Validation of typhoon intensity prediction by MRI typhoon-ocean coupled model

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1. Introduction

The typhoon-ocean coupled model has been developed at Meteorological Research Institute (MRI) in Japan Meteorological Agency (JMA) (Wada and Mino 2002). On a parallel with the development, a mixed layer model, which is an ocean part of the coupled model, has also developed (Wada 2002a). Owing to the improvement of turbulent mixing processes in mixed layer model, decreases of sea surface temperature (SST) could be simulated greater than those of previous model (Wada 2002a). Using this upgraded mixed layer model, numerical simulations for typhoons during 2000-2002 seasons are conducted. Here, we focus on typhoon intensity prediction and validate it by upgraded typhoon-ocean coupled model.

2. Numerical Simulations

Numerical simulations are conducted by both typhoon-ocean coupled model (CM) and operational typhoon model (TYM20) for the sake of comparison. Both models have 20km horizontal resolution of the typhoon center. Solar radiation, long-wave radiation and turbulent mixing processes near the surface are included in CM. Of numerical experiments over 100 cases, 27 cases are selected on the criteria of the errors of tracking prediction of typhoons from JMA best track positions: within 20km at T+0h, 100km at T+24h, 200km at T+48h, 300km at T+72h, which T is the initial time. The tracking limit is set for the sake of reliance of typhoon intensity prediction. The tracking map of all selected typhoons is shown in Fig.1.

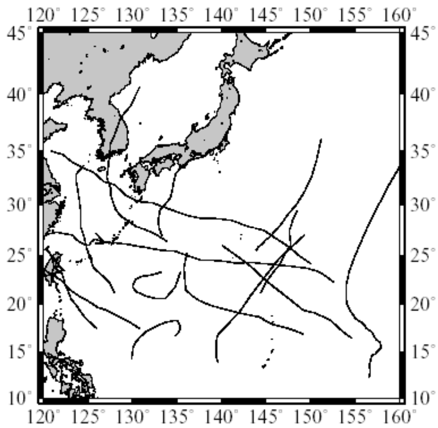

Fig.1 Japan Meteorological Agency (JMA) best track of selected typhoons during 2000-2002 seasons under the criteria of prediction of typhoon movement by coupled model of which position is within 20km at T+00h, 100km at T+24h, 200km at T+48h, and 300km at T+72h from JMA best track positions

Table 1 shows the list of 27 typhoons selected of all simulated typhoons on the criteria of tracking prediction. The range of JMA best track minimum sea level pressure (MSLP) during 72 hours integration is from 920hPa to 985hPa, while the MSLP by coupled model is from 921hPa to 979.8hPa. *Italic* characters in table 1 represent that minimum MSLP is detected at the initial time. For the purpose of investigating the ocean coupling effect, the maximum MSLP rising is defined as maximum MSLP (CM) - MSLP (TYM20) during 72 hours integration. The greatest deference of maximum MSLP rising is 10.1hPa on Typhoon PODUL at 12UTC in October 22 2001. The ocean coupling effects can be recognized from these results, however they seem to be smaller in comparison with related results by Bender and Ginis (2000).

SST cooling by CM is from -0.41℃ to -2.23℃ of which temperatures are smaller in comparison with observed SST cooling by Black (1983) or Bender et al.(1993) of which range is from -1℃ to -6 ℃ and observed SST cooling by TRMM/TMI of which range is from -2.7℃ to -7.2℃ in Table 1. SST cooling by CM seems to be underestimated as well as maximum MSLP rising.

One of the reasons of weaker SST cooling is that TYM20 cannot simulate the real intensity of strong typhoons such as Typhoon WUTIP on August 28 and Typhoon Higos on September 27.

Table 1 List of selected typhoons (name and initial time), their minimum MSLP and maximum SST cooling by JMA best track and coupled model and maximum MSLP rising between typhoon model and coupled model.

Typhoon NAME	INITIAL TIME (12UTC)	BEST TRACK MSLP (hPa)	MIN. MSLP by coupled model (hPa)	MAX. MSLP RISING (hPa)	MAX. SST COOLING (℃) by coupled model	MAX. SST COOLING by TRMM/TMI (℃)
BILIS	2000/08/20	920	922.2	7	-1.79	-4.80
TORAJI	2001/07/27	960	959.1	3.8	-1.15	-4.05
MAN-YI	2001/08/05	955	954.4	5.7	-2.14	-5.10
PABUK	2001/08/19	960	947.8	2.6	-2.03	-3.45
WUTIP	2001/08/28	930	950.7	4.6	-1.56	-6.90
NARI	2001/09/10	960	967	1.7	-1.51	-4.50
NARI	2001/09/16	970	979.8	0.9	-0.48	-3.59
LEKIMA	2001/09/25	970	961.8	1.4	-1.19	-2.70
LEKIMA	2001/09/26	985	979.1	1.8	-1.06	-3.15
PODUL	2001/10/21	930	959.9	6.5	-1.09	-3.60
PODUL	2001/10/22	925	943.1	10.1	-1.40	-4.20
PODUL	2001/10/24	925	935	9.5	-1.53	-4.05
MITAG	2002/03/05	930	940.4	0.3	-0.64	-3.60
HAGIBIS	2002/05/17	935	959.2	6	-0.41	-3.30
RAMMASUN	2002/07/02	945	937.4	4.4	-2.16	-5.25
FENGSHEN	2002/07/22	925	921	2.1	-1.31	-5.10
FUNG-WONG	2002/07/22	960	969.6	2.4	-1.09	-3.30
FENGSHEN	2002/07/23	945	942.4	1.6	-0.92	-3.75
FENGSHEN	2002/07/24	965	966.4	0.5	-0.69	-2.70
PHANFONE	2002/08/13	940	926.8	7	-1.89	-4.35
RUSA	2002/08/28	950	940.8	3.6	-2.19	-4.20
RUSA	2002/08/29	950	947.9	3.8	-2.23	-4.65
SINLALU	2002/08/30	950	961.2	2.7	-0.64	-2.40
SINLALU	2002/08/31	950	947.4	3.3	-1.08	-2.70
SINLALU	2002/09/01	950	935.5	1	-1.28	-2.84
SINLALU	2002/09/04	955	950.6	5.4	-2.11	-5.10
HIGOS	2002/09/27	930	943	3.6	-0.55	-7.20

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This issue is related to modeling of initial condition and physical processes in TYM20. Intensity errors at the initial time in TYM20 often occur because the structure at the typhoon center, particularly of strong typhoon, has too sharp pressure gradient to be fully expressed with 20km horizontal resolution. Concerning with the underestimation of strong typhoon, maximum wind velocity of TYM20 is smaller than that of JMA best track under the same MSLP. The weaker wind stress causes weak ocean response to typhoons and leads to small SST cooling after the passage of typhoons. The issue is closely related with atmospheric physical processes of TYM20 and CM. Actually, the parameterizations in the planetary boundary layer and cumulus parameterization in TYM20 are different from those of Bender and Ginis (2000).

The other reason is associated with oceanic conditions. The amount of SST cooling shown in Table 1 isn't proportional to the amount of maximum MSLP rising between TYM20 and CM. That is because SST cooling after the passage of typhoons is related to not only the magnitude of wind stresses but also the translation speed of typhoons and ocean conditions such as the thickness of the mixed layer and the vertical gradient of sea temperature in the thermocline (Wada 2002b). The mixed layer temperature with deep mixed layer is difficult to decrease, while the temperature with shallow mixed layer is easy to decrease.

3. Improvement of Intensity Prediction

Here, we focus on the tendency of MSLP during and every 6 hours in 72 hours. As a typhoon has been developing (weakening) during 6 hours, the tendency has a minus (plus) sign. If a typhoon doesn't change its intensity during 6 hours, the tendency will be zero. Therefore, using the tendency of MSLP to validate the typhoon intensity prediction is significant. For the purpose of investigating the similarity of model tendency to JMA best track tendency, correlation coefficients between in MSLP tendency as it is by both TYM20 and CM and JMA best track MSLP tendency are examined. Fig 2. shows time series of the correlation coefficients of MSLP tendencies of 27 typhoons every 6 hours. It should be noted that JMA best track MSLP is recorded every 5 hPa unlike outputs as it is by both models. Here, the MSLP tendency by both models is converted as below formulas.

$$P'_{tend} = Round(P_{tend} / 5) \times 5$$

P_{tend} is the MSLP tendency. *Round* is a function for half adjust. The time series of correlation coefficients by converted MSLP tendency (not shown) is almost the similar to that shown in Fig. 2. The correlation coefficients of CM are greater than that of TYM20 after T+42h. This result suggests that the prediction of MSLP tendency during 6 hours by CM is more accurate after T + 42h than that by TYM20. However, the correlation coefficient at T+24h is the worst in the integration time.

4. Concluding Remarks

The results suggest that CM has the possibility of improving the intensity prediction of typhoons. Through the numerical simulations for typhoons, however, physical processes in the planetary boundary layer and cumulus parameterization will need to be further improved to simulate greater SST cooling after the passage of typhoons.

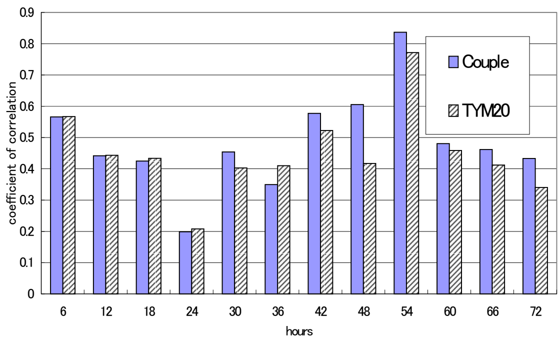

Fig.2 Correlation coefficients of tendency of minimum sea level pressure (MSLP) during 6 hours between models and JMA best track data

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