Aerosol and water vapor variability near Cumulus Clouds from Raman lidar and HSRL measurements

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SGP CART Raman Lidar

- Water vapor, aerosol, depolarization profiles
- Precipitable water vapor and aerosol optical thickness (355 nm)
- Designed for continuous, autonomous (24/7) operation
- Operational retrievals since 1998
- Hardware (2004) and software (2006-2007) upgrades now permit rapid (10 sec – 1 min) water vapor and aerosol profiles

(Turner et al., JAOT, 2002)
Changes in aerosol properties near clouds measured by SGP Raman Lidar

SGP Raman lidar measurements used to study spatial variations of relative humidity and aerosol optical properties near clouds:
- Temporal resolution: 10 sec (RH, backscatter)
- Vertical resolution: 75 m (possible to go lower)
- Compare RH and aerosol properties adjacent to cloud edge with properties some time (distance) away from cloud edge
- Examined several altitudes above/below cloud base
- Both Raman lidar data and TSI images are used to determine time (distance) from cloud

~ 10 min

Changes in aerosol properties near clouds measured by SGP Raman Lidar

SGP TSI image
Significant changes in aerosol properties within 1-2 km of clouds. Ground based Raman lidar measurements show that as distance from cloud increases:
- On average, 20-40% decrease in aerosol backscattering
- On average, 5-10% decrease in relative humidity
- Variations confined to altitudes between ~200-400 m above/below cloud base
HSRL Technique:
• Independently measures aerosol backscatter, extinction, and optical thickness
• Provides intensive aerosol parameter to help determine aerosol type
• Deployed on NASA LaRC B200 King Air
• Flight altitude = 9 km

HSRL Aerosol Data Products:
• Scattering ratio (532 nm)
• Backscatter coefficient (532, 1064 nm)
• Extinction Coefficient (532 nm)
• Backscatter Wavelength Dependence (532/1064 nm)
• Extinction/Backscatter Ratio (“lidar ratio”) (532 nm)
• Depolarization (532, 1064 nm)
Study by Su et al. (2008, JGR) used HSRL measurements during three days in August 2007 over the eastern U.S. to study spatial variations of aerosol optical properties near clouds.

- Temporal resolution: 2 sec
- Vertical resolution:
  - 30 m backscatter
  - 300 m extinction
- Averaged data within +/- 60 m of cloud top
- Compare aerosol properties adjacent to cloud edge with properties as a function of distance away from cloud edge.
Changes in aerosol properties near clouds measured by airborne HSRL over eastern U.S.A.

Study by Su et al. (2008, JGR, 2008) found using HSRL data from these 3 days:
- Aerosol backscatter and extinction ~ 20-30% higher in proximity to clouds as compared to 4-5 km away
- Aerosol optical thickness ~ 8-17% higher
- Changes are consistent with hygroscopic swelling
Changes in aerosol properties near clouds measured by airborne HSRL over the ARM SGP CRF

HSRL measurements used to study spatial variations of aerosol optical properties near clouds
- Temporal resolution: 2 sec
- Vertical resolution:
  - 30 m backscatter
  - 300 m extinction
- Averaged data within +/- 60 m of cloud top
- Compare aerosol properties adjacent to cloud edge with properties some distance away from cloud edge

Image from digital camera on NASA B200 King Air

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~ 10 min (60 km)

~ 10 km
Significant changes in aerosol properties within 1-2 km of clouds. As distance from cloud increases:

- AOT decreases 5-10%
- Aerosol backscatter and extinction decrease 10-40%
- Aerosol depolarization increases 10-15%
- Not much consistent change in lidar ratio or backscatter wavelength dependence
Changes in aerosol properties measured by Raman lidar and HSRL as a function of RH

- Increases in aerosol backscatter with RH near the top of the boundary layer
- HSRL measurements suggest that as the RH increases, aerosols become more spherical and that a larger fraction of scattering comes from accumulation mode aerosols
Summary

- Raman lidar data show increases in relative humidity (5-10%) near clouds.
- Raman lidar and HSRL measurements show increases in aerosol extensive parameters (backscatter (20-40%), AOT (5-10%)) near clouds; these increases appear consistent with observed increase in RH near clouds.
- Decreases in aerosol depolarization near clouds (10-20%) suggest that aerosols become more spherical with higher RH near clouds.
- Variations in aerosol properties and RH are largest at or within about 200 m below cloud base.
- Aerosol humidification factor (f(RH)) derived from Raman lidar data 1-2 km above the surface is consistent with that derived from surface in situ measurements.