Effects of atmospheric physical processes to the intensity of typhoons and their ocean responses

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1. Introduction

In the Japan Meteorological Agency (JMA), a typhoon model with renewal physical processes has been operated since July, 2003. In the present report, this model of which horizontal resolution was 20km around the typhoon center was coupled with a mixed layer ocean model. Numerical experiments concerning with the intensity prediction of typhoons and their ocean responses were conducted using the typhoon model and the coupled model. Conveniently, only sea surface boundary process was replaced into the old version which was based on Kondo (1975). Consequently, precipitation and radiation processes are modified from the old typhoon-ocean coupled model. Three cases are numerically experimented with two different precipitation and radiation schemes and with or without ocean coupling. Naming convection of the numerical experiments is shown in Table 1. Typhoon BILIS in August 20, 2000, Typhoon WUTIP in August 28, 2001, and Typhoon PHANFONE in August 13, 2002, which dates mean the initial time of time integration, are taken as the case study.

2. Precipitation and Radiation

In the previous typhoon model (TYMOLD), cloud water content and cloud cover were diagnostically estimated by empirical formulas. In the case of TYMKON and CMKON, cloud processes are described by prognostic equations for cloud liquid water and by diagnostic relation for precipitation. As for the mixed phase, the distinction between the water and ice phase is made as a function of temperature. At the temperature less than -15℃, the phase was assumed to be ice. At the temperature more than 0℃, the phase was assumed to be water. Cloud ice content is proportionally determined in the mixed phase between -15℃ and 0℃. In the cumulus parameterization of Arakawa and Shubert (1974), an enhanced mechanism of cumulus convection is introduced. However, a treatment of the vertical transport of horizontal momentum by convection has not been introduced. A treatment of mid-level convection would change to a mass flux scheme, which was previously treated as the moist convective adjustment. A broad-band flux emissivity method for four spectral bands is used for longwave radiation. A two-stream formulation using the delta-Eddington approximation of which spectrum is divided into 18 bands is used for shortwave scattering and absorption. In the previous shortwave model used in TYMOLD and CMOLD, planetary albedo under a clear sky was under-evaluated in comparison to the observation. Here, a scheme with Briegleb (1986) parameters is used. A direct effect of aerosol to shortwave and longwave radiation is additionally installed. A treatment of cloud fraction under a clear and cloudy sky in the shortwave radiation is also refined in TYMKON and CMKON. This enables to treat multiple reflections between layers accurately. A parameterization of an ice particle effective radius is modified. A parameterization of cloud emissivity for longwave radiation is newly formulated. Absorption coefficients of cloud water and ice represent a function of the effective radius. The cloud emissivity is estimated by formulas of Kiehl and Zender (1995) and Chin (1994).

3. Results

Differences of minimum sea level pressures (MSLPs) between TYMOLD and TYMKON and between CMOLD and CMKON are evident in Fig. 1(a)-(c) and Table 2-1. However, the issue that the amount of MSLP is under-evaluated still remains in the predictions of Typhoon BILIS and Typhoon WUTIP. In the predictions of Typhoon WUTIP and Typhoon PHANFONE, each intensity in the cases of TYMKON and CMKON is stronger than that in the cases of TYMOLD and CMOLD (Table 2-2), while this result seems not to be in accordance with that in the prediction of Typhoon BILIS (Fig.1(a)) particularly at around T+30h. Nevertheless, the intensity in the prediction of Typhoon BILIS in the cases of TYMKON and CMKON is stronger than that in the cases of TYMOLD and CMOLD in the latter integration. Modification of precipitation and radiation processes doesn’t affect only the intensity prediction but also the size of typhoons. The sizes of the typhoons in the case of CMKON are respectively larger than those in the case of CMOLD (Table 3-1). This result is completely opposite to that by the ocean coupling effect (Table 3-2). In addition, the modification causes the differences of horizontal distribution of precipitation and turbulent heat fluxes. The precipitation in the cases of TYMKON and CMKON tends to concentrate on around a typhoon although that in the cases of TYMOLD and CMOLD which is covered the wider region. In fact, the modification of physical processes including prognostic the cloud water content leads to change the distributions of cloud fraction, solar radiation and long-wave radiation. Rainfall is related to the variation of salinity near the sea surface. The decrease of sea surface temperature (SST) by turbulent mixing is comparably small due to stabilization in the upper layer caused by fresh water. Table 4 indicates maximum SST decrease of three typhoons during 72 hours in the cases of CMOLD and CMKON. In the prediction of Typhoon BILIS, maximum SST decrease is greater in the CMOLD experiment than that by a new model, while maximum SST decrease is greater in the CMKON experiment than that in the CMOLD experiment. In particular, the difference of 0.6 degree between CMOLD and CMKON is occurred in the prediction of Typhoon PHANFONE. The difference of SST decrease is concerned with the simulated intensity of the typhoons. The differences of MSLPs between TYMOLD and TYMKON are greater than that between CMOLD and CMKON (Table 2-2). In consequence, modification of the precipitation and radiation processes has less impact on the intensity of typhoon in the coupled model than that in the typhoon model.

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Table1 Kinds of numerical experiments and their naming convention

	Couple	Non-couple
OLD PHYSICS	CMOLD	TYMOLD
NEW PHYSICS	CMKON	TYMKON

Table 2-1 The greatest MSLP difference between TYM and CM.

CM-TYM	BILIS(hPa)	WUTIP(hPa)	PHANFONE(hPa)
OLD	10.5	8.4	15
KON	9.4	15.9	16.3

Table 2-2 The greatest MSLP difference between OLD and KON.

OLD-KON	BILIS(hPa)	WUTIP(hPa)	PHANFONE(hPa)
TYM	10.1	14.1	11.3
CM	11.8	8.0	8.6

Table 3-1 Averaged ratio of size by the couple model with an old physical package to that by the coupled model with a new one

Couple	BILIS	WUTIP	PHANFONE
OLD/KON	1.12	1.03	1.03

Table 3-2 Averaged ratio of size by the couple model to that by the non-coupled model

CM/TYM	BILIS	WUTIP	PHANFONE
OLD	0.976	0.964	0.976
KON	0.979	0.967	0.954

Table 4 Maximum SST decrease during 72 hours by coupled models

	BILIS	WUTIP	PHANFONE
OLD	-2.14℃	-1.82℃	-2.15℃
KON	-1.71℃	-1.96℃	-2.75℃

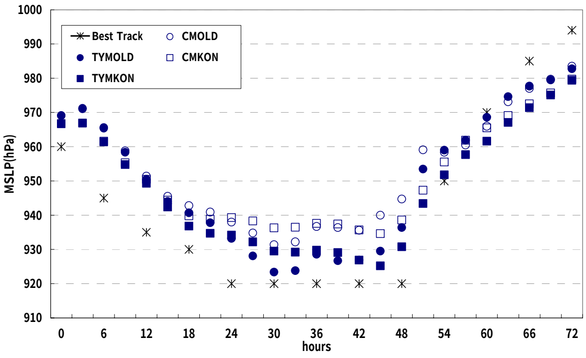

Fig.1(a) Minimum sea level pressure for Typhoon BILIS.

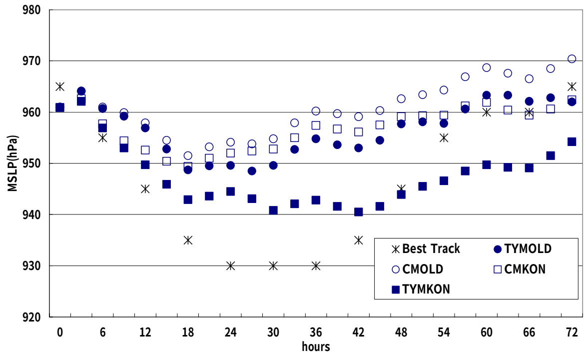

Fig.1(b) Minimum sea level pressure for Typhoon WUTIP.

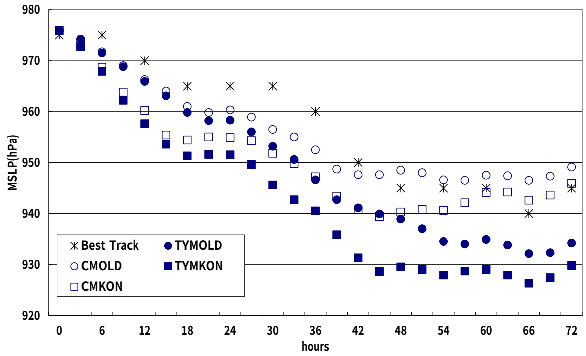

Fig.1(c) Minimum sea level pressure for Typhoon PHANFONE.