Measurements of Liquid Water Content with the Atmospheric Radiation Measurement Program Raman Lidar at Southern Great Plains

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1. Abstract

The aerosol indirect effect is the effect that aerosols have on cloud microphysics and lifetime [1]. In the first indirect effect, assuming the same amount of liquid water is available, an increase in the number of cloud condensation nuclei (aerosols) would result in a decrease of the average cloud droplet size. The study of cloud microphysics is essential to reach a better understanding of the first aerosol indirect effect, whose influence on the global radiative budget is currently very poorly understood.

Here an investigation of the algorithm to extract liquid water content measurements from the Atmospheric Radiation Measurement Program (ARM) Climate Research Facility Raman Lidar (CARL) is pursued. The resulting liquid water path (LWP) is validated by comparison with the MIXed-phase Cloud properties Retrieval Algorithm (MIXCRA) [2] and a Radar–Lidar based retrieval [3]. Finally a retrieval of the droplet average radius and average number density from Raman Lidar data is presented [4].

2. Calibration

The first principle calibration technique used here consists of transferring the calibration of the water vapor mixing ratio measurements, obtained by comparison with measurements of PWV from a microwave radiometer, to determine the calibration of the liquid water measurement [5].

The main assumptions of this technique are:

- **The ratio between the channel efficiencies can be calculated.**
- **The relationship between the two Raman cross sections is:**

$$\frac{d\sigma_{liq}(\pi)}{d\Omega} \cong 2^{[6]} \times 5^{[7]} \frac{d\sigma_{W}(\pi)}{d\Omega}$$

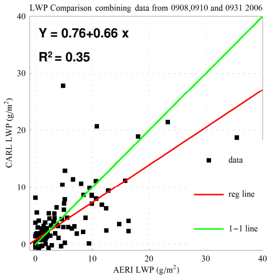

Figure 1: CARL LWP obtained using the first principle calibration is displayed versus the LWP retrieved by AERI using the MIXed-phase Cloud properties Retrieval Algorithm (MIXCRA).

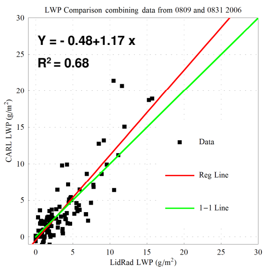

Figure 2: The CARL LWP obtained using the first principle calibration is displayed versus the LWP retrieved with a Radar-Lidar based retrieval [3]. This retrieval uses the effective radius measurements from the MMCR and the extinction measurements from the MPL at SGP to retrieve the liquid water path.

3. Droplet size and number density retrieval

The combination of the calibrated measurements of the liquid water content and aerosol backscattering coefficient from lidar can be used to retrieve the average droplet radius and number density within clouds [4]. From the retrieved average radius and the liquid water content the droplet number density can be calculated. The retrieval used here assumed a Khrgian-Mazin Gamma droplet size distribution.

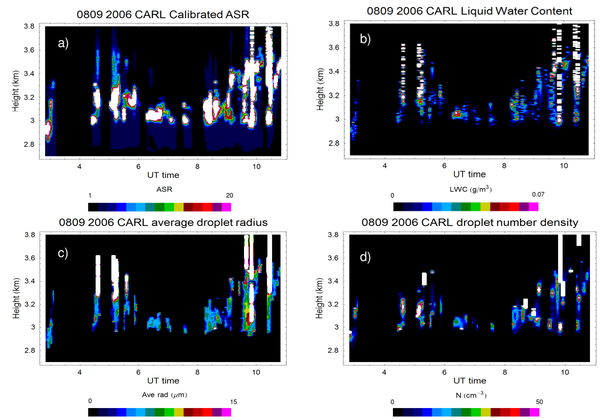

Figure 3: Time series of ASR (a), LWC (b), droplet radius (c) and number density (d).

The retrieval of droplet average radius gives an average radius between 5 and 10 μm and a corresponding average number density between 10 and 60 cm^{-3}. In a few cases the average droplet radius is larger than 50 μm, where the LW measurement is very noisy. Noise discrimination on the input quantities will be used to improve the retrievals in the future.

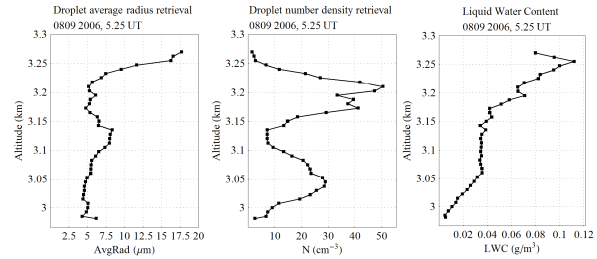

Figure 4: Example of droplet radius and number density retrieval for one case of the time series in Figure 3.

Summary

A first principle technique for the calibration of the liquid water measurements with the ARM Raman Lidar CARL has been presented. The resulting LWP measurements compare reasonably well with the Radar-Lidar retrieval while seeming to have a tendency to underestimate the LWP when compared to the MIXCRA algorithm. More statistics are needed to better understand this behavior.

An example retrieval of average droplet radius and number density based on the liquid water measurements from the Raman Lidar has been presented. The values of both quantities are typical for low level liquid clouds. Comparisons with the effective droplet radius from MIXCRA will be studied in the near future.

The Raman Lidar retrieval of liquid water content, droplet size and number density, combined with the measurements of aerosol extinction below cloud can offer a valuable contribution to the study of microphysics of clouds and therefore to the study of the first aerosol indirect effect by correlating changes in the aerosol extinction below the cloud with changes in the microphysics in the cloud. This will be the focus of the next phase of this research.

References

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