3.7 LIDAR VALIDATION OF CALIPSO AND OMI USING GROUND-BASED SENSORS FROM REALM

R. M. Hoff*, O. Torres, R. Delgado and R. Rogers
JCET/Univ. of Maryland Baltimore County, Baltimore, MD

1. INTRODUCTION

With the launch of the Clouds and Aerosol Lidar for Pathfinder Spaceborne Observation (CALIPSO) satellite into the A-Train, synergistic observations of aerosols from multiple sensors in the train are now possible. CALIPSO joined Aqua (containing MODIS and the AIRS instruments) and AURA (containing TES and OMI instruments) in a sequence of satellites that can make measurements related to atmospheric chemistry and air quality. With its sister satellite, CLOUDSAT, CALIPSO provides unprecedented ability to determine the spatial (both horizontal and vertical) extent of atmospheric aerosols and clouds.

All of the previously launched sensors in the A-Train are passive instruments and, with the exception of the planned limb-sounding capability on the Tropospheric Emission Spectrometer (TES), these sensors integrate entire column radiances. The ability of sensors such as the Advanced Infrared Sounder (AIRS) and the Ozone Measuring Instrument (OMI) to determine correct column amounts of gases or aerosols is based on assumptions of the vertical distribution of those constituents or on broad vertical weighting functions. In particular, we are interested in the aerosol index and aerosol absorption optical depth derived from the OMI instrument (Torres et al., 2002). In the OMI aerosol absorption retrieval, which is based on a solar-backscatter ultraviolet (SBUV) measurement, the height at which the absorption occurs is important, particularly because of the large column Rayleigh scattering at these wavelengths. Absorption by the aerosol layer of the Rayleigh scattered light is the basis of the OMI particle absorption sensing capability. An absorbing aerosol layer at 10 km is much more visible to the AURA-OMI sensor than is an identical one at 2 km, because of the larger Rayleigh scattering available for absorption underneath the aerosol layer. The assumption of the height of the absorbing layer is an input to the OMI aerosol optical depth retrieval and, in some cases, the normal assumption of a lower tropospheric aerosol may not be correct. We will show that data from CALIPSO, when added to the OMI product, can improve our understanding of what we see with both instruments.

2. SMOKE OBSERVATIONS

* *Corresponding Author Address:* Raymond Hoff, UMBC JCET, 5523 Research Park Drive, Suite 320, Baltimore MD 21228 email: hoff@umbc.edu

CALIPSO was launched in April, 2006, and the first light image came on June 8. In early June and July, we started evaluating the combination of CALIPSO and the Ozone Monitoring Instrument (OMI) aerosol products. As part of the CALIPSO validation process, UMBC has operated a ground based elastic lidar (ELF) for over four hundred hours. 214 of those hours occurred within two hours of the overpass of the A-Train. CALIPSO validation results have recently been presented (McCann et al., 2006; Delgado et al., 2006).

During the period from July 4-8, 2006, forest fire plumes from Alberta and the Yukon progressed across Canada and the US midwest, arriving in Maryland on July 8-9 (Figure 1).

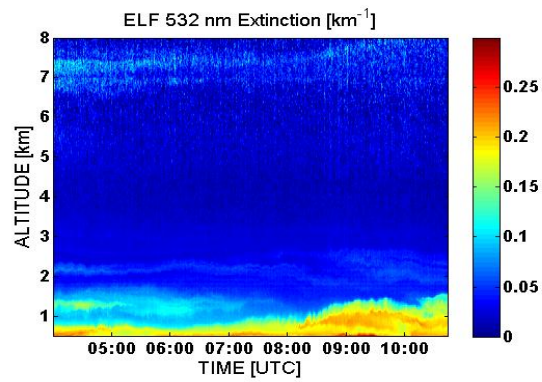

Figure 1: REALM uplooking lidar data from UMBC showing the aerosol extinction coefficient in km^{-1} for the morning of July 9, 2006. The extinction at 7-8 km in the early morning is smoke from the Canadian wildfires.

Over the previous days, OMI's aerosol retrieval showed a large plume with high aerosol absorption optical depth (Figure 2a,b). These results seemed anomalous compared to the MODIS optical depth at the same time (see discussion in Figure 5,6 below).

In Figures 3 and 4, the CALIPSO overpasses from July 5 to 7 are shown. On July 5 and 6 the plumes from the fires in Canada are very high, over 10 kilometers. It is apparent that this has a positive effect on the radiances seen in the OMI retrieval assuming a 2 km aerosol height. In Figure 2 c, d, we show the reduced aerosol absorption optical depth for the data recalculated using a 10 km plume height.

The CALIPSO data have the potential for giving a significant amount of information on the smoke aerosol morphology and optical properties. While the figures shown are preliminary unvalidated CALIPSO results and should be viewed with some care, it is

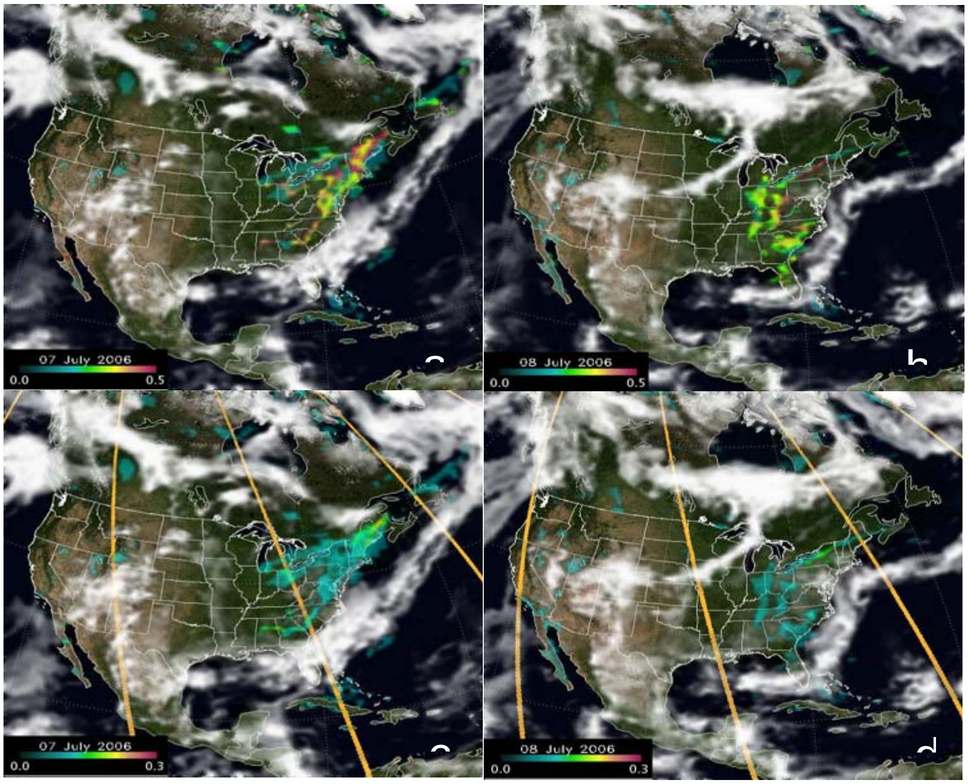

Figure 2: OMI Aerosol Absorption Optical Depth for (a) July 7, 2006, (b) July 8, 2006 assuming a standard 6 km aerosol height. The same values for (c) July 7, 2006, (d) July 8, 2006. assuming a 10 km aerosol height.

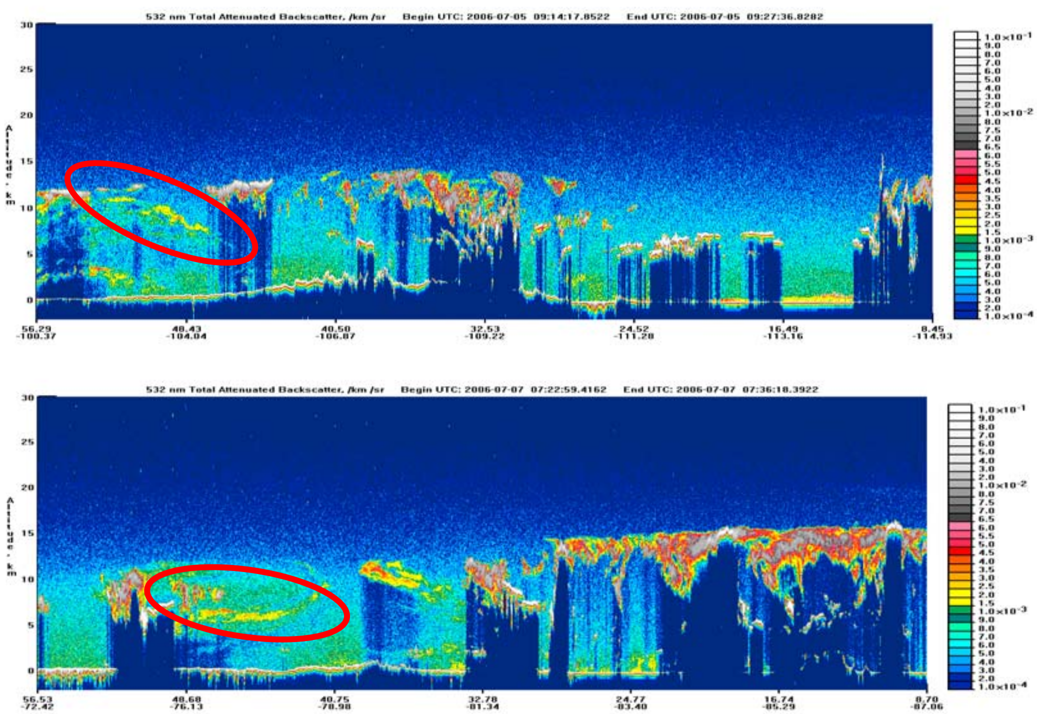

Figure 3: CALIPSO overpasses on July 5 (top) and July 7(bottom). The circled freatures are the smoke from the Canadian fires. There is an evident shift from a plume height of over 10 km on July 5 to July 7 as the plume moves south.

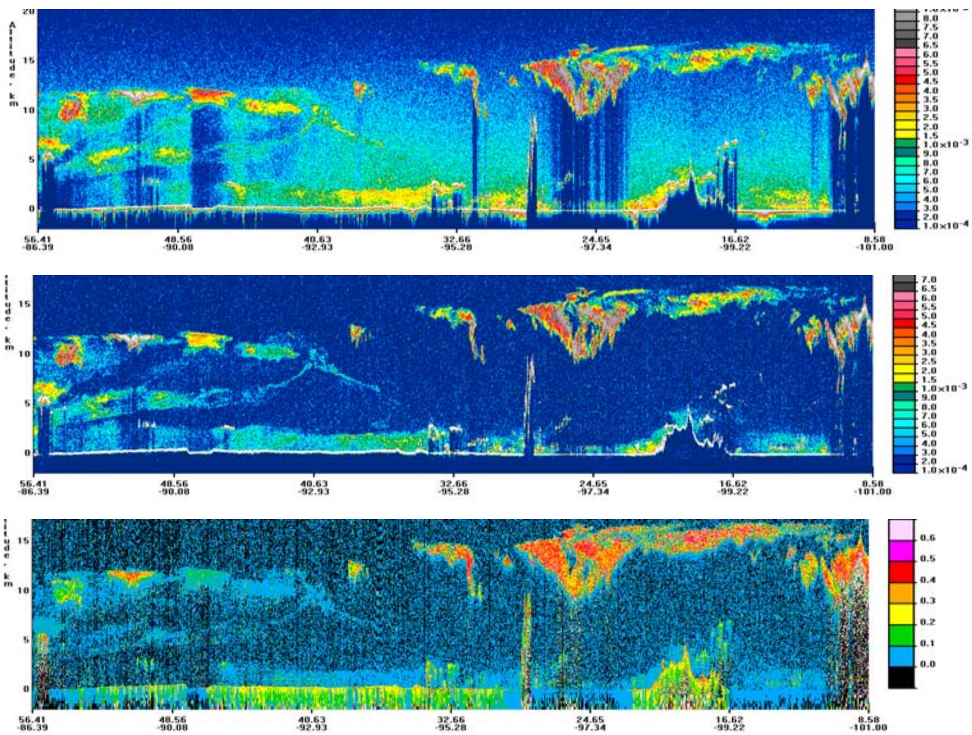

Figure 4: The July 6 CALIPSO overpass. The top panel is the 532nm attenuated backscatter coefficient, the middle panel is the 1064 nm attenuated backscatter coefficient, and the bottom panel shows the depolarization ratio at 532 nm. The smoke features from the Canadian fires are widely distributed at several altitudes between 3 and 12 kilometers from 40°N to 55°N. The depolarization ratio of >0.1 is indicative of the smoke plume in this region and indicates that these are not spherically scattering aerosols. At 50°N and 12 km, the smoke appears to have nucleated a cirrus cloud (high depolarization). However, the highest scattering is seen at about 46°N and 10-12 km.

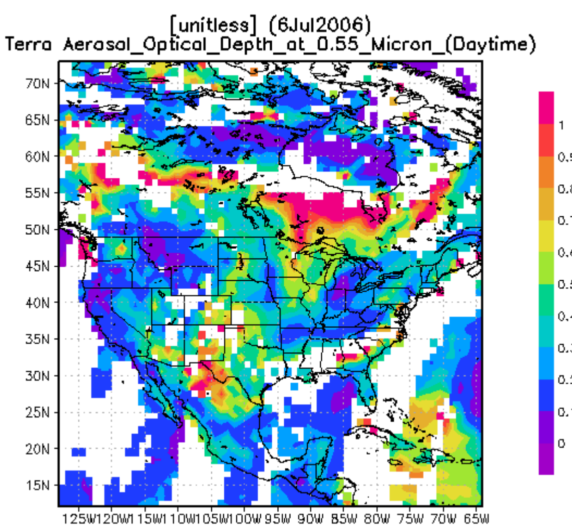

Figure 5: MODIS Terra Optical Depth on July 6. While significant AOD is seen in the OMI image as far south as Arkansas, the mean AOD from MODIS through this region is 0.4-0.7. Data courtesy of the Giovanni Team, GSFC.

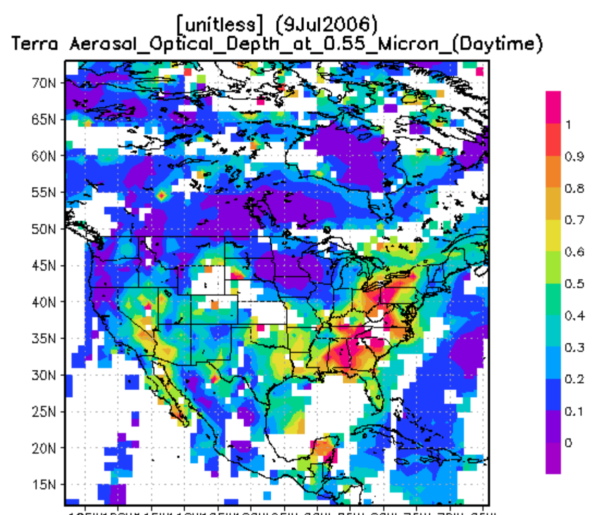

Figure 6: MODIS Terra Optical Depth on July 9 showing the arrival of the smoke plume over Maryland. Data courtesy of the Giovanni Team, GSFC. (AQUA MODIS data not available at time of writing this paper).

obvious that the nearly identical backscatter at the 1064 and 532 nm wavelengths in Figure 4 within the highest layers of the smoke plume indicates large aerosol particles. The high depolarization (10%-20%) indicates that these are not ice crystals or clouds, but are rather amorphous, non-spherical particles.

Unfortunately, we did not have close CALIPSO overpasses to the UMBC site during the July 4-8 period. The nearest overpass was on July 9 (Figure 1) and this was not the most opaque of the smoke plume. Figure 7 shows the comparison of the extinction from the ELF lidar (using a lidar backscatter extinction ratio from closure on the Maryland Science Center AERONET site optical depth of 0.35 on the afternoon of July 8). The agreement between the ELF and CALIPSO attenuated backscatter results in the smoke plume are excellent. There is disagreement in the optical depth in the PBL and this could be due to the mismatch of the CALIPSO track and local pollution near Baltimore or to the lack of correction for extinction in the CALIPSO profile down to the surface. This comparison will need to be redone when CALIPSO extinction data (a Level-2 product) are available.

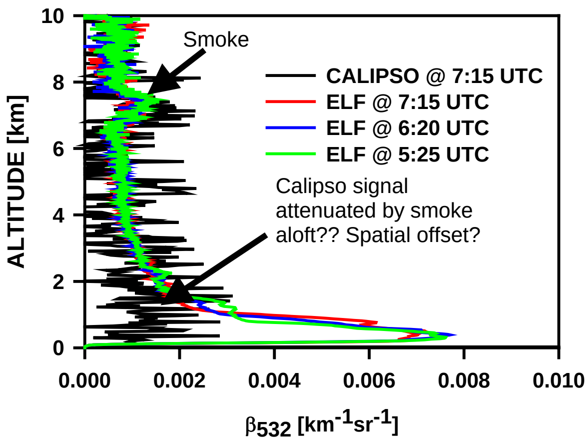

Figure 7: Comparison of CALIPSO and ELF attenuated backscatter on July 9, 2006. The smoke plume at 7 km has an optical depth of about 0.08.

Importantly, though, is the observation that the smoke attenuated backscatter was of order 0.001 km^{-1} sr^{-1}. With a extinction/backscatter ratio of 80 sr for smoke (Cattrall et al., 2004), this would give a smoke optical depth of 0.08 over UMBC on July 9. With an overall optical depth of 0.35, most of the optical depth is still in the boundary layer and probably is not smoke. The 355 nm optical depth from the ALEX system (Figure 8) within the smoke plume is approximately 0.1, which is consistent with the 532 nm optical depth inferred from Figure 7. It would also indicate a single scatter albedo of the smoke of ~ 0.90, when combined the aerosol absorption optical depth from OMI in Figure 2d.

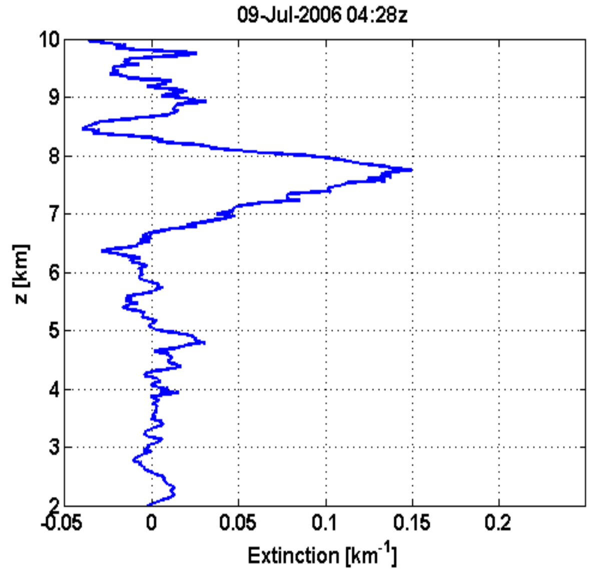

Figure 8: Smoke extinction at 355 nm retrieved from the Atmospheric Lidar Experiment (ALEX) Raman Lidar at UMBC.

3. ACKNOWLEDGEMENTS

This work was supported by the NOAA CREST Cooperative Agreement (National Oceanic and Atmospheric Administration Contract Number NA17AE162), a NASA AURA Validation Grant (NNG06GA73G) and a NASA Langley CALIPSO Project Contract NAS1-99107. The statements contained within the manuscript are not the opinions of the funding agency or the U.S. government, but reflect the authors' opinions.

4. REFERENCES

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