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Microdroplets growth by condensation in warm clouds

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Understanding the mechanisms leading to fast initiation of rain in warm clouds is of crucial importance in atmospheric sciences, both for meteorological and climate modelling. The initial stage of microdroplets growth is due to condensation/evaporation of supersaturated vapour onto the surface of activated cloud condensation nuclei. It is only when droplets are sufficiently large (about 0.01 mm), and massive, that collisional and gravity effects start to play a role.

We consider the problem of droplet growth by condensation in a turbulent flow of nearly saturated vapour. The microscopic description of the phenomenon is complex and would involve evolution equations for the turbulent flow, the scalar fields of temperature and water vapour, as well as the motion and the growth of the small droplets within a three dimensional air volume. Classical approaches consider besides also the macroscopic equation representing the growth of a population of small droplets, all exposed to the same macroscopic supersaturation, in an ascending updraft.
Here we consider a different approach: microdroplets move and grow in a turbulent supersaturation field, passively advected by a turbulent flow. The source of supersaturation fluctuactions comes from the adiabatic ascent, while its loss is due to the condensation of vapour onto the droplet surface. Temperature effects are neglected in this first attempt to have a simple model. Water droplets are inertial particles, subject to gravity and to the Stokes drag, transported by the turbulent flow, and whose size depends on the saturated vapour turbulent fluctuations available in the flow.

We report results from a series of high resolution 3D direct numerical simulations (up to 512^3 grid points) of a warm cloud: increasing the numerical resolution corresponds to increasing the cloud size. Starting from a delta-like distribution of (millions of) droplets injected in the turbulent stationary flow, we follow the system evolution for few large scale eddy turn over times. We show that the presence of an underlying turbulent velocity field is crucial both for the enhancement of the droplet growth rate and for the fast spreading of droplet size distribution. We also numerically show that the measured trend in the enlargement of droplet size distribution σ_R, at increasing the level of supersaturation fluctuations, gives a value of σ_R compatible with that observable in real warm clouds. We conclude that the enlargement of droplet size spectrum crucially depends on the turbulent fluctuations that droplets experience along their lagrangian motion.