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Can Large Precipitating Cloud Hydrometeors Generate Secondary Cloud Droplets in its Wake?

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Atmospheric clouds play a very important role in the evolution of global atmosphere and climate through various interactive physical processes dynamically active over a huge range of scales [Devenish et al. QJRMS 2012, Grabowski and Wang. ARFM 2013]. However, many of such processed are yet to be understood; and in such context, we attempt to understand such a scientific question: whether large precipitating cloud drops can generate secondary droplets in it's wake. Motivated by experimental investigation of large sedimenting cloud droplets [~ mm radius] which showed presence of secondary cloud droplets in it's wake [Prabhakaran et al. PRL 2017, ArXiv 2019]; we conduct direct numerical simulations of such precipitating hydrometeors using Lattice-Boltzmann method (LBM) to simulate cloud like ambient solving the evolution of the supersaturation field in the wake of the hydrometeor, and to investigate it's impact on the nucleation of cloud aerosols. In our simulation results, we found various flow regimes based on the Reynolds number (Re = Droplet Diameter * Droplet Velocity / Kinematic Viscosity) in compliance with past researches. Steady axisymmetric wake for Re up to ~ 220, after that steady oblique wake up to Re ~ 280, then a transient oscillating nature of the wake up to Re ~ 350, and beyond that Re, the wake is observed to become chaotic and turbulent. Comparison of drag coefficient, recirculation length and separation angles for fluid velocity at various Re shows good agreement with existing numerical and experimental simulations. The temperature profiles also fit well with other researches for similar Prandtl number (ratio of kinematic viscosity to thermal diffusivity). Evolution of the density of water vapor is similar to the temperature field, since both the equations show similar structure and the mass diffusivity of water vapor is almost same to the thermal diffusivity for atmospheric clouds. Distribution of the supersaturation field is computed using Clausius-Clapeyron Equation which gives saturation vapor pressure depending on temperature. In such simulations with background flow at -15° C temperature with 60% relative humidity (RH) and with the hydrometeor as a warm cloud droplet at 4° C temperature and 100% RH at it's surface, the wake shows symmetric regions of supersaturation in the near vicinity of the hydrometeor at Re = 200. Whereas, at Re = 273, the wake is observed to become oblique, so the supersaturated region. Small pockets of supersaturated warm air parcels are observed to travel in the downstream direction when the hydrometeor started shedding vortices at higher Re. However, while traveling downstream, such supersaturated pockets also lost its' excess of water vapor depending on the ambient cloud conditions. Due to higher supersaturation at the near vicinity of the warm hydrometeor, the cloud aerosols trapped inside the wake can be activated. However, whether such activated aerosols can become a drizzle drop, or may evaporate its liquid water content in subsaturated region, is to be understood by Lagrangian tracking of such aerosol tracers.