High-resolution simulation results of kinematic and dynamic collision statistics of cloud droplets

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Collision-coalescence of cloud droplets is a necessary step for the development of warm rain, namely, the transformation of small cloud droplets into rain drops. Research in recent years has demonstrated that small-scale turbulent motion can enhance the collision rate of droplets by either enhancing the relative velocity and collision efficiency or by inertia-induced droplet clustering. Quantitative description of the effects of air turbulence remains challenging due to experimental difficulties in probing statistics at droplet scales and computational difficulties in simulating all relevant scales of the turbulent flow.

Recently developed highly scalable DNS code based on two-dimensional domain decomposition can take full advantage of available computational resources. This allows increasing the range of resolvable scales so that most turbulence scales affecting droplet pair statistics can be faithfully represented. The new implementation makes it possible to perform simulations with background-flow Taylor microscale Reynolds number up to 500 and with up to 50 million droplets.

Here, we present results of dynamic and kinematic collision statistics (i.e., radial distribution function and relative velocity) from these high-resolution simulations. A key issue to be discussed is how these statistics vary with droplet size and flow Reynolds number. We also examine the effect of forcing method (in DNS) on collision statistics and sedimentation velocity. Comparison of two different forcing schemes i.e. random and deterministic is performed base on results from the numerical experiments. Finally, we evaluate the role of gravity on droplet clustering. It has been shown that the presence of gravity enhances for clustering of monodisperse heavy drops that are greater than 50 μm in radii but weakens the clustering of lighter droplets 20-45 μm in radii.