Geophysical Research Abstracts, Vol. 7, 02825, 2005
SRef-ID: 1607-7962/gra/EGU05-A-02825

Comparable effects of cloud base velocity, CCN and atmospheric instability on droplet concentration and height of the first radar echo

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Lightening activity is believed to be related to existence of a wide zone of mixed-phase clouds where small cloud droplets coexist with ice crystals and graupel. The existence of this zone has to be well correlated to the first radar echo height (FREH) that reflects the level of the raindrop formation. The difference in FREH in maritime and continental clouds is often attributed to difference in the atmospheric instability over the sea and continents. Observations and numerical studies indicate that aerosol properties (e.g. CCN concentration, N_{ccn}) affect droplet concentration (N_d) at cloud base. Since the droplet concentration affects, in its turn, the efficiency of collisions and the time of raindrop formation, aerosol properties has to affect also FREH and the lightening occurrence. The problem addressed in the study is: what are comparable role of aerosols and the atmospheric instability in the determination of the cloud properties mentioned above (N_d and FREH)?

A set of numerical simulations of cloud development has been performed using a 2000-mass bin Largangian cloud parcel model. Simulations were conducted under thermodynamic conditions typical of Congo and Amazon during different months. To investigate quantitatively the comparable role of dynamics and microphysics, a method of experiment planning theory was used. We have chosen three factors influencing N_d: N_{ccn}, vertical velocity at cloud base W_{cb}, and the width of CCN spectrum (WID_{ccn}). To investigate comparable role of mechanisms influencing FREH, a temperature gradient above cloud base (dT/dz) is added as a new parameter. The dependence of FREH and N_d on these parameters was represented as a regression equation of the second order. Simulations performed according to the rules of the theory

of optimum planning allow determination of coefficients of the regression equation performing 15 numerical experiments with different combinations of the governing parameters.

Regression equations determining the dependence of droplet concentration on aerosol properties and cloud base velocity are obtained. The results show that N_d is determined mainly by CCN concentration (at $W_{cb} > 0.5$ m/s).

Since thunderstorms develop from convective clouds with large Wcb, the effect of the vertical velocity at cloud base W_{cb} is of the secondary importance on FREH. As a result, regression equations representing FREH as the function of N_{ccn}, WID_{ccn} and dT/dz were determined. These equations allow one to evaluate the comparable contribution of each factor on the first radar echo height, i.e., on the lightening activity.

One of possible applications is the utilization of these simple regression equations in large scale models, where aerosol effects are to be investigated.