Regional Climate Prediction using a Japan Meteorological Agency Nonhydrostatic Model with a High Resolution.
Part 2: Performances of the Model with the Spectral Boundary Coupling Method.

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1. Introduction

We are trying to predict climate around Japan using a high-resolution nonhydrostatic model that is nested within a global climate model (GCM) when concentrations of carbon dioxide in the atmosphere increase (Kato et al. 2004). Earth Simulator, which is the fastest computer around the world, has enabled long-term prediction by a nonhydrostatic model with a horizontal grid of a few kilometers.

For the high-resolution long-term prediction, a nonhydrostatic model developed jointly by the Meteorological Research Institute and Numerical Prediction Division, Japan Meteorological Agency (Saito et al., 2001, JMA-NHM) is applied. JMA-NHM has been used for the short-term prediction (less than 1 day). Therefore, to use JMA-NHM as a regional climate model, some improvements and evaluation of model performances are necessary.

The Spectral Boundary Coupling (SBC) method, which the Meteorological Research Institute, JMA (MRI) has been developing (ref. Kida et al. 1991), is introduced into JMA-NHM for the purpose of conducting regional climate simulations. The SBC method is the technique of nesting a high-resolution limited area model in such a low-resolution global model as GCM. In practice, the SBC method is to replace the large-scale fields (the long wave part) of a fine mesh model with the corresponding large-scale fields supplied externally from a coarse mesh model. When the conventional nesting method is used, the lateral boundary of an inner fine mesh model is adjusted only to the limited area of an outer coarse mesh model in real space, and other information of the outer coarse model has no effects on the fine mesh model. On the contrary, when the SBC method is used, the connection between the two models is made in wave number space. Accordingly, with the SBC method, the discrepancies between the phases and the positions of disturbances in the two models (fine and coarse mesh models) can be small, and the long-term integration could be is conducted smoothly.

Sasaki et al. (1995) and Sasaki et al. (2000) used the objectively analyzed fields instead of the forecasts of GCM, and it was found that two limited areas models for the regional climate simulation with resolutions of 127 km and 40 km reproduced the objective analysis with a high accuracy when the SBC method was employed. The models are hydrostatic models, and the dynamical and physical frameworks of the two models are similar to those of GCM or the model used for objective analysis, and such similarity is favorable to suppress noise when the long wave part is replaced in the SBC method. On the other hand, JMA-NHM is a nonhydrostatic model with cloud microphysics, and much finer resolution is generally employed for the regional climate simulation. Therefore, it is unknown that the SBC method also works well for such a model with different dynamical and physical frameworks. In the present study, it is investigated that whether the long-term simulations by the high-resolution JMA-NHM show high performances when the SBC method is used.

2. Numerical Model and Experimental design

The horizontal grid size of JMA-NHM used in this study is 5 km, and the domain covers 4000 km x 3000 km. The model has 48 vertical layers, and the 6-hourly regional analyses of JMA are used instead of the forecasts of GCM. The integration starts from 20 May, 2003, and its period, including the rainy season of Japan, is 70 days. The major specifications of JMA-NHM and experimental designs are detailed by Kato et al. (2004).

3. Results and Conclusions

Figure 1 shows the analyzed and predicted sea level pressure fields after the integration of 10 days. When the SBC method is employed (Fig. 1b), the value of sea level pressure at the center of a depression (988 hPa) agrees with the analysis, and the center is predicted close to the analyzed position. On the other hand, when the SBC method is not employed (Fig. 1c), the value of sea level pressure at the center (1000 hPa) is much lager than that of the analysis, and the center is predicted apart from the analyzed position.

Figure 2 represents time series of the root mean square error (RMSE) of sea level pressure for the

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objectively analyzed values over the model domain. The RMSEs in the prediction with the SBC method (the red line in Fig. 2) are much smaller than those without the SBC method (the green line in Fig. 2).

The following verifications were conducted in order to examine the performances of the SBC method over Japan and five local regions of Japan. Figure 3a shows correlation coefficients between observed and predicted surface temperature, and Fig. 3b shows RMSE of precipitation during the simulation period (The predictions during the first 11 days of integration are not verified in order to exclude the influence of the initial fields). When the SBC method is employed, the correlation coefficients (Fig. 3a) and the RMSE of precipitation (Fig. 3b) are lager and smaller over all regions than those when the SBC method is not employed, respectively.

As verified above, all results of JMA-NHM are improved, by using the SBC method. Therefore, it is concluded that the SBC method could work well even for a nonhydrostatic model with the high-resolution.

Acknowledgements

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References

[1] Kato, T., K. Yasunaga, C. Muroi, M. Yoshizaki, S. Kanada, A. Hashimoto, Y. Wakazuki, H. Eito, S. Hayashi, and H. Sasaki, 2004: 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. *CAS/JSC WGNE Research Activities in Atmospheric and Oceanic Modeling, submitted.*

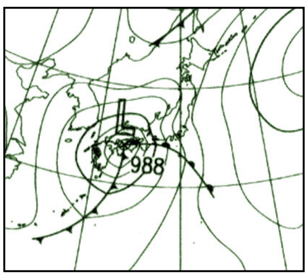
[2] Saito, K., T. Kato, H. Eito and C. Muroi, 2001: Documentation of the Meteorological Research Institute / Numerical Prediction Division Unified Nonhydrostatic Model. *Tech. Rep.of MRI*, **42**, p133.

[3] Kida, H., T. Koide, H. Sasaki, and M. Chiba, 1991: A new approach to coupling a limited area model with a GCM for regional climate simulations, *J. Meteor. Soc. Japan,* ***69****, 723-728*

[4] Sasaki, H., Y. Sato, K. Adachi, and H. Kida, 1995: The performance of long-term integration of a limited area model with the spectral boundary coupling method. *J. Meteor. Soc. Japan,* ***73****, 165-181*

[5] Sasaki, H., Y. Sato, K. Adachi, and H. Kida, 2000: Performance and Evaluation of the MRI Regional Climate Model with the Spectral Boundary Coupling Method. *J. Meteor. Soc. Japan,* ***78****, 477-489*

(a)



(b)

(c)

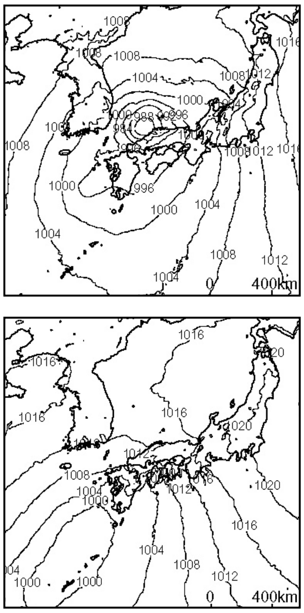


Fig. 1 (a) Analyzed sea level pressure at 09 JST on 26 May 2003, predicted sea level pressure (b) with SBC method, and (c) without SBC method.

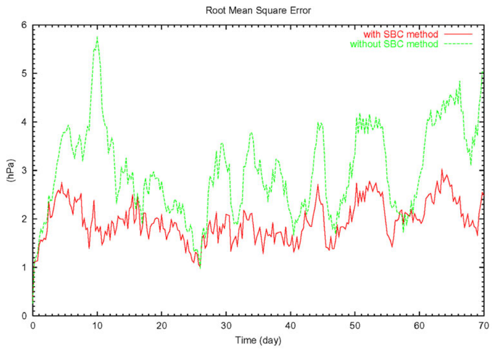


Fig. 2 Time series of the root mean square error of sea level pressure (a green line: with the SBC method, a red line: without the SBC method).

(a)

(b)

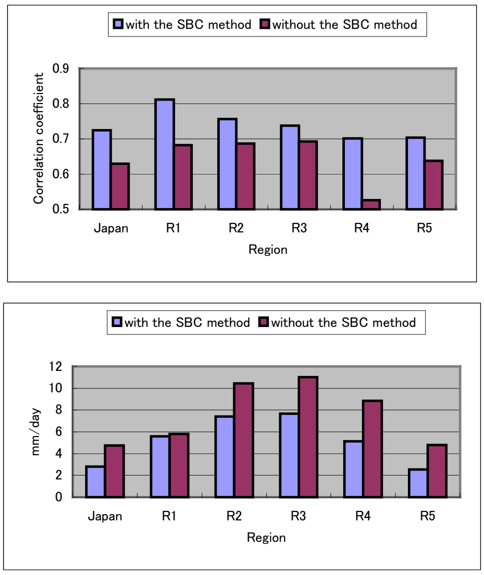


Fig. 3 (a) correlation coefficients between observed and predicted surface temperature, and (b) RMSE of the precipitation during the simulation period.