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# Collision rate enhancement in turbulent clouds of different types

**M. Pinsky** and A. Khain

The Hebrew University of Jerusalem, Israel (khain@vms.huji.ac.il / Fax: +972 2 5662581 / Phone: +972 2 6585822 )

A new method has been developed and applied to calculate collision efficiencies and collision kernels between cloud droplets under turbulent conditions typical of real clouds. Analytical considerations indicate that at small scales droplet motion in a turbulent flow is fully determined by turbulent strains and the Largangian accelerations. Scale analysis suggests that turbulent strains and accelerations can be considered "frozen" during the process of hydrodynamic droplet interaction (HDI). At the scales of HDI, the homogeneous and isotropic turbulent flow is represented as a set of "elementary" volumes with a linear size of about 1 mm. Within any elementary volume, turbulent strains and accelerations do not change, but they do change randomly from one elementary volume to another. A statistical model is developed to generate long series of turbulent strains and accelerations reproducing probability distribution functions (PDF) at high Reynolds numbers, as they were obtained in recent laboratory and theoretical studies. The droplet fluxes of droplets of one size on droplets of another size (normalized swept volumes) are calculated for each sample of an acceleration-strain pair and the PDF of swept volumes is presented for turbulent parameters typical of cloud turbulence.

The collision efficiency is defined and calculated as a ratio of droplet fluxes in the presence of HDI and droplet flux in the absence of HDI. The modified superposition method is applied in calculations of collision kernel and collision efficiency. Collision efficiencies and kernels were calculated for each of many thousand turbulent flow samples. As a result, detailed tables (with the resolution of 1 $\mu m$ in droplet radius) of mean collision efficiencies and kernels between cloud droplets of radius ranged from 1 to 20 $\mu m$ are calculated for dissipation rates and Reynolds numbers typical of different clouds from stratiform cloud to Cb clouds. The collision kernels and efficiencies are

calculated for two height levels corresponding 1000 mb and 500 mb. These tables allow parameterization of turbulent effects on the raindrop formation. It is shown that collision efficiency and kernels increase with the increase of dissipation rate and the Reynolds number. Turbulence can lead to a significant enhancement of the collision rate that can reach several hundred percents. Especially significant increase in the collision kernels as compared to the gravity induced values was found for droplets of close size. Decrease in the air density with height increases the collision kernels and collision efficiencies in a turbulent flow by approximately the same factor as the decrease in the air density in calm air.

Several examples are presented of the droplet spectrum evolution under turbulent conditions typical of different cloud types: from stratiform cloud to Cb clouds.