§15. Development of Direct Numerical Simulation Code for Particles Convected by Turbulence

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We have developed a code to study the transfer mechanism by turbulent flow of particles with or without electric charges such as cloud droplets, very fine yellow sand from the the microscopic view point. Key ingredients of the code are to develop the efficient code which is able to generate the turbulence field with enough spatial resolution, to track the Lagrangian particles and to develop a model of the particle dynamics such as evaporation and condensation, collision, electric static interaction which occur below the Kolmogorov scale. We have considered in this study the turbulent transfer of the cloud droplets and interaction between them.

The continuum part is assumed to be described by the equation of continuity, the Navier-Stokes equation with buoyancy and external force, and the equations of temperature and moisture mixing ratio. The water droplets evaporate and condensate and thus interact with the turbulent flow through the buoyancy due to the latent heat. A dynamical model of the cloud droplets is such that a small water droplet particle experiences the drag force in proportion to the relative velocity and the gravity force. The second order interpolation and PIC were used in the interpolation of the velocity and the redistribution of the particle attributes to the fluid grid points.

In a cubic box with length 25cm the steady turbulence is generated and begins to decay by removing the external force. The small water droplets with radius of 10μm are initially dispersed randomly within a thin horizontal layer and then allowed to be convected. Figure 1 shows the distribution of the cloud droplets in which the color pallet from red to blue indicates their radius from larger to smaller radius. The cloud droplets are quickly dispersed and convected downward. The distribution of particle radius is shown in Fig.2. The peak of the distribution moves toward smaller radius and the distribution becomes wider and asymmetric as time goes on. One interesting observation is that the turbulent kinetic energy tends to slowly decay in time when compared to the case of no buoyancy effects (i.e. dry air turbulence) as seen in Fig.3. This is due to the heat absorption by the surrounding air due to the evaporation of the cloud droplets and considered to be a driving force of turbulent flow.

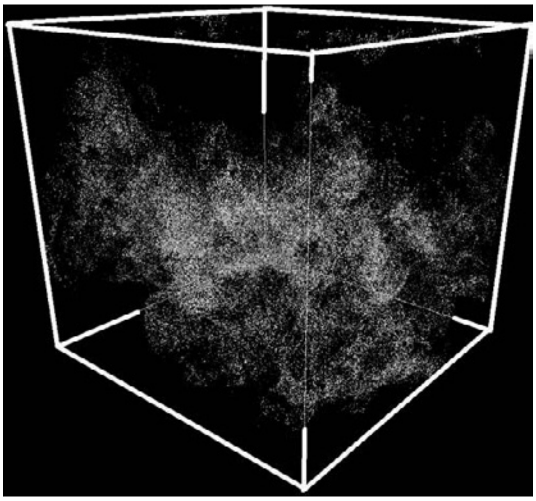

Fig. 1: Cloud particle distribution at 0.6 [sec] after release. Red: droplets of larger radius, blue: droplets of smaller radius.

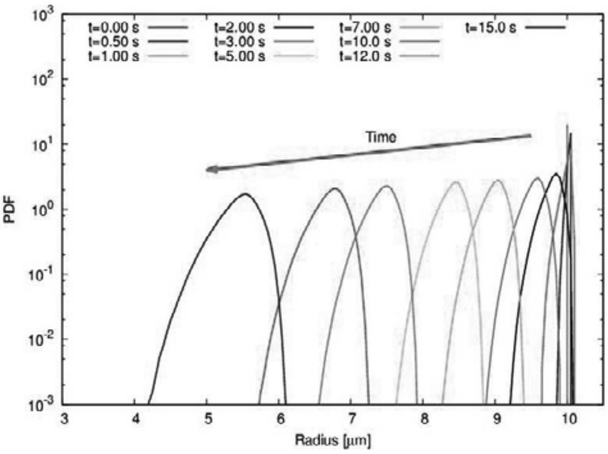

Fig. 2: Evolution of the probability density function of droplet radius.

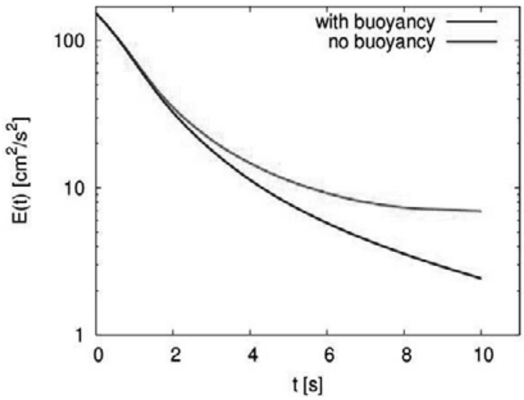

Fig. 3: Decay of the total kinetic energy. Red: Buoyancy on, Blue: Buoyancy off.