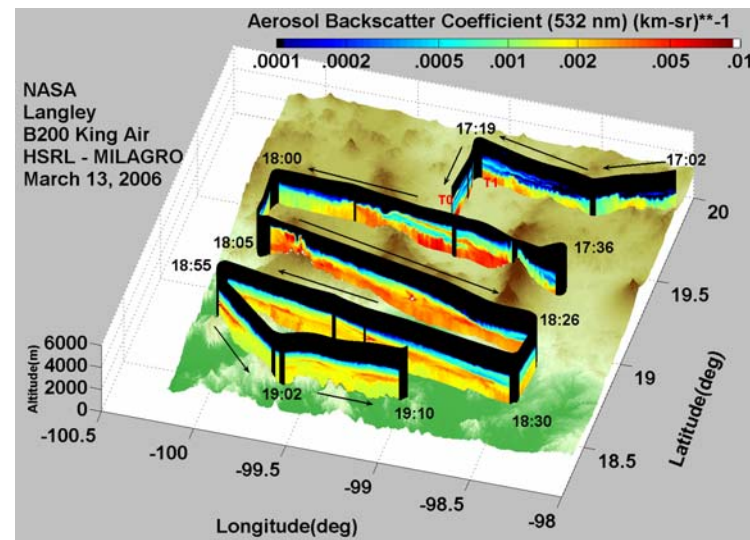


Airborne High Spectral Resolution Lidar Aerosol Measurements



John Hair, Chris Hostetler, Richard Ferrare, Anthony Cook, David Harper

NASA Langley Research Center, Hampton, VA

Sharon Burton

Science Systems and Applications, Inc./NASA Langley Research Center

Antony Clarke

University of Hawaii

Phil Russell, Jens Redemann

NASA Ames Research Center

Larry Kleinman

Brookhaven National Laboratory



Funded by

NASA HQ Science

Mission Directorate

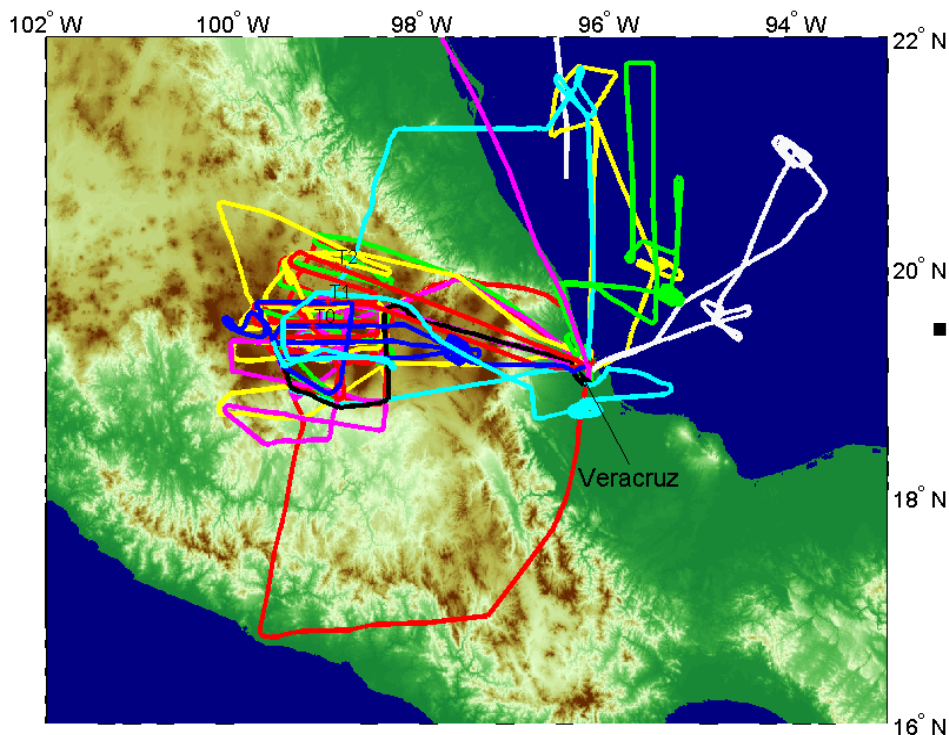
Radiation Sciences Program

Funded by

Department of Energy

Atmospheric Science Program

Airborne High Spectral Resolution Lidar (HSRL)



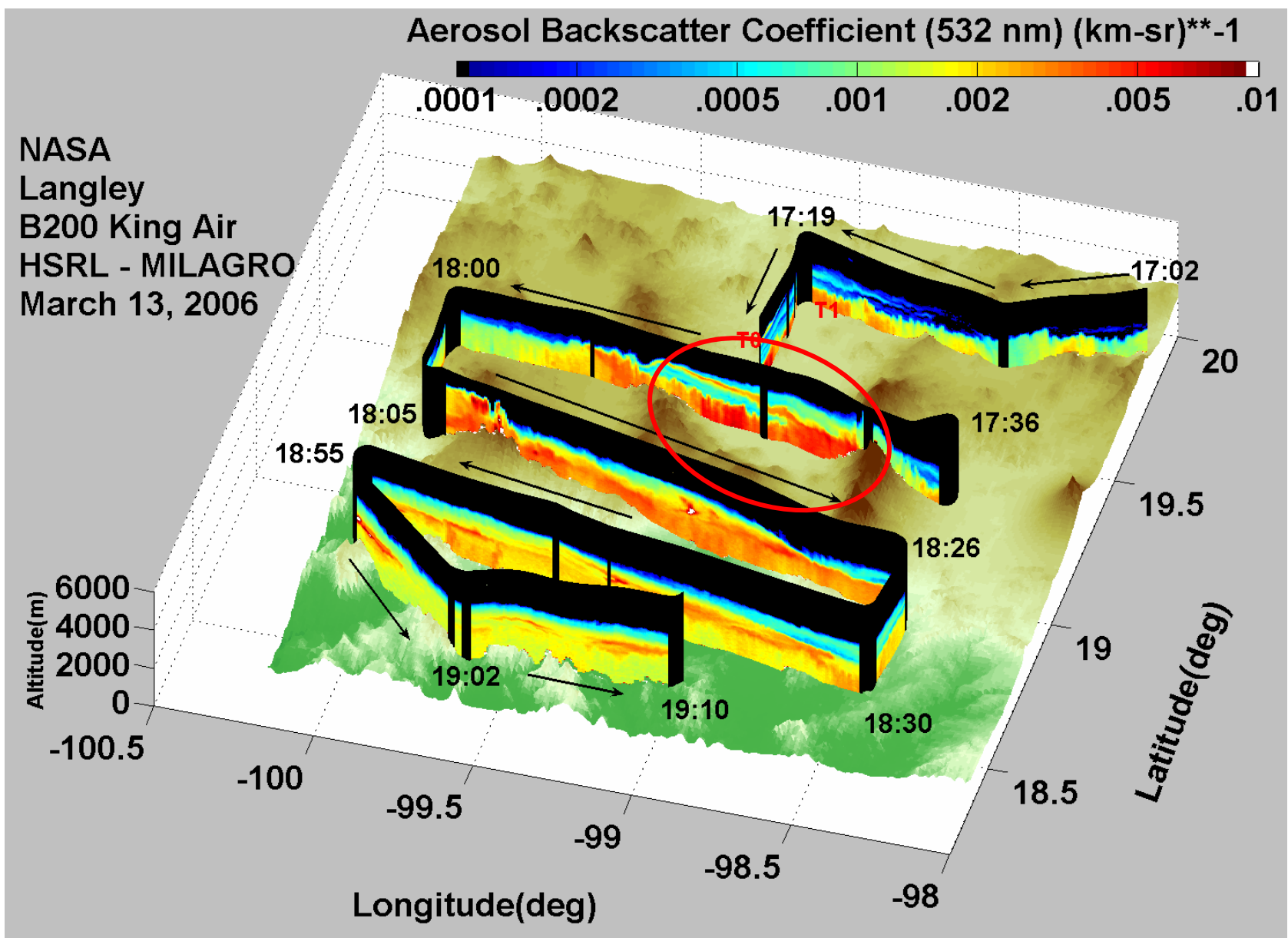
- Focused on providing quantitative measurements of aerosol optical properties
- Different from standard backscatter lidars: **independently measures backscatter and extinction (532 nm)**
 - Aerosol backscatter (532, 1064 nm) ($\Delta x \sim 1$ km, $\Delta z \sim 60$ m)
 - Aerosol extinction (532 nm) ($\Delta x \sim 6$ km, $\Delta z \sim 300$ m)
 - Aerosol depolarization (532, 1064 nm) ($\Delta x \sim 1$ km, $\Delta z \sim 60$ m)
- 15 science flights, 60 flight hours
 - 5 flights with J-31
 - 6 flights with G-1
 - 4 flights with C-130
 - 5 MISR coincidences
 - 9 MODIS coincidences
 - 11 overpasses of T0
 - 8 overpasses of T1

- Map vertical and horizontal distribution of aerosols
 - Use profiles of extinction, backscatter, and depolarization to characterize the vertical distribution of aerosol optical properties *and type*
 - Determine relative contribution of various aerosol types to aerosol extinction and optical depth
 - Provide vertical context for in situ measurements on the G-1 and C-130 and remote measurements on the J-31 and use the in situ measurements to assess the inferred aerosol types from the HSRL lidar.
 - Compare observations to model transport predictions – Jerome Fast
 - Compare aerosol extinction and optical depth measurements with sensors on J-31, G-1, and C-130 – Phil Russell

- Assess satellite (MODIS, MISR) retrievals

- Investigate active–passive retrieval techniques of aerosol optical and microphysical properties

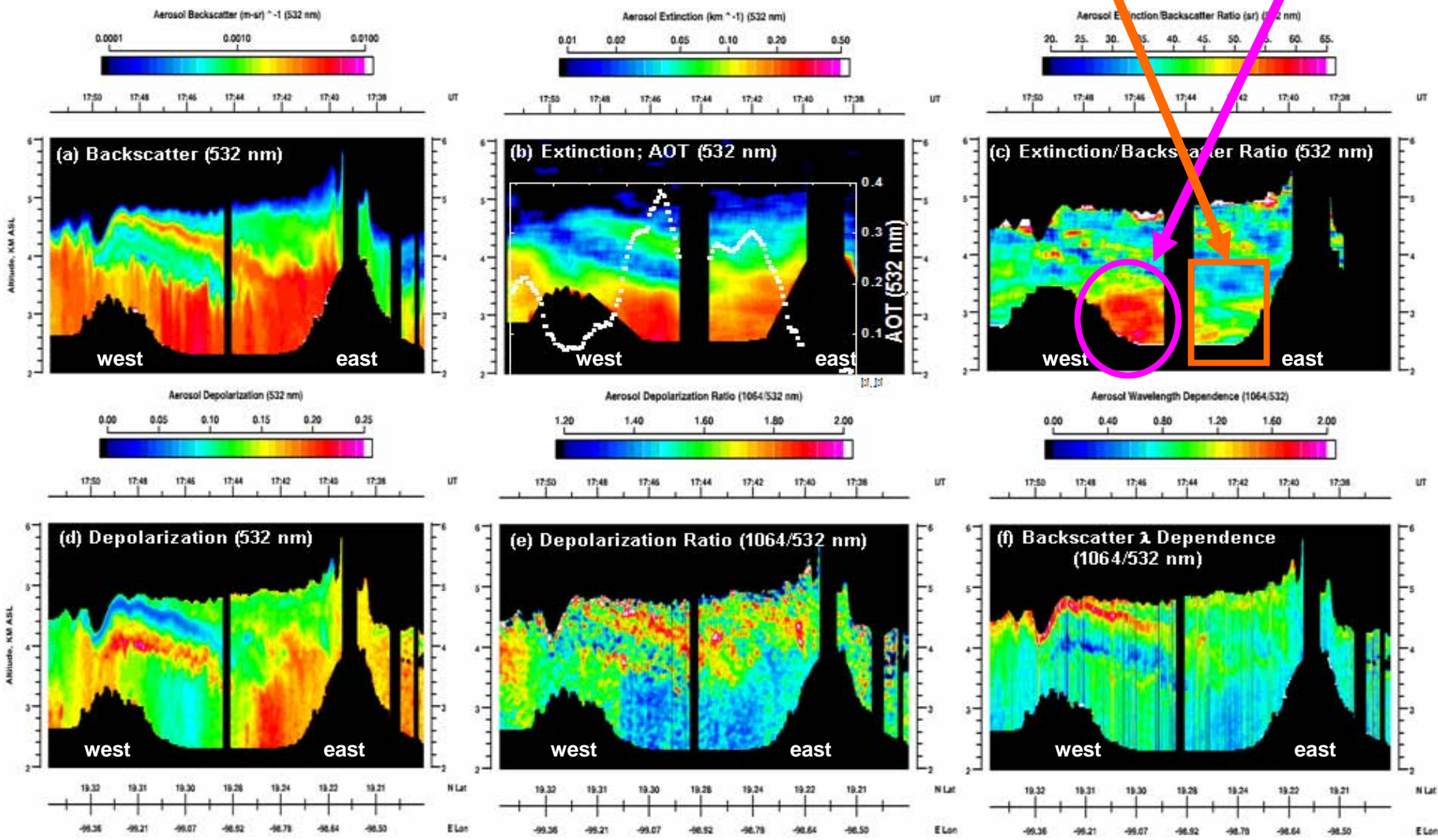
Characterizing Aerosol Spatial Distribution



Characterizing the spatial distribution of aerosol type

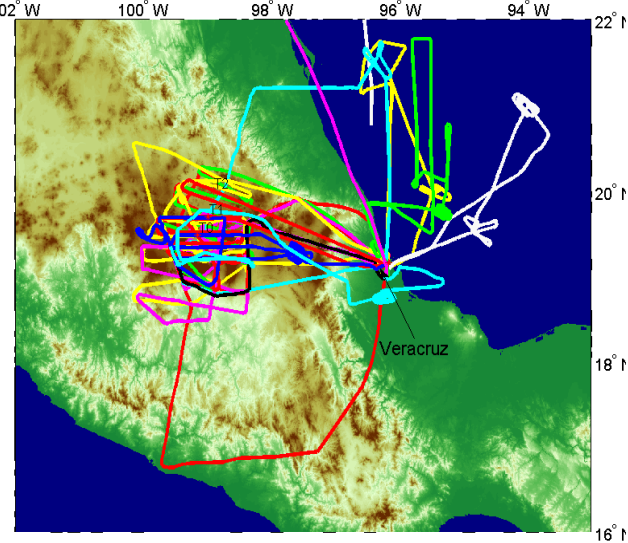
LaRC Airborne HSRL Measurements over Mexico City, March 13, 2006

- western part of city- high S_a , high WVD, low depolarization – urban aerosol
- eastern part of city - low S_a , low WVD, high depolarization – dust



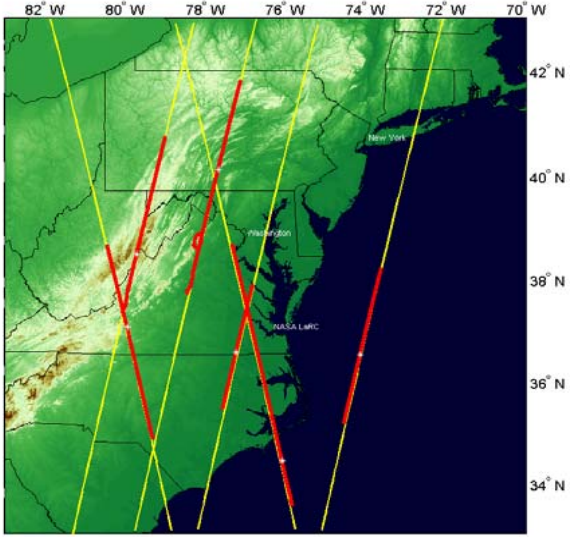
Recent Field Missions

3 major field campaigns during 2006 (over 200 flight hours)



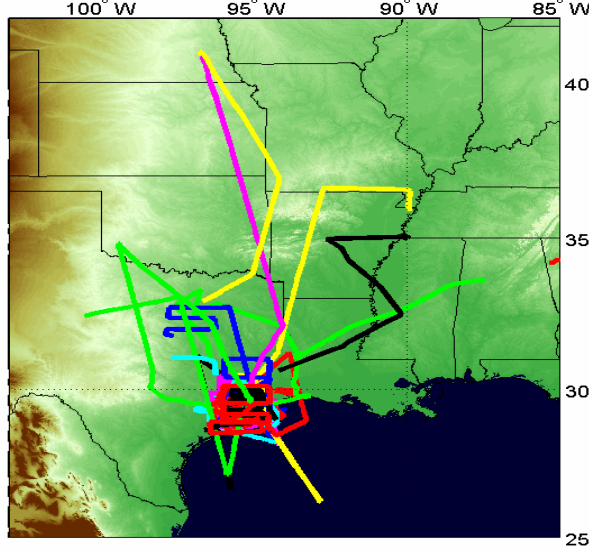
MILAGRO
International, Multi-agency
DOE-NSF-NASA-Mexico
March 1-30

- 15 science flights,
60 flight hours**
- 5 flights with J-31
 - 6 flights with G-1
 - 4 flights with C-130
 - 5 MISR coincidences
 - 9 MODIS coincidences



CALIPSO Validation
Phase 1
June 14-30

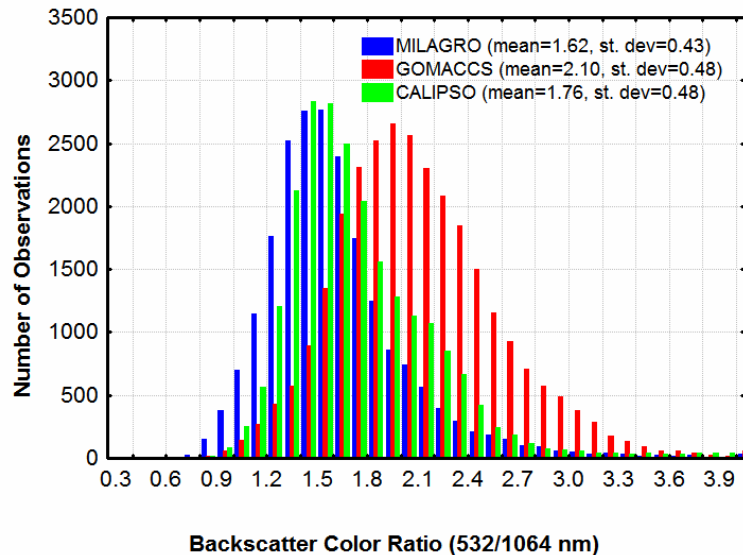
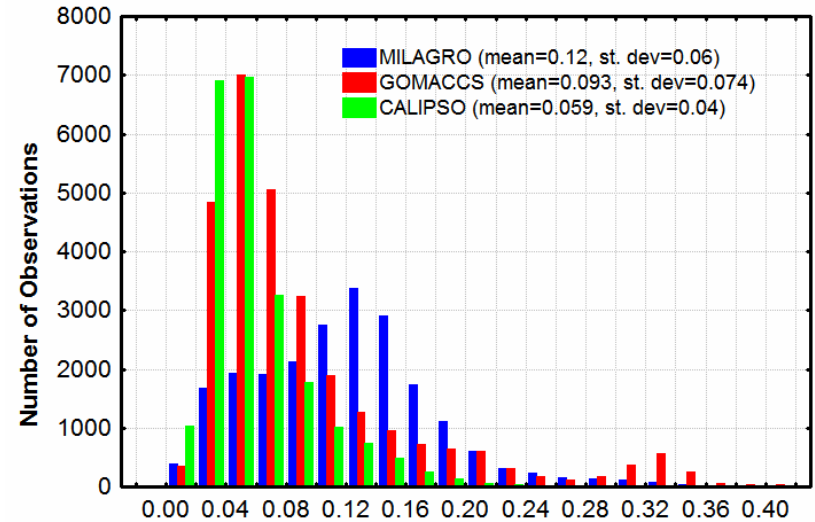
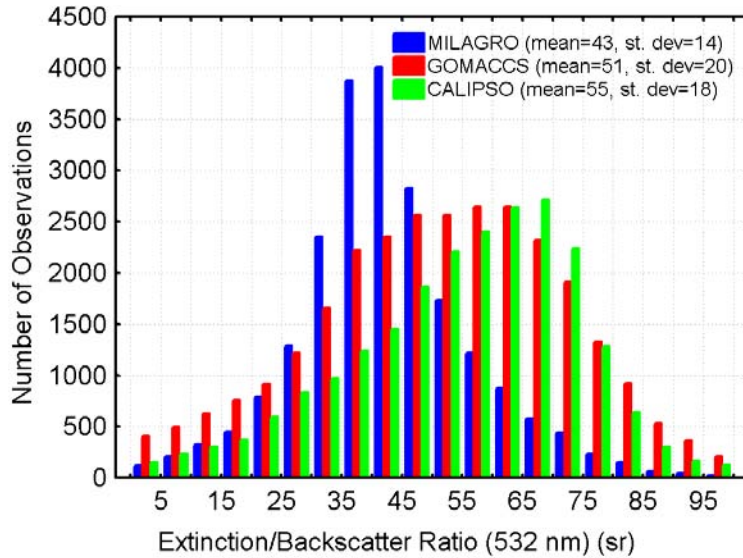
- 20 CALIPSO validation
flights**
- 8 night flights
 - 12 day flights
 - 5 flights coordinated with other platforms on TexAQS/GoMACCS



TexAQS II/GoMACCS
NOAA-DOE-NASA
Aug 27 – Sep 29

- 22 science flights,
>90 flight hours**
- 7 flights with NOAA WP-3
 - 6 flights with NOAA Twin Otter
 - 7 flights with CIRPAS Twin Otter
 - 2 flights over the RHB
 - Numerous Overflights of Moody Tower
 - 10 CALIPSO validation flights
 - 4 MISR LM coincidences
 - 14 MODIS coincidences

Aerosol Intensive Parameters derived from HSRL data



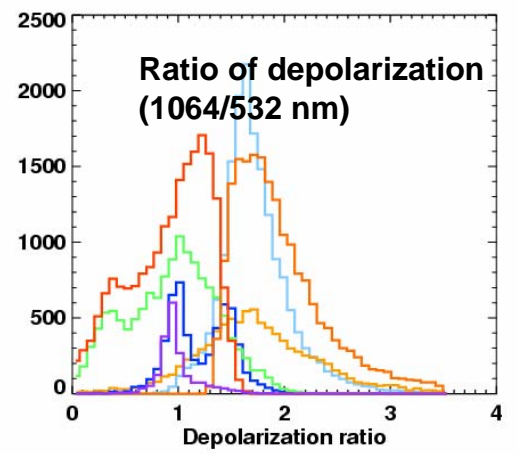
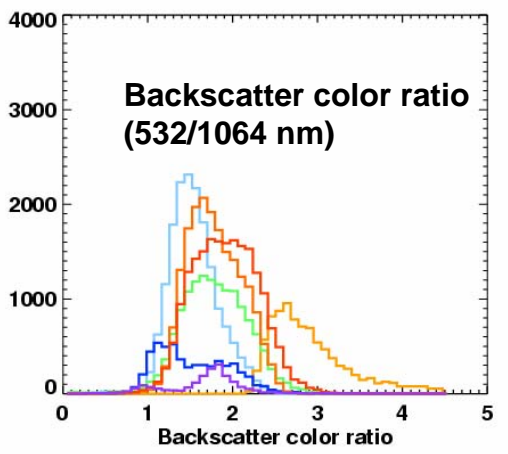
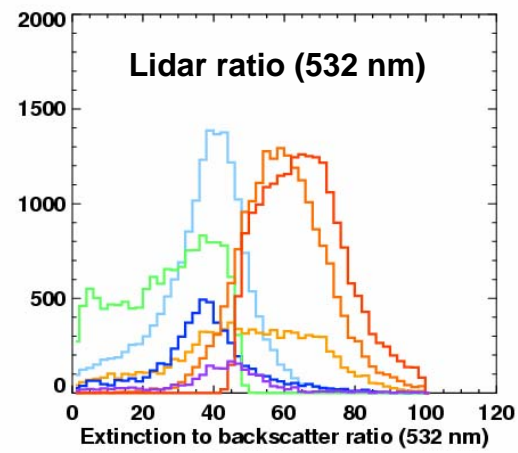
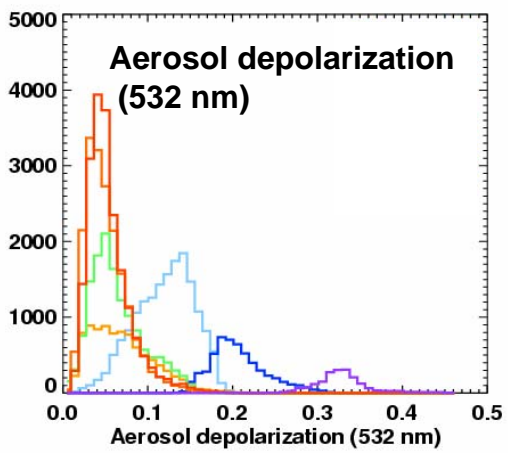
- **MILAGRO**
 - higher depolarization, smaller color ratio, smaller S_a
 - larger, more non-spherical
 - dominated by “dust”
- **GOMACCS/CALIPSO**
 - smaller depolarization, higher color ratio, larger S_a
 - smaller, more spherical
 - dominated by “urban/biomass”

Characterization of aerosol types using HSRL Data

- HSRL measurements from MILAGRO, CALIPSO, GOMACCS
- Cluster analysis of HSRL aerosol intensive parameters used to determine major aerosol types

- 1 pure dust
- 2 dust (large)
- 3 dust (small)+urban
- 4 oceanic
- 5 urban (small)+biomass
- 6 urban (large)+urban (small)+biomass
- 7 biomass+urban (large)+urban (small)

Cluster histograms for vars4clus7manual_3strict

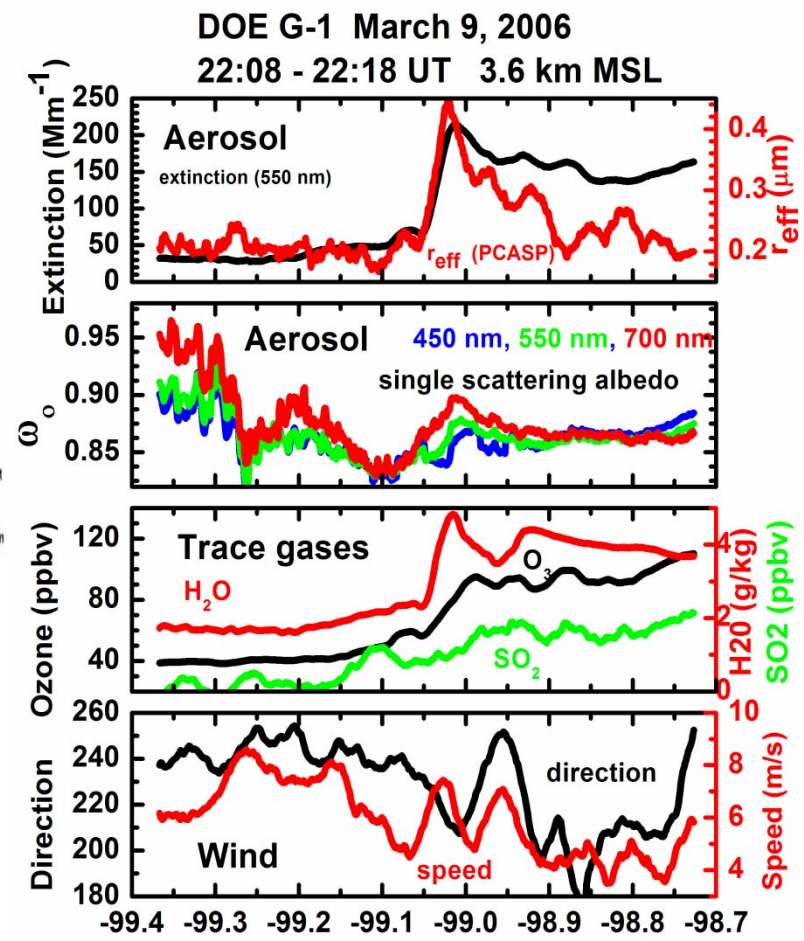
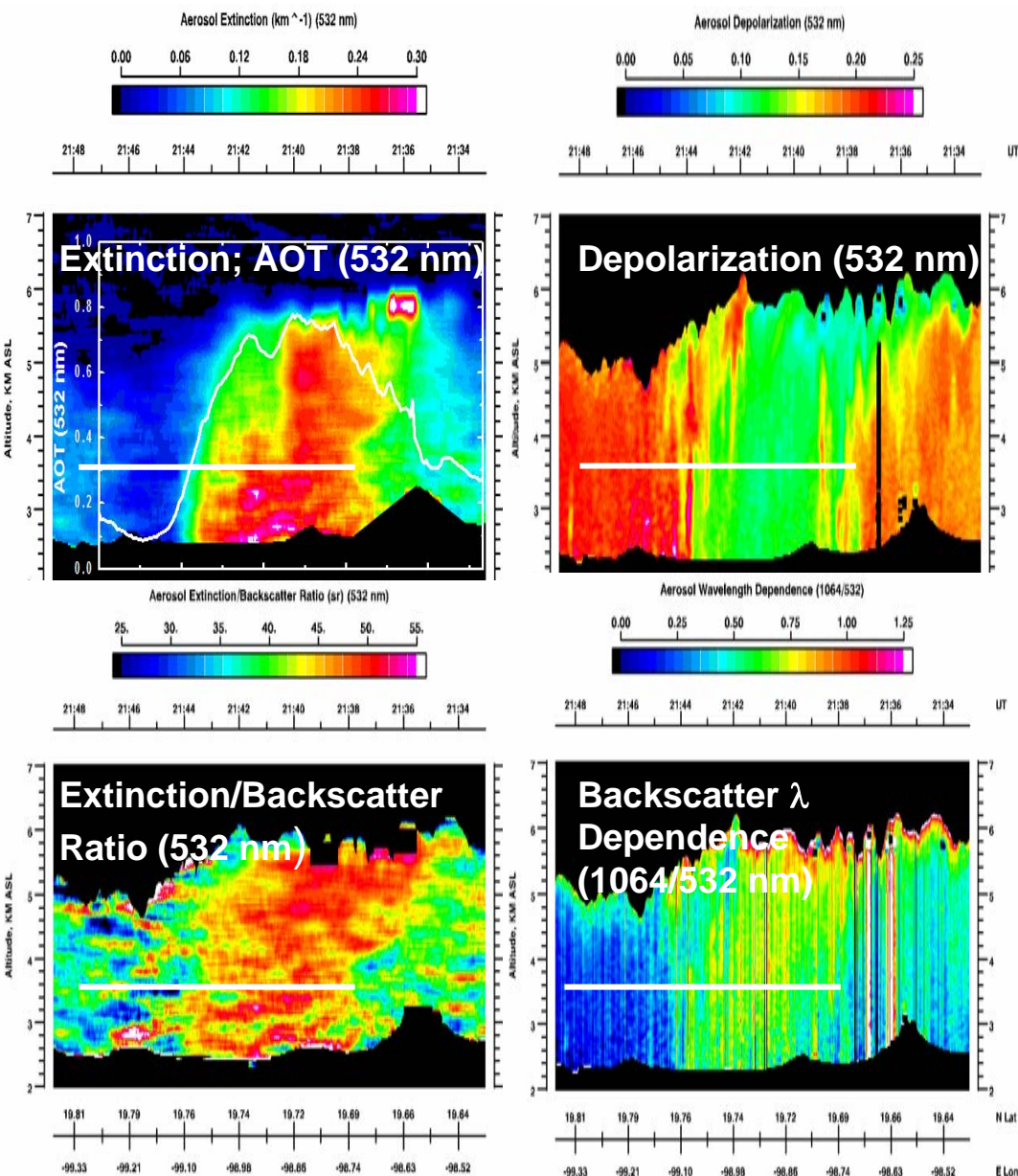




Characterizing/Assessing aerosol optical properties/type

Providing vertical context for G-1 in situ measurements

NASA King Air & DOE G-1
coordinated flight – March 9, 2006



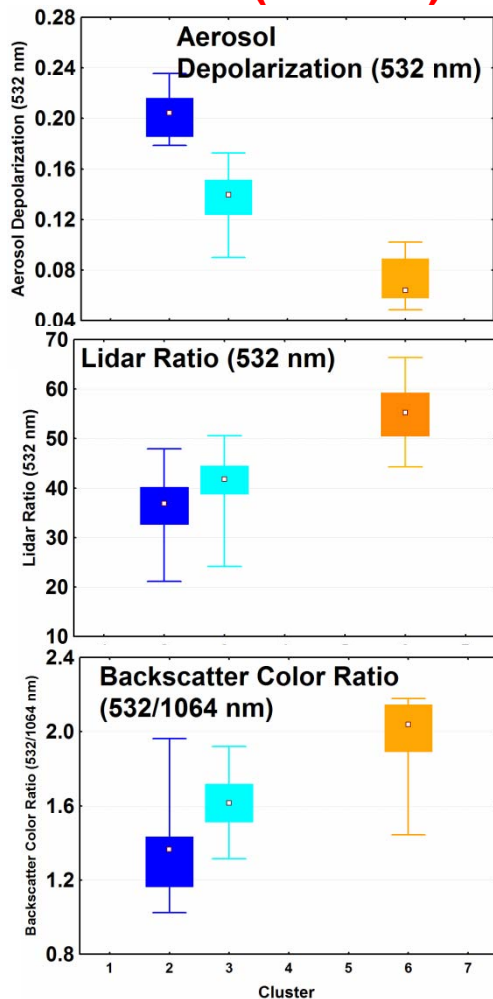
PRELIMINARY DATA

Assessment of Inferred Aerosol Types

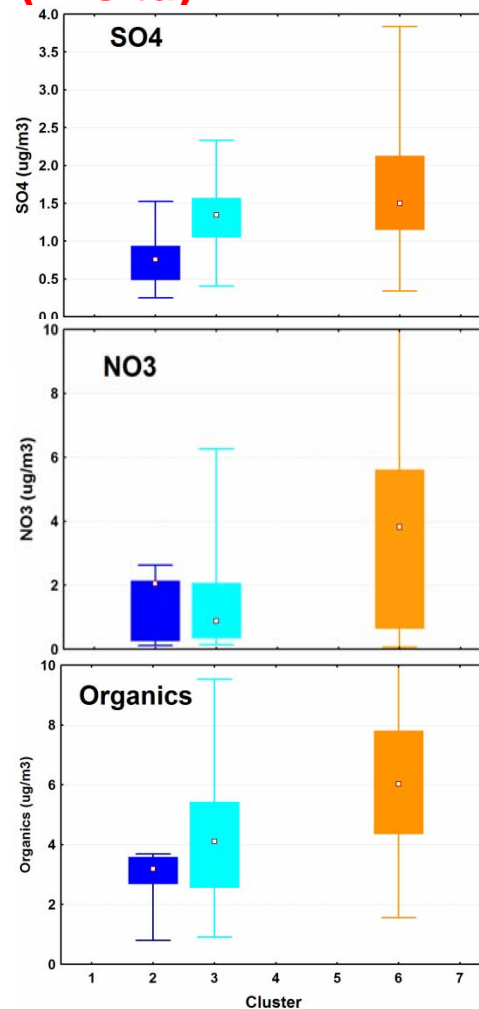
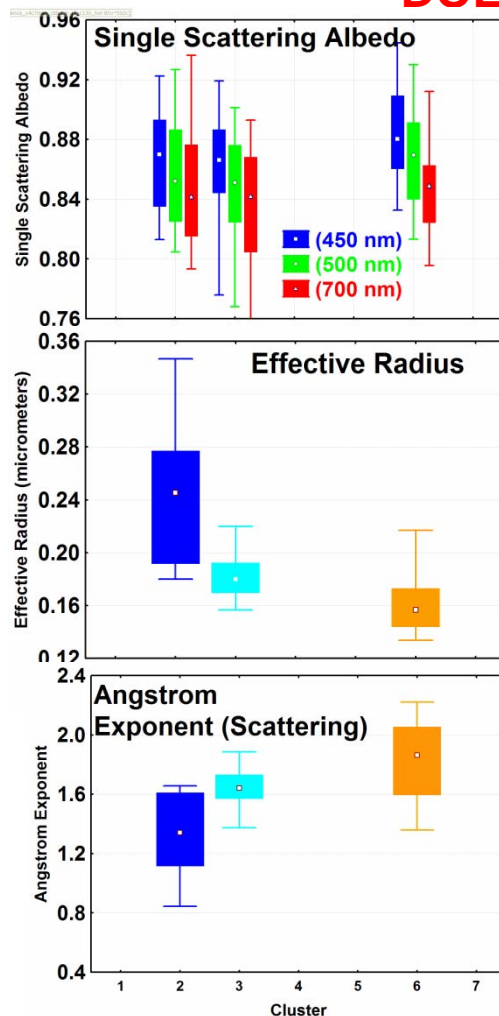
In situ measurements generally support inferred aerosol types

- nonspherical, larger dust (HSRL) → larger, slightly more absorbing particles (G-1)
- smaller, urban/biomass (HSRL) → smaller, slightly less absorbing particles (G-1)

HSRL (remote)



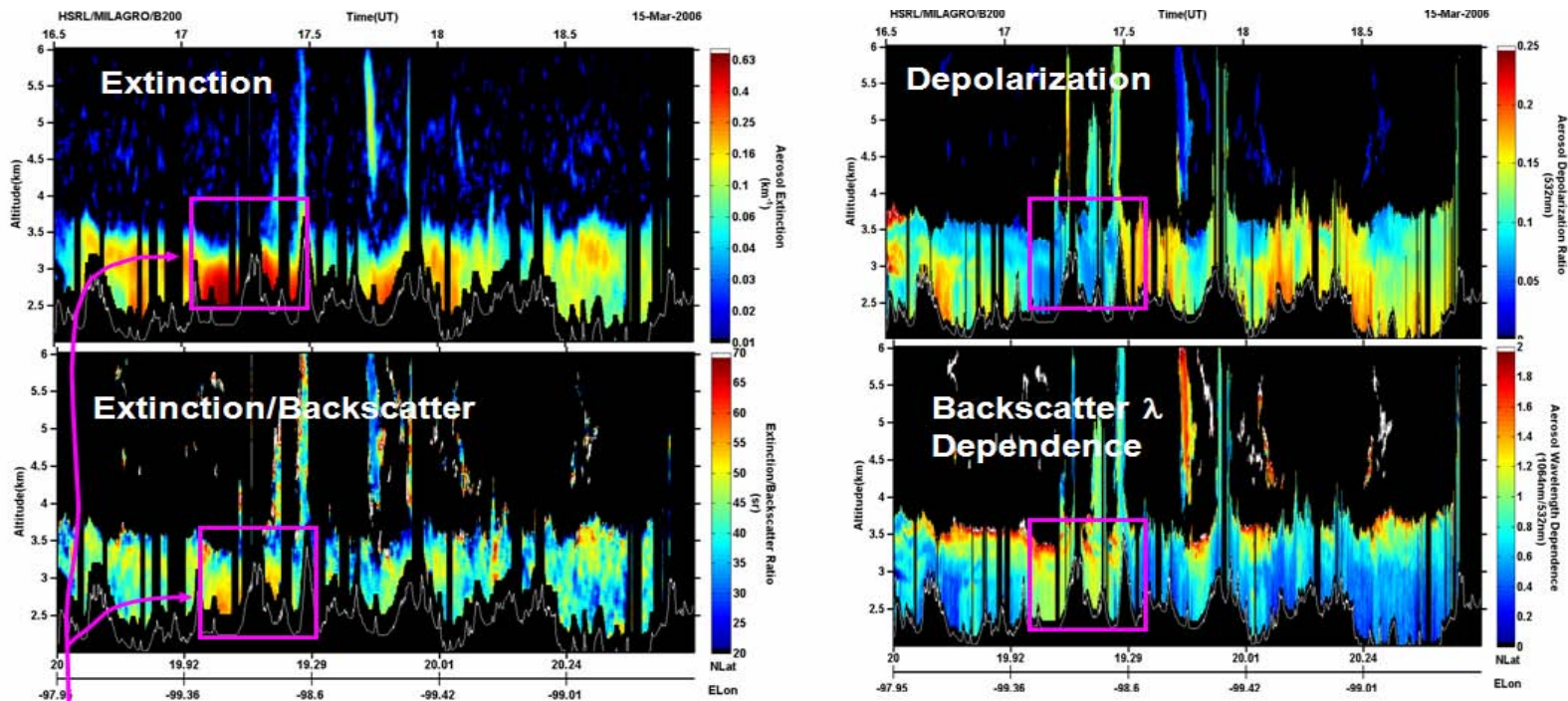
DOE G-1 (in situ)



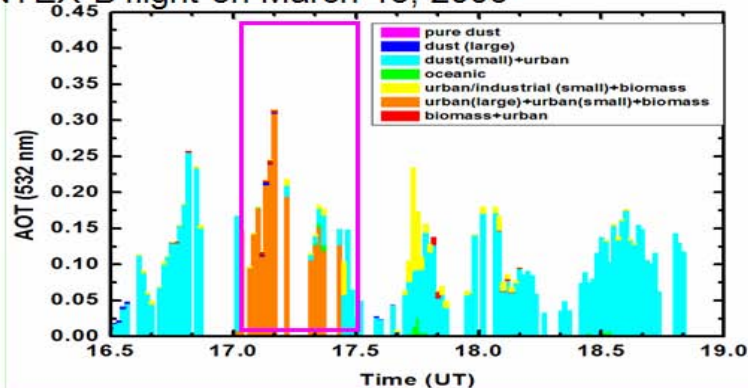
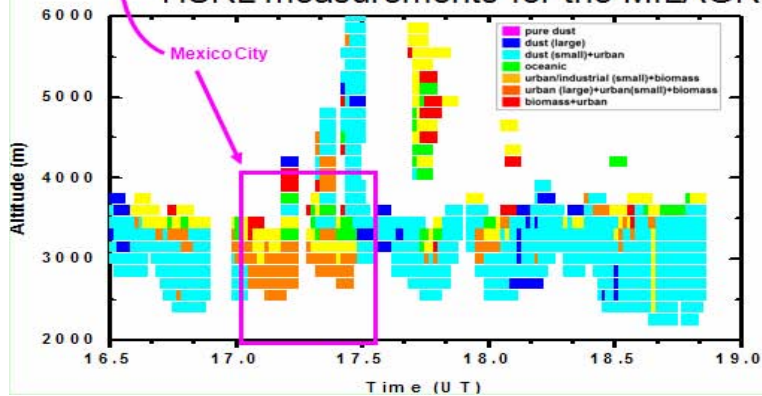
Aerosol Characterization Example



March 15, 2006 flight around Mexico City



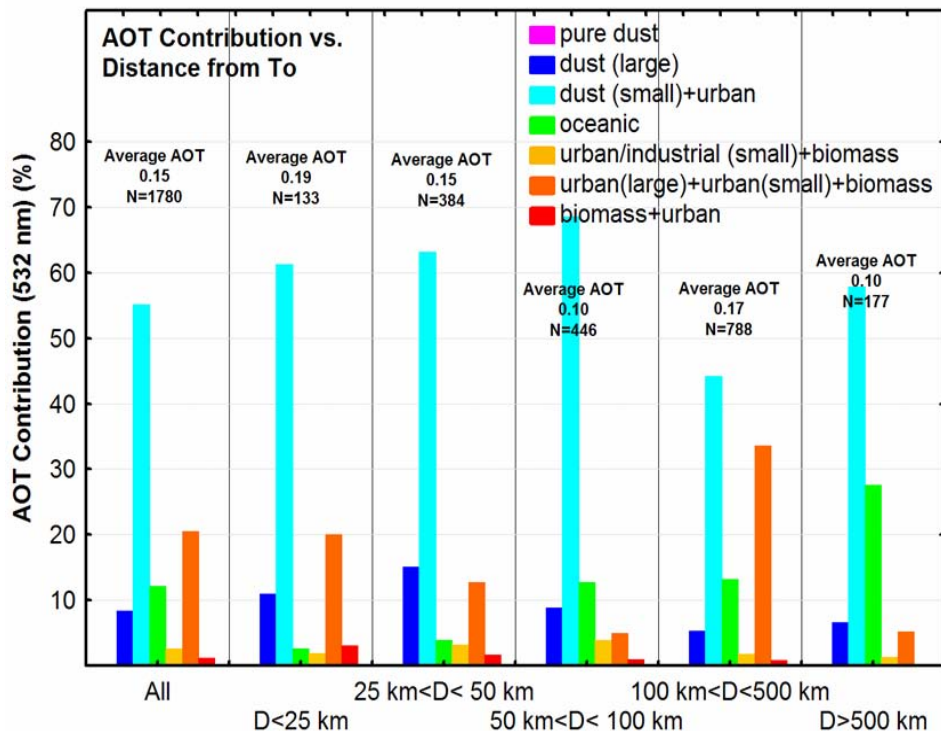
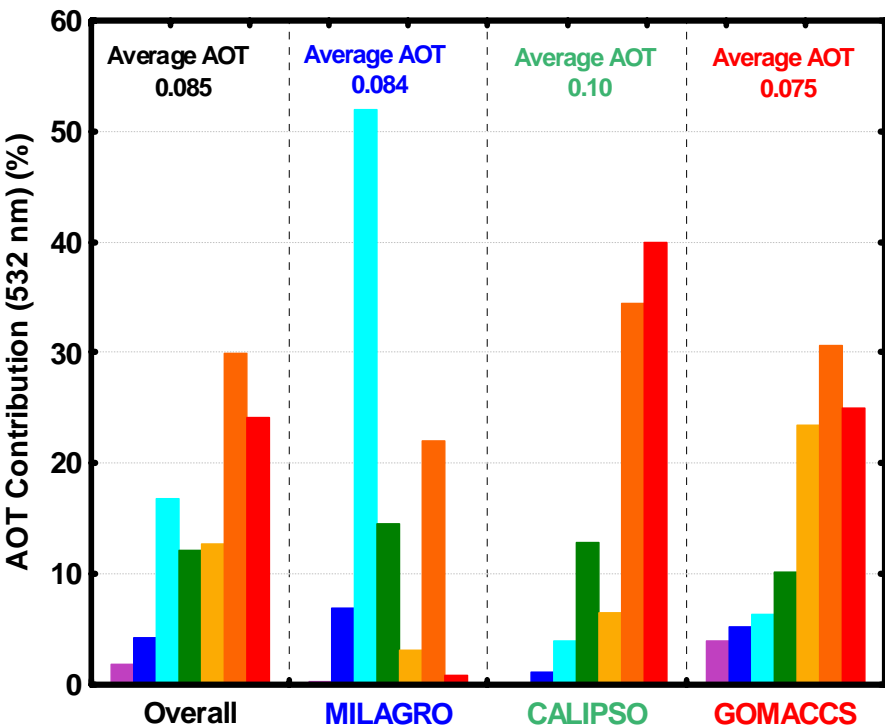
HSRL measurements for the MILAGRO/INTEX-B flight on March 15, 2006



Apportionment of Aerosol Optical Thickness

- MILAGRO
 - AOT dominated by dust
- CALIPSO/GOMACCS
 - AOT dominated by urban/biomass

For distances within 100 km, urban mixture contribution decreases with increasing distance



Summary and Future Analyses



- **NASA/LaRC airborne HSRL acquired extensive aerosol data during MILAGRO/MAX-Mex/INTEX-B.**
 - **Data Archived (INTEX-B Archive), HDF Files also available**
 - **Data Images and flight track maps available on website**
 - ***<http://science.larc.nasa.gov/hsrl/>***
- **HSRL aerosol measurements are used to infer aerosol types**
- **MILAGRO (Mexico City) – aerosols were dominated by nonspherical dust particles**
- **CALIPSO/GOMACCS (eastern U.S. and Houston) – aerosols were more characteristic of urban/biomass**

Future Studies

- Assess aerosol model simulations
- Compare aerosol extinction and optical depth measurements with sensors on J-31, G-1, and C-130
- Integrate HSRL measurements with airborne and surface aerosol measurements to assess aerosol optical and physical properties
- Assess satellite (MODIS, MISR) retrievals
- Investigate active–passive retrieval techniques of aerosol optical and microphysical properties

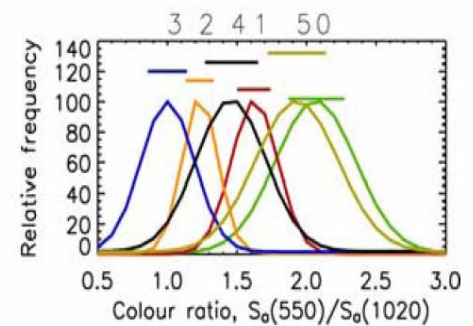
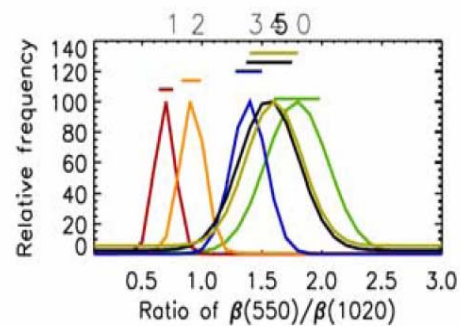
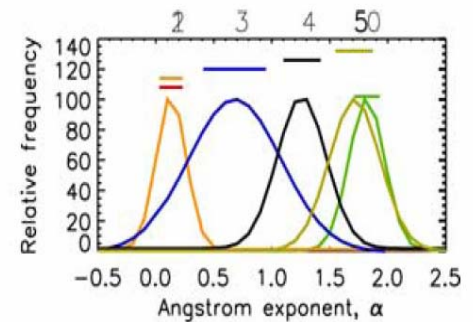
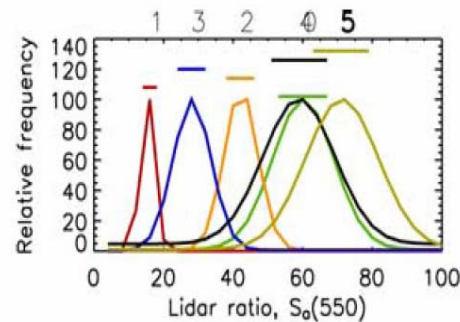


End of Presentation

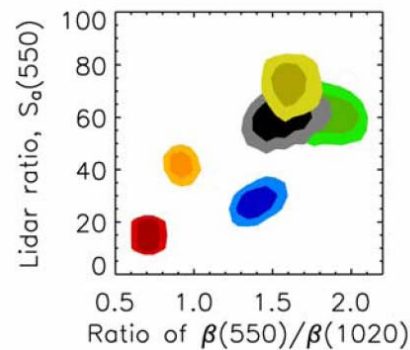
Backup Slides

Characterization of aerosol types using HSRL Data

- Use aerosol intensive parameters
 - backscatter, extinction wavelength dependence
 - depolarization
 - extinction/backscatter ratio derived from lidar measurements to infer aerosol types



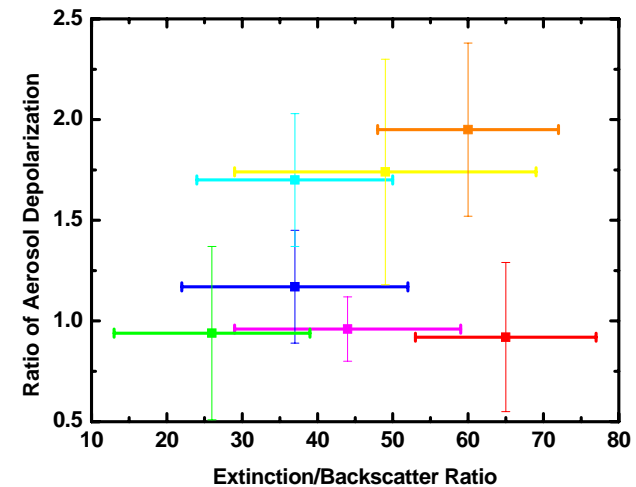
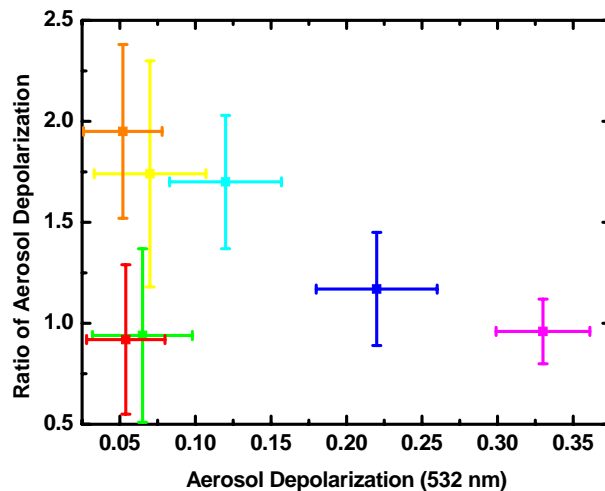
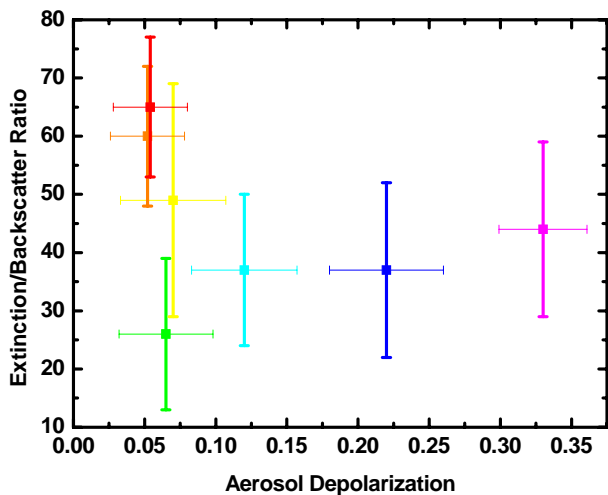
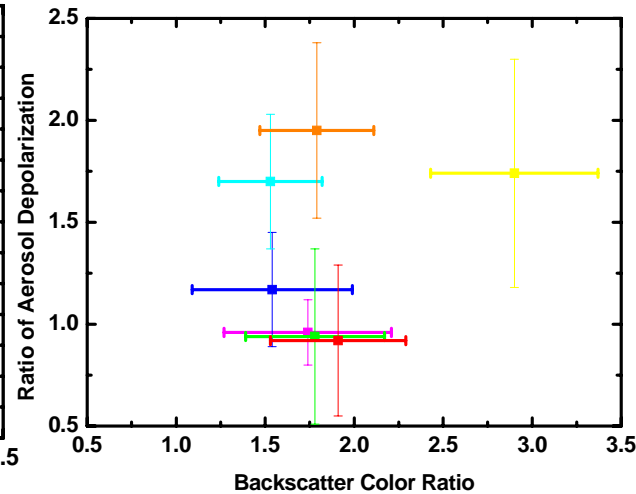
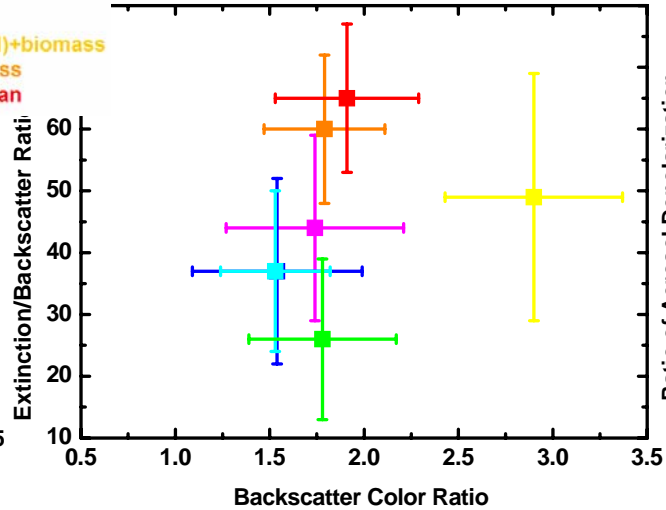
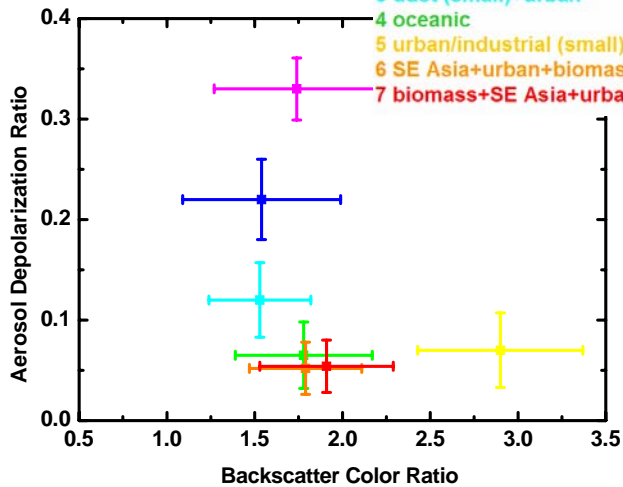
- Lidar aerosol intensive parameters corresponding to various aerosol types were derived using ground based AERONET retrievals (Cattrall et al., 2005)



- 0 — Biomass burning
- 1 — Dust(spheres)
- 2 — Dust(spheroids)
- 3 — Oceanic
- 4 — SE Asia
- 5 — Urban/Industrial

Characterization of aerosol types using HSRL Data

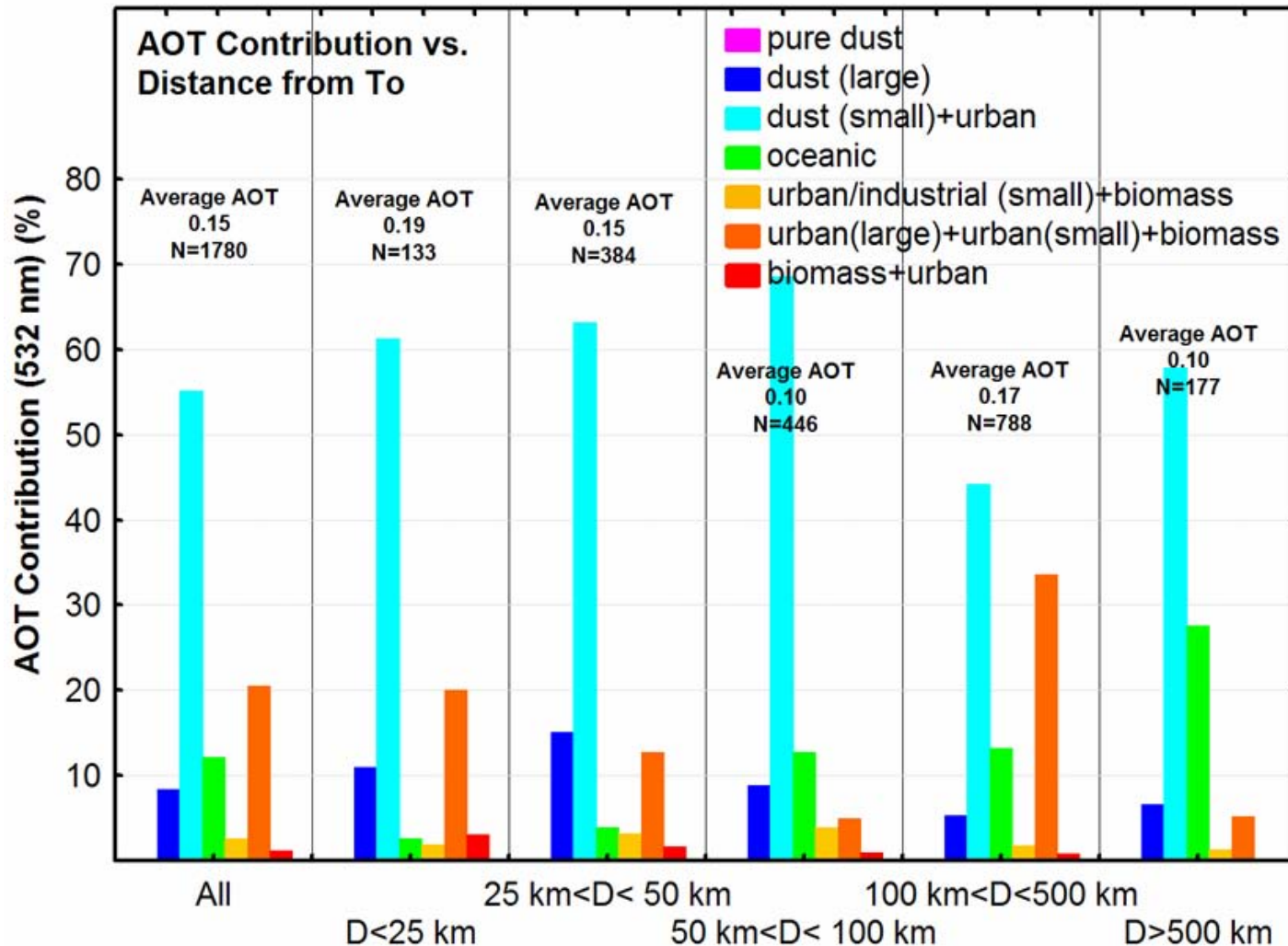
- 1 pure dust
- 2 dust (large)
- 3 dust (small)+urban
- 4 oceanic
- 5 urban/industrial (small)+biomass
- 6 SE Asia+urban+biomass
- 7 biomass+SE Asia+urban



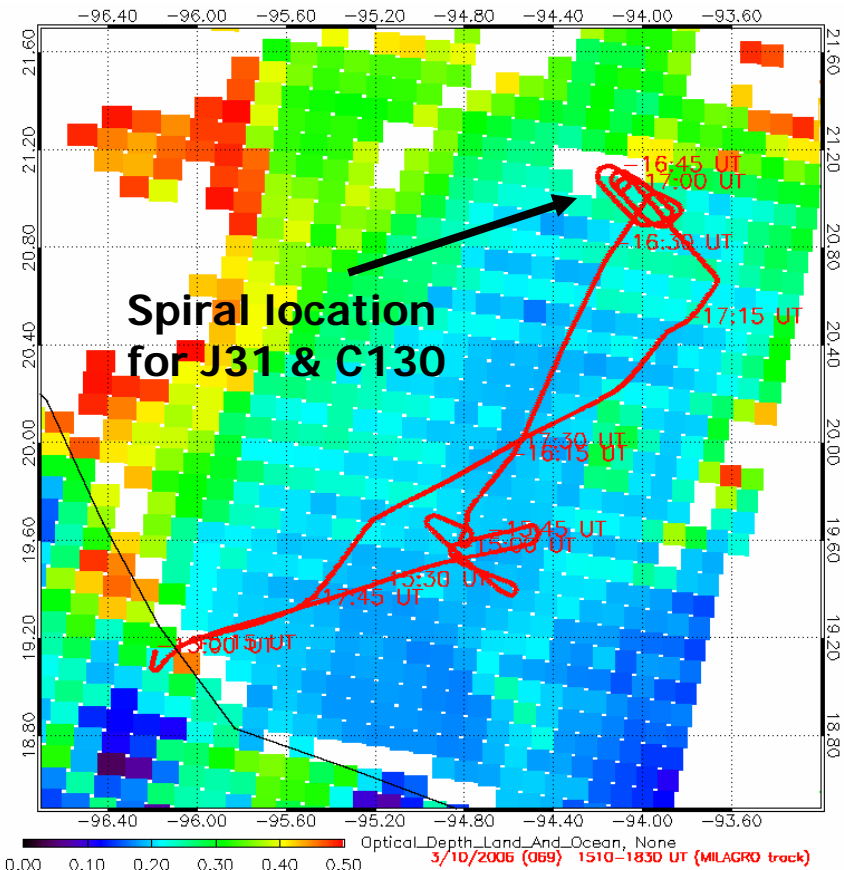


Apportionment of Aerosol Optical Thickness vs. Distance from Mexico City

For distances within 100 km, urban mixture contribution decreases with increasing distance

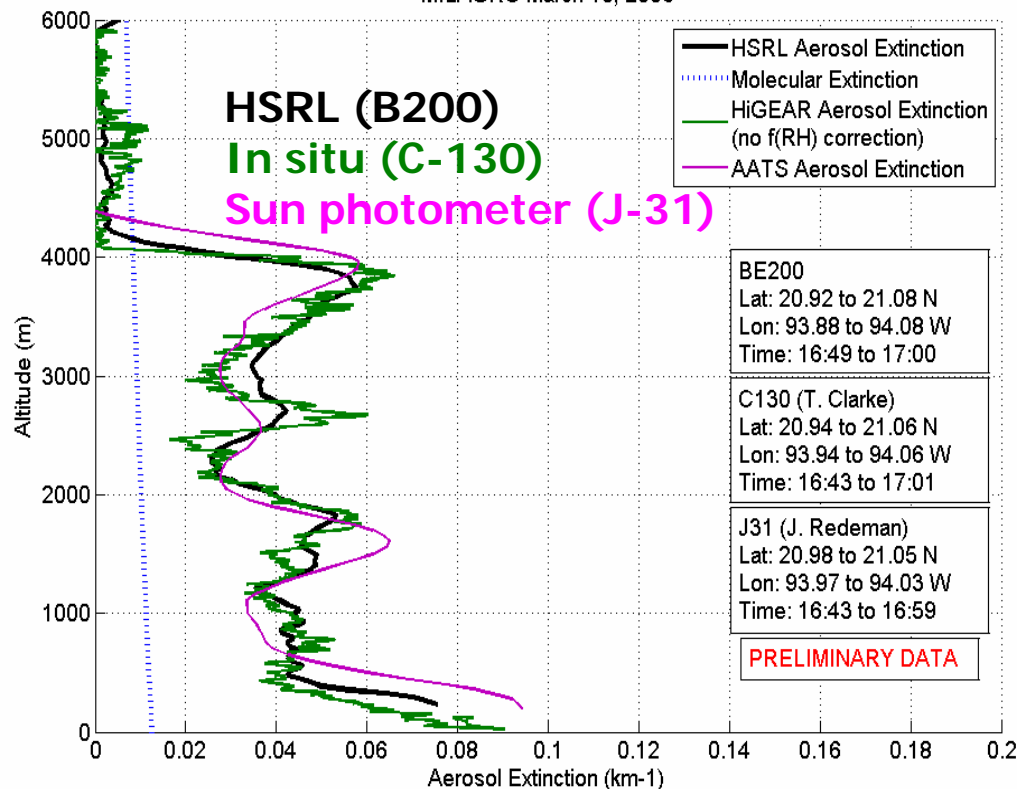


MODIS Optical Depth



Aerosol Extinction

HSRL/BE200 & HiGEAR/C130 & AATS-14/J31
MILAGRO March 10, 2006



- Several flights coincident with MODIS (10) and MISR (5) for retrieval studies
- Coordinated flights with J-31 and C-130 for comparison of data products (aerosol extinction) and retrieval studies (e.g., combined HSRL and RSP photo-polarimeter)