Implementation of the Targeted Moisture Diffusion to JMA-NHM

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The Japan Meteorological Agency (JMA) started the operational run of a nonhydrostatic model ('JMA-NHM'; hereafter simply mentioned as 'NHM') on 1 September 2004 in place of the former operational hydrostatic mesoscale model of JMA (MSM). NHM is a community nonhydrostatic model for both operational NWP and research, whose original root is based on the Meteorological Research Institute/Numerical Prediction Division unified nonhydrostatic model (Saito et al. 2001).

As for the moist physical processes, the Kain-Fritsch (K-F) parameterization scheme has been implemented in addition to the bulk cloud microphysics. Several modifications have been done to improve its performance in a 10 km resolution NWP, especially for prediction of heavy rainfall events in Japan where moist and unstable maritime air-mass prevails (Ohmori and Yamada, 2004). One of the modifications is the “closure assumption”, where the default setting assumed that the convection consumes the pre-existing CAPE by 90 % in a single application of the K-F scheme. However, forecast experiments showed that this setting tended to over-stabilize the model atmosphere, and strong rain decreased with time in the forecast period. To prevent this undesirable excessive stabilization of the model atmosphere, CAPE left in the column after a single application of the K-F scheme was increased from the default value (10 %) to 15 %. With this modification, heavy rainfall events were well reproduced by NHM compared with NHM using the original K-F scheme and MSM. However, on the other hand, intense grid scale updrafts often developed in the model with this increased rate of residual CAPE, because this change allows more convective unstableness in the model atmosphere.

In order to control the grid point storms and the associated intense grid scale precipitation, the targeted moisture diffusion (TMD) has been newly implemented to NHM. The basic idea of TMD was developed by Dr. Terry Davies of the UK Met Office for the Unified Model (UM; Staniforth et al., 2004), where a second order horizontal diffusion is applied to water vapor when strong upward motions exist to selectively damp the grid point storms and associated intense grid scale precipitation. In the mesoscale UM with 38 levels and a horizontal resolution of 0.11 deg (12km), TMD is applied to all grid points in a column where the upward motion exceeds 1.0 m/s. In case of NHM, horizontal diffusion with an *e*-folding time of 300 sec is applied to water vapor at grid points where the upward motion exceeds 2.0 m/s.

Figure 1 shows an example of time sequence of the maximum updraft and rainfall intensity by NHM which covers the MSM domain. The initial time is 18 UTC 18 July 2003. Without TMD, the maximum updraft reaches 6 m/s at FT=5-8hr, and very intense rains about 140 mm/hr are predicted at FT=7-8hr. At FT=16.8hr, a spike-like strong updraft of 8 m/s is seen, which is caused by grid point deep convection. With TMD, the maximum updraft and the maximum rain intensity are reduced to reasonable values, less than 4.5 m/s and 80 mm/hr, respectively. Figure 2 shows the one hour precipitation at 02 UTC 19 July 2003 predicted by NHM with and without TMD. As seen in this figure, major precipitation pattern is not affected by the inclusion of TMD. Figure 3 shows the histogram of 1 hour precipitation intensity for the model grid of NHM. TMD effectively reduces the over-intense precipitation greater than 50 mm/hr without changing the weak to moderate rains. TMD has been implemented to the JMA new operational nonhydrostatic mesoscale model (Saito et al., 2005).

References

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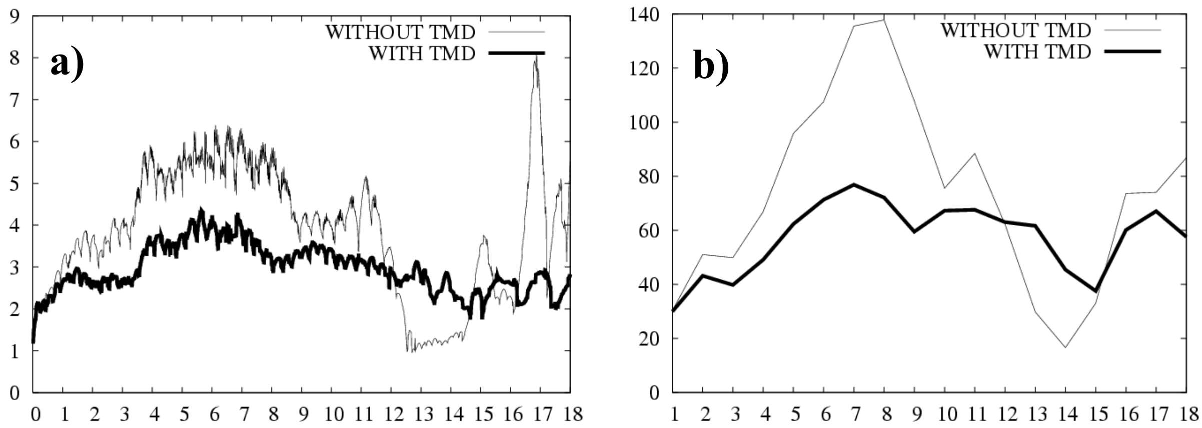

Fig. 1. a) Time sequence of the maximum updraft in a simulation with and without TMD. Initial time is 18 UTC 18 July 2003. Units of horizontal and vertical axes are hr and ms^{-1}, respectively. **b)** Same as in a) but the maximum one hour rain intensity. Unit of vertical axis is mm/hr.

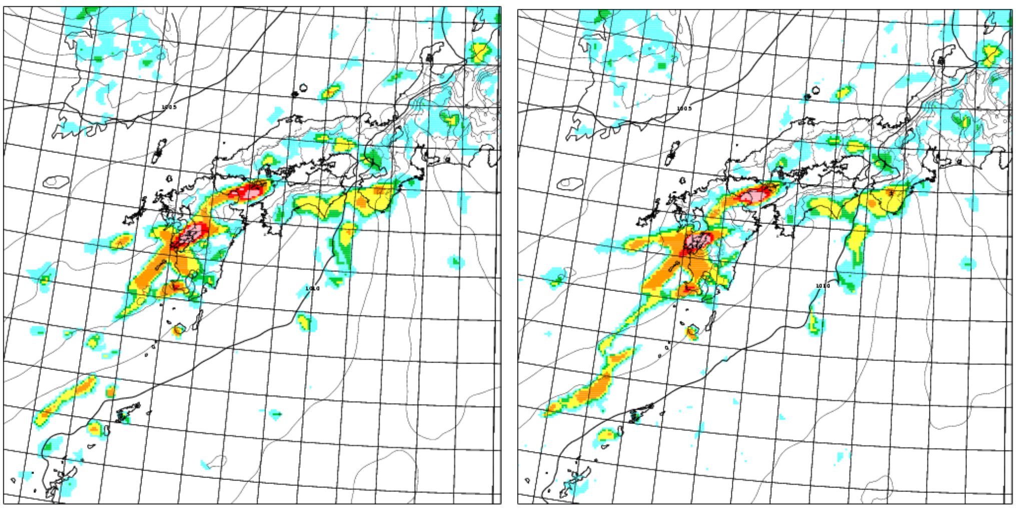

Fig. 2. One hour precipitation at 02 UTC 19 July 2003 predicted by NHM (FT=8hr). **a)** With TMD. **b)** Without TMD.

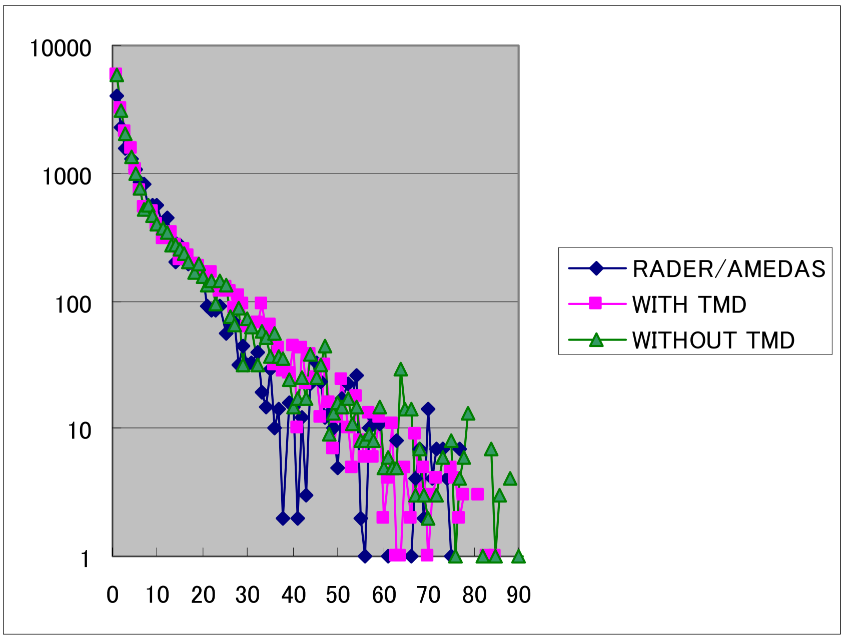

Fig. 3. Histogram of 1 hour precipitation intensity for the model grid of NHM. Horizontal axis is rain intensity (mm/hr), and vertical axis is frequency. The samples are taken from all forecast times of 18 hour forecast starting from 18UTC 18 January 2003.