Numerical Experiments of Typhoon Bilis using a non-hydrostatic atmospheric model coupled with a mixed-layer ocean model

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1. Outline of a coupling procedure of a mixed layer model

A non-hydrostatic atmospheric model (NHM), which is the same model as the model running operationally in the Japan Meteorological Agency (JMA), is coupled with the ocean model of which type is a slab-type mixed layer model. Numerical experiments of intensity predictions of tropical cyclones are carried out using the NHM-ocean coupled model with different horizontal resolutions. Vertical configuration of the mixed layer model is comprised of a mixed layer, thermocline, and a bottom layer. Unlike the experiment by a typhoon-ocean coupled model of Wada (2003), initial depths of a mixed layer and a thermocline are simultaneously determined dependent on seasons and areas in the ocean. The mixed layer model consists of equations of motion, continuous equations, equations for sea temperature and salinity, *etc*. Almost all the model specification is the same as that of Wada (2005). However, equations for sea temperature and salinity are applied for Ginis (1995). Moreover, pressure gradient terms in the equations of motion are derived from the formulation of Ginis (1998). ETOPO5 data are used by linear interpolation as model oceanic topography. Map projection of the ocean model is conveniently copied with that of the NHM. Message Passing interface (MPI) is available so that we can run the coupled model more economic. At the initial stage, oceanic currents are assumed to be motionless. At the first step in the computation of the ocean part, a spin up procedure is carried out to estimate the ocean currents until total kinetic energy in the ocean becomes constant.

2. Numerical experiments

Atmospheric initial and lateral conditions are prepared in the following procedure; The JMA global spectral model (GSM of which version is T213L40) is preliminarily carried out to obtain 72-hour predictions every three hours apart. Then, the JMA typhoon model (TYM) with 20km horizontal resolution is also carried out to obtain 72-hour predictions every three hours apart like those of GSM. Atmospheric initial and lateral conditions are obtained from predictions by the TYM. The typhoon bogusing using in the TYM is reflected on the initial field. Initial conditions of sea surface temperature (SST) are obtained by linear interpolation from the JMA daily global analysis data (1x1 degrees). Initial conditions of salinity and sea temperatures except the SST are extracted by linear interpolation from World Ocean Atlas in 1998 (WOA98). Two different horizontal resolutions (6km and 18km in this study) are prepared to evaluate the dependency of tropical cyclones' intensity on the horizontal resolutions. In the NHM, a parameterization of sea spray effect (Bao, 2000) is optionally introduced. The cumulus parameterization by Kain and Fritsch (1990) is used in all numerical experiments although finer horizontal resolution of 6km is applied for the simulations.

3. Results

Numerical experiments in the case of Typhoon Bilis are conducted using the NHM-ocean coupled model. The initial time of the numerical experiment is 1200UTC on August 20 in 2000. Table 1 show results of minimum sea level pressure (MSLP), maximum sustained wind (MSW), and maximum sea surface cooling (SSC) of four kinds of numerical experiments. Finer horizontal resolution, introduction of sea spray effect, and no oceanic mixed layer process, all are factors of intensification of Typhoon Bilis. The numerical experiment with 6km horizontal resolution, sea spray effect, and an oceanic process is the best of all experiments in the light of the prediction of MSLP (920hPa) reported from JMA best track data. Even in the case, maximum SSC is smaller than that of TRMM/TMI SST observation (about 5℃) although the SSC becomes greater than that of previous studies by Wada (2003). Figure 1 shows relationship between MSLP and MSW in the numerical experiments with a sea spray process. The relationship in the NHM experiments agrees well with the JMA best track one. This is also considered to contribute to the production of larger SSC in the ocean model after the passage of Typhoon Bilis due to proper estimation of wind stresses. Figure 2 indicates that the NHM with 6km horizontal resolution and sea spray effect can reproduce more realistic horizontal distribution of cloud and SST of Typhoon Bilis. The NHM-coupled model has been still under development. We will challenge numerical simulations of tropical cyclone in 2004 seasons when ten tropical cyclones were extraordinarily landing on Japan Island.

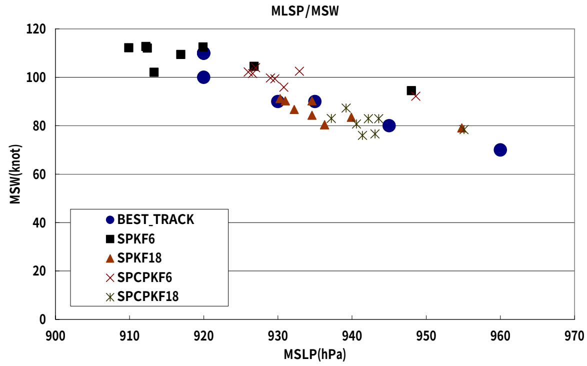

Figure 1 Relationship between MSLP and MSW in numerical experiments with a sea spray process.

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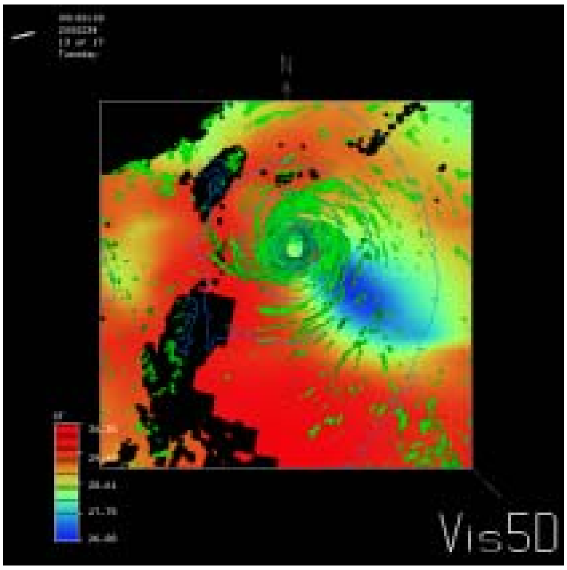

Figure 2. Cloud water content, sea level pressure, and SST at T+36h.

Table 1. Results of numerical experiments of Typhoon Bilis under different specifications.

	No ocean No Sea Spray	No ocean Sea Spray	Ocean No Sea Spray	Ocean Sea Spray
18km				
MSLP(hPa)	941.0	929.5	945.7	934.2
MSW(knot)	82.6	94.3	81.4	87.5
SSC(℃) (T+48h)			2.17	2.66
6km				
MSLP(hPa)	925.4	910.8	939.1	926
MSW(knot)	104.7	117.4	98.6	108.1
SSC(℃) (T+48h)			3.01	3.39