Large-Eddy Simulations of Cumulus Congestus Cloud Using Super Droplet Method

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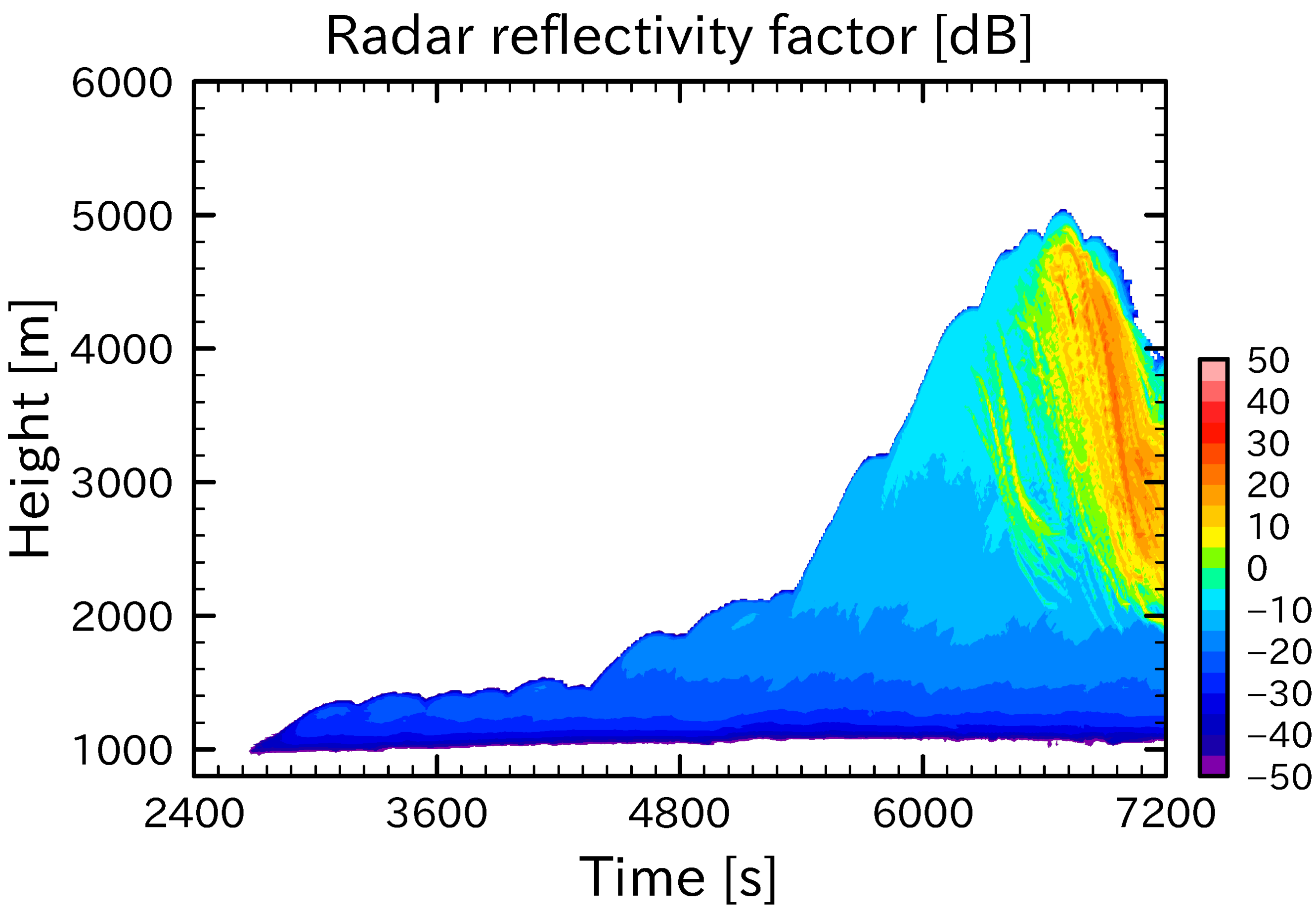
A spectral width of the size distribution of cloud droplets has an impact on determining the onset of precipitation. For improving prediction of precipitation in meteorological numerical models, it is necessary to calculate spectral width more accurately. It is known that a spectral width of an observed size distribution in a cloud is broader than that calculated adiabatically, and turbulence in a cloud is considered to be an important factor to determine spectral width.

Recently, the super-droplet method (SDM) to solve the time evolution of “super-droplets” which represent multiple real droplets has been developed (Shima et al., 2009). Since the SDM is a Lagrangian method, it has an advantage that the calculated particle size distribution is free from numerical diffusion. For this reason, it may be possible to predict size distribution more accurately than a bin method which is an Eulerian cloud microphysical model. However, in a study using SDM, the spectral width of the size distribution was underestimated compared with the observation (Arabas and Shima, 2013). Thus, another case should be also investigated.

In this study, large eddy simulations of the cumulus congestus cloud observed during Small Cumulus Microphysics Study (SCMS) campaign were conducted, and they were compared with the observation. SCMS is an observation campaign for the purpose of detecting the precipitation initiation (Knight and Miller, 1998), and cloud microphysical variables have been obtained by aircraft observation (Hudson and Yum, 2001, Brenguier et al., 2011) and radar observation. The numerical setup generally followed that of the previous studies (Lasher-Trapp et al., 2001, 2005). Using SCALE-SDM (Nishizawa et al., 2015, Sato et al., 2015, Sato et al., 2018), we conducted sensitivity experiments on different resolution (50 m –12.5 m) and different number of super-droplets per cell (32 –256), and the results were compared with those of previous studies and observed cloud dynamical fields. Frequency distributions of cloud microphysical variables were examined in the case of 25 m resolution and 256 super-droplets per cell which was anticipated to be consistent with the observation. As a result, it is shown that the mean values and the fluctuation ranges of droplet number density, liquid water content and cubed ratio of mean volume radius to effective radius agree well with the observation after the cloud reaches its maximum height. It is also shown that the obtained spectral width is well broadened as well as a typically observed. In addition, the logarithmic radar reflectivity factor is found to be consistent with the observation. It implies that the large-eddy simulation using SDM has realistically predicted the turbulence in the cloud and the fluctuation of cloud microphysical variables and the subsequent raindrop generation.

Keywords: large-eddy simulation, super-droplet method, cumulus congestus cloud, precipitation initiation



Radar reflectivity factor [dB]
6000
5000
4000
3000
2000
1000
Height [m]
2400
3600
4800
6000
7200
Time [s]
50
40
30
20
10
0
−10
−20
−30
−40
−50