Performance of the improved Mellor-Yamada Level 3 scheme on JMA-NHM

Tabito Hara[1]

Numerical Prediction Division, Japan Meteorological Agency,
1-3-4, Otemachi, Chiyoda-ku, Tokyo 100-8122, Japan

1 Introduction

The Japan Meteorological Agency (JMA) has been developing a non-hydrostatic model, which is called JMA-NHM, for operational and research purpose. The model with 5-km horizontal resolution (MSM) is employed for the operational mesoscale numerical prediction which aims at providing the information to prevent disaster(Saito et al. 2007).

In May 2007, the model was replaced by a new one in which implemented physics included the improved Mellor-Yamada Level 3 scheme (Nakanishi and Niino 2004)(MYNN3) and the partial condensation scheme (Sommeria and Deardorff 1977), which have brought considerable improvement. The new model can predict more suitable boundary layer and reduce the negative bias of shortwave radiation flux toward surface(Hara 2007).

In this report, the performance of MYNN3 will be shown through an example of prediction for the case of the mixed layer generated on the Sea of Japan in winter. Compared with the former turbulence scheme of JMA-NHM, based on the eddy-diffusive model (Deardorff 1980) with non-local like effect (Sun and Chang 1986), height of mixed layer is higher and structure of wind in the mixed layer can be well realized.

2 Impact on mixed layer on the Sea of Japan in winter

In winter, mixed layer is often developed on the Sea of Japan because the continental cold air is advected to on the warm sea surface, where cloud are observed to streak along the wind direction from the northwest to the southeast. When cold advection is strong enough to cross the Japan island, mixed layer is also seen on the Pacific Ocean. The typical case is shown in Fig.1, which includes the observation by MTSAT-1R satellite and the simulated satellite images with the predicted quantities of the model with MYNN3, and the one with the previous turbulent scheme based on the eddy diffusive model. Attention should be drawn to the representation of cloud on the Sea of Japan and the Pacific Ocean. Detailed cloud structures can be observed in the image simulated by the model with MYNN3. With the eddy diffusive model, cloud spreads excessively wider. It is because vapor is concentrated as a result of the suppression of its vertical diffusion, and then more cloud is generated due to condensation, which is supported by Fig.2, or the cross section of relative humidity.

A remarkable difference between the results of the model with MYNN3 and the one with the eddy diffusive model can be seen in the vertical profile of wind velocity. Fig.3 shows the cross section of potential temperature and the wind velocity along the line crossing the Sea of Japan. The uniformly diffused distribution, which characterizes mixed layer, is realized for the potential temperature by both of schemes, but as for the wind velocity, horizontal contours come into sight with the eddy diffusive model while uniform wind velocity are seen with MYNN3. It means that vertical transportation of momentum with the eddy diffusive model is not large enough to generate uniform mixed layer which should be generated under this environment.

The difference is made by the order of closure. MYNN3 is based on the second order closure while the eddy diffusive model has the first order closure. In the first order closure model, an eddy diffusive coefficient is determined by the product of square root of turbulent kinetic energy, mixed length, and a proportional constant, which is usually set to 0.1 - 0.2. On the other hand, in the second order closure model, the proportional constant in the first order one is no longer a constant; a variable which depends on environmental field, and it ranges about 1 - 2 under unstable layer, much larger than the value of 0.1 - 0.2 in the first order model. It can provide larger diffusive coefficients which make the turbulence diffusion more active.

3 Concluding Remarks

It has been confirmed that MYNN3 is superior to the previous eddy diffusive model through the example of prediction. The superiority of MYNN3 is demonstrated also through the other cases and statistical verification against observations of sondes and wind profilers.

References

Deardorff, J.W., 1980: Stratocumulus-capped mixed layers derived from a three-dimensional model. *Bound.-Layer Meteor.*, **18**, 495–527.

Hara, T., 2007: Implementation of improved Mellor-Yamada Level 3 scheme and partial condensation scheme to JMANHM and their performance. *CAS/JSC WGNE Res. Activ. Atmos. Oceanic Modell.*, **37**, 0407–0408.

Nakanishi, M. and H. Niino, 2004: An improved Mellor-Yamada level 3 model with condensation physics : Its design and verification. *Bound.-Layer Meteor.*, **112**, 1–31.

Saito, K., J. Ishida, K. Aranami, T. Hara, T. Segawa, M. Narita, and Y. Honda, 2007: Nonhydrostatic Atmospheric Models and Operational Development at JMA. *J. Meteor. Soc. Japan*, **85B**, 271–304.

Sommeria, G. and J.W. Deardorff, 1977: Subgrid-Scale Condensation in Models of Nonprecipitating Clouds. *J. Atmos. Sci.*, **34**, 344–355.

Sun, W. Y. and C. Z. Chang, 1986: Diffusion model for a convective layer. Part I: Numerical simulation of convective boundary layer. *J. Climate Appl. Meteor.*, **25**, 1445–1453.

[1]E-mail: `tabito.hara@met.kishou.go.jp`

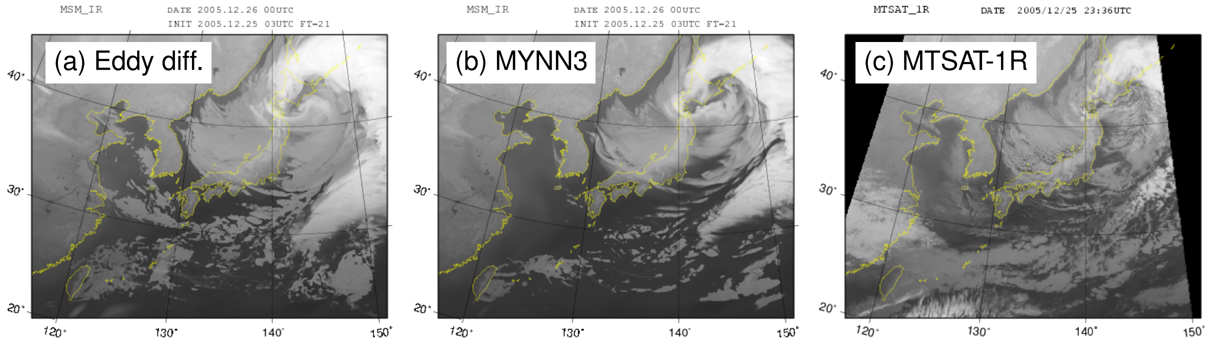

Fig. 1: Simulated IR channel satellite images with predicted quantities and observed image at 0000UTC Dec. 26 2005. (a) simulated image at T+21h with the eddy diffusive model, (b) the same as (a) but with MYNN3, (c) corresponding observed image.

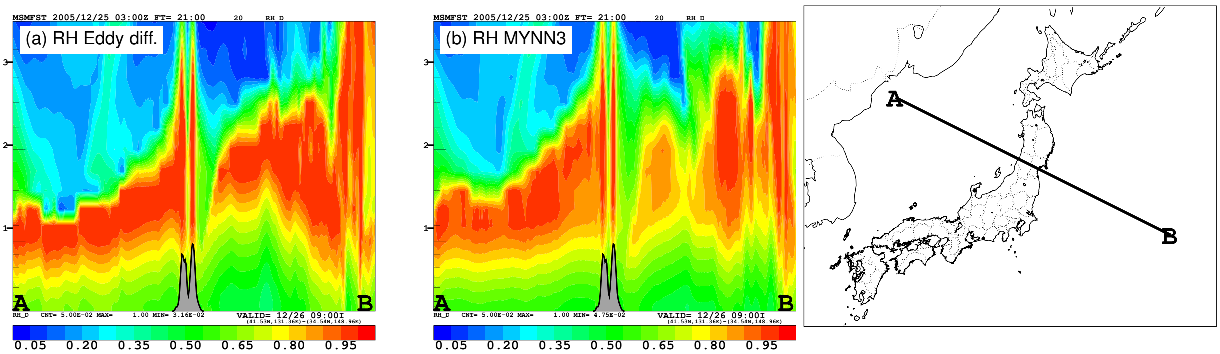

Fig. 2: Cross section of predicted relative humidity along the line AB in the right figure at 0000UTC Dec. 26 2005. Its initial time is 0300 UTC Dec. 25 2005. (a) with the eddy diffusive model, (b) the same as (a) but with MYNN3.

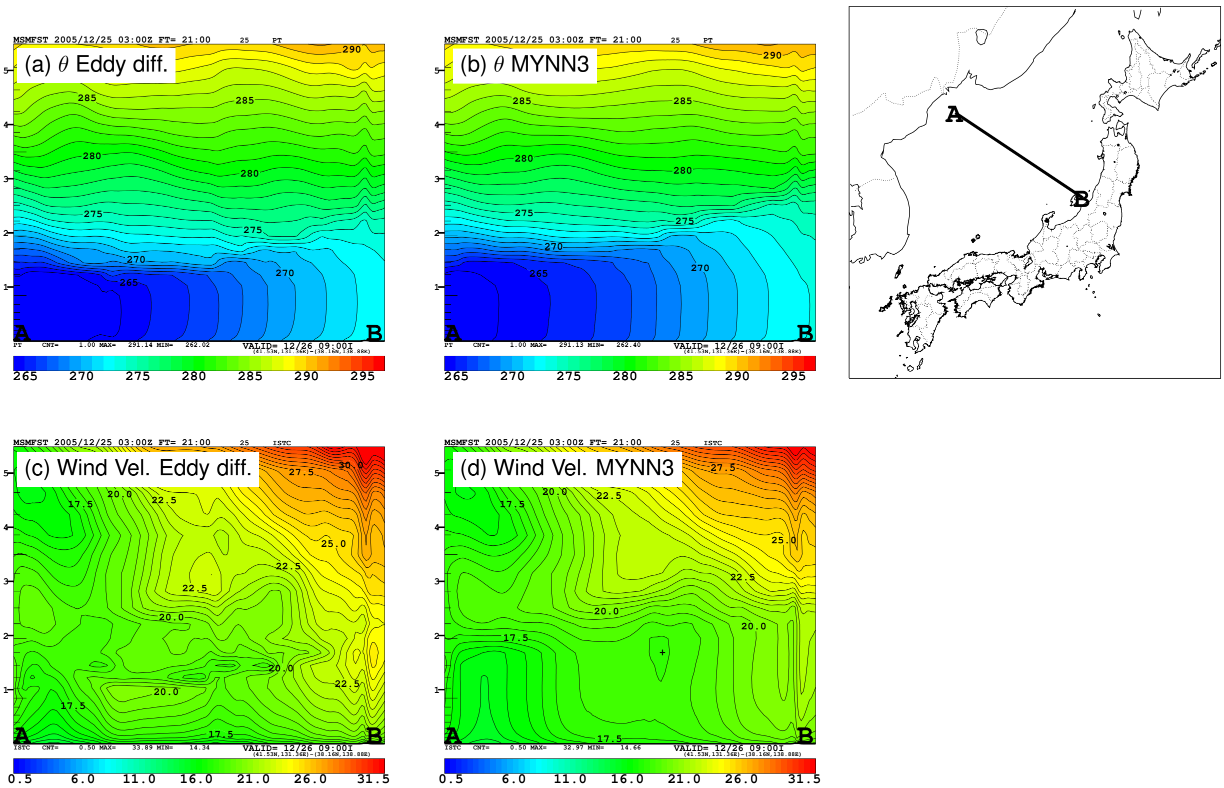

Fig. 3: Cross section of predicted potential temperature and wind velocity along the line AB in the upper-right figure at 0000 UTC Dec. 26 2005. Its initial time is 0300 UTC Dec. 25 2005. (a) potential temperature with the eddy diffusive model, (b) the same as (a) but with MYNN3, (c) wind velocity with the eddy diffusive model, (d) the same as (c) but with MYNN3.