Modification to the mixing rate of a convective cloud in the Kain-Fritsch scheme

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To represent the effects of subgrid-scale convection, the Kain-Fritsch (KF) convective parameterization scheme (Kain and Fritsch, 1990; Kain, 2004) is adopted simultaneously with a cloud microphysics scheme to the Japan Meteorological Agency mesoscale model (MSM) of 5-km grid spacing. The KF scheme utilizes a one-dimensional entraining/detraining plume model and the mixing rate δM_{e} at which environmental air mixes into an updraft over a pressure interval δp is expressed as

$$\delta M_{\mathrm{e}} = M_{\mathrm{u0}}\left(\frac{-0.03\delta p}{R}\right), \qquad (1)$$

where R and M_{u0} are the updraft radius and the updraft mass flux at cloud base, respectively (Kain and Fritsch, 1990). In the current KF scheme, R varies between 1000 m and 2000 m based on the vertical velocity at the lifting condensation level (Kain, 2004).

According to Fig. 1, strong and deep convection near a typhoon center is represented mainly by cloud microphysics scheme. On the other hand, contribution of the KF scheme to precipitation is mainly distributed over the area with relatively weak precipitation, where the large scale forcing is weak and the height of cloud top is low. It is suggested that MSM of 5-km grid spacing can explicitly treat the large scale deep convection, while it still needs the parameterization for relatively small convective clouds. Considering that the original KF scheme was successfully developed in the model of grid spacing $\Delta x_0 = 25\,\mathrm{km}$ and smaller convective clouds in more stable area mix more with their environment (Cohen, 2000), R in Eq. (1) is modified as $kR\Delta x/\Delta x_0$, where k is a parameter and Δx is the grid spacing of MSM.

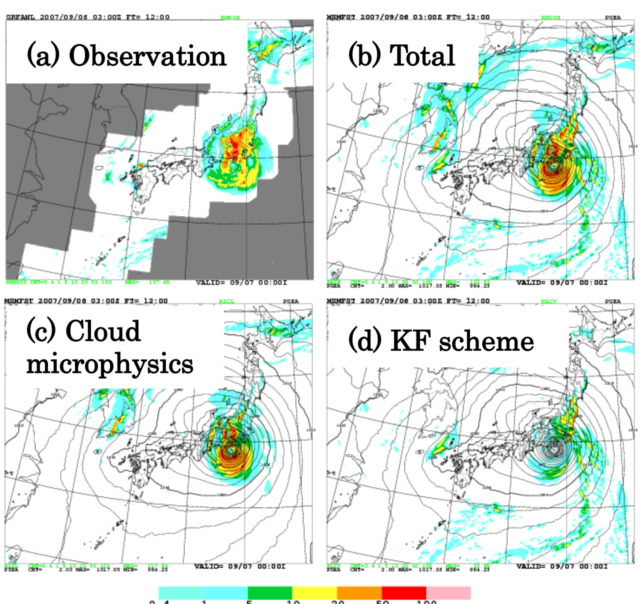

Fig. 1. Accumulated precipitation [mm/3h] at 15 UTC on September 7, 2007.
(a) Observation, (b) Contribution of cloud microphysics and the KF scheme, (c) Contribution of cloud microphysics, (d) Contribution of the KF scheme.

Figure 2 shows the results of precipitation by the MSM forecast with the original and modified KF scheme and that by the observation. Compared with the observation (a), too excessive orographic precipitation along the western coast of the Kyushu Island is calculated (b). This unnatural precipitation is the weak point of the current KF scheme in the MSM. On the other hand, as shown in Fig. 2 (c), (d), and (e), enlargement of the mixing rate δM_{e} by making k smaller eliminates this weak point. Vertical profile of heating rate above the western part of the Kyushu Island due to moist processes of the modified KF scheme in

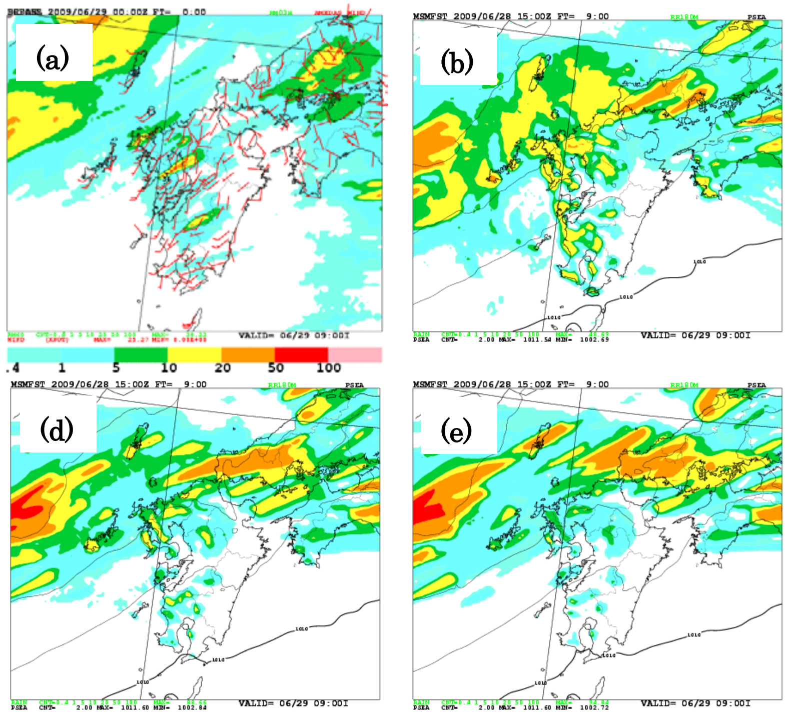

Fig. 2. Accumulated precipitation [mm/3h] at 00 UTC on June 29, 2009.
(a) Observation, (b) Original KF scheme, (c), (d), (e) Modified KF scheme with $k = 0.3, 0.2, 0.1$.

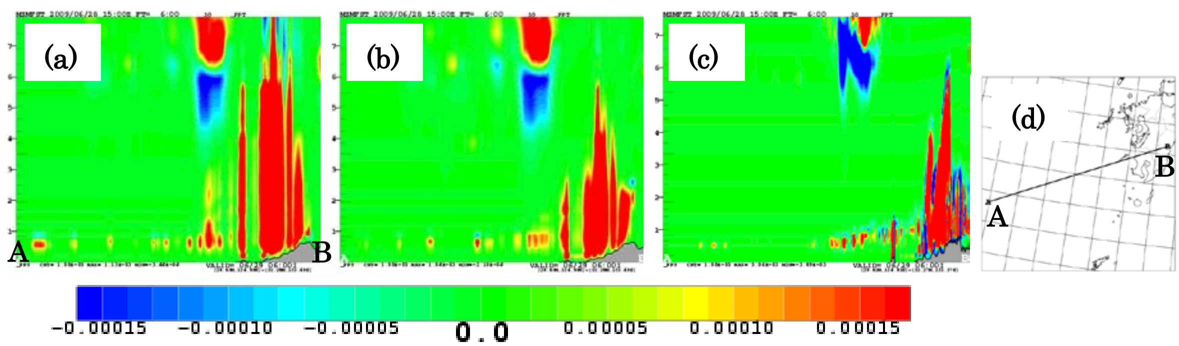

Fig. 3. Vertical profiles of heating rate [K/s] due to moist processes at 21 UTC on June 28, 2009.
(a) Original KF scheme, (b) Modified KF scheme, (c) 1-km model with only cloud microphysics, (d) Locations of A and B.

the MSM becomes closer to that by a high resolution (grid spacing is 1 km) model without convective parameterization (Fig. 3). These results show the modification of the mixing rate in the KF scheme improves the forecasts of precipitation and heating rate by convection.

Further investigation such as the inclusion of variable mixing rate of convective clouds according to the height of cloud base has been continued.

References

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