Numerical Investigation of Droplet Micro-Physical Growth inside Atmospheric Clouds

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Atmospheric clouds are well known for their impact on the evolution of global or local climate, but science has not yet understood many of the physical processes, interactions and the interplays happening inside and out of the clouds, spanning over a vast range of spatial and temporal scales [1, 2]. I present two complementary parts of my PhD activity, focused to contribute to the understanding of the interplay between cloud droplet micro-physical growth and various small-scale cloud turbulent processes, using numerical methods.

In the first part, I looked into the broadening of cloud droplet population inside small-scale turbulent mixing at the cloud and clear air interface [3]. Using pseudo-spectral direct numerical simulation along with Lagrangian droplet equations, transient evolution of in-cloud turbulent kinetic energy, density of water vapour and temperature was simulated to investigate its impact on size broadening of three initial mono-disperse cloud droplet populations. Larger droplet populations ($\sim 20\ \mu$m initial radii) showed significant growth by droplet-droplet collision and a higher rate of gravitational sedimentation. Whereas, the smaller droplets (6 μm initial radius) did not show any collision or significant sedimentation, but a large size distribution broadening due to differential condensation/evaporation induced by turbulent mixing.

The second part attemps to understand the role of large hydrometeors [$\sim \mathcal{O}(mm)$ size] on secondary droplet generation. Motivated by the experimental investigation of comparatively large sedimenting droplets which generated secondary cloud droplets in it's wake in an atmospheric cloud like environment [4], we conduct incompressible direct numerical simulations of such precipitating large hydrometeors using Lattice-Boltzmann method in a cloud like ambient. Fluid flow and advected in-cloud temperature and water vapor fields are simulated around a fixed hydrometeor, and we investigate the development of supersaturation in its wake. In-cloud aerosol populations are simulated as tracer particles, which follow the fluid field exactly due to negligible Stokes number of the aerosols. Depending on the hydrometeor Reynolds number, various flow regimes such as, steady axisymmetric, steady oblique, transient oscillating, and chaotic wakes are observed. Depending on the ambient temperature and the relative humidity conditions, various extent of supersaturated air parcels are formed inside the wake, which can activate aerosols.

References

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