Implementation of the Kain-Fritsch Convective Parameterization scheme in the JMA's Non-hydrostatic Model

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1. Introduction

A mesoscale non-hydrostatic model (JMA-NHM hereafter) is being developed at JMA for operational use. The model includes an explicit mixed-phase three-class bulk microphysical model, in which mixing ratios and number concentrations of water substances are predicted. In the early stage of its operation, a horizontal resolution of 10km and relatively longer time step of about 40 seconds are expected. It was, however, found from preliminary experiments that a convective parameterization scheme should be jointly employed in order that the stability of the model is assured, and that representation of relatively weak precipitation is good enough. Even though the JMA-NHM has been equipped with two convective parameterization schemes (Arakawa-Schubert and moist convective adjustment schemes), the Kain-Fritsch convective parameterization scheme (Kain and Fritsch 1990, hereafter K-F CPS) based on the convective available potential energy (CAPE) seems to be appropriate because the model under development will be executed in a region at midlatitude, where CAPE is closely related to the convective activities. In addition, the K-F CPS is designed to work well in models with finer resolutions.

The parameterization code of the K-F CPS as of Apr. 2002 for the Eta model is provided from the WRF (Weather Research and Forecasting) model with permission of Dr. Kain (Yamada 2003). Minor improvements of the K-F CPS made in February 2003 (Kain 2002) have also been reflected in the K-F CPS incorporated in the JMA-NHM. The original code has a high performance in the Eta model with a 25km resolution, its performance in the JMA-NHM with a 10km resolution is, however, not very good regarding precipitation representation. Thus, adjustments of the original parameterization code have been made in order to obtain sufficient performance in the JMA-NHM with such finer resolution of around 10 km. These adjustments may be natural because the parameterization depends on the three-dimensional thermodynamical structures of the model atmosphere.

This paper describes adjustments of the K-F CPS and a new precipitation formation scheme for reproducing precipitation fields satisfactorily.

2. Adjustments of the parameterization

Since the original parameterization code of the K-F CPS didn't give good results in precipitation forecasts as mentioned above, adjustments of the scheme important to the improvement of its performance are made in its three major components, namely "trigger function", "updraft property", and "closure assumption".

In the "trigger function", a concept of temperature increment is introduced as in Fritsch and Chappell (1980) to simulate local perturbation forcing as a function of grid-scale motion. Even though this temperature increment is formulated in the original K-F CPS code as a function of horizontal grid resolution, a value from this formulation may be too large for 10km horizontal resolution, leading to producing undesirable rainfall in regions where no precipitation was observed. Thus, the increment of temperature is reduced by a certain amount of the values determined in the K-F CPS in the original code.

As for the calculation of "updraft property", precipitation is continuously produced in the updraft regardless of the content of condensates by a method proposed by Ogura and Cho(1973). With this precipitation formation scheme, unnatural precipitation patterns were sometimes obtained such as elongated precipitation regions whose orientations were perpendicular to those of major rain bands. In order to ameliorate such precipitation patterns, a new precipitation scheme is introduced; this new scheme will be explained in the next section.

Concerning the "closure assumption", the default setting is assumed that the convection consumes the pre-existing CAPE by 90%. Forecast experiments showed that this closure assumption tends to considerably stabilize the model atmosphere, especially at around the end of forecast period of 15 and 18 forecast hours. Accordingly, the consumption of CAPE is changed.

3. New scheme for precipitation formation in the K-F CPS

In order to improve the aforementioned precipitation patterns, a new scheme of precipitation formation is introduced. This new scheme is based on the concept of the Kessler type autoconversion scheme, that is, the condensates in the updraft are converted into precipitation only when their condensates exceed a prescribed value. This scheme functions fairly well, and is now used taking the place of the Ogura and Cho (1973) scheme.

4. Forecast experiments

Forecast experiments of a heavy rain fall event, which occurred on 20 July 2003 over Kyushu Island, western part of Japan, are conducted by the JMA-NHM of 10km resolution in order to compare performance of the adjusted K-F CPS to that of the original one. In this event, a maximum rain rate reached 81mm hr^{-1}, and three hourly accumulated rain was 142 mm. In these experiments, a mixed-phase three-class bulk microphysical model, in which mixing ratios of water substances are predicted, are employed in conjunction with the K-F CPS.

With the adjusted K-F CPS, heavy rain fall is well reproduced (Fig.1a) over Kyushu Island, consistent with observations (Fig.1b). On the contrary, the original K-F CPS gives relatively weak rain fall spread over and around Kyushu Island (Fig.1c).

5. Future Plan

In the present K-F CPS, occurrence of convection is diagnosed by forecast variables at each grid. This may lead to form convective precipitation at a scale of grid resolution. Thus, it is planed to use forecast variables averaged over horizontal scale 30km to diagnose an occurrence of convection.

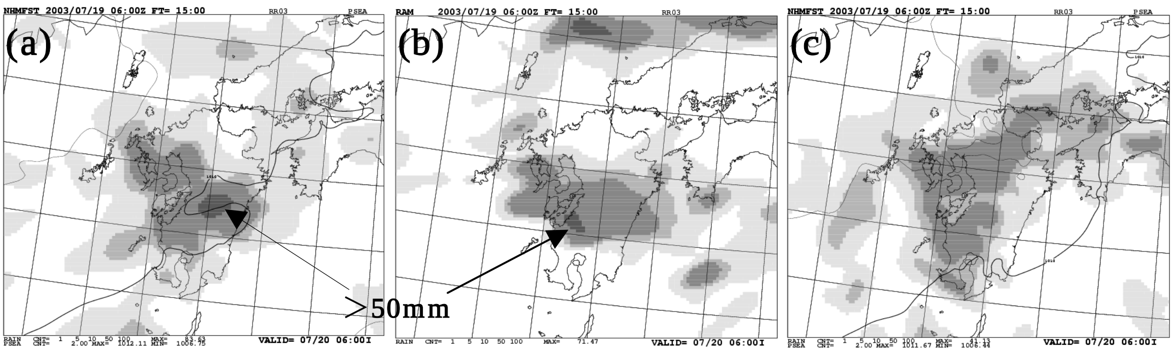

Fig. 1. (a) Three hourly accumulated precipitation(mm) in between forecast hours from 12 to 15 with the adjusted K-F CPS. Initial time for forecast experiments is 06UTC July 19 2003. The accumulated rain amount is depicted by shading of four levels indicating 1-5mm, 5-10mm, 10-50mm, and over 50mm from the most light shading. (b) Three hourly accumulated rain derived from radar data corrected by rain gauge data in the period corresponding to Fig.1a. (c) As in Fig.1a, but with the original K-F CPS.

References

Fritsch, J.M. and C. F. Chappell, 1980: Numerical prediction of convectively driven mesoscale pressure systems. Part Ⅰ: Convective parameterization. *J. Atmos Sci.,* 37, 1722-1733.

Kain, J.S., and J.M. Fritsch, 1990: A one-dimensional entraining/detraining plume model and its application in convective parameterization. *J. Atmos Sci,* 47, 2784-2802.

Kain, J.S., 2002: The Kain-Fritsch Convective Parameterization: An Update. *Submitted to J. Appl Meteor.*

Ogura, Y. and H.-R. Cho, 1973: Diagnostic determination of cumulus cloud populations from observed large-scale variables. *J. Atmos. Sci.,* 30, 1276-1286.

Yamada, Y. 2003: Cumulus Convection Schemes. *Suuchiyohou-ka Houkoku Bessatsu* 49, 84-89.(in Japanese)