A study of aerosol effect in cloud system with direct numerical simulations

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Atmospheric aerosol particles affect the Earth's radiative balance both by scattering solar radiation and by acting as cloud condensation nuclei (CCN). CCN are a subset of all particles that are able to form cloud droplets in specific atmospheric conditions. Radiative properties of clouds are dependent on the number of cloud droplets and according to Twomey (1977) an increase in the CCN concentration leads to an increase in the cloud droplet number concentration (CDNC). The change in CDNC combined with the decrease of the direct aerosol effect would lead to a change in aerosol forcing.

We study the effect of aerosol dynamics on turbulent motion (and vice versa) inside the cloud area with direct numerical simulations (see details in Babkovskaia et al. 2011, Babkovskaia et al. 2015). The observational data obtained by ACTOS platform are used for setting the initial conditions. We consider the calculation domain of the size of 10 cm x 10 cm x 10 cm located on the height of about 2000 m from the see level and set the periodic boundary conditions. We take the distribution of aerosol particles detected on the see level and assume that it is initially the same everywhere in the domain. To generate the initial turbulent field we make 40 first iterations without aerosol dynamics, but with included randomly directed external forces. Then we switch off the external forces and allow the aerosol particles to evolve.

To study the effect of the aerosol we vary the total number of particles taking N_{tot} = 5550 cm^{-3}, 555 cm^{-3} and 55.5 cm^{-3}. We find that the total number of particles in the domain is crucial for distribution of temperature and for developing of turbulence. The number of activated particles approximately linearly depends on the total number, whereas the change of N_{tot} in 100 times leads to increase of LWC just for 40 %. Therefore, in the case of large number of particles the particle size appears to be smaller than in the case of the smaller N_{tot} (see Fig.1). Moreover, comparing the supersaturation in these three cases we find that in the case of the largest N_{tot} after 3 s the supersaturation is close to zero and particles stop to grow, while for the smaller N_{tot} at t =3 s the supersaturation is about 3% and particles continue growing. Thus, our results show that aerosol particles can grow and possibly achieve the size of the rain drop only in the case of small total number, N_{tot}.

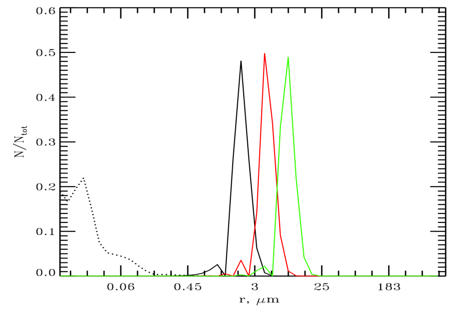

Figure 1. Relative distribution of particles averaged over the domain at t=0 s (*black dotted curve*) and t=3.5 s (*solid curve*) for the cases of N_{tot}=55.5 cm^{-3} (*green curve*), N_{tot}=555 cm^{-3} (*red curve*), N_{tot}=5550 cm^{-3} (*black curve*).

Also, we analyse the effect of aerosol dynamics on the turbulent kinetic energy. We compare the case of equilibrium between the air inside and outside the puzzle (calculation domain), and when the temperature inside the puzzle is smaller than outside on 0.5 K and the puzzle is moving down in vertical direction because of buoyancy force. We find that in an equilibrium aerosol dynamics changes TKE less than on 1 %, while in the case of intensive vertical motion the change of TKE can achieve 100 % for the first 3 s.

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