Reply

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First, we appreciate the comment on our paper (Jung and Arakawa 2005, hereafter JA05) by Grabowski (2006, hereafter G06), which has given us an opportunity to clarify the point of JA05. It was by no means our intention to deemphasize the pioneering role played by Grabowski (Grabowski and Smolarkiewicz 1999; Grabowski 2001) in proposing the new superparameterization (SP) approach in representing moist-convective processes in large-scale models. The approach is innovative and promising, and many authors have already shown its usefulness and aptitude (e.g., Grabowski 2001; Khairoutdinov and Randall 2001). Yet, the approach has drawbacks in its original form because of the use of cyclic lateral boundary condition as Grabowski himself recognized (Grabowski 2001). This is the main thrust of JA05 and we understand that it is not disputed by G06. Instead, the argument of G06 is ". . . the particular test applied in JA05 is misleading as far as the validity of the original approach is concerned." In response, we would like to make the following points.

One purpose of JA05 is to illustrate the potential impact of the use of the cyclic lateral boundary condition on systematic errors in actual predictions. The results from a single realization presented in Fig. 6 in JA05, which are disputed by G06, are only an example of the impact. Our main results are presented in Fig. 7, which shows systematic errors in the predicted vertical structures of moist static energy and total water. Here ensemble/domain averages of 1-day predictions starting from different realizations in the benchmark simulation are shown. In G06, on the other hand, Hovmöller diagrams of consecutive 5-day simulations of surface precipitation are shown. Thus, JA05 and G06 examined quite different aspects of model performance that cannot be directly compared.

For the purpose of comparison, we show our own simulation results here using a format similar to the one used by G06. As a benchmark, a cloud-resolving simulation is carried out for 5 days under a maritime condition. The results are presented in Fig. 1. The two panels show Hovmöller diagrams of the surface precipitation rate and cloud-top temperature. Figures 2 and 3 show the corresponding results from the simulations using the original SP with the 16- and 64-km grid sizes of the large-scale model, respectively. The initial conditions for these simulations are taken from the benchmark simulation at $t = 24$ h. The results of Figs. 2 and 3 *generally* resemble those in Fig. 1 as far as the overall propagation is concerned, as G06 concludes in the comment. However, the results also show the obvious impact of cyclic lateral boundary condition; for example, the spatial trapping of the cloud system appears between days 4 and 5 in Fig. 3. JA05's application of the original SP to convection over land with diurnally changing forcing additionally exhibits a complicated propagation pattern of the cloud system (not shown), especially when the 64-km grid size is used for the large-scale model, because of the interference between the tendencies for being trapped within a grid interval and for being more active in the daytime.

The emphasis of JA05 is that the cyclic lateral boundary condition in the original SP has serious impacts on the results while the overall propagation may look acceptable. This point can be clearly seen from Fig. 7 in JA05. With the original SP, there are large biases in the ensemble/domain-averaged thermodynamic fields, such as deficits of moist static energy and total water in the mid- to upper troposphere and surpluses in the lower

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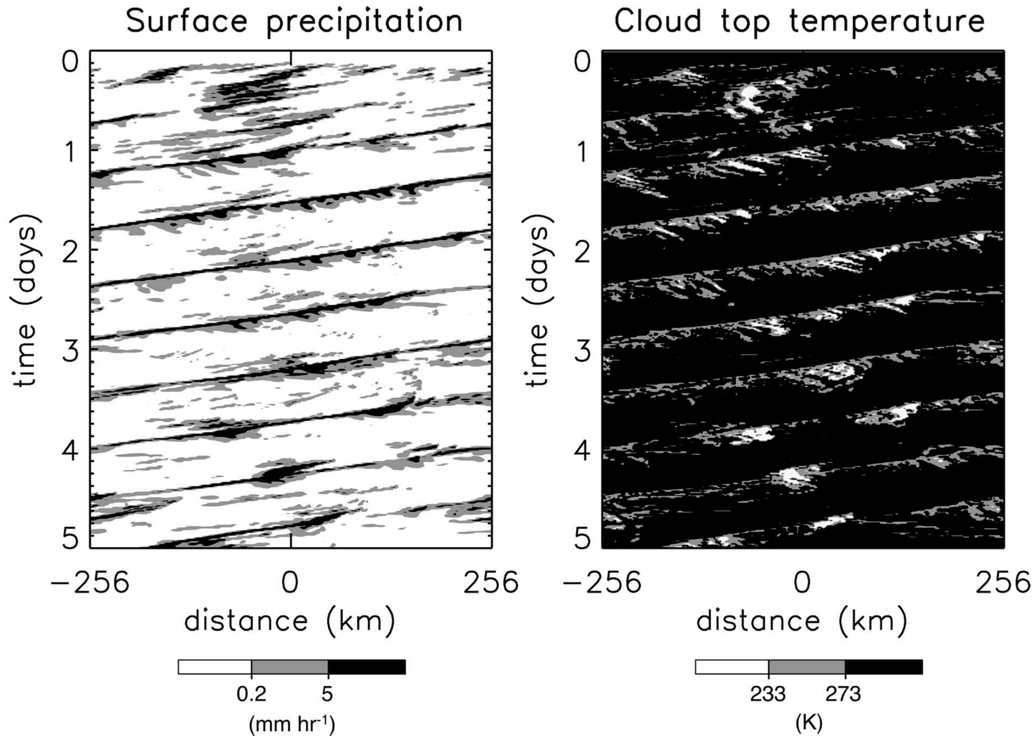

FIG. 1. Hovmöller diagrams (*x–t*) of surface precipitation rate and cloud-top temperature obtained from a 5-day-long cloud-resolving simulation. Precipitation intensities larger than 0.2 and 5 mm h^{-1} are shown using gray and black shadings, respectively. Cloud-top temperatures colder than 273 and 233 K are shown using gray and white shadings, respectively.

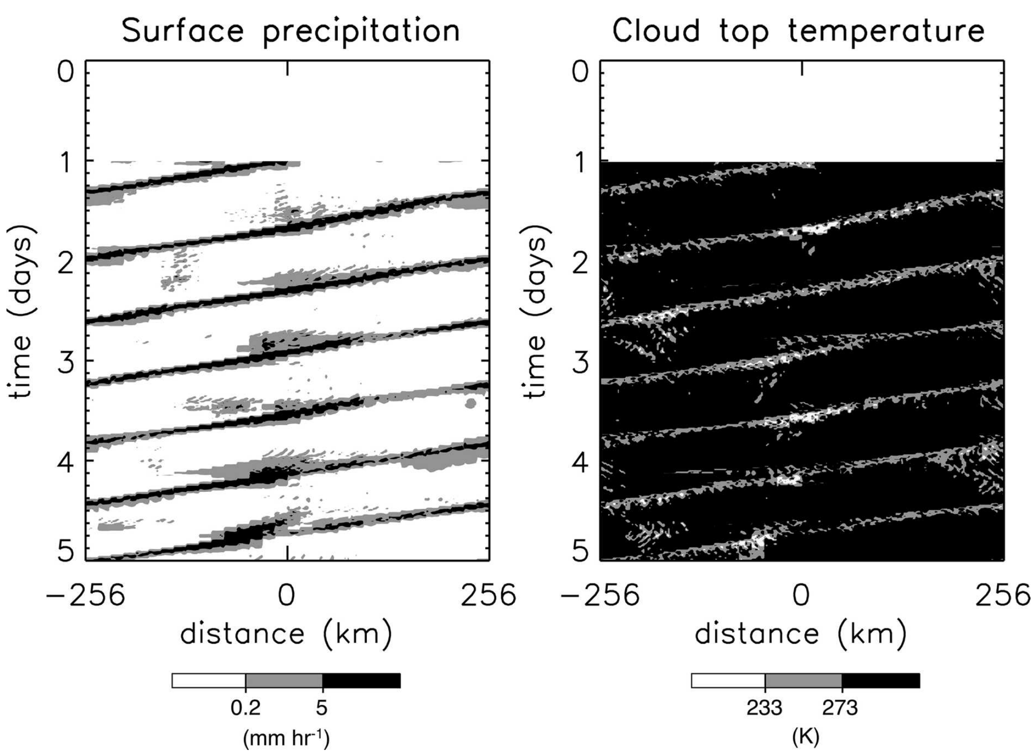

FIG. 2. Same as in Fig. 1, but from a simulation using the original SP approach with the 16-km grid size of the large-scale model.

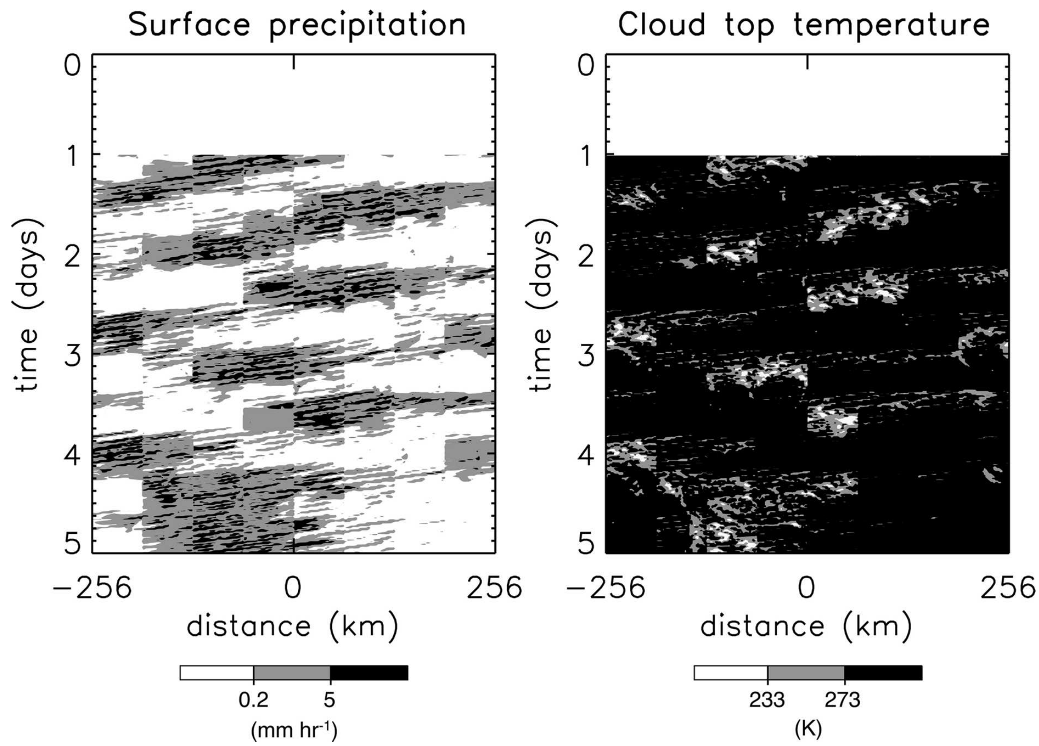

FIG. 3. Same as in Fig. 1, but from a simulation using the original SP approach with the 64-km grid size of the large-scale model.

troposphere. Such biases seem to reflect the lack of strong deep convection, which is responsible for the upward transport of moist static energy and total water from the surface.

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