

Development of cumulus parameterization scheme in the non-hydrostatic mesoscale model at the Japan Meteorological Agency

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1. Introduction

The Japan Meteorological Agency non-hydrostatic model (hereafter JMANHM) has been used for operational mesoscale model with a horizontal resolution of 10-km since September 2004 (Saito et al., 2005). The moist process is a combination of a three-class bulk microphysical modeling and the Kain Fritsch cumulus parameterization scheme (Kain and Fritsch, 1990; Kain, 2004, hereafter K-F scheme). Since the K-F scheme has a large impact on the precipitation forecast, several parameters in the scheme were adjusted so that the precipitation forecast becomes better (Yamada, 2003; Ohmori and Yamada, 2004).

The horizontal resolution of the operational mesoscale model will be enhanced to be 5-km from March 2006. Even in the 5-km resolution model, the K-F scheme is still used for better precipitation forecasts. With the important parameters adjusted for the current 10-km resolution model, the K-F scheme may, however, not work well at 5-km resolution. In this paper, we will describe results of refinements of the K-F scheme for the 5-km mesoscale model.

2. Control Experiment with the same setting as horizontal resolution 10-km

First of all, we have examined the performance of precipitation forecasts of the 5-km resolution model with the same parameters in the K-F scheme as those for the current 10-km resolution model. As indicated by statistical verification scores (Fig. 1), the accuracy of precipitation forecast of the 5-km resolution model is almost the same as that of the current mesoscale model, suggesting that a fine tuning of the K-F scheme is required. In the following, we show the result of sensitivity experiment on the three important parameters in the K-F scheme in order to improve precipitation forecasts.

3. Important parameters of K-F scheme

a. Threshold of condensates to convert into precipitation

In the K-F scheme a Kessler-type precipitation formation is adopted such that condensates in the updraft are converted into precipitation when their amount exceeds a prescribed threshold value. The increase in this threshold from $8.0 \times 10^{-4} \text{ kg kg}^{-1}$ in the 10-km resolution model to $2.0 \times 10^{-3} \text{ kg kg}^{-1}$ ameliorates the representation of the occurrence of weak rain (around a few millimeters per three hours) in summer season. The resultant effect is the increase in threat scores due to the reduction in the false alarm.

b. The life time of deep convection

The K-F scheme assumes that the convection consumes the convective available potential energy (CAPE) in a certain time scale. This time scale lying within 1800 to 3600 seconds is used to determine the heating and moistening ratios, and is based on the advective time scale. The original formulation of the K-F scheme has tendency to assign this time scale of 1800 seconds for a fine mesh model with horizontal resolution $< 10 \text{ km}$. A shorter time scale of 900 seconds improved the three-hourly accumulated precipitation forecast by increasing the occurrence frequency at rain rate around 20 millimeters per three hours.

c. The life time of shallow convection

The K-F scheme also includes the shallow convection other than deep convection. The shallow convection produces non-precipitable condensates and no precipitation. The shallowness of the convection is determined by a vertical extent of the cloud layer that is given by a function of temperature at lifting condensation level of rising air parcel. A time scale is also prescribed as in the deep convection.

The importance of the time scale for shallow convection has appeared in the precipitation forecasts during cold air outbreaks of winter monsoon. Under these conditions, shallow convective clouds developed over the sea bring about precipitation. With a default value of 2400 seconds, the band-shaped weak rain is sometimes excessively reproduced to degrade the statistical verification scores. With a shorter life time of 600 seconds, the excessive weak rain is ameliorated well (Fig. 2).

4. Forecast experiments

With the fine-tuned K-F parameters mentioned above, experiments with the 5-km resolution

model are made for both summer (June and July 2004) and winter (December 2004 and January 2005) seasons to investigate the performance of the precipitation forecast to be evaluated by statistical verification scores.

a. Summer season

The threat scores at all rain rates are larger than those from the current 10-km model. Taking into account that the bias scores of 5-km model is much close to unity, it is clear that the overall performance of precipitation forecasts of the 5-km is improved (Fig. 1).

b. Winter season

Both bias and threat scores from 5-km resolution model were comparable at all rain rates, unlike the summer season (not shown). The enhancement of the horizontal resolution did not bring about sizable improvements. One reason of this may in part be explained in terms of the smaller spatial scale of convection in cold season relative to that in summer time. The horizontal resolution of 5-km seems to be still much larger than the spatial scale of the convective clouds in cold season.

5. Future Plan

In 2007, the 5-km resolution mesoscale model is planned to be operated up to 33 forecast hours, the current operational being up to 15 hours. Fine tuning of the K-F scheme for such prolonged forecasts may be necessary for better precipitation forecast.

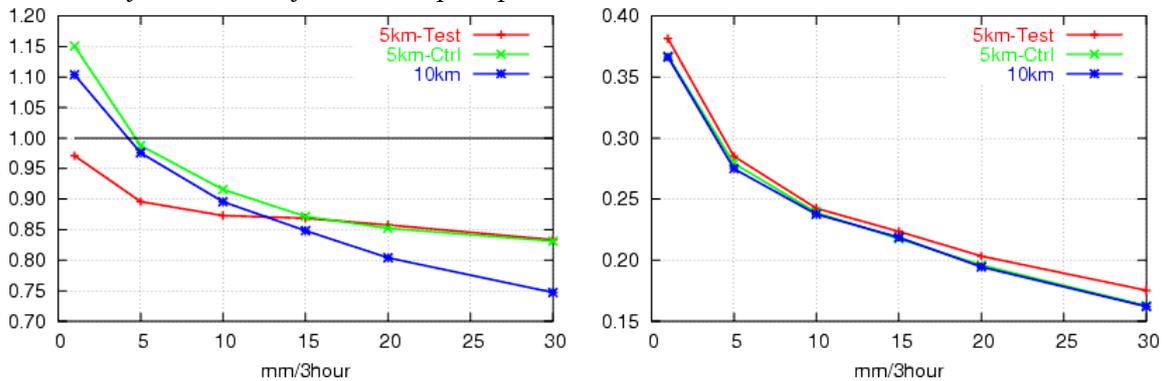


Fig. 1 The bias scores (left) and threat scores (right) against the radar rain gauge composite data. The experiment periods are 6-12th June, 20-26th June and 7-20th July 2004. Red, green and blue lines mean the result from optimized 5-km experiment, that from pre-optimized 5-km experiment and that from 10-km experiment, respectively.

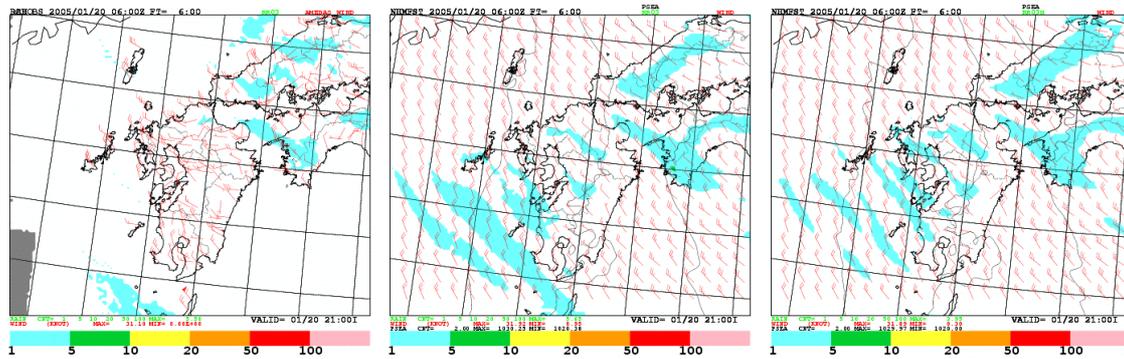


Fig. 2 Observed rain and wind at 20th January 2005 12UTC (left) and the results of 6 hours forecast with 5-km horizontal resolution. The shallow cumulus life time is 2400 seconds (center) and 600 seconds (right). Initial time of forecast is 20th January 2005 06UTC. Rain rates are in millimeter per three hours.

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