# Comparison of simulated diabatic heating profiles between 5km and 1km models in western Japan during the warm season

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In the previous report (Kato and Hayashi, 2008), the relation between levels of neutral buoyancy (LNB) thermodynamically estimated from atmospheric condition and cloud-top heights (CTOPs) simulated by a cloud-resolving model with 1 km horizontal grids (1km-CRM) is examined statistically in western Japan during the 2007 Baiu season (June and July). It showed that the deep convection and the warm-rain type convection coexisted in correspondence with upper-level (~ 200 hPa) and middle-level (~ 700 hPa) peaks in LNB appearance frequency obtained statistically from objective analysis data (Kato et al., 2007). In this study, vertical profiles of diabatic heating and cooling are also investigated during the 2008 warm season (from April to August). Moreover, simulated results of a 5km-nonhydrostatic model (5km-NHM) that was used to produce initial and boundary conditions of 1km-CRM are compared with those of 1km-CRM. Numerical models used in this study are the Japan Meteorological Agency NHM (JMANHM, Saito et al., 2007).

At first, the 5km-NHM was nested within JMA mesoscale objective analysis data with a horizontal resolution of 10 km, available 3 hourly (MANAL). Its initial times are 00 UTC, 06 UTC, 12 UTC and 18 UTC of every day, and its integration time is 12 hours (later 6-hour simulated data are used in statics). Next, the 1km-CRM was nested within the output of the 5km-NHM. Its initial time is 3-hour forecast time of the 5km-NHM and hourly simulated data between 4 and 9 forecast hours are used in statics. Accumulated diabatic amounts at every time step are used in this study. In the 1km-CRM, a bulk-type microphysics scheme predicting the specific humidity of cloud water $q_c$, cloud ice $q_{ci}$, rainwater $q_r$, snow $q_s$, and graupel $q_g$ are used, while a moist convection parameterization scheme (Kain and Fritsch, 1990) is additionally used in the 5km-NHM.

LNB and levels of free convection (LFC) are estimated by a low-level air with the maximum equivalent potential temperature below an 800 hPa level. The cases in which the distance between the originating level of the air and its LFC is longer than 2 km are excluded from statics. CTOPs and cloud-bottom heights (CBTMs) are determined by the threshold values of $q_c + q_{ci} + q_s = 0.01$ g kg$^{-1}$ and $q_c + q_{ci} = 0.1$ g kg$^{-1}$, respectively. Cumulonimbi are defined as the moist convection with rainfall in this study. The following conditions for their judgment are used; 1) the distance from the ground to CTOP > 2 km, 2) the distance from the ground to CBTM < 2.5 km, 3) the distance between CTOP and CBTM > 1 km, and 4) vertically-integrated $q_r + q_s + q_g$ below a 5-km height ≥ 0.1 mm for CTOP < 8 km. Noted that the location of CTOP may be different from that of CBTM, due to the tilting of cumulonimbi. The difference of vertical scales of cumulonimbi is accepted in this study.

In western Japan, more heavy rainfall events were observed in June 2008, while the Baiu season much earlier ended (~ on 6 July) in comparison with the common year. Moreover, more heavy rainfall events were also observed in August 2008 because of the inflow of humid airs. The upper peak in the LNB appearance rate is very small on the land in June (Fig. 1b), as well as the common year. However, the deep convection, corresponding with the upper peak of 12-13 km in Fig. 2, is more frequently simulated (> 0.3 %) than the LNB appearance rate (< 0.2 %) and could cause heavy rainfall in June. The most part of the deep convection on the land could form over the sea, because the LNB appears at the upper level at a higher rate over the sea.

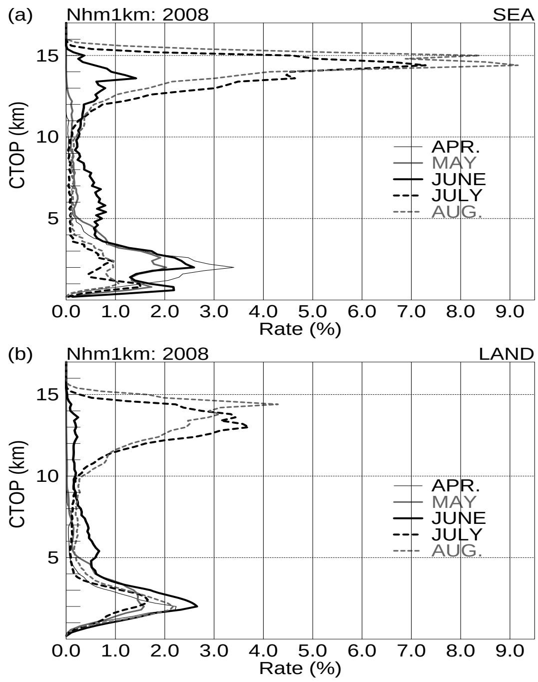


Fig. 1 Vertical profiles of the monthly-averaged LNB appearance rates (a) over the sea and (b) on the land, estimated from 1km-CRM. Each rate is calculated by dividing heights into 80 levels with an interval of 200 m.

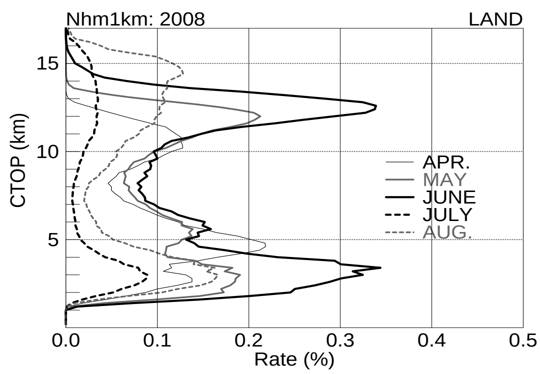


Fig. 2 Same as Fig. 1b, but for the CTOP appearance rate.

The upper peak of CTOPs (Fig. 2) gradually becomes higher associated with the rise of tropopause: from 10 km on April to 15 km on August. However, such a shift in the upper peak of LNB is found only in July and August (Fig. 1b). This suggests that the deep convection form in considerably limited areas around Japan, except during the summer season.

The previous report (Kato and Hayashi, 2007) showed that the 5km-NHM overestimated (underestimated) the appearance rate of the deep convection (the warm-rain type convection), compared with the 1km-CRM. In 2008, the characteristic features of the moist convection simulated by the 1km-CRM are rarely changed. However, the replacement of the boundary conditions of MANAL with the forecast of the JMA global model from that of JMA regional model caused the decrease of the appearance frequency of the moist convection simulated by the 5km-NHM, especially over the sea (not shown). This could be brought from the low-level cold and humid bias, which should be solved in the JMA global model.

Monthly-averaged vertical profiles of the difference of simulated diabatic heating (excluding radiation) and cooling between 5km-NHM and 1km-CRM shows that the difference below a height of 1-4 km is very small over the sea (Fig. 3a), while the 5km-NHM overestimates diabatic heating below a 4 km height on the land (Fig. 3b). Moreover, the 5km-NHM underestimates diabatic heating above a height of 5km both over the sea and on the land. Since these tendencies are also found during the 2007 Baiu season, the difference between 5km-NHM and 1km-CRM could not be caused by the replacement of the boundary conditions of MANAL.

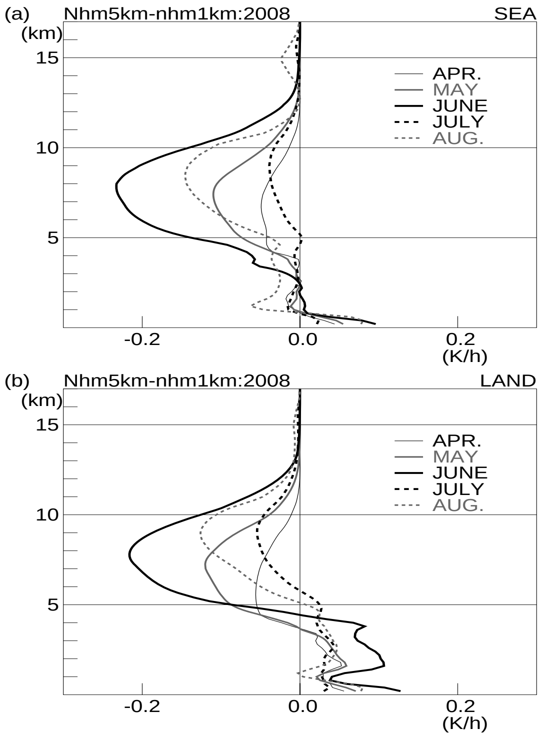


Fig. 3 Monthly-averaged vertical profiles of the difference of simulated diabatic heating and cooling between 5km-NHM and 1km-CRM (a) over the sea and (b) on the land.

The profiles of diabatic heating and cooling in June 2008 are examined in detail. Noted that diabatic cooling is estimated from hourly output, not accumulated at every time step. The 5km-NHM underestimates diabatic cooling, especially at the lower level on the land (see dashed lines in Fig. 4). This is mainly brought from the suppression of raindrop evaporation at a half rate in the 5km-NHM. This rate could be too large, especially on the land.

The profile of diabatic heating simulated by the 1km-CRM has a peak around a height of 1km on the land (Fig. 4b). This is mainly produced by the formation of cloud water due to the terrain-forced updrafts. Moreover, the 5km-NHM underestimates diabatic heating around a height of 7 km. This could be caused by underestimating the upward transportation of water vapor.

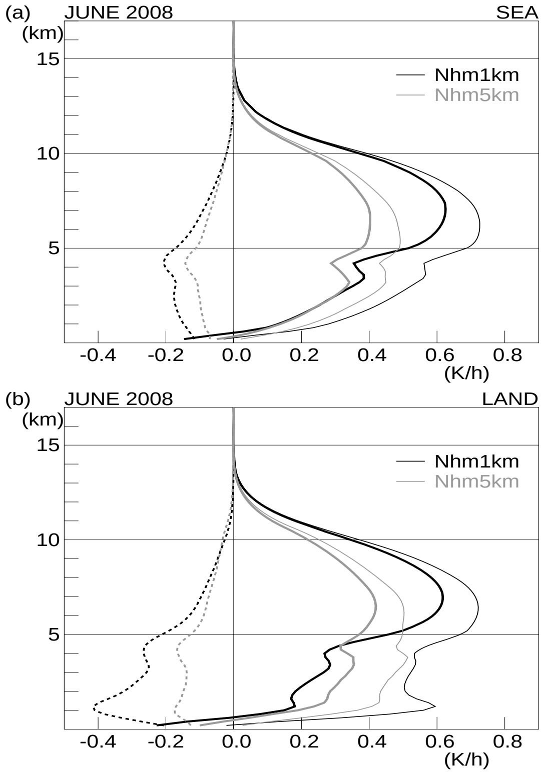


Fig. 4 Vertical profiles of diabatic heating (thin lines) and cooling (dashed lines) simulated by 1km-CRM (black color) and 5km-NHM (gray color) (a) over the sea and (b) on the land, averaged in June 2008. Thick lines represent total of diabatic heating and cooling.

**REFERECES**

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.

Kato, T., S. Hayashi, and M. Yoshizaki, 2007: Statistical study on cloud top heights of cumulonimbi thermodynamically estimated from objective analysis data during the Baiu season, *J. Meteor. Soc. Japan*, **85**, 529-557.

Kato, T. and S. Hayashi, 2008: Problems on the usage of Kain-Fritsch parameterization in a 5km model: Statistical comparison with cloud-top heights of cumulonimbi simulated by a cloud resolving model. *CAS/JSC WGNE Research Activities in Atmospheric and Oceanic Modeling*, **38**, 4.05-4.06.

Saito, K., J. Ishida, K. Aranami, T. Hara, T. Segawa, M. Nareta, and Y. Honda, 2007: Nonhydrostatic atmospheric models and operational development at JMA. *J. Meteor. Soc. Japan*, **85B**, 271-304.