Aerosol Retrieval Comparison During the SGP Summer '98 IOP From Multiple Lidar Probing

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Introduction

As part of the Aerosol Intensive Operational Period (IOP) during late summer 1998 at the Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) site, three Micropulse Lidars (MPLs) were operated simultaneously at complementary viewing angles providing an in-depth look at surface and vertical boundary layer structure. The MPL (Spinhirne 1993; Spinhirne et al. 1995) is an integral member of the Atmospheric Radiation Measurement (ARM) active remote sensing instrument suite, providing full-time vertical profiling of all significant tropospheric cloud and aerosol at each of the central facilities. An important goal for the MPL data is to routinely provide the profile of aerosol extinction scattering cross section for all of the ARM sites. The main purpose of the 1998 IOP was to test the techniques and results of aerosol cross-section profiles from routine zenith MPL observations. The multi-spectral CART Raman Lidar (Goldsmith et al. 1998) serves as an independent source of verification.

Of the three systems operated during the IOP, one pointed vertically (the operational SGP MPL), another horizontally, and the last at a 30° slant angle (off vertical). This abstract will deal with results garnered from the first two, while a separate presentation discusses the slant angle measurements (Powell et al. 1999). As work continues at the National Aeronautics and Space Administration (NASA)/Goddard Space Flight Center (GSFC) towards developing an automated real-time aerosol retrieval value added process, this experiment provided a valuable test for current and proposed algorithm techniques (a relevant summary is available in Hlavka et al. 1998). Due to the respectable wavelength discrepancy between the MPL and Raman systems (the MPLs operate at 523 nm and the Raman at 355 nm), the comparison between measurements is not direct, and is somewhat subjective. A qualitative analysis is instead relied upon.

Horizontal/Surface Analysis

A ground-based horizontally pointed lidar offers a direct measurement of the surface aerosol extinction coefficient under homogeneous scattering conditions. Campbell et al. (1998) discuss this measurement and its application as it relates to the MPL in detail. In the current study, an MPL (unit 51) operated as such for approximately eight days beginning August 15. Using hourly averaged data files, extinction cross sections were calculated using average values determined from 30-m range bins between 5.85 km and 7.00 km. This range setting guaranteed that system optical/geometric overlap had been reached while curvature of the earth was not yet a significant concern. The results are presented in Figure 1 versus somewhat similar values derived from cloud-cleared Raman Lidar profiles. Whereas the MPL operated at approximately 2 m above ground level (AGL), the vertically pointing Raman first records data at 117 m AGL. The Raman value is not a direct measurement near the ground. Instead, extinction is directly measured first near 1.0 km. The extinction-to-backscatter ratio calculated at this height is carried as a constant through the lower levels. Extinction coefficients for the lower bins are then found using the corresponding backscatter measurement. A separate presentation discusses the CART Raman Lidar and its algorithms (Ferrare et al. 1999). Overall, the comparison is quite favorable, with the wavelength difference responsible for higher Raman values. The Raman processing assumptions noted above are expected to be quite stable. Therefore, subtle discrepancies are likely the result of inconsistencies in either the range-interpolating regime of the MPL calculation, or lack of horizontal homogeneity.

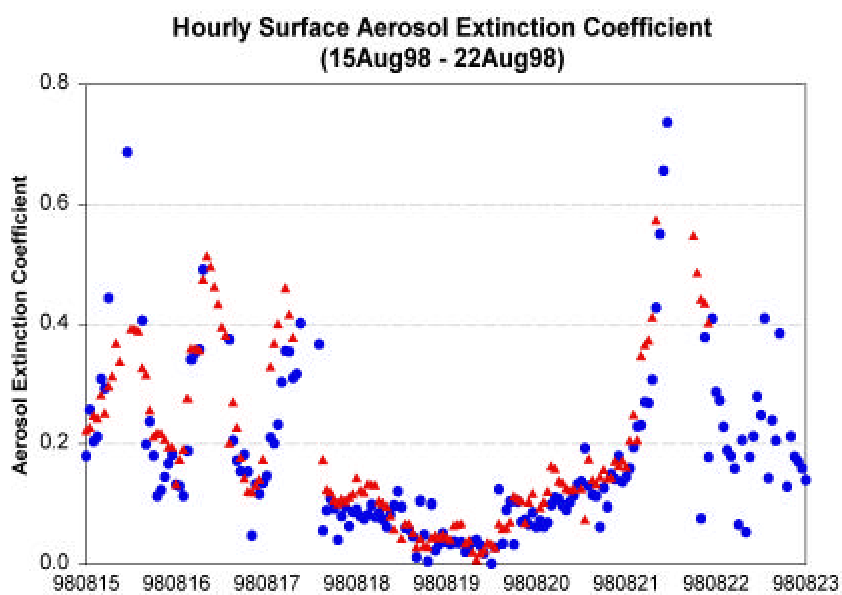

Figure 1. Comparison of surface aerosol extinction rates from the MPL (523 nm - circles) and Raman Lidar (355 nm - triangles) at 2 m and 117 m AGL, respectively, during August 15-22, 1998.

Vertical Analysis

A high-resolution (30-m) MPL (unit 54) was installed as the operational system at the SGP CART in late August and served as the vertically pointing system in this study. This range-resolution represented a ten-fold increase over the previous version. The 13 days beginning August 29 and ending September 12, 1998, serve as the focus for work presented in this section. Figure 2 displays near-range corrected raw backscatter returns for the first week of the sample. Conditions throughout the period were unseasonably dry, with only one rain event recorded. Elevated aerosol layers were quite frequent, drifting as high as 5 km AGL on September 4.

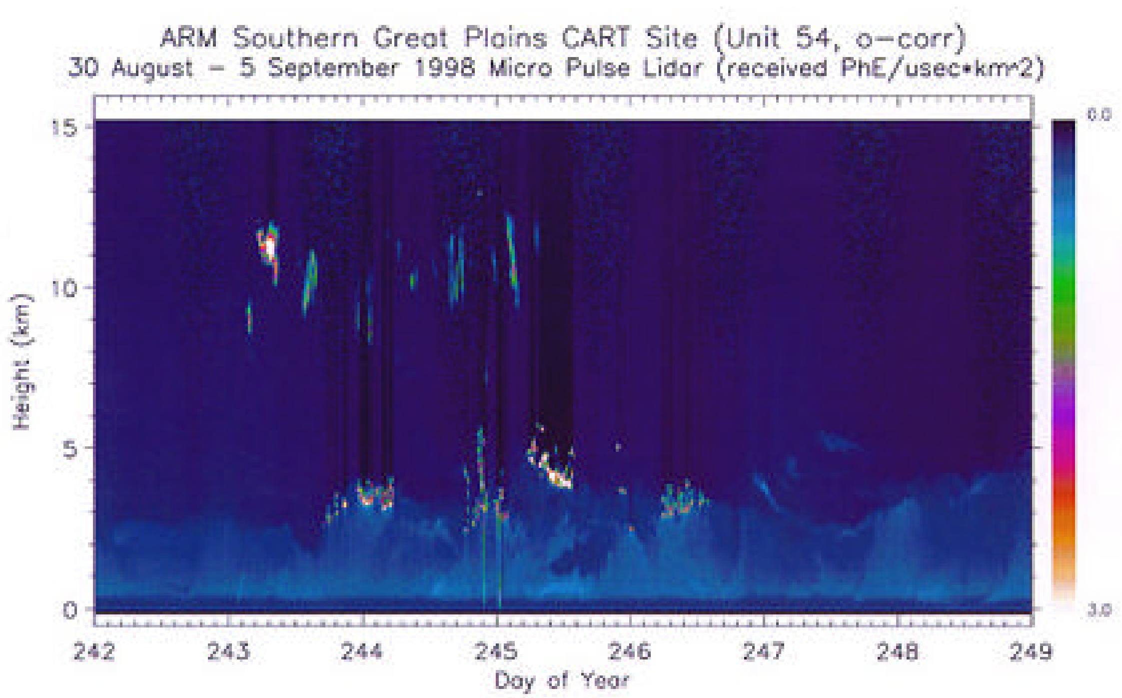

Figure 2. Overlap corrected returned raw backscatter counts from the SGP CART MPL for the week August 30 through September 5.

Figure 3 plots averaged vertical aerosol extinction cross-section profiles from the MPL and Raman system for 2200 Universal Time Coordinates (UTC), August 30, and the theoretical Raman profile converted to the 523-nm wavelength. Good agreement between systems with respect to magnitude, as a function of wavelength, is evident. A sharp transition between the boundary layer and middle troposphere is noted just under 3 km, agreeing well with Figure 2. Differences in vertical structure are likely due to the differing system methodologies. The Raman measurement is direct. With the MPL, an average extinction-to-backscatter ratio is calculated representing the integrating column. Vertical extinction values are then solved for, by range bin, based on corresponding backscatter returns. Additionally, field-of-view conflicts in the shared MPL transmitter-receiver design, and inadvertent pulse-induced saturation of the photon-counting detector can limit the initial effective sampling range of the instrument. Methods to improve the reliability of data retrieved in the first 3 μs sampling period

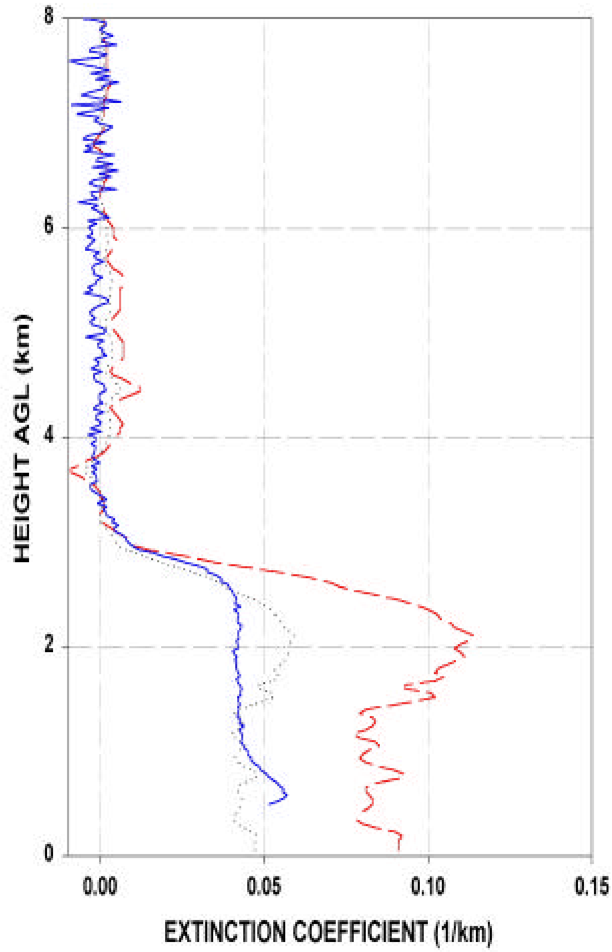

Figure 3. 60-minute averaged profiles of aerosol extinction cross section for the MPL (solid), the CART Raman Lidar (long dash), and a conversion of the Raman profile to the 523-nm MPL wavelength (short dash) for 2200 UTC, August 30, 1998.

(~400 m) are being investigated. Clouds can taint an averaging sample. MPL algorithms rely on a 2-km cloud-free region immediately above the boundary layer to calibrate versus a theoretical Rayleigh scattering atmosphere. After which, aerosol retrievals in the similarly cloudless boundary layer are performed. Automated processing requires a simple threshold of clear ‘shots’ to cloudy ones in a temporal average profile to insure data quality.

Table 1 lists column-averaged aerosol extinction-to-backscatter ratios (AEBR) from the MPL and Raman Lidar for 0.5 Julian day periods of the daylight hours August 29-30 (Julian days 241-242). Both days were completely clear, the latter of which can be seen in Figure 2. Results derived from the two systems agree well with modeled results for a ‘continental’ aerosol derived by Ackerman (1998). The MPL, though, appears to show a diurnal signature not evident in the Raman. Ackerman suggests a relatively large dependence of AEBR in continental aerosol with relative humidity at the 355-nm and

Table 1. Comparison of temporal/column-averaged extinction-to-backscatter ratios from daytime MPL (523 nm) and Raman (355 nm) data for August 29-30, along with the corresponding approximate Cimel Sunphotometer aerosol optical depth (AOD) at 523 nm.

Julian Day	MPL	Raman	AOD
241.60-.65	56.61	64.53	0.110
.65-.70	45.21	65.86	0.110
.70-.75	44.14	53.18	0.110
.75-.80	42.92	66.99	0.105
.80-.85	48.97	61.11	0.105
.85-.90	55.41	63.31	0.100
.90-.95	58.81	59.59	0.100
242.60-.65	57.18	67.68	0.125
.65-.70	54.65	66.20	0.125
.70-.75	49.29	57.46	0.125
.75-.80	50.88	60.33	0.125
.80-.85	57.56	59.36	0.125
.85-.90	58.46	59.36	0.125
.90-.95	59.43	62.23	0.125

532-nm wavelengths. Therefore, some diurnal variation in AEBR should be expected. Results derived from the Raman do not necessarily agree for this case. This discrepancy will require further study.

Proper calculation of the case-dependent MPL calibration constant (via the lidar equation) requires an independent estimation of the aerosol optical depth (AOD). However, an automated algorithm may lack such processed information in a timely fashion. Even worse, such data may not even exist. Figure 4 plots hourly MPL-calculated AOD values versus similar Cimel Sunphotometer values (modified from the 500-nm channel) for a one-week period. The calibration constant for this case was calculated from an hour average from the beginning and carried constant through the sample. A case-by-case calculation of this constant has shown variation by as much as 20% during daytime hours. However, these results agree quite well with the Cimel Sunphotometer. The dependence of the AOD calculation on the calibration constant is fortunately quite low as the variable is relegated to a low order term (Hlavka et al. 1998). This suggests that the MPL can be relied upon to deliver relatively stable AOD calculations at 523 nm for extended time periods if the calibration constant can be initialized correctly. In fact, observations at the Nauru Island ARM site begun in November 1998 lacked proper radiometric data. Campbell et al. (1999) note that the MPL calibration constant could be solved for as a ‘best-fit’ compromise with the AOD and AEBR for a model marine atmosphere. In this manner, the MPL may be able to supplement this unfortunate AOD data gap.

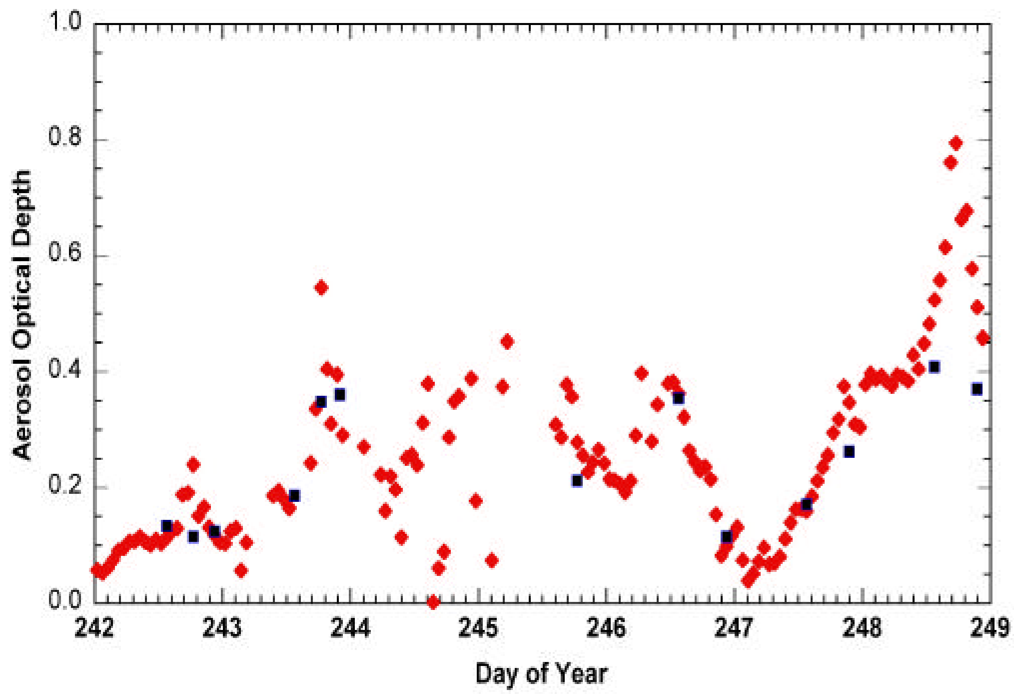

Figure 4. Aerosol optical thicknesses calculated from the MPL (squares) and Cimel Sunphotometer (diamonds) for August 30 through September 5, 1998, at the SGP CART site.

Conclusions

Automated MPL (523-nm) aerosol retrieval algorithms are tested in this abstract during the Summer ’98 Aerosol IOP at the SGP CART site using separate horizontally and vertically pointing systems. Independent validation is attempted using the CART Raman Lidar operated at 355 nm. Preliminary analysis shows that aerosol retrievals are quite reasonable. Work will now focus on adaptation of these methods into a unified value added processing routine. In principle, it would be simple to modify existing ARM MPL units into multi-angle scanning lidars, by adding a turning mirror equipped with a rotary motor and software capable of stamping raw data files with relevant angular diagnostics. In fact, this technology is being developed at the GSFC with testing hoped to begin shortly. Such a unit would allow for routine sampling of the surface aerosol layer, and provide a means for frequent recalibration of the transmitter-receiver field-of-view correction.

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