5.5 EFFECTS OF FLOW ACCELERATION ON COLLISIONS OF SMALL DROPS IN A TURBULENT FLOW

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INTRODUCTION

Theoretical estimations (e.g. Pinsky *et al*., 2000) and laboratory experiments (Vohl *et al*., 1999) indicate that the different response of inertial droplets to turbulent accelerations and shears (turbulent-inertial mechanism) significantly accelerates collisions between cloud drops. However, the quantitative evaluation of the effect in clouds presents a difficult problem. The Taylor microscale Reynolds numbers Re_λ in the atmospheric turbulence is much larger than the values used either in DNS simulations or in most laboratory experiments. Since both Lagrangian acceleration and the intermittency rate increase with the increase in Re_λ, it is not clear how the results obtained in laboratory experiments and DNS can be extended to atmospheric conditions. We investigate here the effects of Largangian acceleration on collision efficiency and collision kernels of small droplets in a turbulent flow using the results of unique laboratory experiments by La Porta *et al*., (2001) conducted under high Re_λ flow of pronounced intermittency.

CALCULATION OF THE PDF OF DROP COLLISION EFFICIENCY

For small cloud droplets the drop motion equation can be written as $\frac{\vec{U}}{V_t} = \vec{e}_z - \frac{1}{g}\frac{d\vec{W}}{dt}$, where $\vec{V}$ and $\vec{W}$ are drop and flow velocities, $\vec{U} = \vec{V} - \vec{W}$, V_t is droplet fall velocity. The statistics of collision efficiencies is determined by the statistics of the relative velocities $\vec{U}$, playing the role of boundary conditions in the hydrodynamics of droplet collision. Thus, the statistics of the collision efficiency is determined by the statistics of the Lagrangian accelerations. The following results obtained by La Porta *et al.*, (2001) concerning the statistics of the Lagrangian accelerations and allowing their use for atmospheric conditions are: a) An expression for the PDF is proposed, according to which the PDF tends to a certain limit function when Re_λ increases. b) Variance of Lagrangian accelerations increases with Re_λ and tends to the value: $a^2 = a_0 \varepsilon^{3/2} \nu^{-1/2}$, where ε is turbulent dissipation rate, ν is fluid viscosity, $a_0 = 5.5$ (as compared to 1 in the classic Kolmogorov theory). c) The acceleration field becomes isotropic at high Re_λ. This means that components of acceleration under atmospheric conditions are non-correlated and are actually independent. Using these results of the measurements, a three-dimensional PDF of acceleration $W(|a|)$ was calculated, where $|a| = \sqrt{a_x^2 + a_y^2 + (a_z - g)^2}$. **Figure 1** shows the PDF of absolute values of acceleration $W(|a|)$ for the non-Gaussian (solid lines) and the Gaussian (dotted lines) cases at different values of ε. Using the PDF of acceleration, the PDF of the collision efficiencies between droplets of different size were calculated using the method described in Pinsky *et. al*., (1999).

RESULTS AND DISCUSSION

The results indicate that an increase in the collision kernel at low and intermediate dissipation rates is determined mainly by the increase in the collision efficiency. At high values of ε contribution of the increase in the swept volume becomes also significant. **Figure 2** shows the averaged values of the collision kernel, normalized by their values in the pure gravity case at $\varepsilon = 1000\ cm^2 s^{-3}$. The maximum increase in the kernels (by factor of 5) (and the corresponding increase in the collision efficiencies by factor of 2.6) takes place for drop pairs containing comparatively large droplet collectors of 15-20 μm radii. When both droplets are smaller than 15 μm in radius, the effect of turbulent accelerations becomes weaker. The utilization of the Gaussian PDF of flow acceleration shows that the effect of intermittency on droplet collisions is negligible. This is because: a) the fraction of collisions with high efficiency is very small; b) the value of collision efficiency is limited from above and cannot exceed the value of one. This means that even extremely high flow accelerations that might take place under high intermittency cannot affect collision process. Analysis shows that flow accelerations are not the single source of the collision rate increase. One has to take into account the effects of turbulent shears as well.

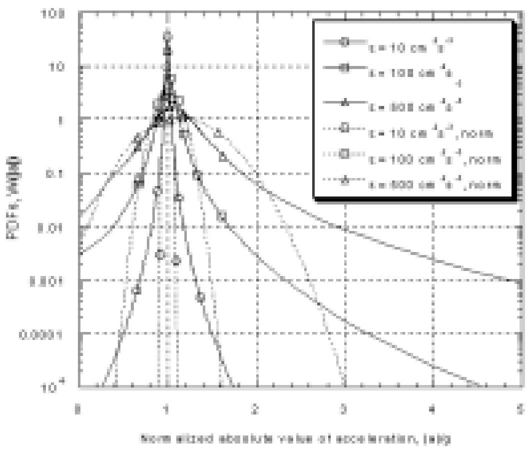

Figure 1. PDF of the absolute drop acceleration for the non-Gaussian and the Gaussian cases.

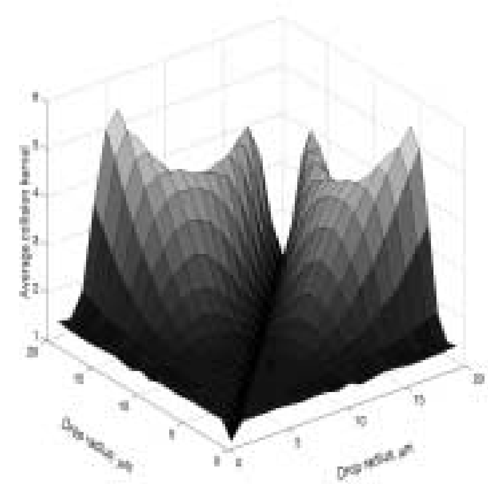

Figure 2. Normalized average values of the collision kernel

CONCLUSION

The effect of turbulent accelerations of collisions of droplets is very significant and highly depends on the intensity of turbulence. The measurements of cloud turbulence and its structure are required for better understanding processes of rain formation.

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