Geophysical Research Abstracts, Vol. 8, 04963, 2006
SRef-ID: 1607-7962/gra/EGU06-A-04963

Turbulent collision-coalescence of cloud droplets and its impact on warm rain formation

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While it has long been speculated that air turbulence could accelerate the collision-coalescence of cloud droplets and as such promotes the formation of warm rain, progress has been very slow in quantifying the turbulence effects. This results from the complexity of the problem and the lack of quantitative research tools. In this talk, we will report on an on-going, systematic effort to quantify various effects of turbulence on the growth of small cloud droplets, including (1) the enhanced relative motion due to differential acceleration and shear effects, (2) enhanced average pair density due to local clustering of droplets, and (3) enhanced collision efficiency due to turbulent fluctuations.

A Hybrid Direct Numerical Simulation (HDNS) approach was developed to treat the motion and interactions of a large number of particles suspended in a turbulent flow. The HDNS approach integrates an improved superposition method for the disturbance flows due to droplets into a pseudospectral simulation of undisturbed air turbulence. This allows, for the first time, the direct incorporation of hydrodynamic interactions within DNS and computations from first principles of statistical information related to collision-coalescence. The HDNS results reveal that the levels of enhancements by turbulence on collision-coalescence statistics depend, in a complex manner, on the size of droplets (which in turn determines the inertial response time and settling velocity), the strength of air turbulence (as measured by the flow dissipation rate), and flow Reynolds number. New theoretical formulations on the collision kernel, relative collision velocity, and angle-of-approach of droplets, validated by HDNS results, will also be reported. Implications of these results on warm rain formation will be discussed.