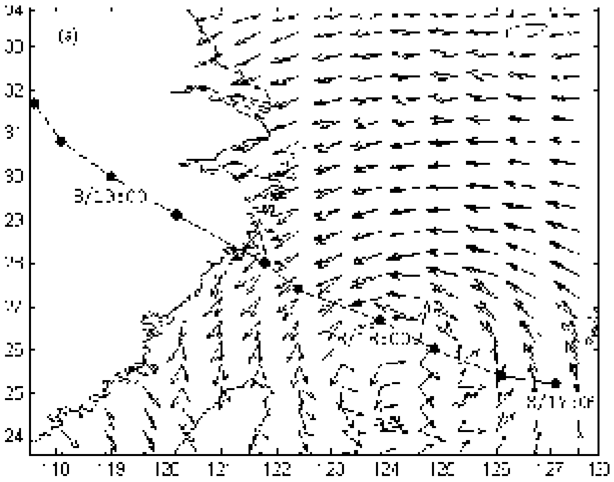
(1) The model for sea surface wind field driven wave model, simulated with the mesoscale atmospheric model MM5, is used to replaced the empirical conceptual wind field currently popular to drive the wave model SWAN with better results.

(2) In the application of SWAN, physical processes such as wind – wave interactions, dissipation, wave – wave interactions are considered.

(3) As shown in the comparison between the simulated significant wave height and the data of T/P satellite altimeter, there is very high correlation between the simulation and observation, showing that the simulation conducted in this work is successful.

(4) There have been a number of successful cases of applying SWAN in offshore study. Our simulation has shown that SWAN can also have desirable results if it simulates open ocean by truly reproducing the development of wave and reasonably reflecting the distribution of typhoon waves.

(5) Elements of the typhoon wave are distributed in the following way. Over the open ocean, there is usually an area of maximum wind speed to the right of the typhoon center in the moving direction of the typhoon, large wind speed and significant wave height, and wave direction that generally agrees with wind direction. The wind speed is usually smaller to the left of the typhoon center, wind speed and significant wave height are usually smaller than those to the right and wave direction is not consistent with wind direction. In the offshore are, elements of the typhoon wave are subject to larger topographic features, which is different from the distribution over the ocean.



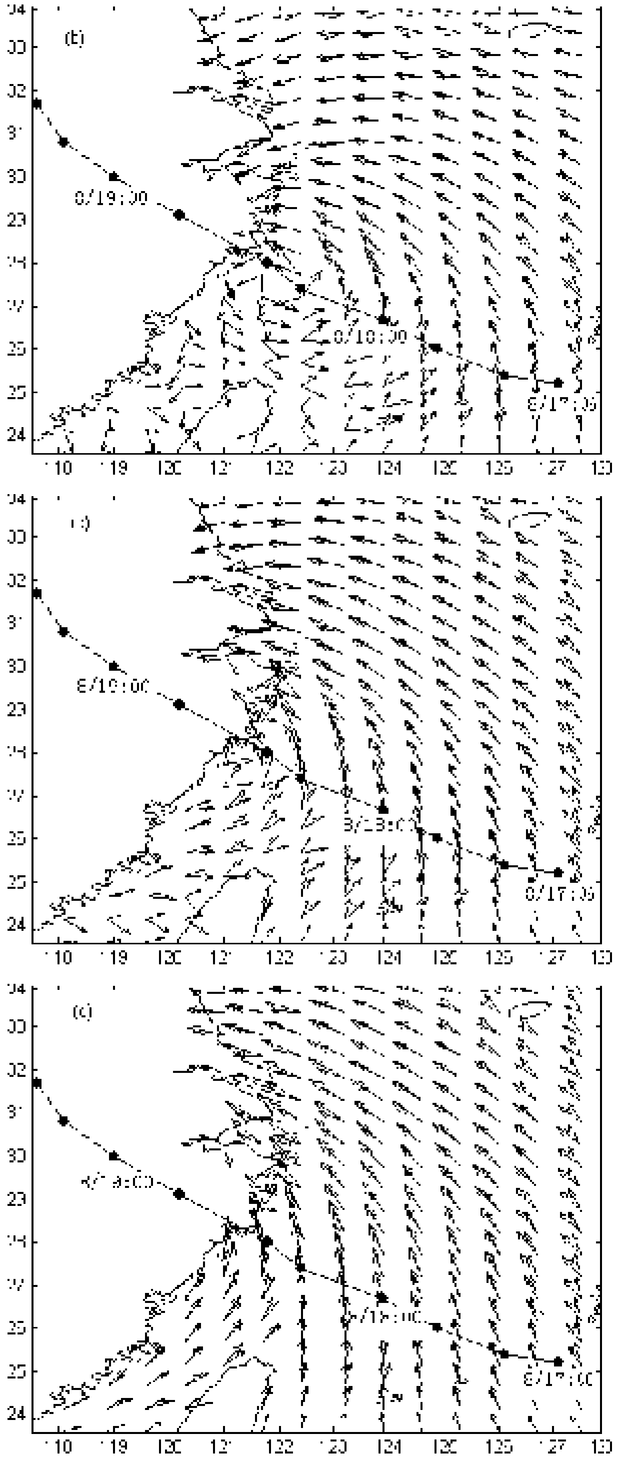


Fig.3 Distribution of the included angle between wave direction and wind direction at different time. a. 22:00 Aug.17, representing the time when the typhoon center is over the ocean; b. 08:00 Aug.18, representing the time just before landfall; c. 13:00 Aug.18, representing the time during landfall; d. 21:00 Aug.18, representing the time after landfall.

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