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Hindcast of abnormal high waves with depression bogussing
보거싱 기법을 이용한 동해의 이상파고 재현

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1. INTRODUCTION

The Disaster Prevention Research Institute (DPRI), Kyoto University has conducted field observation of sea surface wind, coastal waves and currents in the near-shore region under the storm condition of winter monsoon every year since 1997 using the T-shaped Observation Pier (TOP). This pier and Ogata Wave Observatory (OWO) are located at the center of the Jouetsu-Ogata Coast, Niigata, Japan. The sea surface elevation and wind direction and speed are measured with seven down-looking ultrasonic wave gauges and a propeller anemometer set along the Pier, TOP. The extreme wave condition was observed in Ogata observation station on 20th of December, 2003. However, the TOP's observation system could not measure the waves during the maximum wave conditions because of data transfer cable troubles due to severe wave condition.

The Mesosclae Model (MM5) was computed for simulating winter storm status of the East Sea. The analysis period is from 00UST (09JST) 17 December 2003 to 00JST 23 December 2003. The initial and lateral boundary conditions are imported by the Japan's operational global simulation system (JMA-GSM). The sea surface temperature field is provided by the weekly 1.0 x 1.0 degree resolution optimum interpolation SST analysis (Reynolds and Smith 1994), and is held constant throughout the whole periods in the simulations. Also the suitability of typhoon bogussing scheme was tested. WAVEWATCH III (WW3) was used for computing wave condition using MM5 results. Computed wave height and period were presented and compared with observed data.

2. EXPERIMENT

2.1 Bogussing Scheme

A simple scheme for bogussing low pressures (or typhoons) into the initial condition of MM5 can be used for improving computational result. The scheme is designed to be robust and provide a significant enhancement of initial tropical storm strength and positioning relative to what is available in the background gridded information obtained from global or large region models. A flow diagram of the bogussing scheme shows in Figure 1.

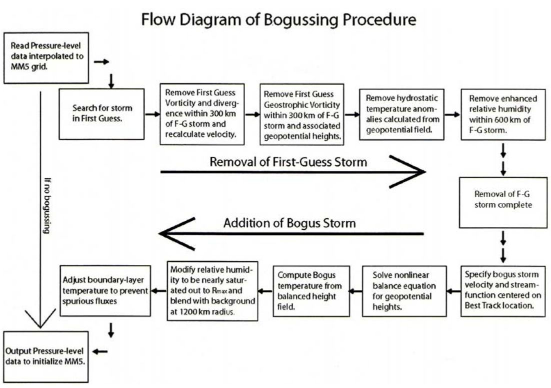

Fig. 1. Flow diagram of bogussing calculations (Low-Nam and Davis, 2001)

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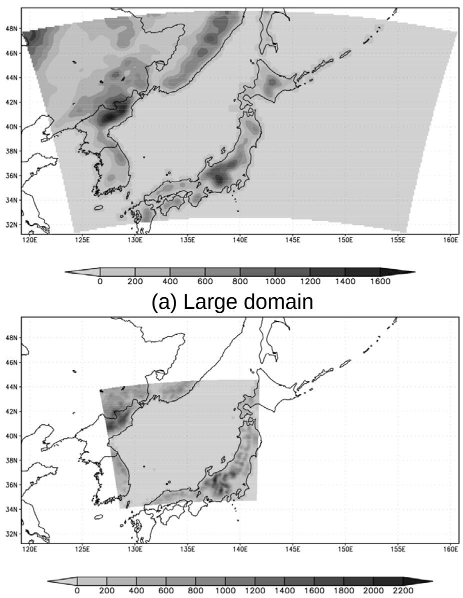
2.2 Computation of wind fields using MM5

MM5 computation was carried out for simulating winter storm status of the East Sea during 2003. The large domain has the grid increment of 27 km (Figure 2-a). Lambert-Conformal map projection was hired for composing domain. Calculation is performed for mesh size of 112 x 90 point, and time steps of 60 seconds. 23 vertical full-sigma levels are used from surface pressure level to 100 hPa in all domains. The analysis period is from 00UST 17 December 2003 to 00UST 22 December 2003. The initial and lateral boundary conditions of the first domain are imported by the operational global analysis model (JMA-GSM) and the analysis nudging is applied in the whole experiments (D1 case). The sea surface temperature field is provided by the weekly 1.0 x 1.0 degree resolution optimum interpolation SST analysis (Reynolds and Smith 1994),and is held constant throughout the whole periods in all simulations. Typhoon bogussing scheme was applied and verified to modify pressure and wind fields using JMA's weather charts for representation of low atmospheric pressure at 00UTC 20 December 2003 (D1-TB case). Also the nesting domain of MM5 was tested to enhance the results (D2-TB case). The second domain has the grid increment of 9 km (Figure 2-b)

2.3 Computation of wave fields using WW3

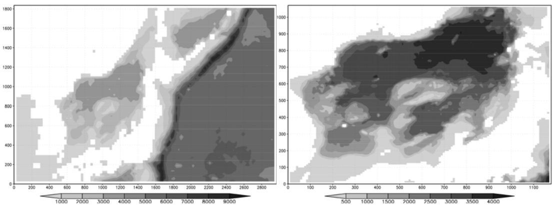
The same grid systems with MM5 were assigned for computational domains with the resolution in Cartesian space grid of 27 km and 9 km (Figure 3). The wave number grid in WW3 is corresponded using these parameters; frequency increment factor $X\sigma = 1.1$, first frequency $\sigma 0 = 0.0412$ (Hz), number of frequencies $m = 25$. The direction is divided by 24 (15 degree). The global and intra-spectral propagation time steps are taken as 600s, and the spatial propagation and integration of source terms time step is 60s. Suggested constants of unstable atmospheric stability were tested in the source term package. Three cases of WW3 simulation were tested by using the results of MM5 simulation with 1 hour time interval; (1) Large domain by the initial and lateral boundary conditions of JMA-GSM (D1 case), (2) Large domain by modification of low pressure by typhoon bogussing scheme (D1-TB case), and (3) Small domain by multi-nested simulation with typhoon bogussing scheme (D2-TB case). The computation period is from 00UST 17 December 2003 to 00UST 22 December 2003, same as MM5 simulation.



(a) Large domain

(b) Small domain

Fig. 2. Model domains and terrain elevation of MM5 in Spherical coordinate



(a) domain 1 (b) domain 2

Fig. 3. Model domains and water depth (unit:m) of WW3 in Cartesian coordinate (unit: km)

3. RESULTS

3.1 Wave Observation in Ogata Coast

T-shaped Observation Pier (TOP) and Ogata Wave Observatory (OWO) are located at the center of the Jouetsu-Ogata Coast. The sea surface elevation and wind direction and speed are measured with seven down-looking ultrasonic wave gauges and a propeller anemometer along TOP (see Figure 4). Wave height is compared on the two different grid points, nearshore (P33) and off the land (P45).

Observed data of wave heights and wave periods in wave gauges from 00UTC 19 December 2003 to 00UTC 21 December 2003 was compared. OWO's wave data observed inside the surf zone during the peak time on 20th December was not suitable for the verification of offshore wave simulation. Wave data observed at OWO have transfer cable trouble due to high wave attack. So data observed at the Naoetsu Harbor was used in this study.

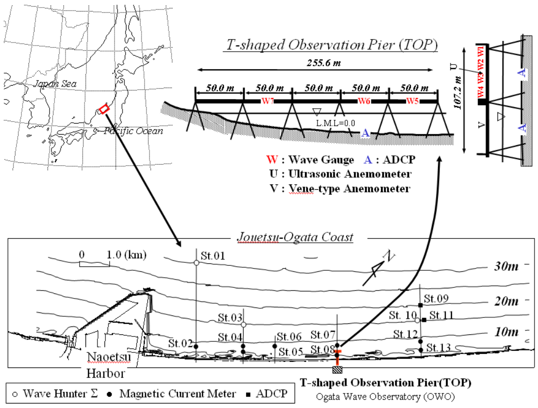


Fig. 4. Location of Ogata Wave Observatory (OWO) and T-shaped Observation Pier (TOP)

3.2 MM5 simulation of winter storm event in 2003

The following three cases of simulations were carried out and compared in this study;

(i) D1 case: MM5 simulation using JMA/GSM data for initial and lateral boundary conditions

(ii) D1-TB case: Same as D1 case and typhoon bogussing scheme was tested for low pressure

(iii) D2-TB case: Sub-nesting system was simulated with D1-TB case

The JMA weather chart is shown in Figure 5, and the sea-level pressure field of the operational global analysis model (GSM) of JMA is shown in Figure 6-a, at 00UTC 20 December 2003. It is observed that a small-scale low pressure area (992hPa), called a pressure dip, located off Akita Prefecture at 00UTC, 20th. The depth of low pressure simulated in GSM is about 994hPa, which is slightly weak comparing with JMA weather chart. Figures 6-b~d show the computed sea-level pressures of D1 case, D1-TB case and D2-TB case at 00UTC 20 December 2003. The low pressure located off Akita Prefecture could be simulated in D1-TB case, but that effect is too much. In the result of 2nd nesting domain (D2-TB case) shows better distribution of sea-level pressure.

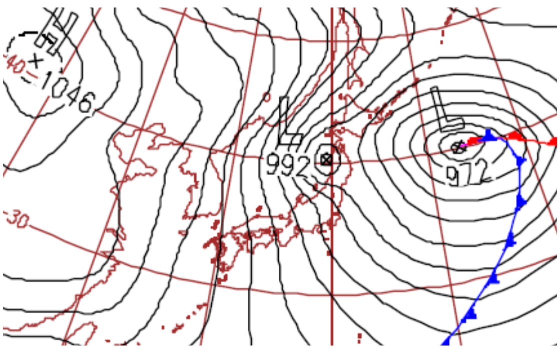
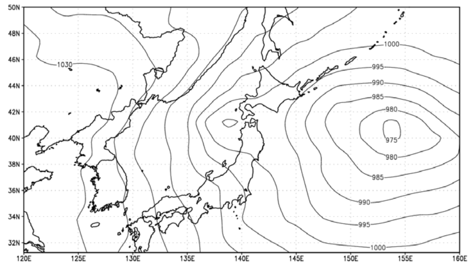
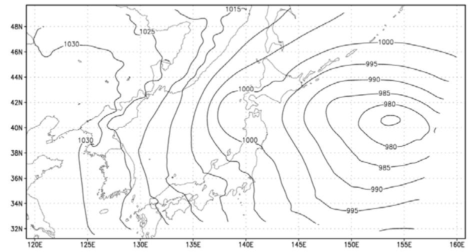


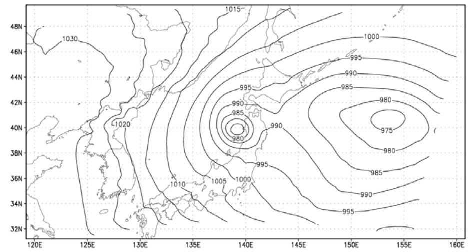
Fig. 5. Weather charts of JMA at 00UTC 20 Dec 2003.



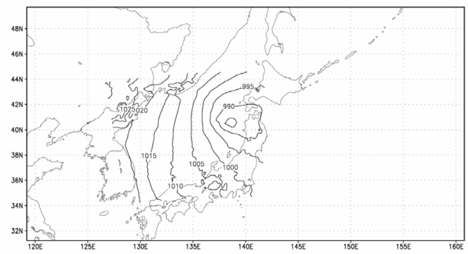
(a) operational global analysis model (GSM)



(b) D1 case



(c) D1-TB case



(d) D2-TB cases.

Fig. 6. Sea-level pressures at 00UTC 20 Dec 2003.

Figure 7 shows the time series of the observed wind data at the meteorological observatory in Ogata supplied by JMA and computed (D1, D1-TB and D2-TB cases) wind speeds at observatory location. Figure 8 shows the time series of the observed wind speed at Ogata Observation Pier using propeller type anemometer and computed wind speeds at P33 location. The result of non-typhoon bogussed simulation shows week trends. The wind of original GSM (D1 case) can not reproduce the strong wind speed at 06UTC. Using typhoon bogus and multi-nesting system (D2-TB case) can improve the results and shows better agreement with the observation of sea surface wind speed near OWO.

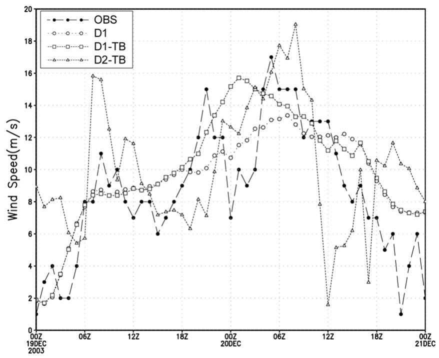


Fig. 7. Observed (JMA) and computed wind speed at the meteorological observatory in Ogata.

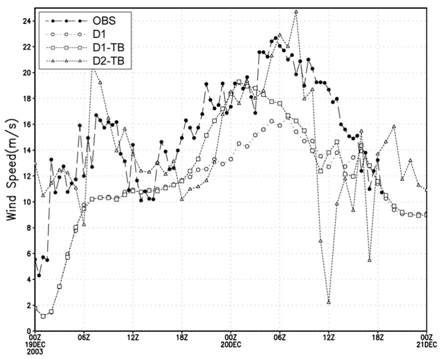


Fig. 8. Observed (propeller anemometer) wind speed at TOP and computed wind speed at P33.

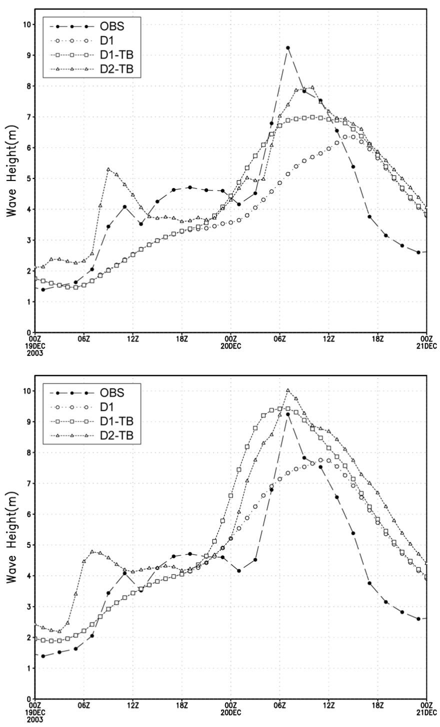


Fig. 9. Observed (JMA) significant wave height at Naoetsu Harbor and computed significant wave heights at P33 (upper) and P45 (lower)

3.3 Wave simulation of winter storm event in 2003

Figures 9 show the computed and observed significant wave heights at P33 and P45. Observed data at Naoetsu Harbor is used for comparison with computational results (D1, D1-TB and D2-TB cases). Maximum value of observed significant wave height is 9.24m at 07UTC 20 December. Maximum values of the computed wave height of D2-TB case at observation point, P33, about 8m and D1-TB case about 7m. This is smaller than observation. Finer grid system should be used for wave simulation in the shallow sea. Maximum value of significant wave height computed at the point, P45, of D2-TB case is about 10m and of D1-TB case is about 9m.

4. CONCLUSION

The mesoscale meteorological model (MM5) was coupled with ocean wave model (WW3) to simulate the extreme wave generation due to moving atmospheric low pressure in the East Sea.

The wind of original GSM can not reproduce the magnitude of observed wind speed. GSM wind may not be directly applied to wave simulation as sea surface external forces. The computed wave period shows slower changes in time, but wave height shows good agreement with observation.

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