Mixing and Entrainment in Clouds

R. A. Shaw

Department of Physics, MTU

Microphysical interactions between cloud droplets occur over a range of temporal and spatial scales, but at least the local diffusive interactions that govern condensation growth or evaporation occurs on scales ranging from the droplet size to tens of centimeters. For instance, entrainment of dry air into clouds strongly influences their microphysical properties as well as their depth and lifetime. The thermodynamic equilibrium state after dilution and evaporation can be reached through a variety of microphysical pathways, such as uniform evaporation of all droplets in the diluted volume, or the complete evaporation of a subset of droplets. These pathways are described as homogeneous and inhomogeneous mixing, respectively, and the concept has generated an active debate in the several decades since it was formulated.

In this presentation the homogeneous/inhomogeneous mixing problem is addressed from three points of view: 1. Field measurements from cumulus and stratocumulus clouds provide a large-scale context for the thermodynamic, microphysical, and turbulence conditions associated with entrainment and mixing events. 2. A set of detailed, Eulerian-Lagrangian simulations of a cloud mixing event elucidate the role of the Damkoehler number in the mixing process, and provide insight into the evolution of the cloud droplet size distribution during the phase relaxation process. 3. Measurements from a holographic instrument allow droplet size distributions to be measured at centimeter scales, or what might be termed 'microphysically relevant' scales. The three approaches give insight into the scale dependence of mixing, including the transition from inhomogeneous to homogeneous mixing, as well as the behavior of the cloud droplet size distribution during mixing events.

In collaboration with M. Beals, J. Fugal, B. Kumar, J. Schumacher, H. Siebert, S. Spuler, J. Stith