Introduction

The NASA Langley Research Center airborne combined Differential Absorption Lidar (DIAL) High Spectral Resolution Lidar (HSRL) characterized ozone and aerosol distributions while deployed on the NASA DC-8 during the Studies of Emissions and Atmospheric Composition, Clouds and Climate Coupling by Regional Surveys (SEAC4RS) field campaign. In addition to measuring ozone concentrations throughout the troposphere and lower stratosphere, this advanced lidar system simultaneously measures aerosol extinction and aerosol optical thickness (AOT) at 532 nm via the HSRL technique, as well as aerosol backscatter and depolarization at 355, 532, and 1064 nm in both nadir and zenith directions.

The DIAL/HSRL measurements of lidar ratio (i.e., the ratio of extinction and backscatter), aerosol depolarization ratio, backscatter color ratio, and spectral depolarization ratio (i.e., the ratio of aerosol depolarization at the two wavelengths) provide information about the aerosol physical properties and so are combined to infer aerosol type. Aerosol extinction and optical thickness are apportioned to these aerosol types. Smoke from biomass burning is identified by the lidar data and the optical parameters along with the vertical and horizontal distributions are presented from the SEAC4RS campaigns. In addition, the DIAL/HSRL measurements from the research flight on August 6, 2013 are used to quantify and characterize smoke above uniform stratus clouds.

Example of DIAL/HSRL Data Products
High Spectral Resolution Lidar (HSRL) Measurements

Parameters shown below are expanded views of flight segments outlined above

Extensive Parameters
(Depend on particle type and concentration)
Aerosol Backscatter (532nm)
Aerosol Backscatter (1064nm)
Aerosol Extinction (532nm)
Aerosol Extinction (1064nm)
Aerosol Optical Thickness (AOT – 532nm)

Intensive Parameters
(Depend only on particle type - composition, size, shape)
Aerosol Depolarization (532nm)
Spectral Depolarization Ratio (1064/532nm)
Backscatter Angstrom Exponent (1064/532nm)
Lidar Ratio (Extinction to Backscatter Ratio 532nm)

Comments on the Smoke Lidar Observations with Altitude

The DIAL/HSRL technique allows independent measurements of the backscatter and extinction. In addition, using the methodology outlined by Burton et al., aerosol type can be inferred as a function of altitude and azimuth along the flight tracks. Using these measurements and typing retrievals, the fraction of aerosol optical thickness (AOT) can be partitioned by type and altitude (see figure above). Compositing only aerosol types identified as smoke, the vertical variability was assessed for all the flights. As has been observed in previous individual flights, the averaged lidar ratio increases with altitude. This is correlated with an increase in the 532nm depolarization (the 1064nm does not show significant change) and the therefore anticorrelated with the spectral depolarization ratio shown in the correlation plot.

Case Study: Changes in Optical Properties

Above Cloud AOD Retrieval Assessment

Case study to assess accuracy of ACAOD retrievals from CALIOP

Summary

- Smoke plumes were identified using the intensive parameters of the lidar observables during the SEAC4RS field mission. These are plotted to show the geographical distribution over the sampling region.
- The vertical distribution of aerosols was assessed based on the types identified:
  - The aerosol optical thickness (AOT) was assessed as a function of aerosol types and altitude. The AOT was dominated by urban sources in the lower altitudes (<3km) and by smoke at higher altitudes (4-5km).
  - For smoke types, the lidar ratio (extinction to backscatter) increased with altitude from a value near 60 below 5km to ~70 at 8km. This increase is anticorrelated with the spectral depolarization ratio indicating potential changes in the smoke microphysical properties or mixing of aerosol types and relative humidity changes.
  - The changes in the smoke properties with altitude can be important when deriving extinction from lidar systems that assign a lidar ratio in their retrievals (i.e. CALIOP) and it could be important in understanding the radiative effects of smoke in models.
- Observed changes in the spectral depolarization in various smoke plumes might provide more information about the smoke microphysics or aging. Further analyses using the depolarization and lidar ratio are required to assess the information content of the smoke particle microphysics (i.e. particle structure, number of primary particles).

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