Aerosol Characterization Study Using Multi-Spectrum Remote Sensing Measurement

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Sandia National Laboratories

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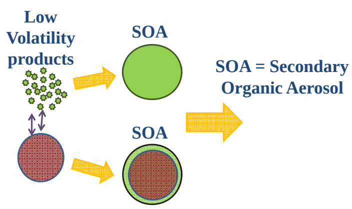
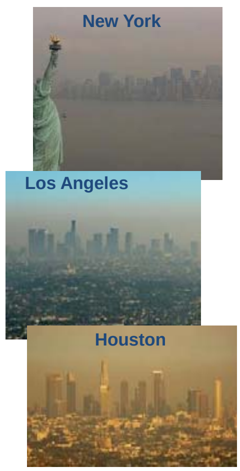
Early Career R&D Program

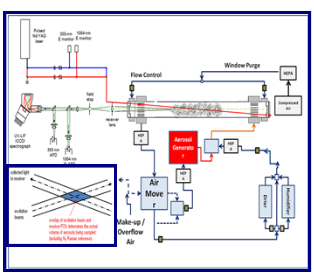
Problem



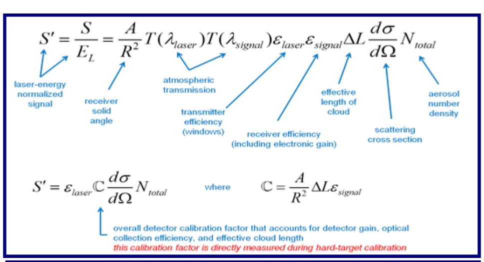


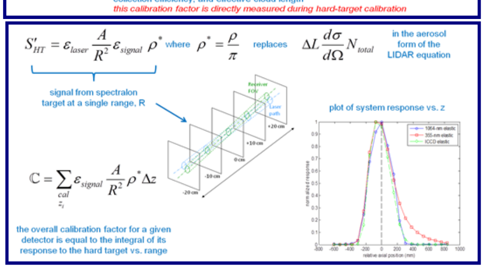
- Atmospheric VOC oxidation may lead to nonvolatile and semi-volatile products that may condense onto existing particles or nucleate to form new particles
- Current optical measurement techniques of atmospheric particulates only involves determining size distribution and conc.
- There is an experimental gap in determining particle type and chemical composition remotely
- Also a need to measure particle specific scattering cross-sections for climate calculations

Approach



- Laboratory based short-standoff bistatic Lidar system.
- Facilitates isolated study of aerosols with control of particle size distribution and particle concentrations.
- The bistatic configuration naturally defines a limited region in space where the laser beams and the receiver field-of-view overlap.
- The limited 2° crossing angle is similar to the direct backscatter angle used in Lidar measurements which allows for a direct comparison between laboratory and field measurements





Results

$$S'_{Raman} = \varepsilon_L \mathbb{C}_{ICCD} \frac{d\sigma}{d\Omega_{Raman}} N_{N_2}$$

LIDAR equation for N_2 Raman signal

$$S'_{1064\,back} = \varepsilon_L \mathbb{C}_{1064\,back} \frac{d\sigma}{d\Omega_{1064\,back}} N_{total}$$

LIDAR equation for 1064 nm signal

$$\frac{d\sigma}{d\Omega_{1064\,back}} = \frac{S'_{1064\,back}}{S'_{N_2 Raman}} \frac{\varepsilon_{L355}}{\varepsilon_{L1064}} \frac{\mathbb{C}_{ICCD}}{\mathbb{C}_{1064\,back}} \frac{d\sigma}{d\Omega_{N_2 Raman}} \frac{N_{N_2}}{N_{total}}$$

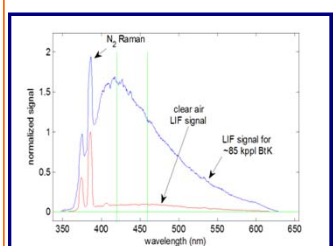
ratio of the above equations rearranged to solve for the 1064-nm elastic backscatter cross section

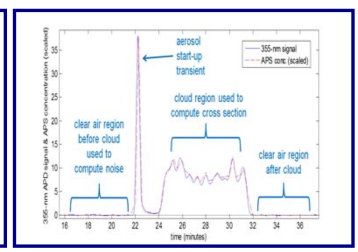
$$\frac{d\sigma}{d\Omega_{355\,back}} = \frac{S'_{355\,back}}{S'_{N_2 Raman}} \frac{\mathbb{C}_{ICCD}}{\mathbb{C}_{355\,back}} \frac{d\sigma}{d\Omega_{N_2 Raman}} \frac{N_{N_2}}{N_{total}}$$

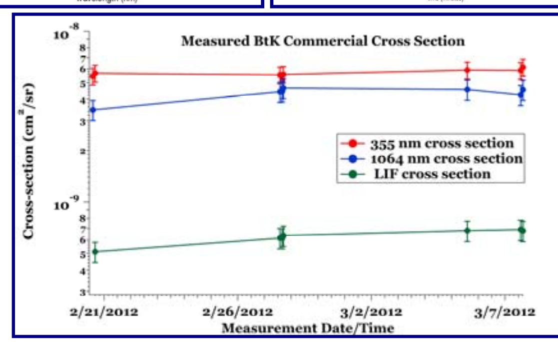
likewise for the 355-nm elastic backscatter cross section

$$\frac{d\sigma}{d\Omega_{LIF}} = \frac{S'_{LIF}}{S'_{N_2 Raman}} \frac{\mathbb{C}_{ICCD}}{\mathbb{C}_{ICCD}} \frac{d\sigma}{d\Omega_{N_2 Raman}} \frac{N_{N_2}}{N_{total}}$$

likewise for 355-nm-excited spectrally resolved laser induced fluorescence cross section







Repeat trials show excellent reproducibility over days and weeks!

System is being upgraded to provide depolarization measurements, and atmospheric particulates including Ammonium Sulfate, Soot, and Mixed organics will be optically measured for discrimination capability

Significance

Results from this study can be applied to ambient Lidar efforts for tracking and understanding the atmospheric aerosol population. Applications include monitoring influences from climate change, understanding bioaerosol (and chemical) detection in an urban atmosphere, developing methods of early detection for nuclear particles released in the atmosphere under various background aerosol concentrations and chemical composition.

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