Numerical Simulation of Wind Wave in Bohai Sea Induced by Cold Wave

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Abstract. This paper using WRF mesoscale atmospheric model, the reanalysis wind field data provided by ncep global forecast field as the initial condition and boundary condition with time, calculated the wind field with sufficient precision, provided the driving wind field for the wave numerical calculation, calculated the corresponding wave field with model SWAN, and simulated the wind wave process caused by a cold wave wind in the Bohai sea area from 5 to 7 November 2015. The calculated model was verified by the measured wind and waves data at the stations of Huanghua and Dongying. The results show that the simulation values of wind and wave elements are in good agreement with the measured values. The model can reproduce the characteristics of wind and wave distribution during the cold tide in Bohai Sea.

1. Introduction
The cold wave usually brings strong winds, is one of the worst disastrous weather that affects our country in the winter half year, Bohai Sea is in the northern part of the China sea, cold wave strong wind is more frequent. The high storm and storm surge caused by cold wave have serious influence on marine engineering, shipping operations, channel silting and coastal economy. So the wind and waves numerical simulation of the Bohai Sea during the cold wave is of practical significance.

The disaster caused by cold wave is more serious, the impact of cold wave cannot be ignored[1]. Many scholars have done a lot of research on the wave characteristics of the Bohai Sea[2-6], and the cold wave is relatively scarce, so the numerical simulation of the wave field under the cold wave has certain significance.

With the rapid development of wave theory and computer technology, it is more effective to study the wave propagation law by numerical model. In this paper, the wind and waves caused by a cold wave wind in the Bohai sea between November 5 and 7, 2015 are simulated and validated by the wind and wind data measured at the observation stations of huanghua and dongying. The results show that the simulation values of wind and wave elements are in good agreement with the measured values. The model can reproduce the characteristics of wind and wave distribution during the cold tide in Bohai Sea.

2. Wind Field Numerical Calculation

2.1. Atmospheric Patterns
WRF is a mesoscale atmospheric prediction model developed by NCAR and NECP. It has been widely studied and applied in the world[7-9].

2.2. Initial and Boundary Conditions
The initial conditions and boundary conditions in the WRF model are provided by the NCEP historical reanalysis wind field data with a time accuracy of 6h and a spatial resolution of $1.0^\circ \times 1.0^\circ$.

2.3. Model Area
The WRF model is calculated using double mesh nesting technique. See Figure 1. A quadrilateral grid is used. The latitude and longitude range of the large model is $114.05^\circ \sim 130.95^\circ$ E, $24.05^\circ \sim 41.95^\circ$ N, and the grid number is 170 x 1. The longitude and latitude range of the small model A2 is $117.03^\circ \sim 128.98^\circ$ E, $29.03^\circ \sim 40.98^\circ$ N, with a grid number of 240 x 240.

![Figure 1. Computational domain](image)

2.4. Parameter Settings
There are many kinds of physical modes to choose from for each kind of meteorological physical process provided by WRF mode. In this calculation, the vertical stratification is taken to 35 layers, the maximum pressure is taken to 1000 Pa at the top, the integral time step is 30 S and the output time interval is 1 H.

2.5. Wind field Calculation and Verification
The cold and windy process from 5 to 7 November 2015, lasted 48 hours and above, with an initial wind direction of E, then ENE and finally NE.

To verify the validity of the wind field model, Figure 2 show the measured wind speed and wind direction data of Huanghua and Dongying stations during the cold wave storm in November 2015 were compared with the model.

![Figure 2. Comparison of measured and calculated wind speed and direction](image)
Figure 2. Comparison of calculated wind velocity and measured

The results show that the calculated and measured values are well verified in terms of magnitude and trend. WRF model can reasonably describe the wind speed and wind direction during the cold wave wind process. It can provide high precision wind speed and ensure the rationality of wave field simulation.

Figure 3 and Figure 4 show the calculated domain wind velocity isobaths and wind vector field at 2015-11-5 23:00 UTC. At this time, the sea area of the Bohai Sea is basically SE direction wind, wind speed distribution is small in the Northeast and large in the Southwest, the maximum wind speed is about 20 m/s.

Figure 3. wind field contour
Figure 4. wind field vector

3. Numerical Calculation of Waves

3.1. Model Area
SWAN is the third generation of coastal shallow water wave numerical computing model developed by Delft University of Technology in the Netherlands. After years of improvement, SWAN has gradually matured and has been widely used in many shallow sea numerical studies[10,11]. Waves are calculated using locally encrypted unstructured grid terrain, as shown in Figure 5, covering the area of the Yellow Bohai Sea with a single node number, with a maximum grid space step length of 0.1 ° and a minimum of 0.001 °. The high resolution wind field calculated by WRF is used to calculate the parameters of wave height, mean period and wave direction in the region of concern.

Figure 5. Computational domain of wave
Figure 6. Wave field (2015-11-5 11:00 UTC)
3.2. Wave Calculation and Verification

Figure 6–8 gives the calculation domain effective wave high isobath wave field at 2015-11-5 11:00 2015-11-5 23:00 2015-11-7 2:00 UTC time during cold and strong winds. During high winds, the wave field in the Bohai Sea was small in the Northeast and large in the Southwest, and the maximum effective wave was above 5.5 m/s.

The calculation value of Dongying station model is compared with the measured wave data (Figure 9). The calculated values of wave height and wave direction and measured values are well proved in terms of magnitude and time variation.

This cold wave wind is mainly ENE ~ NE, the wave distribution in the Bohai sea area is small in the Northeast, increasing gradually to the Northwest sea area, the maximum effective wave height is over 4 meters, the largest wave reaches 3.9 m in Dongying. From the wind energy, the reconstruction period is about 25 a once. The channel of Huanghua port and Binzhou port caused serious siltation. The study of wave growth process and wave field distribution during the cold-tide wind can provide accurate wave dynamic force field for the model of sudden deposition in the high-wind.

4. Conclusions

By using WRF mesoscale atmospheric model, the wind field with sufficient precision in the Bohai Sea area is calculated, which provides the driving wind field for the numerical calculation of the waves.

(1) The calculation model was verified by the measured wind and waves data at the observation stations of Huanghua and Dongying. The results show that the simulation values of wind and wave elements agree well with the measured values.

(2) The cold and strong winds are mainly ENE ~ NE, and the wave distribution in the Bohai Sea is small in the Northeast, increasing gradually to the Northwest, the maximum effective wave height is over 4 meters.

(3) The study of wave growth process and distribution of wave field during the cold wave and high wind can provide accurate wave dynamic force field for the model of sudden deposition in the high wind.

5. References
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