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Numerical and experimental investigation of cloud droplet collision-coalescence

B. Rosa (1), A. Aliseda (2), C. Bateson (2), O. Ayala (3), H. Parishani (3), and L.P. Wang (3)

(1) Institute of Meteorology and Water Management – National Research Institute, 61 Podlesna St., 01-673 Warsaw, Poland (bogdan.rosa@imgw.pl), (2) University of Washington, Mechanical Engineering, 4000 15th Ave NE, Seattle, Washington 98195-2600, United States, (3) University of Delaware, Mechanical Engineering, 126 Spencer Laboratory. University of Delaware, Newark, Delaware 19716-3140, United States

In recent years there has been significant progress in the field of numerical weather prediction (NWP). New and more efficient algorithms together with modern supercomputers offer hitherto unattainable possibilities of modeling severe weather phenomena with greater accuracy. Spatial resolution of the contemporary NWP models is of the order of 1km and is being further reduced. Such a resolution approaches the regime for which the convective processes can be explicitly represented. Nevertheless, moist processes related to cloud physics still need to be better parameterized. Investigation of the moist processes by direct measurements of droplet-droplet and droplet-turbulence interactions in real clouds is difficult due to the short time and length scales involved.

In this study we focus on the numerical and laboratory-experimental investigation of collision-coalescence of cloud droplets. Quantitative description of this process is of great importance since the collision-coalescence plays important role in the development of warm rain, that is, transformation of small cloud droplets to rain drops. Our experimental approach is aimed at developing in the wind tunnel a turbulent flow and droplet distribution similar to those occurring in the real cloud. Using direct numerical simulations (DNS) we are able to realistically reproduce the conditions that take place in the wind tunnel. Together, we hope to combine these two different tools to gain a better quantitative understanding of turbulent collision-coalescence of cloud droplets.

In the simulations we modeled motion of small inertial droplets (Stokes number in the range of 0.1 to 10) immersed in homogeneous slowly decaying isotropic turbulent flow. Droplet statistics have been analyzed for different initial spectra of the turbulent flow. The Reynolds number was limited by the laboratory and DNS accessibility to around 400.

The key result is the comparison of the one-dimensional (1D) Radial Distribution Function (RDF) from the experiments with the 1D and 3D RDFs from the simulations. The comparison allows us to validate the numerical treatment of the droplet dynamics in close proximity, and to develop methods to extrapolate the experimental measurements to 3D. We will also compare the relative velocity of droplet pairs, obtained along a line or plane from PDPA and PIV measurements, to the equivalent statistics obtained from the 3D velocity fields in the DNS.