Typhoon-ocean coupled model with upgraded mixed layer model

Akiyoshi WADA
Meteorological Research Institute, Tsukuba, Ibaraki, Japan

1. Introduction

Local sea surface temperature (SST) cooling underneath typhoons and occurred after their passage has an influence on intensity of typhoons through air-sea interaction. To predict intensity of typhoons more accurately, the typhoon-ocean coupled model has been developed at Meteorological Research Institute (MRI) in Japan Meteorological Agency (JMA). According to the report by Wada (2003a), the ocean coupling was effective after T+42h for intensity prediction of typhoons, which T was the initial time of the integration. However, SST cooling by MRI typhoon-ocean coupled model has been still underestimated. One of the reasons is that turbulent mixing processes in the mixed layer model are not enough to simulate SST variations under various wind conditions. Consequently, Wada (2003b) improved the turbulent mixing processes in the mixed layer model. As the result of the improvement, the mixed layer model can successfully simulate SST variations under various wind conditions including local SST cooling after the passage of Typhoon REX on August 1998. Using the mixed layer model with upgrade turbulent mixing processes, MRI typhoon-ocean coupled model (Wada 2003a) has reconstructed. In the present report, the atmospheric response of Typhoon BILIS to local SST cooling will be represented through the difference of horizontal distribution or vertical profile of physical elements between typhoon model and typhoon-ocean coupled model.

2. The atmospheric response to local SST cooling

Numerical simulations on Typhoon Bilis of which initial time is at 12UTC on August 20 2000, are conducted using the upgraded typhoon-ocean coupled model and operational typhoon model for the sake of comparison. Horizontal resolutions of both models are 20km at the typhoon center. Compared with the previous result by Wada and Mino (2002), ocean coupling effects become more prominent for Typhoon Bilis. The ocean coupling effect is recognized from a rise of 16.8hPa at T+42h in minimum sea level pressure (MSLP) of Typhoon BILIS (Fig.1). Fig.1 also shows that the tendency of MSLP during T+24h to T+48h when Typhoon BILIS sustains its intensity is well simulated. However, the coupled model cannot simulate the maximum intensity of Typhoon BILIS. This issue may be associated with the atmospheric physical processes in operational typhoon model (Wada 2003a).

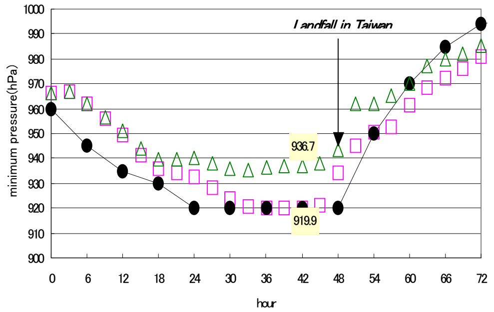

Fig. 1 Time series of minimum sea level pressure (MSLP) on Typhoon BILIS of which initial time is at 12UTC on 20 August 2000. Close circle indicates JMA best track MSLP, triangle MSLP by coupled model, and square MSLP by operational typhoon model.

The ocean coupling effects have influences on simulated inner structure of Typhoon BILIS. Vertical wind profiles concentrically averaged at radius from the typhoon center in the radius-pressure coordinate system indicate that maximum wind velocity of the operational typhoon model (Fig.2a) is greater than that of the coupled model (Fig.2b). Maximum wind velocity of typhoons is generally situated in eyewall region. The position of the maximum wind velocity of the coupled model moves outward from that of the operational typhoon model. To be more precise, maximum wind velocity of the operational typhoon model is situated within 100km from the typhoon center (Fig.2a), while that of the coupled model is situated outside 100km from the typhoon center (Fig.2b). Sharp horizontal gradient of horizontal wind velocity becomes loose particularly at the eyewall. Tangential wind velocity of the coupled model is weaker within 150km radius than that of the operational typhoon model (not shown). Radial velocity of the coupled model represents weak convergence near the surface and weak divergence in the upper layer around 200hPa (not shown). The potential temperature and specific humidity also decrease within 100km radius throughout the layer and in the lower layer from nearly 800hPa to the surface by ocean coupling (not shown).

The horizontal distribution of precipitation is clearly changed by ocean coupling (Fig.3). In the

* Corresponding author address: Akiyoshi Wada, Meteorological Research Institute, 1-1 Nagamine, Tsukuba, Ibaraki 305-0052 Japan: email: awada@mri-jma.go.jp

typhoon model, precipitation is dominant ahead and on the rightward of the running typhoon (Fig.3a). In contrast, precipitation is dominant behind and on the rightward of the running typhoon in the coupled model (Fig.3b). The difference of horizontal distribution of precipitation is concerned with the difference of the distribution of turbulent heat fluxes associated with SST cooling underneath typhoons. Variations of potential temperature and specific humidity near the surface may reflect the distribution of precipitation through the vertical transport of turbulent heat fluxes.

(a) (b)

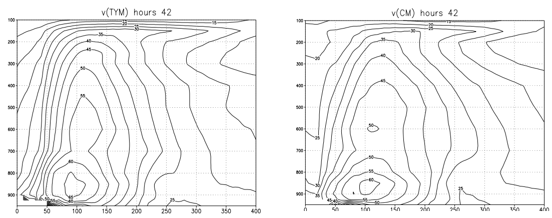

Fig. 2 Vertical profiles concentrically averaged at distances from the typhoon center in the pressure-distance coordinate system: (a) by operational typhoon model,(b) by coupled model

(a) (b)

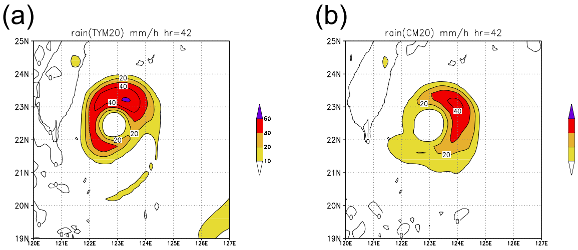

Fig. 3 Horizontal distribution of 1-hour precipitation at T + 42h: (a) by operational typhoon model (b) by coupled model

SST cooling after the passage of Typhoon BILIS is prominent in the rightward of the running typhoon. The maximum SST cooling is -2.8℃ (Fig.4a), which is greater than that of previous study (Wada and Mino 2002, Wada 2003a). Nevertheless, the maximum SST cooling by TRMM/TMI (Fig.4b) is nearly 4.8℃ (Wada 2003a) and greater than that by typhoon-ocean coupled model. To investigate the effect of atmospheric forcing to local SST cooling, SST cooling after the passage of Typhoon BILIS is reexamined using the mixed layer model with Rankin vortex which is produced using JMA best track maximum wind velocity and global analysis data in JMA. SST cooling by upgraded mixed layer model with Rankin vortex is nearly 5℃ (Fig.4c) and close to that by TRMM/TMI. Considering from the results so far obtained, errors of computed SSTs seem to be caused by underestimation of sea surface wind velocity or wind stresses in the typhoon and coupled model.

3. Concluding remark

The ocean coupling effects for Typhoon BILIS are recognized from MSLP (Fig.1), maximum wind velocity and vertical concentric averaged wind profile (Fig.2), and precipitation (Fig.3). The ocean coupling effects can be also found in the averaged vertical profile of potential temperature, specific humidity, and sea surface heat fluxes. All responses represent the negative feedback against typhoon development. The simulated SST cooling by the coupled model (Fig.4) indicates that wind stresses near the surface aren't fully simulated by typhoon and coupled models.

References

Wada, A. (2002): Improvement of SST prediction by diurnal cycling algorithm in the MRI mixed layer ocean model. *CAS/JSC WGNE Research Activities in Atmospheric and Oceanic Modelling.* 08-29.

Wada, A., and H. Mino (2002): Implementation of the JMA typhoon model coupled with the MRI mixed layer ocean model and its application for Typhoon BILIS *CAS/JSC WGNE Research Activities in Atmospheric and Oceanic Modelling*. 09-08

Wada. A (2003a): Validation of typhoon intensity prediction by MRI typhoon-ocean coupled model. *CAS/JSC WGNE Research Activities in Atmospheric and Oceanic Modelling* submitted

Wada. A (2003b): Improvement of wind induced mixing and entrainment in the MRI mixed layer model. *CAS/JSC WGNE Research Activities in Atmospheric and Oceanic Modelling* submitted

(a) (b) (c)

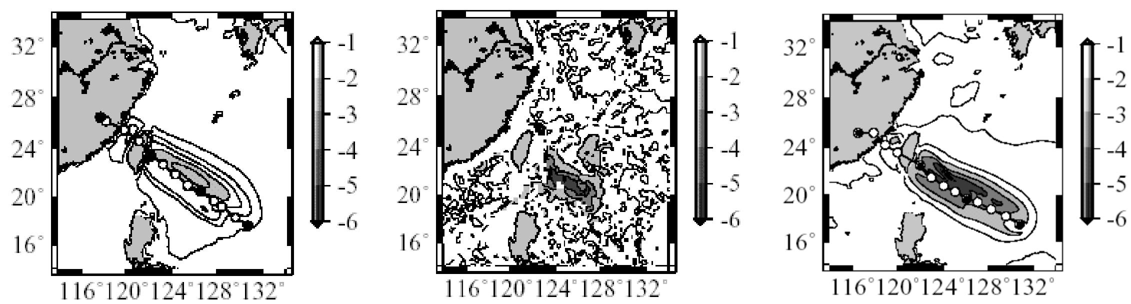

Fig.4 Distributions of SST deviation at T+72h from the initial time: Open and close circles indicate the position of typhoons every 6 hours (open) and every 24 hours (close) (a) SST cooling by coupled model, (b) SST cooling by TRMM/TMI, (c) SST cooling by mixed layer model with Rankin vortex based on JMA best track data.