Does Aerosol Concentration Affect Whether Mixing Occurs Inhomogeneously or Homogeneously in Warm Cumulus?

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We analyze the affect of aerosol on mixing processes in warm cumulus clouds observed during the GoMACCS field campaign near Houston, TX in summer 2006. Cloud drop size distributions and cloud liquid water contents from the Artium flight phase Doppler interferometer in conjunction with clouds simulated with LES model will be used to investigate whether inhomogeneous verses homogenous mixing is preferred for different aerosol regimes.

1. INTRODUCTION

Clouds are important for transporting both moisture and energy in the atmosphere. Small warm continental cumulus clouds are of particular interest due to their extensive coverage. Indirect effects of aerosol on clouds such as a reduction of cloud drop size and increased drop number ($N_d$) with increasing aerosol concentration ($N_a$) have been related to a reduction in precipitation (Warner, 1968; Rosenfeld and Lensky, 1998) and increased cloud albedo. There have been few studies looking specifically at the effects of aerosol concentration on mixing processes in warm cumulus.

Previous investigators have described how evaporation, via inhomogeneous and/or homogenous entrainment mixing can alter drop size distributions and thus other processes such as precipitation initiation. If we consider the process of homogeneous mixing we see that as unsaturated air is entrained into cloudy air the size distribution would have the same number of drops as prior to mixing but with decreased diameters shifting the distribution to smaller sizes. If we consider the process of inhomogeneous mixing we see that for each size drop some of them fully evaporate. Thus, after a cloudy parcel is inhomogeneously mixed the total number of drops in each size class decreases without shifting the distribution to a new size range (Latham and Reed, 1977) also known as ‘extreme’ inhomogeneous mixing (Blyth and Latham, 1990).

Mixing and entrainment are intimately related to drop size and drop number. As we decrease drop size and increase drop number evaporation becomes easier (Wang et al, 2003). Increased evaporation is also related to increased entrainment that can lead to more extreme horizontal buoyancy gradients (Xue and Feingold, 2006) and increased vortical circulation (Zhao and Austin, 2005). Jiang et al (2006) show evidence of increased horizontal buoyancy gradients with increasing aerosol concentrations. Small and Chuang (2008, in prep) show similar results (Figure 1) with observations made during the Gulf of Mexico Atmospheric Composition and Climate Study (GoMACCS) in 2006.

![Figure 1. Positive and negative virtual potential temperature perturbations in clean and polluted clouds.](image-url)
The goal of this work is to explore if aerosol effects whether mixing occurs homogeneously or inhomogeneously in continental cumulus clouds sampled during the GoMACCS.

2. DATA

The GoMACCS project took place during August and September 2006. Data used in this study were obtained with a flight phase Doppler interferometer (f-PDI) and cabin instrumentation on the Center for Interdisciplinary Remotely-Piloted Aircraft Studies (CIRPAS) Twin Otter. Data from two flights, one clean case and one polluted are the focus of this study. During each flight an individual cloud was penetrated multiple times. From each cloud pass f-PDI cloud drop number concentrations (CDNC) and cloud liquid water content (LWC) were obtained.

3. METHODS

Following Small and Chuang (2008), conditional sampling was used to look for signs of inhomogeneous or homogeneous mixing at all sampled levels. CDNC and spectral width of observed distributions are then correlated to out of cloud aerosol concentrations observed at each level. Continental cumulus clouds simulated with an LES model for both a polluted case and a clean case. They are then compared to observed clouds on the clean and polluted days.

For both observed and modeled clouds clean and polluted cases will be compared by producing 2-D PDFs of the density function for each aerosol regime to evaluate the mixing process represented in LES when viewed from this perspective. In depth analysis will be conducted using data from multiple passes (at many altitude levels) through individual well developed warm cumulus clouds for both a clean case and a polluted case.

4. REFERENCES


