The Vertical Distribution of Aerosols: Lidar Measurements vs. Model Simulations

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Atmospheric Radiation Measurement Program

Outline

- Evaluation of upgraded ground based DOE ARM SGP CRF Raman lidar (CARL) aerosol extintion measurements
- Update on previous AEROCOM comparison results using ground based Raman lidar
- GOCART evaluation during TRACE-P, INTEX-NA missions
- New airborne HSRL system for aerosol measurements

Acronyms

DOE = Department of Energy
ARM = Atmospheric Radiation Measurement
SGP = Southern Great Plains
CRF = Climate Research Facility
CARL = CRF Raman Lidar
TRACE-P = Transport and Chemical Evolution over the Pacific
INTEX-NA = Intercontinental Chemical Transport Experiment – North America
DIAL = Differential Absorption Lidar
HSRL = High Spectral Resolution Lidar

Major Objective

Evaluate aerosol transport model simulations of aerosol profiles using lidar data

CART Raman Lidar (CARL)

- DOE ARM SGP CF site (Lamont , Oklahoma) (36° 37 ' N, 97° 30 ' W)
- Nd:YAG (355 nm) (day/night)
- Wavelengths
  - Rayleigh/Mie (355 nm)
  - Depolarization (355 nm)
  - Raman water vapor (408 nm)
  - Raman nitrogen (387 nm)
- 39 meter range resolution
- water vapor and aerosol profiles
- precipitable water vapor and aerosol optical thickness
- aerosol and cloud depolarization
- designed for continuous, autonomous operation

<u>Data:</u> available via ftp from ARM (http://www.arm.gov)

Additional information: http://www.arm.gov/docs/instruments/static/rl.html

(Turner et al., JAOT, 2002)

CARL Aerosol Extinction Profile Evaluation

• CARL extinction profiles were evaluated using airborne remote sensing and in situ measurements acquired during May 2003 Aerosol IOP

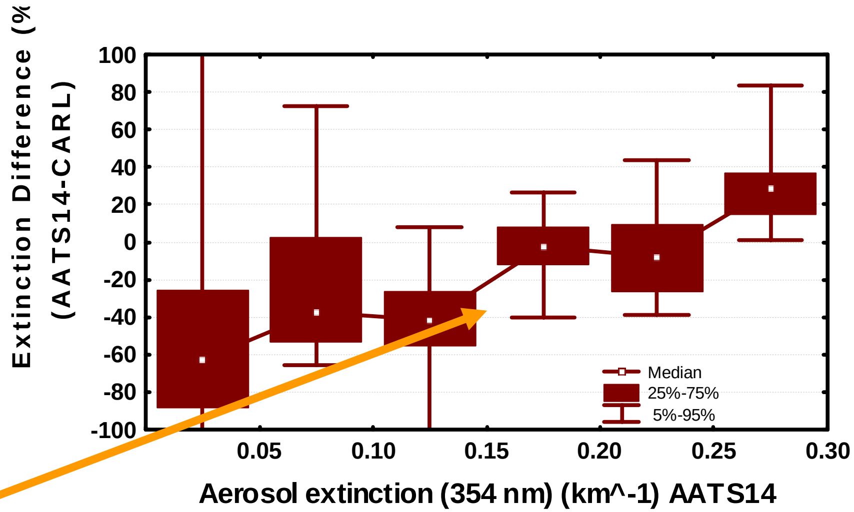
• CARL extinction values generally larger (20-30 Mm^{-1}) than values from other sensors

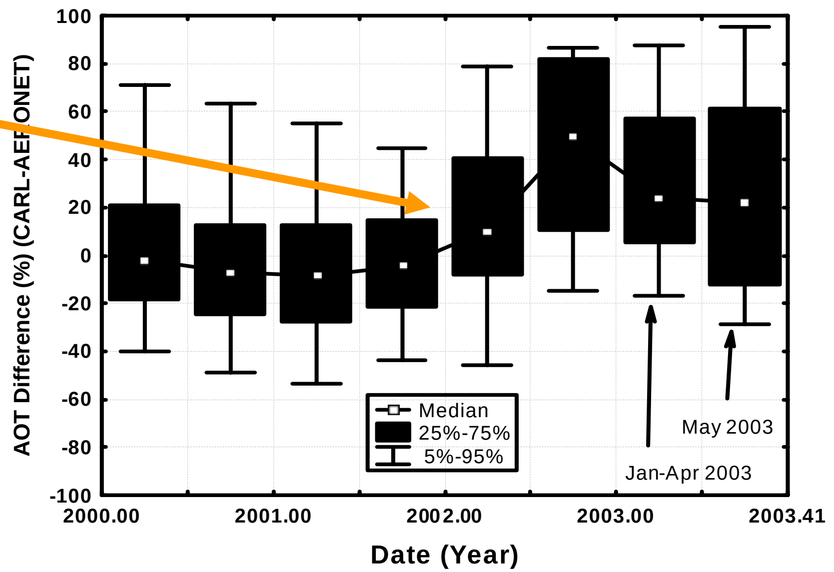
• Largest differences were found for low (<50 Mm^{-1}) aerosol extinction values and were significantly less (~10%) for higher (150-300 km^{-1}) values of aerosol extinction.

• Larger differences were due to impacts of loss of sensitivity of CARL since early 2002

• Absolute differences (~30 Mm^{-1}) between the CARL aerosol extinction values and values from the other instruments are within the range deemed acceptable (larger of 50 Mm^{-1} or 20%) when evaluating the lidars within the EARLINET project [*Pappalardo et al.*, 2004]

➢ **Major upgrades and modifications were made to CARL in summer 2004 to improve performance**



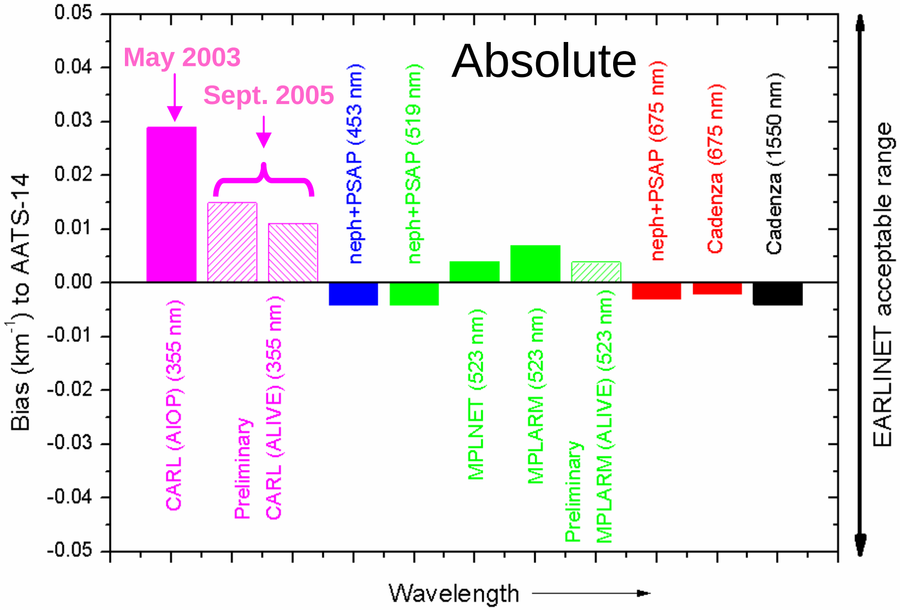


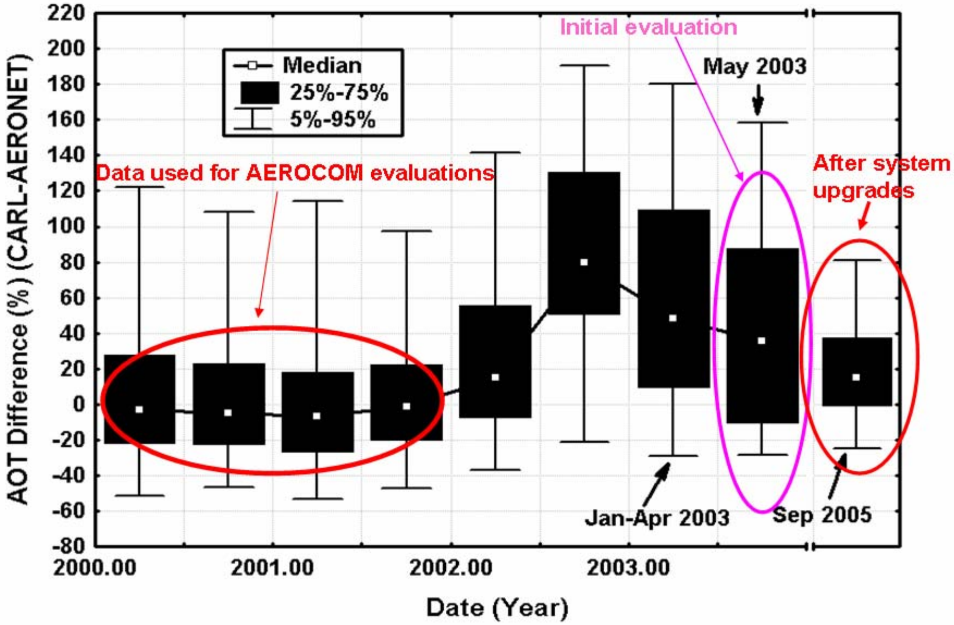
Ferrare et al., 2006

Evaluation of Raman Lidar Extinction

ALIVE – Aerosol Lidar Validation Experiment – conducted in Sept. 2005 to evaluate upgraded SGP Raman Lidar (CARL) and MPL

- CARL modifications performed in 2004 significantly improved accuracy and temporal resolution of aerosol measurements
- CARL aerosol extinction bias was:
  - About 50% smaller than the bias derived from May 2003 Aerosol IOP
  - 0.011-0.015 km^{-1} or 21-36% higher than airborne Sun photometer
  - About 10% of the annual median value of aerosol extinction within the lowest km
  - Well within the range deemed acceptable (larger of 0.05 km^{-1} or 20%) when evaluating the lidars within the EARLINET project
- MPL aerosol extinction (523 nm) high bias was about 0.004 km^{-1} (17%)
- AOT comparisons indicate that data used for AEROCOM comparisons has lower bias

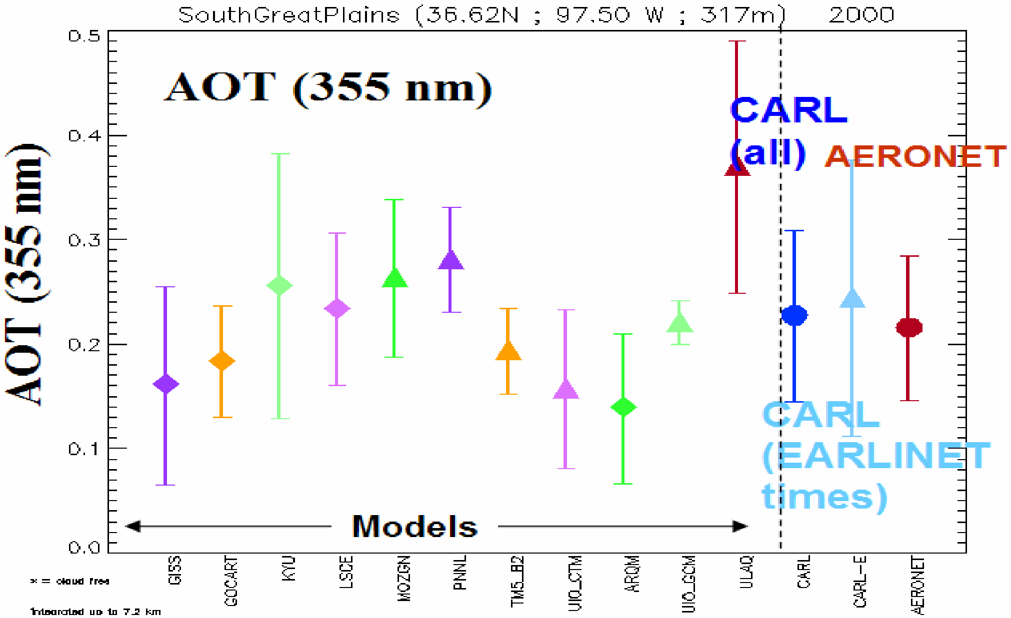


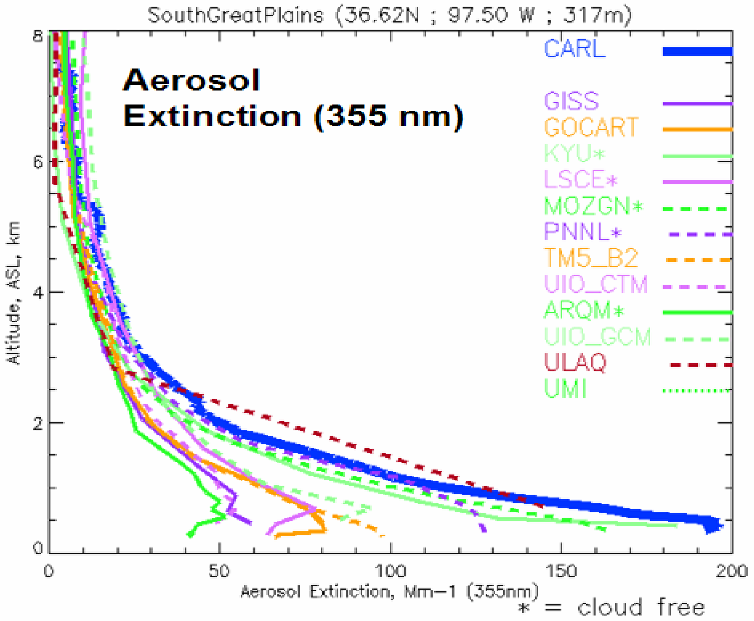


Measured vs. Modeled AOT and Aerosol Extinction - 2000

- Aerosol measurements acquired over the SGP site are used to evaluate and hopefully improve global aerosol transport model simulations
- Although model simulations of total column AOT show agreement among themselves and with measurements, significant differences exist in vertical distributions
  - Deviations between mean aerosol extinction profiles are generally small for altitudes above 2 km, and grow considerably larger below 2 km
  - Models have lower aerosol extinction near the surface

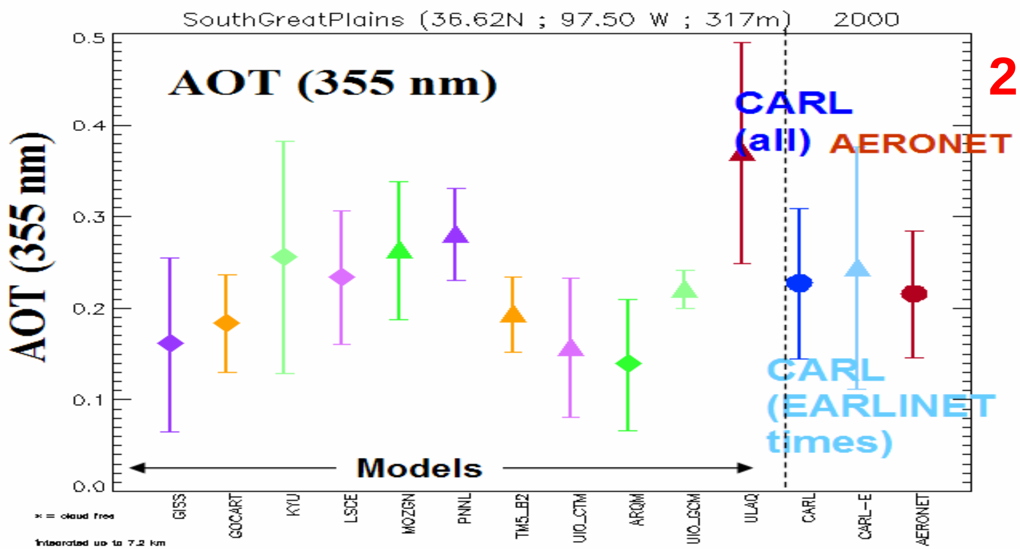
2000



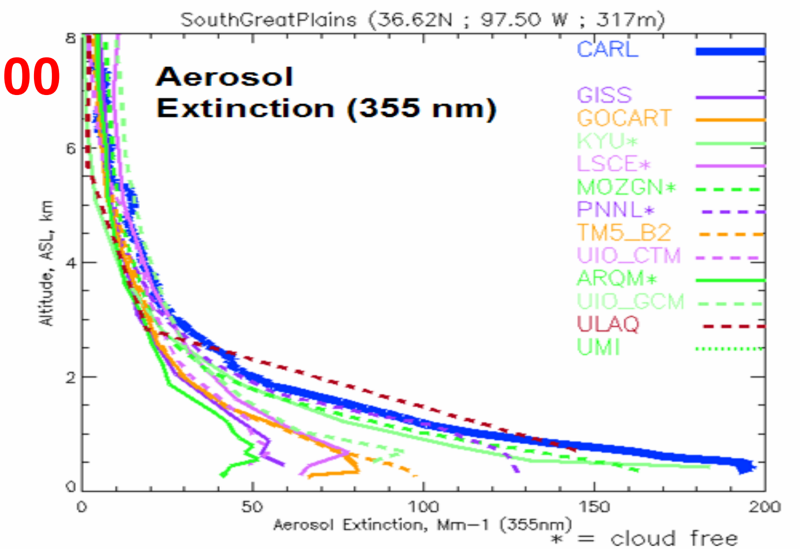


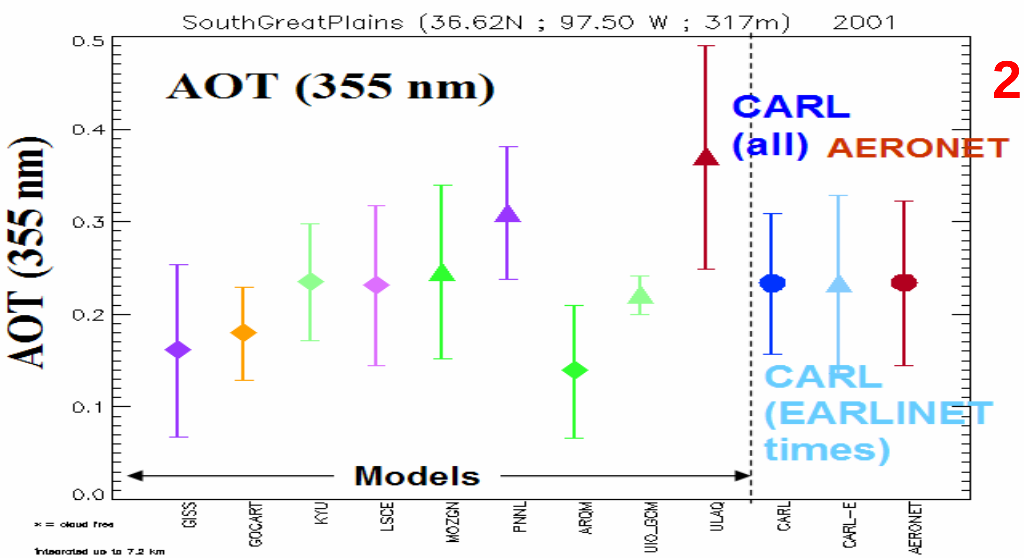
Measured vs. Modeled AOT and Aerosol Extinction – 2000 vs. 2001

- Compared models and measurements for both 2000 and 2001
- 2001 results include IMPACT simulations (Chuang – LLNL)
- Measured vs. model performance is essentially the same for both 2000 and 2001

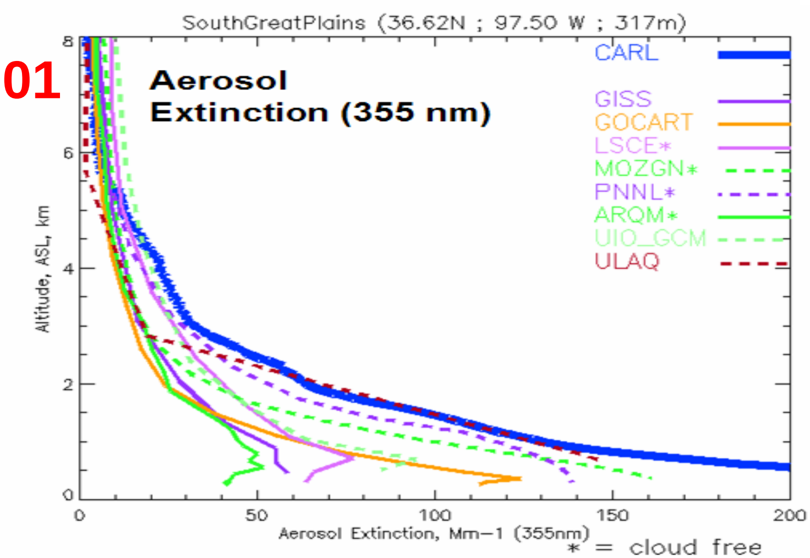


2000





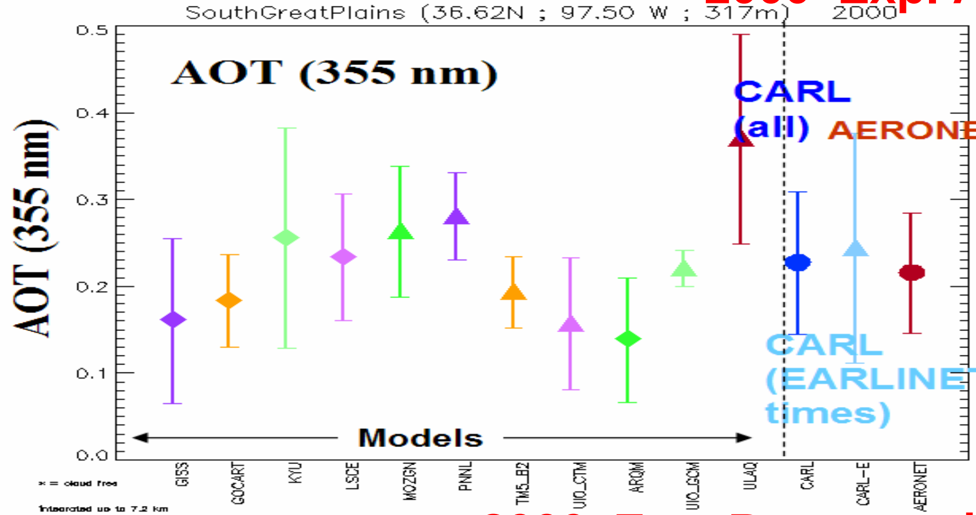
2001

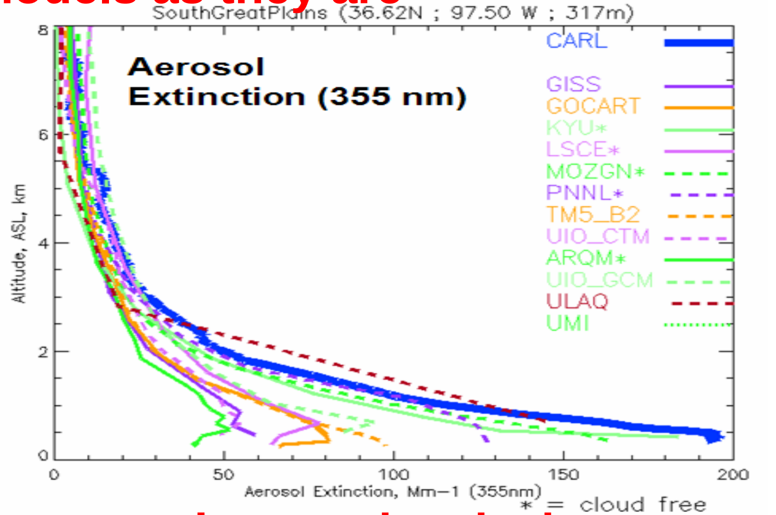


Measured vs. Modeled AOT and Aerosol Extinction – Exp. A and B

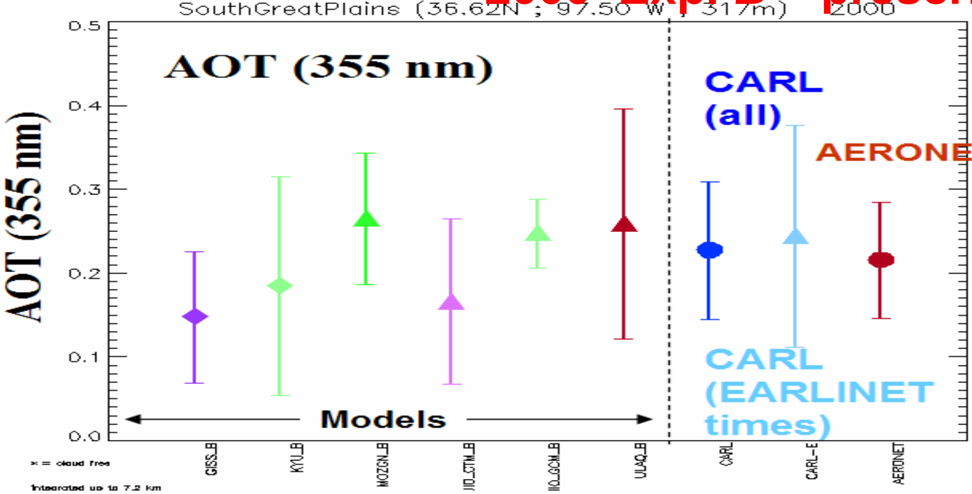
- Significant differences in vertical distributions remain even when prescribed emissions and meteorology are used
- Model extinction profiles do not change appreciably when prescribed emissions and meteorology are used

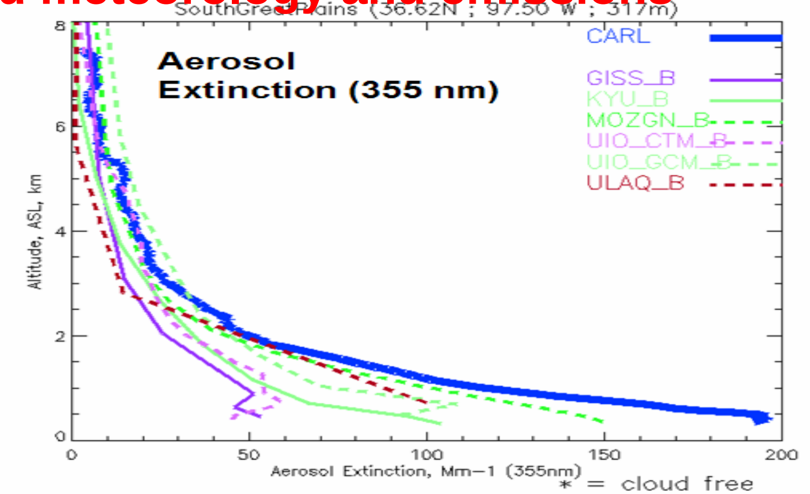
2000 Exp. A – models as they are





2000 Exp. B – prescribed meteorology and emissions



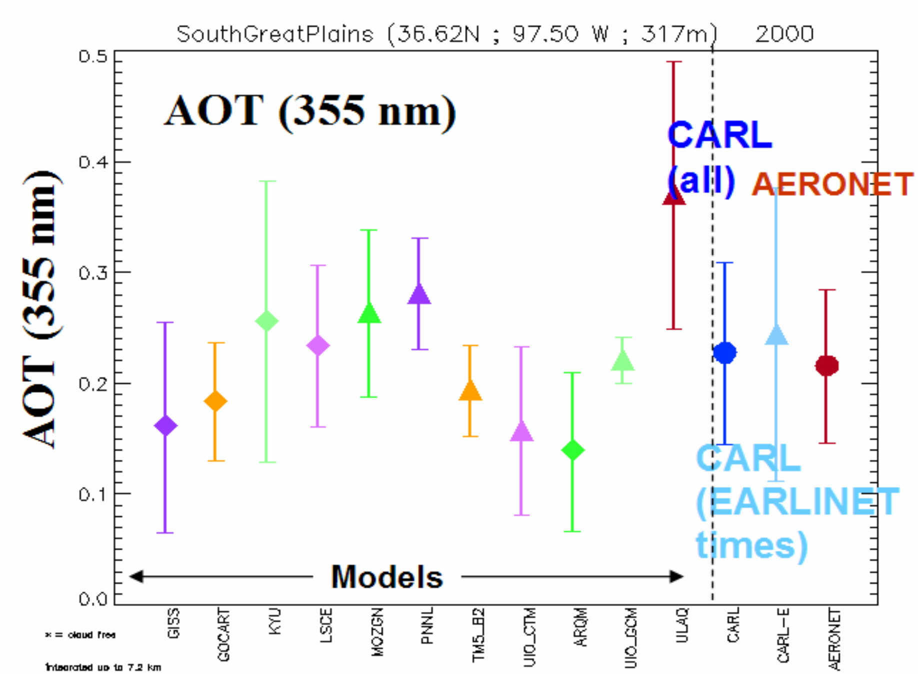


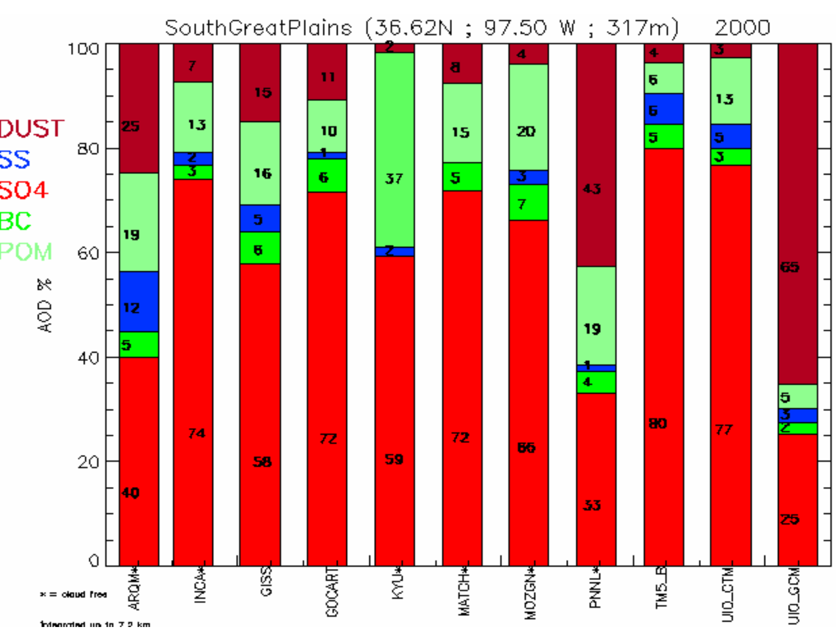
ARM SGP

General agreement in total AOT

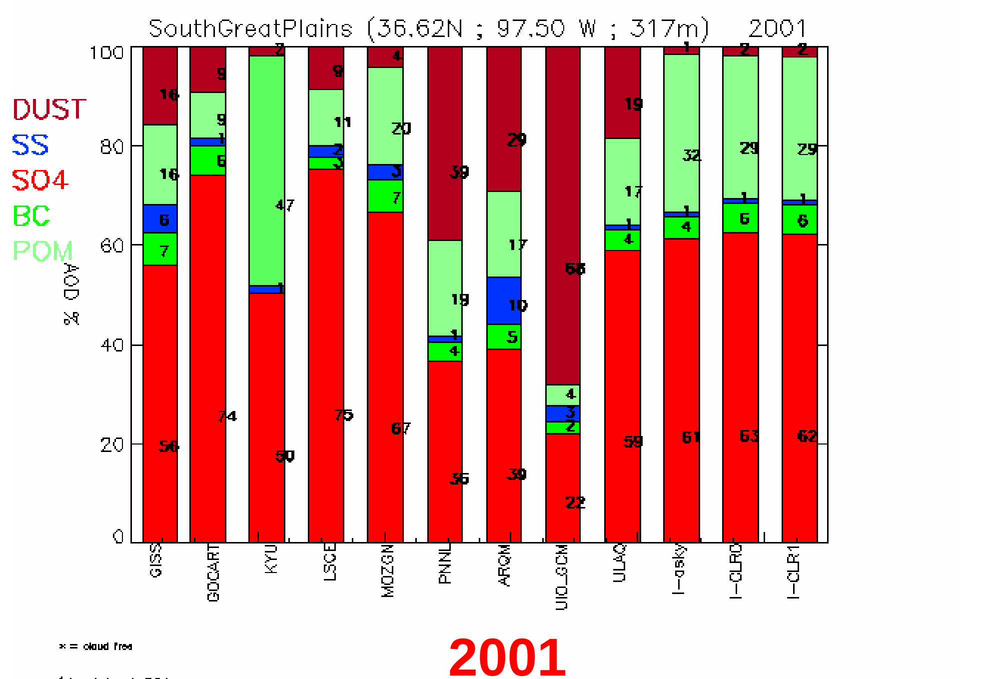
But…

Large differences in compositional mixtures

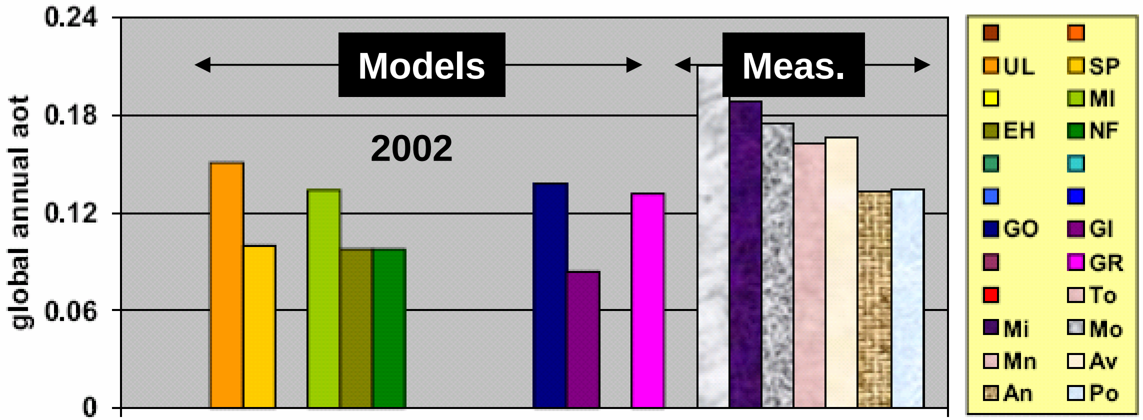




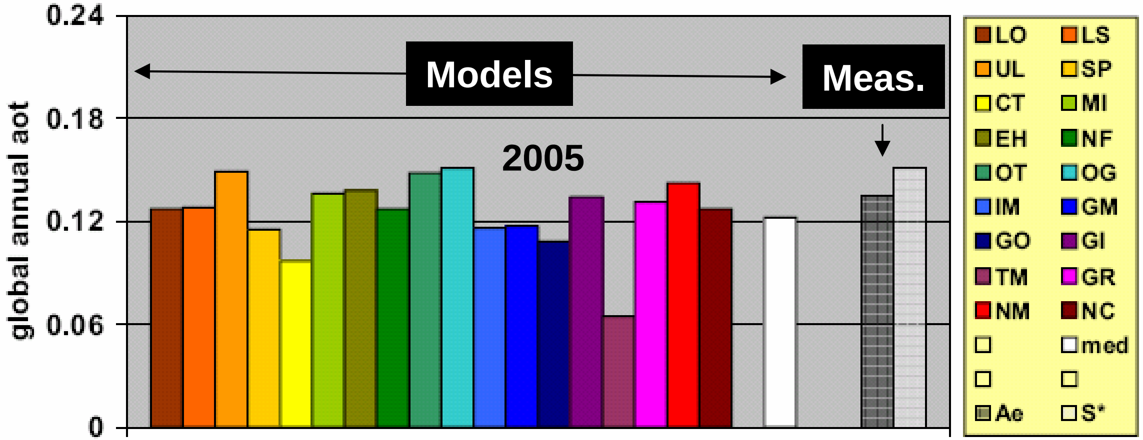
2000



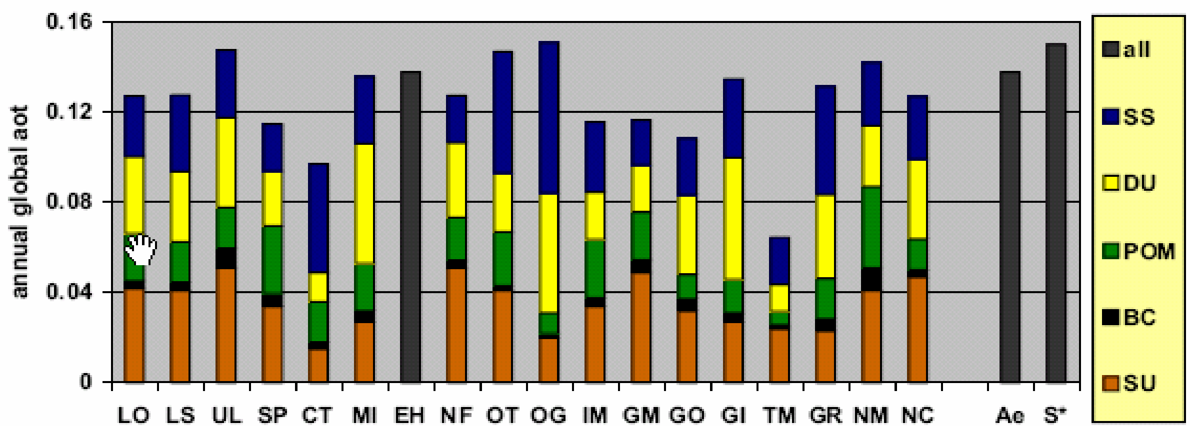
2001



2002: MODEL simulations (solid bars) vs. satellite DATA (textured)



2005: MODEL simulations and its median (white) vs. DATA (dotted)



Global

Model representations of global annual AOT have become closer to observations between 2002 to 2005

But…

Large model differences compositional mixture

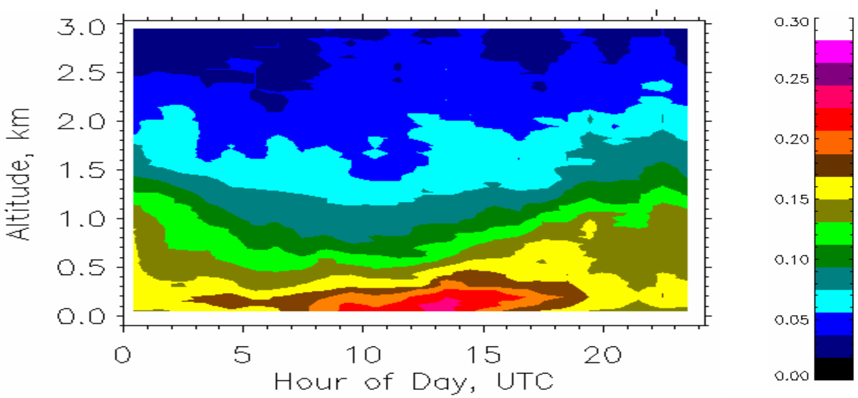
Kinne et al., 2005

Relative Humidity Profile Comparisons

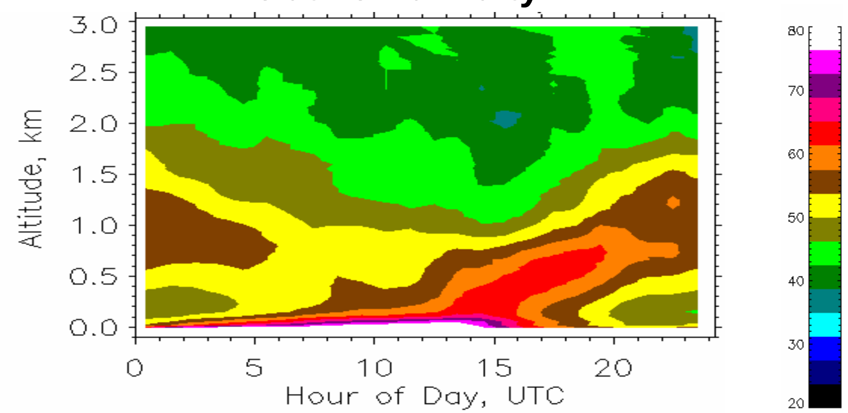
- Higher extinction concentrated over smaller vertical extent at night
- Highest extinction and RH near surface near sunrise
- Models appear slightly drier within a few hundred meters of surface

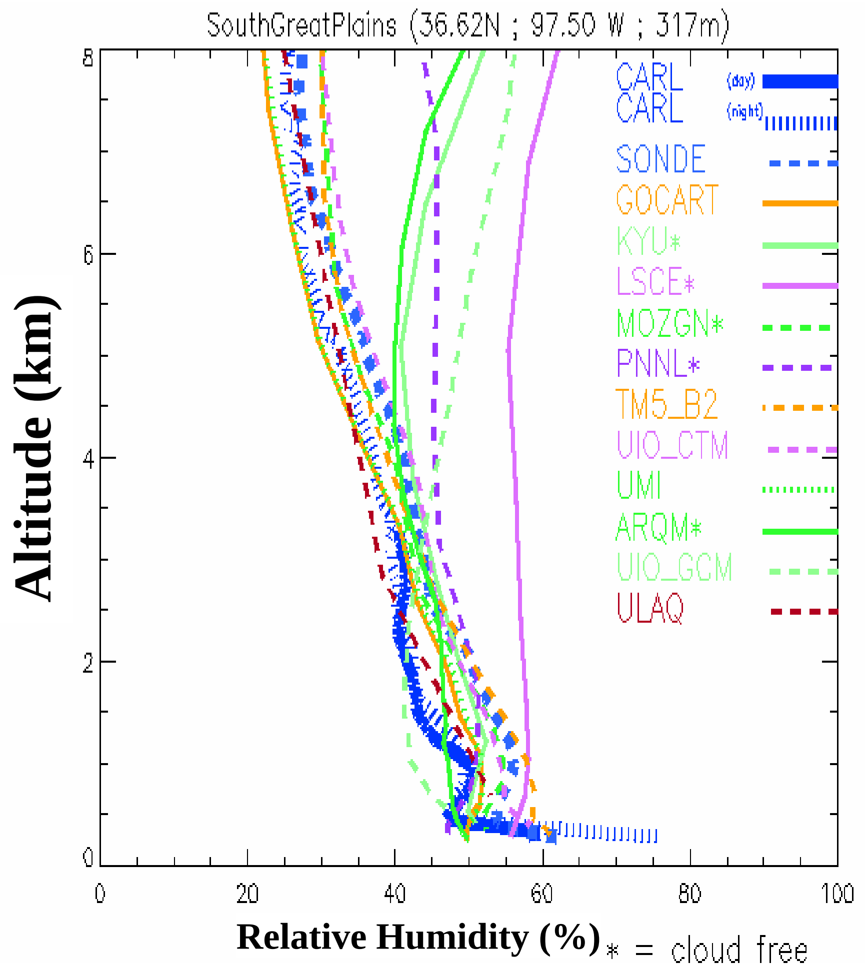
Average Diurnal Variability

Aerosol Extinction



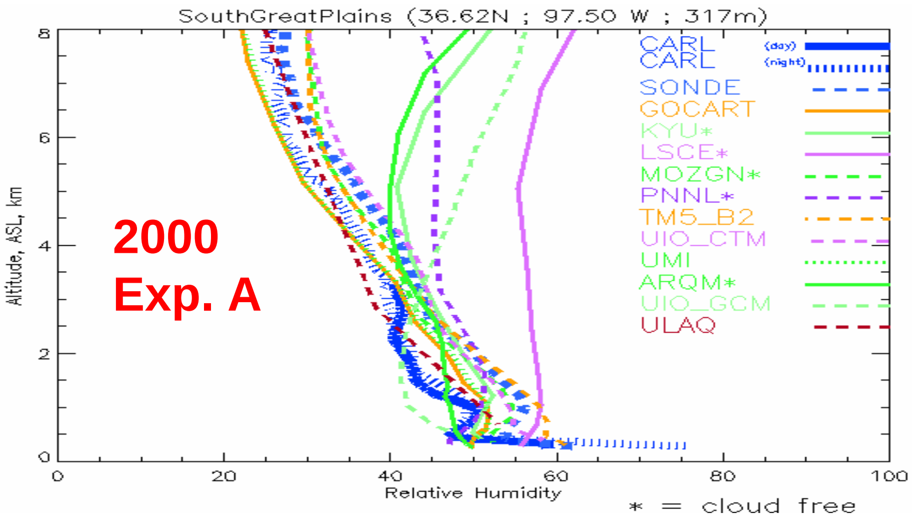
Relative Humidity

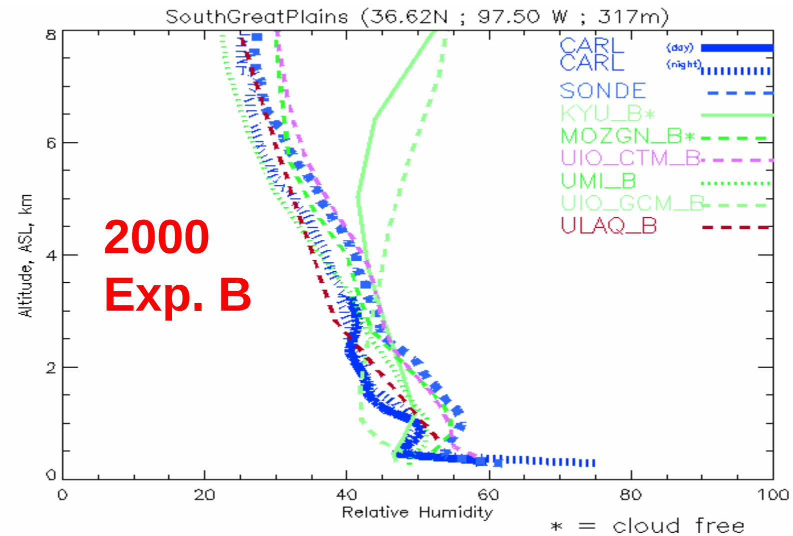


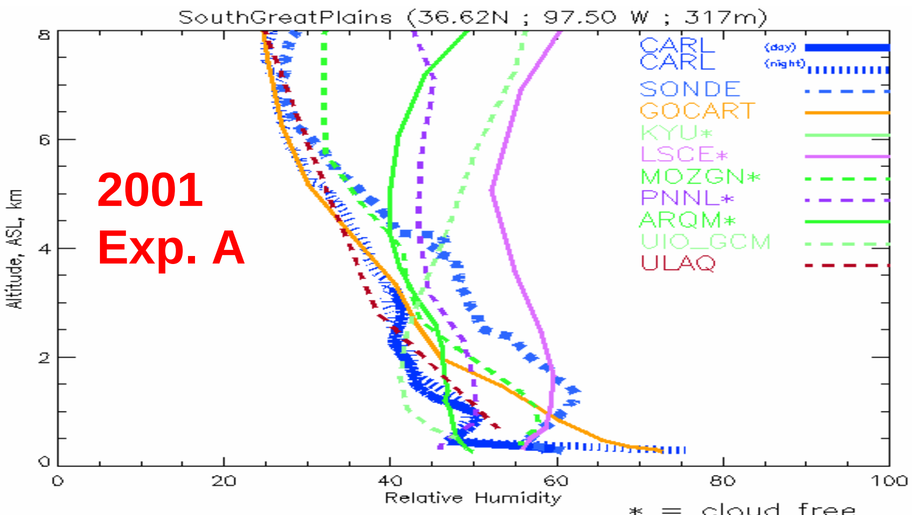


Relative Humidity Profile Comparisons

- Measured vs. model performance is essentially the same for both 2000 and 2001
- Comparisons do not change appreciably when prescribed meteorology is used
- CARL (clear sky) measurements are drier than radiosonde (all sky) measurements





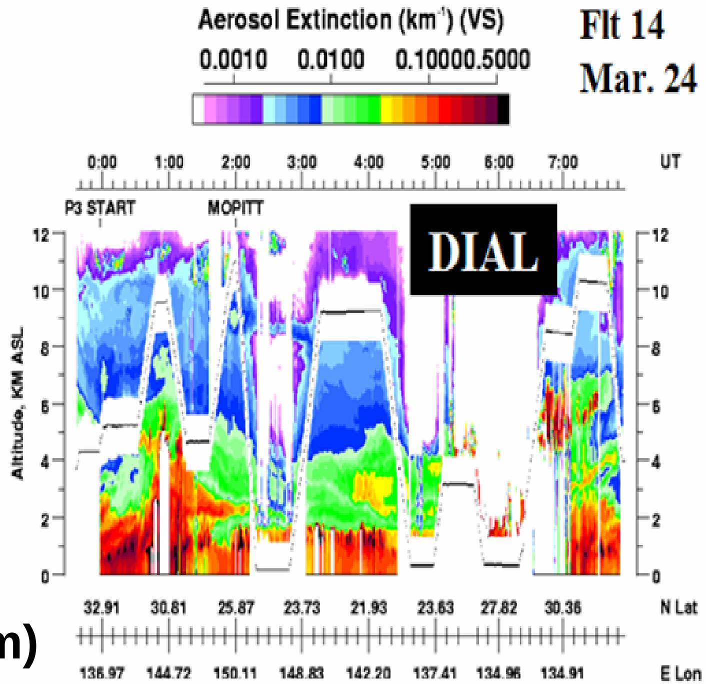


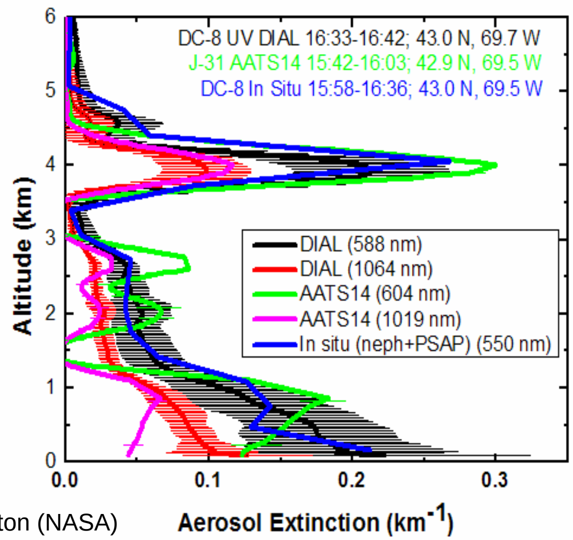
Exp. A – models as they are
Exp. B – prescribed emissions and meteorology

Aerosol Extinction Retrieval from Airborne Backscatter Lidar

NASA Langley Airborne UV DIAL Measurements

- **Simultaneous Nadir & Zenith Ozone & Aerosol Profiling**
- **Deployed on NASA DC-8 for:**
  - **TRACE-P (2001) (western Pacific)**
  - **INTEX NA (2004) (eastern U.S.)**
  - **INTEX B (2006) (Mexico, southeast U.S., northwest U.S.)**
- **Aerosol extensive parameters (300, 576, 1064 nm)**
  - **aerosol scattering ratio**
  - **backscatter**
  - **extinction (derived using model and/or MODI AOT to constrain retrieval)**
- **Aerosol intensive parameters**
  - **backscatter wavelength dependence**
  - **depolarization**

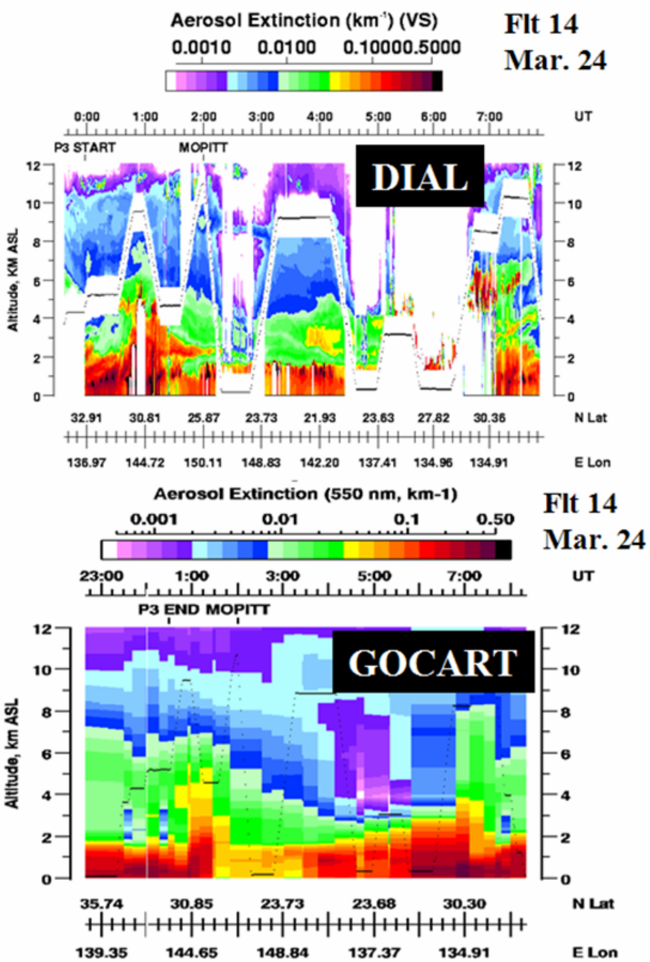


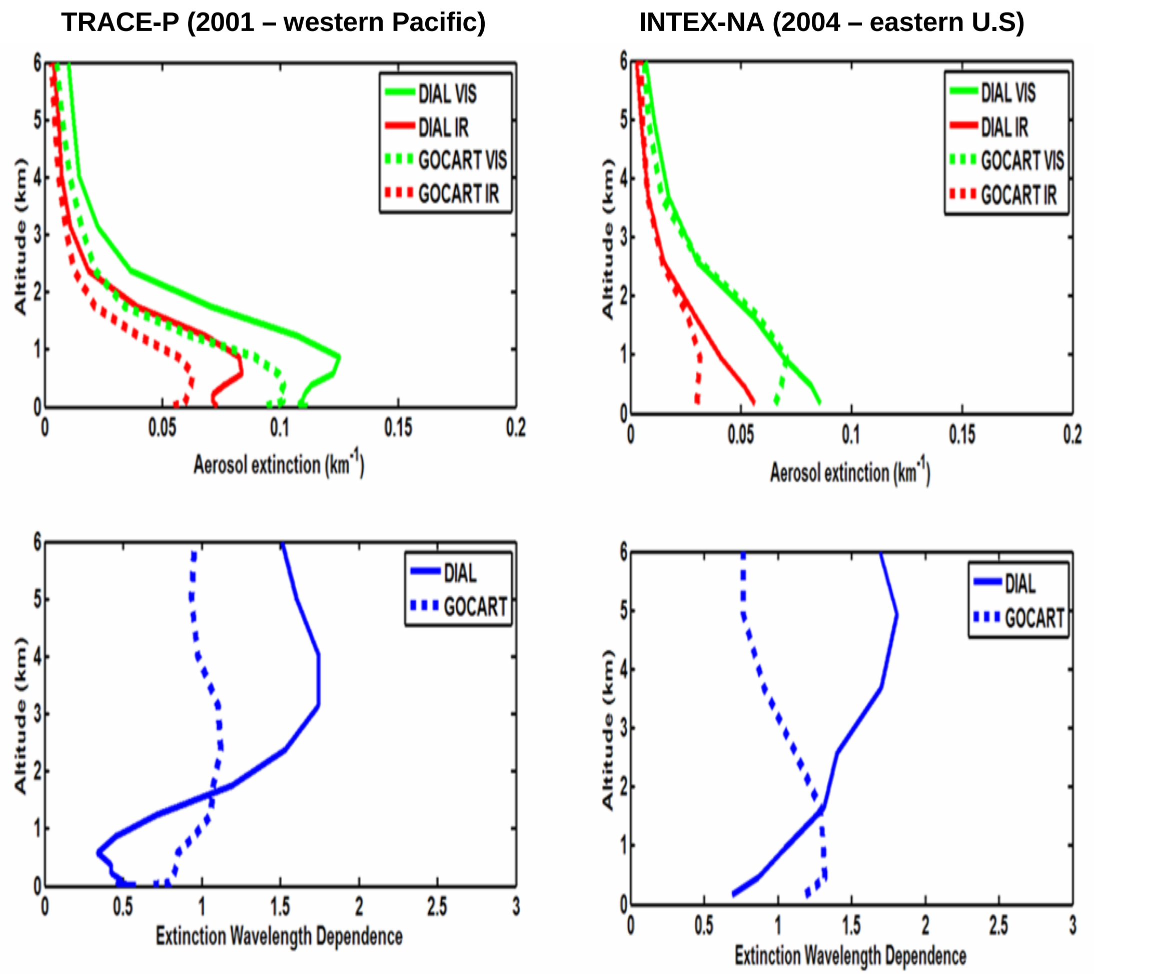


AATS14 data courtesy of Phil Russell, Jens Redemann, John Livingston (NASA)
HIGEAR data courtesy of Tony Clarke (Univ. of Hawaii)

GOCART Aerosol Evaluation using Airborne Backscatter Lidar

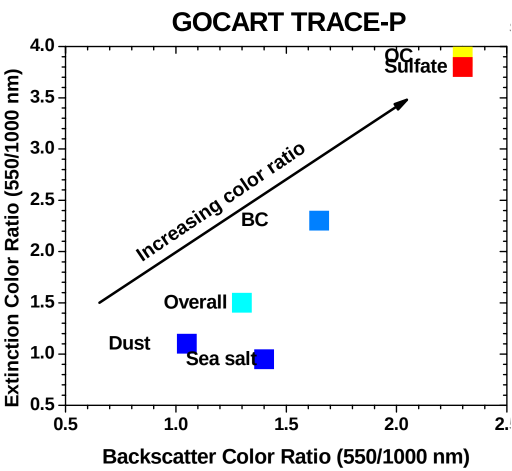
- Lidar aerosol extinction profiles are used to evaluate GOCART aerosol simulations
- During TRACE-P, GOCART profiles were lower than lidar throughout troposphere, with smallest differences near the surface
- During INTEX-NA, GOCART and lidar profiles agreed above 1 km, largest differences near the surface
- Different behavior may be related to more frequent occurrence of elevated layers during TRACE-P
- GOCART shows less vertical variability in wavelength dependence (particle size) than lidar

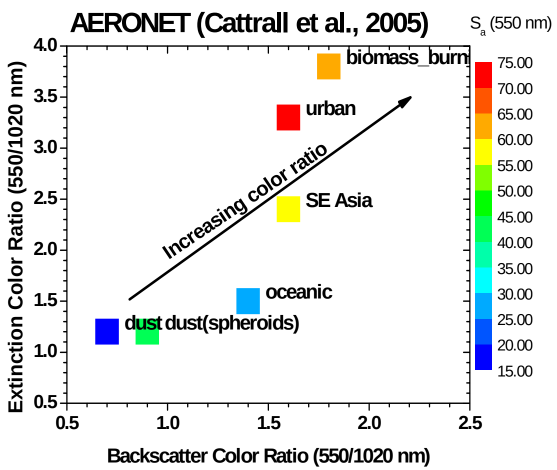




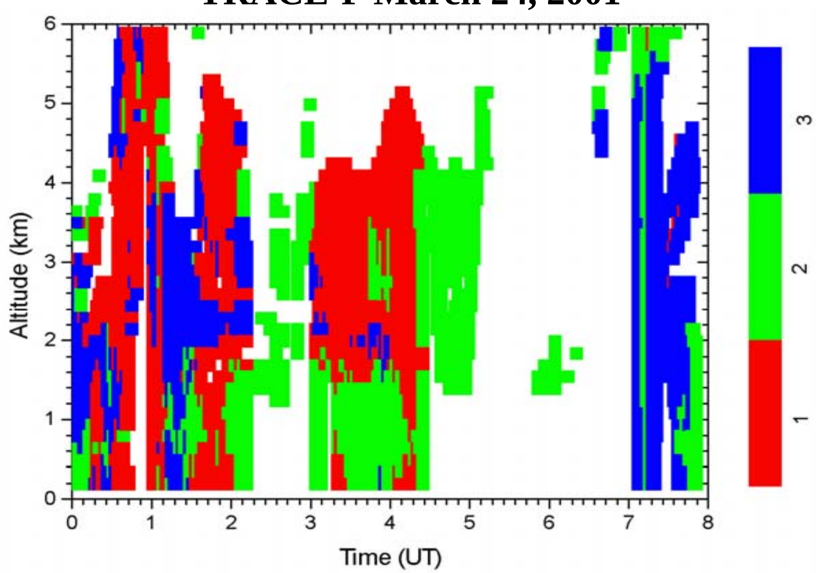
Aerosol Classification Using Lidar Measurements

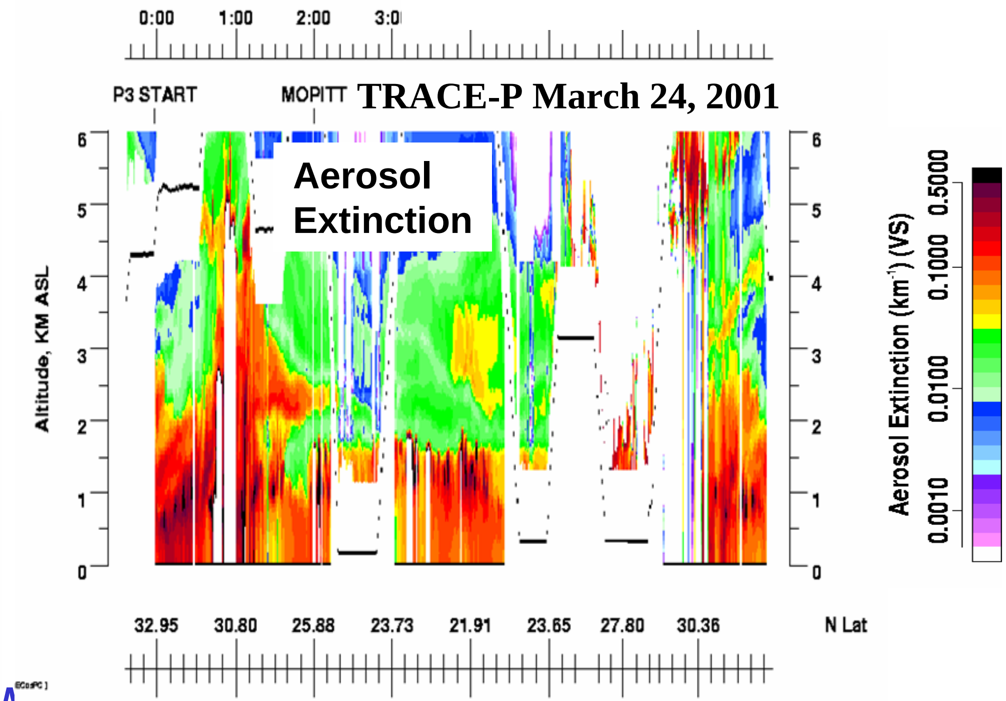
- Aerosol types were grouped using intensive parameters derived from DIAL
  - Extinction color ratio
  - Backscatter color ratio
  - Depolarization
- Three main clusters were identified
  - Cluster 1 – high ratio, elevated depol – mix of dust, urban (sulfate)
  - Cluster 2 – mid ratios, low depol – mix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





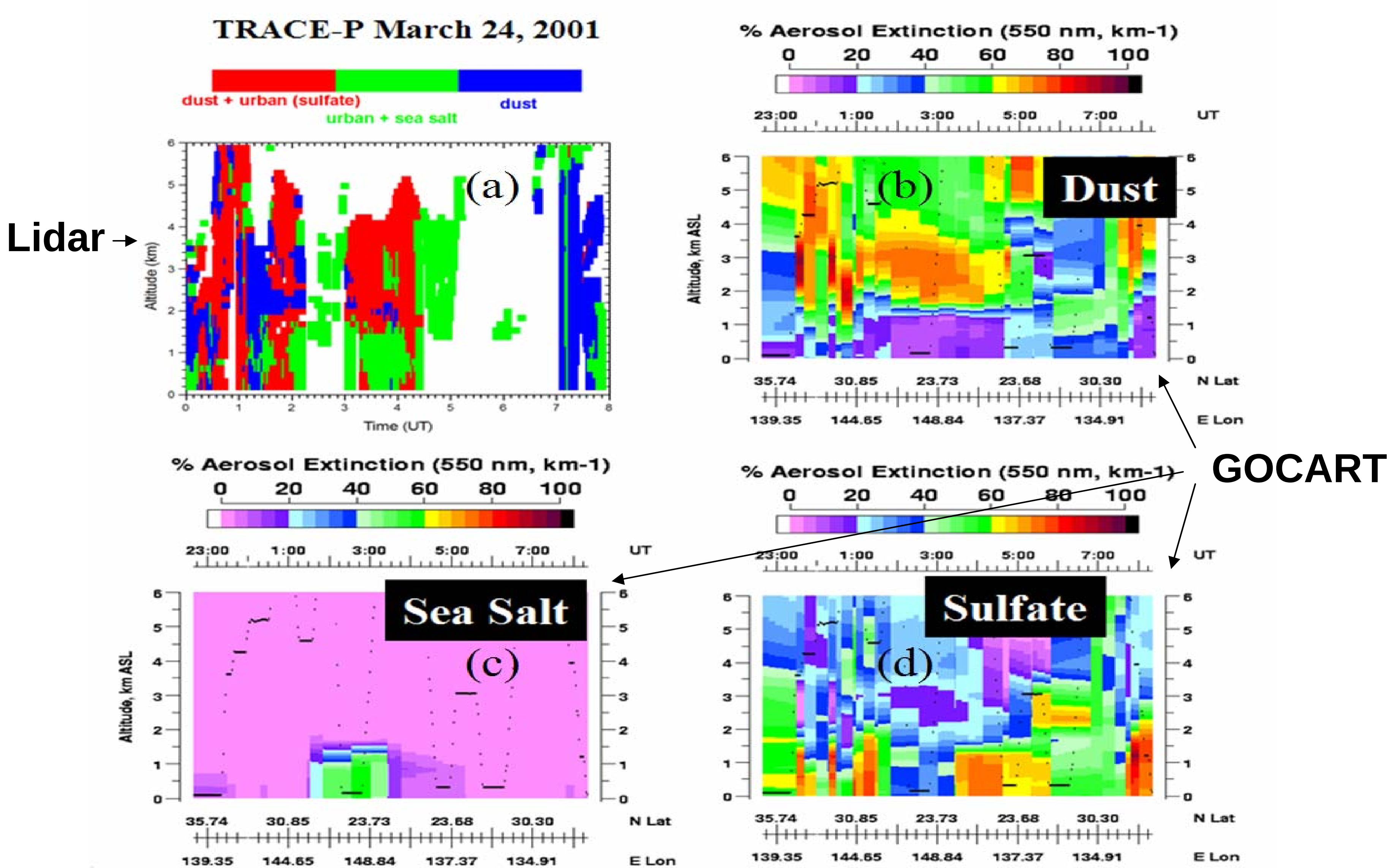
TRACE-P March 24, 2001





Evaluate GOCART model simulations of aerosol type

Initial attempts to use lidar profile measurements to evaluate GOCART model simulations of aerosol type



NASA Langley Airborne High Spectral Resolution Lidar (HSRL)

New

New

- **HSRL independently measures aerosol and molecular backscatter**
  - Can be internally calibrated
  - No correction for extinction required to derive backscatter profiles
  - More accurate aerosol layer top/base heights

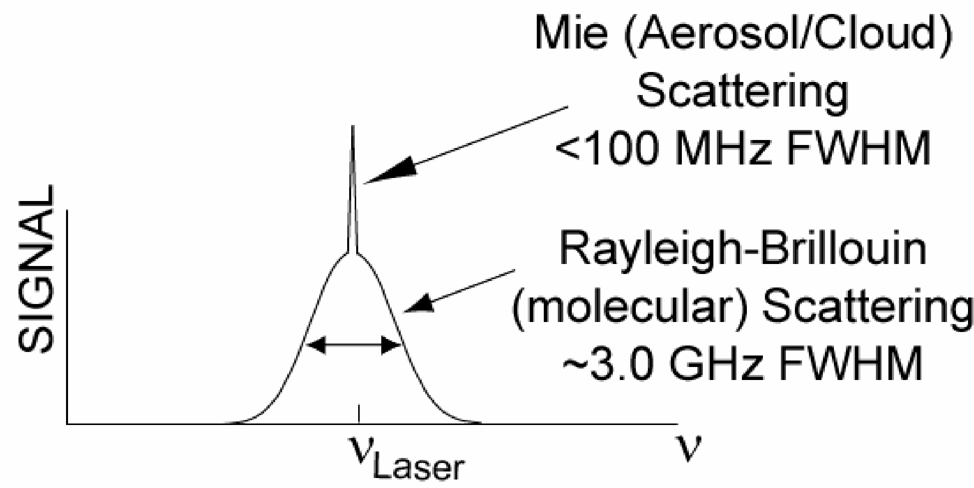
- **HSRL enables independent estimates of aerosol backscatter and extinction**
  - Extinction and backscatter estimates require no S_a assumptions
  - Provide *intensive* optical data from which to infer aerosol type

Products

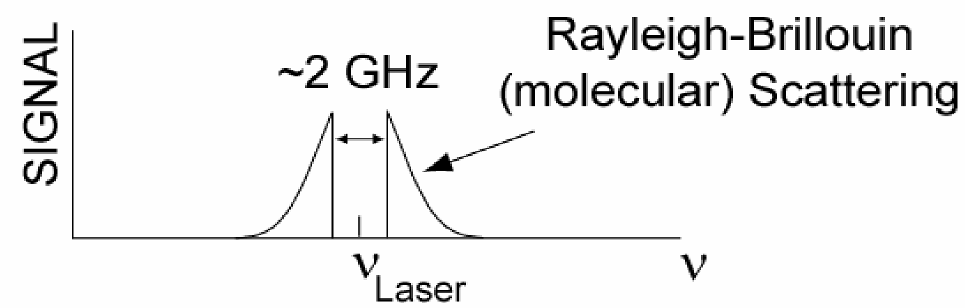
Extensive – depend on type and amount
Aerosol Backscatter 532 nm
Aerosol Backscatter 1064 nm (standard retrieval)
Aerosol Extinction and Aerosol Optical Thickness

Intensive – depend on type
Extinction-to-Backscatter Ratio (S_a) (532nm)
Aerosol Depolarization (532 & 1064 nm)
Aerosol Depolarization Ratio (1064/532 nm)
Aerosol Wavelength Dependence (1064/532 nm)

Atmospheric Scattering



Effect of Iodine Vapor Notch Filter



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Aerosol Backscatter 532 nm
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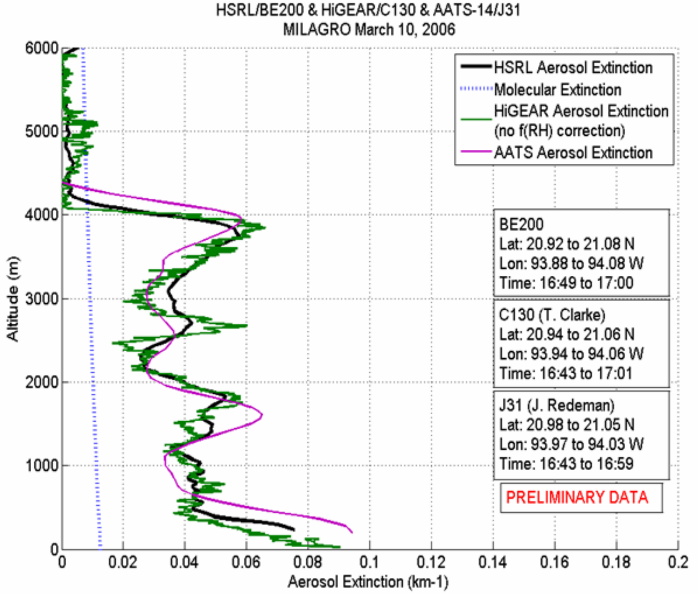
Intensive – depend on type

Extinction-to-Backscatter Ratio (S_a) (532nm)
Aerosol Depolarization (532 & 1064 nm)
Aerosol Depolarization Ratio (1064/532 nm)
Aerosol Wavelength Dependence (1064/532 nm)

Comparison of Aerosol Extinction Measurement (Preliminary Data)



- AATS14 data courtesy of Phil Russell, Jens Redemann, John Livingston (NASA)
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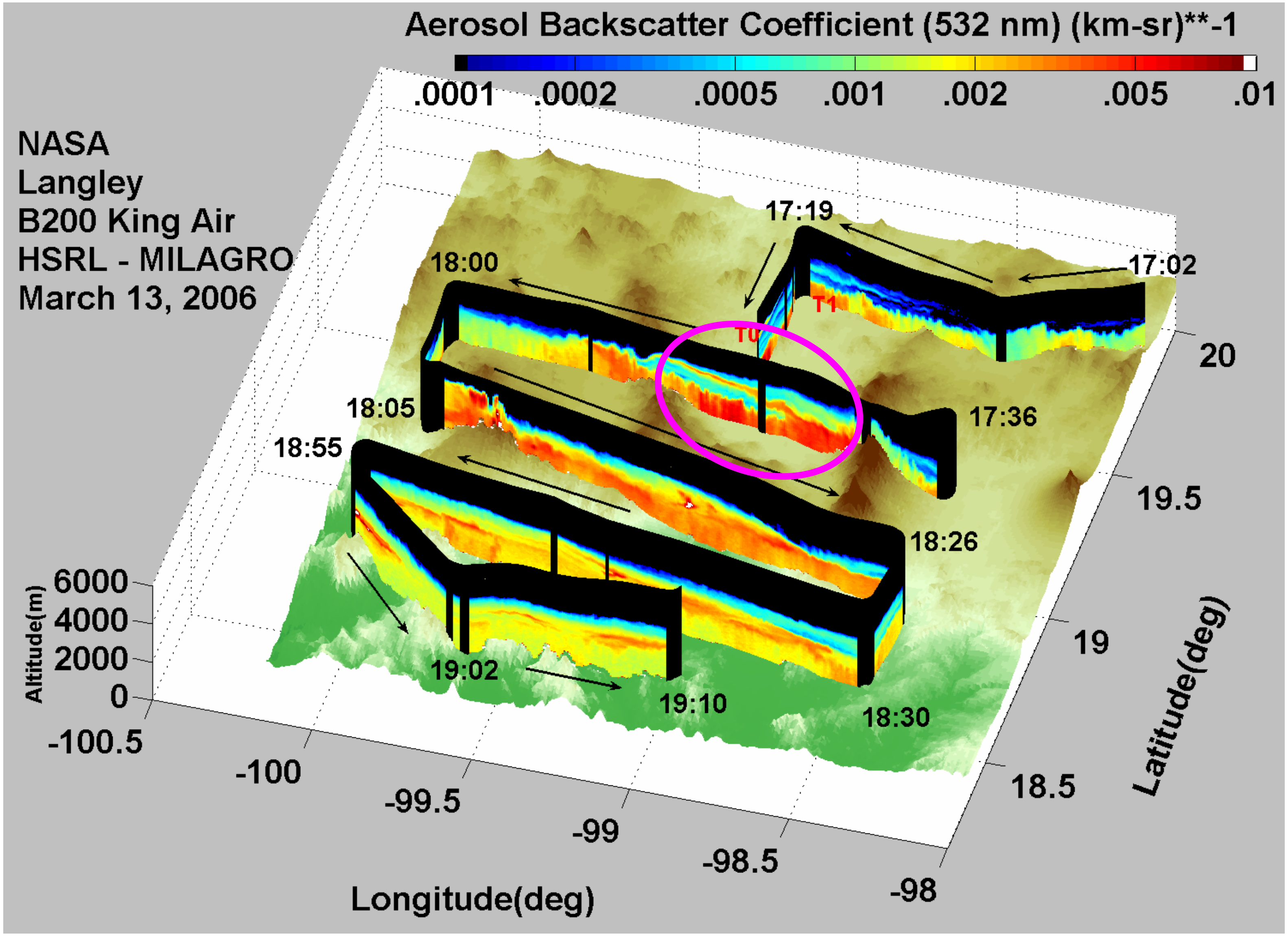
HSRL Measurements over Mexico City region

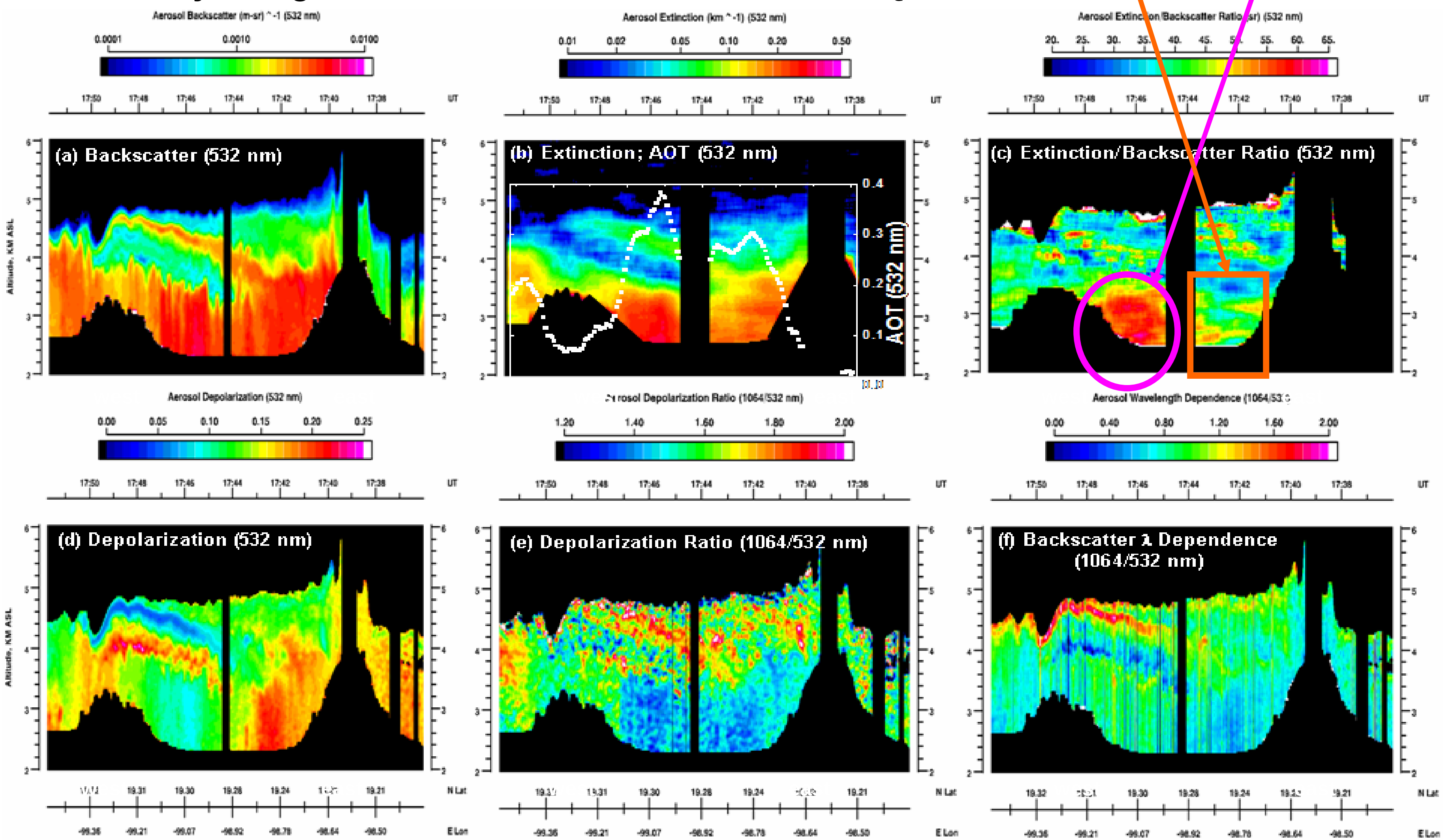


Characterize the horizontal distribution of aerosol types

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

➢ Currently using HSRL measurements to assess RAQMS and STEM models



Summary

- AEROCOM vs. ground-based Raman lidar
  - AEROCOM average aerosol extinction profiles
    - In good agreement with the Raman lidar profiles above about 2 km
    - Below 2 km the average model profiles are significantly (30-50%) lower
    - Vertical variability in the average model aerosol extinction profiles is less than the variability in the corresponding Raman lidar profiles
    - Measured vs. model performance is essentially the same for both 2000 and 2001
    - Model extinction profiles do not change appreciably when prescribed emissions and meteorology are used
  - AEROCOM average relative humidity profiles
    - Typically between CARL (clear sky) and radiosonde (all sky) measurements
    - Measured vs. model performance is essentially the same for both 2000 and 2001
    - Comparisons do not change appreciably when prescribed meteorology is used
- GOCART vs. airborne lidar
  - During TRACE-P, GOCART profiles were lower than lidar throughout troposphere
  - During INTEX-NA, GOCART and lidar profiles agreed above 1 km, largest differences near the surface
  - GOCART shows less vertical variability in wavelength dependence (particle size) than lidar

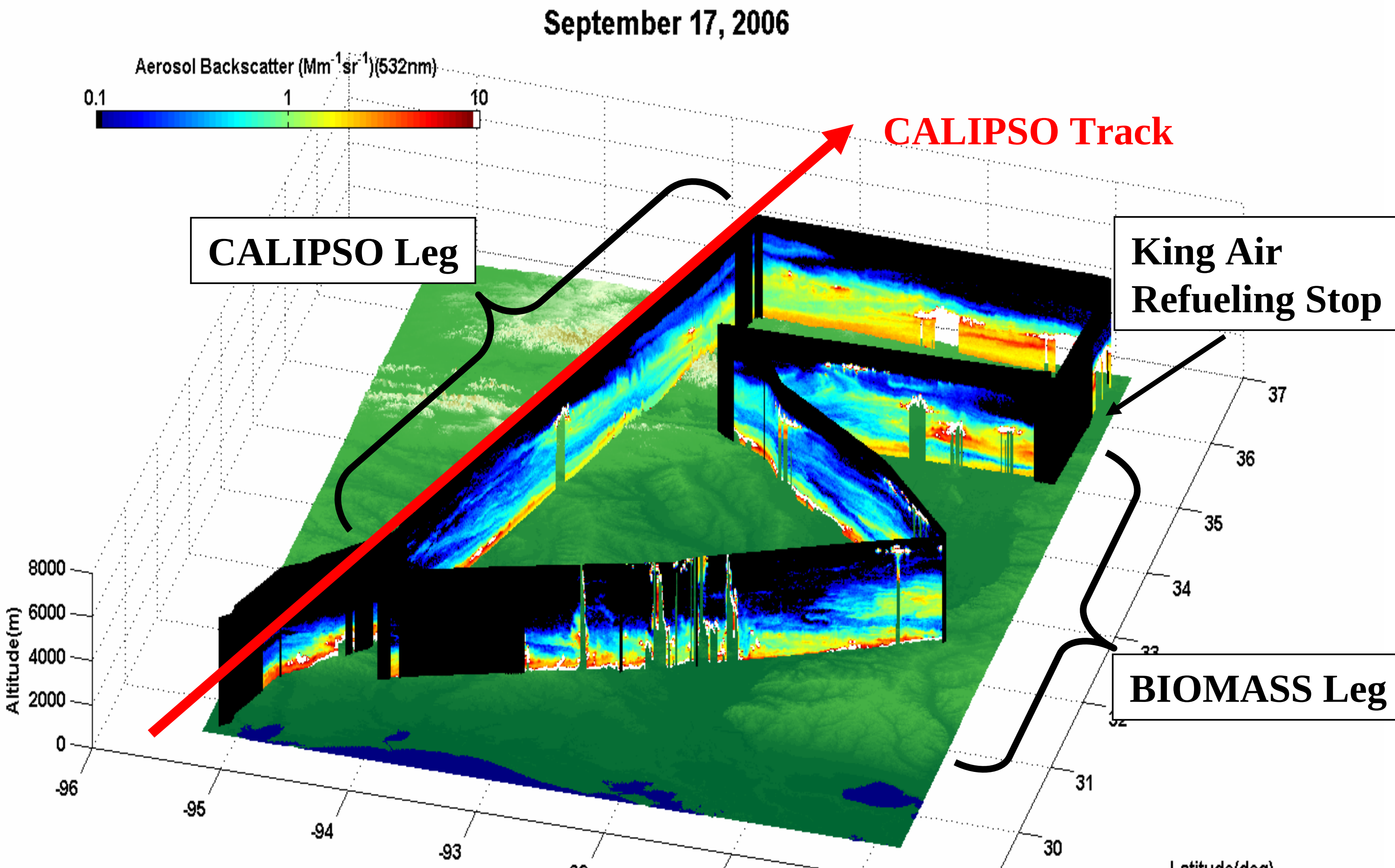
Future

- Evaluating model profiles with CALIPSO aerosol profiles
- Use airborne DIAL and HSRL measurements from recent missions to evaluate model simulations of particle type

What future space-based aerosol measurements would be most useful for models?

Backup Slides

NASA LaRC High Spectral Resolution Lidar (HSRL) Backscatter

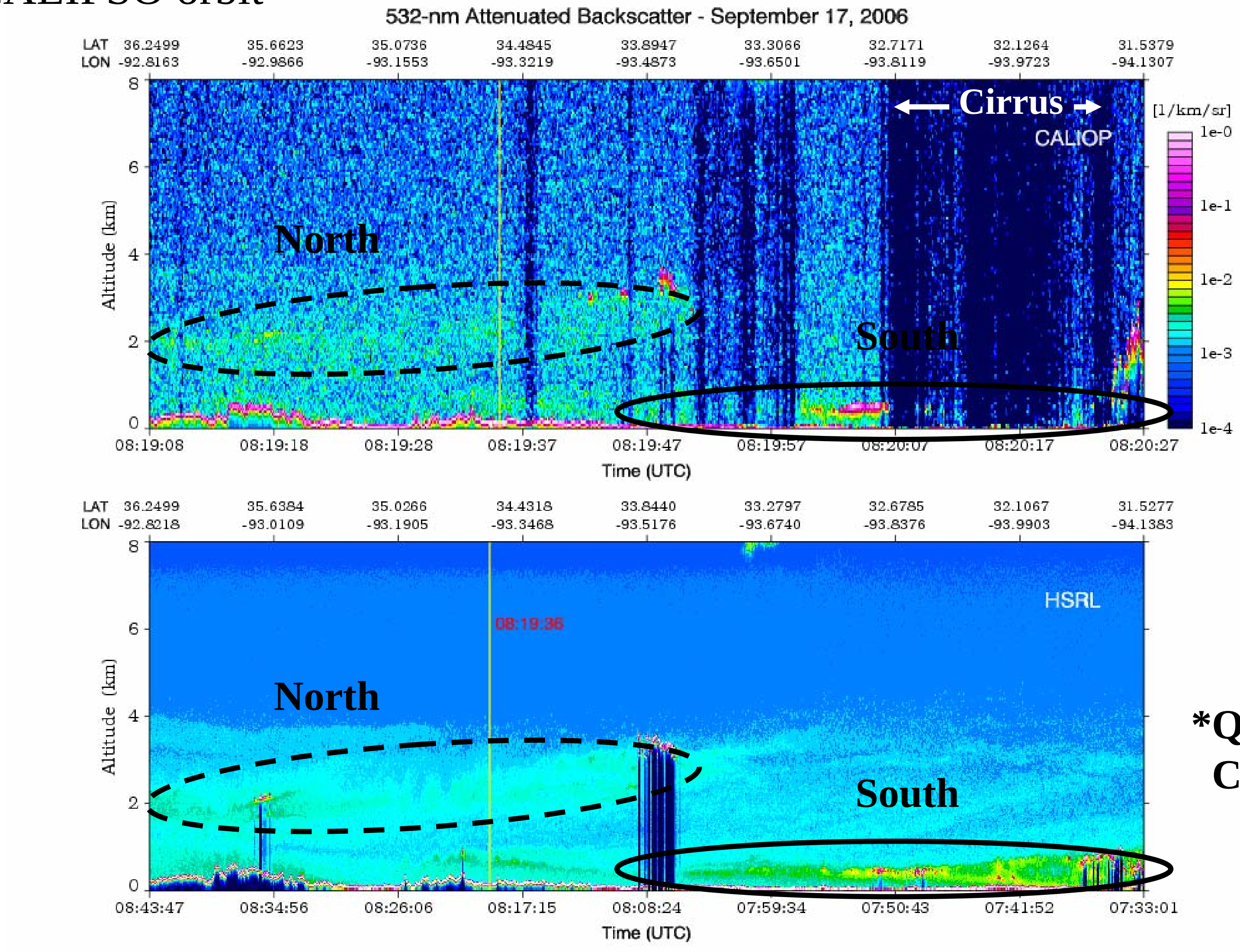


Elevated aerosol seen along CALPISO track and in region where fires have been detected.

CALIPSO* validation Leg:

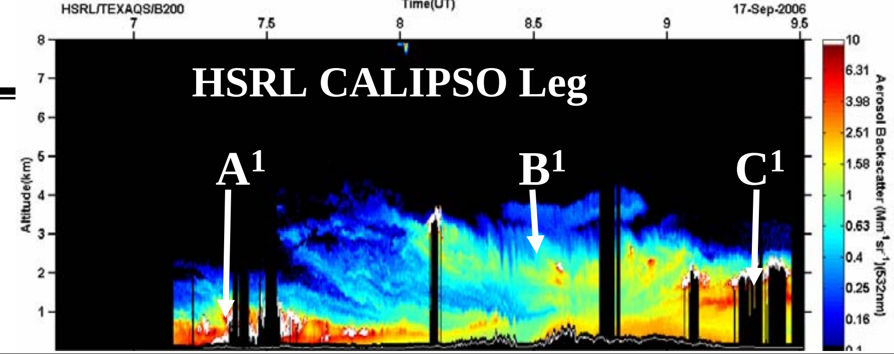
•Both attenuated backscatter measurements show elevated layer of enhanced aerosol on northern portion of CALIPSO leg (dash).

•Aerosol observed by HSRL on southern portion (solid) is obscured by high cirrus along CALIPSO orbit

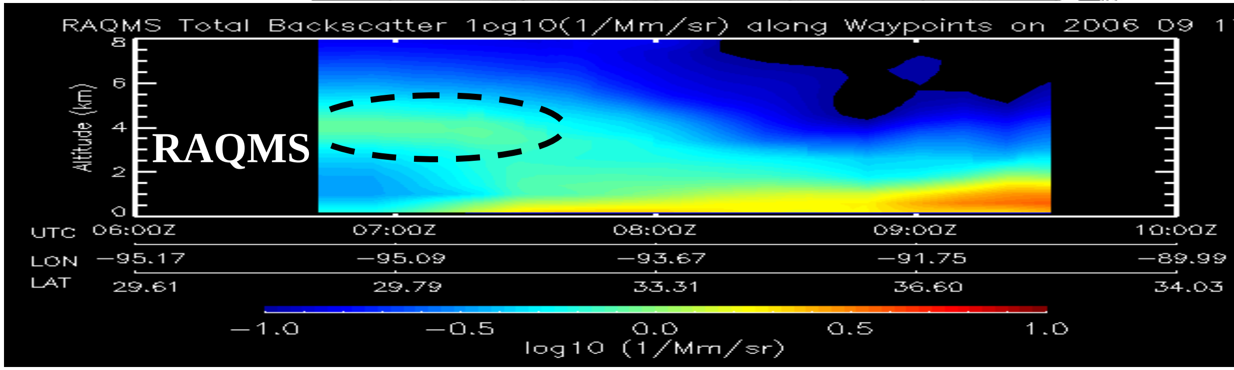


*Quick look CALIPSO data

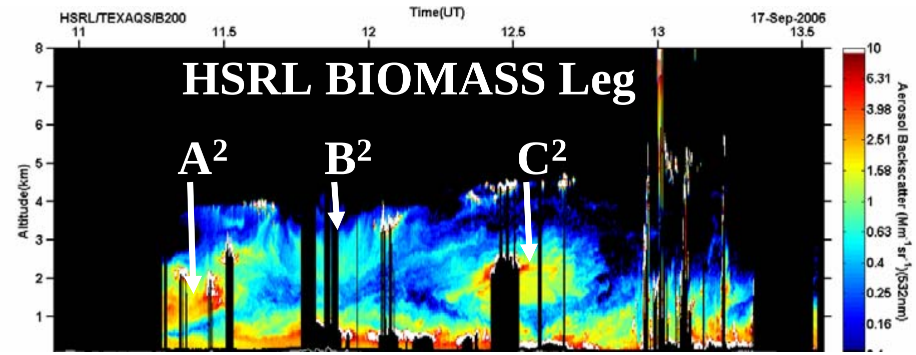
HSRL Model Verification: aerosol backscatter $RAQMS_{regional}$ (80km)

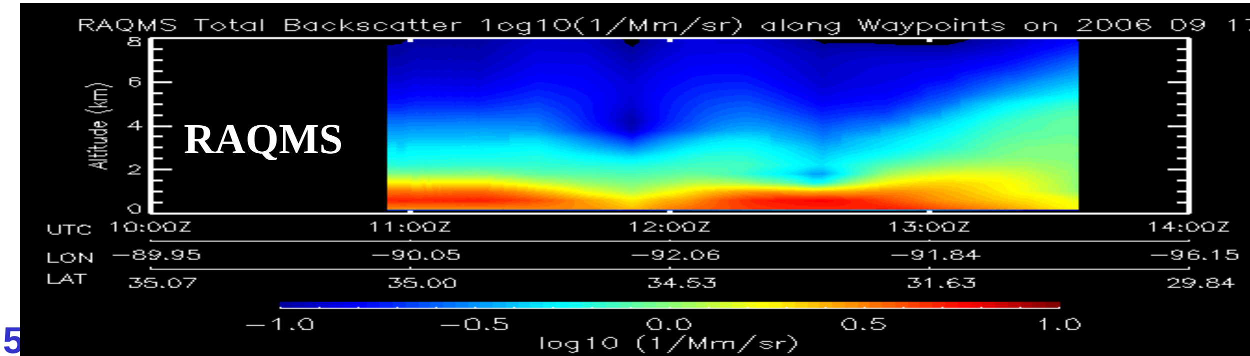


RAQMS provides a good prediction of the magnitude of BL aerosol backscatter, but:



1) misses elevated aerosol suspected of being smoke (B^1, C^1, A^2, B^2, C^2) and BL enhancement near Houston (A^1)
1) predicts elevated aerosol layer at beginning of CALIPSO underflight that is not observed (dash)

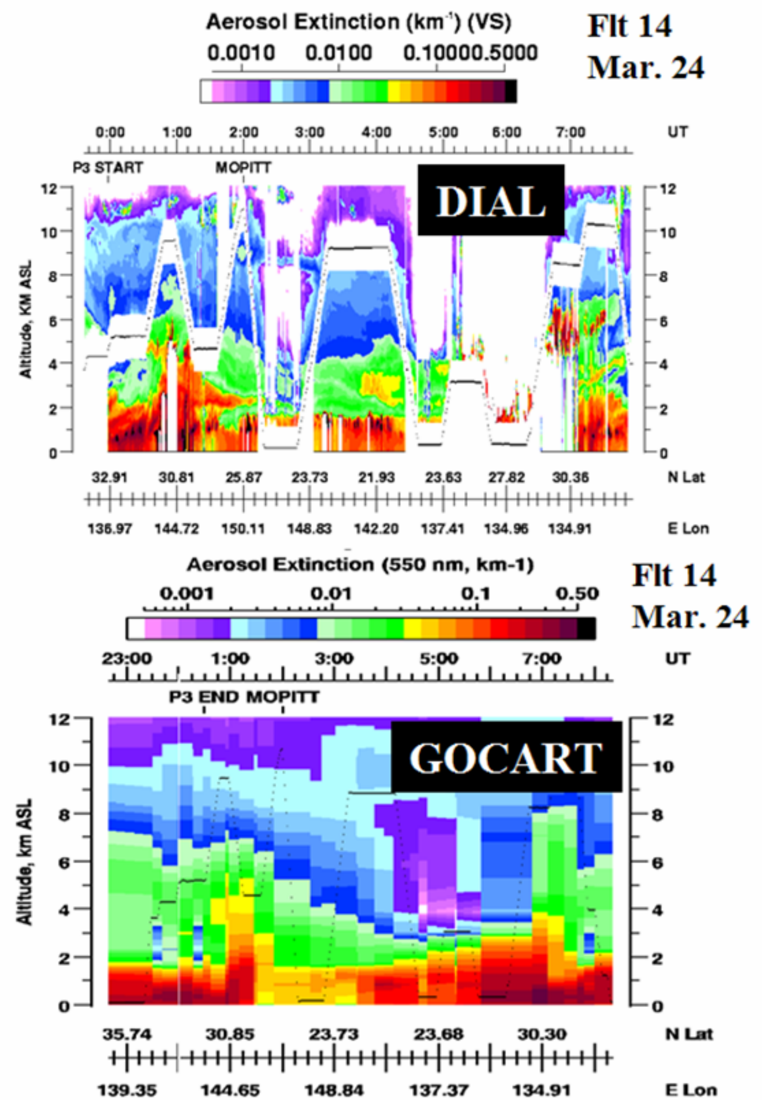




NASA Langley Airborne UV DIAL Measurements

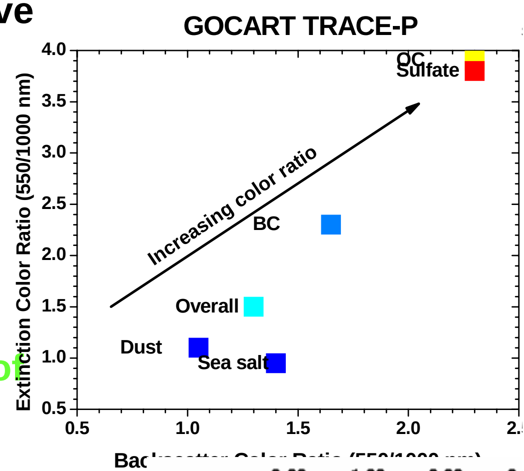
- Simultaneous Nadir & Zenith Ozone & Aerosol Profiling
- Deployed on NASA DC-8 for:
    - TRACE-P (2001) (western Pacific)
    - INTEX NA (2004) (eastern U.S.)
    - INTEX B (2006) (Mexico, southeast U.S., northwest U.S.)
- Aerosol extensive parameters (300, 576, 1064 nm)
    - aerosol scattering ratio
    - backscatter
    - extinction (derived using model and/or MODIS AOT to constrain retrieval)
- Aerosol intensive parameters
    - backscatter wavelength dependence
    - depolarization

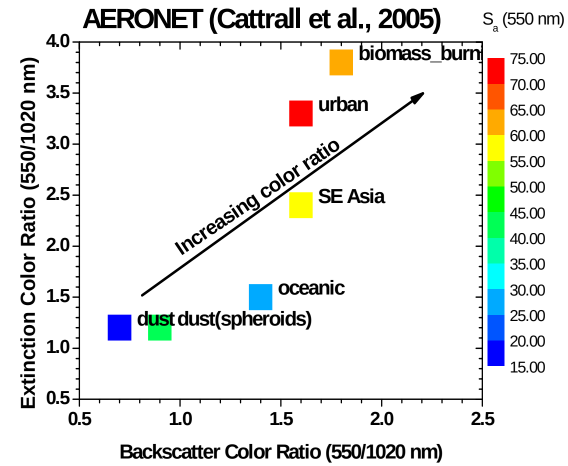
➢ Use lidar extinction profiles to evaluate GOCART model

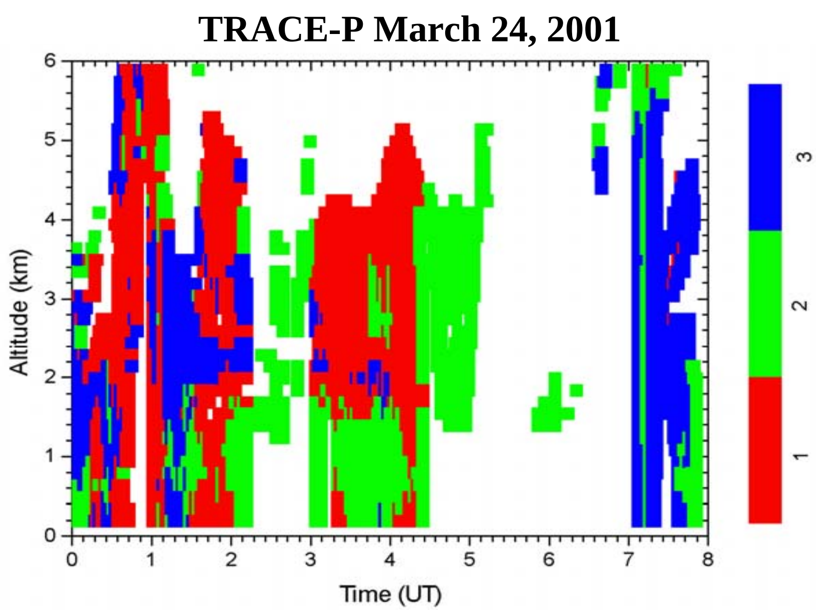


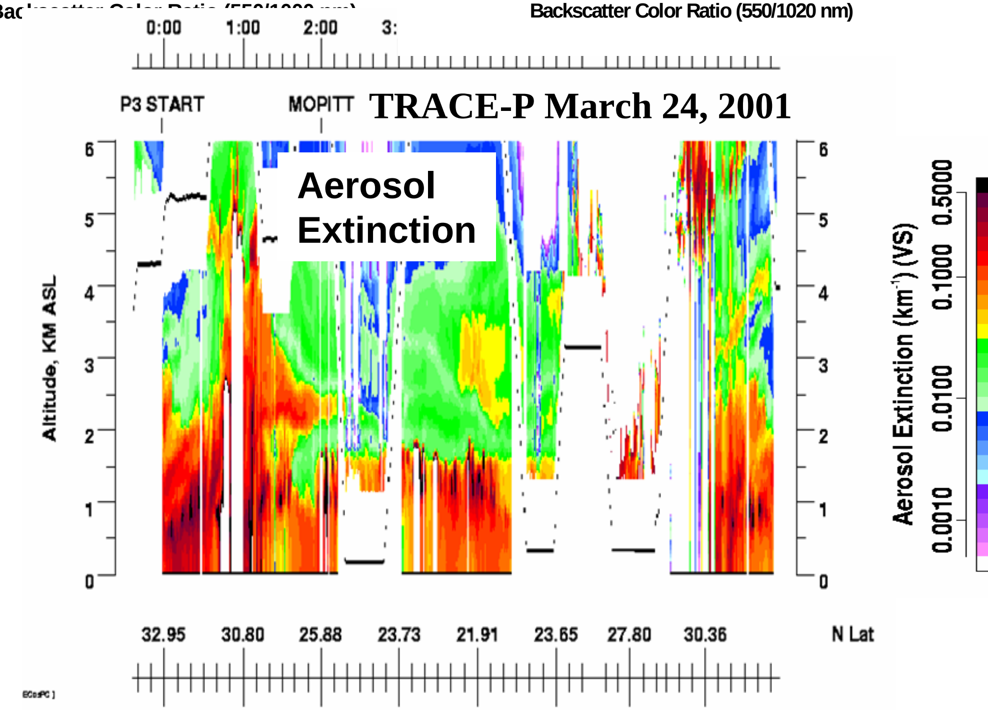
Aerosol Classification Using DIAL Measurements

- 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 (sulfate)
  - Cluster 2 – mid ratios, low depol – mix of urban and oceanic (sea salt)
  - Cluster 3 – low ratios, high depol - dust









Aerosol Profile Retrievals

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

Measured Signal; Range from Instrument; Calibration Constant; Molecular Backscatter Coefficient; Molecular Extinction Coefficient ← **Known**

Determined from measured signals and meteorological data

$$P(r) = \frac{C}{r^2}\left[\beta_m(r) + \beta_p(r)\right]\exp\left\{-2\int_0^r \left[\sigma_m(r') + \sigma_p(r')\right]dr'\right\}$$

Particulate Backscatter Coefficient; Particulate Extinction Coefficient ← **Retrieved Parameters**

"Lidar Ratio" = $\frac{\sigma_p(r)}{\beta_p(r)} = S_p$ ← Assumption of value for extinction-to-backscatter (S_p) ratio required for backscatter lidar retrieval

• 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

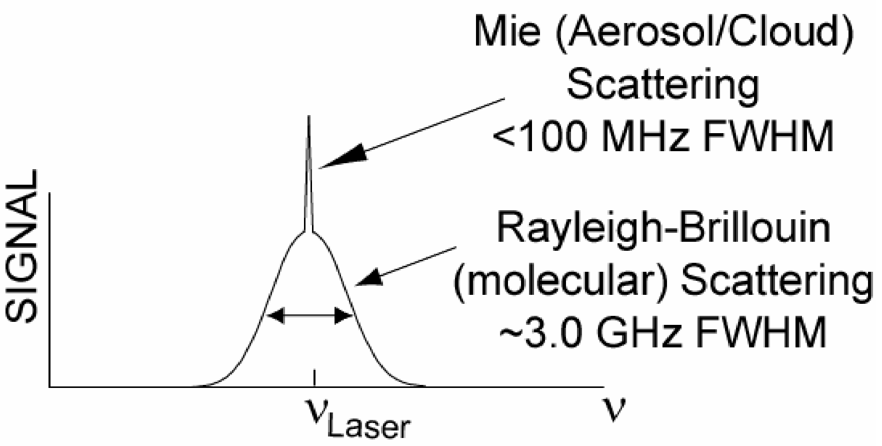
High Spectral Resolution Lidar (HSRL)

HSRL relies on spectral separation of aerosol and molecular backscatter in lidar receiver.

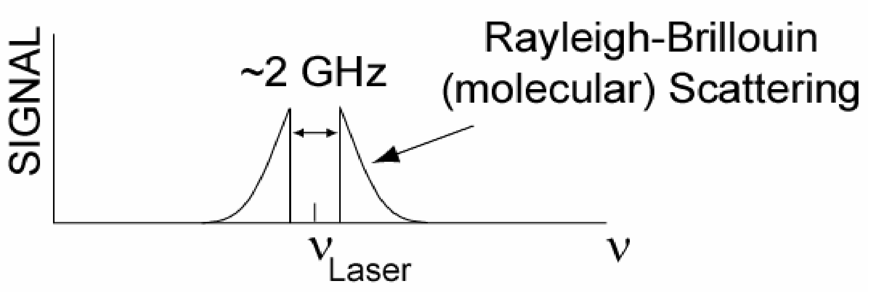
- **HSRL independently measures aerosol and molecular backscatter**
  - Can be internally calibrated
  - No correction for extinction required to derive backscatter profiles
  - More accurate aerosol layer top/base heights

- **HSRL enables independent estimates of aerosol backscatter and extinction**
  - Extinction and backscatter estimates require no S_a assumptions
  - Provide *intensive* optical data from which to infer aerosol type
  - Measurements of extinction at 2 wavelengths and backscatter at 3 wavelengths enables retrieval of aerosol microphysical parameters and concentration

Atmospheric Scattering



Effect of Iodine Vapor Notch Filter



HSRL: 2 equations, 2 unknowns

Measured Signal on Molecular Scatter (MS) Channel:

$$P_{MS}(r) = \frac{C_{MS}}{r^2} F(r)\,\beta_m(r)\,\exp\left\{-2\int_0^r \left[\sigma_m(r') + \underline{\sigma_p(r')}\right] dr'\right\}$$

Particulate Extinction

Measured Signal on Total Scatter (TS) Channel:

$$P_{TS}(r) = \frac{C_{TS}}{r^2}\left[\beta_m(r) + \underline{\beta_p(r)}\right]\exp\left\{-2\int_0^r \left[\sigma_m(r') + \sigma_p(r')\right] dr'\right\}$$

Particulate Backscatter

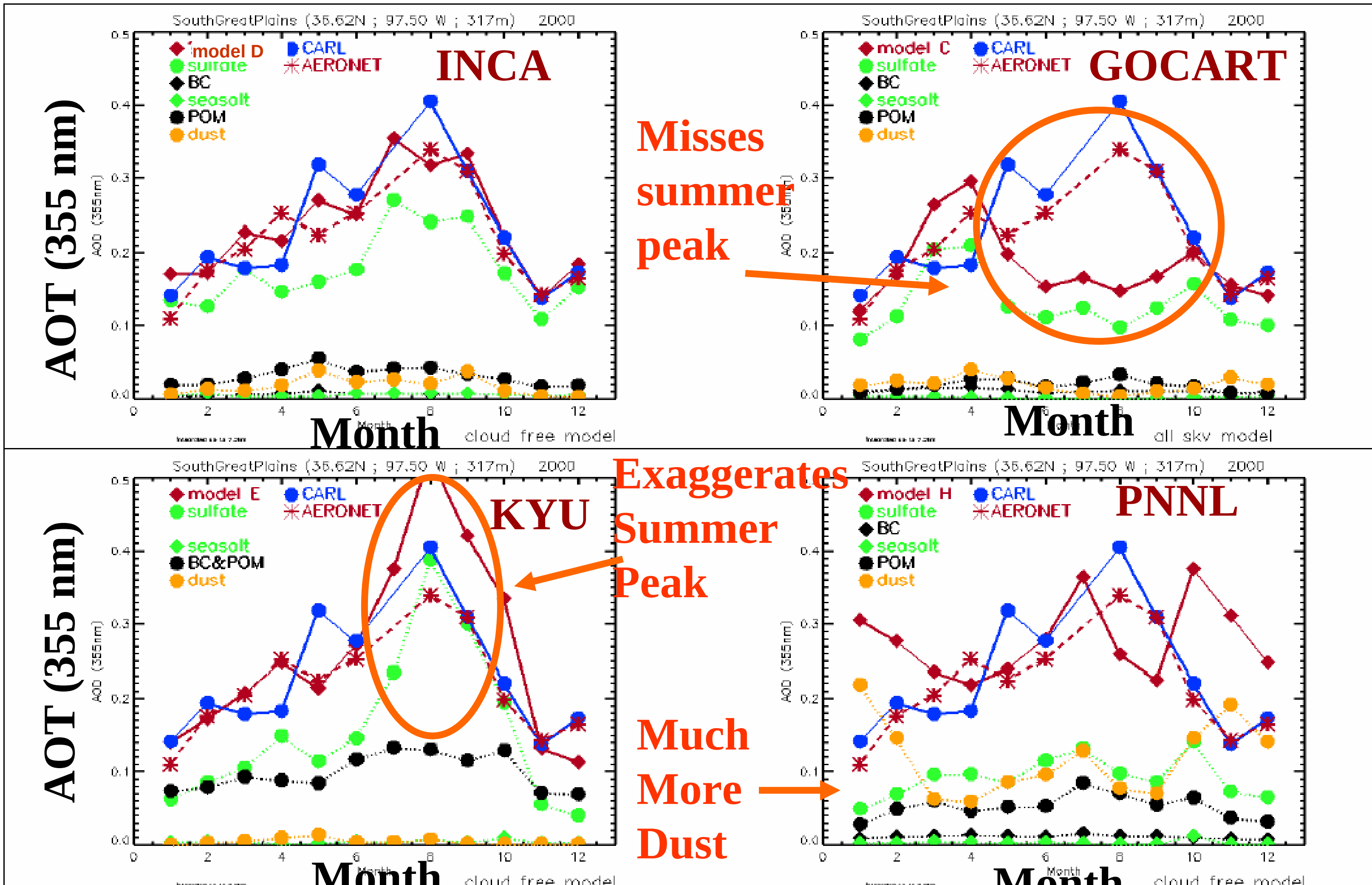
$$\frac{\sigma_p(r)}{\beta_p(r)} = \underline{S_p}$$

Ext / Backscatter

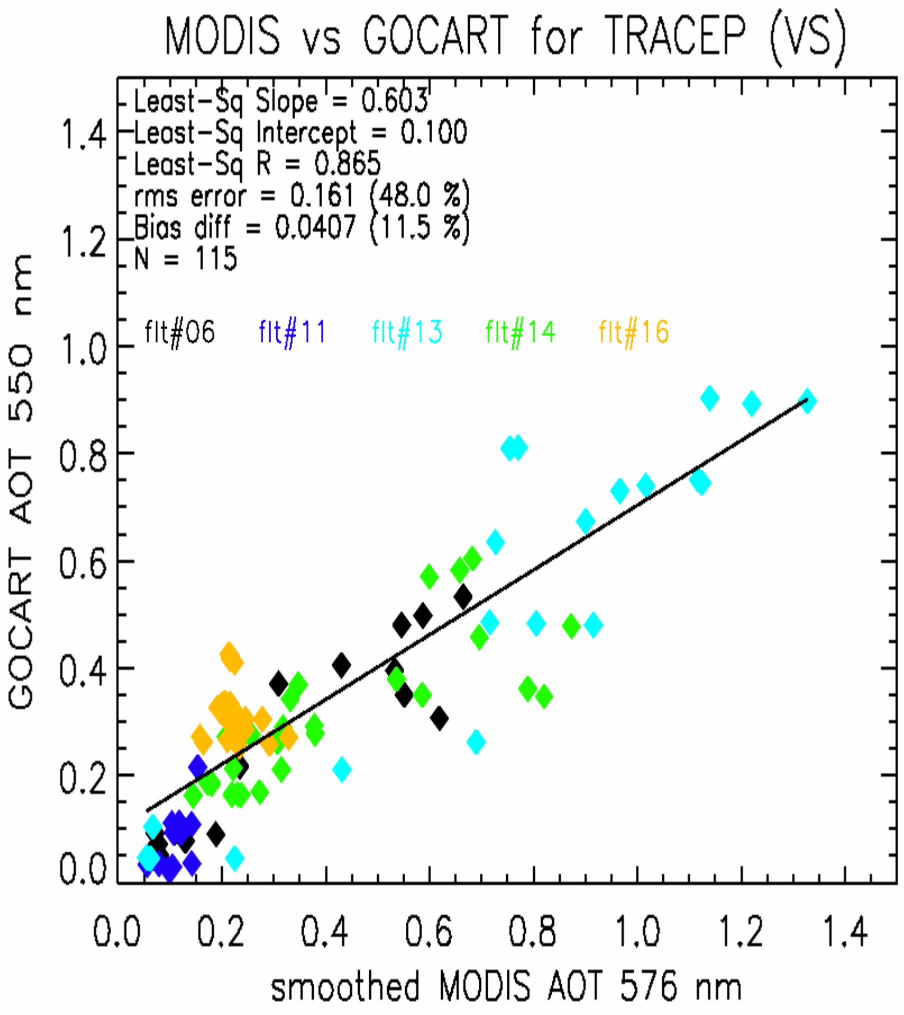
Retrieved Parameters

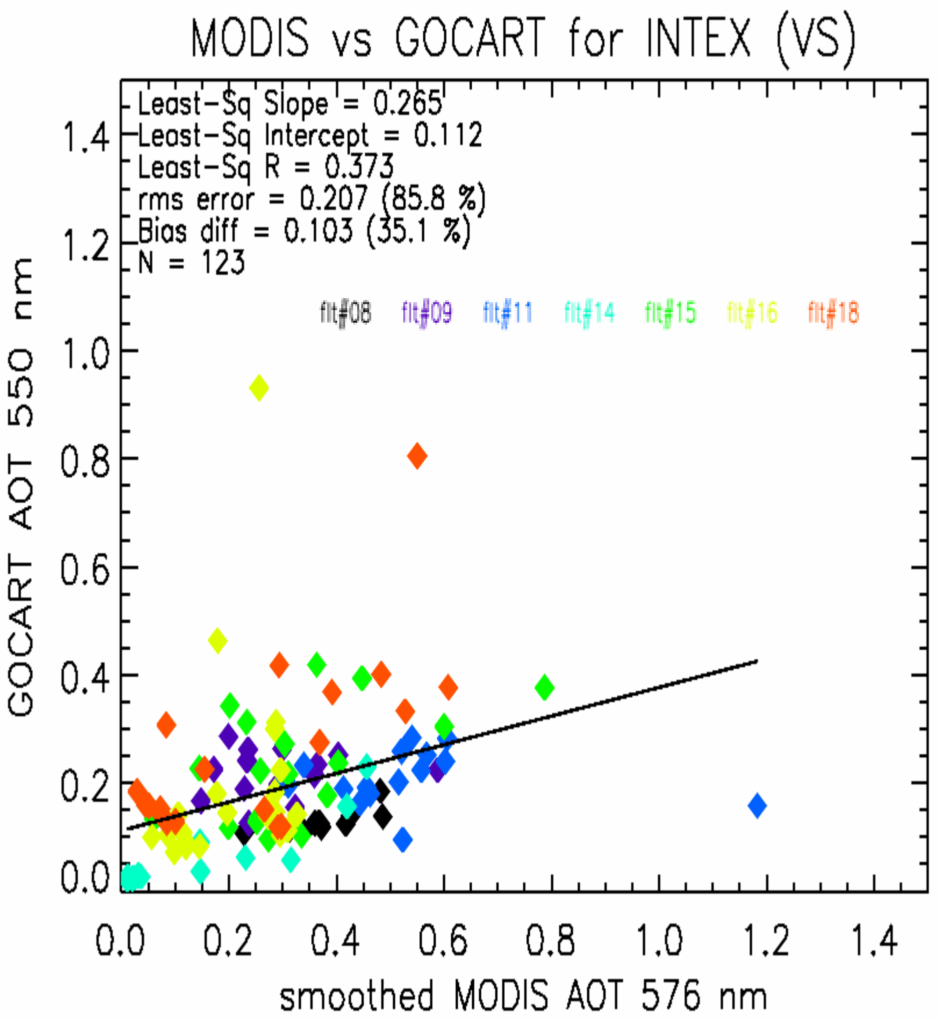
Measured versus Modeled AOT

- Seasonal variation of total AOT varies among the models
- Proportion of AOT due to various aerosol components varies



GOCART and MODIS AOT Comparisons





Aerosol module inter-Comparison in global models (AEROCOM)

Goals:

- Compare an ensemble of global aerosol models
- Eliminate weak components
- Reduce uncertainty in simulated radiative forcing

Strategy:

- Multi-model evaluation with observations
  - surface (AERONET, IMPROVE, GAW, ARM)
  - profile (EARLINET, ARM)
  - satellite (MODIS, AVHRR, TOMS, POLDER, MISR)
- Analyze and improve critical parameters and processes
- Experiments
  - A – models as they are
  - B – models with prescribed 2000 emissions and meteorology

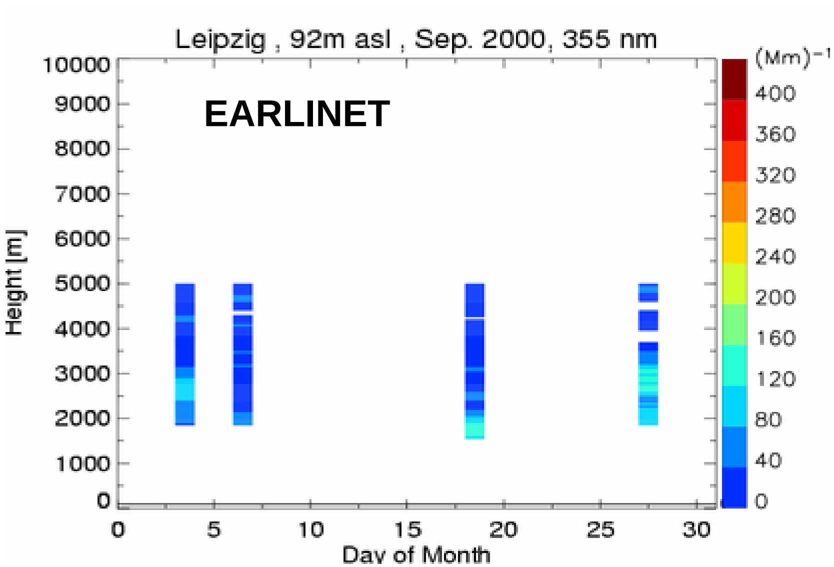
http://nansen.ipsl.jussieu.fr/AEROCOM/
http://nansen.ipsl.jussieu.fr/AEROCOM/DATA/lidar.html

Participating Models

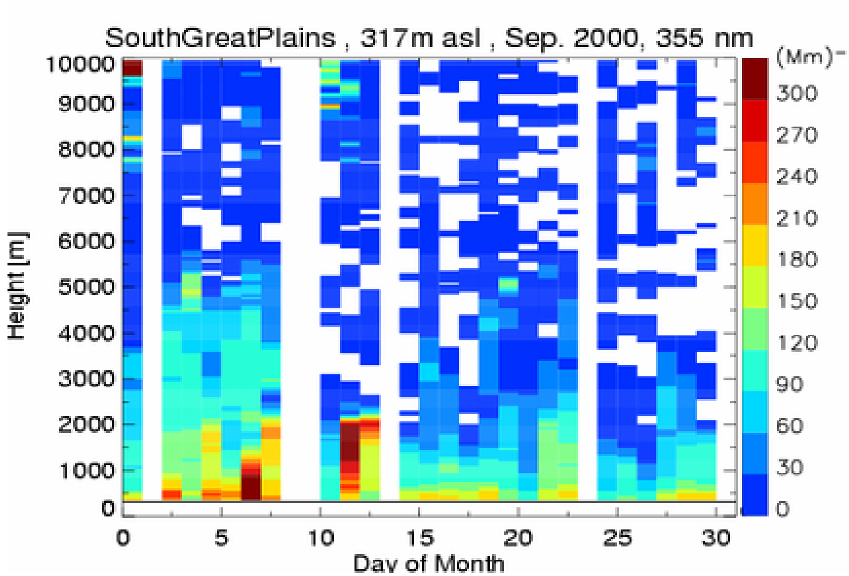
Sprintars, Kyushu University, Kyushu (KYU) Toshihiko Takemura et al.
LMDzT-INCA, Lab Science Climat et de l'Enivonnement, Paris (LSCE) Michael Schulz, Yves Balkanski, Christiane Textor, Sylvia Generoso, Sarah Guibert, Didier Hauglustaine
GCM/ CAM, ARQM Met Service Canda, Toronto (ARQM) Sunling Gong et al.
MIRAGE, Battelle, Pacific Northwest National Laboratory, Richland (PNNL) Steve Ghan and Richard Easter
CTM2,Univ. of Oslo, Oslo (UIO- CTM) Gunnar Myhre et al.
ULAQ- CCM, Universita degli Studi L'Aquila (ULAQ) Giovanni Pitari, Eva Mancini and Veronica Montanaro
CCM- Oslo, Univ. of Oslo, Oslo(UIO- GCM) Trond Yversen, Oyvind Seland, J. E. Kristjansson
MATCH, NCAR, Boulder (MATCH) David Fillmore, Phil Rasch, Bill Collins
IMPACT/ DAO, Univ Michigan, Ann Arbor (UMI) Joyce Penner et al.
GISS, Dorothy Koch und Susanne Bauer
TM5 (IMAU) Maarten Krol, Frank Dentener
GOCART, Mian Chin, Paul Ginoux
MOZART- GFDL- NCAR (MOZGN) (NOAA- GFDL& NCAR) Larry Horowitz, Xuexi Tie, Jean-Francois Lamarque, Paul Ginoux

Periodic (EARLINET) vs. Continuous (ARM) Measurements

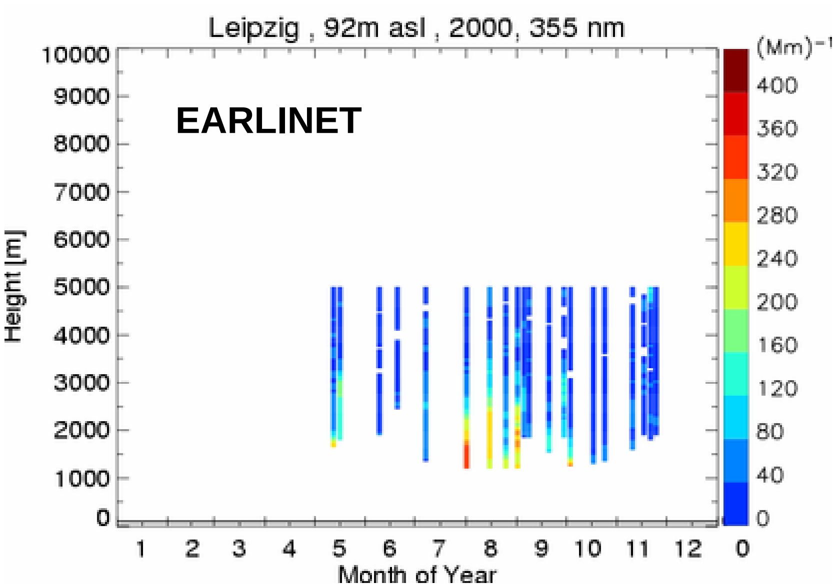
EARLINET



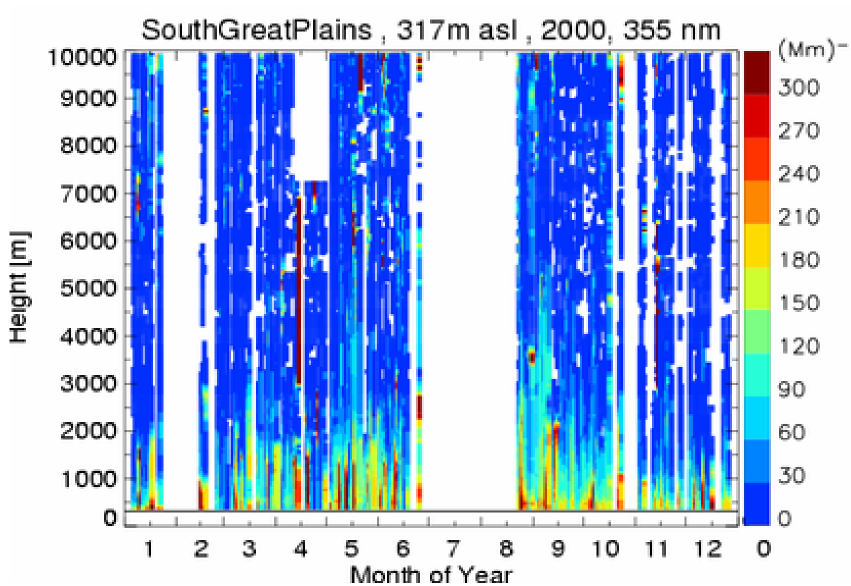
CARL



Sept 2000

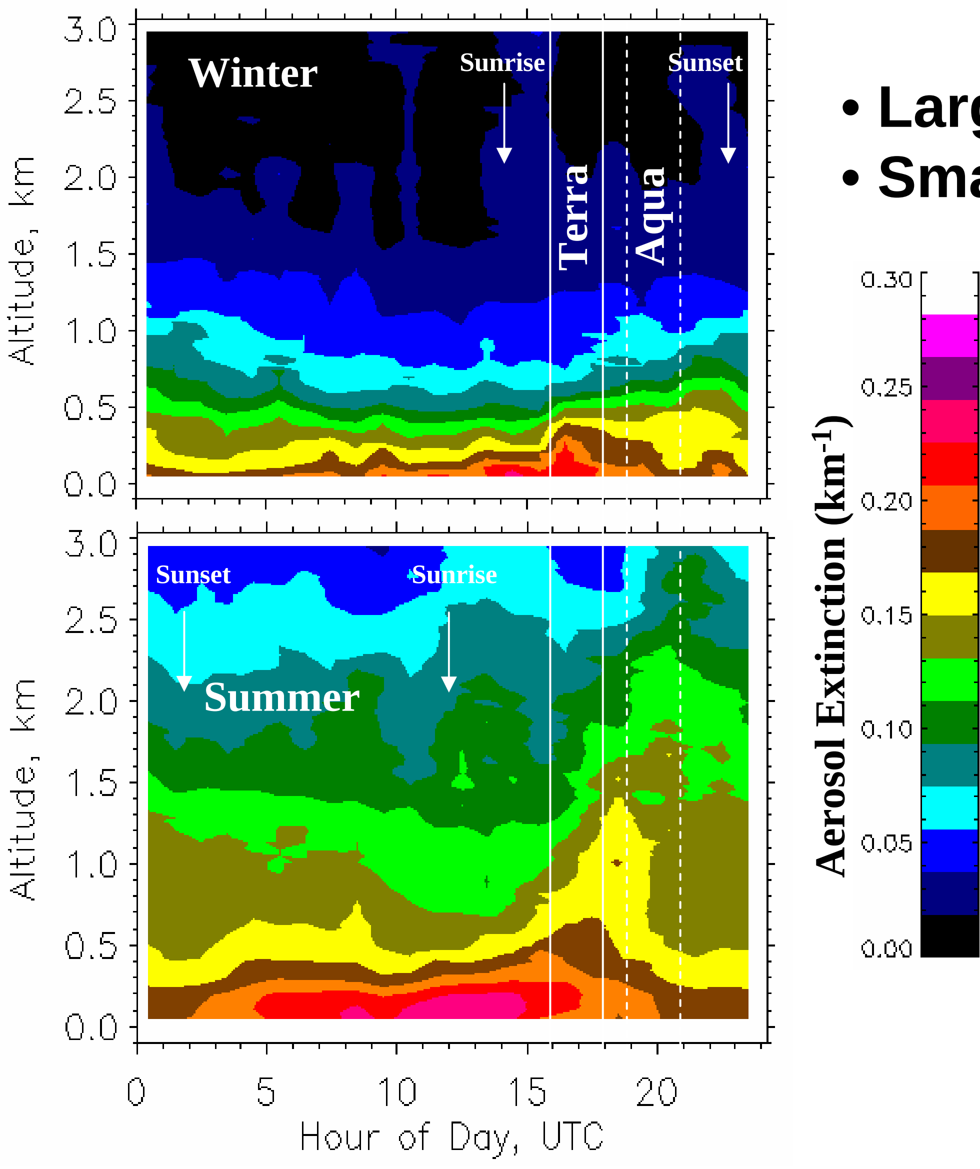


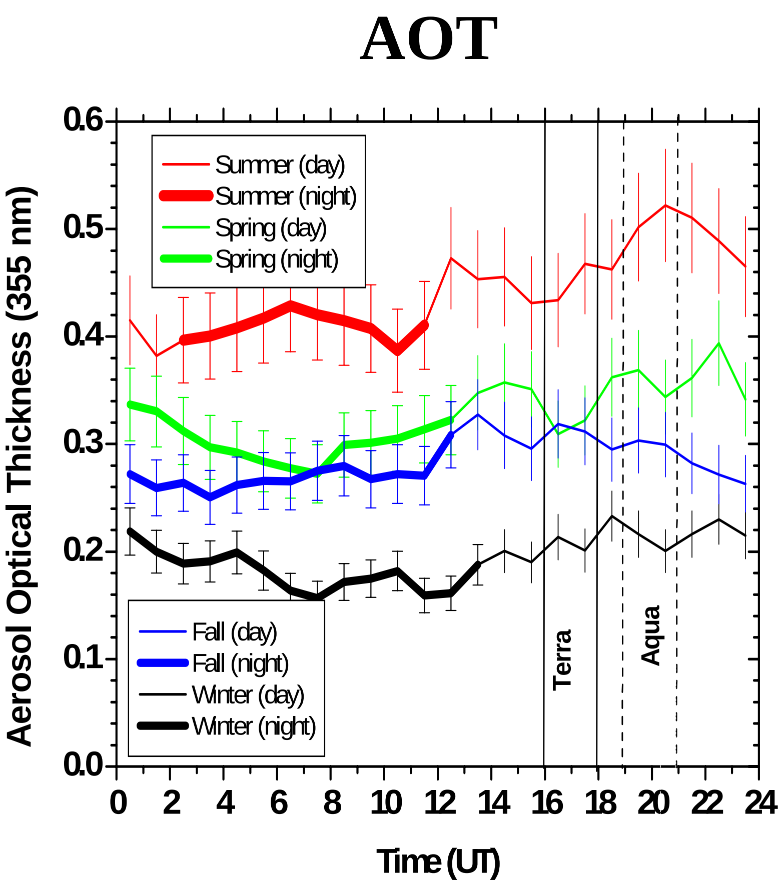
All of 2000



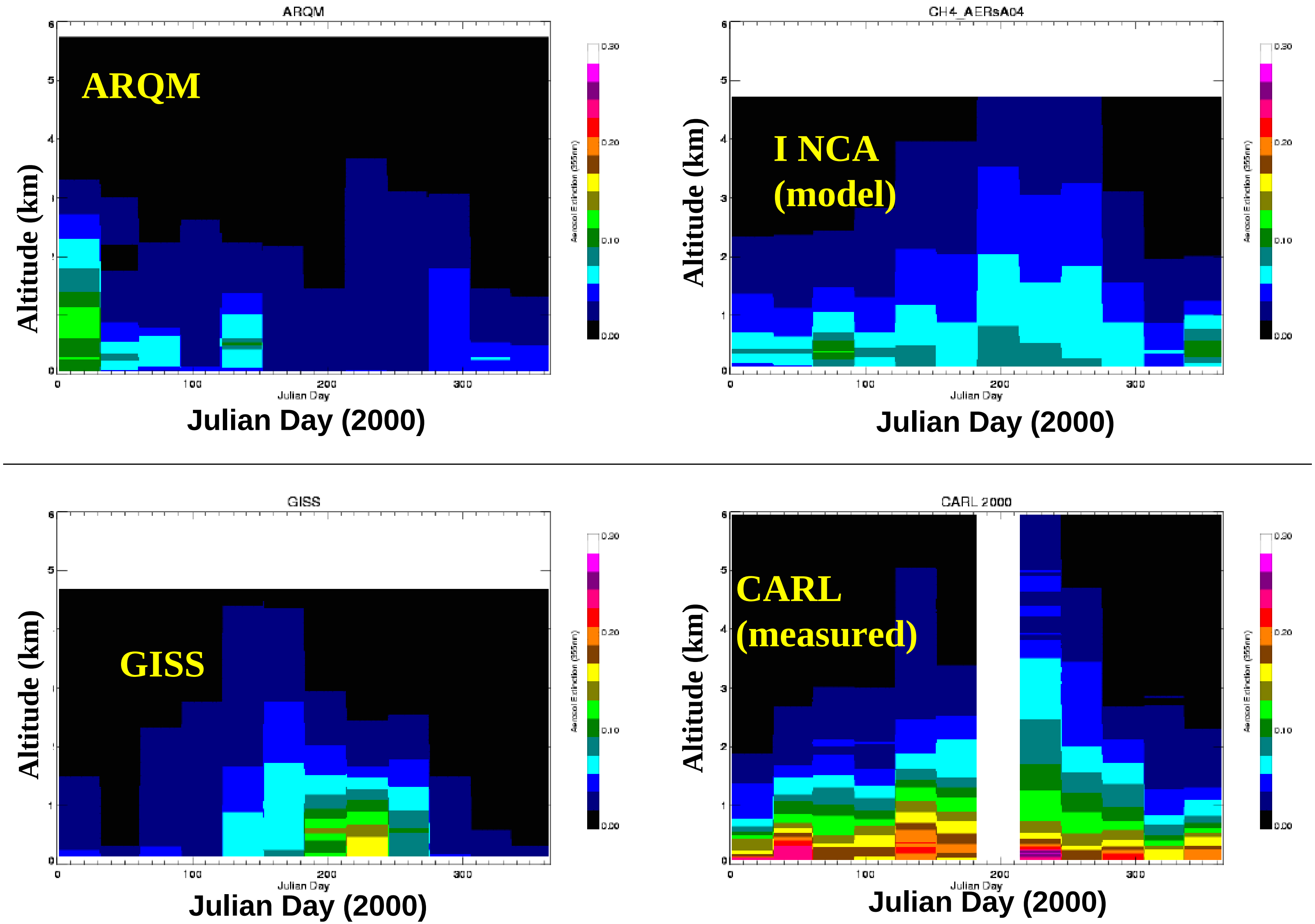
Average Diurnal Variation of Aerosol Extinction Profiles and AOT

- **Large changes in vertical profile**
- **Smaller changes in AOT**



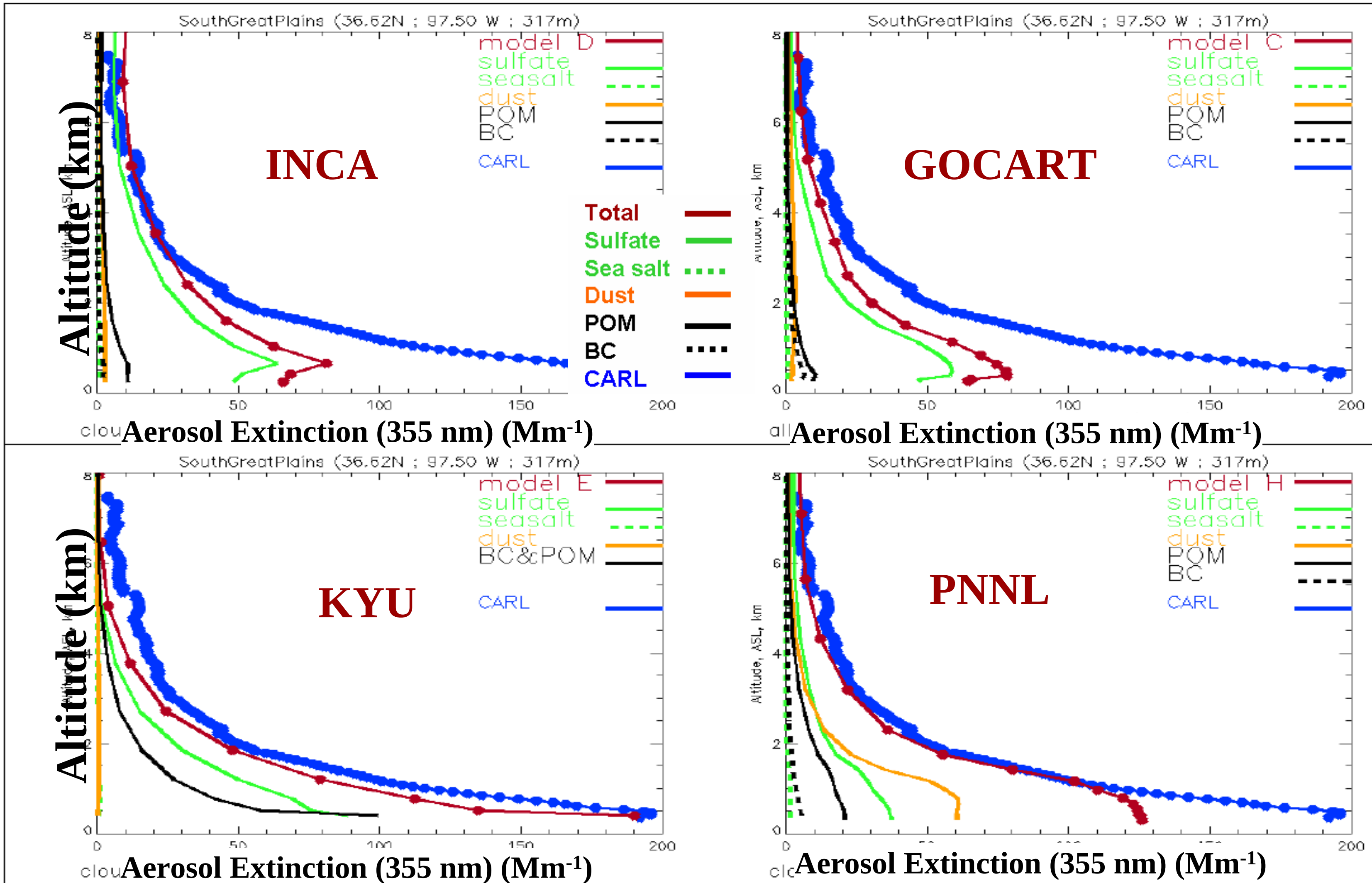


Monthly Average Aerosol Extinction Profiles



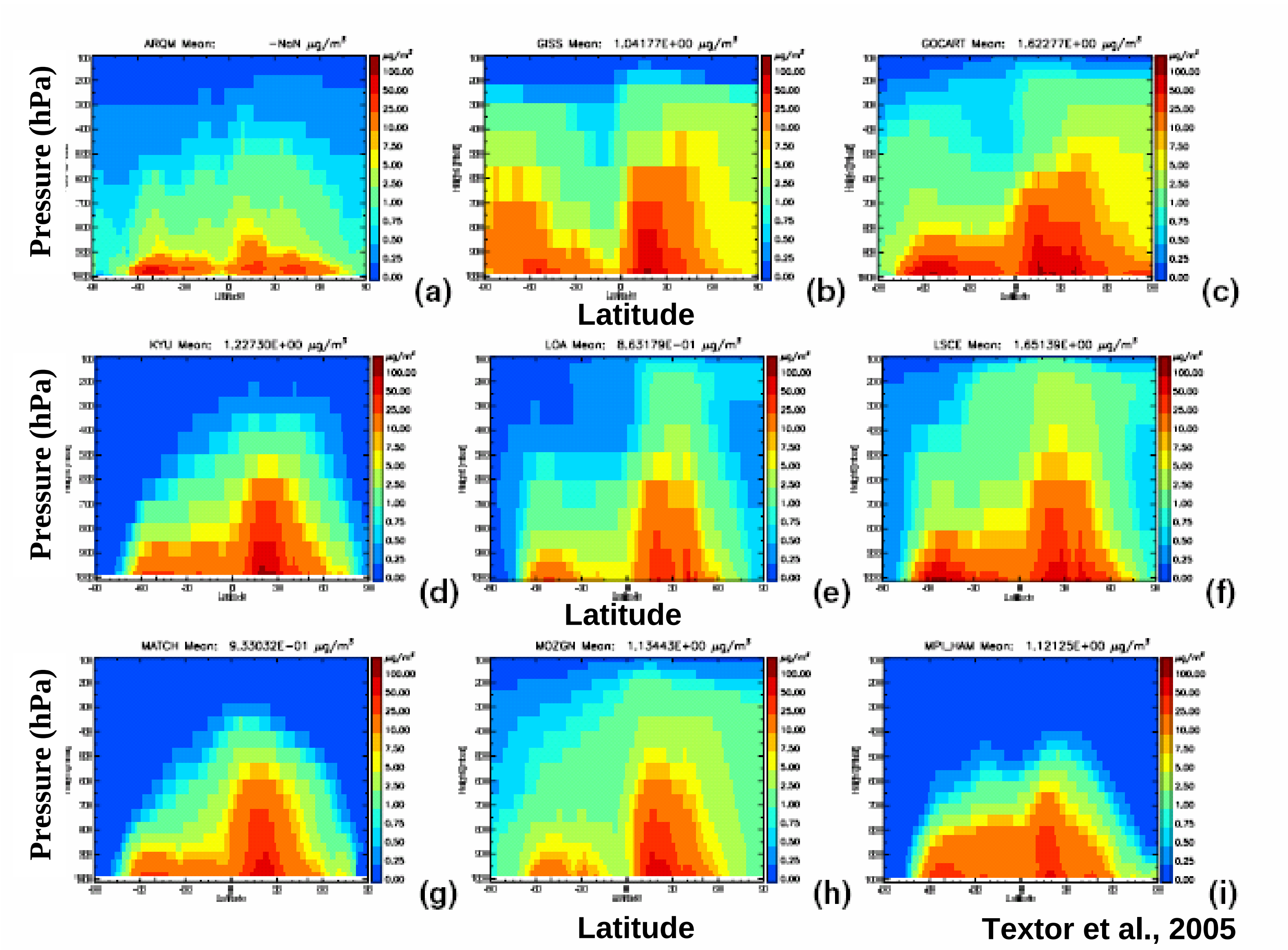
Yearly Average Aerosol Extinction Profiles

- **Large variability in modeled vertical distributions and aerosol components**
- **Profile behavior of various aerosol constituents may give indication of model strengths and weaknesses**



Problem Area – Model Aerosol Profiles Vary Widely

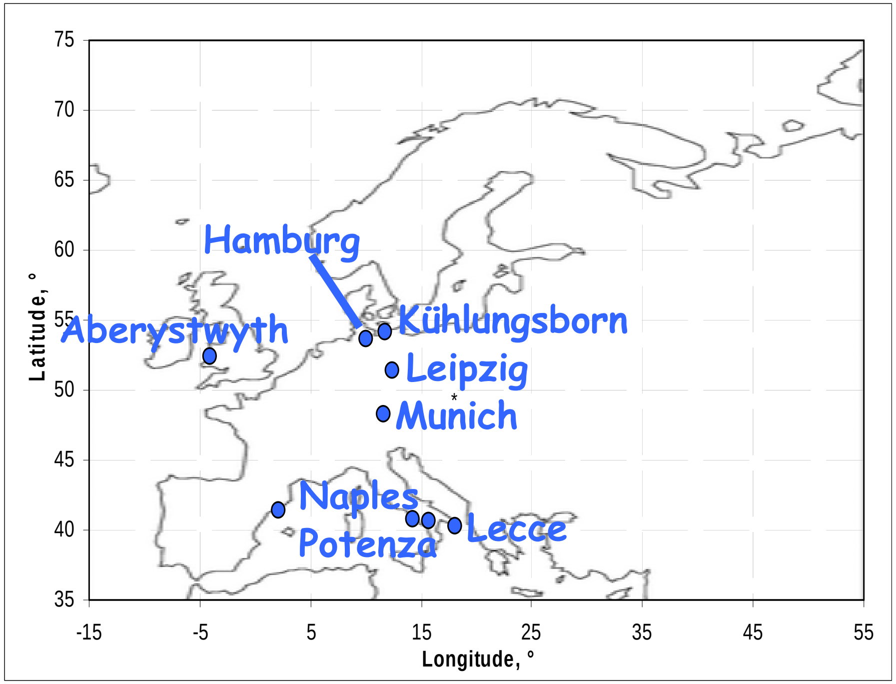
Global Annual Mean Aerosol Concentration (μg/m³)



Textor et al., 2005

Raman Lidar Measurements

EARLINET



- Measurements during 2000 and 2001
- Measurements twice a week : Monday and Thursday
- Measurements at sunset
- Raman lidar : extinction coefficient without hypothesis on lidar ratio

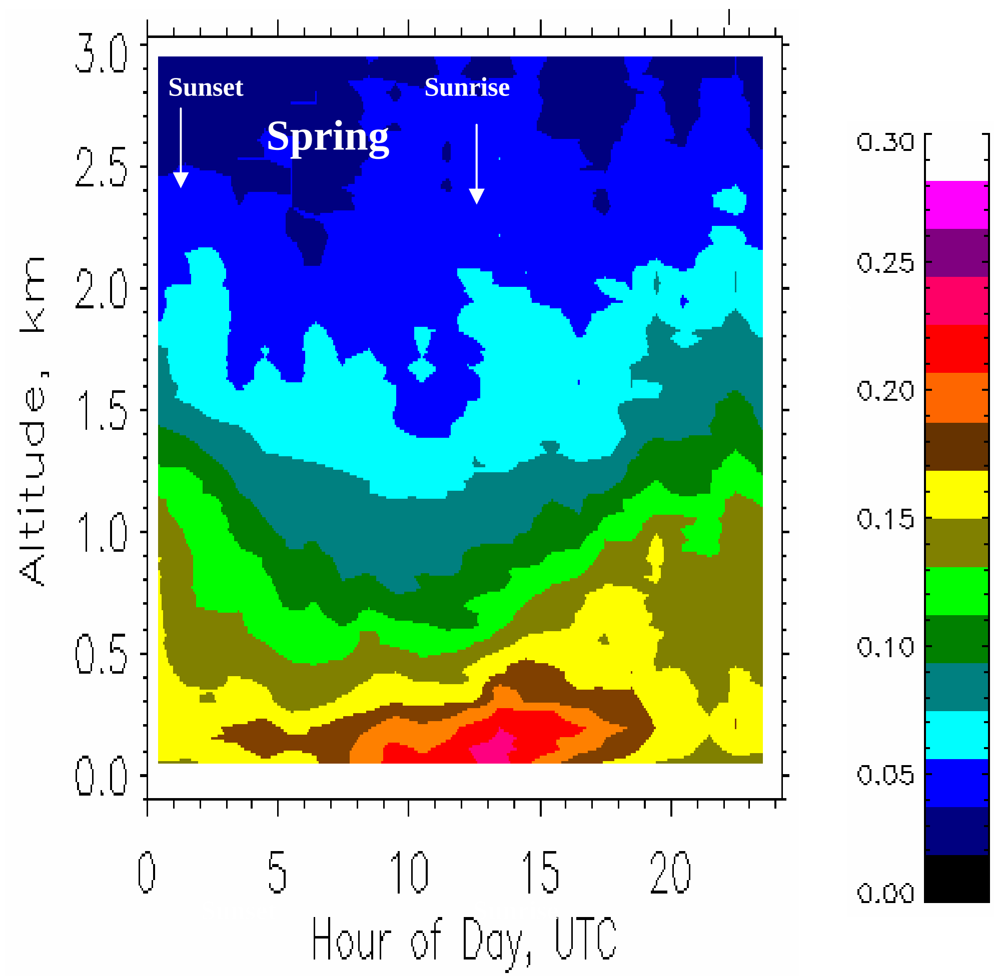
ARM SGP

- ARM SGP CRF Raman Lidar (CARL)
- Measurements during 2000 and 2001
- Measurements (24/7): Every 10 minutes
- Extinction coefficient, scattering ratio, backscatter coefficient, optical depth relative humidity, cloud detection
- Additional measurements:
  airborne in situ, surface

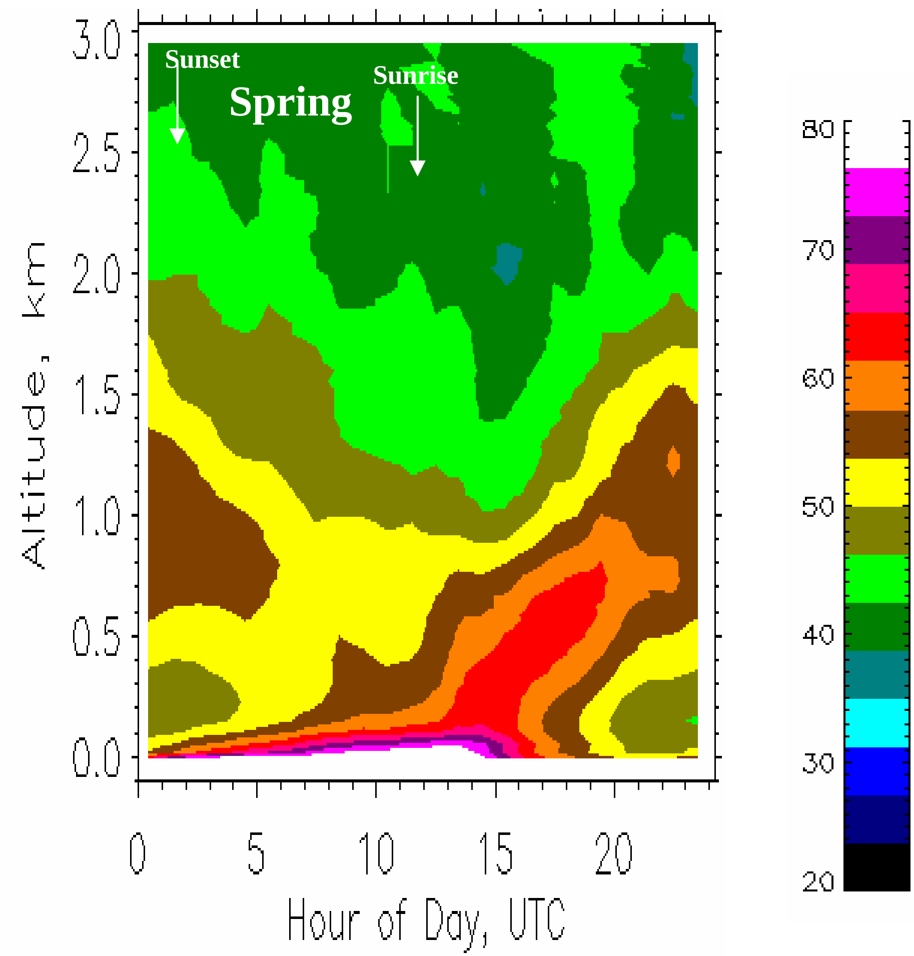
Correlation between Aerosol Extinction and Relative Humidity

- CARL aerosol extinction profiles averaged between Mar. 1, 1998 – Dec. 31, 2001
- Higher extinction concentrated over smaller vertical extent at night
- Highest aerosol extinction and RH found near surface at night

Aerosol Extinction

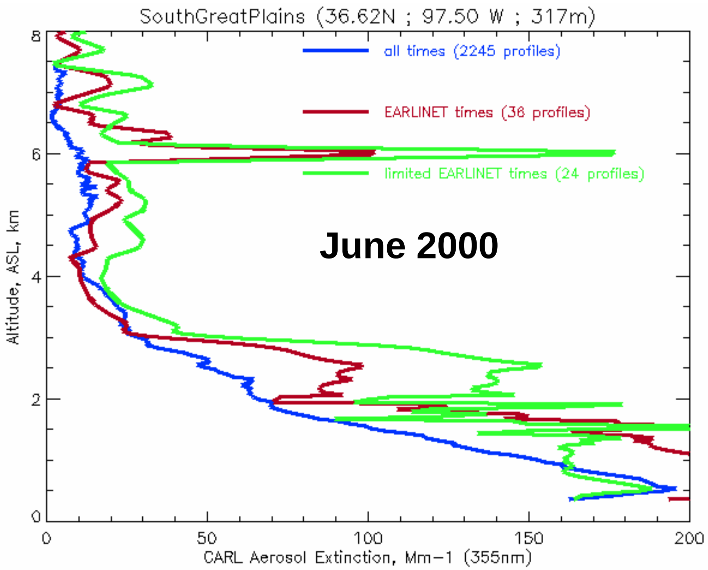


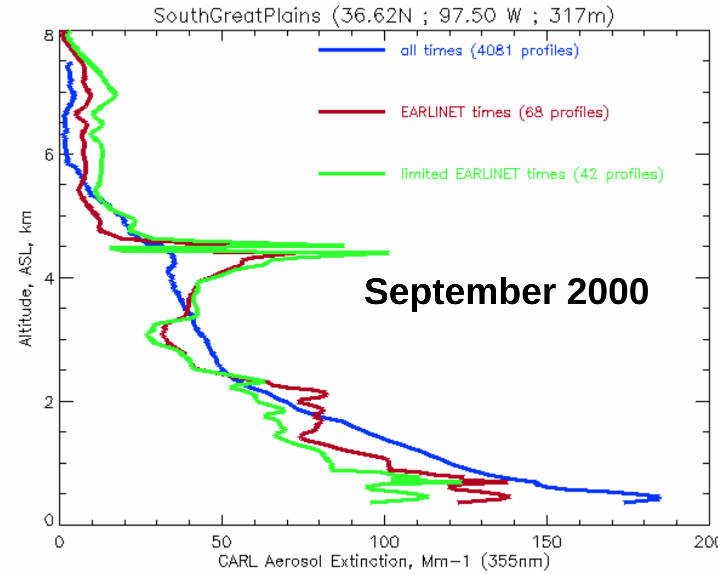
Relative Humidity

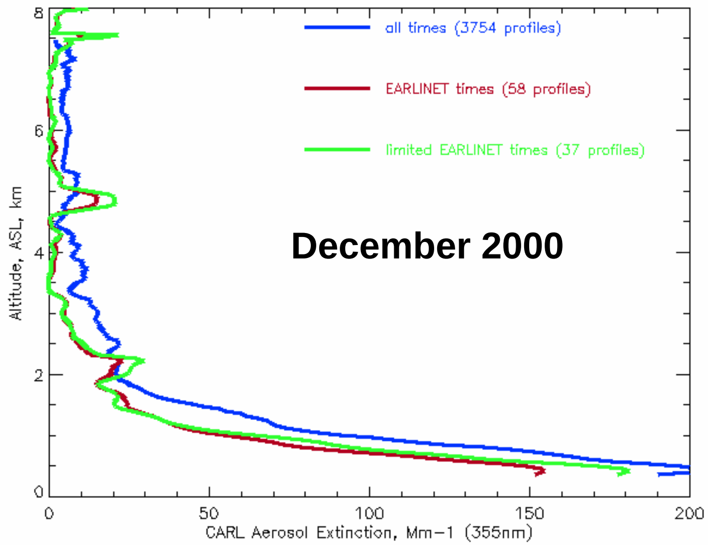


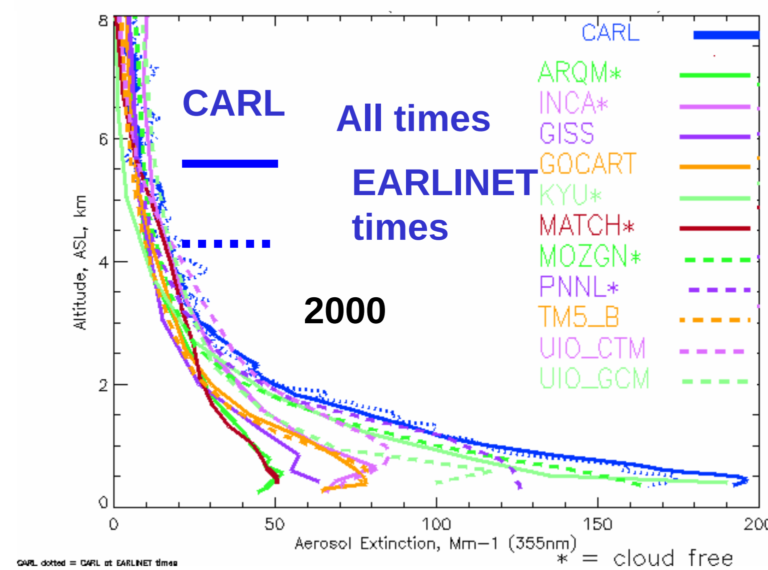
CARL Continuous vs. Periodic Measurements

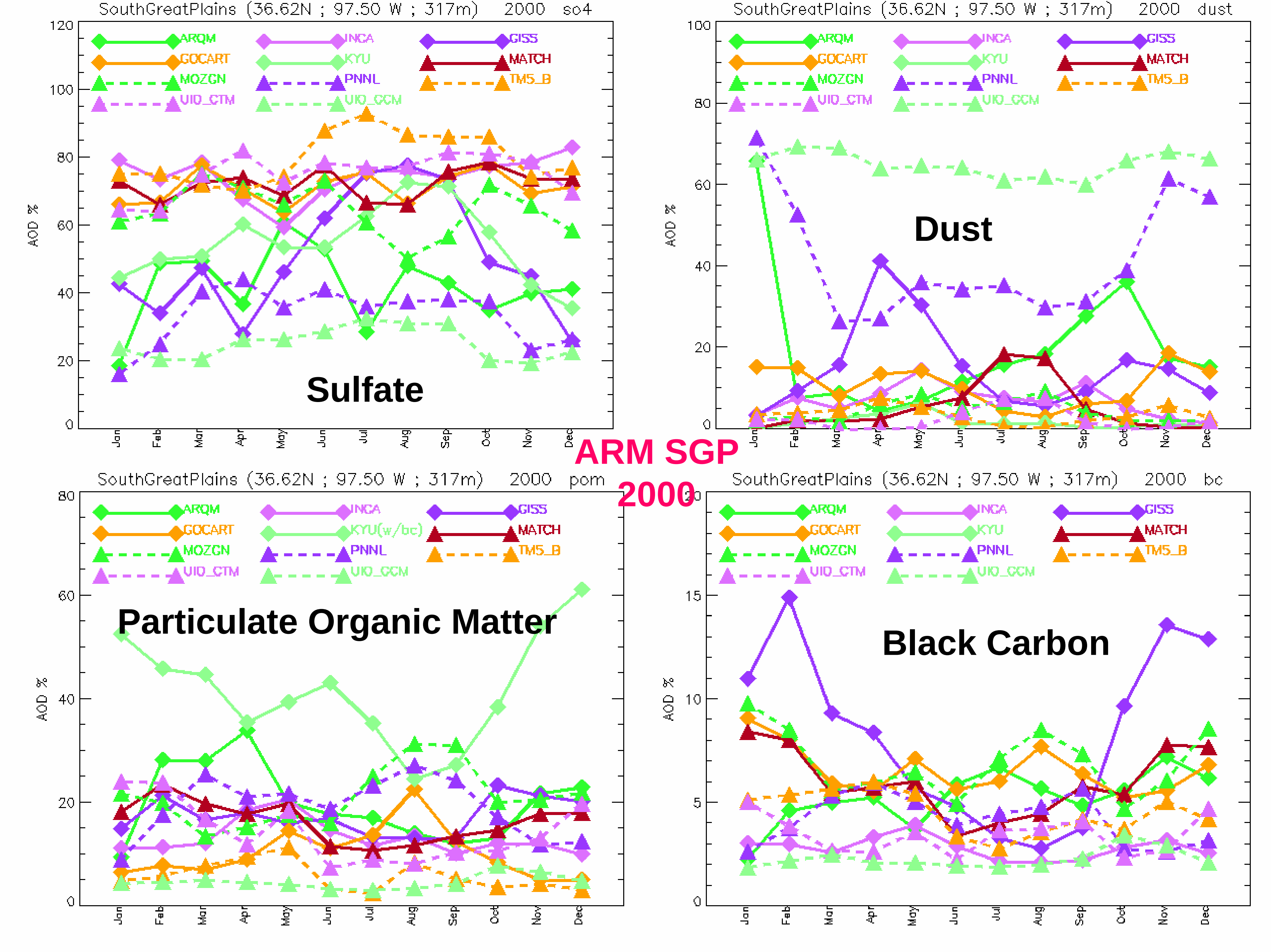
Periodic measurements show more variability







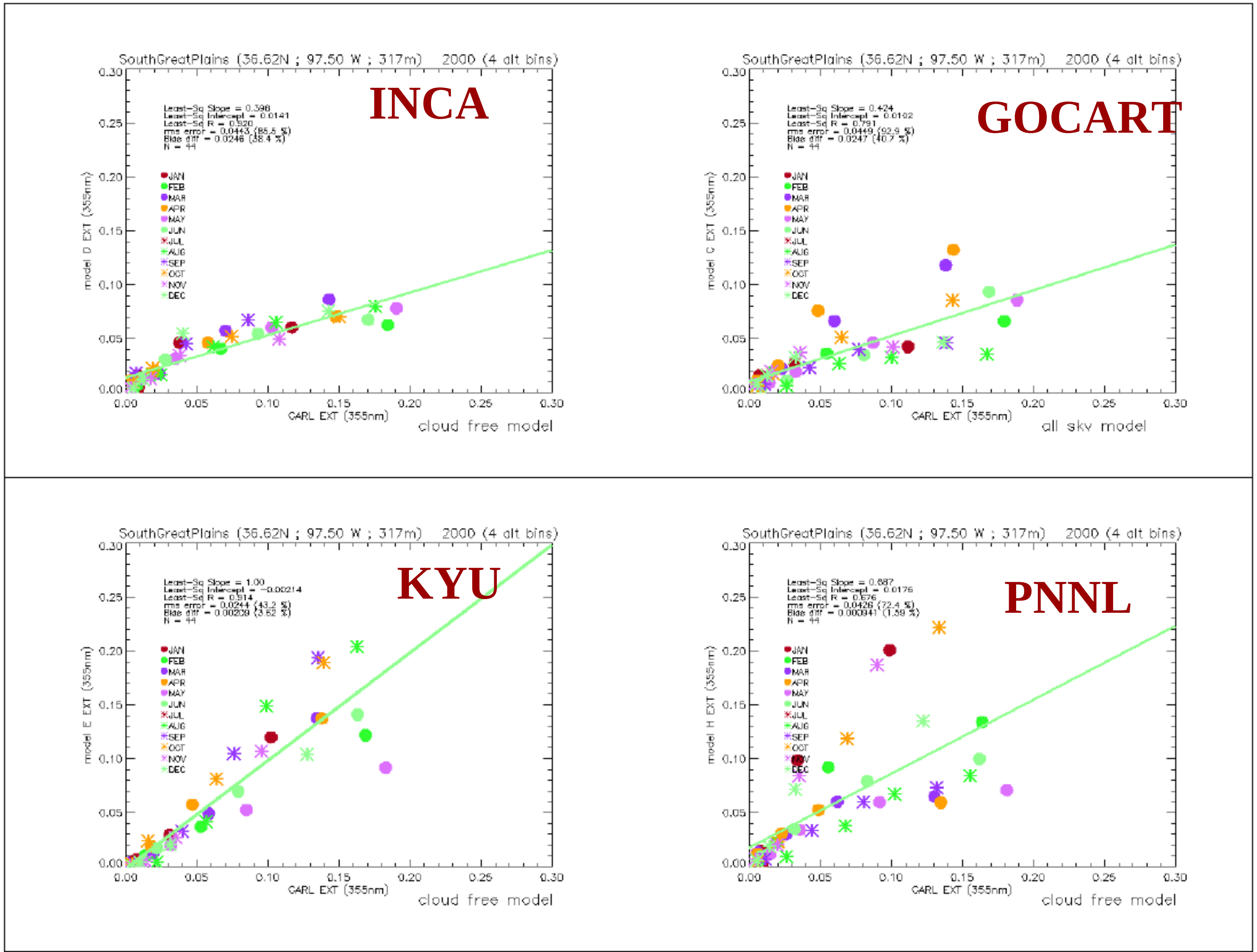




ARM SGP
2000
SouthGreatPlains (36.62N ; 97.50 W ; 317m) 2000 so4
ARQM
INCA
GISS
GOCART
KYU
MATCH
MOZGN
PNNL
TM5_B
UIO_CTM
UIO_GCM
Sulfate
AOD %
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
SouthGreatPlains (36.62N ; 97.50 W ; 317m) 2000 dust
Dust
SouthGreatPlains (36.62N ; 97.50 W ; 317m) 2000 pom
KYU(w/bc)
Particulate Organic Matter
SouthGreatPlains (36.62N ; 97.50 W ; 317m) 2000 bc
Black Carbon

Aerosol Extinction Regression Results

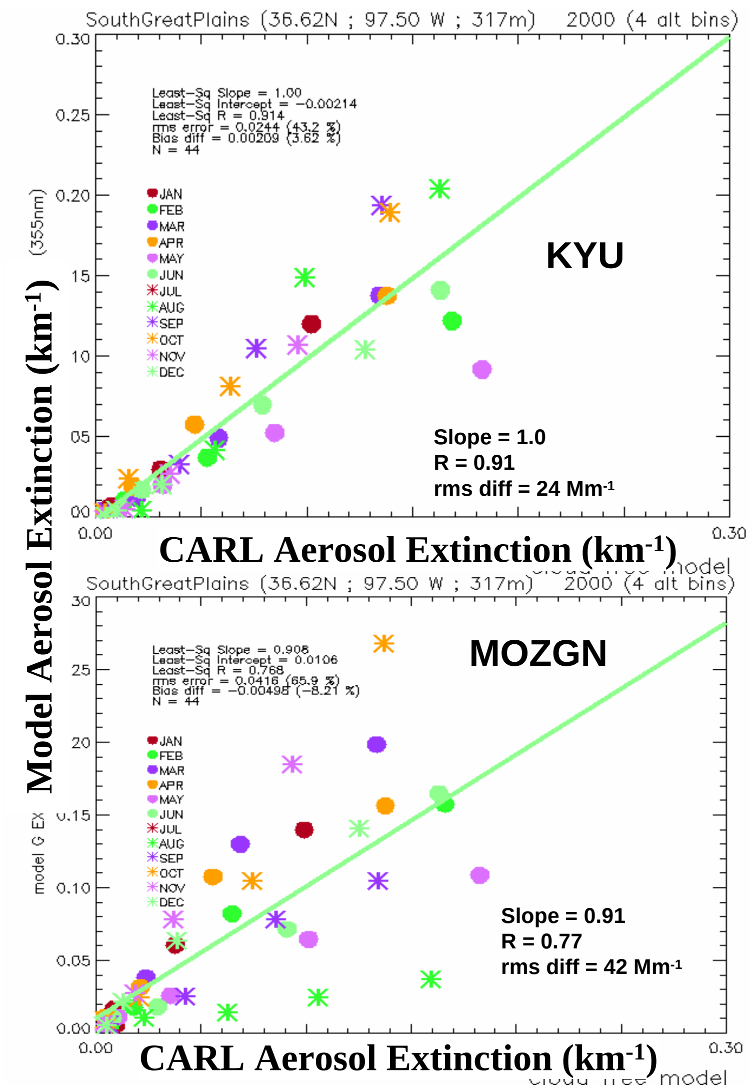
- Regressions computed using monthly averages from 0-8 km
- Slopes 0.4-1.0, indicative of differences in the lowest few km
- Correlation coefficients 0.7-0.9; Bias differences 0-30 Mm^{-1}



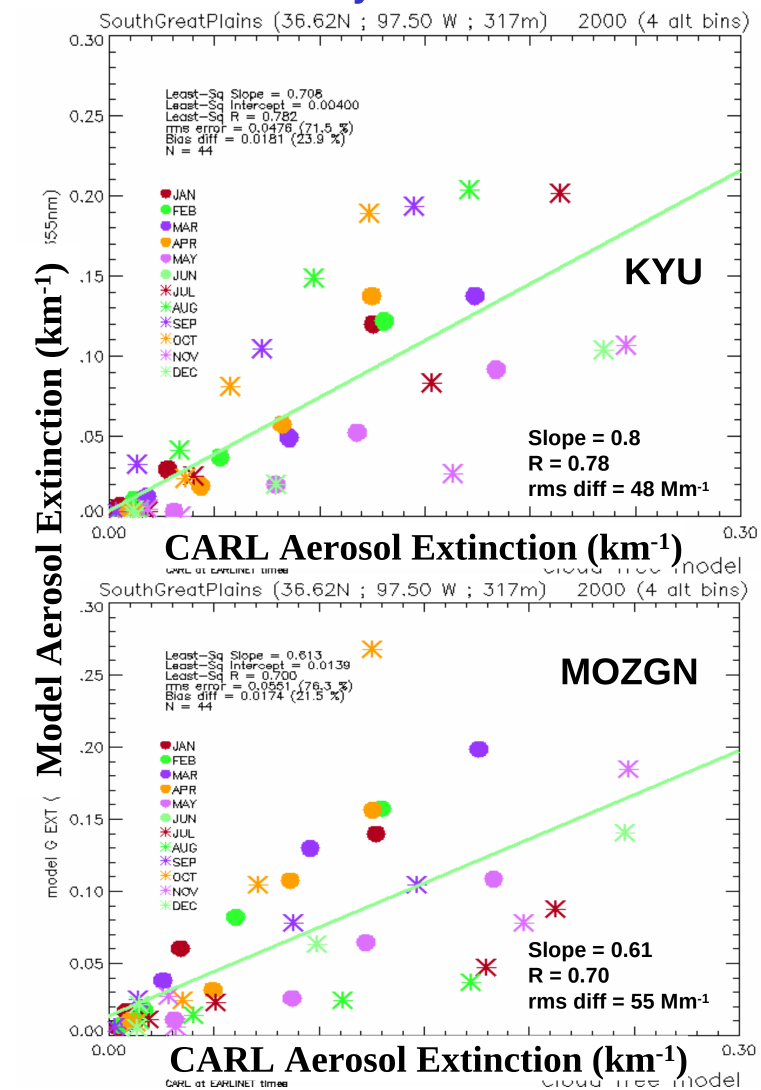
Aerosol Extinction Regression Results

- **Using continuous instead of periodic data, reduces bias errors, increases correlation, and increases slopes**

CARL data at all times

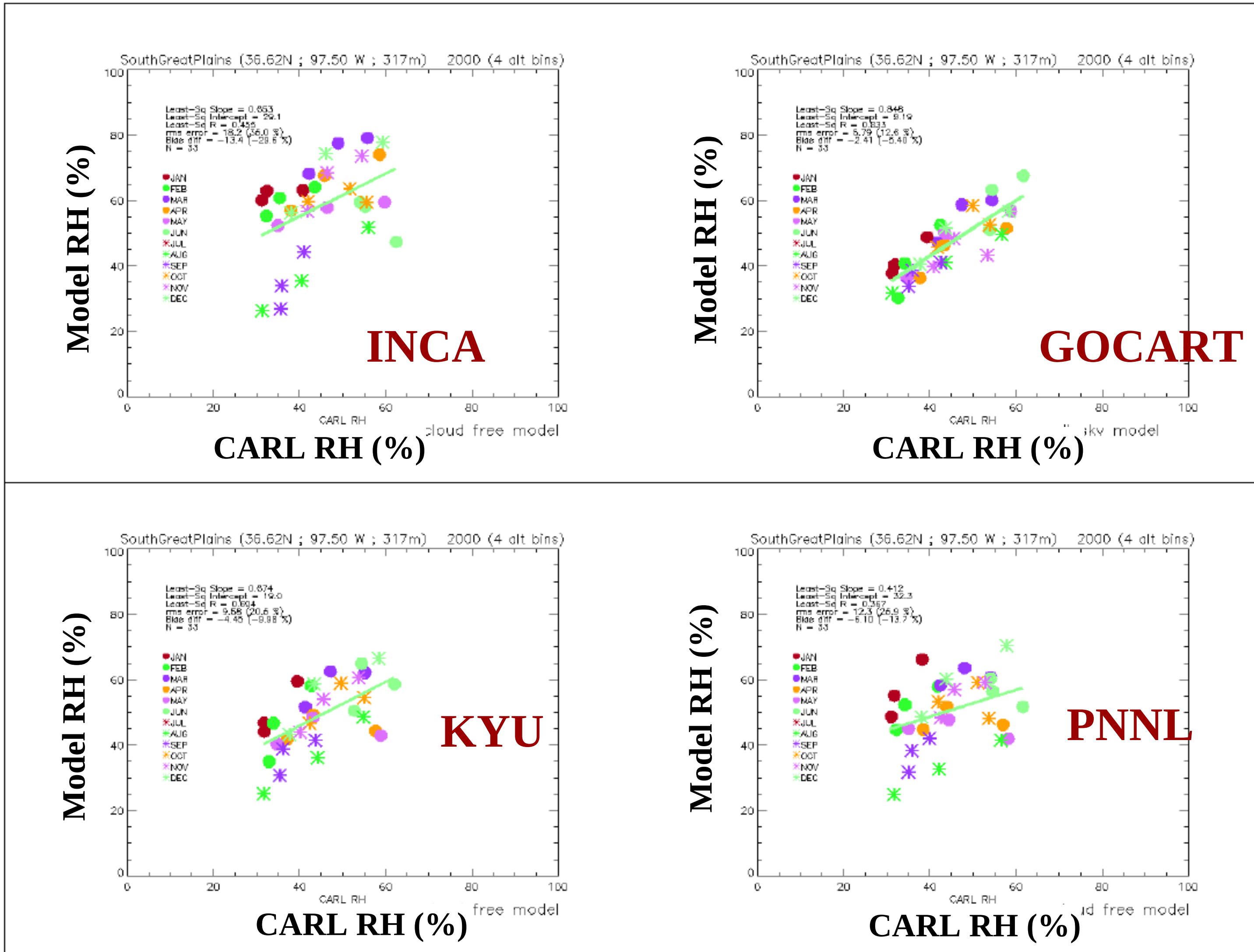


CARL data only at EARLINET times

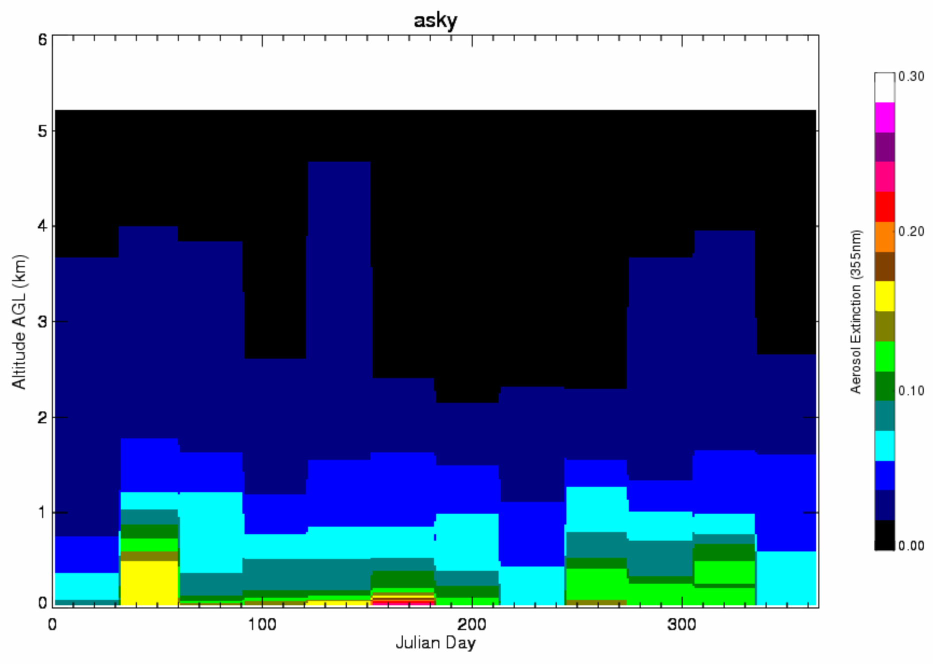


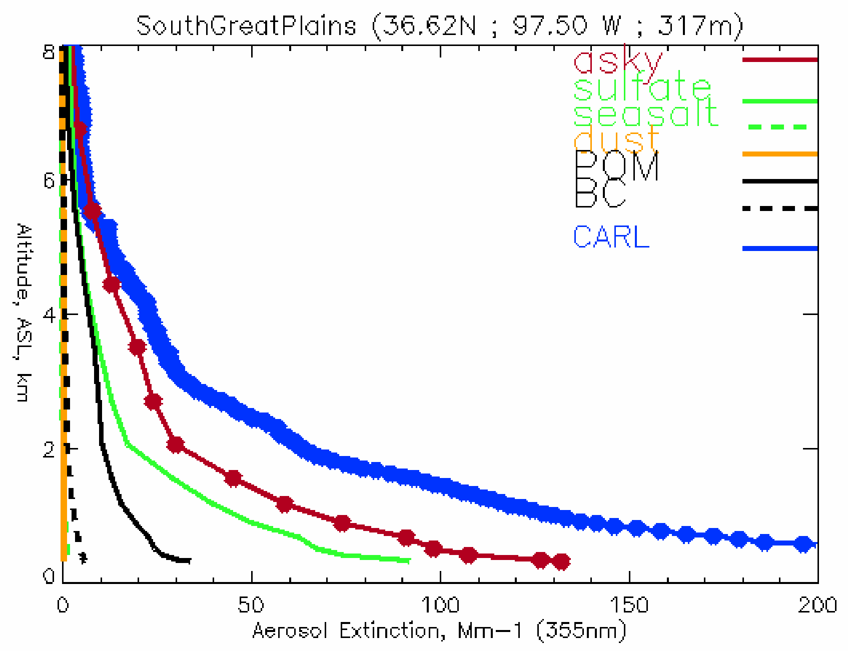
Relative Humidity Regression Results

- Slopes 0.6-1.0; Correlation coefficients 0.4-0.8; Bias differences 4-8 %

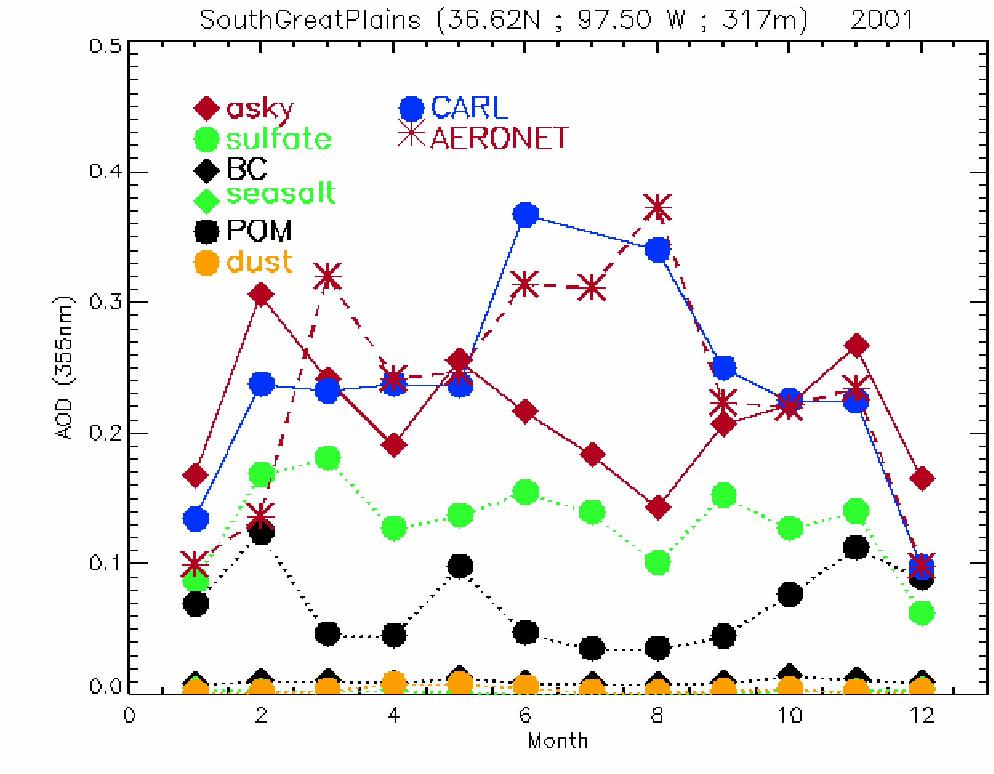


Impact 2001 all sky

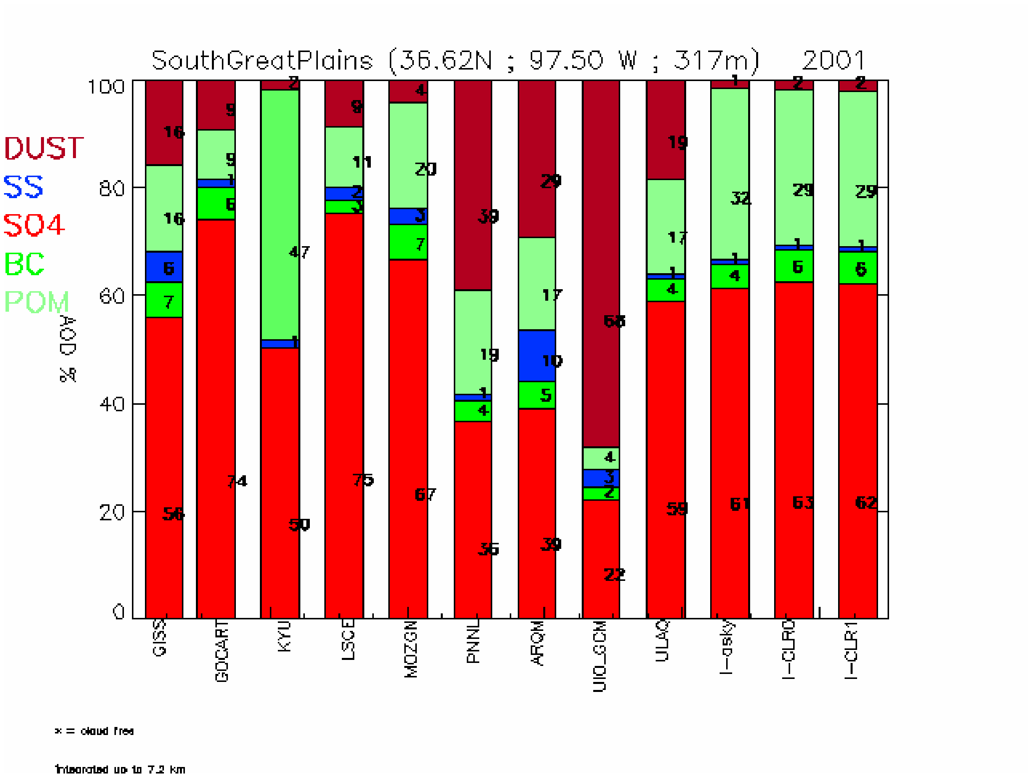


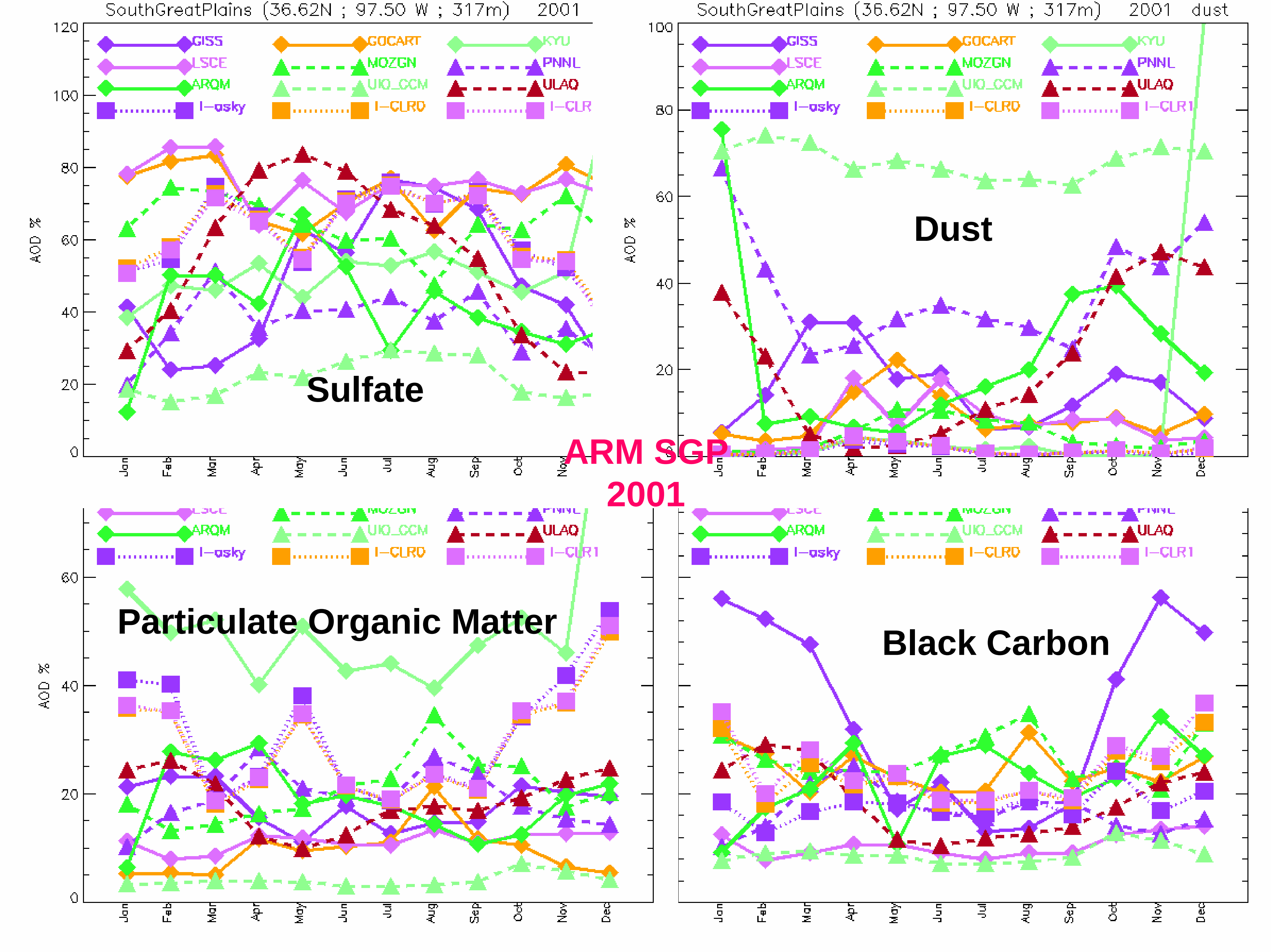


Impact 2001 all sky

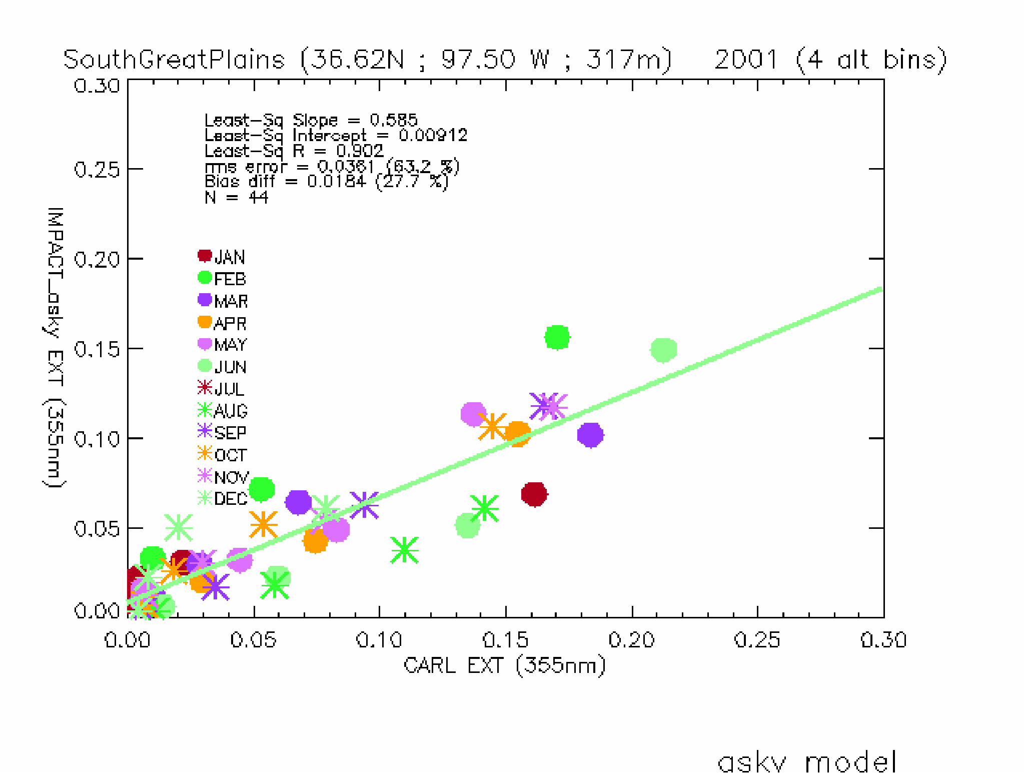


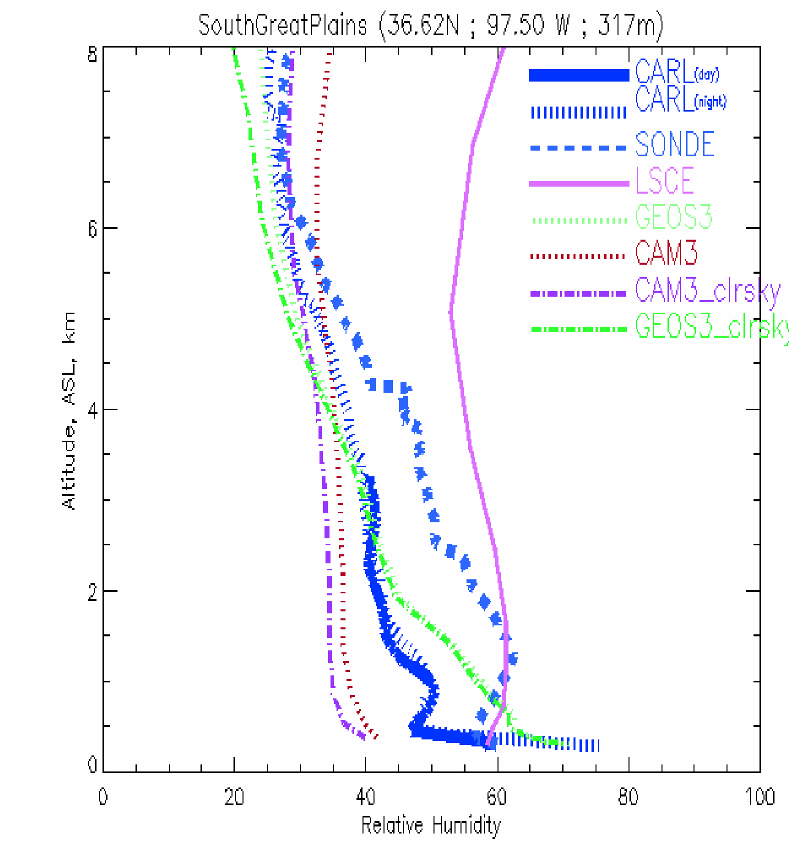
Includes Impact 2001 all sky

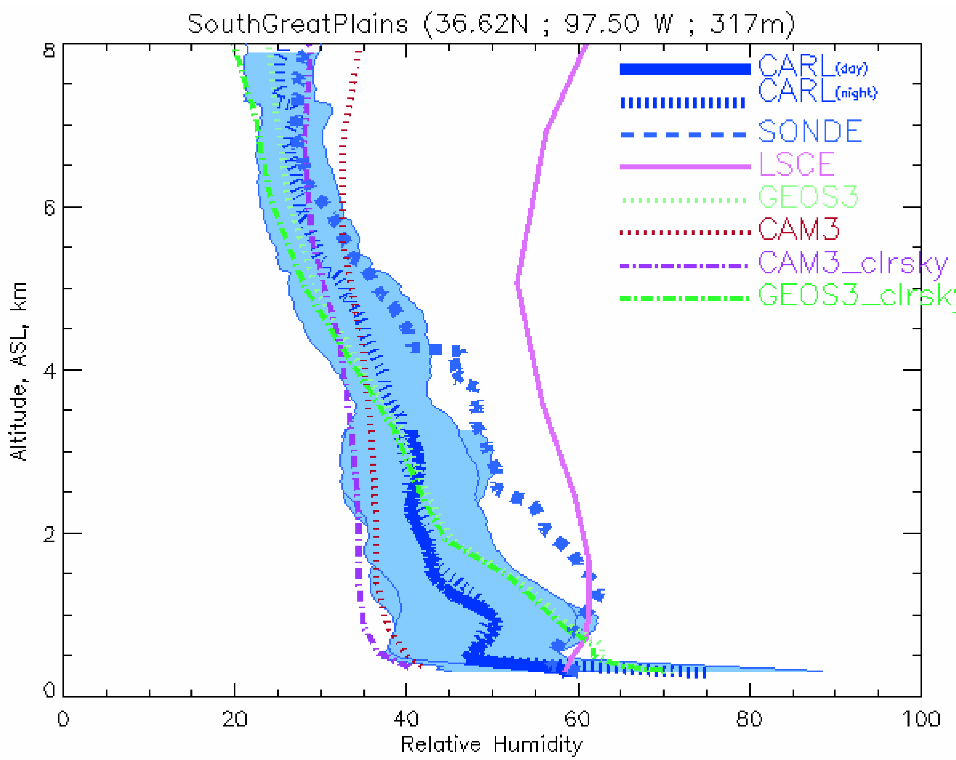


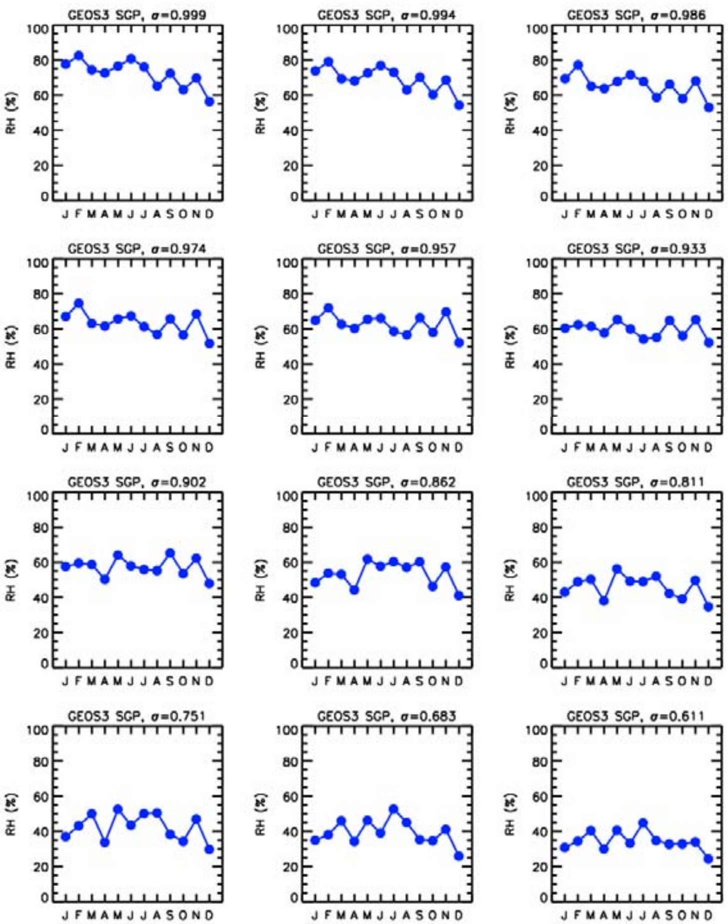

SouthGreatPlains (36.62N ; 97.50 W ; 317m) 2001
SouthGreatPlains (36.62N ; 97.50 W ; 317m) 2001 dust
GISS
GOCART
KYU
LSCE
MOZGN
PNNL
ARQM
UIO_CCM
ULAQ
I-asky
I-CLRD
I-CLR
I-CLR1
AOD %
Sulfate
Dust
ARM SGP
2001
Particulate Organic Matter
Black Carbon
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
0
20
40
60
80
100
120

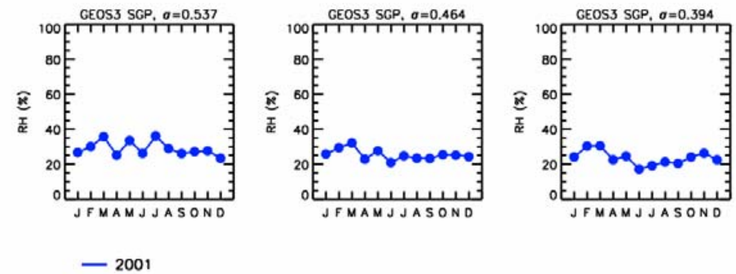
Impact 2001 all sky




SouthGreatPlains (36.62N ; 97.50 W ; 317m)
CARL(day)
CARL(night)
SONDE
LSCE
GEOS3
CAM3
CAM3_clrsky
GEOS3_clrsky
Altitude, ASL, km
Relative Humidity
0
2
4
6
8
0
20
40
60
80
100

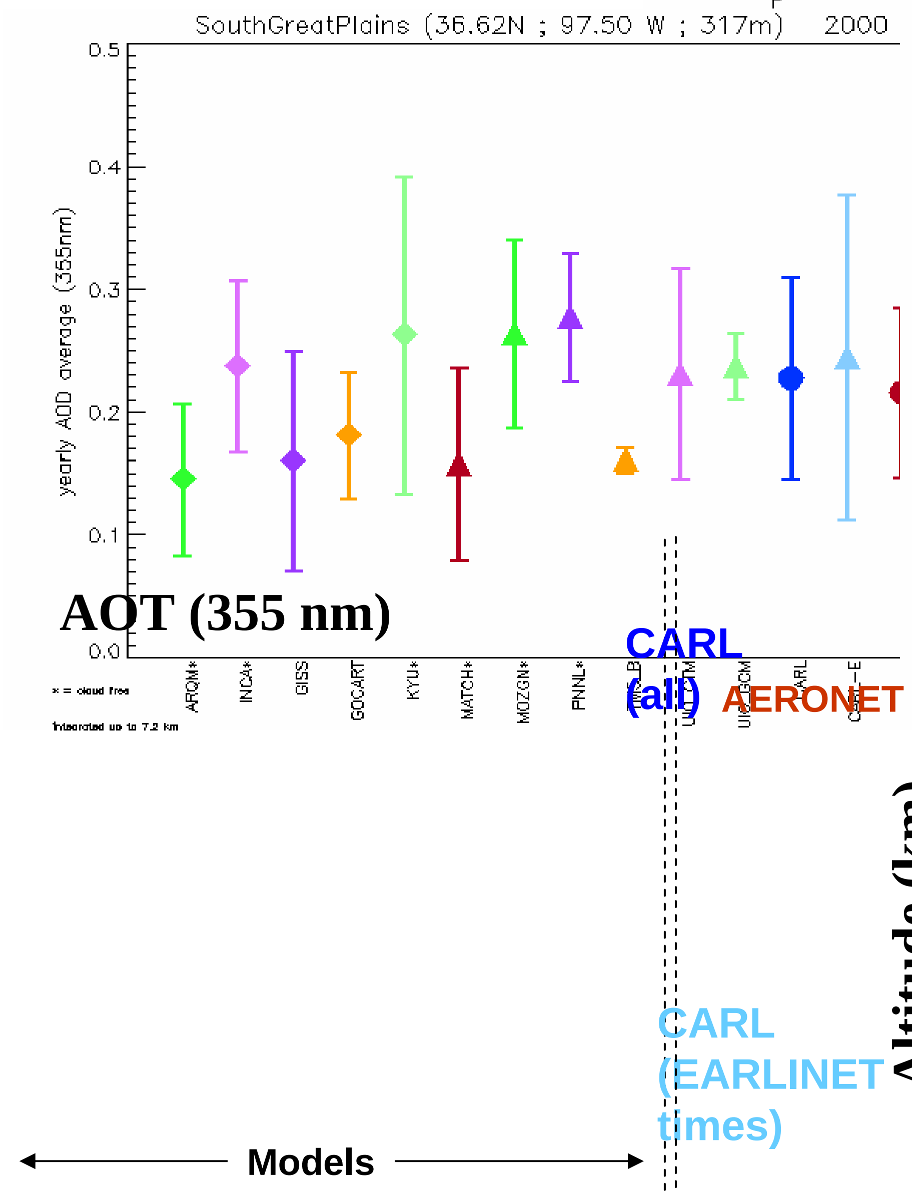

SouthGreatPlains (36.62N ; 97.50 W ; 317m)
CARL(day)
CARL(night)
SONDE
LSCE
GEOS3
CAM3
CAM3_clrsky
GEOS3_clrsky
Altitude, ASL, km
Relative Humidity
0
2
4
6
8
0
20
40
60
80
100


GEOS3 SGP, σ=0.999
GEOS3 SGP, σ=0.994
GEOS3 SGP, σ=0.986
GEOS3 SGP, σ=0.974
GEOS3 SGP, σ=0.957
GEOS3 SGP, σ=0.933
GEOS3 SGP, σ=0.902
GEOS3 SGP, σ=0.862
GEOS3 SGP, σ=0.811
GEOS3 SGP, σ=0.751
GEOS3 SGP, σ=0.683
GEOS3 SGP, σ=0.611
RH (%)
0 20 40 60 80 100
J F M A M J J A S O N D

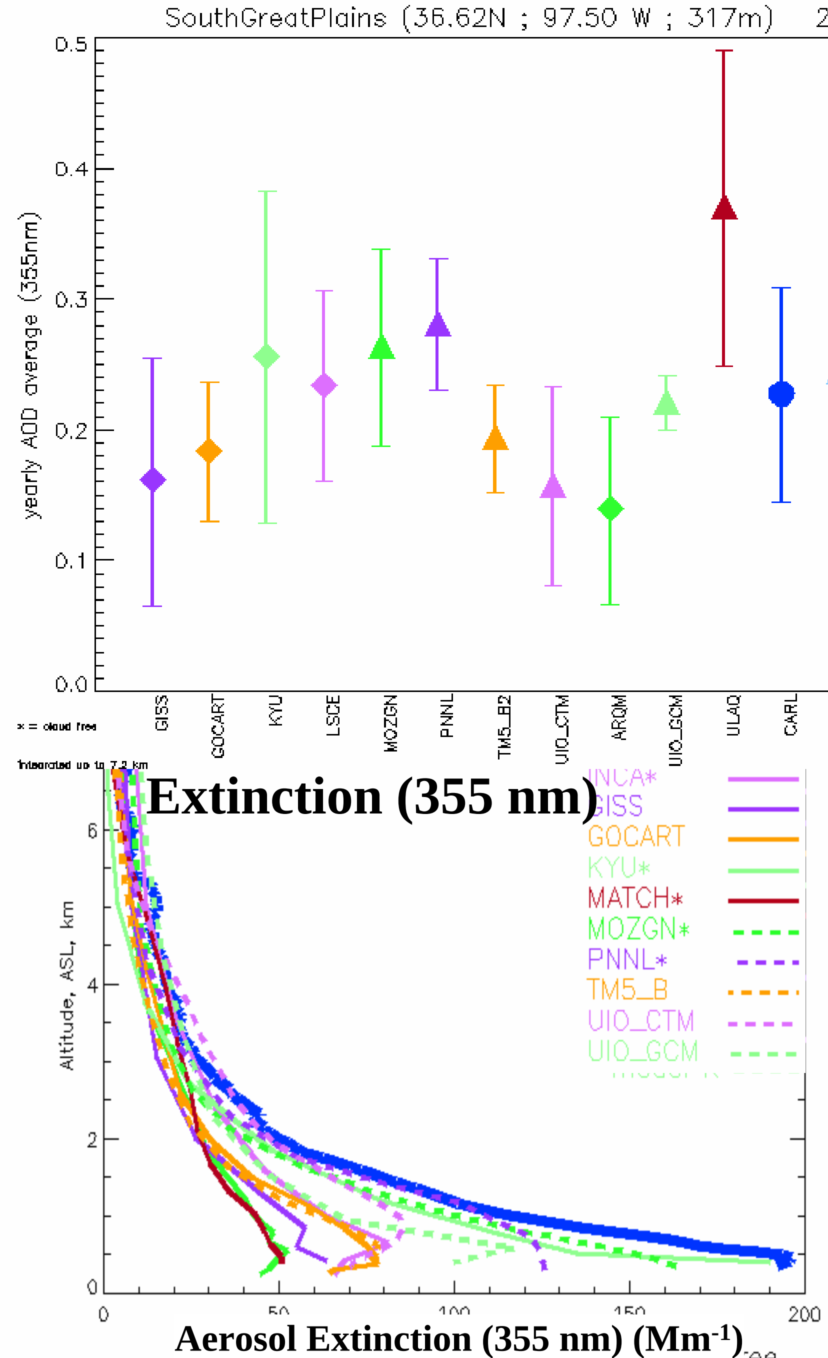

GEOS3 SGP, σ=0.537
GEOS3 SGP, σ=0.464
GEOS3 SGP, σ=0.394
RH (%)
0 20 40 60 80 100
J F M A M J J A S O N D
2001

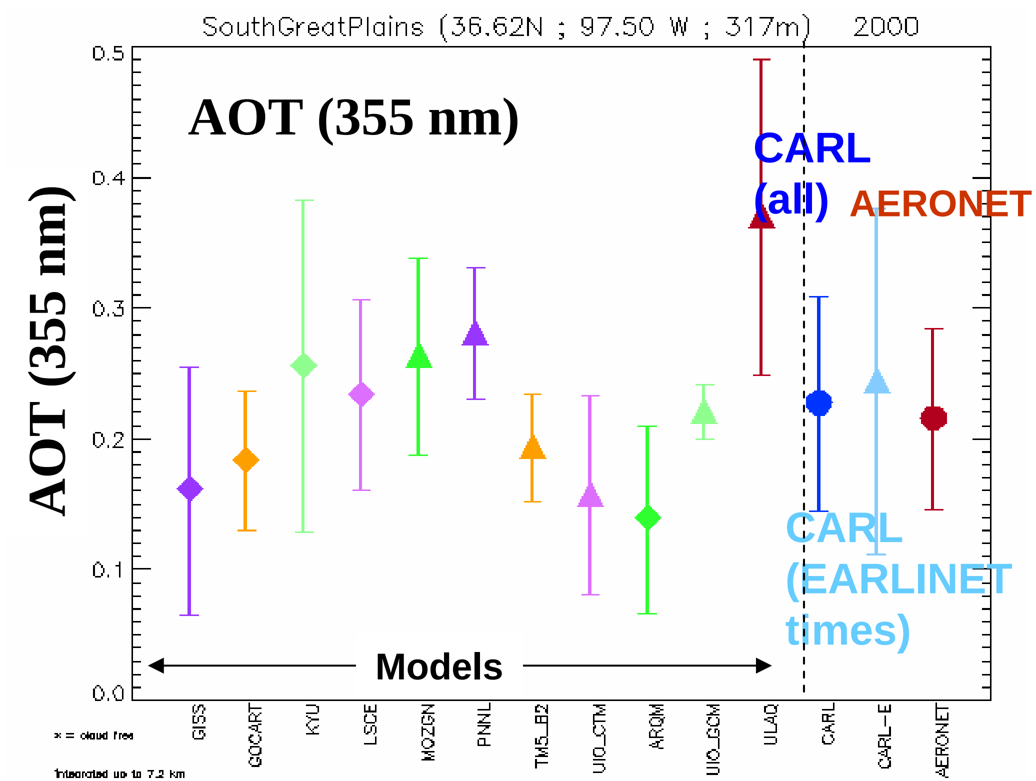
Measured versus Modeled AOT and Profiles

AOT (355 nm)

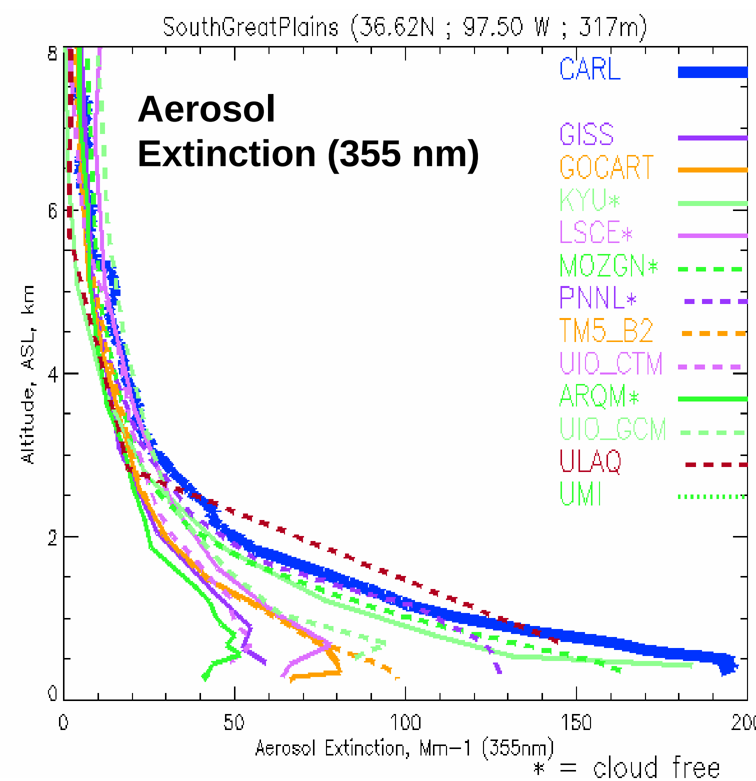


Altitude (km)

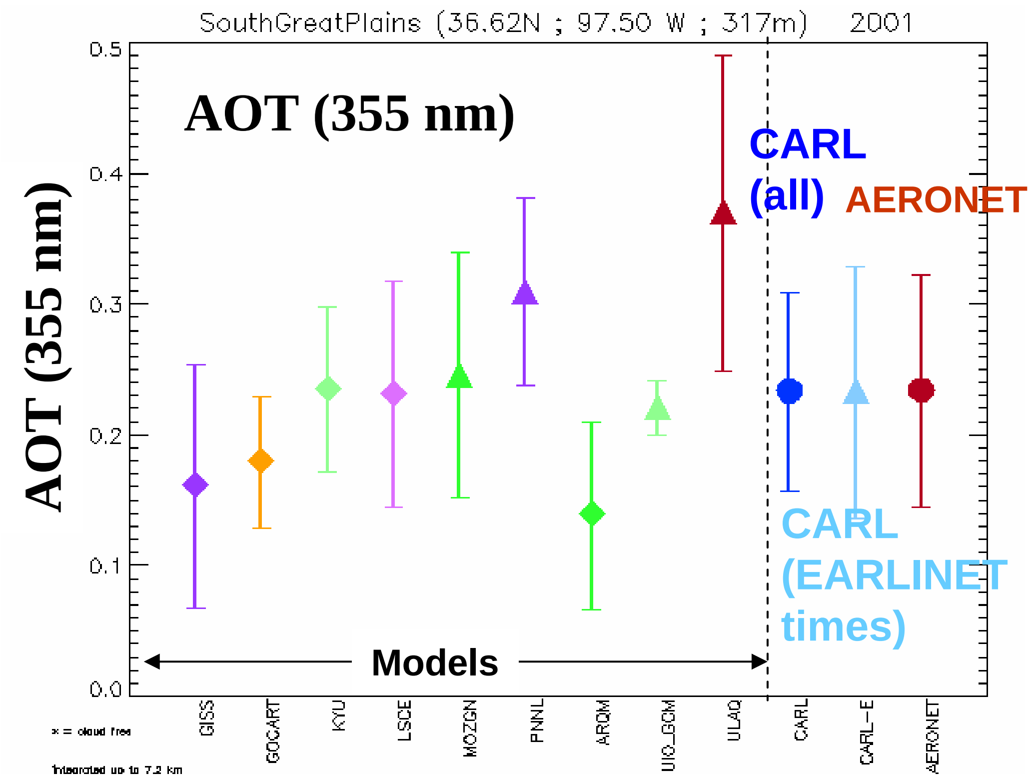


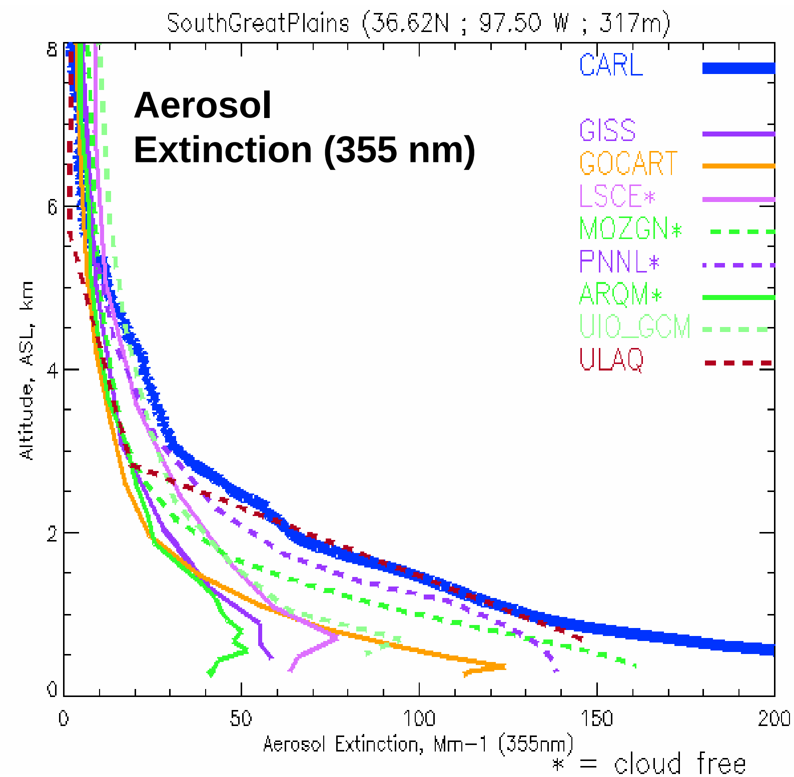


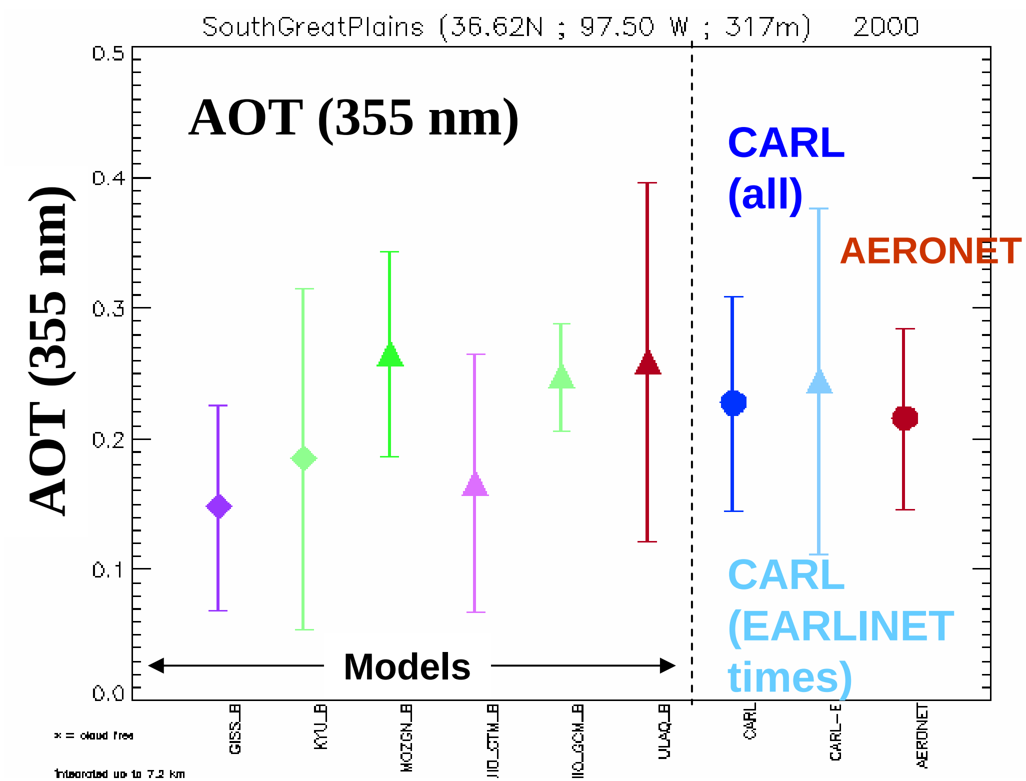
SouthGreatPlains (36.62N ; 97.50 W ; 317m) 2000
AOT (355 nm)
AOT (355 nm)
CARL (all)
AERONET
CARL (EARLINET times)
Models
0.0
0.1
0.2
0.3
0.4
0.5
GISS
GOCART
KYU
LSCE
MOZGN
PNNL
TM5_B2
UIO_CTM
ARQM
UIO_GCM
ULAQ
CARL
CARL-E
AERONET
* = cloud free
Integrated up to 7.2 km

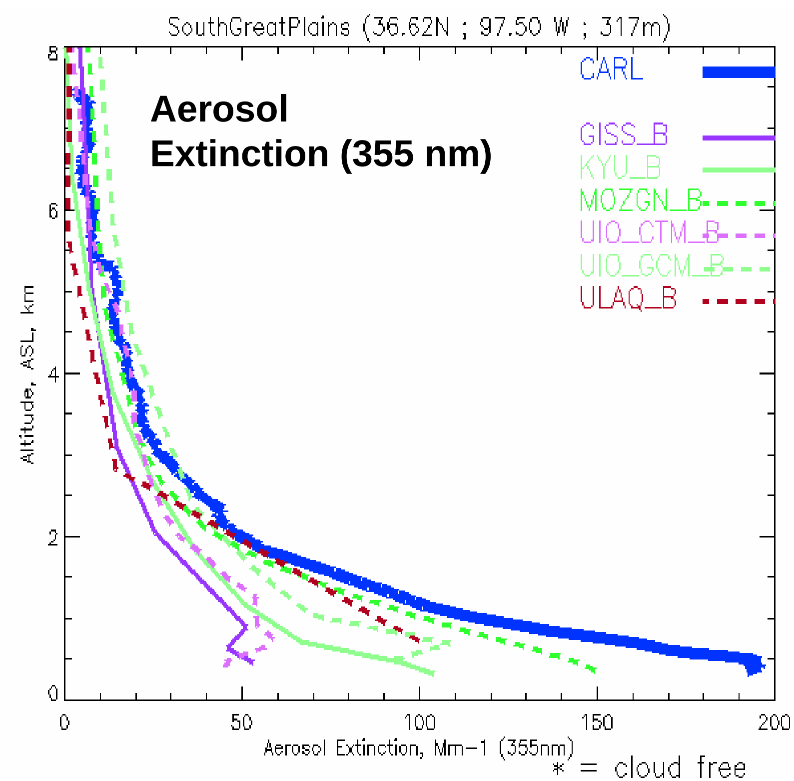


SouthGreatPlains (36.62N ; 97.50 W ; 317m)
Aerosol Extinction (355 nm)
Altitude, ASL, km
Aerosol Extinction, Mm-1 (355nm)
0
2
4
6
8
0
50
100
150
200
CARL
GISS
GOCART
KYU*
LSCE*
MOZGN*
PNNL*
TM5_B2
UIO_CTM
ARQM*
UIO_GCM
ULAQ
UMI
* = cloud free


SouthGreatPlains (36.62N ; 97.50 W ; 317m) 2001
AOT (355 nm)
AOT (355 nm)
CARL (all)
AERONET
CARL (EARLINET times)
Models
0.0
0.1
0.2
0.3
0.4
0.5
GISS
GOCART
KYU
LSCE
MOZGN
PNNL
ARQM
UIO_GCM
ULAQ
CARL
CARL-E
AERONET
* = cloud free
Integrated up to 7.2 km

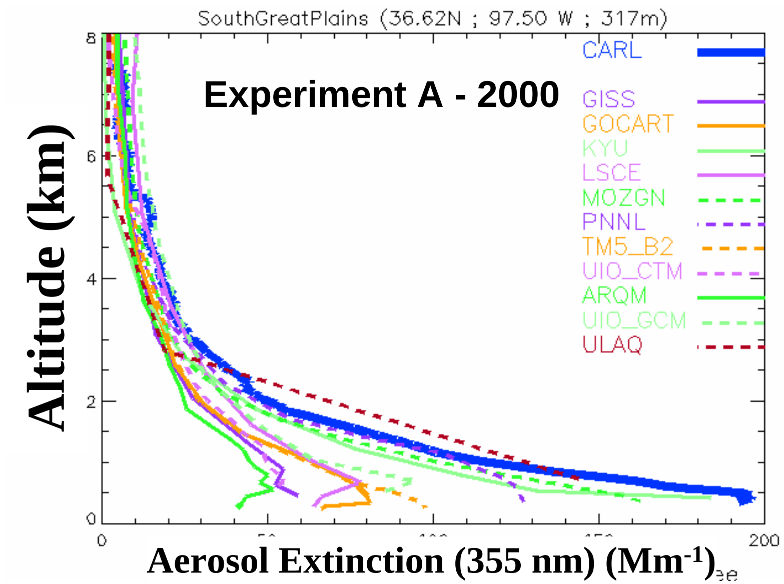

SouthGreatPlains (36.62N ; 97.50 W ; 317m)
Aerosol Extinction (355 nm)
Altitude, ASL, km
Aerosol Extinction, Mm-1 (355nm)
0
2
4
6
8
0
50
100
150
200
CARL
GISS
GOCART
LSCE*
MOZGN*
PNNL*
ARQM*
UIO_GCM
ULAQ
* = cloud free

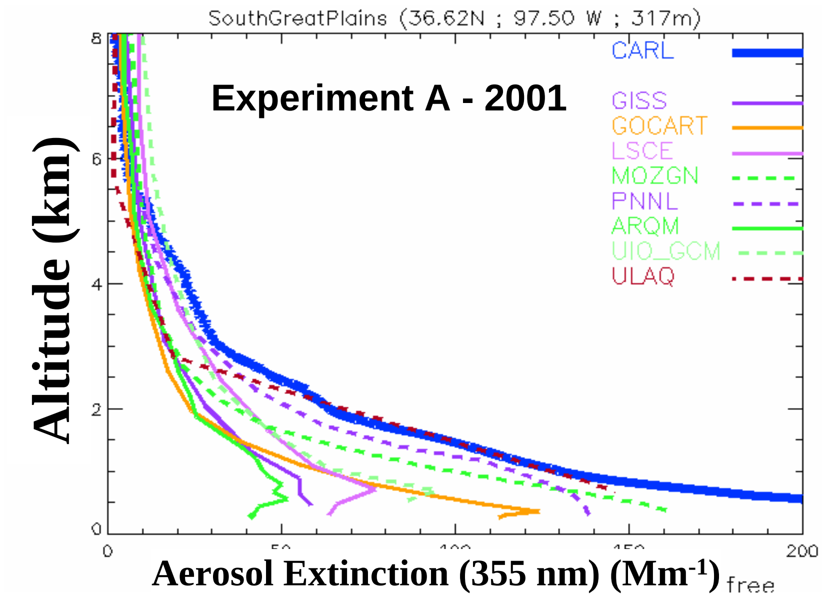


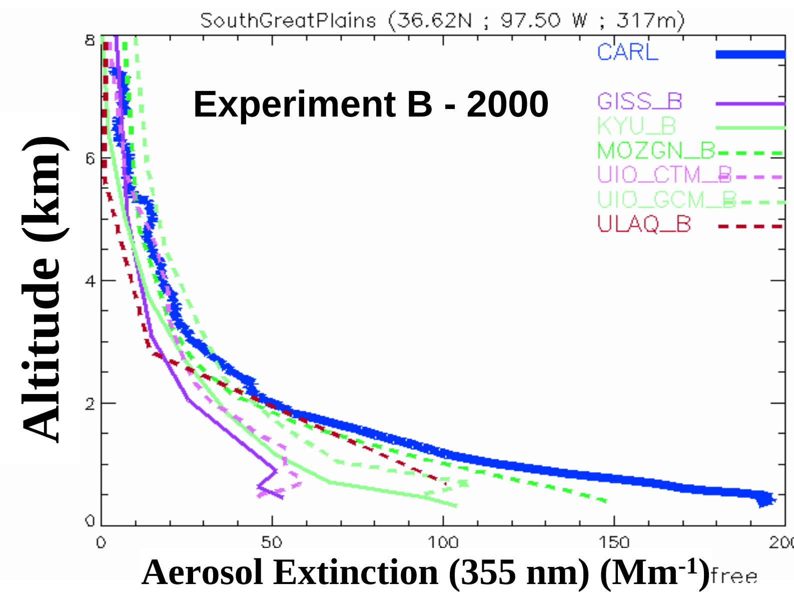


5th AeroCom Workshop October 2006

Measured versus Modeled Aerosol Extinction Profiles

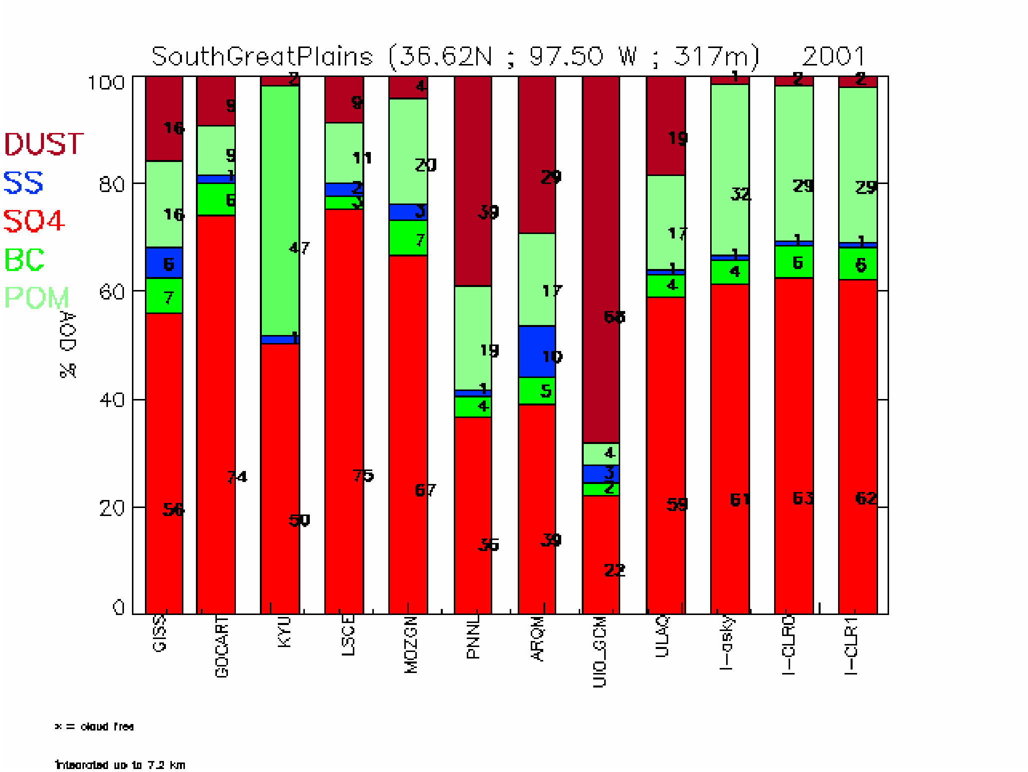


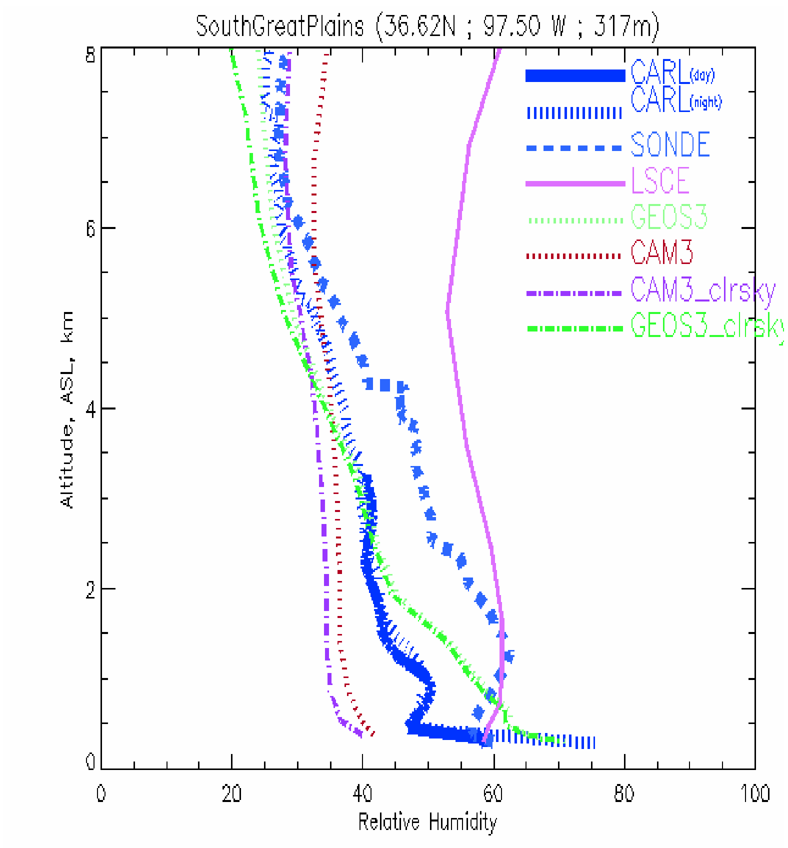




- **Measured vs. Model performance is essentially the same for both 2000 and 2001**
- **Model extinction profiles do not change appreciably when prescribed emissions and meteorology are used**

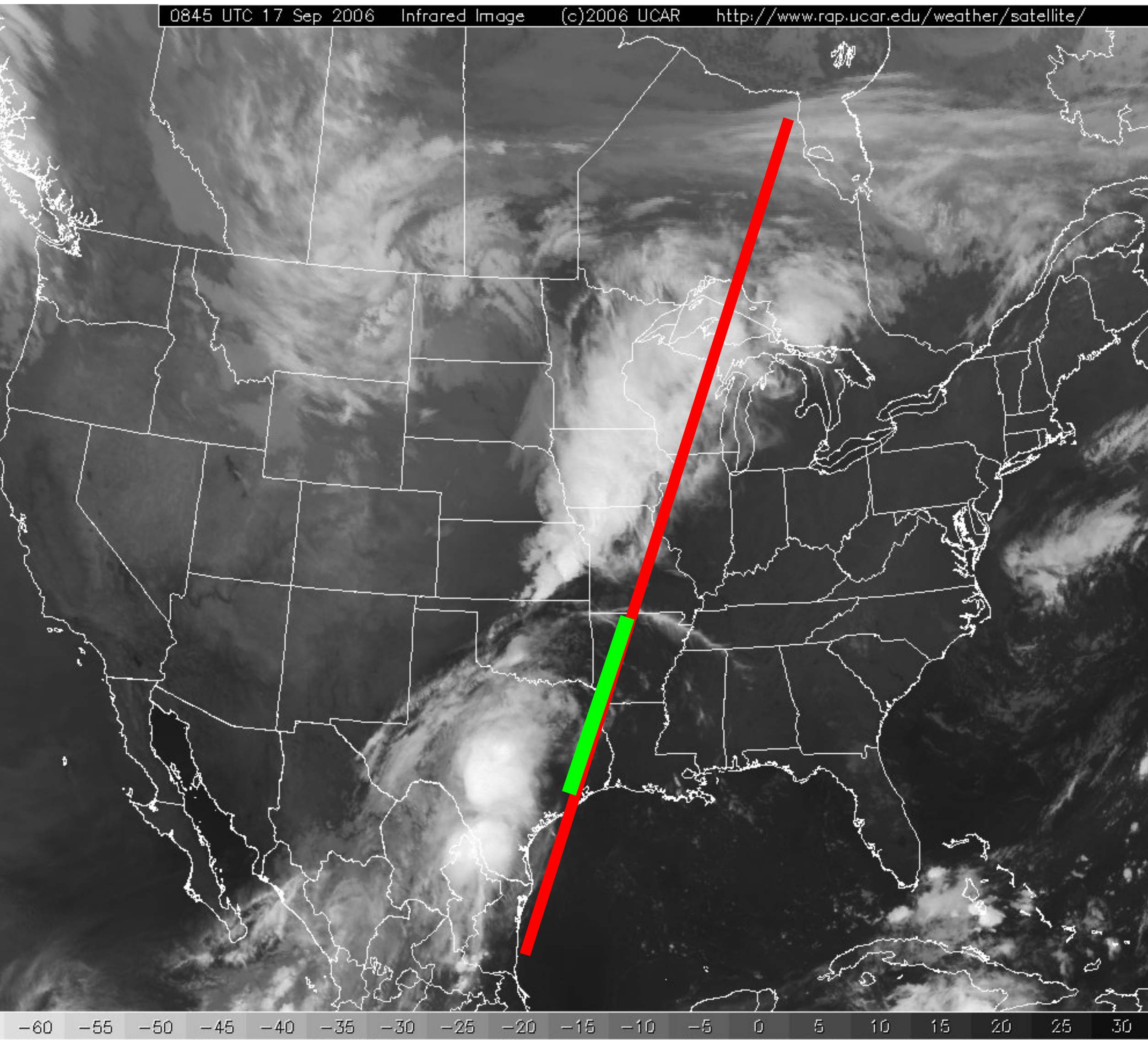
Includes Impact 2001 all sky



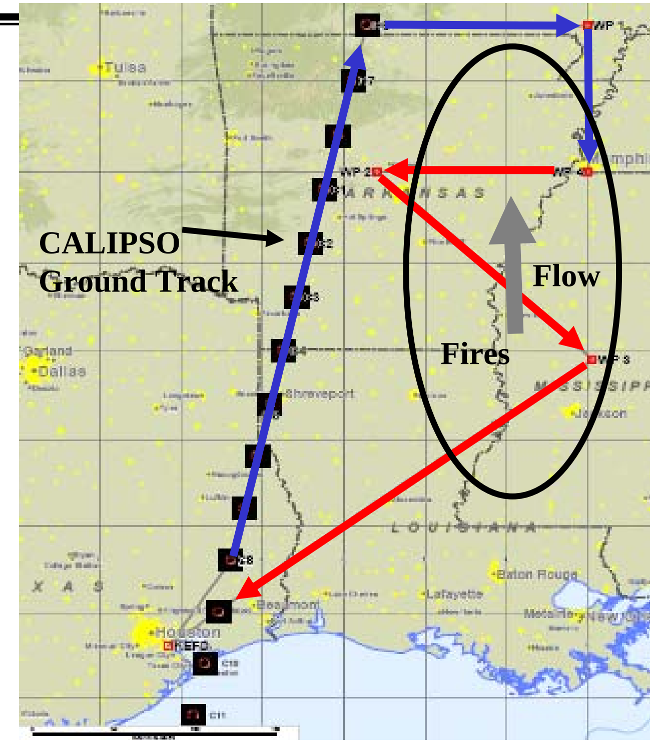

SouthGreatPlains (36.62N ; 97.50 W ; 317m)
CARL(day)
CARL(night)
SONDE
LSCE
GEOS3
CAM3
CAM3_clrsky
GEOS3_clrsky
Altitude, ASL, km
Relative Humidity
0
2
4
6
8
0
20
40
60
80
100

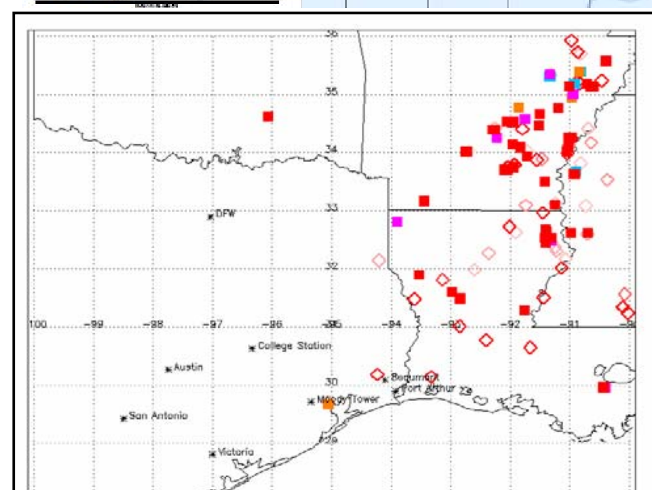
NASA King Air 09/17/06 Objectives:

- CALIPSO validation under-flight
- Raster pattern to sample smoke from fires



NASA King Air Flight Plan





GOES (ABBA) + MODIS
Fire Counts 9/16-9/17

HSRL Model Verification: aerosol extinction STEM (60km)

STEM provides a better prediction of elevated aerosols (C[1],A[2],C[2]) but:

1) also misses elevated lower backscatter features (B[1],B[2]) and aerosol loading near Houston (A[1])
2) underestimates aerosol extinction, particularly above 2 km.

HSRL 532nm Extinction