Characterization of aerosols using airborne lidar and MODIS

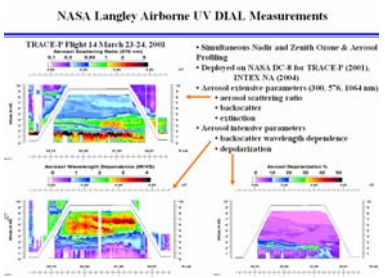
Richard Ferrare [1], Edward Browell [1], Syed Ismail [1], Yoram Kaufman [2], Mian Chin [2], John Hair [1] , Carolyn Butler [1,3] , Vince Brackett [1,3] , Marta Fenn [1,3]
Anthony Notari [1,3], Susan Kooi [1,3], Marian Clayton [1,3] Phil Russell [4], Jens Redemann [4,5], John Livingston [4,6], Beat Schmid [4,5], Gao Chen [1], Antony Clarke [7], Jean Francois Léon[8]

(1) Atmospheric Sciences Research, NASA Langley Research Center, MS 401A, Hampton, Virginia, 23681,USA; (2) Climate and Radiation Branch, NASA Goddard Space Flight Center, Code 613.2, Greenbelt, Maryland, 20771,USA ; (3) Science Application International Corporation, Hampton, NASA Langley Research Center, MS 927, VA 23666 USA; (4) NASA Ames Research Center, Moffett Field, CA; (5) Bay Area Environmental Research Institute, Sonoma, CA; (6) SRI International, Menlo Park, CA; (7) University of Hawaii, Honolulu, HI; (8) Laboratoire d'Optique Atmospherique, Lille, France

Objectives

- Use combination of airborne lidar and MODIS to provide information regarding the vertical distribution of aerosol properties
- Retrieve aerosol extinction and optical thickness profiles from lidar data
- Identify aerosol types vs. altitude
- Evaluate ability of GOCART model to simulate aerosol extinction profiles and aerosol type

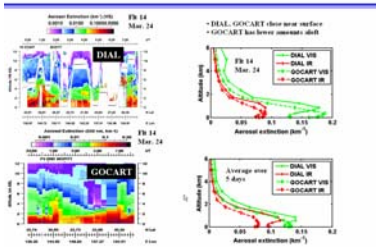
NASA Langley Airborne UV DIAL Measurements



MODIS+lidar Aerosol Retrieval

- Retrieval algorithms – (2 Wavelength)
  - (Kaufman et al., IEEE, 2003; GRL, 2003; Léon et al., JGR, 2003)
  - Aerosol size distribution – bimodal lognormal
  - MODIS aerosol models – 20 combinations of 4 fine, 5 coarse particles
  - Size of each mode is assumed to be altitude independent
  - Relative weight of each mode is determined as a function of altitude from lidar backscatter color ratio
  - Retrievals are constrained to fit MODIS measurements
    - Spectral reflectance
    - Column AOT and r_{eff}
- Modifications – (3 Wavelength)
  - UV wavelength (300 nm) – more information on fine particle size
  - Depolarization – adjust the backscatter phase function for nonsphericity

Comparison of Vertical Profiles – DIAL and GOCART (TRACE-P)



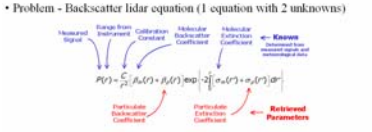
- DIAL, GOCART close near surface
- GOCART has lower amounts aloft

Summary

- MODIS data helped constrain airborne lidar retrievals of aerosol extinction profiles, and backscatter and extinction color ratios - TRACE-P (2001) and INTEX NA (2004)
- Combination of three-wavelength lidar/MODIS measurements over ocean used to retrieve profiles of fine mode fraction and effective radius
  - INTEX NA data used to evaluate results
  - General good agreement with extinction, fine mode fraction
- Evaluating GOCART simulations (TRACE-P)
  - Aerosol extinction - GOCART in generally good agreement with lidar near surface, somewhat lower amounts aloft
  - Backscatter and extinction color ratios – GOCART shows less vertical variability than derived from lidar
- On-going work (TRACE-P and INTEX NA, B)
  - Use cluster analysis techniques to identify and group aerosols
  - Derive aerosol types to help evaluate GOCART aerosol compositions
- Future
  - Use aerosol extinction, backscatter, depolarization measurements from LaRC airborne High Spectral Resolution Lidar (HSRL) – MILAGRO, GoMACCS
  - Proposed to use combination of CALIPSO/MODIS/PARASOL data

Aerosol Attenuation Correction

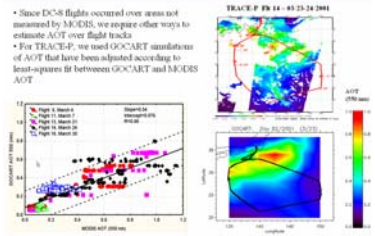
- Problem - Backscatter lidar equation (1 equation with 2 unknowns)



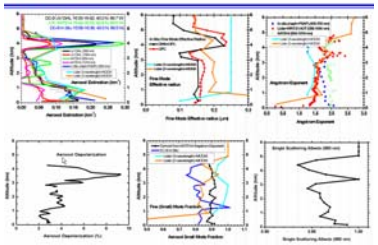
- Solution – we use aerosol optical thickness (e.g. total aerosol transmission) derived from MODIS and or model (e.g. GOCART) to constrain solution and derive average lidar ratio

MODIS and GOCART AOT – TRACE-P

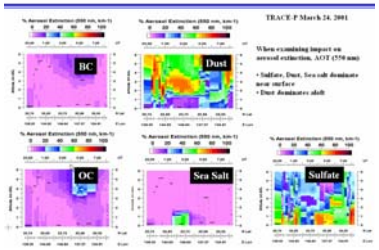
- Since DC-8 flights occurred over areas not measured by MODIS, we require other ways to estimate AOT over flight tracks
- For TRACE-P, we used GOCART simulations of AOT that have been adjusted according to least-squares fit between GOCART and MODIS AOT



Preliminary Aerosol Profile Properties – Retrieval Results - July 22, 2004

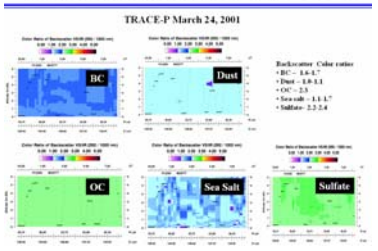


Vertical Profile of Aerosol Composition – GOCART



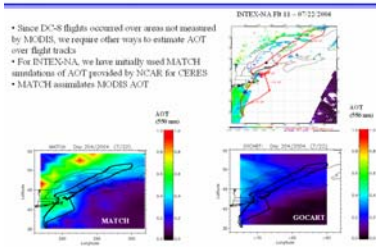
- When examining impact on aerosol extinction, AOT (550 nm)
- Sulfate, Dust, Sea salt dominate near surface
- Dust dominates aloft

Vertical Profile of Aerosol Backscatter Color Ratio – GOCART



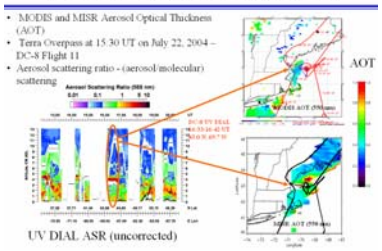
MODIS and MATCH AOT – INTEX NA

- Since DC-8 flights occurred over areas not measured by MODIS, we require other ways to estimate AOT over flight tracks
- For INTEX-NA, we have initially used MATCH simulations of AOT provided by NCAR for CERES
- MATCH assimilates MODIS AOT



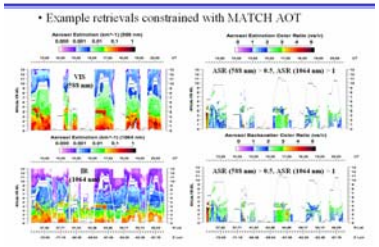
Aerosol Profile Retrieval – July 22, 2004

- MODIS and MISR Aerosol Optical Thickness (AOT)
- Terra Overpass at 15:30 UT on July 22, 2004 – DC-8 Flight 11
- Aerosol scattering ratio - (aerosol/molecular) scattering

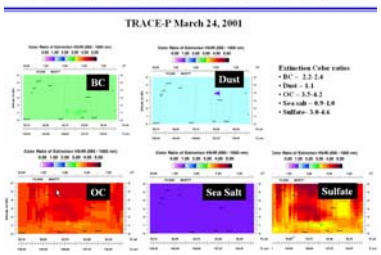


Aerosol Extinction and Color Ratio Profiles – July 22, 2004

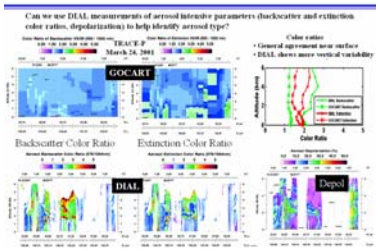
- Example retrievals constrained with MATCH AOT



Vertical Profile of Aerosol Extinction Color Ratio – GOCART

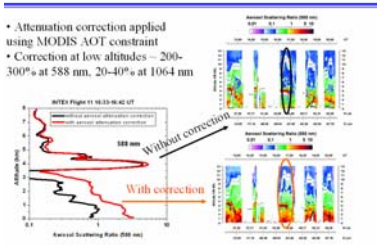


Comparison of Vertical Profiles – DIAL and GOCART- TRACE-P



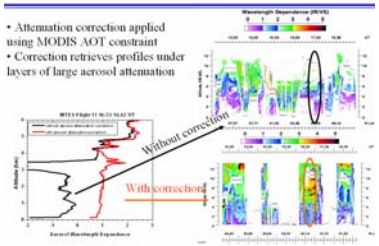
Aerosol Scattering Ratio – July 22, 2004

- Attenuation correction applied using MODIS AOT constraint
- Correction at low altitudes – 200-300% at 588 nm, 20-40% at 1064 nm



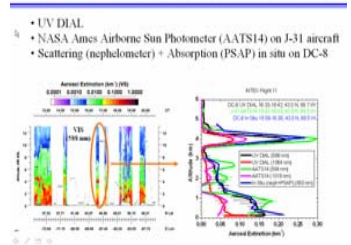
Aerosol Wavelength Dependence – July 22, 2004

- Attenuation correction applied using MODIS AOT constraint
- Correction retrieves profiles under layers of large aerosol attenuation



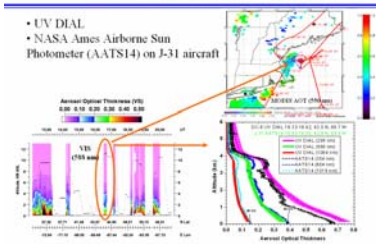
Preliminary Aerosol Extinction Comparison – July 22, 2004

- UV DIAL
- NASA Ames Airborne Sun Photometer (AATS14) on J-31 aircraft
- Scattering (nephelometer) + Absorption (PSAP) in situ on DC-8



Preliminary AOT Comparison – July 22, 2004

- UV DIAL
- NASA Ames Airborne Sun Photometer (AATS14) on J-31 aircraft



Aerosol Classification Using DIAL Measurements

- Aerosol types were grouped using intensive parameters derived from DIAL
  - Extinction color ratio
  - Backscatter color ratio
  - Depolarization
- Three main clusters were identified
  - Cluster 1 – high ratio, elevated depol - mix of dust, urban pollutes
  - Cluster 2 – mid ratios, low depol - mix of urban and oceanic aerosols
  - Cluster 3 – low ratios, high depol - dust