熱帯の深い湿潤対流の統計的性質の数値的収束性
Numerical Convergence for Statistics of Deep Moist Convection in the Tropics

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According to the grid-refinement experiments of the global nonhydrostatic atmospheric model, statistical characteristics of deep moist convection, such as the number of updraft cores and the frequency distribution of the distance between two nearest-neighbor cores, begin to show signs of convergence around 2-km grid spacing but does not converge even at sub-kilometer grid spacing (Miyamoto et al., 2013). If we perform higher-resolution experiments, its horizontal grid spacing (100–1000 m) will overlap with the range of “grey zone” of planetary boundary layer turbulence. In order to clarify the statistical characteristics of deep moist convection in nature, it is necessary to perform experiments in frameworks of both Reynolds averaged Navier–Stokes (RANS) and large eddy simulation (LES), and compare the numerically converged solutions obtained in these two frameworks. In this study, we perform super high-resolution simulation of group of cumulonimbus clouds in the tropics by using a regional atmospheric model and investigate the numerical convergence of collective behavior of them.

At first, in order to make initial and boundary conditions of the RANS experiment, we simulated Madden–Julian oscillation (MJO) developed significantly in the Indian Ocean around November 24, 2011 by using the global nonhydrostatic model NICAM with 3.5-km horizontal resolution. Then we performed a regional downscaling experiment for the area of about 500 kilometers square centered on 83.5°E and 0.5°S by using the regional model SCALE-RM ver. 5.2.1 (Nishizawa et al., 2015; Sato et al., 2015). We adopted quintuple one-way nested domains whose horizontal resolution were 3.2 km, 1.6 km, 800 m, 400 m, and 200 m. The model had 93 vertical levels whose intervals gradually increased with height: The lowest model level was 36 m; the model top was about 36 km. We used the 1-moment bulk cloud microphysics scheme (Tomita, 2008), the planetary boundary layer scheme of MYNN lev. 2.5 (Mellor and Yamada, 1982; Nakanishi and Niino, 2004), and the radiation scheme of mstrnX (Sekiguchi and Nakajima, 2008). The LES experiment was also performed by the quintuple one-way nested system with the horizontal resolution of 800 m, 400 m, 200 m, 100 m, and 50 m for the area of about 250 kilometers square. The results of 800-m RANS simulation were used as the initial and boundary conditions. The physical schemes were same as those used in the RANS experiments except that effects of sub-grid turbulence were parameterized by Smagorinsky-type model (Smagorinsky, 1963; Lilly, 1962; Scotti et al., 1993; Brown et al., 1994).

As a result of the experiments, we successfully simulated a mass of convective clouds in the MJO environment. In the present study, we defined an individual convective cloud as a continuously-connected cloudy columns whose vertically-averaged vertical velocity is greater than the given threshold, and investigated the number of the clouds and the distance between their central positions. When the threshold is 0.5 m s^{-1}, the number of convective clouds with the effective radius of 1–2 km is converged to about 300, and the frequency distribution of the distance between two

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nearest-neighbor clouds is also converged to the histogram whose peak is located at 4–5 km around 400-m horizontal resolution in the RANS framework (Figure 1). This mode of histogram does not change depending on the threshold of vertical velocity as long as it falls within the range of 0.2–1 m s^{-1}. As for larger clouds with the effective radius of 2–3 km, the frequency distribution of distance is converged to the histogram having a peak around 6–8 km when the resolution becomes higher than 800 m. It is confirmed that larger convective clouds tend to be located at further distance from each other and their collective behavior is converged at the coarser model resolution. In the presentation, we will also show the result of LES experiment and discuss differences from the RANS results.

キーワード：湿潤対流、数値モデル、グレーゾーン
Keywords: Moist convection, Numerical model, Grey zone

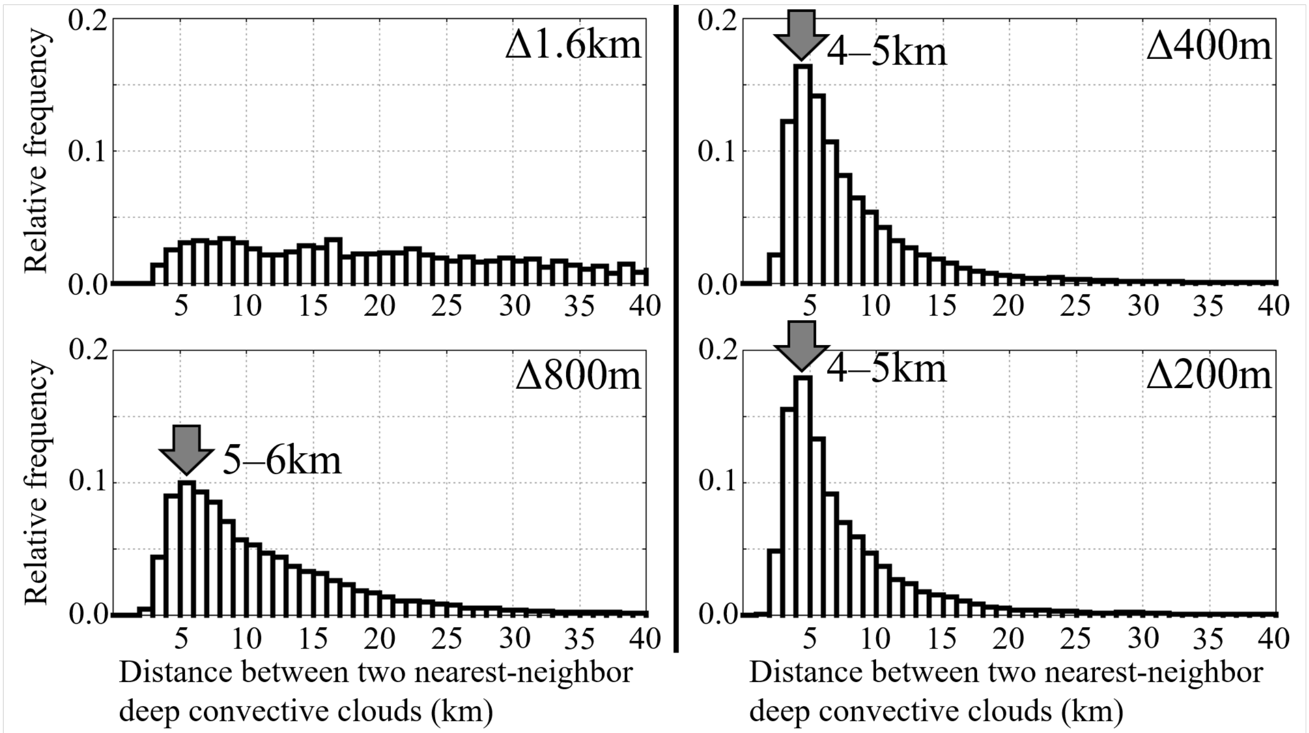

Figure 1 Frequency distribution of the distance between two nearest-neighbor deep convective clouds with the effective radius of 1–2 km, for the horizontal model resolution of 1.6 km, 800 m, 400 m, and 200 m.

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