Airborne High Spectral Resolution Lidar Aerosol/Ice/Cloud observations during ARCTAS/ISDAC

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Background

During the joint 2008 Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS)/Indirect and Semi-Direct Aerosol Campaign (ISDAC) field mission, the NASA Langley Research Center (LaRC) airborne High Spectral Resolution Lidar (HSRL) on the NASA B200 aircraft measured profiles of particulate extinction (532 nm), backscatter (532 and 1064 nm), and depolarization (532 and 1064 nm).

HSRL Technique

- Independently measures aerosol backscatter, extinction, and optical thickness
- Internally calibrated
- Provides **intensive** aerosol parameters to help determine aerosol type
- System and technique: see Hair et al., Appl. Optics, 2008
- Validation: see Rogers et al., ACP, 2009

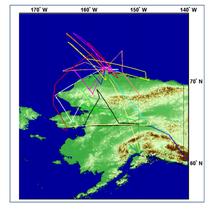
LaRC HSRL Products

- Scattering ratio (532 nm)
- Backscatter coefficient (532, 1064 nm)
- Extinction coefficient (532 nm)
- **Backscatter Wavelength Dependence (532/1064 nm)**
- **Lidar ratio (532 nm)**
- **Depolarization (532, 1064 nm)**

Flight Summary

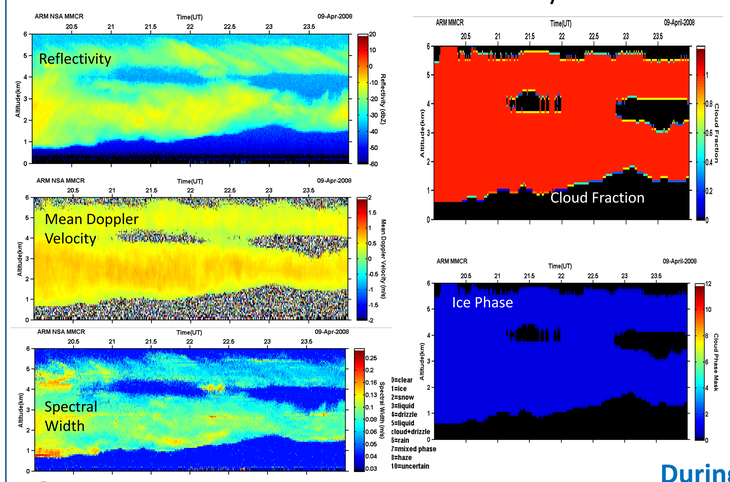
Spring (April, 2008)

- B200 based in Barrow, Alaska
- 15 science flights, 60 hours science
- 5 flights coordinated with NASA DC-8
- 3 flights coordinated with NASA P-3
- 3 flights coordinated with NOAA P-3
- 5 flights coordinated with DOE-sponsored Convair 580
- 12 flights included underpass of CALIPSO
- 10 flights over DOE ARM NSA

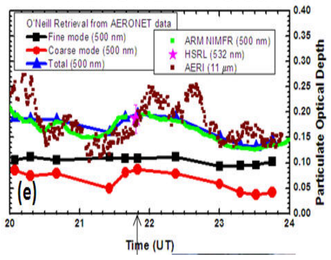


April 9 case: Clear or Cloudy?

Millimeter Cloud Radar — Cloudy

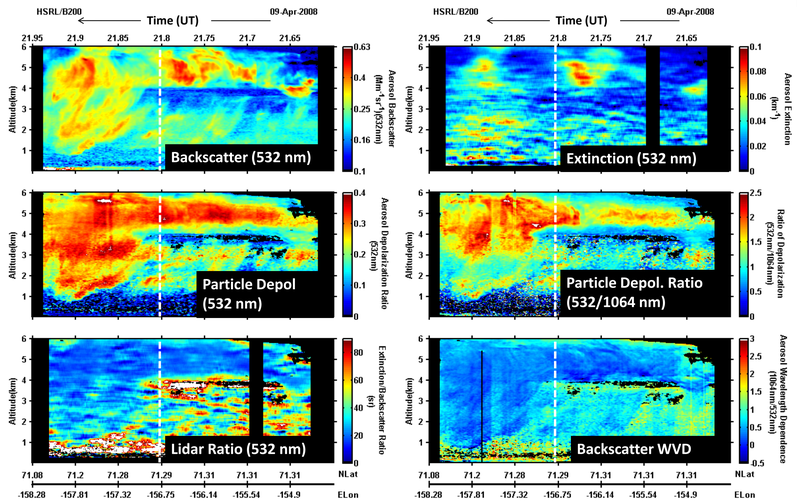


AERONET — Clear

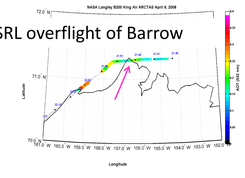


Total Sky Imager — Clear

HSRL — Optically thin Ice

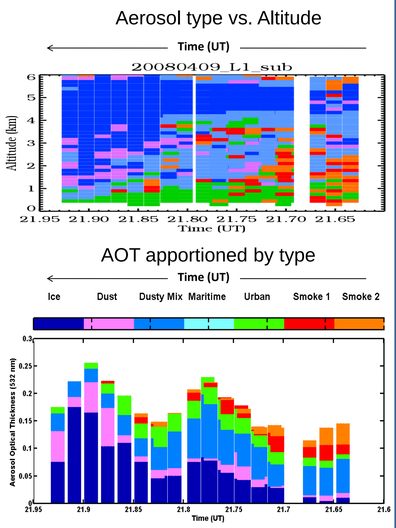


HSRL overflight of Barrow



HSRL measurements show extensive layers of ice crystals can contribute significantly to particulate optical depth derived from surface based passive instruments.

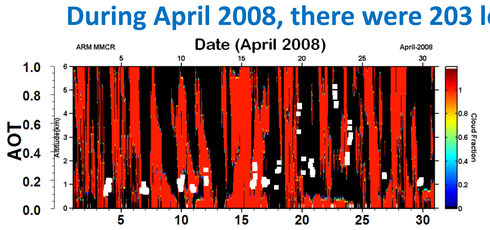
Aerosol type vs. Altitude



Answer:

Radar shows cloudiness, but Total Sky Imager and AERONET indicate clear sky condition.
The radar is sensitive to larger particles, which are few enough that the optical instruments are not sensitive to them.

During April 2008, there were 203 level 2 AERONET AOT measurements

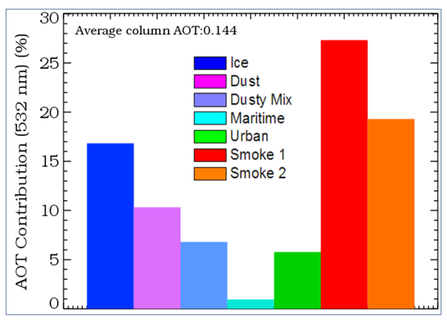


- Of these 203 AERONET measurements, coincident Microbase results showed:
  - 80 (39%) were cloud-free; 123 (61%) had clouds
  - 107 (53%) had cloud thickness of at least 200 m
  - 95 (47%) had cloud thickness of at least 500 m
  - 78 (38%) had cloud thickness of at least 1 km

When interpreting AERONET or other column AOT measurements over Barrow, be aware that some of these smaller particles can be ice crystals, not aerosol (e.g. dust, smoke, pollution). The HSRL measurements of lidar ratio and depolarization are especially helpful for discriminating these small ice crystals from aerosols.

Apportionment of Aerosol Optical Thickness

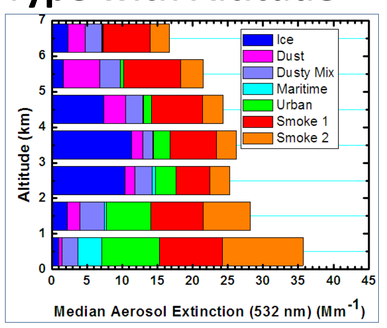
- HSRL intensive parameter measurements were used in a cluster analysis scheme to discriminate aerosol type
- Aerosol optical thickness was apportioned to seven aerosol types
- Smoke 1 — higher lidar ratio, more often lofted (aged)
- Smoke 2 — lower lidar ratio, closer to surface (fresh)
- ARCTAS 1 and 2 were dominated by smoke
- ARCTAS 1 had significant fraction (~17%) of aerosol type classified as ice



Variation of Aerosol Type with Altitude

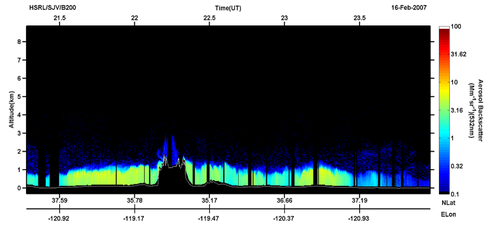
ARCTAS 1 (Spring – Alaska)

- Ice was pronounced from 2-5 km
- Dust fraction increased with altitude
- Lowest altitudes — variety of types
- Urban type decreased with altitude

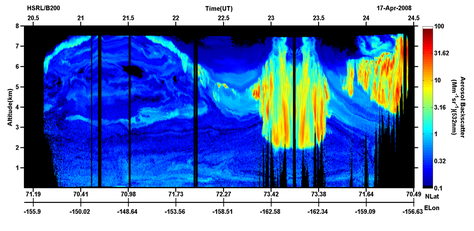


Vertical Distribution of Aerosols

San Joaquin Valley, California, Feb. 16, 2007



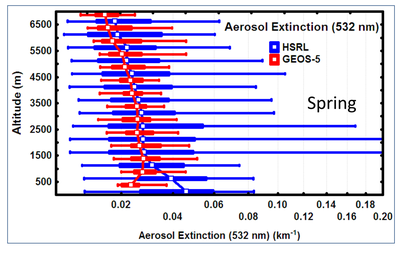
Barrow, Alaska, Apr. 17, 2008

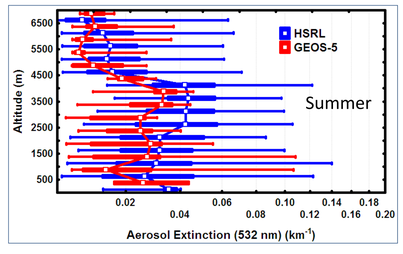


During ARCTAS aerosols were distributed throughout the entire troposphere and not primarily in the lowest 1-2 km, in contrast to previous HSRL missions at lower latitudes

Evaluation of NASA GEOS-5 Model Reanalysis Results

- GEOS-5 Model - atmospheric general circulation model and data assimilation system
  - Aerosols simulated using online version of GOCART
  - Inventory based emissions of anthropogenic and biogenic aerosol
  - Biomass burning emissions from daily MODIS fire counts calibrated with Global Fire Emissions Database
- Reanalysis results computed for ARCTAS are evaluated using airborne HSRL data
- Median aerosol extinction profiles in good agreement with median HSRL extinction profiles





Summary

- Smoke was the dominant aerosol type inferred from HSRL measurements
- Significant fraction of aerosol type classified as ice
- Dust (urban) type increased (decreased) with altitude
- Aerosols distributed throughout troposphere, unlike campaigns at lower latitudes
- HSRL and GEOS-5 median aerosol extinction profiles in good agreement

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