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TYPHOON SIMULATION WITH THE JMA/MRI 20 KM MESH HIGH-RESOLUTION GLOBAL SPECTRAL MODEL

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1. INTRODUCTION

The Advanced Earth Science and Technology Organization (AESTO), the Meteorological Research Institute (MRI), and the Numerical Prediction Division of the Japan Meteorological Agency (JMA) have developed a high-resolution (TL959L60; triangular truncation 959 with the linear Gaussian grid which is equivalent to 20 km-mesh horizontally and 60 layers vertically) AGCM (Mizuta et al., 2006; hereafter referred to as "JM-AGCM"). It is used for both weather forecasting and climate research on the effect of global warming on tropical cyclones (TCs) (Oouchi et al., 2006) and Baiu (Kusunoki et al., 2006) under the Intergovernmental Panel on Climate Change (IPCC) scenarios.

Although Oouchi et al. (2006) insist that the JM-AGCM is more excellent than other coarse models in the intensity forecast of TCs, there is no remark of experiments that compares TCs by different resolutions. Even in the medium-range forecast, there is no research that statistically shows the superiority of such a high-resolution global model from the viewpoint of the TCs prediction.

This study aims to statistically evaluate the predictability of TCs with the JM-AGCM in terms of tracks and intensity through medium-range forecasts. Twelve TCs over the western North Pacific Ocean, namely, typhoons, were simulated with the JM-AGCM. They were compared with the simulations produced by the 60 km-mesh JMA operational global spectral model (hereafter referred to as "GSM"). The simulated track position and intensity are verified with the post-analyzed best-track data distributed by the Regional Specialized Meteorological Center of Tokyo (RSMC-Tokyo).

2. EXPERIMENTAL DESIGN

2.1 *MODELS*

The JM-AGCM adopts a semi-Lagrangian scheme (Yoshimura and Matsumura, 2003) which enables integration with a longer time step without being constrained by the Courant-Fredrichs-Lewy (CFL) condition. As a cumulus convection scheme, which is important for typhoon formation, a prognostic Arakawa and Schubert (1974) scheme is implemented. The level 2 turbulence closure scheme of Mellor and Yamada (1974) is used to represent the vertical diffusion of the momentum, heat, and moisture. The resolution of the model is TL959L60, namely, triangular truncation 959 with the linear Gaussian grid which is equivalent to 20 km-mesh horizontally and 60 layers vertically. The initial condition was obtained by interpolation from the 60km-mesh JMA Global Analyses (JMA, 2002) (GANAL) to the 20km-mesh grids.

The dynamics of the GSM is an Eulerian form. The resolution of the GSM is T213L40, namely, triangular truncation 213 which is equivalent to about 60km-mesh horizontal grids and vertical 40 layers.

Most of physical processes in the forecast mode of the JM-AGCM are the same as those of the GSM. For the GSM typhoon simulations, outputs by the JMA operational routine are used.

2.2 *SIMULATED TYPHOONS*

Twelve typhoons to be simulated were selected using the following subjective criteria while considering the limitation of the computational resources;

- hazardous typhoons which come close to or land on Japan,
- typhoons that recurve (or never recurve),
- recent typhoons from 2002 to 2005,
- typhoons whose track was well (or badly) predicted by the GSM.

The list of selected typhoons and their experiment periods of initial time are summarized in Table 1.

2.3 *BEST-TRACK DATA*

The best-track data used in this study is produced by the RSMC-Tokyo (Kamahori et al., 2006). It contains the central position, central pressure, estimated 10 minute-averaged maximum sustained wind speed, and size (e.g., the radius of 30 knots and 50 knots). They are estimated from observations, namely, aircraft, satellite, surface, and upper

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air observations. In this study, the central position, the central pressure, the maximum 10 minutes-averaged sustained wind speed, and the radius of 30-knot and 50-knot winds in the data set are used as an observation.

2.4 *METHOD TO DETECT THE POSITION OF A TYPHOON*

The method for detecting the typhoon central position by simulations is the same as Sakai and Yamaguchi (2005) except for the mean sea level pressure (MSLP), for which outputs of 6-hour intervals are used. The method is as follows. At an initial time, the nearest position of the minimum MSLP points from the best-track position is defined as the central point of a typhoon. At 6 forecast hours, the minimum MSLP point within 500 km from the central point at the initial time is defined as the central point. After 12 forecast hours, the minimum MSLP point within 500km from the point of the linearly extrapolated point by the last 2 forecast positions is defined as the central point. In the case of missing the minimum MSLP point, the tracking is terminated. For homogeneous verification, only samples which are determined by both models are used.

3. RESULTS

3.1 *POSITION ERRORS*

Figure 1 presents all the result of the simulated tracks. When these results are viewed as a whole, most tracks by the JM-AGCM are very similar to those by the GSM. Figure 2 shows the statistics of position error for all typhoon cases. Although the two models show almost the same track errors in the early forecast hour, the model difference becomes larger approximately after 36 hours. In general, model difference at each forecast hour are not statistically significant because of large variance and lack of sampling cases.

3.2 *INTENSITY PREDICTION*

Figure 3 and Figure 4 show the simulated central pressure and maximum sustained wind, respectively. When viewed as a whole, the GSM predicts both the central pressure and maximum wind too weakly, while the JM-AGCM predicts them as strongly as, or stronger than the best-track data. Figure 5 shows the tendencies of central pressure (maximum wind velocity) at the intense stage, in which the observed typhoon records a 10 hPa decrease (10 knot increase) between 24 and 72 forecast hours. The JM-AGCM can simulate the intense tendency better than the GSM. Some simulations by the JM-AGCM also reach 920 hPa (100 knot for maximum wind velocity), which is close to the observation. However, the GSM cannot simulate the typhoon intense tendency as most of the simulated central pressure records more than 960 hPa (less than 60 knot for maximum wind velocity).

3.3 *TYPHOON STRUCTURE*

A comparison between the infrared image by a satellite and the expected image by simulated outputs helps to visually grasp the structure of a storm. Figure 6 is a comparison of a satellite infrared image for T0310 case by the GOES-9 and that by model simulations. The infrared image by the simulations is derived using a radiative transfer model based on a method in the GSM (Oowada, 2006). In this case, it is conspicuous that the typhoon structure by the GSM is very vague (e.g., the eye is not resolved). On the other hand, the typhoon structure by the JM-AGCM is much finer than that by the GSM. For example, it is noted that the typhoon eye is well resolved by the JM-AGCM. The central pressure was 955.0 hPa, 951.0 hPa, and 966.2 hPa for the observation, the JM-AGCM, and the GSM, respectively. The eye wall by the JM-AGCM is also more realistic than that by the GSM. It is also remarkable that the cloud bands of the typhoon that run from northeast to southwest are much clearer than those by the GSM. It is reasonable to suppose that the high resolution enables it to represent the typhoon structure more realistically.

Figure 7 shows the mean wind profile of all typhoons. The averaged samples are used only the maximum velocity records more than 50knot. It is interested that the outer structure of 200km or more from the center is almost the same between models. The difference is distinct in the inner-core structure. The drastic transformation of wind profile can be simulated by the JM-AGCM, whereas it can not be simulated by the GSM. This gives us justification for the assumption that high resolution is required in order to evaluate typhoon strength, because high resolution makes it possible to capture the inner-core structure realistically.

4. SUMMARY AND CONCLUDING REMARKS

Tropical cyclones over the western North Pacific Ocean were simulated by the 20 km-mesh JM-AGCM. The simulations were compared with the 60 km-mesh GSM as a coarse global model in order to evaluate differences in resolution. The best-track data of the RSMC-Tokyo are also used as the observation data. The verification was conducted for twelve typhoon cases from 2002 to 2005 over the western North Pacific Ocean.

Table 1: List of all simulated typhoons.

Number	Name	Dates	Cases
T0206	Chataan	Jun 29,2002-Jul 11	48
T0207	Halong	Jul 07,2002-Jul 16	38
T0310	Etau	Aug 03,2003-Aug 09	25
T0314	Maemi	Sep 06,2003-Sep 13	32
T0406	Dianmu	Jun 13,2004-Jun 21	34
T0412	Meranti	Aug 04,2004-Aug 09	20
T0418	Songda	Aug 27,2004-Sep 07	45
T0421	Meari	Sep 20,2004-Sep 29	37
T0422	Ma-on	Oct 04,2004-Oct 09	23
T0423	Tokage	Oct 12,2004-Oct 20	33
T0513	Talim	Aug 29,2005-Sep 02	17
T0514	Nabi	Aug 29,2005-Sep 08	41

The difference in the position errors of typhoons between the JM-AGCM and the GSM is very small, though the position error of the JM-AGCM seems slightly smaller.

However, there are significant differences in intensity (maximum sustained wind and central pressure) predictions, mainly due to the resolution difference. As a whole, the GSM simulates both the central pressure and maximum wind too weekly, whereas the JM-AGCM simulates them quite realistically but somewhat too strongly. It is also remarkable that the JM-AGCM can simulate the intense tendency much more realistically than the GSM. These results indicate that the JM-AGCM has better predictability on the intensity of tropical cyclones than the GSM.

The typhoon structure was also compared by creating infrared images from model outputs. It was visually confirmed that the structure of a typhoon by the JM-AGCM is much finer and more realistic than that by the GSM. The composite structure of the wind profile were also compared, It is found that the JM-AGCM simulates quite realistic inner-core structure of typhoon, which has the drastic transformation of wind profile within 100km from the center. The drastic transformation seems to be unable to be resolved by the GSM because of the low resolution.

On the basis of these results, it can be concluded that the JM-AGCM simulates typhoons more realistically than the GSM in terms of intensity and wind profile.

REFERENCES

Arakawa, A. and W. H. Schubert, 1974: Interaction of a cumulus cloud ensemble with the large-scale environment, part i. *J. Atmos. Sci.*, **31**, 674–701.

JMA, 2002: Outline of the operational numerical weather prediction at the japan meteorological agency. 157 pp.

Kamahori, H., N. Yamazaki, N. Mannoji, and K. Takahashi, 2006: Variability in intense tropical cyclone days in the Western North Pacific. *SOLA*, **2**, 104–107.

Kusunoki, S., J. Yoshimura, H. Yoshimura, A. Noda, K. Oouchi, and R. Mizuta, 2006: Change of baiu rain band in global warming projection by an atmospheric general circulation model with a 20-km grid size. *J. Meteor. Soc. Japan*, **84**, 581–611.

Mellor, G. L. and T. Yamada, 1974: A hierarchy of turbulence closure models for planetary boundary layers. *J. Atmos. Sci.*, **31**, 1791–1806.

Mizuta, R., K. Oouchi, H. Yoshimura, A. Noda, K. Katayama, S. Yukimoto, M. Hosaka, S. Kusunoki, H. Kawai, and M. Nakagawa, 2006: 20-km-mesh global climate simulations using JMA-GSM model -mean climate states-. *J. Meteor. Soc. Japan*, **84**, 165–185.

Oouchi, K., J. Yoshimura, H. Yoshimura, R. Mizuta, S. Kusunoki, and A. Noda, 2006: Tropical cyclone climatology in a global-warming climate as simulated in a 20km-mesh global atmospheric model: Frequency and wind intensity analyses. *J. Meteor. Soc. Japan*, **84**, 259–276.

Oowada, H., 2006: Satellite forecasted image. *Meteor. Res. Note*, **212**, 140. (in Japanese).

Sakai, R. and M. Yamaguchi, 2005: The WGNE intercomparison of tropical cyclone track forecasts by operational global models. *CAS/JSC WGNE Research Activities in Atmospheric and Oceanic Modeling*, **35**, 0207–0208.

Yoshimura, H. and T. Matsumura, 2003: A semi-lagrangian scheme conservative in the vertical direction. *CAS/JSC WGNE Research Activities in Atmospheric and Oceanic Modeling*, **33**, 0319–0320.

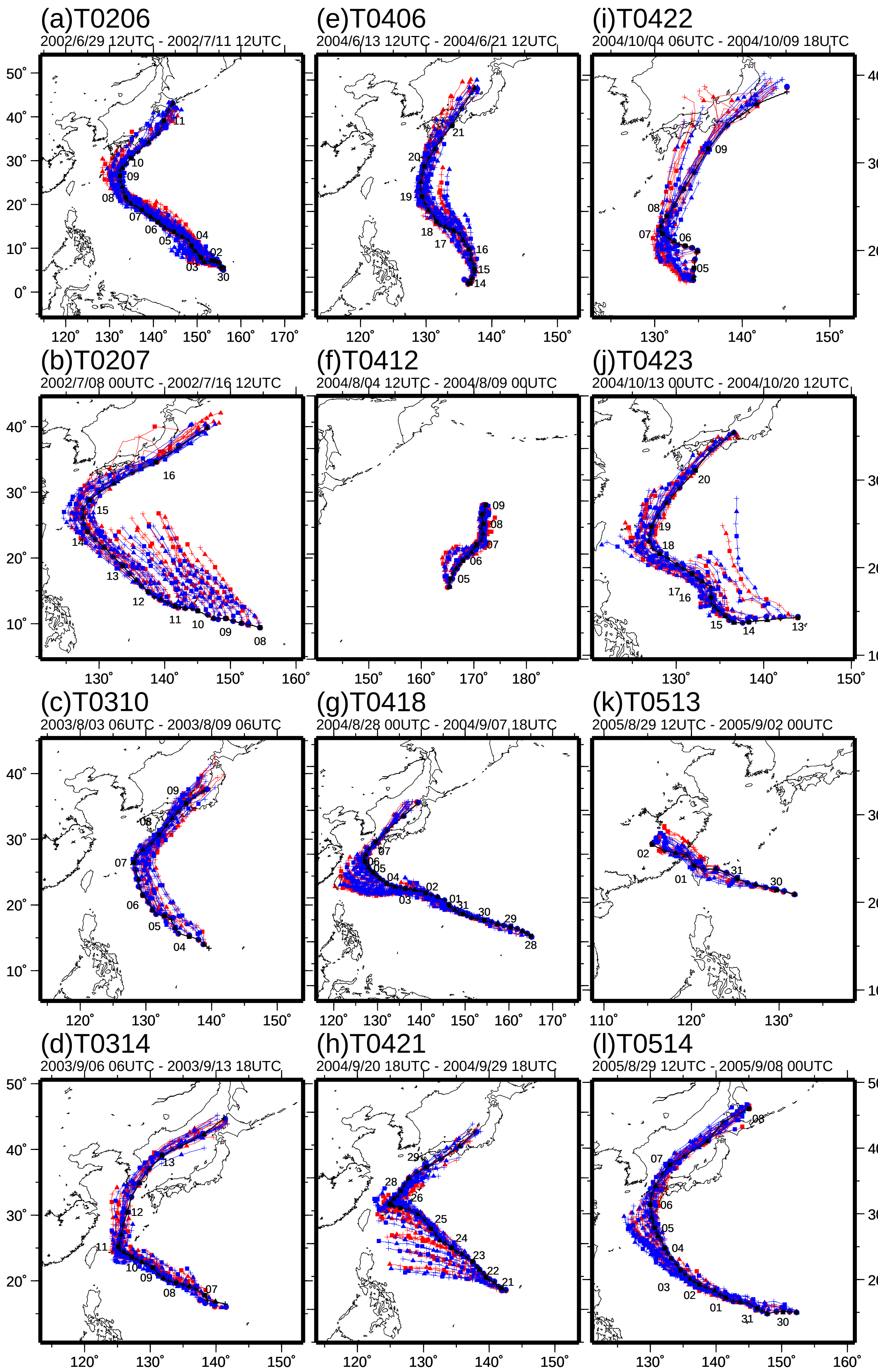

FIG. 1: The blue and red lines are the results according to the JM-AGCM and the GSM, respectively. The black lines are according to the best-track data. The numerical annotations denote dates.

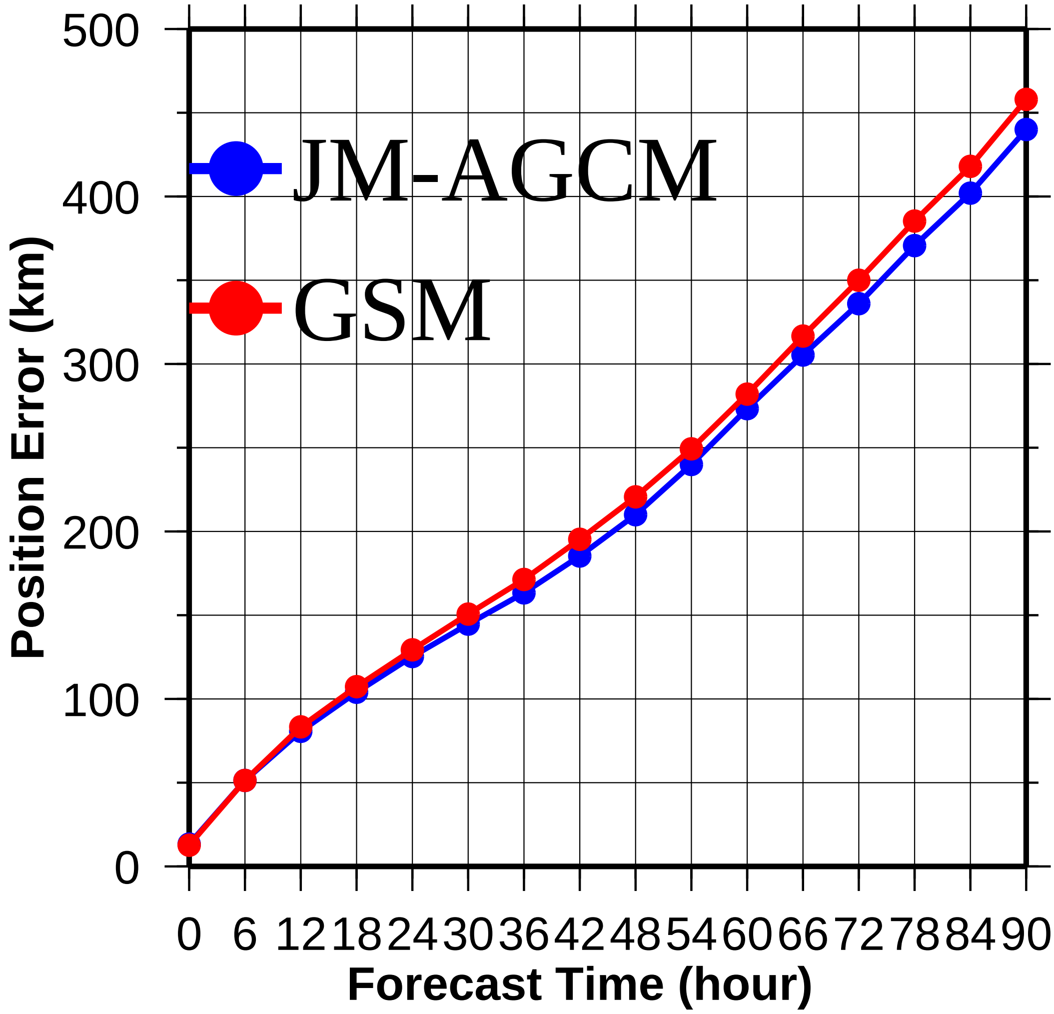

FIG. 2: Simulated position error (km).

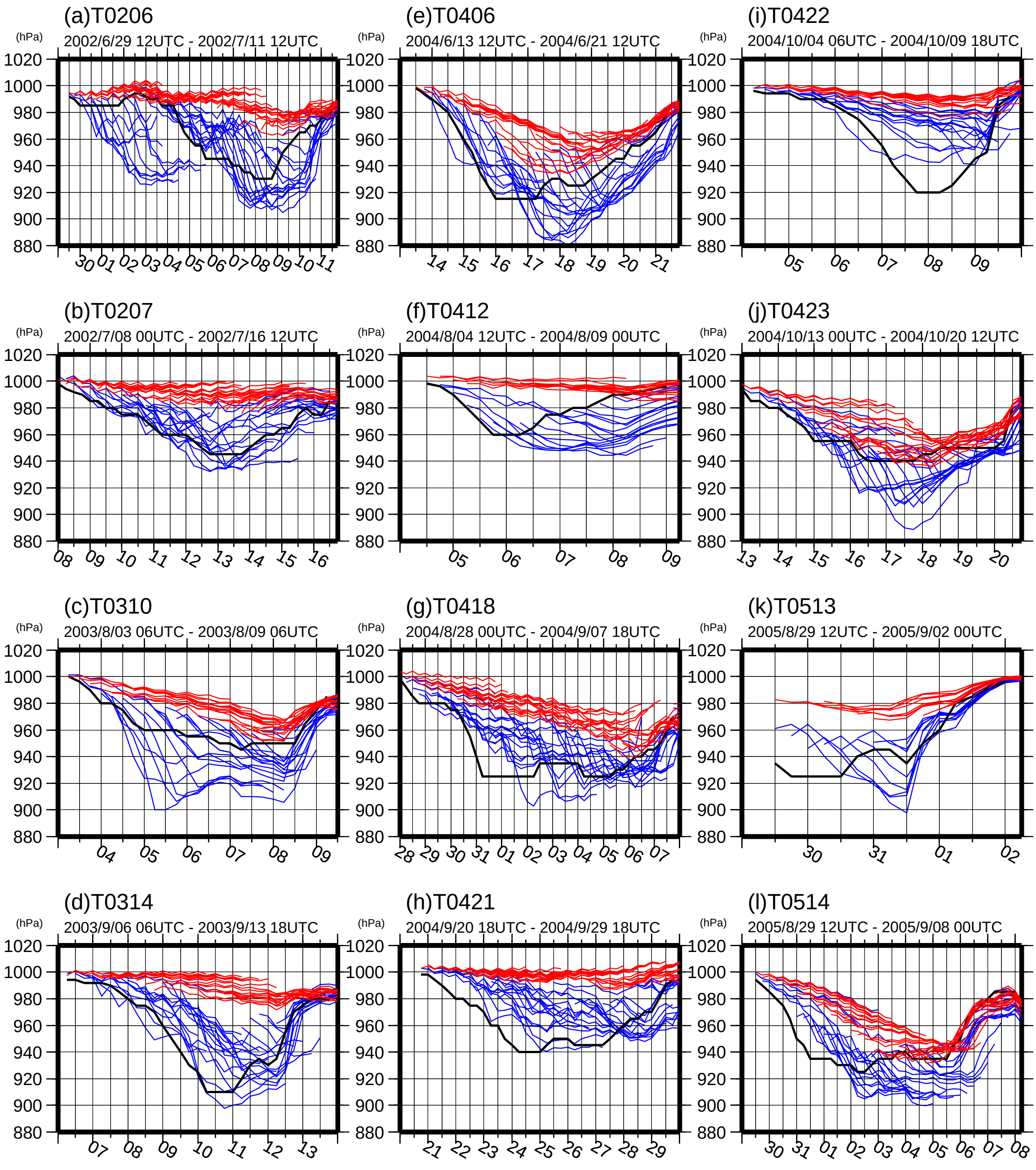

FIG. 3: Simulated typhoon central pressure (hPa) by each model. For each typhoon, the blue and red lines show the central pressure by the 20 km-mesh AGCM and by the GSM, respectively, The black lines display the central pressure by the best-track data. The numerical annotations of the abscissa denote the date.

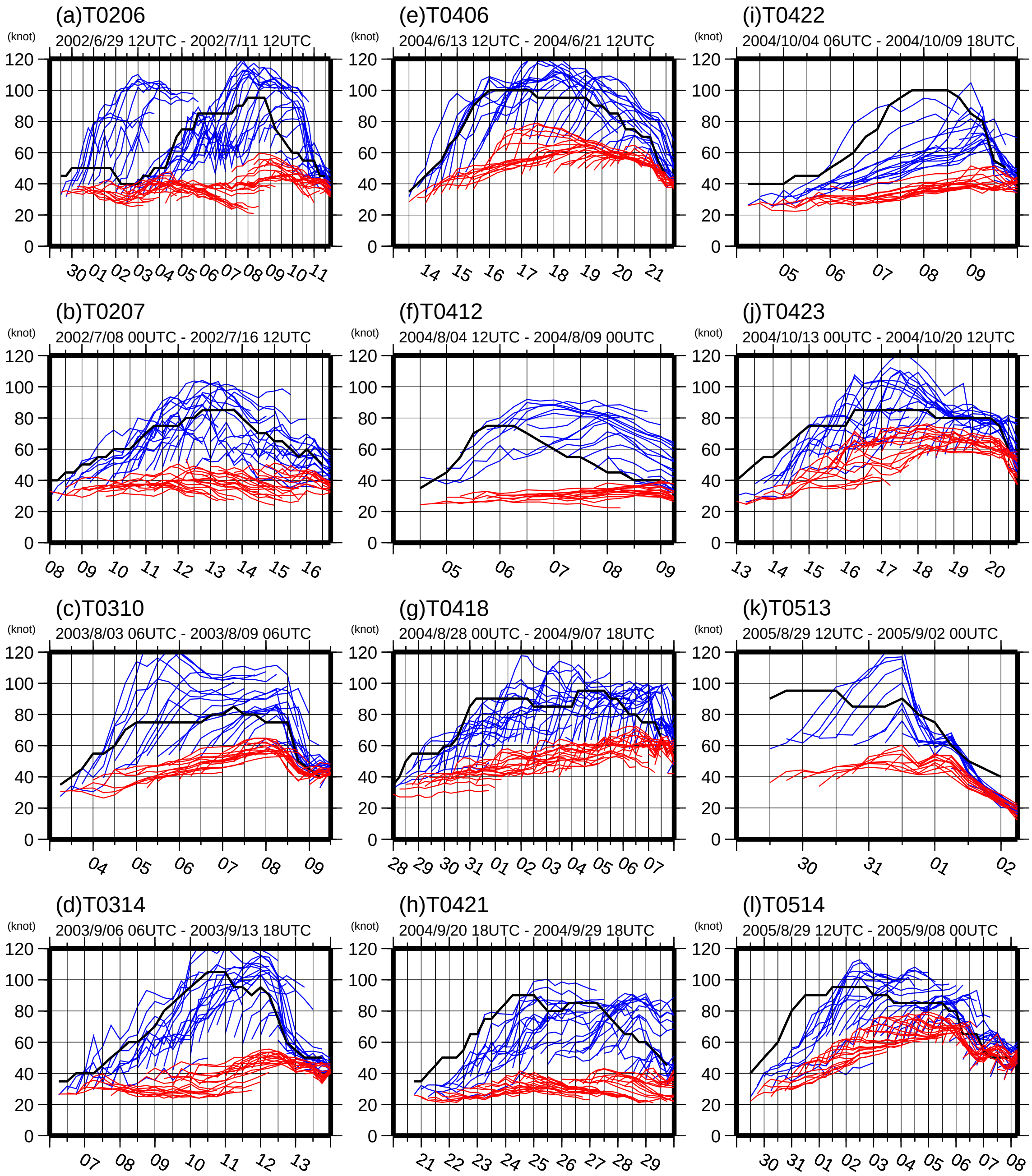

FIG. 4: Same as Figure 3 but for the maximum sustained wind [knots].

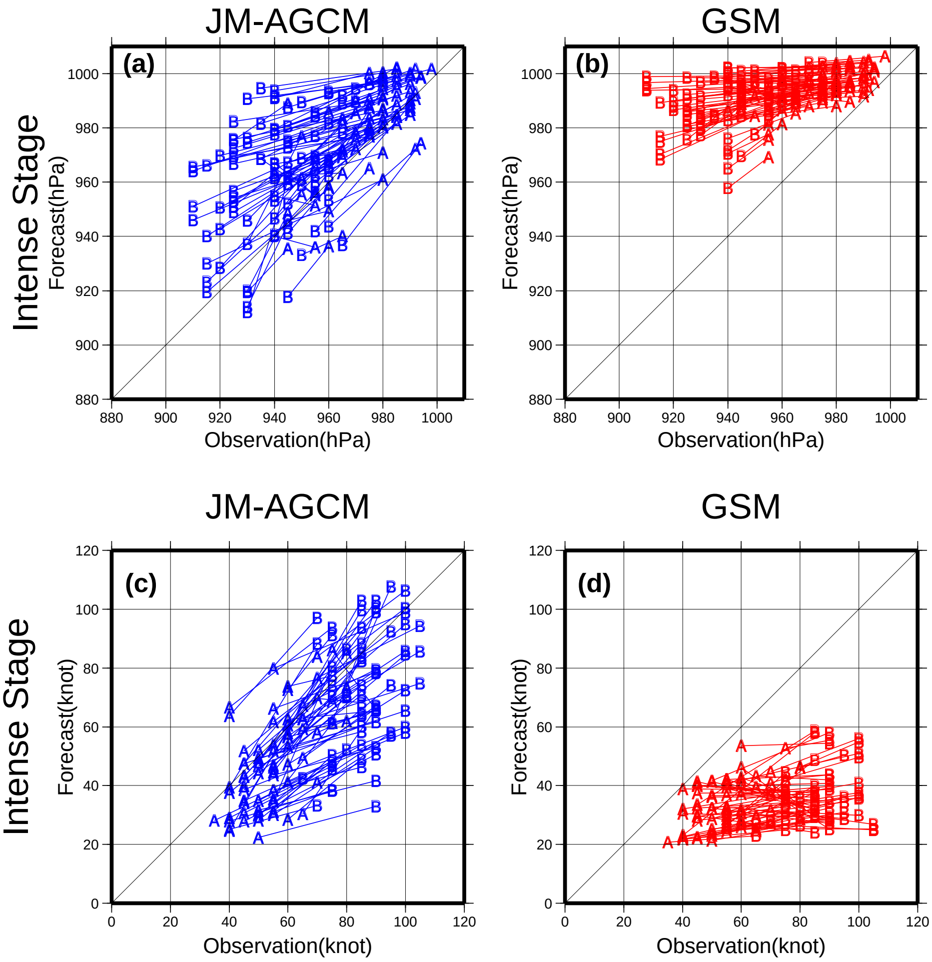

FIG. 5: Tendency of the central pressure (hPa) and maximum wind velocity (m/s) at the intense stage. The ordinate is the simulated result, whereas the abscissa is the corresponding observation data. "A" denotes value at 24 forecast hours. whereas "B" denotes that at 72 forecast hours. The intense stage is defined when the observed typhoon records a more than 10 hPa decrease for the central pressure case (a),(b) and more than 10 knot increase for the maximum wind velocity case (c),(d), respectively. Blue and red plots show by the JM-AGCM and GSM, respectively.

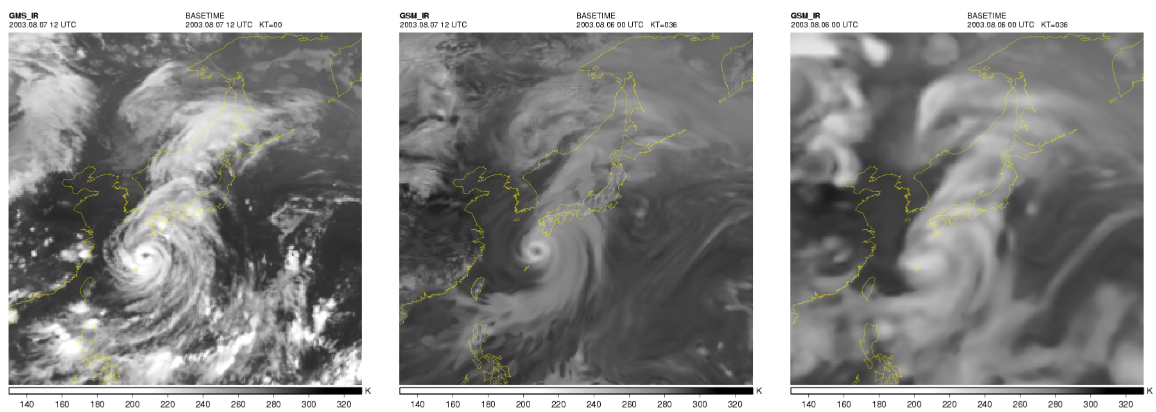

FIG. 6: Comparison of infrared images. Left: image by the GOES-9. Middle: image by the JM-AGCM. Right: image by GSM. The typhoon of the image is the T0310. The date is 00 UTC August 06, 2003. The simulated forecast hour is 36.

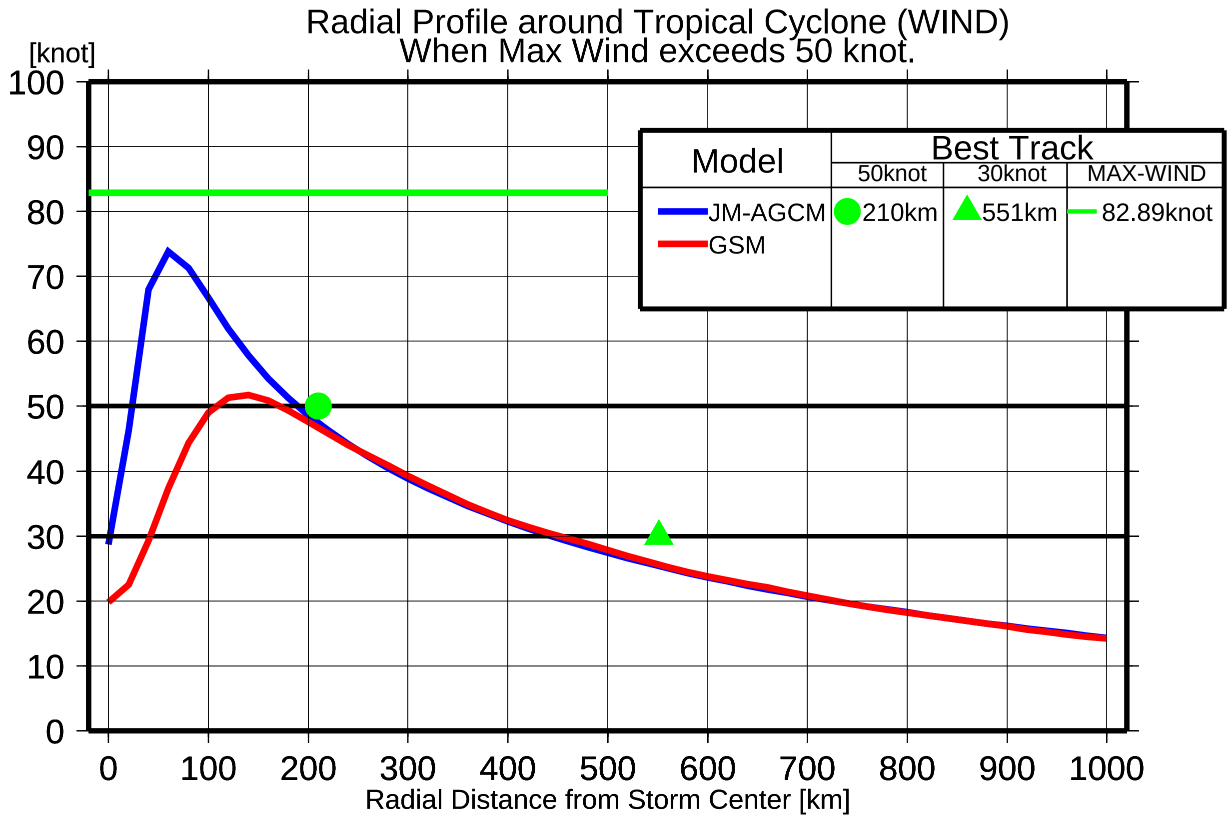

FIG. 7: Mean wind profile of storms whose wind velocity is more than 50knot. The abscissa shows the distance from the storm center. The ordinate shows the averaged wind velocity [knot]. The blue line shows by wind profile by the JM-AGCM. The red line shows that by the GSM. The green triangle (circle) plot shows the 30 (50) knot radius by the best-track data, which were averaged by the corresponding time. The green line shows the maximum wind velocity by the best-track. (radius is unknown)