Intercomparison of Model Simulations of Cloudy Rayleigh-Bénard Convection in a Laboratory Chamber

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Introduction

The Michigan Tech Cloud Chamber: “The Pi Chamber”

The intercomparison protocol for the steady-state intercomparison

a. Boundary conditions: The top wall temperature is 320 K, the bottom temperature is 305 K, and the side wall temperature is 310 K. The relative humidity of the side wall is 100%. The relative humidity of the top and bottom walls is 50%. The temperature of the side wall is adjusted in the models with side walls such that the supersaturation model the chamber is 10% in steady-state before aerosols are injected into the chamber. After reaching steady-state, the aerosols (brown dots in the diagram) are injected into the chamber to form droplets (blue dots).

b. Aerosol injection: Continuously inject sodium chloride aerosols with a dry diameter of 125 nm to a range of rates.

c. Duration: Run simulation for 1 to 2 h after injection commences, to achieve a steady state.

The model configuration for the steady-state intercomparison

The processes that determine ψ are in a cloud chamber are:

- aerosol injection
- condensation growth due to mean saturation
- condensation growth due to supersaturation fluctuations
- droplet fall out

If we neglect soluble and curvature effects in the droplet growth equation, the resulting analytic steady-state DSD depends on three flow parameters: mean supersaturation, the supersaturation variance, and the Lagrangian autocorrelation time scale of the supersaturation, as well as on the aerosol injection rate, the chamber height, and the Stokes fall speed parameter. For fixed flow parameters, the corresponding PDF does not depend on the injection rate. The PDF shape has only a weak dependence on the relative magnitudes of the mean supersaturation and the supersaturation variance, which combined with the difficulty of measuring supersaturation in the Pi Chamber, has made quantifying the role of supersaturation fluctuations from measurements challenging. Recent efforts by the MTU Pi Chamber group used the impacts of supersaturation fluctuations on droplet activation to infer the role of supersaturation fluctuations.

The droplet number concentration, NC, is a function of the mean supersaturation, and the liquid water content, LWC, is a function of the mean supersaturation and the droplet size, R. The mean supersaturation and the droplet size are related through the equilibrium value of the supersaturation, which is a function of the mean supersaturation and the droplet size. The DSD is a function of the mean supersaturation and the droplet size.

Summary of the Models

Steady-state distribution of droplet radius

Let ψ(r) be the number of cloud droplets per unit mass of air with droplet radius r in the interval (r − dr). The processes that determine ψ in a cloud chamber are:

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Summary

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Acknowledgment

This material is partly based upon work supported by the National Science Foundation Science and managed by Michigan Technological University under Grant 1543229.

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