CART RAMAN LIDAR AEROSOL AND WATER VAPOR MEASUREMENTS IN THE VICINITY OF CLOUDS

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ABSTRACT

Aerosol and water vapor profiles acquired by the Raman lidar instrument located at the Climate Research Facility (CRF) at Southern Great Plains (SGP) provide data necessary to investigate the atmospheric variability in the vicinity of clouds near the top of the planetary boundary layer (PBL). Recent CARL upgrades and modifications to the routine processing algorithms afforded the necessarily high temporal and vertical data resolutions for these investigations. CARL measurements are used to investigate the behavior of aerosol backscattering and extinction and their correlation with water vapor and relative humidity.

1. INTRODUCTION

Understanding how aerosols and clouds interact is essential for investigating the aerosol indirect effect. Recent observations by surface [1] and airborne Sun photometers [2] and satellite sensors have noted significant changes in aerosol properties in proximity to clouds. These studies have noted increases in AOT of 5-25% in "transition zones" of a few kilometers to several tens of kilometers away from clouds. While it is tempting to conclude that these correlations are evidence of aerosol-cloud interactions, other explanations are also plausible. For example, since aerosols grow in humid environments near clouds, the swelling of aerosol particles in the higher humidity environments near clouds may also produce positive correlations between aerosol optical depth and cloud cover. Other possible processes that may lead to increased aerosol abundance include increased particle production near clouds, increased aerosol size caused by in-cloud processing, and cloud contamination in the satellite pixels.

The high temporal and vertical resolution aerosol and water vapor measurements provided by CARL provide a unique resource to examine aerosol-cloud interactions. We describe our initial efforts to use these measurements to investigate how aerosols and water vapor vary near clouds.

2. CARL INSTRUMENT DESCRIPTION

The U.S. Department of Energy Atmospheric Radiation Measurement (ARM) Climate Research Facility (CRF) Raman lidar (CARL) provides a climatological database of aerosol and water vapor profiles [3]. CARL autonomously measures profiles of aerosols, clouds and water vapor in the low to mid troposphere throughout the diurnal cycle over the ARM Southern Great Plains (SGP) CRF (36.62 N, 97.5 W, 317 m) [4]. Profiles of water vapor mixing ratio, relative humidity, aerosol backscattering, and aerosol extinction (355 nm) are derived using a set of automated algorithms [5]. Water vapor mixing ratio profiles are computed using the ratio of the Raman water vapor signal to the Raman nitrogen signal. Relative humidity profiles are computed using these profiles and the temperature profiles from a colocated Atmospheric Emitted Radiance Interferometer (AERI). Profiles of aerosol scattering ratio are derived using the Raman nitrogen signal and the signal detected at the laser wavelength. Aerosol volume backscattering cross section profiles are then computed using the aerosol scattering ratio and molecular scattering cross section profiles derived from atmospheric density data. Aerosol extinction profiles are computed from the derivative of the logarithm of the Raman nitrogen signal with respect to range. Aerosol optical thickness is derived by integration of the aerosol extinction profile with altitude.

3. DATA ANALYSIS

Upgrades and modifications to CARL performed in 2004 permit a much more detailed view of the variability of aerosols and water vapor near clouds at or near the top of the Planetary Boundary Layer (PBL). The automated routines to process the data from CARL were recently updated to account for the system changes and higher resolution data [6]. CARL can now provide 10 second profiles of aerosol backscattering, water vapor mixing ratio, and relative humidity, and 1 minute profiles of aerosol extinction in the PBL. We have begun to use these high temporal resolution CARL measurements in conjunction with continuous Total Sky Imager (TSI) images of cloud cover to examine

how aerosol and water vapor properties vary in the vicinity of clouds.

4.0 AEROSOL BACKSCATTER NEAR CLOUDS

Figure 1 shows an example of 10 sec resolution relative humidity and aerosol backscatter profiles derived from CARL data acquired between 21:45-22:05 UT on September 13, 2005. Temperature profiles derived from the 20 sec AERI rapid sampling mode were used along with the CARL measurements to derive relative humidity. Cloud base is indicated by the white lines in the aerosol backscatter image. Figure 2 shows a Total Sky Imager (TSI) image acquired at 21:56:30 UT; the two small Cumulus clouds observed in the lidar data can be seen in this TSI image. This imagery is being used to help determine the proximity of the CARL measurements relative to clouds. Note how aerosol backscatter changed by over a factor of 2 in less than a minute in the immediate vicinity of the Cumulus cloud at ~22:00 UT.

In Figure 3, relative humidity and aerosol backscatter are plotted as a function of time and distance from the cloud and each color represents a varying distance above or below the cloud base height. The effects of the cloud can be seen at least 400 meters from the cloud altitude on either side of the cloud.

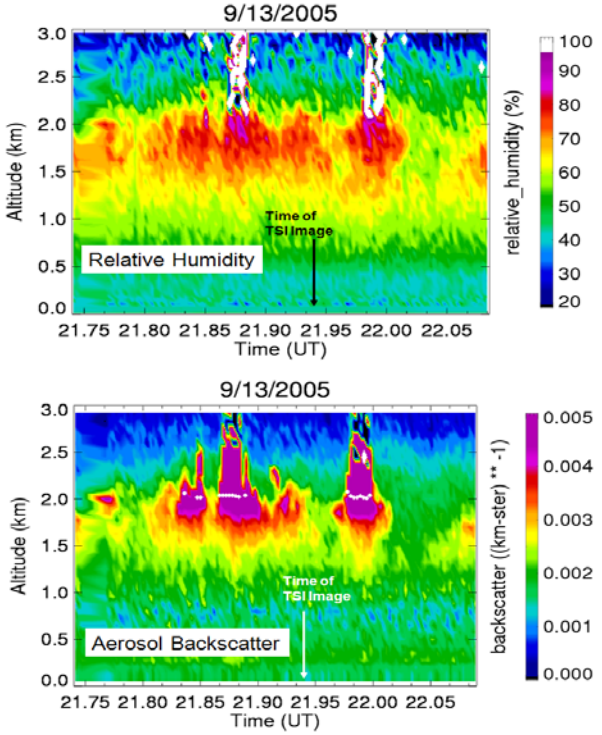

Figure 1: CARL measurements on 9/13/2005

Figure 2: TSI image from 9/13/2005 at 21:56:30

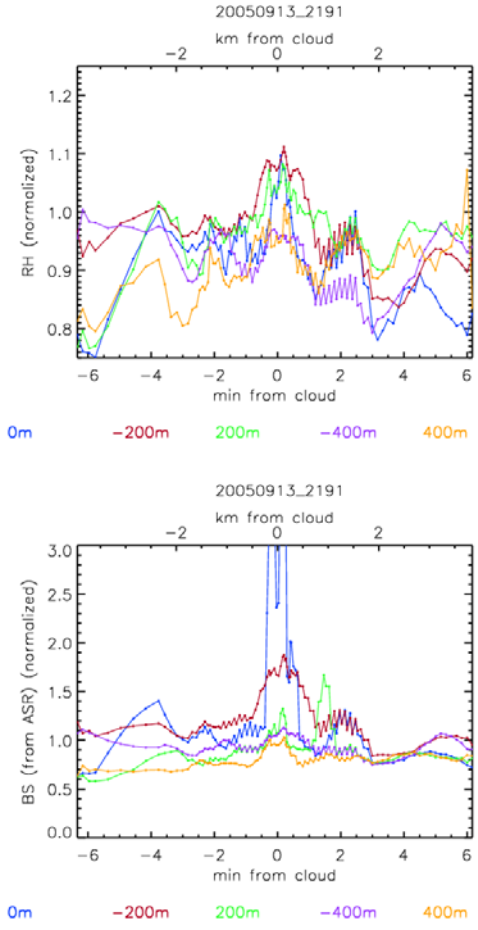

Figure 3: relative humidity and aerosol backscatter measurements with respect to distance and time from clouds

5.0 CARL MEASUREMENTS OF AEROSOL HYGROSCOPICITY

The change in aerosol scattering with increasing relative humidity (i.e. f(RH)) is presently measured at the surface using a humidified nephelometer as part of the ARM SGP Aerosol Observing System (AOS). However, airborne in situ measurements have indicated that f(RH) often varies with altitude [7] so that this surface based measurement may not accurately represent conditions aloft. Figure 4 shows how aerosol extinction computed as 1 minute averages varies with RH for the data shown in Figure 1. Additional investigations are planned to examine the temporal variability of this aerosol hygroscopicity and how these measurements compare with the surface measurements of aerosol hygroscopicity [8].

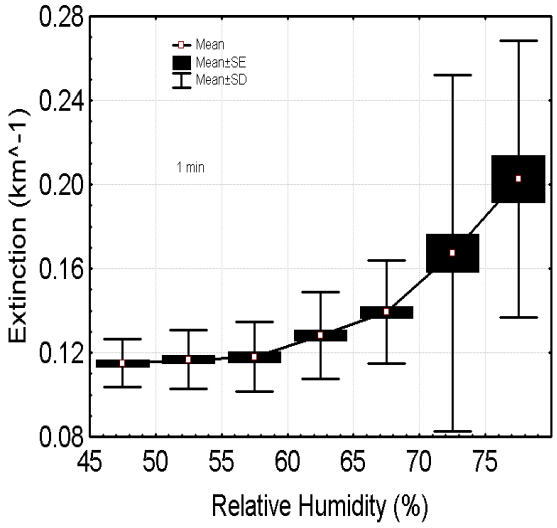

Figure 4. Change in aerosol extinction vs. relative humidity derived from 1 minute averaged CARL data acquired between 21-22 UT on September 13, 2005 during ALIVE (see Figure 3). Results shown here were for altitudes between 1-2 km

6. SUMMARY

High temporal and vertical resolution aerosol and water vapor profiles measured by CARL provide valuable insight on aerosol and water vapor characteristics near to clouds. Initial results show aerosol backscatter and relative humidity can increase in close proximity to the clouds. In addition, the CARL measurements can be used to remotely investigate the dependence of aerosol extinction and backscatter on relative humidity. More detailed comparisons, include those that use data collected during the Cumulus Humilis Aerosol Processing Study (CHAPS)/Cloud-Land Surface Interaction Campaign (CLASIC) that was conducted over the SGP site during June 2007, will be presented at the meeting.

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