Regional Climate Prediction by using a Japan Meteorological Agency Nonhydrostatic Model with a High Resolution. Part 1: Outline/Purpose of a High-Resolution Long-Term Prediction

Teruyuki KATO[1], Kazuaki YASUNAGA[2], Chiashi MUROI[1], Masanori YOSHIZAKI[1], Sachie KANADA[2], Akihiro HASHIMOTO[2], Yasutaka WAKAZUKI[2], Hisaki EITO[1], Syugo HAYASHI[1], Hidetaka SASAKI[1]

[1]*Meteorological Research Institute / Japan Meteorological Agency, Tsukuba*
[2]*Advanced Earth Science and Technology Organization, Tokyo*

1. Introduction

We are trying to predict a regional climate around Japan Islands using a high-resolution nonhydrostatic model at the time of global warming. In East Asia, summer monsoon starts from the south in May, and ends in July, extending to the north. This monsoon produces the rainy season, called Baiu season in Japan, in East Asia. It also produces the frontal zone, called Baiu frontal zone in Japan, in the front of the Continental high pressure. Our motivation is to examine how the position of the Baiu frontal zone and the intensity of the precipitation forming over the frontal zone are changed by global warming, and finally we want to contribute to IPCC.

As the first step, we are verifying the accuracy of the present regional climate that is predicted by using regional analyses of Japan Meteorological Agency (JMA) as initial and boundary conditions. Next, we have a plan to predict the present regional climate by giving boundary conditions produced from the prediction of a global climate model, and we also have to compare the predicted precipitation areas and intensity, depending on the horizontal resolution. As the final step, we will examine the regional climate at the time of global warming by using the predictions of a global climate model.

2. Numerical Model

We have applied a nonhydrostatic model developed jointly by the Meteorological Research Institute and Numerical Prediction Division, JMA (Saito et al., 2001, JMA-NHM) to clarify the mechanisms of mesoscale convective systems. The model horizontal resolution of 1-5 km has been used, and the integration time has been less than 1 day. Therefore, to use JMA-NHM as a regional climate model, we had to make some improvements, and ascertain its stability for a long-term integration.

For a long-term integration, we must prepare a huge amount of boundary condition datasets, and restart the integration repeatedly due to the restrict ion of computation system. All of boundary condition datasets had to be necessary for its restarting. At first, we improved JMA-NHM to restart the integration with the minimum required datasets. We also improved JMA-NHM to nest sea surface temperature. We introduced the spectral boundary coupling (SBC) method to JMA-NHM to take in large scale effects (the explanation of SBC method is seen in Part 2).

Horizontal resolution: 5km (5km-NHM)
Vertical layers (distances): 48 layers
(20m near the surface to 920m at the model top)
Basic equations: Full compressible system
Treatment of sound waves: Horizontally explicit and vertically implicit (HE-VI)
Vertical coordinate: Terrain following
Turbulent closure: Level 2.5
Boundary condition: Rayleigh damping is used for lateral and upper boundaries. SBC method is applied to upper level from 500hPa.
Cloud Microphysics: 3ice＋2 moments (Number densities of all hydrometeors are predicted.)
Convective parameterization: none
Advection: Second order in conjunction with modified advection scheme
Radiation: Cloud amount is determined by relative humidity.
Surface temperature: 4 layer model

The major specifications of JMA-NHM used as a regional climate model are shown in Table 1. The horizontal resolution is set to 5km (5km-NHM), because this grid size had been able to reproduce the heavy rainfall events during the Baiu season. However, we want to up to 2km at the final stage.

3. Experiment Designs at the First Stage

The initial and boundary datasets are produced from the 6-hourly regional analyses of JMA. The integration starts from 20 June, 2001, 2002, and 2003, and its period, including the Baiu season, is 70 days for each year. The model domain and orography are shown in Fig. 1. We also use a JMA-NHM with a 20 km horizontal grid (20km-NHM) to compare the effect of resolution. For 20km-NHM, the moist convective adjustment is used in conjunction with microphysics, and the other specifications are the same as those of 5km-NHM.

*Corresponding author address: Teruyuki Kato, Meteorological Research Institute, 1-1 Nagamine, Tsukuba, Ibaraki 305-0052 Japan: e-mail: tkato@mri-jma.go.jp

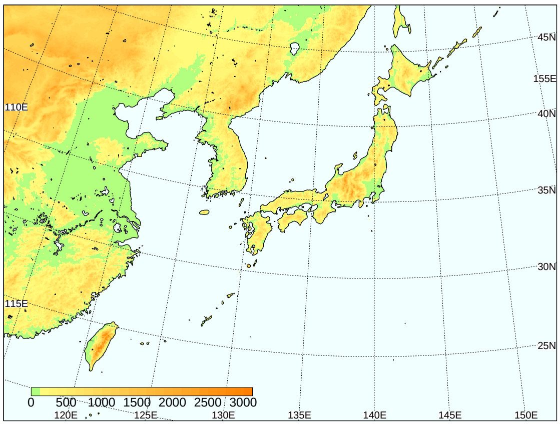

Fig. 1 The model domain and orography.

4. Current Results

Figure 2 shows the observed and predicted 12-hour rainfall after the integration of 5 days. The observed rainfall is estimated by JMA operational radar and ground observation data. The heavy rainfall areas are observed over Kyushu and Shikoku areas. These areas are well reproduced by 5km-NHM, but not for 20km-NHM. This indicates that a high-resolution regional climate model is necessary to predict local heavy rainfalls.

Figure 3 shows the accuracy of 5km-NHM predicted sea level pressure (SLP). During the whole integration period, the differences of the maximum and domain averaged SLP are less than a few hPa. However, the minimum predicted pressure does not decrease to less than 960 hPa. The minimum analyzed pressure less than 960 hPa was produced by typhoons. Since the grid size of 5km can not resolve the eye wall of typhoons, the warm core in the eye that induces the decrease of pressure can not be reproduced. Therefore, at least the grid size of 1km is necessary to predict the accurate minimum pressure.

These results indicate that 5km-NHM has a good accuracy to be used as a regional climate model. Now, we are also verifying the other predicted variables, e.g., near-surface temperature and relative humidity, and rainfall. The results of these verifications may require us to make further improvements of JMA-NHM. Moreover, we plan to estimate Q1 and Q2 (apparent heat source and moisture sink) from the output of 5km-NHM, and want to make new suggestions to convective parameterization.

Acknowledgements

This study is conducted by the fund of Research Revolution 2002, and the numerical calculations are made by NEC SX-6 on Earth Simulator.

Refferences

Saito, K., T. Kato, H. Eito and C. Muroi, 2001: Documentation of the Meteorological Research Institute / Numerical Prediction Division Unified Nonhydrostatic Model. *Tech. Rep.of MRI*, **42**, p133.

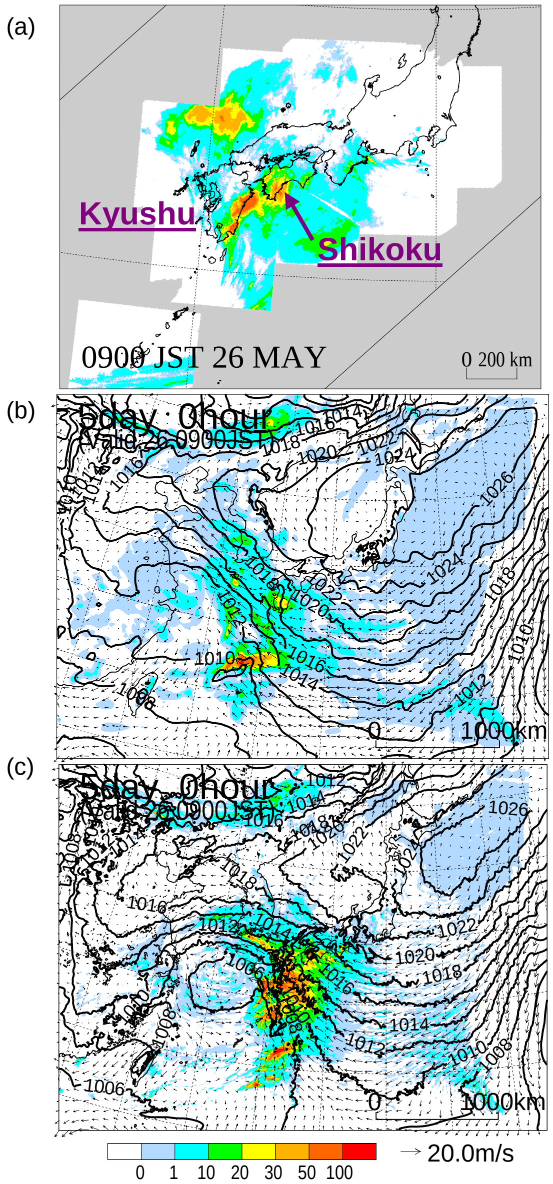

Fig. 2 (a) Observed 12-hour rainfall at 09 JST on 26 May 2003, (b) 20km-NHM and (c) 5km-NHM predicted rainfall and sea level pressure.

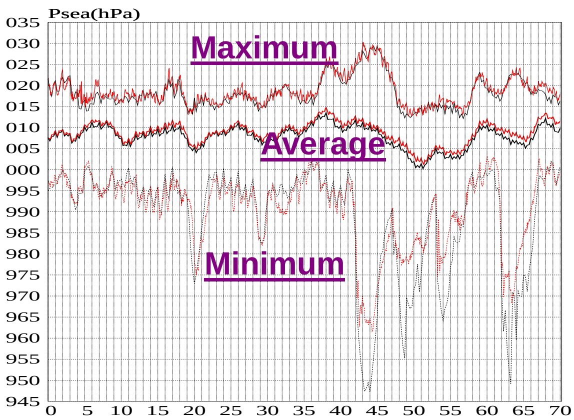

Fig. 3 Time series of the maximum, minimum, and domain averaged sea level pressure of analyses (black lines) and 5km-NHM prediction (red lines) in 2002.