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Large Eddy Simulation on Dust Devils in Convective Mixed Layers

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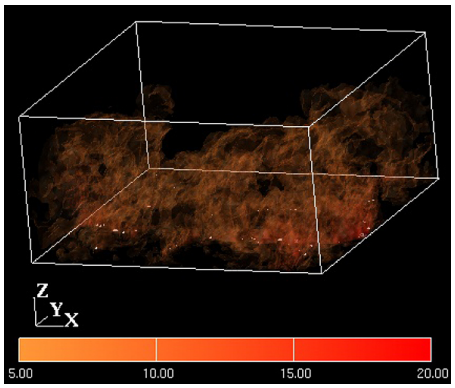
During daytime in fine weather conditions, convective mixed layers in which turbulent convection dominates due to strong sensible heat flux from the surface heated by insolation. Dust devils, which are small-scale strong vertical vortices, occur in the convective mixed layers. They are visualized by dust particles lifted by their strong winds. Dust devils are considered to be ubiquitous in the convective mixed layers not only on the Earth but also on the Mars. Large Eddy Simulations (LESs) have succeeded to reproduce various characteristics of the convective mixed layers such as the fishnet pattern of convective updrafts and entrainments at the top of the atmospheric boundary layer. Recently, LESs with higher resolution start to succeed in reproducing small-scale vortices similar to dust devils. In fact, we have investigated the formation mechanism of the dust devils reproduced in a LES (Ito et al. 2010, JGU Meeting). In the present paper, we report 1) relationship between the intensity of dust devils and that of the convective updrafts and 2) estimation of dust particle concentration in a convective mixed layer in which there is no general wind and dust particles are lifted by sporadic winds due to the dust devils and convective motions.

To study the first subject, a time-evoluving convective mixed layer is reproduced by a LES with grid size of 50 m, in which a quiescent stably-stratified atmosphere is heated from below at a constant surface heat flux Q. Vertical vorticity of dust devils at the lower level is found to increase linearly with convective velocity scale $w_c=(gQh/T_0)^{1/3}$, where g is the gravitational acceleration, h the height of the convective mixed layer, and T_0 standard potential temperature.

As for the second subject, we have incorporated dust concentration and surface dust flux according to an experimental formula by Loosmore and Hunt (2000) in a LES with a grid size of 20 m, and have calculated the dust concentration of suspended dust particles in diurnally-varying convective mixed layers without general winds. The dust concentration is found to be higher in regions of strong vertical vorticity, which is associated with dust devils (see Figure). Dust concentration of 10^{-5} g/m^3 on average is realized in the convective mixed layer. The horizontally averaged concentration is almost uniform in the vertical direction. If similar weather conditions last continuously, a considerable part of the dust particles lifted on the previous days remain in the atmosphere, and the dust concentration could reach 7 times as much as that of the end of the first day.



Keywords: dust devil, vertical vortices, convective mixed layer, large eddy simulation