Overview of NASA King Air Operations on MILAGRO/MAX-MEX/INTEX-B

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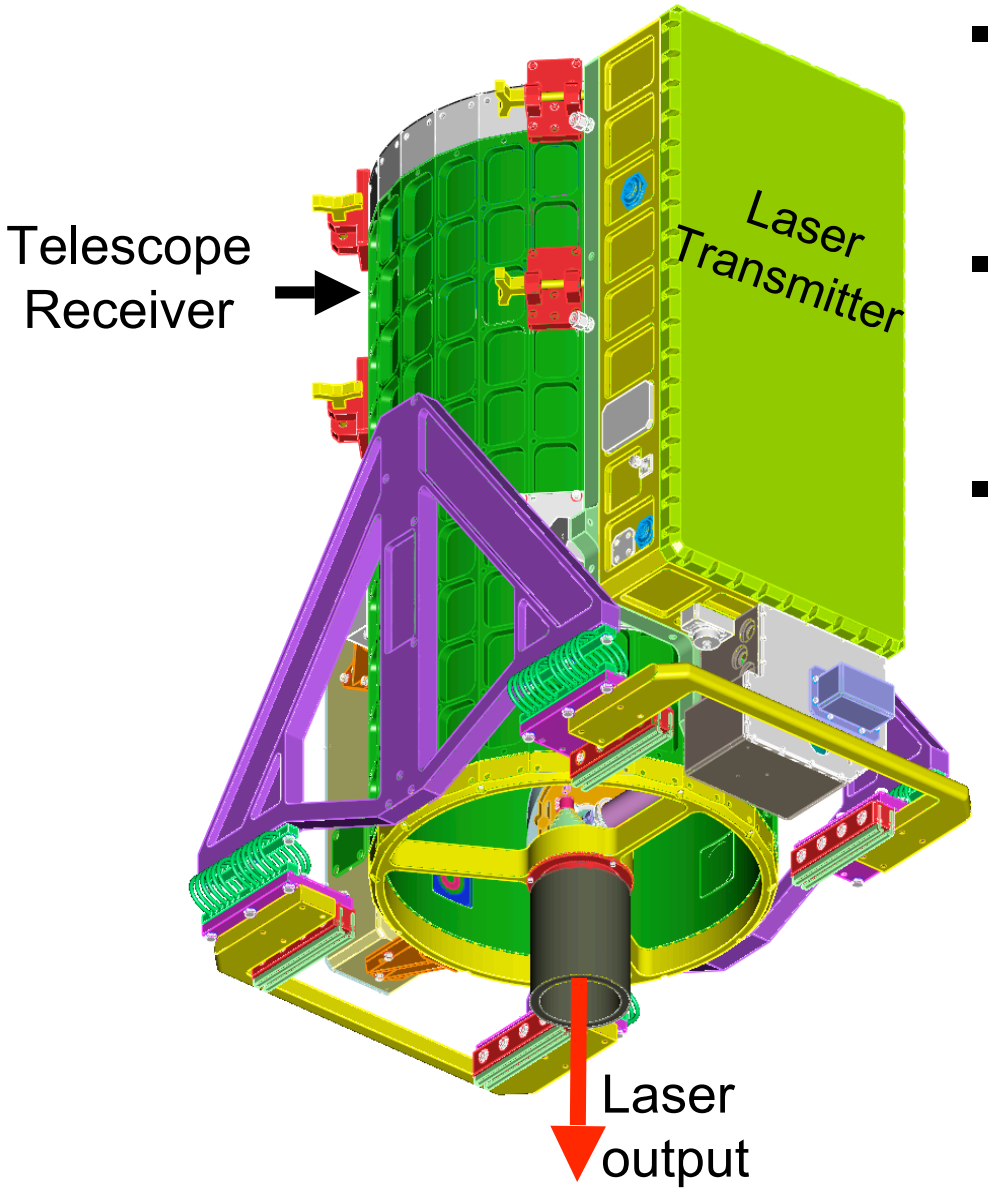
Primary Instrument: Airborne High Spectral Resolution Lidar (HSRL)



- Focused on providing quantitative measurements of aerosol optical properties
- Different from standard backscatter lidars: independently measures backscatter and extinction (532 nm)
- History
  - 2000-2004: instrument development and integration
  - Dec 2004: first test flight on Lear 25-C
  - Dec 2005: first test flight NASA Langley King Air
  - >200 flight hours with instrument since completion, including
    - 60 hours on MILAGRO/MAX-MEX
    - 45 hours on CALIPSO validation (East US)
    - 90 hours on 2006 TexAQS/GoMACCS/MAX-TEX

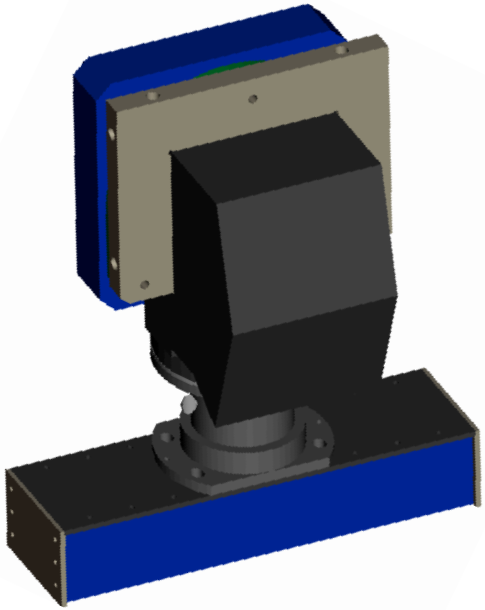
High Spectral Resolution Lidar (HSRL) Data Products

- Aerosol scattering ratio (aerosol/molecular backscatter) (532 nm) ($\Delta x \sim 1$ km, $\Delta z \sim 60$ m)
- Aerosol backscatter coefficient at 532 nm ($\Delta x \sim 1$ km, $\Delta z \sim 60$ m)
- Aerosol extinction coefficient at 532 nm ($\Delta x \sim 6$ km, $\Delta z \sim 300$ m)
- Aerosol extinction/backscatter ratio (532 nm) ($\Delta x \sim 6$ km, $\Delta z \sim 300$ m)
- Aerosol wavelength dependence (532/1064) (i.e. Angstrom exponent for aerosol backscatter)
- Aerosol depolarization (532 nm) ($\Delta x \sim 1$ km, $\Delta z \sim 60$ m)
- Aerosol depolarization (1064 nm) ($\Delta x \sim 1$ km, $\Delta z \sim 60$ m)

HyperSpectral Polarimeter for Aerosol Retrievals
PIs: Yongxiang Hu, David Flittner

- Fundamental measurements
  - Full stokes vector (including circular polarization)
  - Continuous spectral coverage from 412 to 865 nm at 20 nm spectral resolution
  - Multi-angle viewing geometry: +/- 60° along flight vector

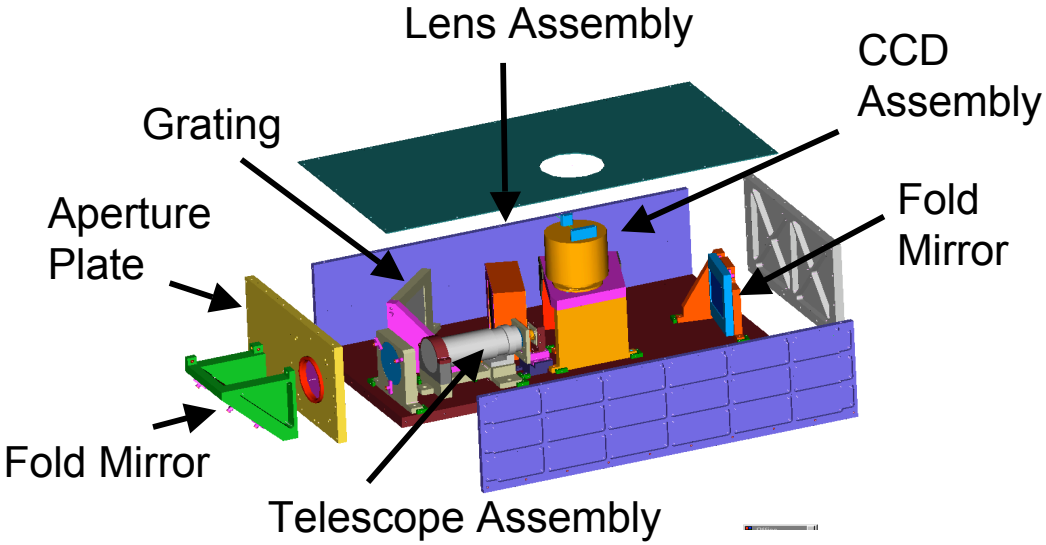
- Retrieval goals
  - scattering optical depth
  - Angstrom coefficient
  - asymmetry parameter
  - size distribution
  - complex index of refraction
  - single scatter albedo



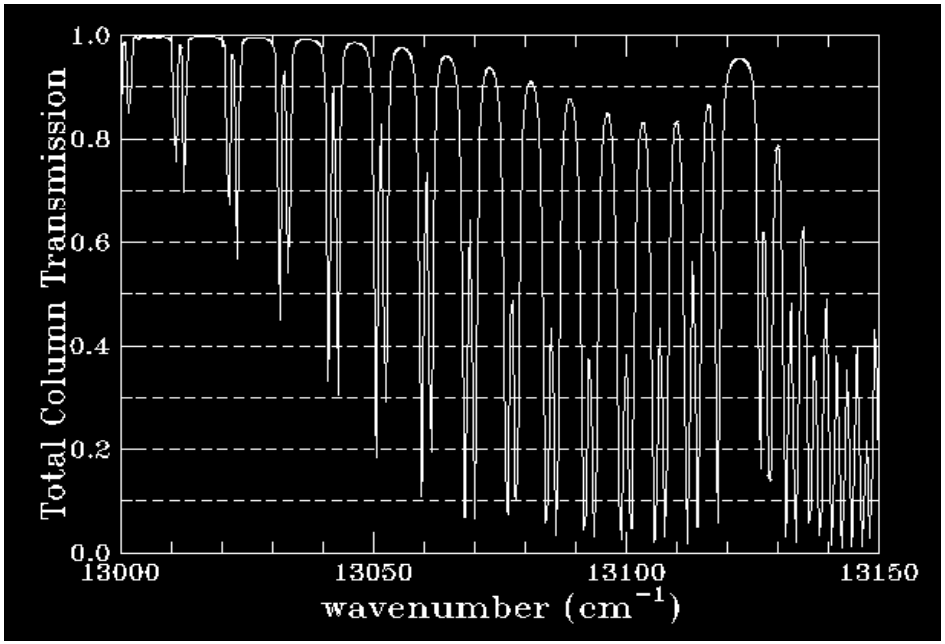
Built by Aerodyne Research, Inc.,

Langley Airborne A-band Spectrometer (LAABS)
PI: Mike Pitts

- Fundamental measurement
  - Spectrum of upwelling radiances in the oxygen A-band (760-770 nm)
  - 0.03 nm spectral resolution



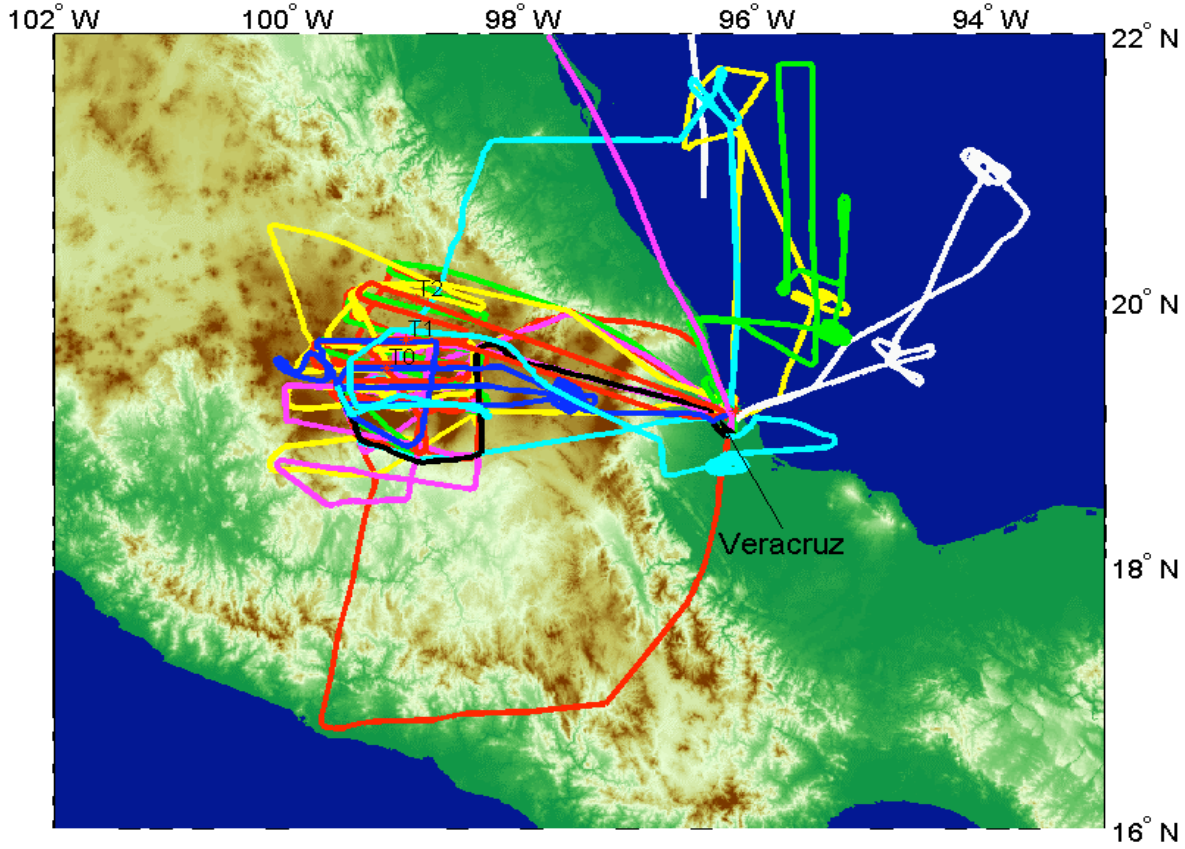
- Retrieval goals
  - surface pressure
  - optical depth of aerosol layers
  - aerosol single scatter albedo



Science Objectives

- 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
  - Compare observations to model transport predictions
  - Provide vertical context for in situ measurements on the G-1 and C-130, remote measurements on the J-31, and ground-based measurements from T0, T1, and T2
  - Compare aerosol extinction and optical depth measurements with sensors on J-31, G-1, and C-130
- Assess satellite (MODIS, MISR) retrievals of aerosol optical depth
- Investigate active–passive retrieval techniques of aerosol optical and microphysical properties
  - HSRL + MODIS → CALIPSO + MODIS
  - HSRL + RSP → CALIPSO + PARASOL
  - HSRL + LAABS + RSP/HySPAR → future satellite mission concept

Deployment Summary



King Air flight tracks
March 2-29, 2006

- Instruments (all nadir)
  - **HSRL (primary)**
    High Spectral Resolution Lidar
  - **LAABS**
    Langley Airborne Oxygen A-band Spectrometer
  - **HySPAR**
    Hyperspectral Polarimeter for Aerosol Retrievals
  - **Digital camera**
- 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

B200 Science Flights out of Veracruz in MILAGRO/INTEX-B

Date, 2006	Track	Comments
2 Mar	Houston - VER	Transit from Houston to Veracruz
3 Mar	VER - MC - Acapulco - VER	Overflight of T0,T1 Overflight of G1 wall patterns in MC
6 Mar	Mexico City Raster Pattern	Overflight of T0, T1 Terra MODIS, MISR LM over MC Coordinated flight with J31 Overflight of G1 wall patterns in MC Survey south of MC
7 Mar	Mexico City Raster Pattern	Mapped plume over MC and region outside MC basin to south Overflight of G1 wall patterns
8 Mar	N from VER over Gulf	Aqua MODIS overpass Principal and cross principal plane patterns for HySPAR
9 Mar	MC Raster	Mapped plume over MC and regions immediately north and south Overflight of G1 wall patterns Overflight of T0, T1

B200 Science Flights out of Veracruz in MILAGRO/INTEX-B

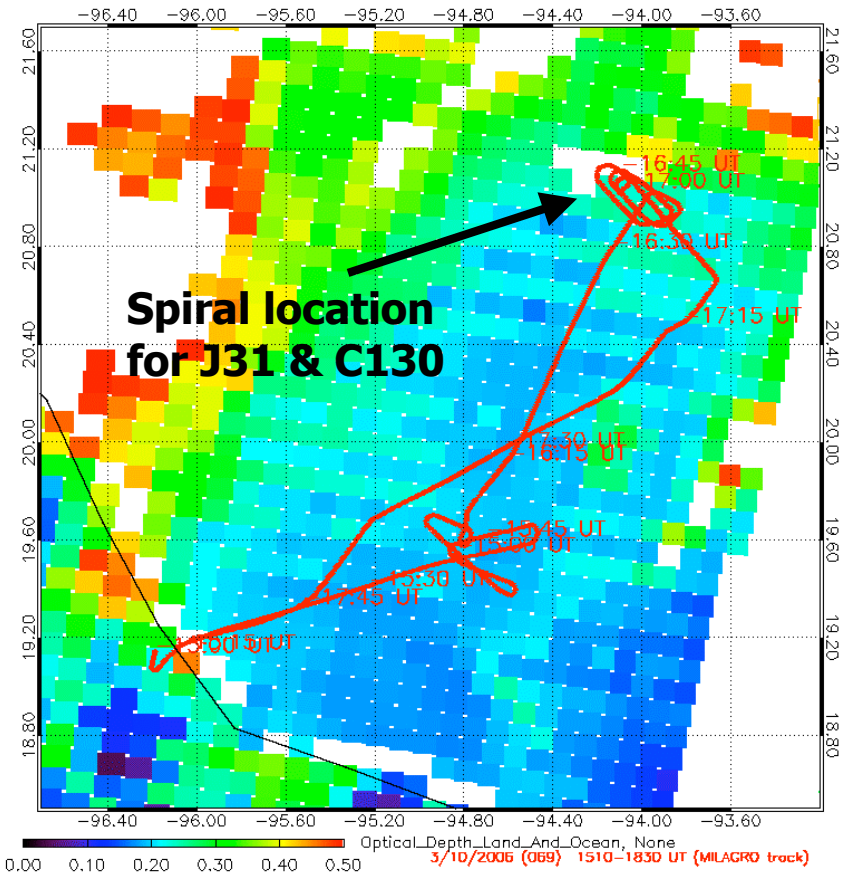
Date, 2006	Track	Comments
9 Mar	Mexico City Raster Pattern	Mapped distribution of plume over MC and plume to north Overflight of G1 wall patterns Overflight of T0, T1
10 Mar	Gulf NE of VER	Terra MODIS, MISR over Gulf Coincident flight with J31 spirals and Figure-4 Coincident flight with C130 spiral
12 Mar	N over Gulf E then S to MC RTB	Terra MODIS over Gulf Coordinated flight with J31 spirals & Figure-4 Located plume NE of MC Overflight of T0, T1, T2
13 Mar	Mexico City Raster Pattern and overflight of area south of MC	Terra MODIS, MISR Local Mode over MC Mapped distribution of plume south of MC
15 Mar	Mexico City Raster Pattern	Terra MODIS, MISR Local Mode over MC Coincident flight with J31 spiral Overflight of G1 wall patterns Overflight of T0, T1

B200 Science Flights out of Veracruz in MILAGRO/INTEX-B

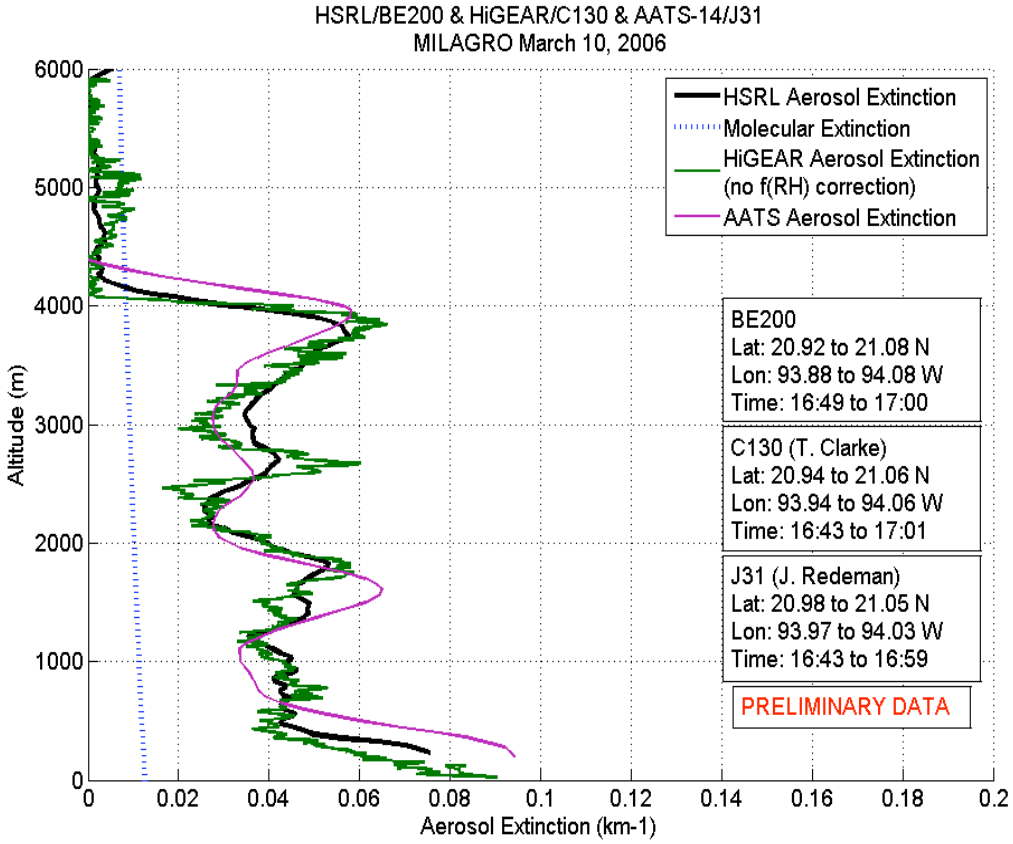
Date, 2006	Track	Comments
25 Mar	Ferry from Toluca to VER	High clouds along most of flight track; aerosol data were acquired on only the first 10-20 minutes of flight.
27 Mar	Mexico City Raster Pattern	Map out distribution of aerosol over MC Terra MODIS overpass of MC Observations of mountain venting Overfly the G1 H-pattern routes
28 Mar	Gulf E-NE of VER	Terra MODIS overpass Overflight of C130 spiral
29 Mar	Mexico City Raster Pattern	Terra MODIS, MISR LM over MC Observations of mountain venting over MC basin. Overflight of C130 spiral Overflight of T0, T1
29 Mar	Mexico City Raster Pattern	Overpass of T1 Overpass of C130 spiral
31 Mar	Ferry to Brownsville	Aerosol data acquired on most of flight
31 Mar	Ferry to Knoxville	Aerosol data acquired on most of flight

Extinction Profile Comparison: HSRL, AATS14, and HIGEAR

MODIS Optical Depth



Aerosol Extinction

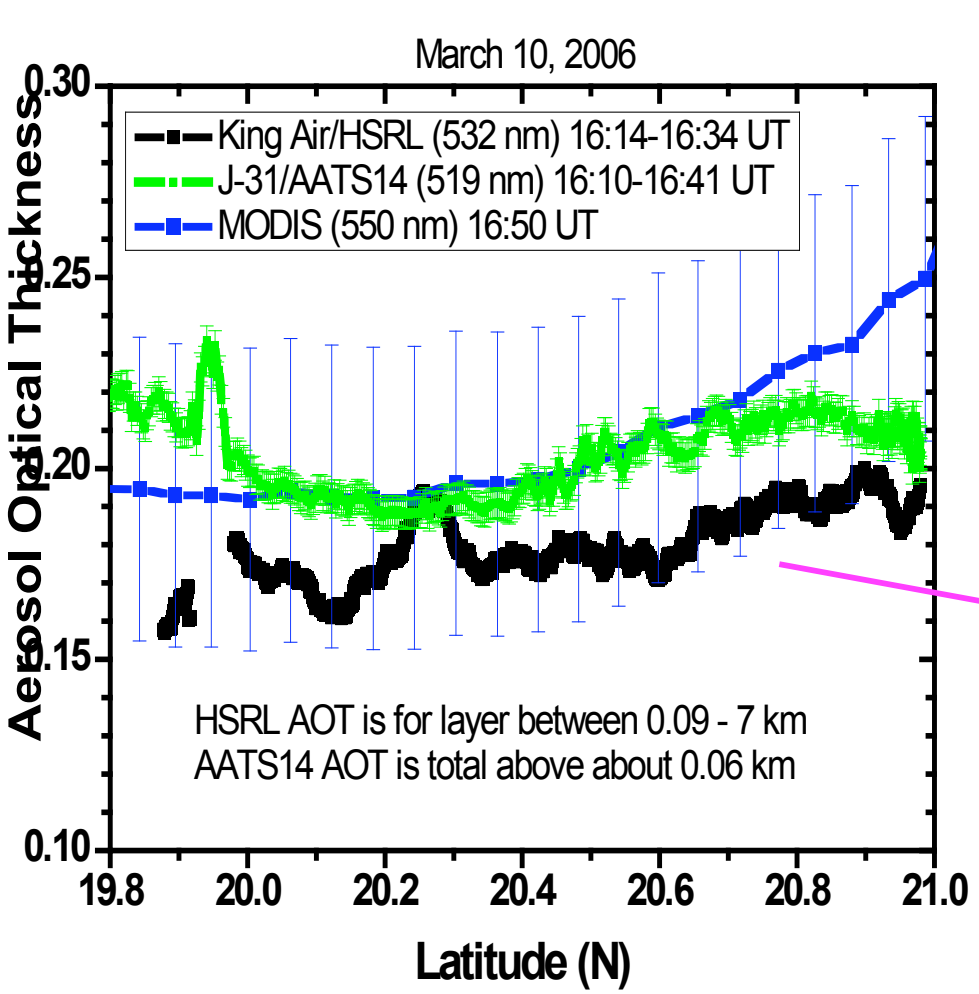


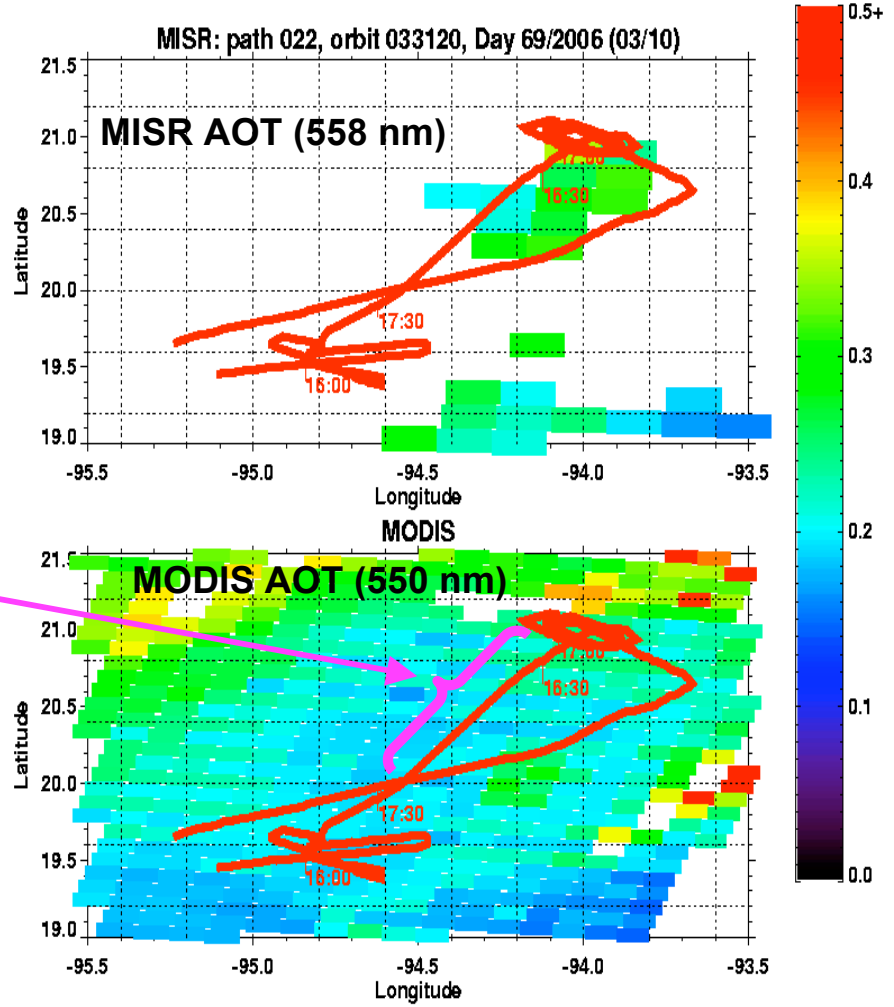
HIGEAR data courtesy of Tony Clarke

AATS14 data courtesy of Phil Russell, Jens Redemann, John Livingston

Satellite Retrieval Studies and Aerosol Optical Thickness Comparison

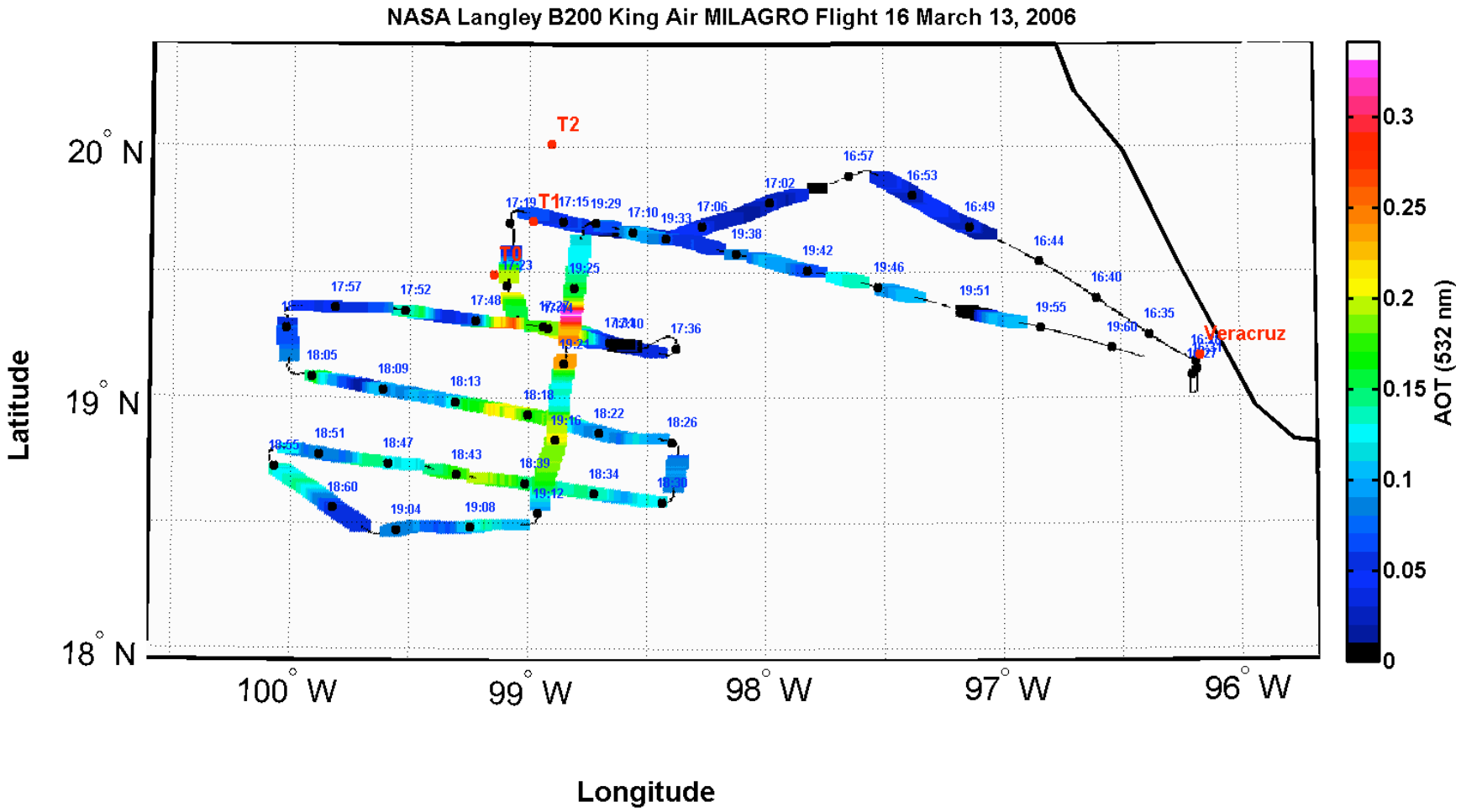
- Several flights coincident with MODIS (9) and MISR (5) for retrieval studies
- Coordinated flights with J-31 and C-130 for comparison of data products (aerosol optical thickness) and retrieval studies (e.g., combined HSRL and RSP photo-polarimeter)



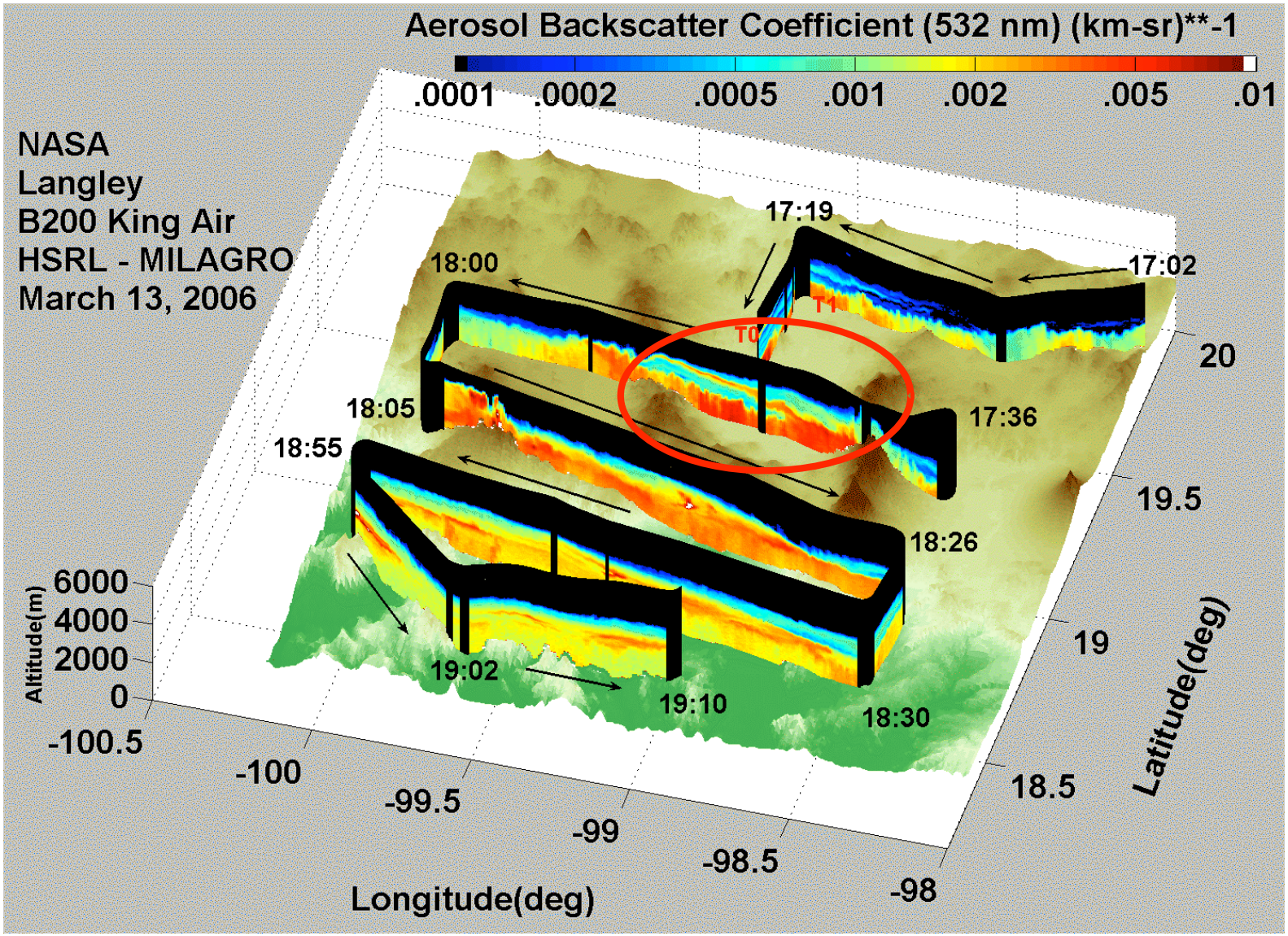


Mapping Aerosol Optical Depth

March 13 Raster scan



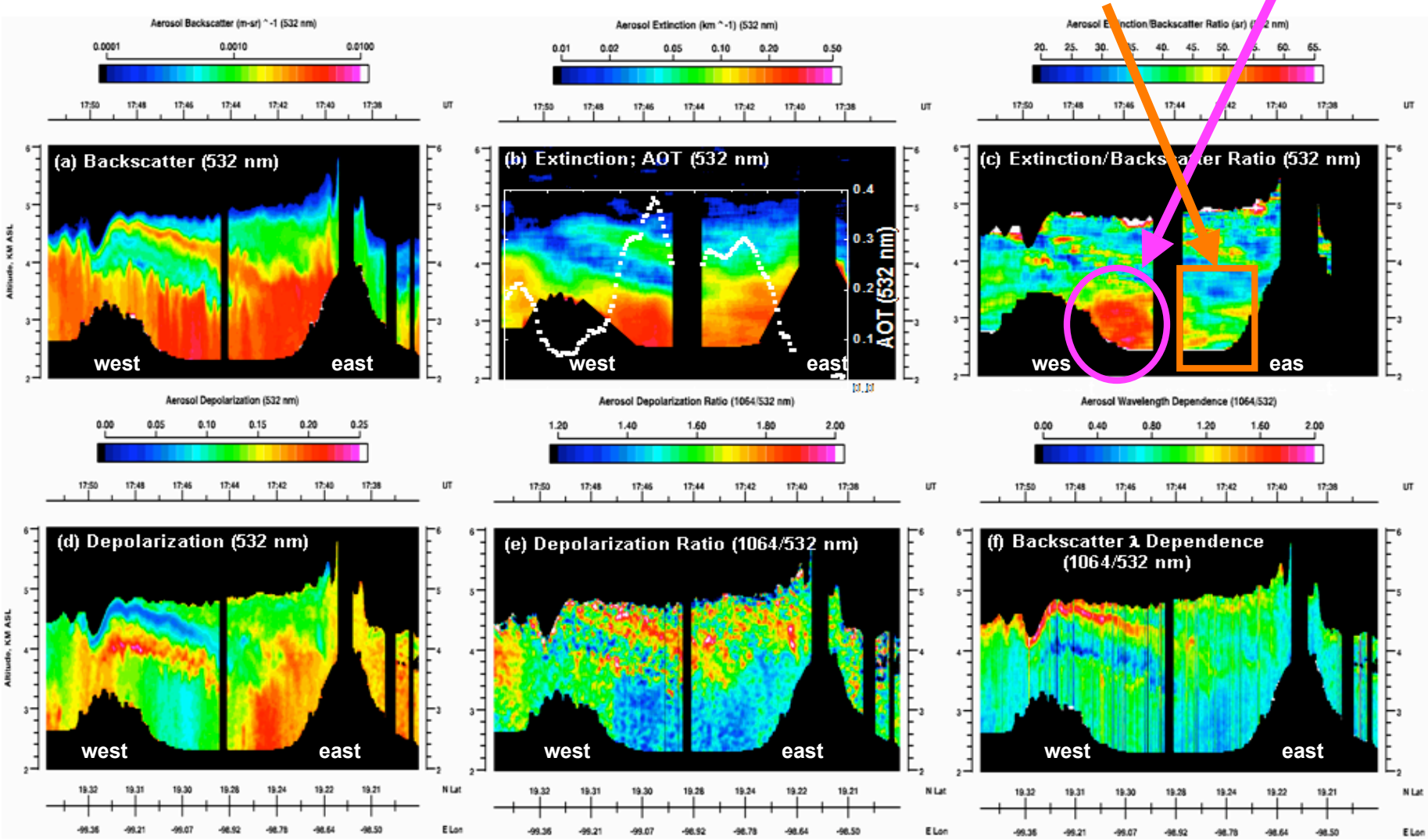
Characterizing Aerosol Spatial Distribution



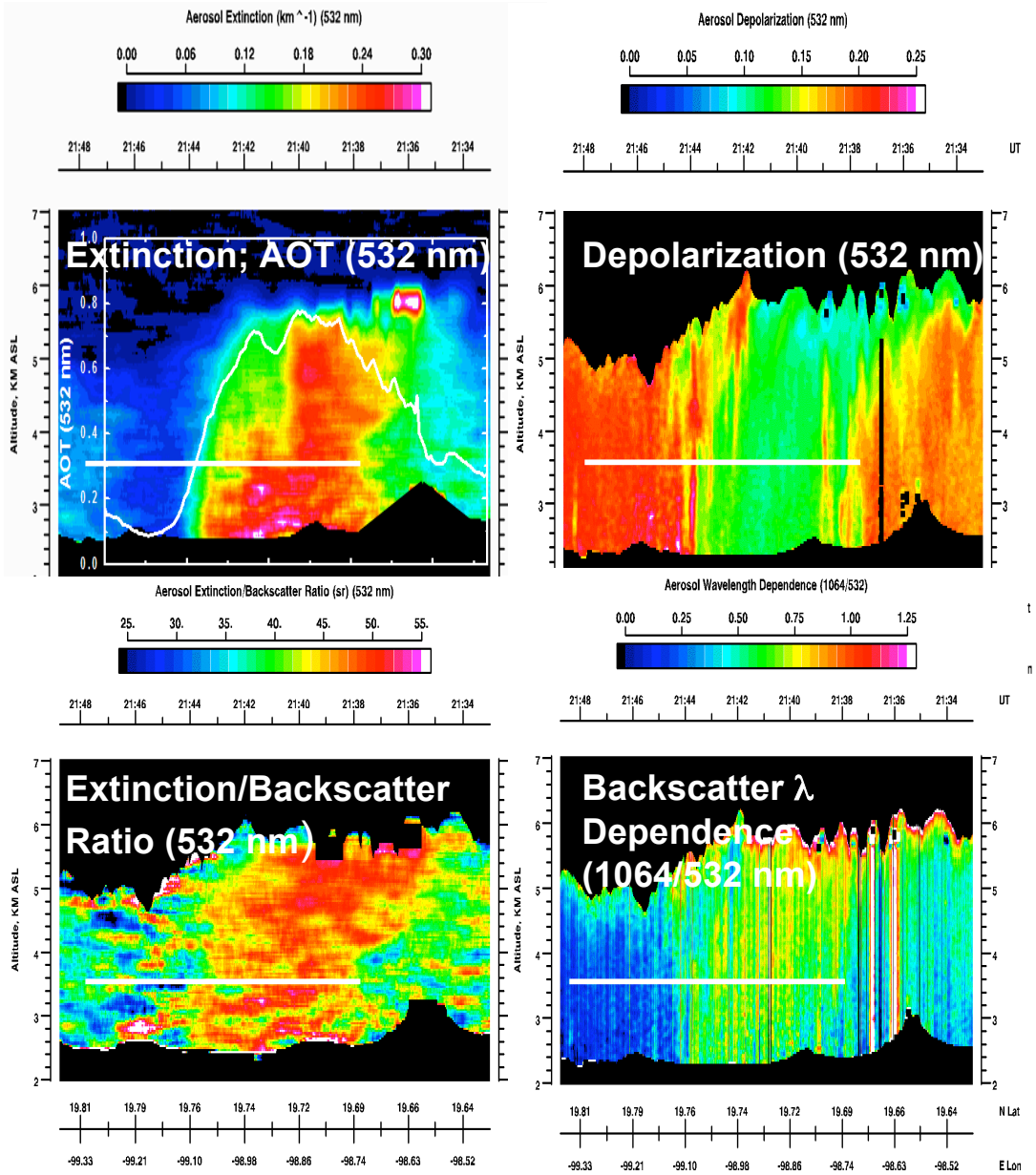
Characterizing the spatial distribution of aerosol type

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

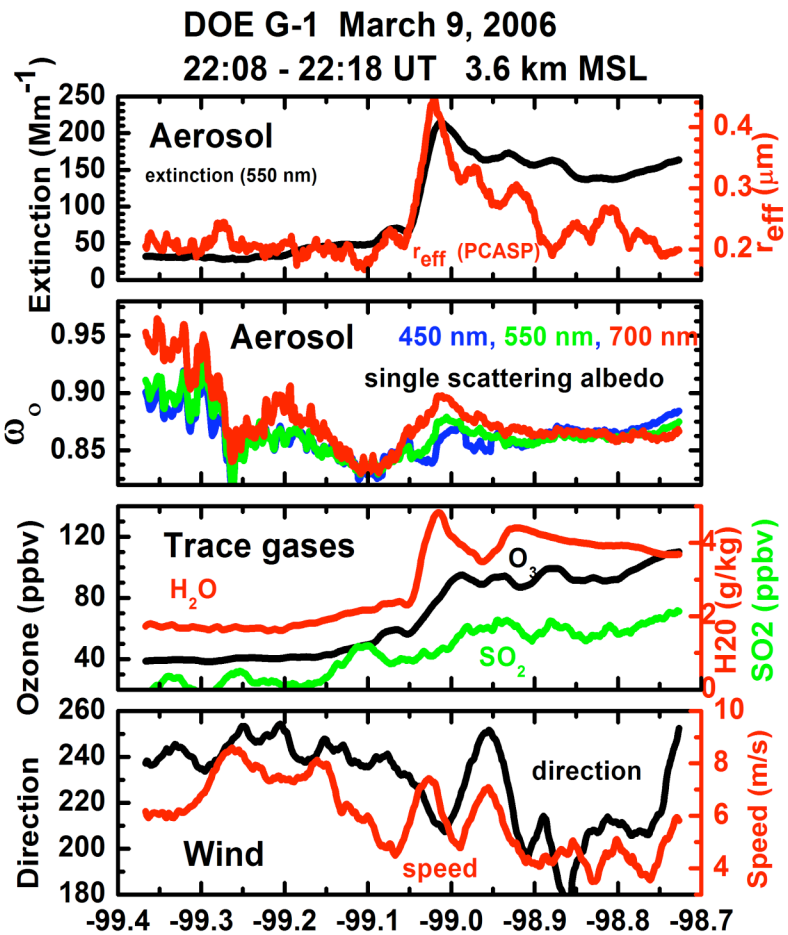
- western part of city- high S_a, high WVD, low depolarization – urban aerosol
- eastern part of city - low Sa, low WVD, high depolarization – dust



Characterizing aerosol optical properties/type, Providing vertical context for G-1 in situ measurements

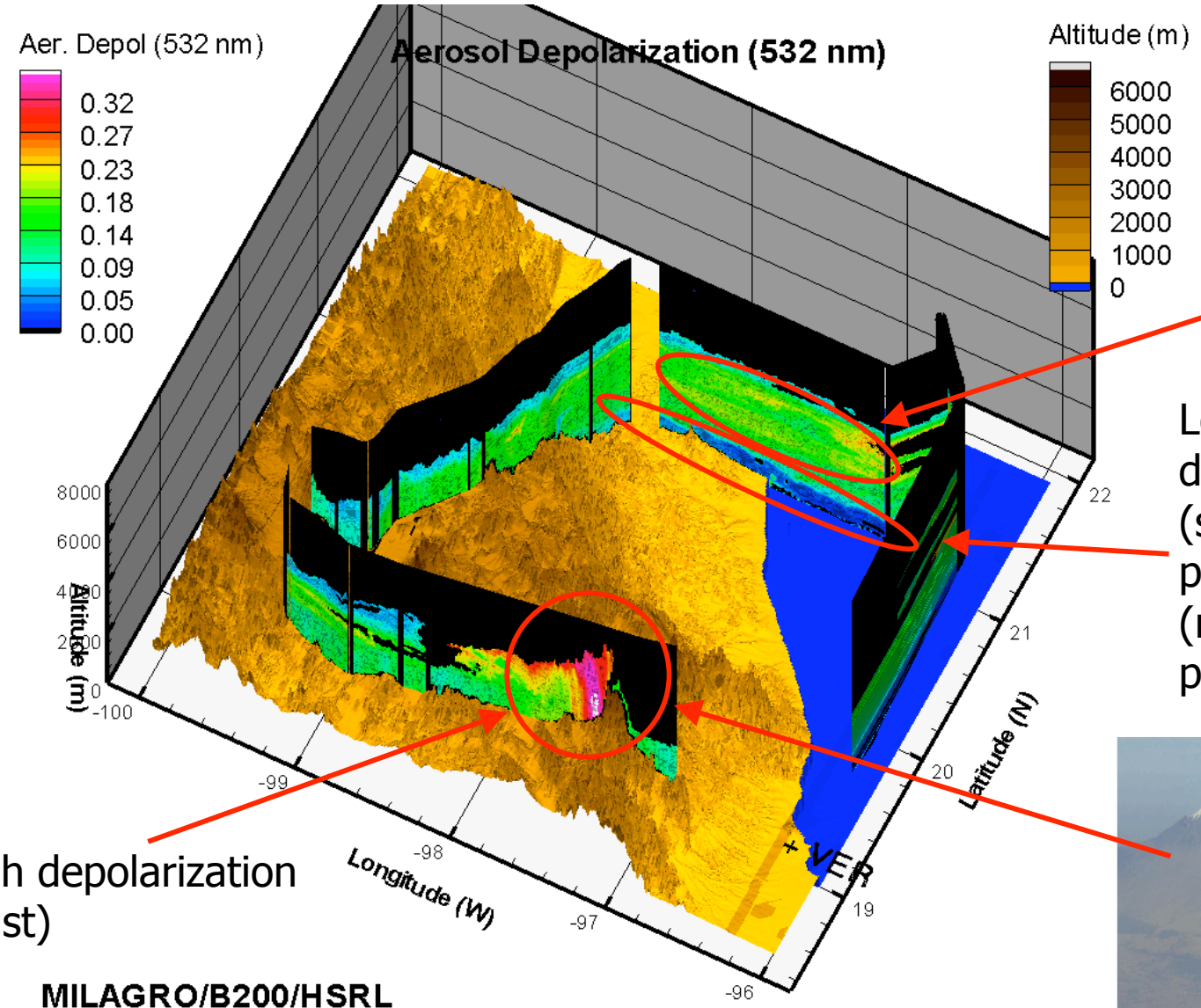


NASA King Air & DOE G-1 coordinated fight – March 9, 2006



PRELIMINARY DATA

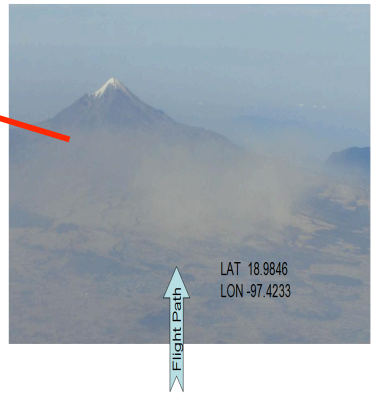
Characterizing the spatial distribution of aerosol type



Medium depolarization (mixture of dust, smoke, and pollution?)

Low depolarization (spherical particles: (marine aerosol, pollution?)

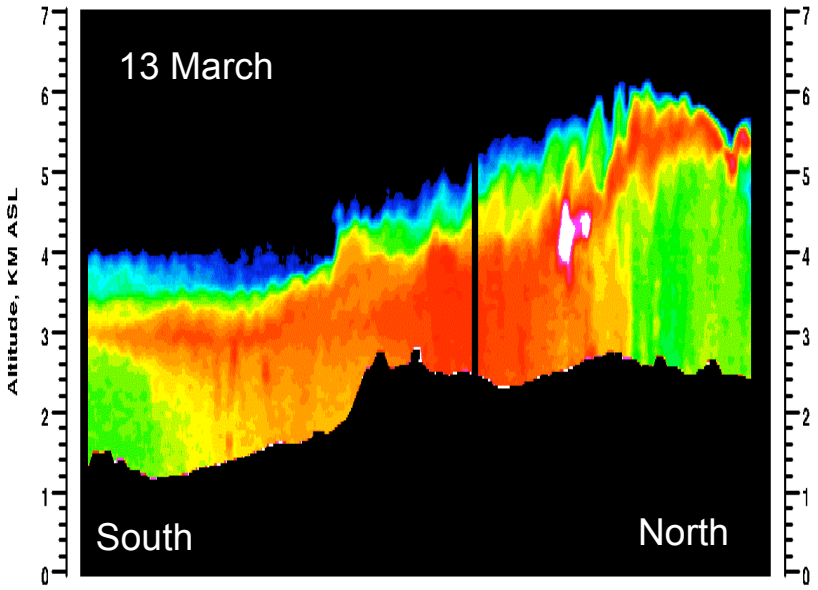
High depolarization (dust)



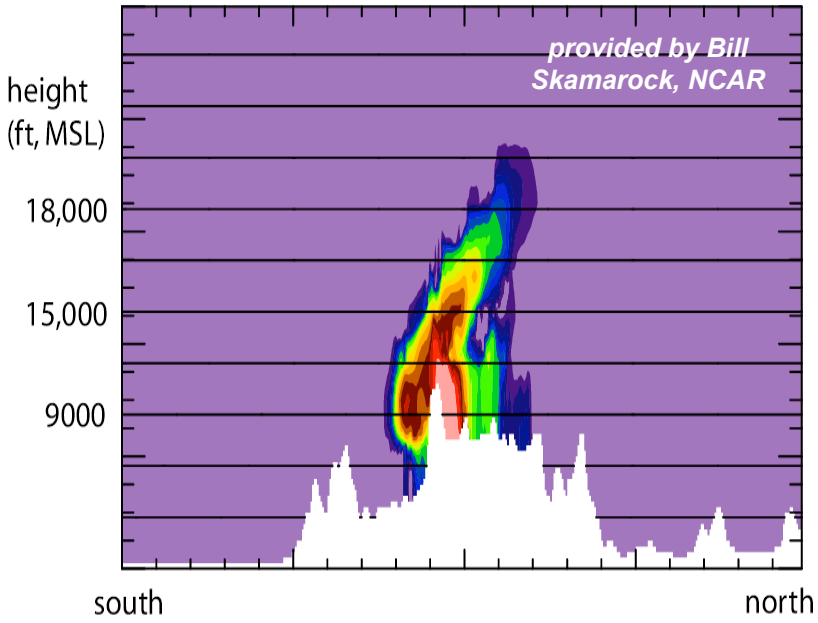
MILAGRO/B200/HSRL
Flight 15, March 12, 2006
Terra Overpass in Gulf and Mexico City Overpass

Comparisons with Models: Aerosol Venting into Free Troposphere

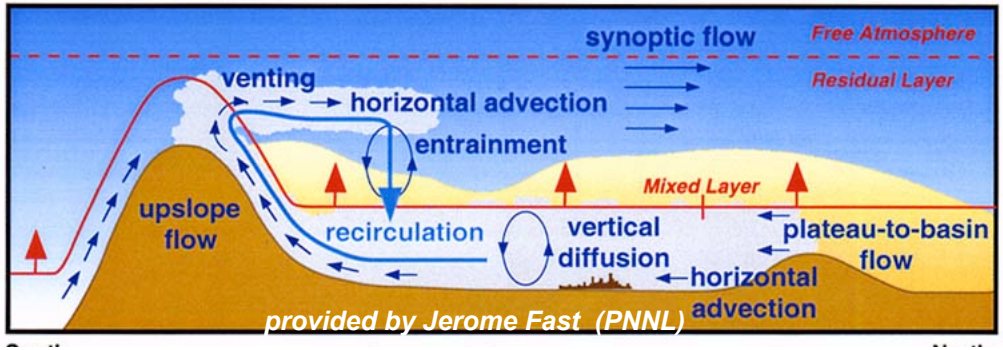
HSRL Curtain from B-200 (looking W)



Operational WRF Tracer Forecast



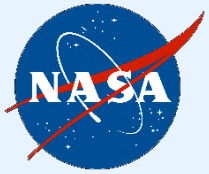
Conceptual Model based on Model Simulations of 1997 IMADA Field Campaign



- **Lidar measurements seem to confirm mountain venting / recirculation processes made by earlier modeling studies**
- **Operational forecast models reproduced feature**
- **How does this affect aerosol and trace gas evolution?**

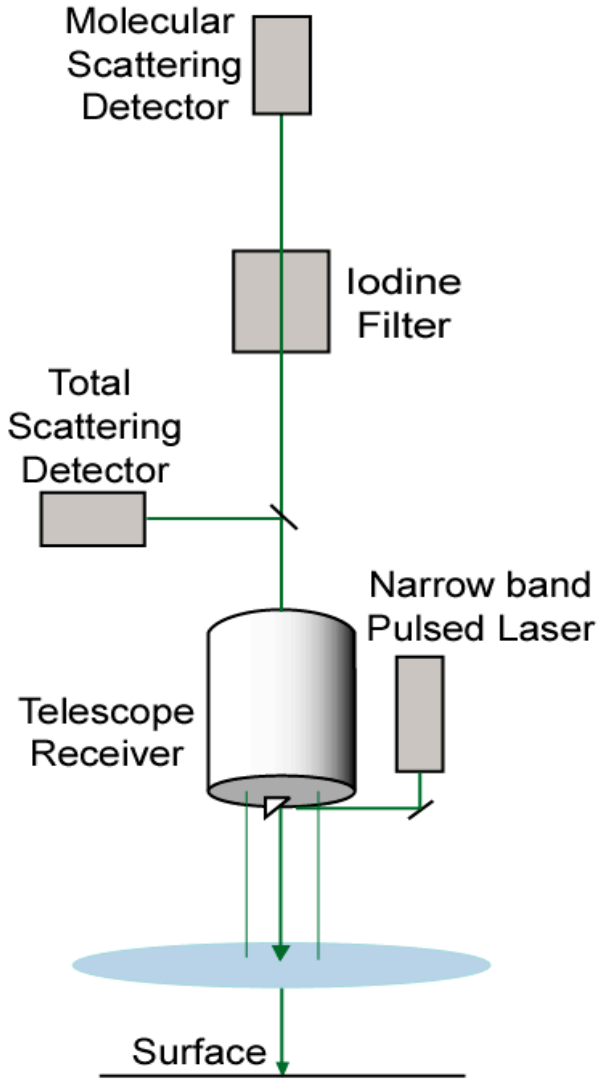
Much to Do ....

- Extensive set of aerosol observations -- have only begun to scratch the surface
- Lidar data are in the NASA INTEX-B archive
  - Plan to set up FTP site with HDF data files and images
- Looking forward to collaborations with other teams!

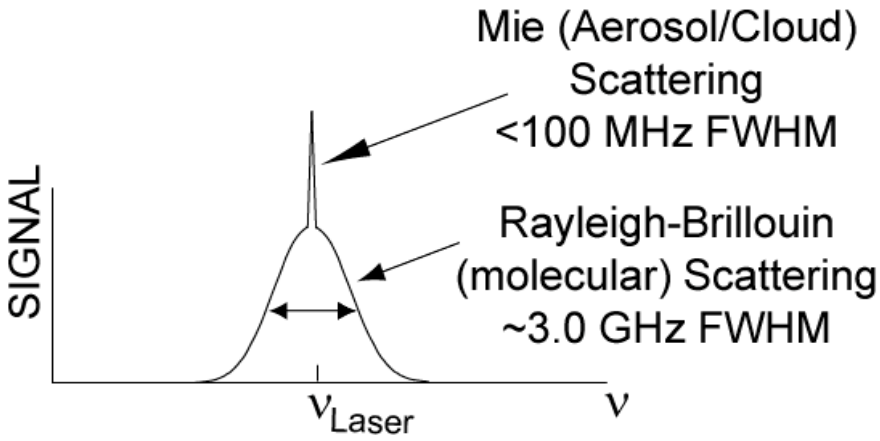


Backups

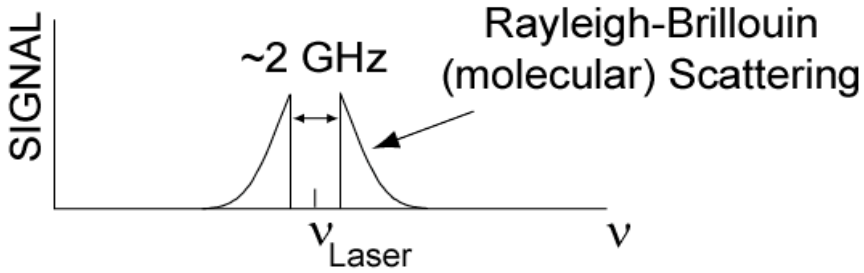
HSRL via Iodine Vapor Filter Technique



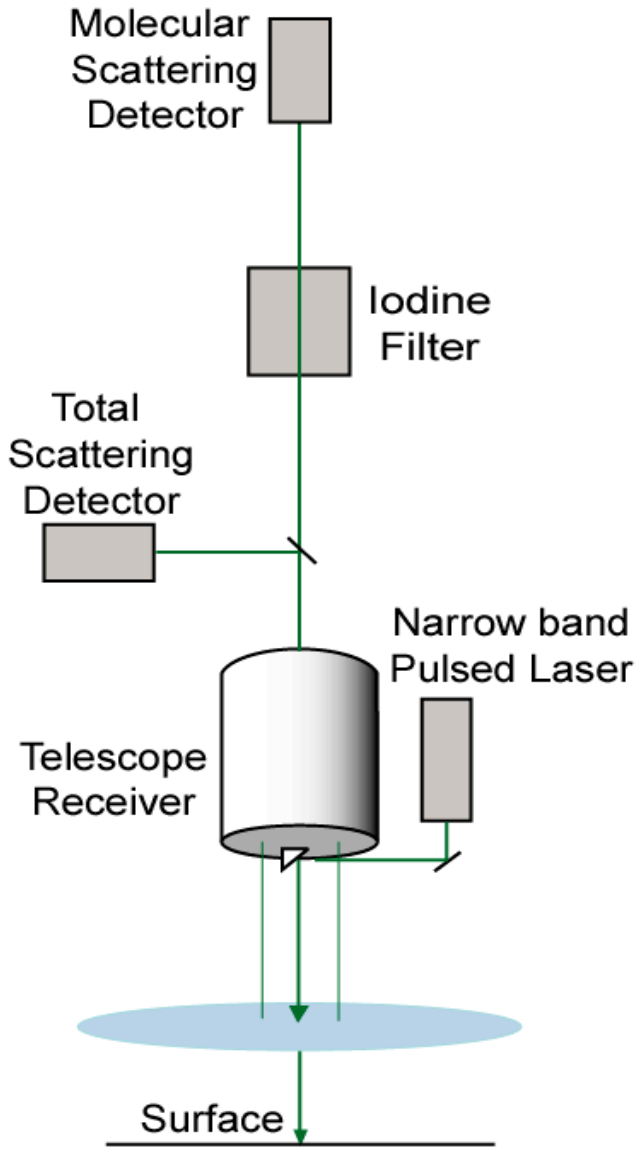
Atmospheric Scattering

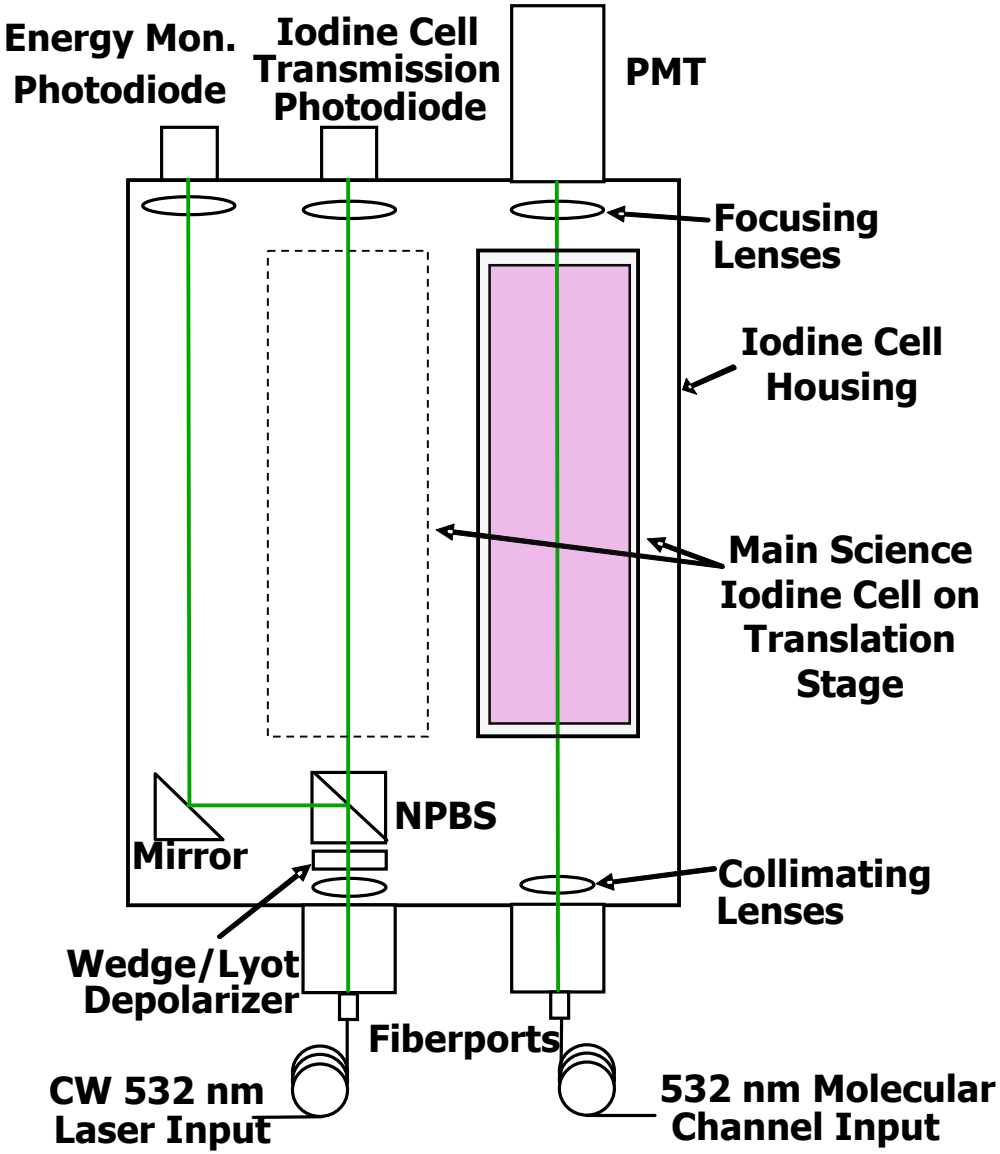


Effect of Iodine Vapor Notch Filter



Internal Calibration of Molecular-to-Total Backscatter Channels





Wavelength Dependence – *wvd*

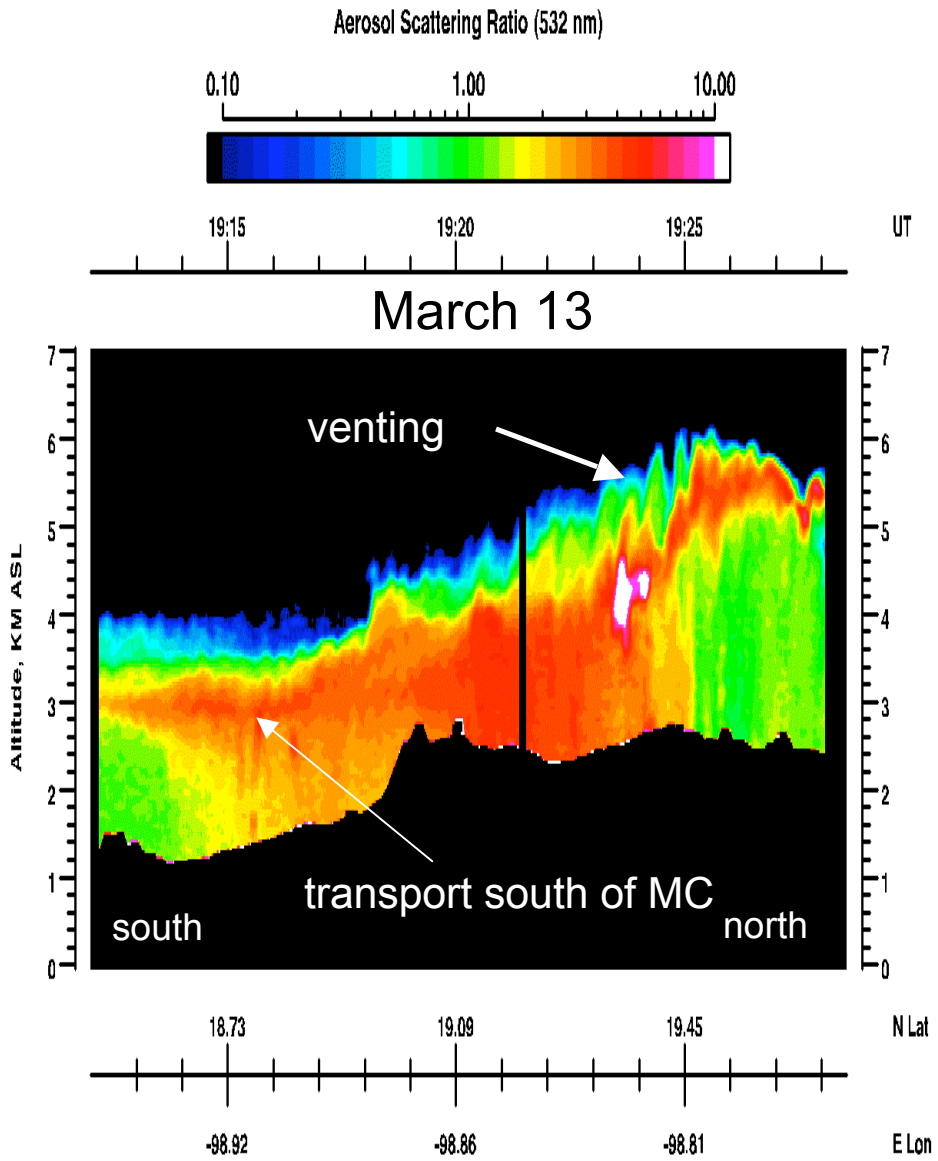
- Defined differently than "color ratio" for CALIPSO
- Analogous to Angstrom coefficient for *aerosol* backscatter

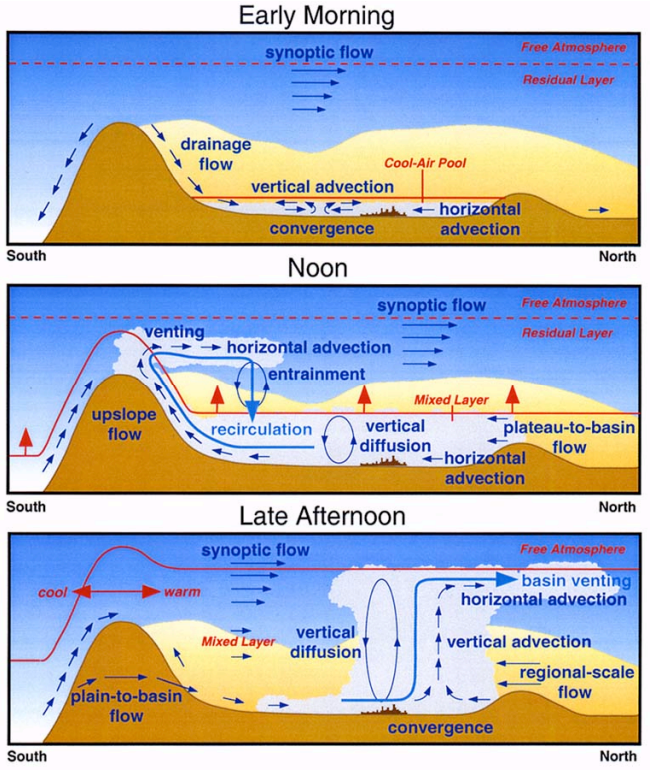
$$wvd = \frac{-\ln \frac{\beta_{aerosol,1064}}{\beta_{aerosol,532}}}{\ln \frac{1064}{532}}$$

Acknowledgements

- HSRL Team
  - John Hair – instrument architect
  - Tony Cook
  - Dave Harper
  - Chris Hostetler
  - Rich Ferrare
- HySPAR Team
  - Steve Jones, Frank Iannarilli from Aerodyn
  - David Flittner, Yongxiang Hu from LaRC
  - Thanks to NASA Earth Science Technology Office for support
- LAABS team
  - Mike Pitts and Larry Thomason from LaRC
- Special thanks to DOE ASP and NASA HQ SMD for funding our participation in this exciting mission!

Comparisons with Models: Aerosol Venting into Free Troposphere





- Lidar measurements confirm earlier DOE / ASP modeling studies
- Models are being used to determine the effect of venting on aerosol evolution and radiative forcing

Airborne High Spectral Resolution Lidar

- Aerosol Measurements
  - Extinction at 532 nm
  - Backscatter at 532 nm
  - Backscatter at 1064 nm
  - Depolarization at 532 nm
  - Depolarization at 1064 nm

- History
  - 2000-2004
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