REPLY TO "COMMENTS ON NUMERICAL STUDY OF MESOSCALE CELLULAR CONVECTION"

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We appreciate Dr. van Delden's concern over the validity of the hydrostatic approximation used in Hsu and Sun's (1991) paper. It is well known that the hydrostatic approximation will introduce a severe error for the short waves in an unstable system. However, this error can be drastically reduced by including a weak horizontal smoothing in a hydrostatic system. For example, the stream-function of the rainband obtained from a nonhydrostatic system (Figure 1a) at $t = 6400$ s is quite comparable with the result obtained from a hydrostatic system with Shuman smoothing (Figure 1b), and the difference in amplitude is about 13%. The shape and phase speed of the rainband are almost identical. On the other hand, it is quite different from that obtained from a hydrostatic system without smoothing as shown in Figure 1c. Meanwhile, the horizontal wavelength of the rainbands is 25 km and $\Delta x = 2.5$, which are comparable to those in Hsu and Sun. Therefore, we believe the hydrostatic approximation is valid in our simulation, in which the horizontal smoothing is included.

We admit that the resolution $\Delta x = \Delta y = 2$ km is not fine enough to simulate the detailed structure of the shortwaves (if the wavelength is less than 8 km); hence, the maximum velocity becomes weaker in Hsu and Sun's results. However, Hsu and Sun did obtain the result that stronger upward motions are confined to a small region, while weak downward motions spread widely (see Figure 10 of Hsu and Sun).

It is also noted that even dw/dt is omitted in the hydrostatics equation, but w , of course, is by no means constant. Hence, Kurihara and Tuleya (1974) used the hydrostatic system with a 20 km (horizontal) resolution to simulate the deep spiral bands around a hurricane in a very convective atmosphere. The hydrostatic approximation has also been used to simulate the land-sea breeze and squall lines in an unstable lower atmosphere.

Fig. 1. The streamfunction of cloud band in (a) a nonhydrostatic system, (b) a hydrostatic system with Shuman smoothing. The intervals between two lines is 60. (c) As in (b) except without smoothing; the interval between two lines is 140.0 (Sun, 1984).

References

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