Inclusion of a temperature perturbation based on the relative humidity to the Kain-Fritsch convective parameterization scheme

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The Japan Meteorological Agency has operated a nonhydrostatic mesoscale model (MSM) of 5-km grid spacing since March 2006. To represent the effects of subgrid-scale convection, the Kain-Fritsch (KF) convective parameterization scheme (Kain and Fritsch 1990; Kain 2004) is adopted to MSM in addition to cloud microphysics (Ohmori and Yamada 2004). The source codes of the KF scheme have been originally developed for the Weather Research and Forecast (WRF) modeling system and implemented to MSM with Dr. Kain's consent in April 2002. In addition to the minor improvements on the KF scheme in WRF before February 2003, some modifications were applied to the KF scheme in MSM.

To identify source layers for convective clouds, the KF scheme utilizes a trigger function based on the temperature at the lifting condensation level (LCL) and the grid-scale vertical velocity (Kain 2004). The KF scheme, applied to the humid climate area of Japan and its surroundings, sometimes fails to initiate parameterized convection when the lowest atmosphere is wet and dynamical forcing is weak. To eliminate this weakness, a temperature perturbation based on the relative humidity, which was originally developed for the High Resolution Limited Area Model by Undén et al. (2002), has been added to the trigger function. This new temperature perturbation ΔT_{RH} is given by

$$\Delta T_{\mathrm{RH}} = \begin{cases} 0, & \text{if } R_{\mathrm{hLCL}} < 0.75 \\ \dfrac{0.25\left(R_{\mathrm{hLCL}} - 0.75\right) q_{\mathrm{mix}}}{\partial q^{*}_{\mathrm{LCL}} / \partial T}, & \text{if } 0.75 \le R_{\mathrm{hLCL}} \le 0.95 \\ \dfrac{\left(1/R_{\mathrm{hLCL}} - 1\right) q_{\mathrm{mix}}}{\partial q^{*}_{\mathrm{LCL}} / \partial T}, & \text{if } R_{\mathrm{hLCL}} > 0.95 \end{cases}$$

where R_{hLCL} is the relative humidity at the LCL, T is the temperature, q^{*}_{LCL} is the saturation mixing ratio at the LCL, q_{mix} is the mixing ratio of updraft source layer. The temperature perturbation determined by the formulation of Undén et al. (2002) is reduced to a certain degree in MSM.

Figure 1 shows the accumulated precipitation forecasts by MSM. In Fig. 1 (a), without the relative humidity based temperature perturbation, considerably intensified precipitation was generated in very small areas such as the western sea of Taiwan (234 mm/3h), the southern sea of Okinawa island (115 mm/3h) and so on. Such intensified precipitation caused by grid-point storms was eliminated with the modified KF scheme as shown in Fig. 1 (b).

The inclusion of the temperature perturbation depending on the relative humidity also improved the forecast of diurnal convective rain (Fig. 2). While the amount of precipitation (b) was not adequate compared to the observation (a), the predicted precipitation pattern calculated by the modified KF scheme (c) was better than that by the KF scheme without the relative humidity based temperature perturbation.

References

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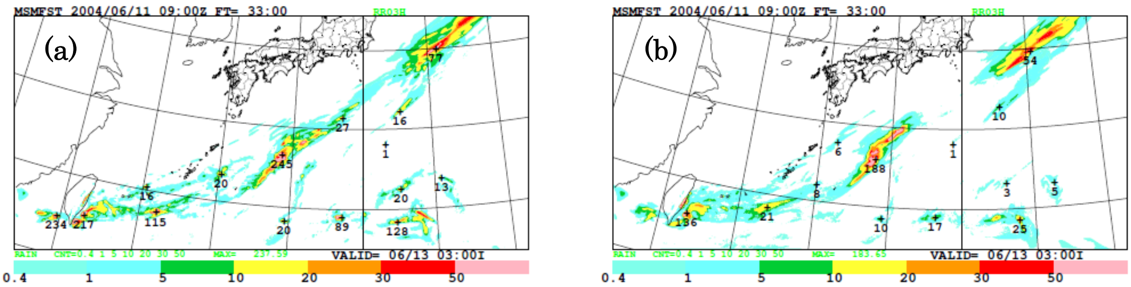

Fig. 1. Accumulated precipitation [mm/3h] from 15-18 UTC on 12th June 2004.
(a) 33-hour forecast by MSM with the KF scheme without the relative humidity based temperature perturbation.
(b) Same as (a) but with the relative humidity based temperature perturbation.

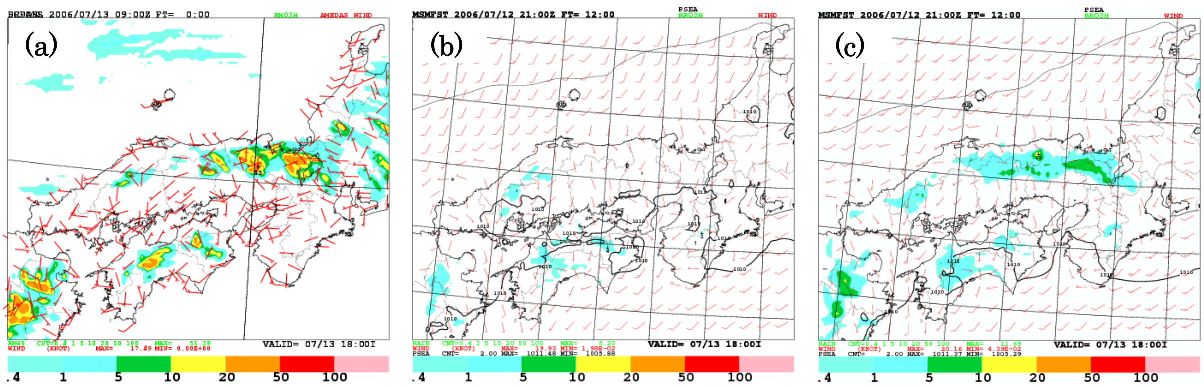

Fig. 2. Accumulated precipitation [mm/3h] from 06-09 UTC on 13th July 2006.
(a) Observation (derived from radar data corrected by rain gauge data).
(b) 33-hour forecast by MSM with the KF scheme without the relative humidity based temperature perturbation.
(c) Same as (b) but with the relative humidity based temperature perturbation.