Reply to a Comment by A. van Delden

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I am grateful that A. van Delden has pointed out some inadequacies of mesoscale entrainment instability (MEI) as an explanation for mesoscale cellular convection (MCC). I agree that the MEI model for MCC suffers because of the requirement that lateral diffusion acts as the large wavenumber cut-off. In order for lateral diffusion to effectively damp out scales immediately smaller than those with the maximum growth rate, the diffusivity K is constrained by

$$k_m^2 K \approx \sigma_m$$

where k_m is the horizontal wavenumber and σ_m the growth rate of the fastest growing mode. (The above criterion can also apply to linear convective models.) For MCC, $k_m \approx 10^{-4}\ \mathrm{m}^{-1}$. Any mesoscale instability worthy of the name would need $\sigma_m > 10^{-5}\ \mathrm{s}^{-1}$. So K must be at least $1000\ \mathrm{m}^2\ \mathrm{s}^{-1}$ if MEI is to account for the cell-size of MCC.

The large eddy simulations of Wyngaard and Brost (1984) and Moeng and Wyngaard (1984) show maximum vertical diffusivities for scalars of order 0.5 w^*H at mid-layer, where w^* is the convective velocity scale, and H is the depth of mixed layer. From Table 1 of Lenschow et al. (1980), we see w^* was typically $1.5\ \mathrm{m\ s}^{-1}$ and H 1500 m in AMTEX cold-air outbreaks. So I think there is a scientific basis for using $K = 1000\ \mathrm{m}^2\ \mathrm{s}^{-1}$ for an AMTEX mixed layer, as in Fiedler (1984), despite the fact that other modelers have usually "assumed" values of K much less.

In my opinion, MEI may be an important process in the formation of MCC in cold-air outbreaks, though the MEI model as presented in Fiedler (1984) and Fiedler (1985) is not the complete explanation. The growth rate was found to be of order $10^{-5}\ \mathrm{s}^{-1}$. If processes could be found to boost the growth rate to $10^{-4}\ \mathrm{s}^{-1}$, then K would have to be $10^4\ \mathrm{m}^2\ \mathrm{s}^{-1}$ in order for the model to predict the right horizontal scale. Such a high value for K is of course unachievable in natural circumstances. I also agree with A. van Delden that MEI may well be irrelevant to those instances of MCC where the cloud is a narrow ring of penetrative cumulus elements.

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