Improvement of Kain-Fritsch Convection Parameterization Scheme To Suppress its False Predictions of Rainfall Areas along Coastal Lines

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The operational mesoscale model (MSM) of the Japan Meteorological Agency (JMA) with a horizontal resolution of 5 km (Saito et al. 2007) often makes false predictions of rainfall areas along coastal lines, not observed, during warm season, especially in July and August (see Fig. 2a). Such a rainfall area is predicted due to the oversensitive activation of the Kain-Fritsch convection parameterization scheme (K-F scheme; Kain 2004) introduced in the MSM, when low-level humid air inflows from the sea into the land. The activation of the K-F scheme is judged by lifting the updraft source layer (USL) to the lifting condensation level (LCL) and checking the atmospheric conditions for the formation of moist convection. In the MSM, the temperature and water vapor in the USL are averaged in the layer with a depth of 50 hPa from the lowest vertical level of the model (~ 20 m). Narita (2008) introduced temperature perturbations based on the relative humidity into the K-F scheme to improve the predictions of the MSM, but the improvement can hardly suppress false predictions of rainfall areas along coastal lines.

At first, to improve the K-F scheme, the appearance frequency of cloud-base heights from the surface (CBHs) of moist convection, simulated by the 1km-cloud-resoluving model (CRM), around Kyushu and Shikoku Islands (see Fig. 2a), western Japan during the 2008 warm season is statistically examined separately over the sea, around the coastal areas and in mountainous regions (heights > 500 m). The frequency in the ordinate of Fig. 1, normalized based on the maximum frequency, is for the case with an updraft exceeding the number (Wmax) shown in the abscissa. Figure 1 also shows the appearance frequency of the Wmax (bold curve). The case with an updraft exceeding 1.0 m s^{-1} appears at rates of 1.52 % ~ 4.64 %, while that exceeding 10.0 m s^{-1} decrease by more than two orders. However, the peak height of CBH appearance frequency changes a little for the increase of the Wmax. The CBHs tend to appear higher around coastal areas than over the sea, and their appearance almost limits below a height of 200 m in mountainous regions.

The CBHs scarcely appear above a height of 1.0 km (1.5 km) over the sea (on the land) for Wmax > 5.0 m s^{-1}. This means that most of moist convection with strong updrafts has a considerably low CBH even on the land in East Asia during warm season, because the inflow of low-level humid air from the sea produces strong convection on the land. It should be noted that the extension of CBH appearance frequency to the upper level is found for weak Wmax (1 – 3 m s^{-1}). This extension could be brought from stratiform clouds.

As shown in Fig. 1, the appearance of CBH is remarkably different among sea, coast and mountain. In this study, the originating level to calculate the USL in the K-F scheme is changed based on the statistical examination of the CBHs. It should be noted that in the K-F scheme introduced into the JMA nonhydrostatic model (JMANHM) the originating level to calculate the USL can be set by a unit of 15 hPa from the lowest vertical level of the model (~ 20 m). In the improved K-F scheme, the originating level over

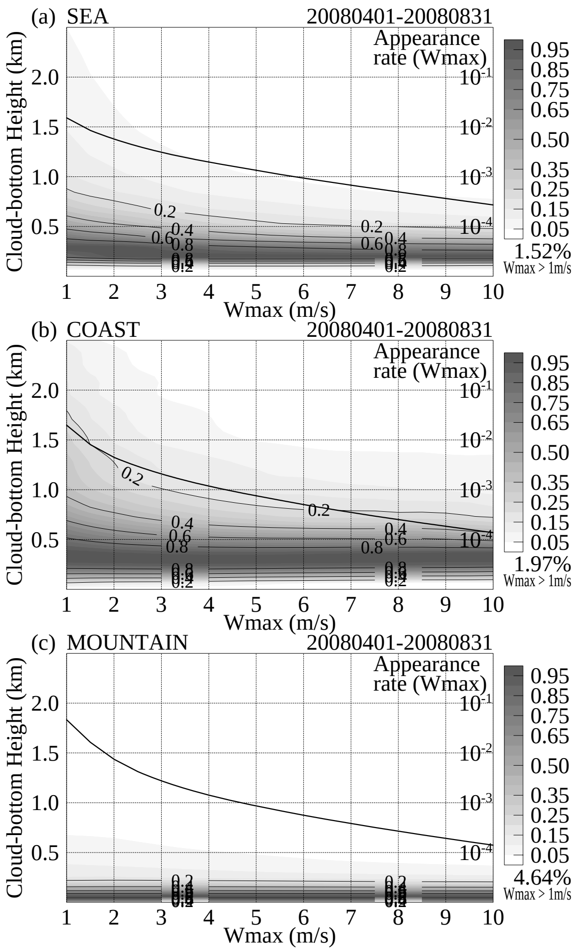

Fig. 1. Appearance frequency distributions of CBHs simulated by the 1km-CRM for maximum updrafts in vertical cores (a) over the sea, (b) around coastal areas and (c) in mountainous regions. The abscissa denotes the case with an updraft (m s^{-1}) exceeding the number (Wmax), and the frequencies are normalized based on the maximum frequency in the ordinate. The bold curve shows the appearance frequency of Wmax. The statistical period is the 2008 warm season between April and August.

the sea and in mountainous regions is set the lowest vertical level, while that around coastal areas is set 45 hPa (~ 500 m) above the lowest vertical level. The above-mentioned setting produces the discontinuity of the originating level. To avoid this discontinuity, the originating level in boundaries is set 15 hPa or 30 hPa above the lowest level of the model. A unit of 15 hPa is changed by two horizontal grids in this study.

Figure 2 shows the distribution of total rainfall amount in July 2006 simulated by the 5km-NHM. The 5km-NHM well reproduces the rainfall distribution, although it fails to simulate areas with total rainfall amount larger than 900 mm over the mountainous regions in the southern part of Kyushu Island. The 5km-NHM with the original K-F scheme (Fig. 2a) makes false predictions of rainfall areas along coastal lines (e.g., western part of Kyushu Island and south part of Shikoku Island). On the other hand, the 5km-NHM with the improved K-F scheme (Fig. 2b) hardly predicts such a rainfall area and the other rainfall distributions don't show a large difference from that with the original K-F scheme.

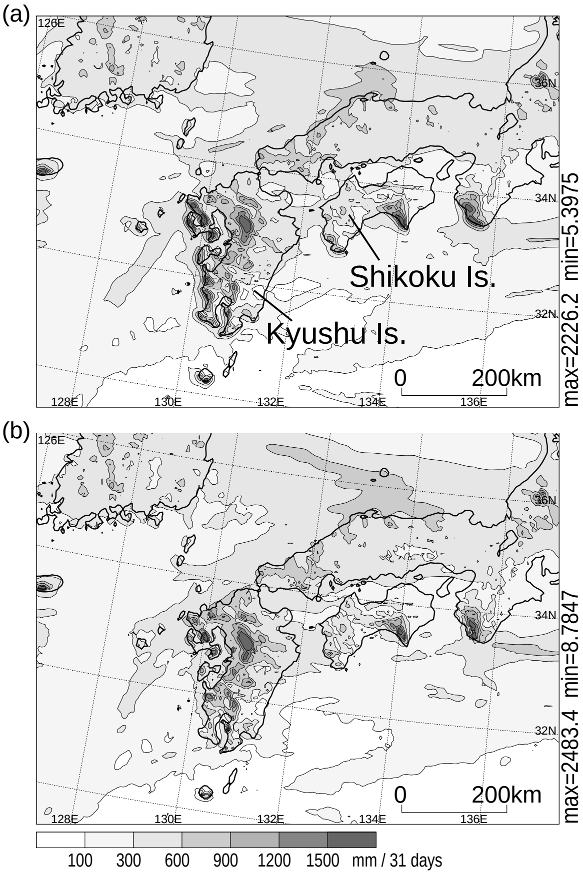

Fig. 2. Distribution of total rainfall amount in July 2006, simulated by the 5km-NHM with (a) the original and (b) improved K-F schemes.

Figure 3 shows the appearance frequency of hourly rainfall amounts in July 2006 observed by JMA raingauges (AMeDAS) and simulated by the 5km-NHM. The improved K-F scheme (thin curve) hardly changes the appearance frequency of rainfall amounts less than 15 mm, while it considerably reduces the underestimation of the 5km-NHM with the original K-F scheme (dashed curve) for rainfall amounts larger than 15 mm. The cumulative appearance frequency (curves increasing to the right in Fig. 3) shows that the improved K-F scheme reduces the overestimation of the 5km-NHM with the original K-F scheme for rainfall intensity less than 15 mm. The appearance frequency of daily rainfall amounts (DRA) in July 2006 is also examined. The improved K-F scheme reduces the underestimation of the 5km-NHM with the original K-F scheme for 20 mm < DRA < 50 mm and its overestimation for 50 mm < DRA < 80 mm (not shown).

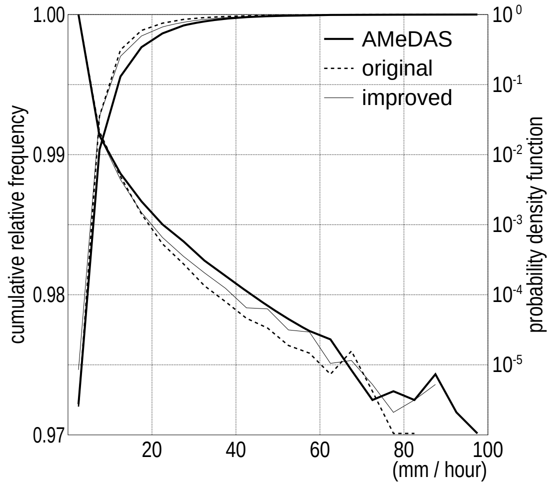

Fig. 3. Appearance frequency of hourly rainfall amounts in July 2006 observed by AMeDAS (bold curves) and simulated by the 5km-NHM with the original (dashed curves) and improved (thin curves) K-F schemes. The curves increasing to the right are the cumulative appearance frequency for the rainfall amounts exceeding the abscissa number, and its values are shown in the left ordinate. The curves decreasing to the right are the appearance frequency of hourly rainfall amounts, normalized based on that less than 5 mm h^{-1}.

In the case that the 5km-NHM is used to examine the change in future weather extremes, since such a false prediction due to the original K-F scheme produces some problems not to make quantitative statics for heavy rainfall amounts and floods, the improved K-F scheme can solve them. However, in this study, the improved K-F scheme is applied only to the 5km-NHM. Therefore, the application to NWP models with the other horizontal resolutions is needed. Moreover, the development of suitable convection parameterization schemes for global and mesoscale NWP models (e.g., the introduction of the level of free convection instead of the LCL in K-F scheme) must be continued to improve the accuracy of their predictions. These are in the future issues.

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