Characterizing the Vertical Distribution of Aerosols Over the ARM SGP site

Richard Ferrare[a], Connor Flynn[b], David Turner [c], Marian Clayton[d]

(a) NASA Langley Research Center, Hampton, Virginia
(b) Pacific Northwest National Laboratory, Richland, Washington
(c) University of Wisconsin, Madison, Wisconsin
[d] Science Applications International Corporation, Hampton, Virginia

DOE ARM Aerosol Working Group Meeting, December, 2005

Objectives and Status

Objectives

- Use Raman lidar and MPL aerosol measurements to investigate:
  - vertical variability of aerosols over SGP
  - the use of these measurements to infer aerosol type
  - aerosol humidification factor [f(RH)]
- Improve the characterization of the vertical distribution of aerosol properties over the SGP site used for modeling radiative fluxes and heating rates
- Assess the ability of the aerosol transport models to simulate aerosol extinction profile and aerosol optical thickness

Status

- Implementing hardware and software modifications to Raman lidar to improve aerosol and water vapor retrievals (Turner)
- Developing/evaluating algorithms for retrievals of aerosol extinction from MPL (Flynn)
- Evaluating ALIVE measurements (Ferrare, Turner, Flynn)
- Evaluating aerosol transport model simulations of aerosol properties using data collected over ARM SGP (Ferrare)
  - Collaboration with Michael Schulz, Sarah Guibert (AEROCOM) project

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

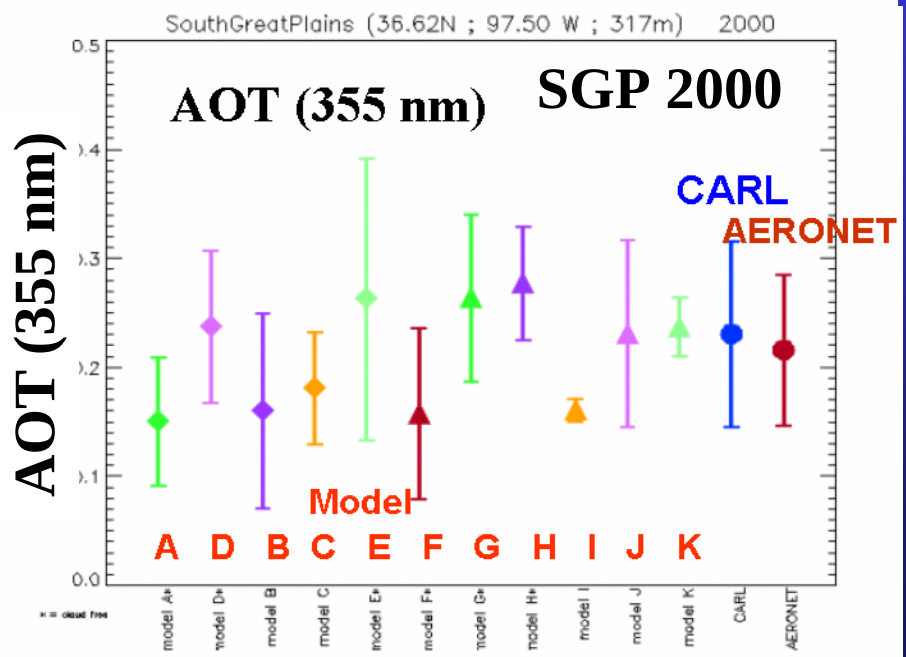
Strategy:

- 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

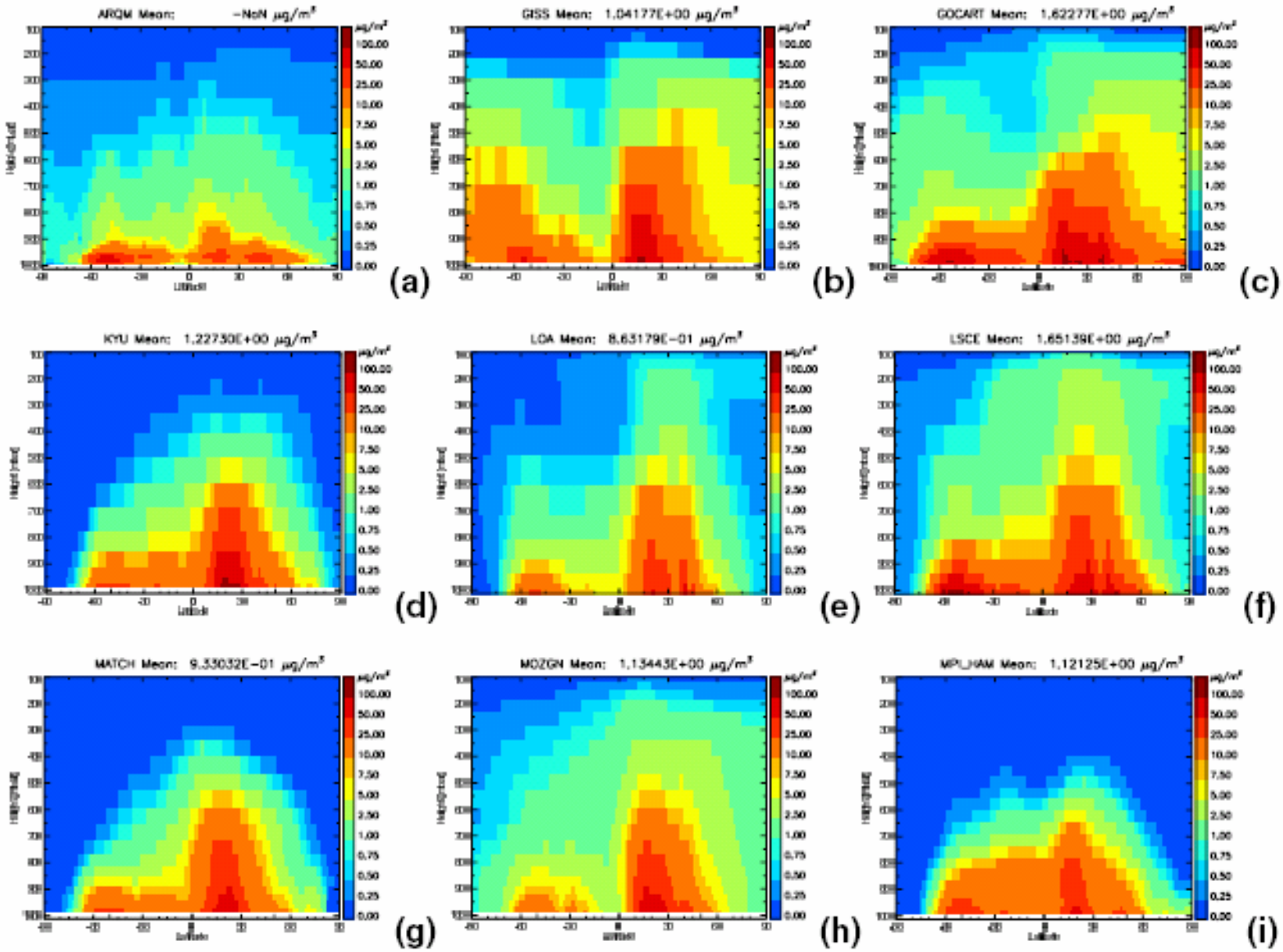
Participating Models

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



Large Variation in How Models Represent Aerosol Profiles

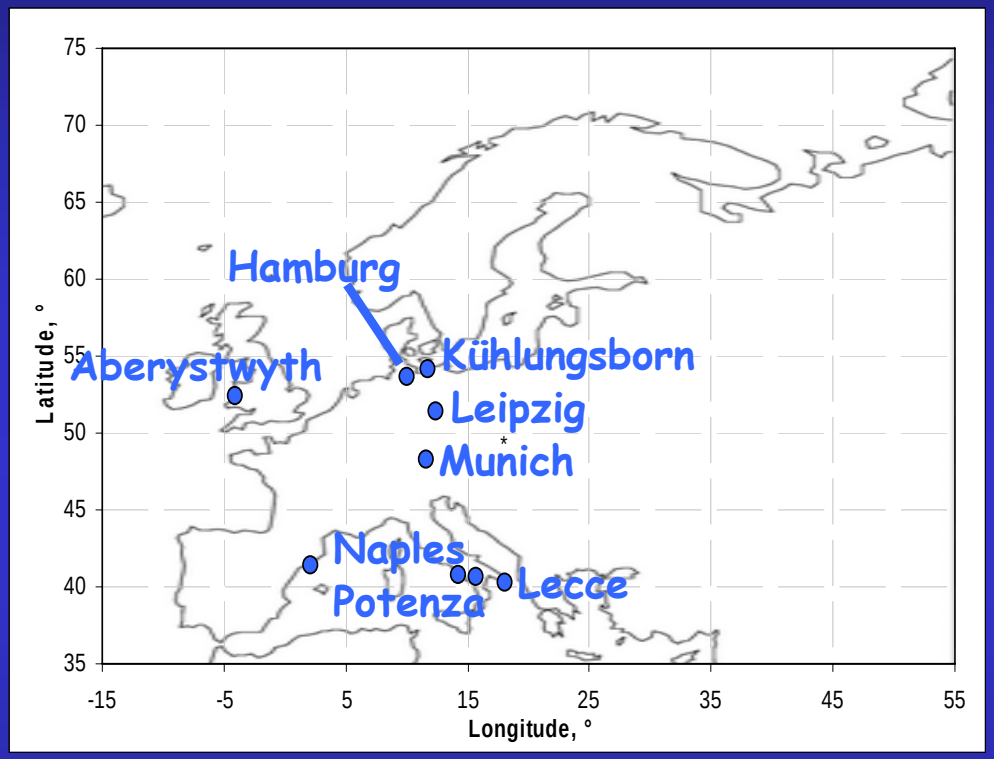
Global Annual Mean Aerosol Concentration (μg/m³)



Textor et al., 2005

Lidar measurements

EARLINET stations

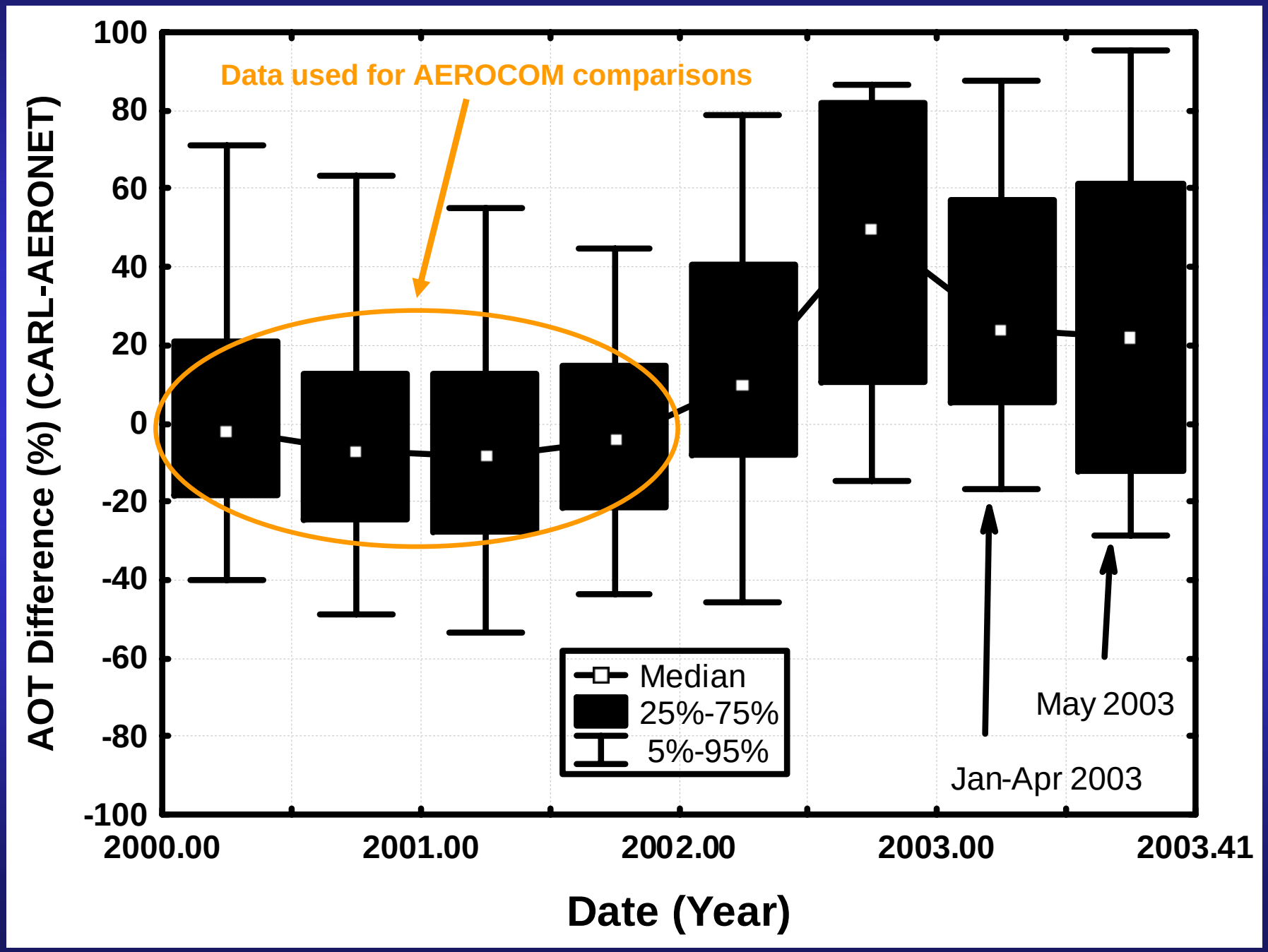


- Use of measurements for 2000 and 2001
- Measurements twice a week : Monday and Thursday
- Measurements at sunset
- Raman lidar : extinction coefficient without hypothesis on lidar ratio

ARM program

- Use of measurements for 2000 and 2001
- Measurements : each day (except specific months) each 10 minutes
- Measurements of : extinction coefficient, scattering ratio, backscatter coefficient, optical depth relative humidity, cloud detection

AOT Comparisons (CARL vs. Cimel)

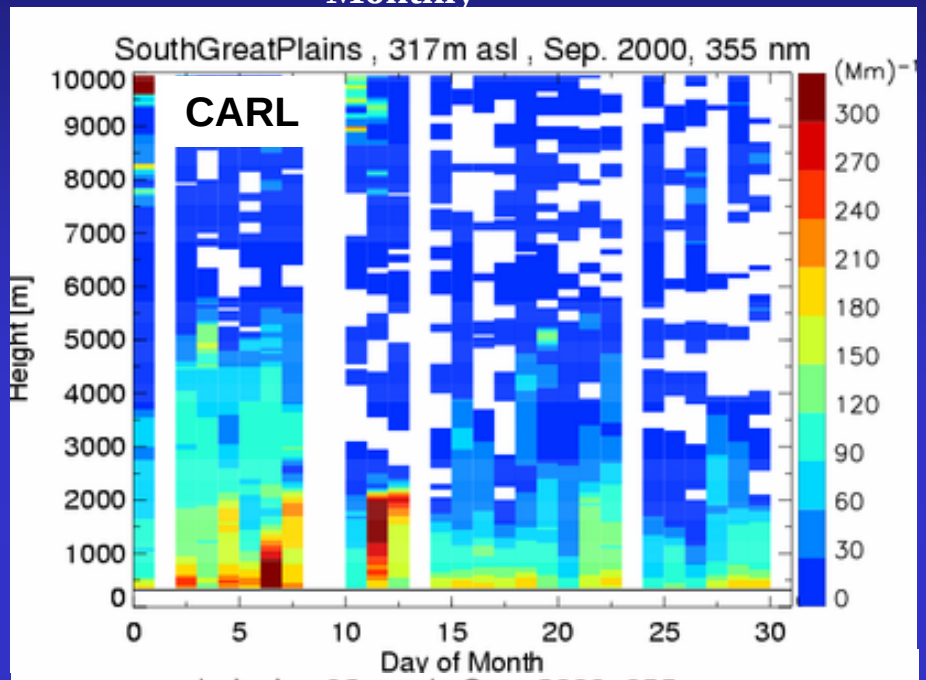


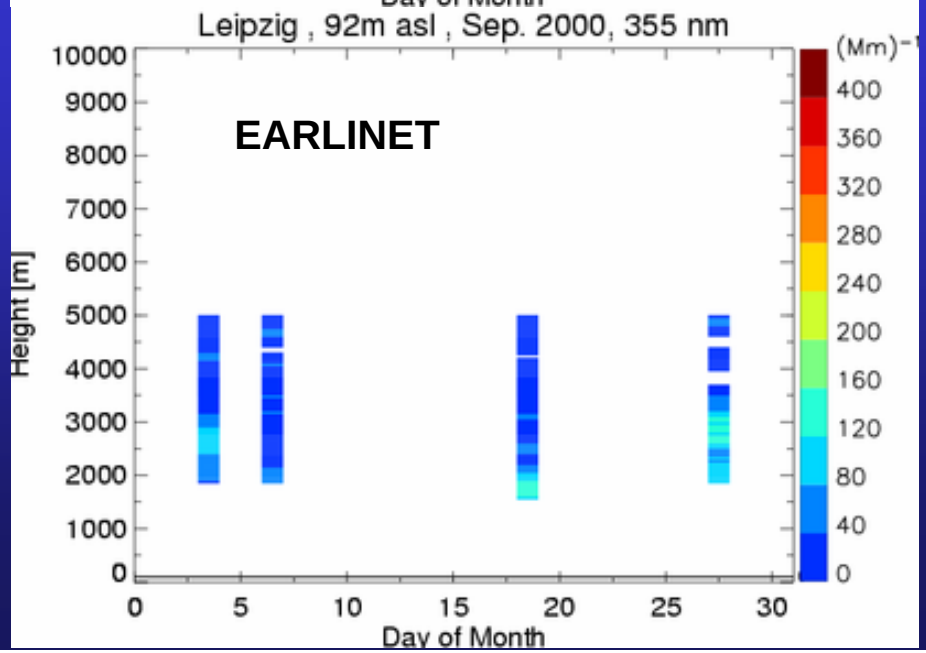
Continuous vs. Periodic Measurements

CARL – continuous

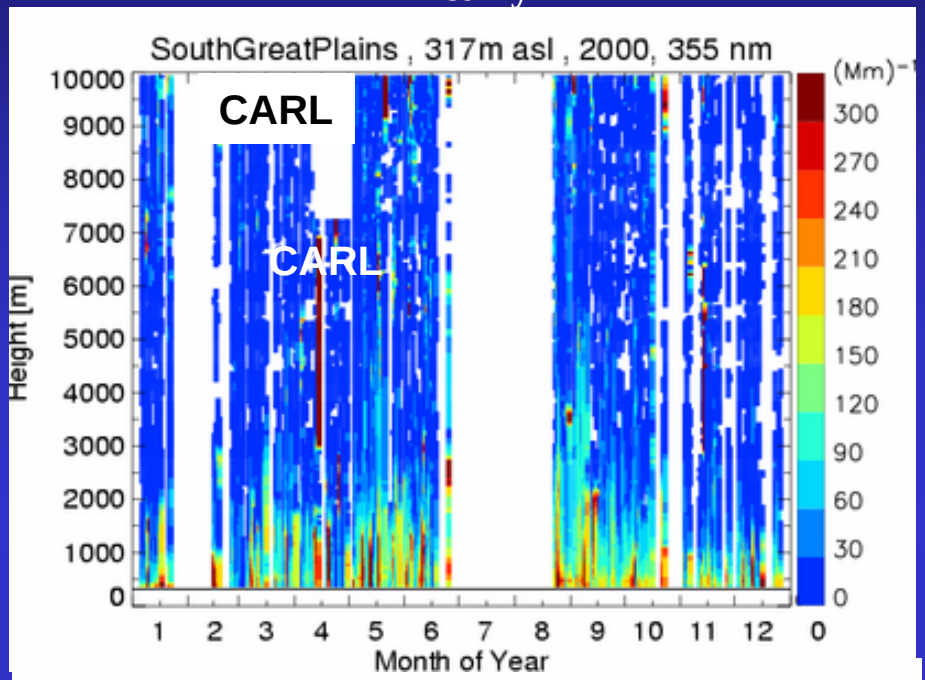
EARLINET – periodic 3 times/week (Monday 13:00 UT; Monday, Thursday 1 hour after sunset)

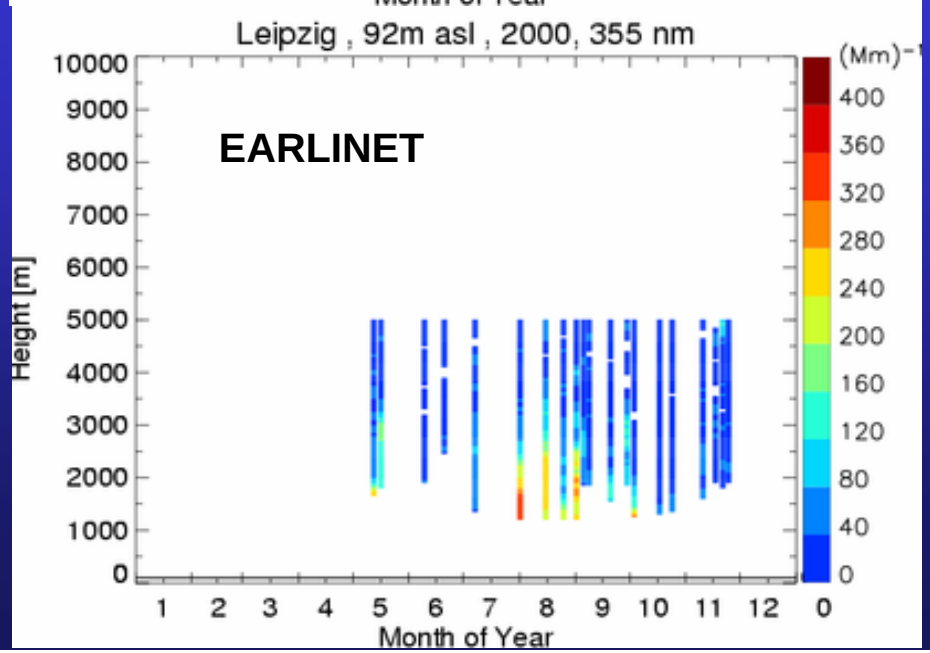
Monthly



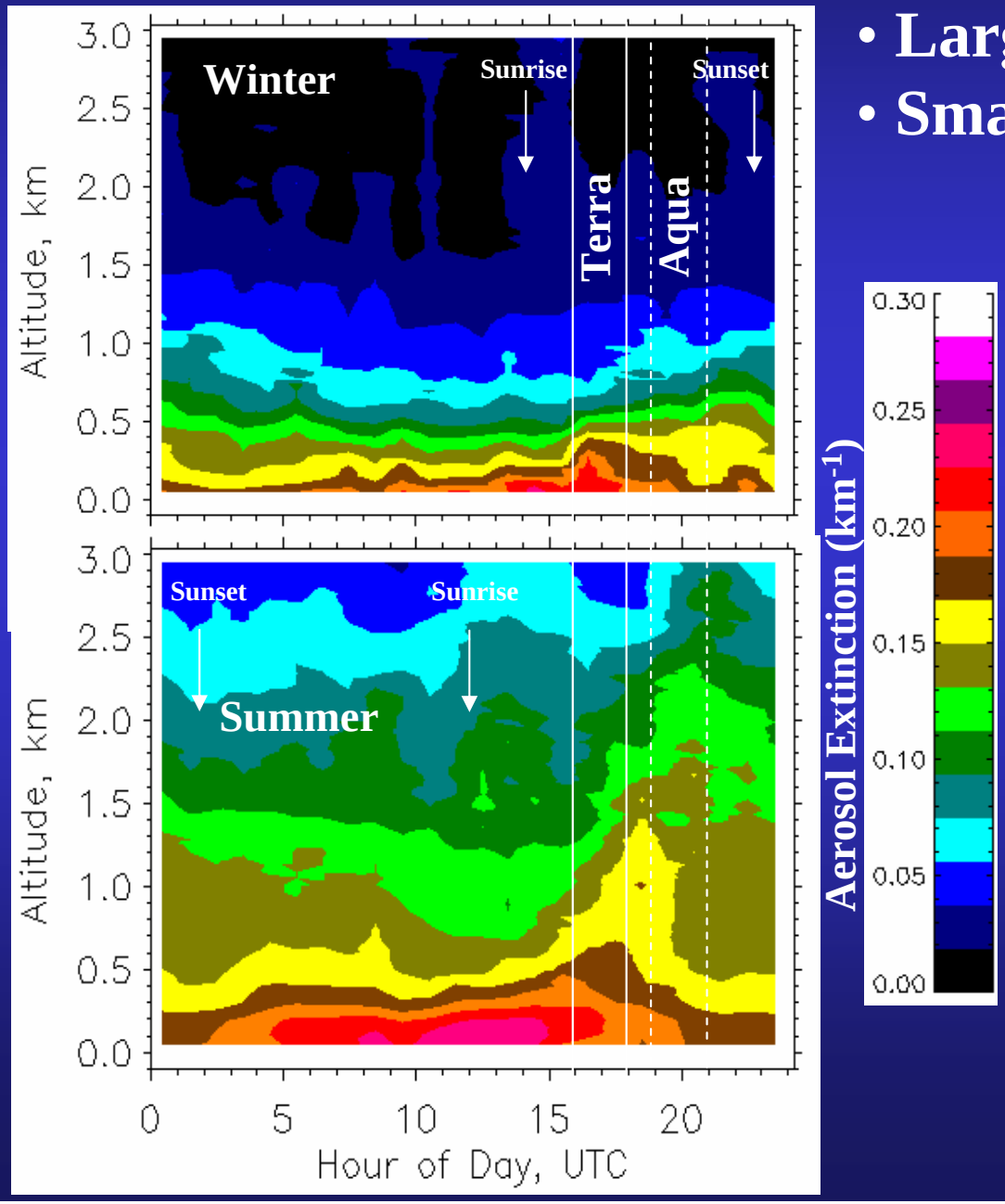


Yearly



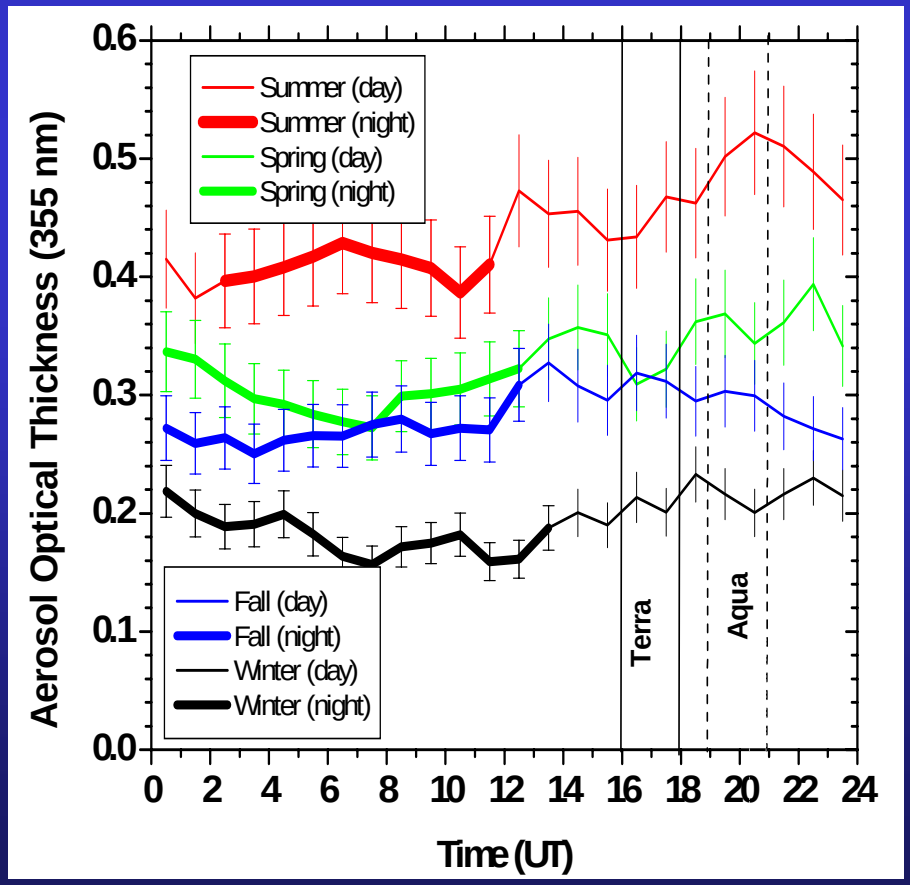


Average Diurnal Variation of Aerosol Extinction Profiles and AOT



- Large changes in vertical profile
- Smaller changes in AOT (st. dev ~ 10%)

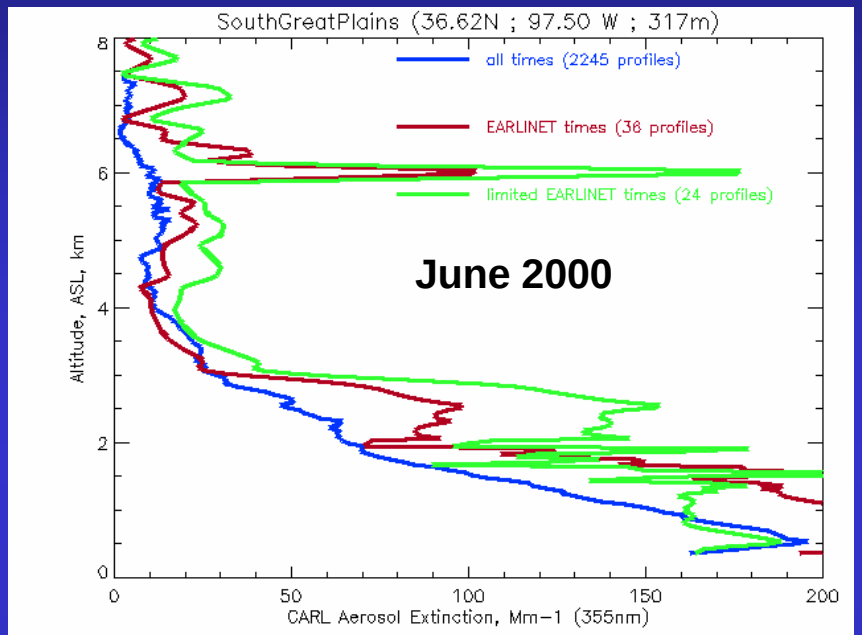
AOT

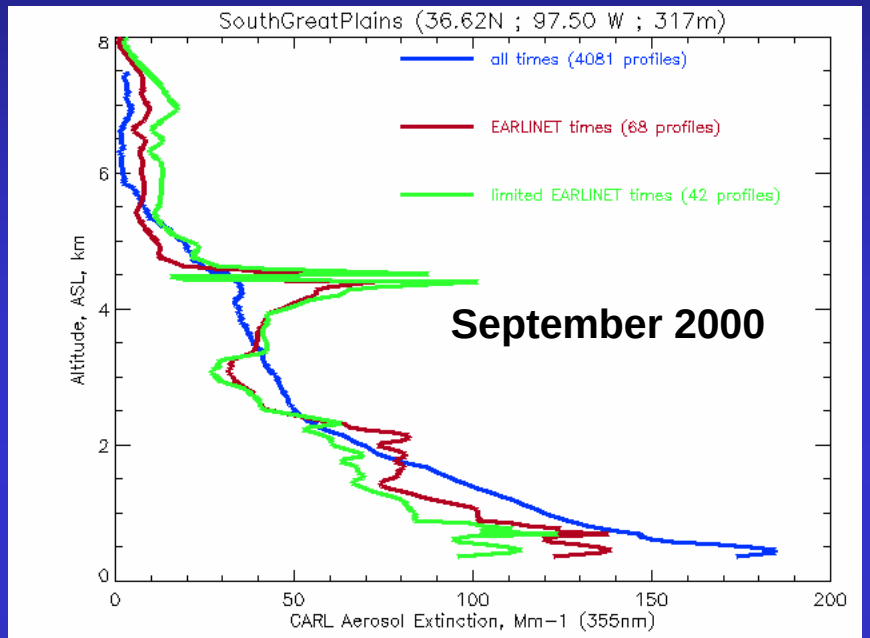


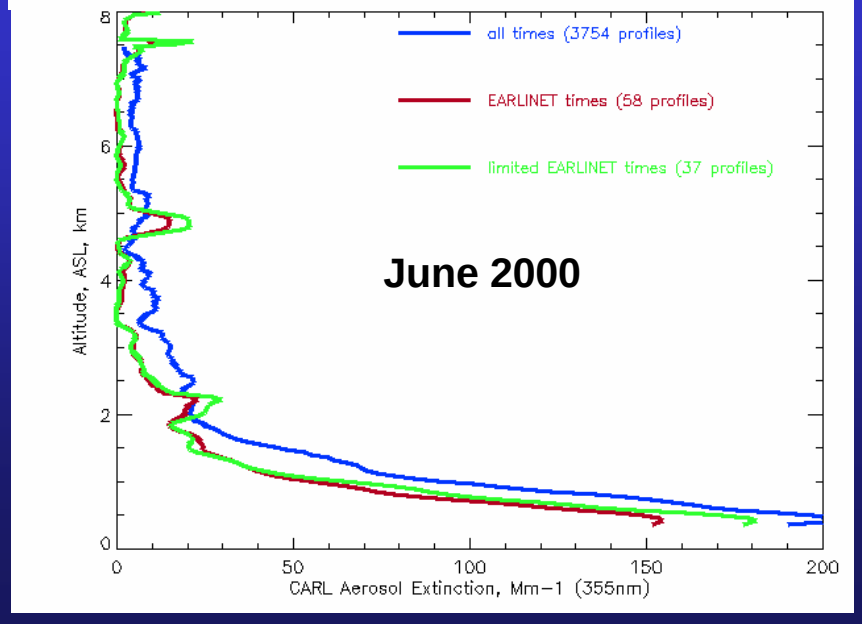
Continuous vs. Periodic Measurements

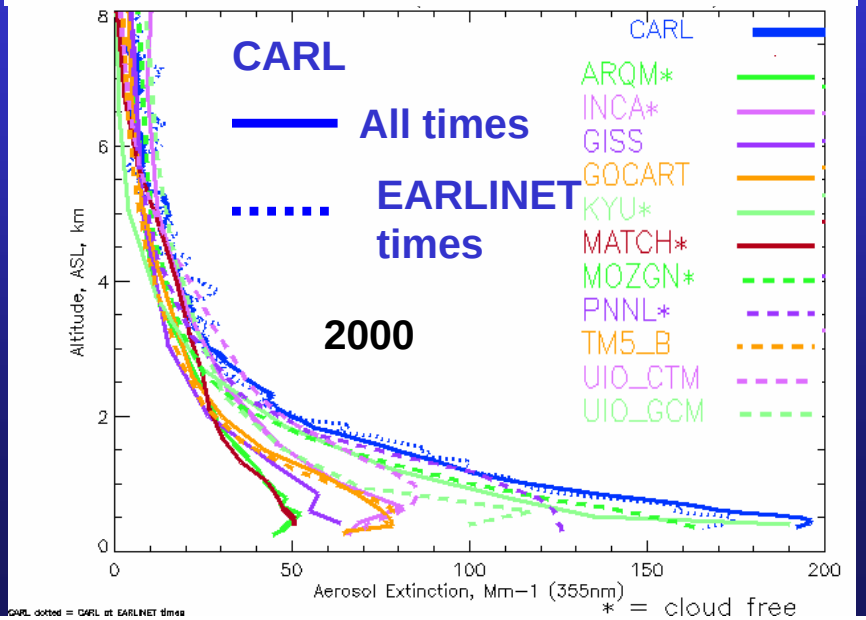
CARL – continuous

EARLINET – 3 times/week (Mon. 13:00 UT; Mon., Thurs. 1 hour after sunset)

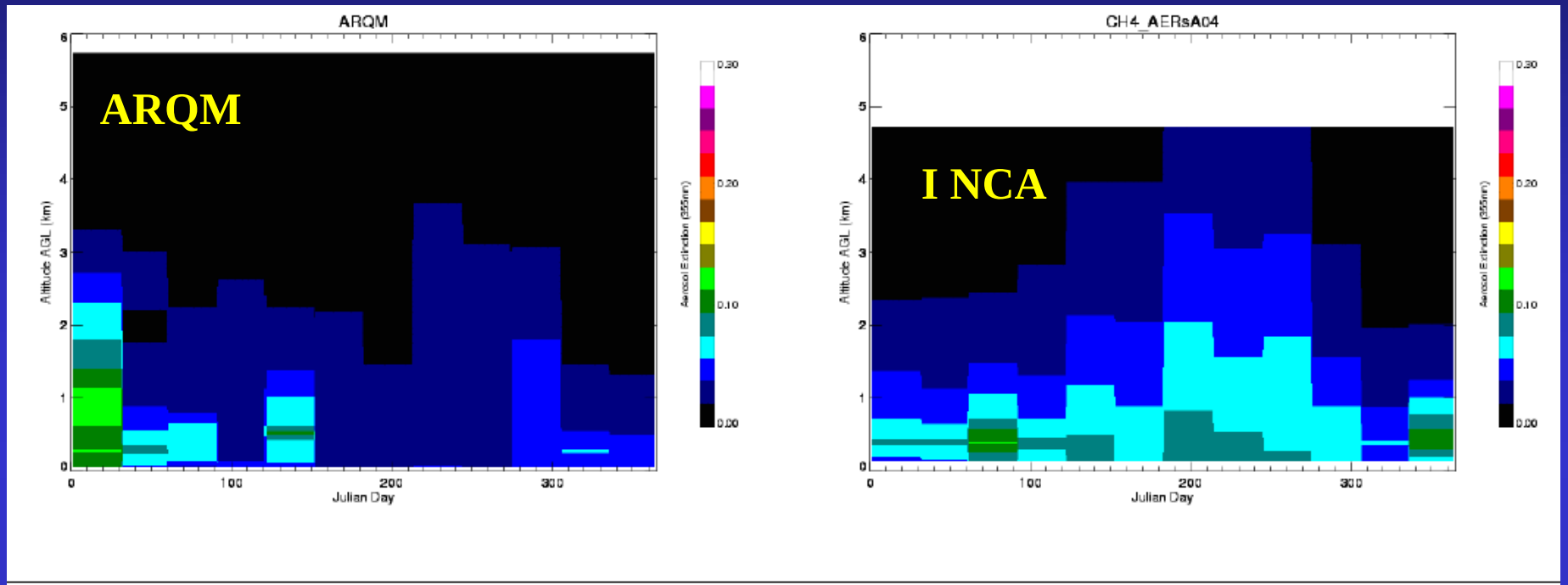


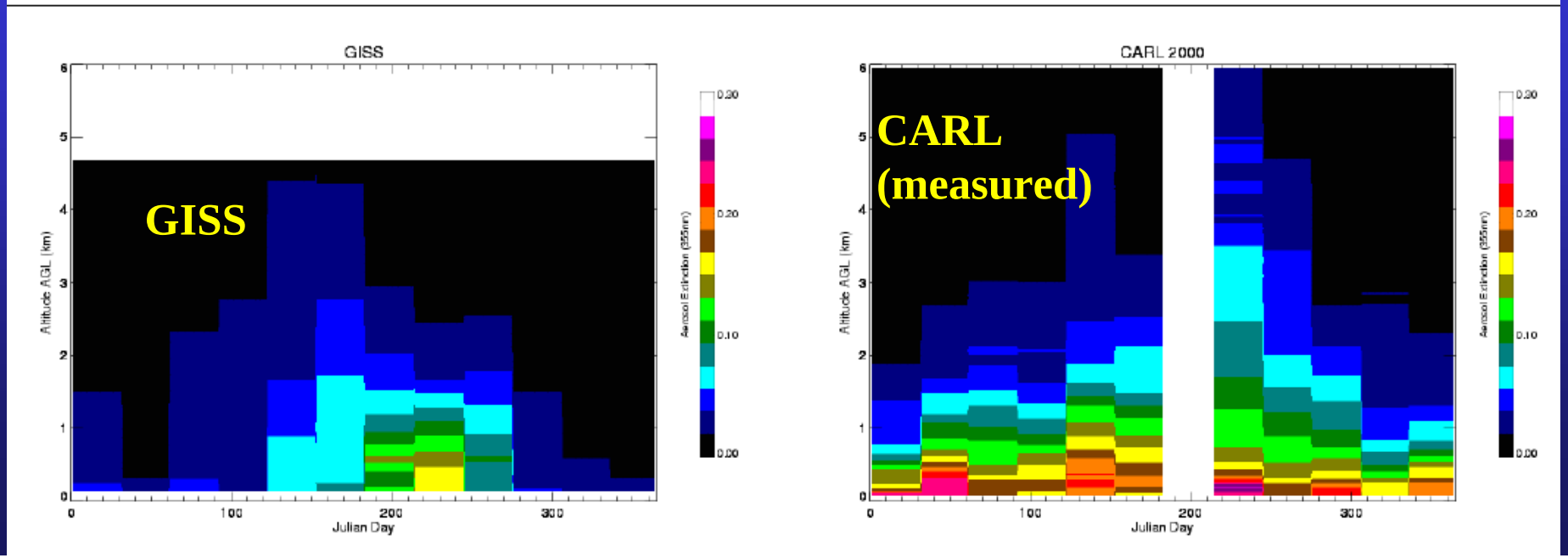






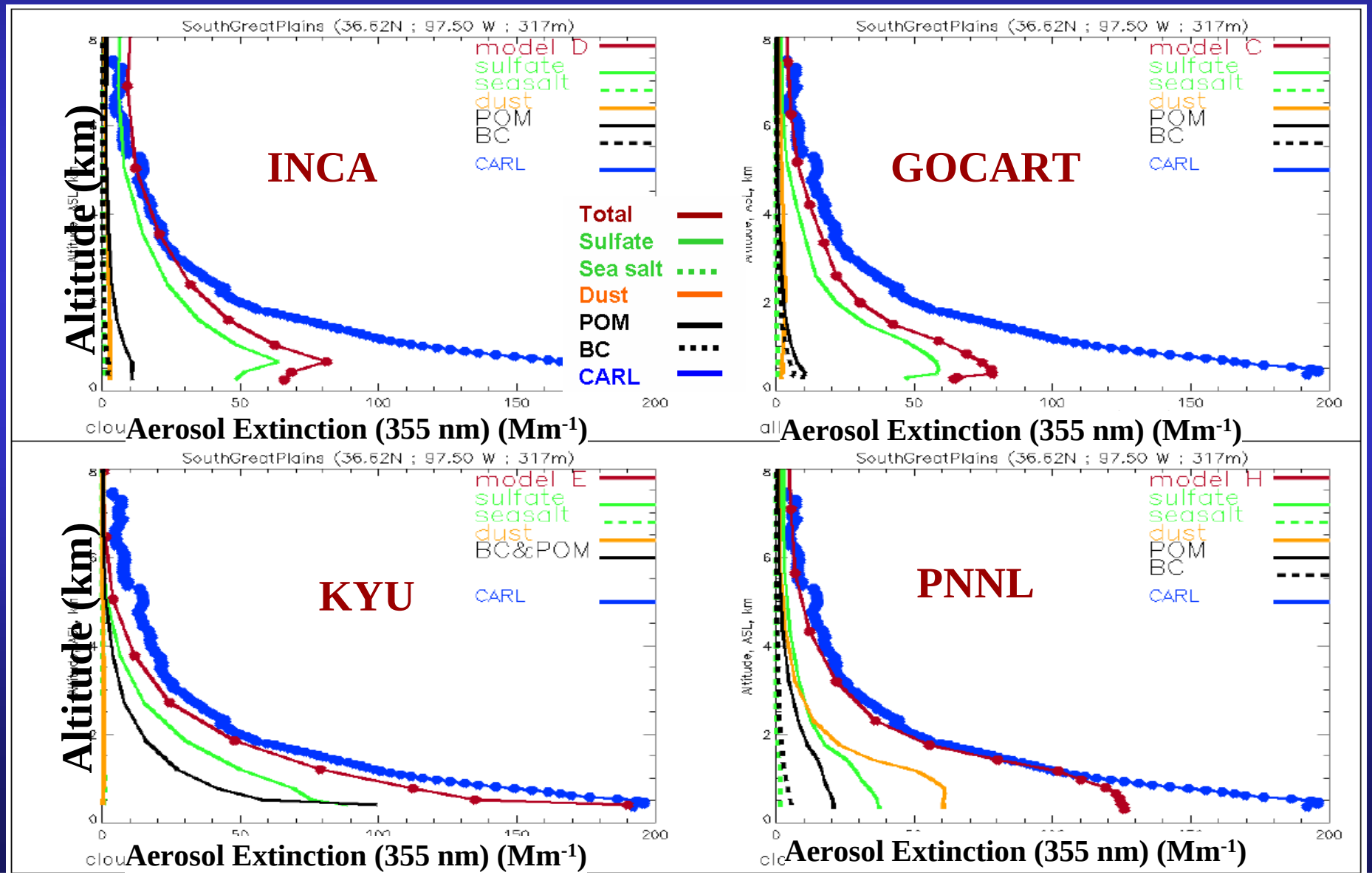
Measured vs. Modeled Monthly Average Aerosol Extinction Profiles





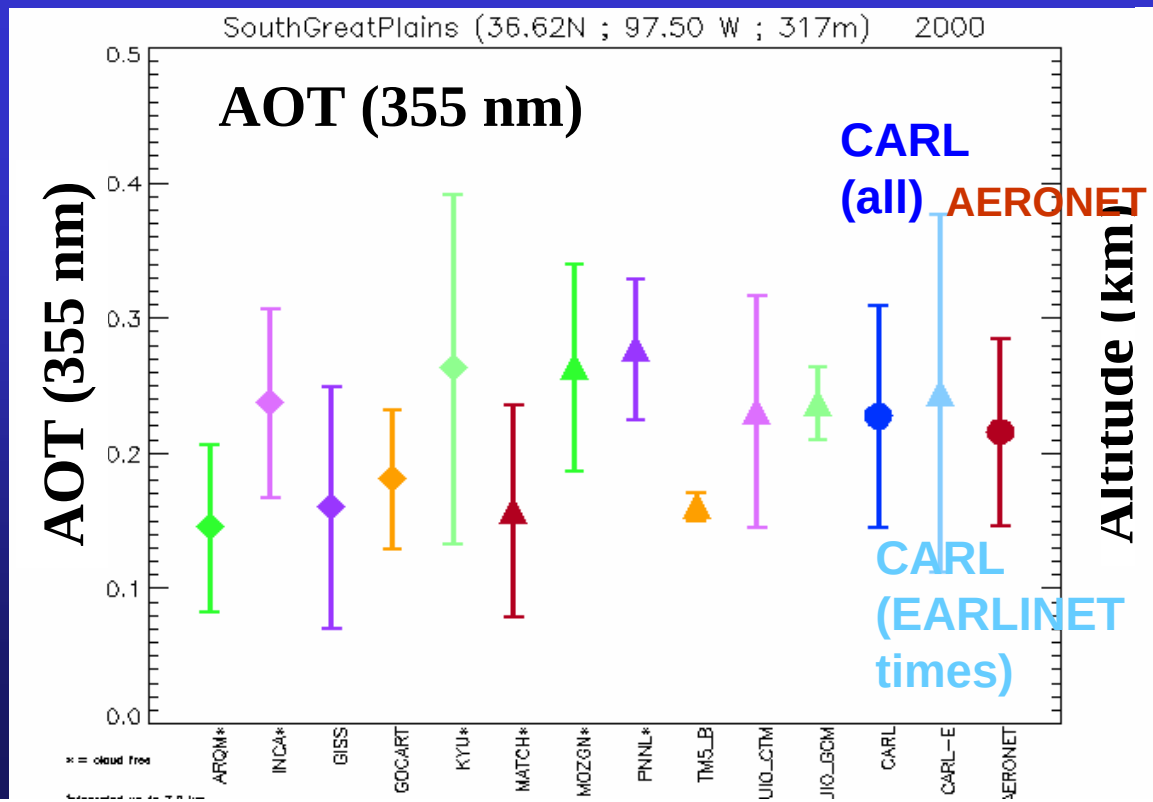
Measured versus Modeled Yearly Average Aerosol Extinction Profiles

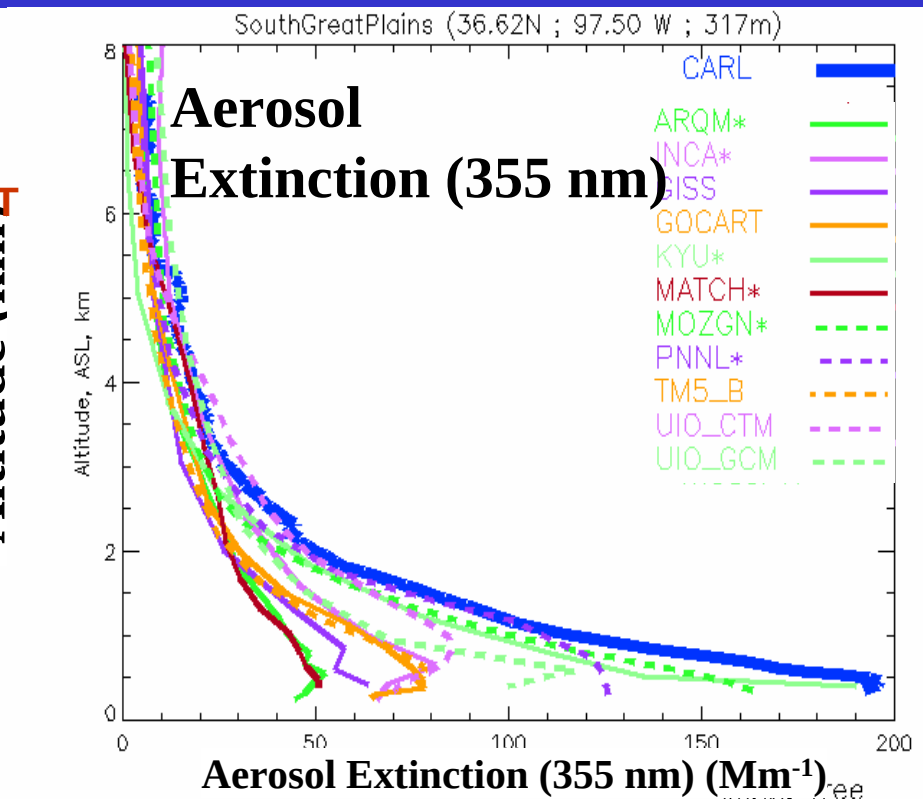
- Large variability in modeled vertical distributions and aerosol components
- Profile behavior of various aerosol constituents may give indication of model strengths and weaknesses



Measured versus Modeled Aerosol Optical Thickness

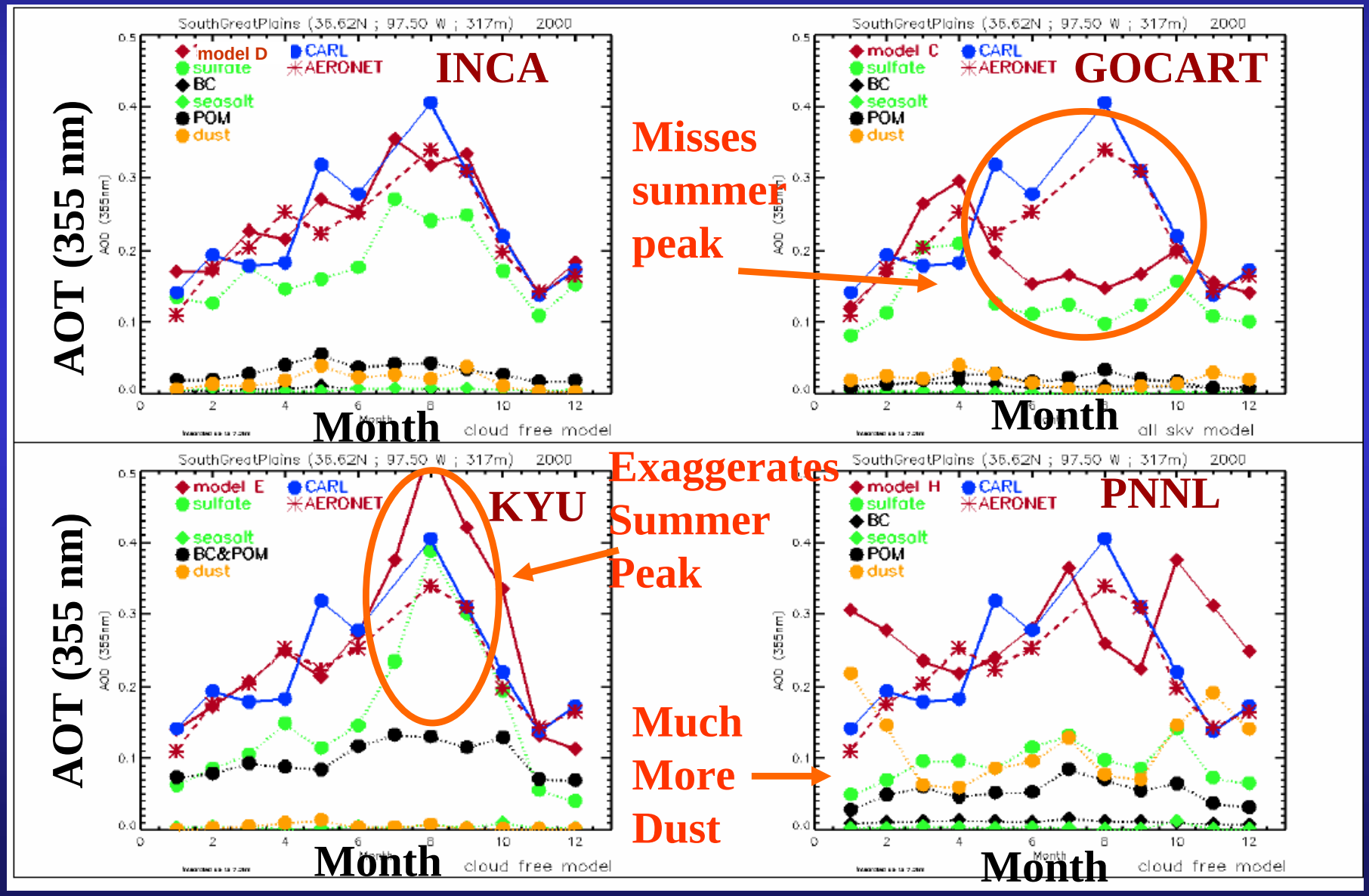
- Although models may agree in total AOT, significant differences can exist in vertical distributions and contributions to AOT from various aerosol components
- Averaging on larger temporal and/or spatial scales gives better agreement
- Deviations between mean aerosol extinction profiles are generally small (~20-30%) for altitudes above 2 km, and grow considerably larger below 2 km
- Models generally have lower aerosol extinction near the surface; perhaps due to
  - too little vertical mixing
  - not enough humidification of aerosol
  - potential high bias of lidar measurements near surface

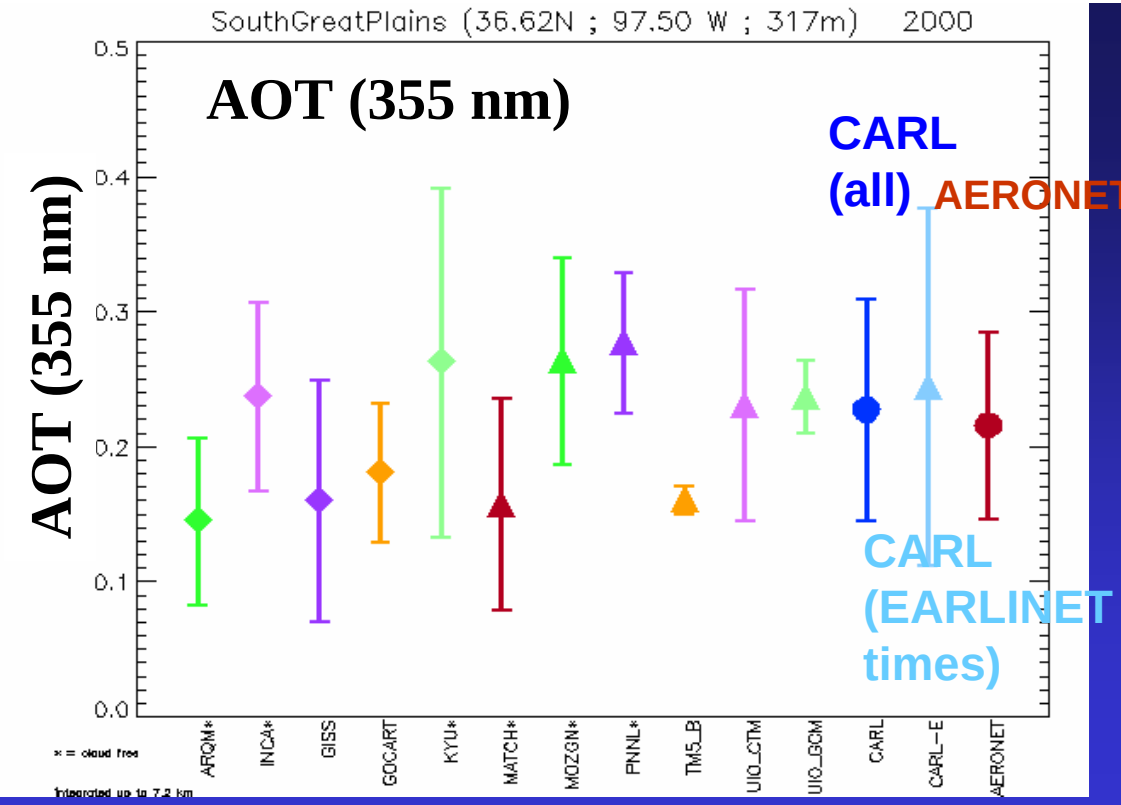


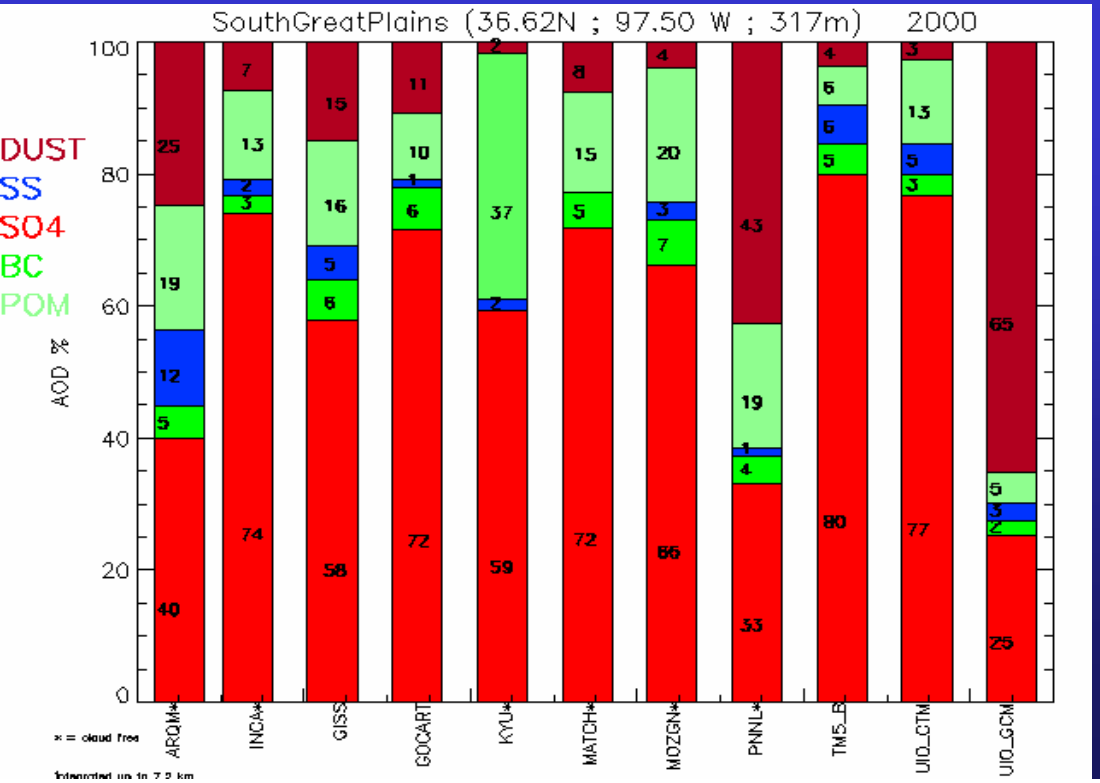


Measured versus Modeled Aerosol Optical Thickness

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





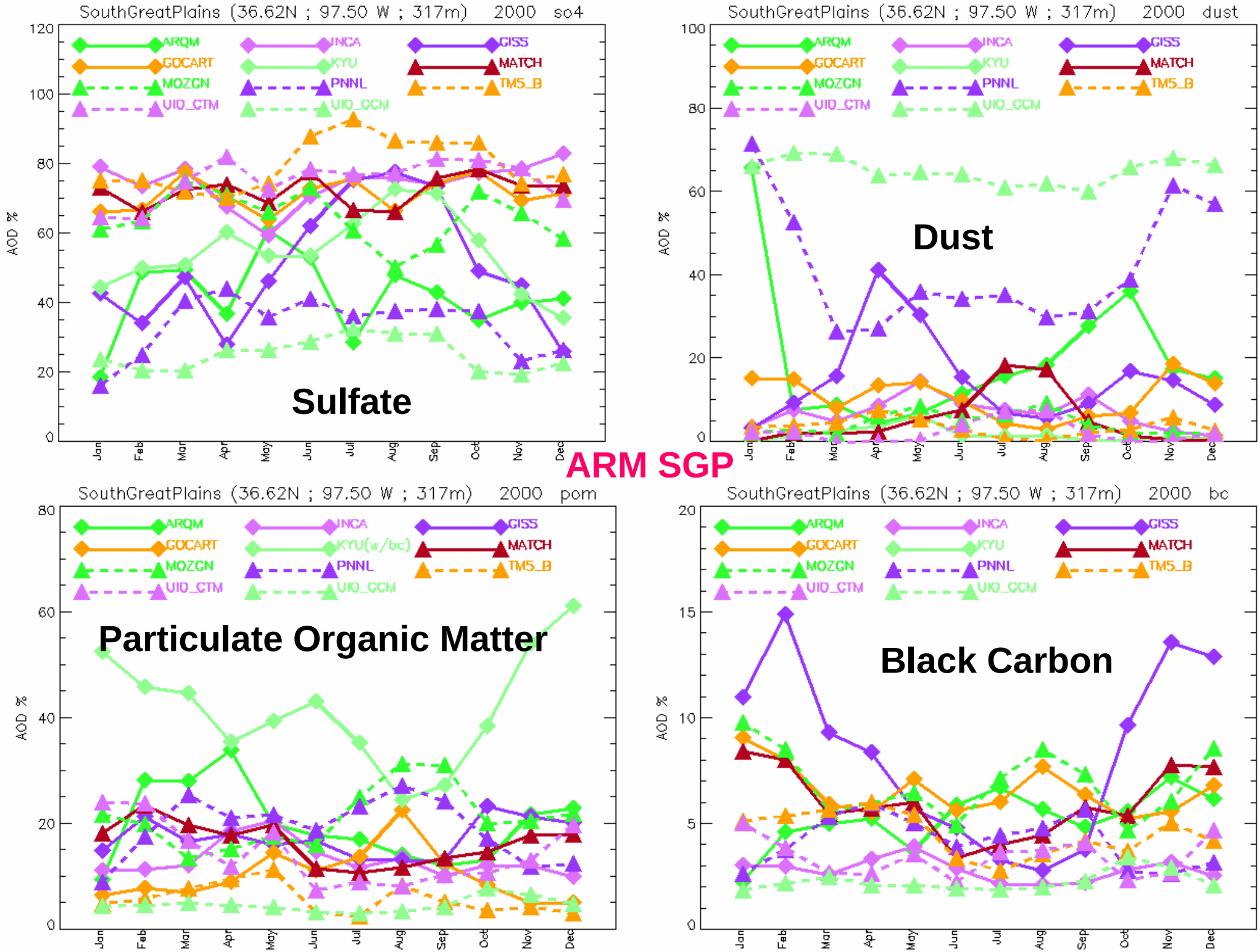


ARM SGP

General agreement in total AOT

But…

Large differences in compositional mixtures


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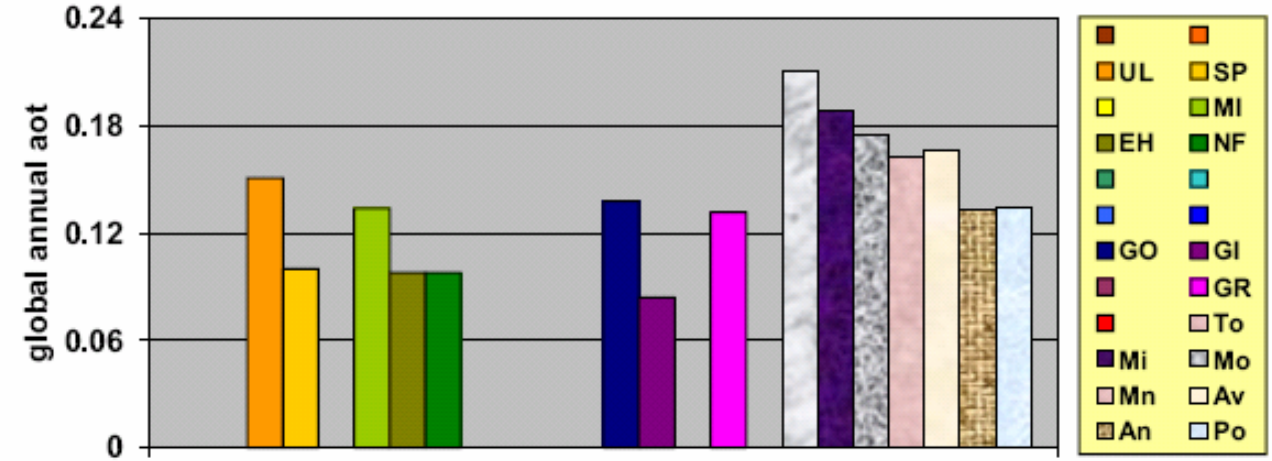
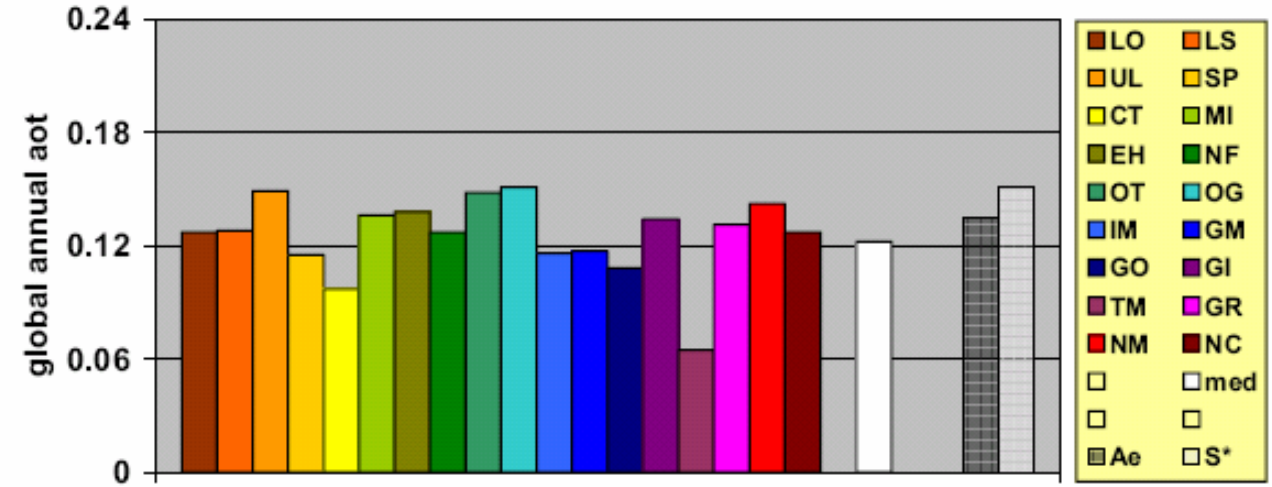
Oct
Nov
Dec

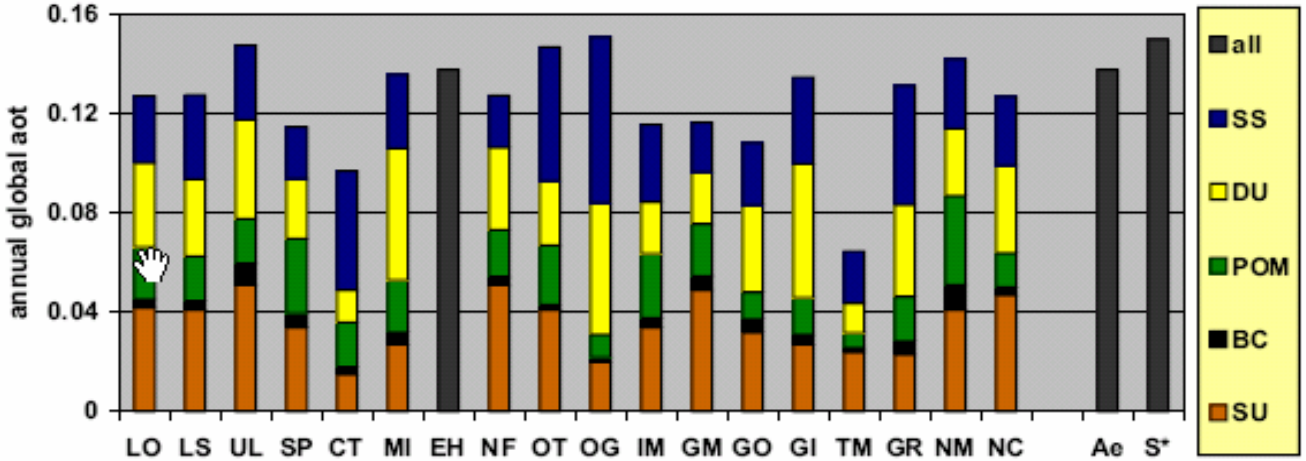
Global



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



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



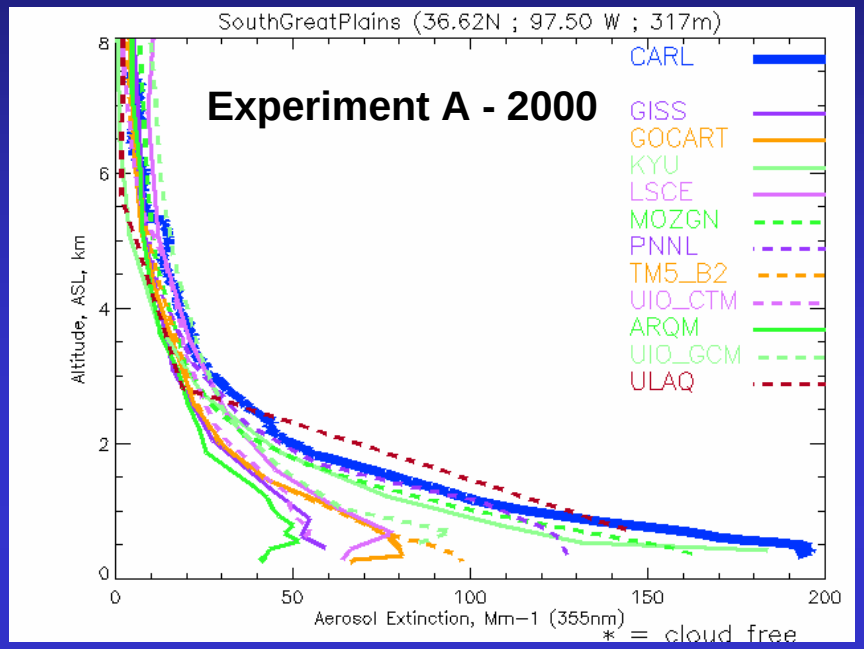
Model representations of global annual AOT have become closer to observations between 2002 to 2005

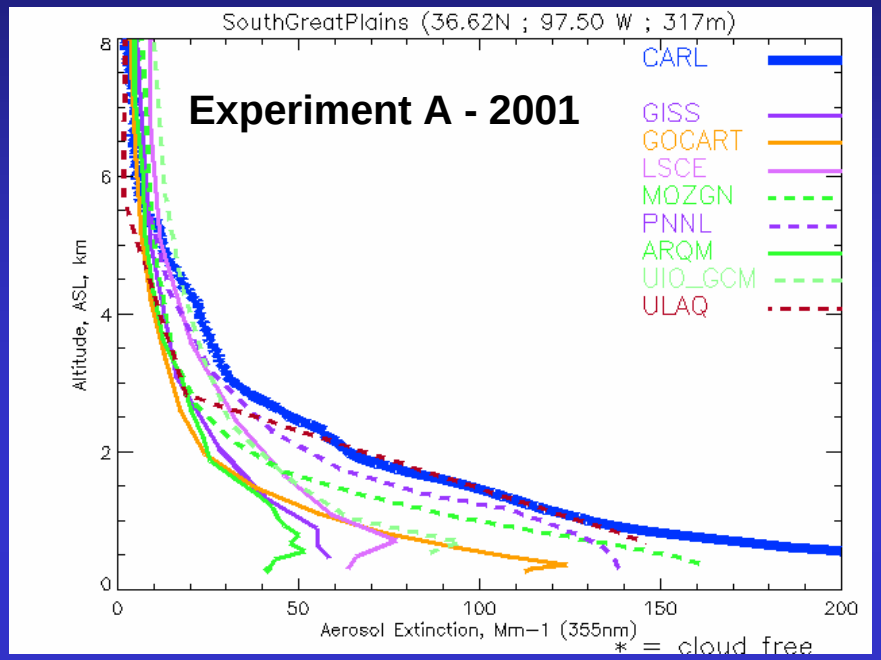
But…

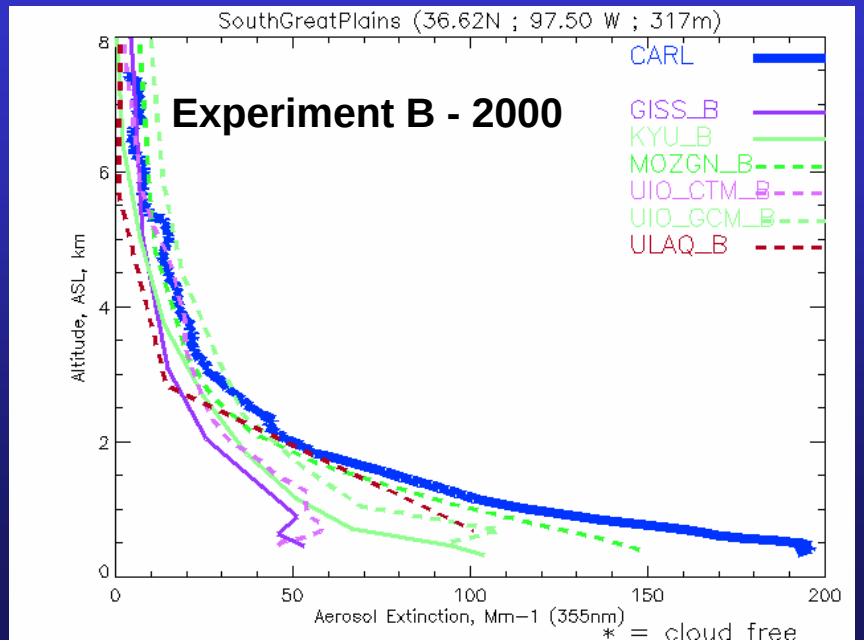
Large model differences compositional mixture

Kinne et al., 2005

Measured versus Modeled Aerosol Extinction Profiles





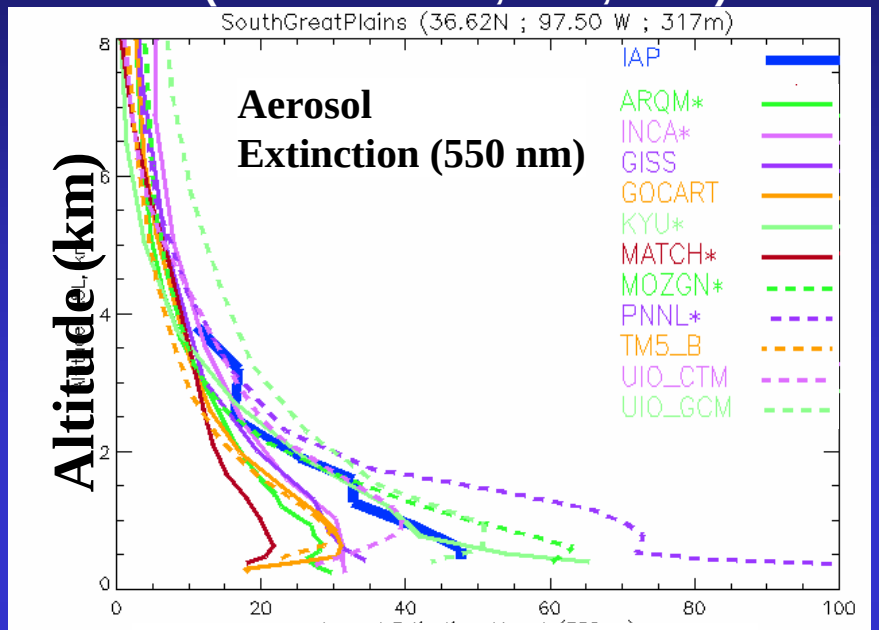


- **Measured vs. Model performance is essentially the same for both 2000 and 2001**

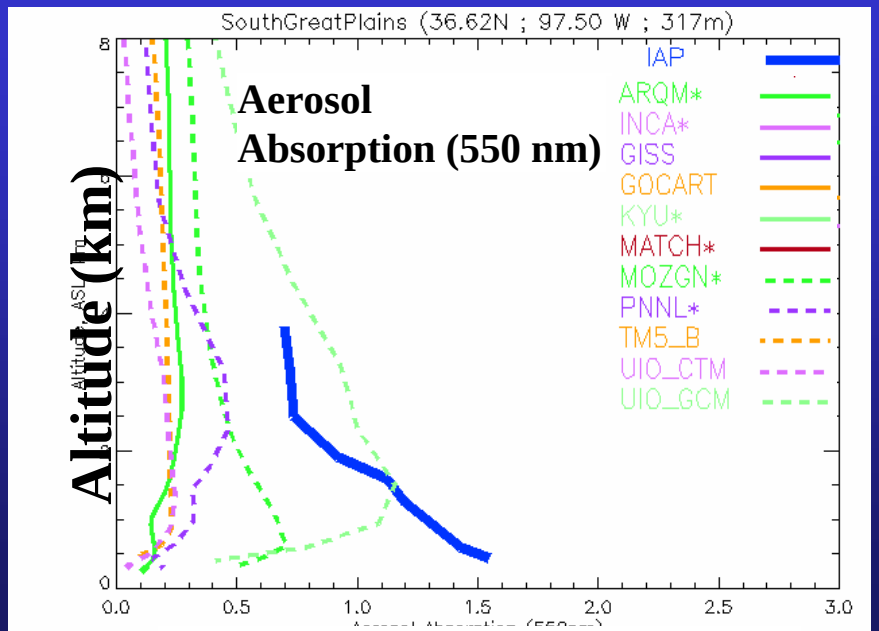
- **Model extinction profiles do not change appreciably when prescribed emissions and meteorology are used**

In Situ Aerosol Profiling (IAP) - 2000

(Andrews et al., JGR, 2004)

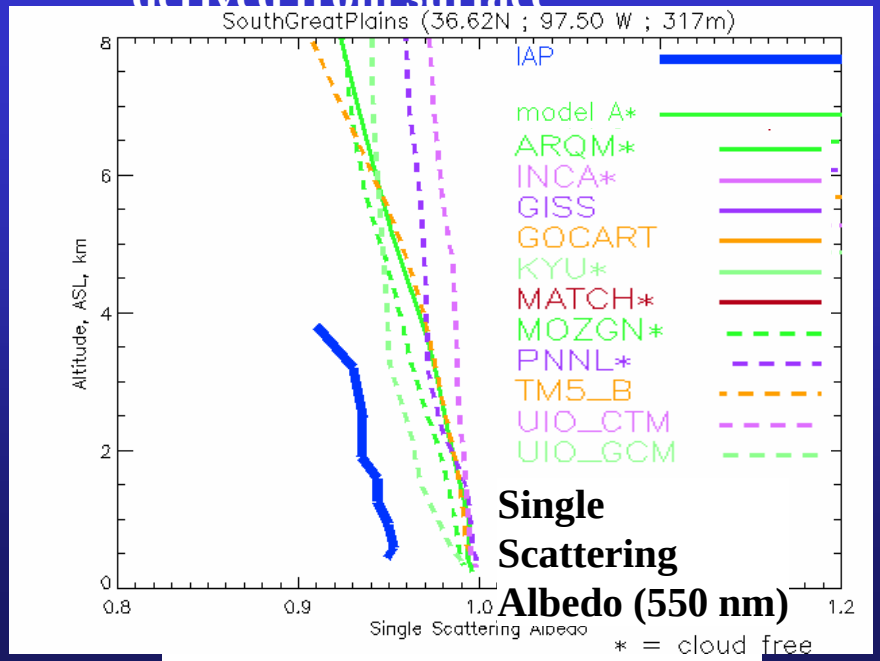


Aerosol Extinction (550 nm) (Mm^{-1})



Aerosol Absorption (530 nm) (Mm^{-1})

- Daytime measurements 2-3 times/week
- Primary Measurements
  - Aerosol scattering (3 λ) (dry)
  - Aerosol absorption (1 λ) (dry)
  - Hemispheric backscatter fraction (dry)
- Derived Parameters
  - Aerosol single scatter albedo
  - Aerosol optical thickness
  - Angstrom exponents
- Converted to ambient humidity using f(RH) measured at surface
- Applied supermicron scattering correction derived from surface

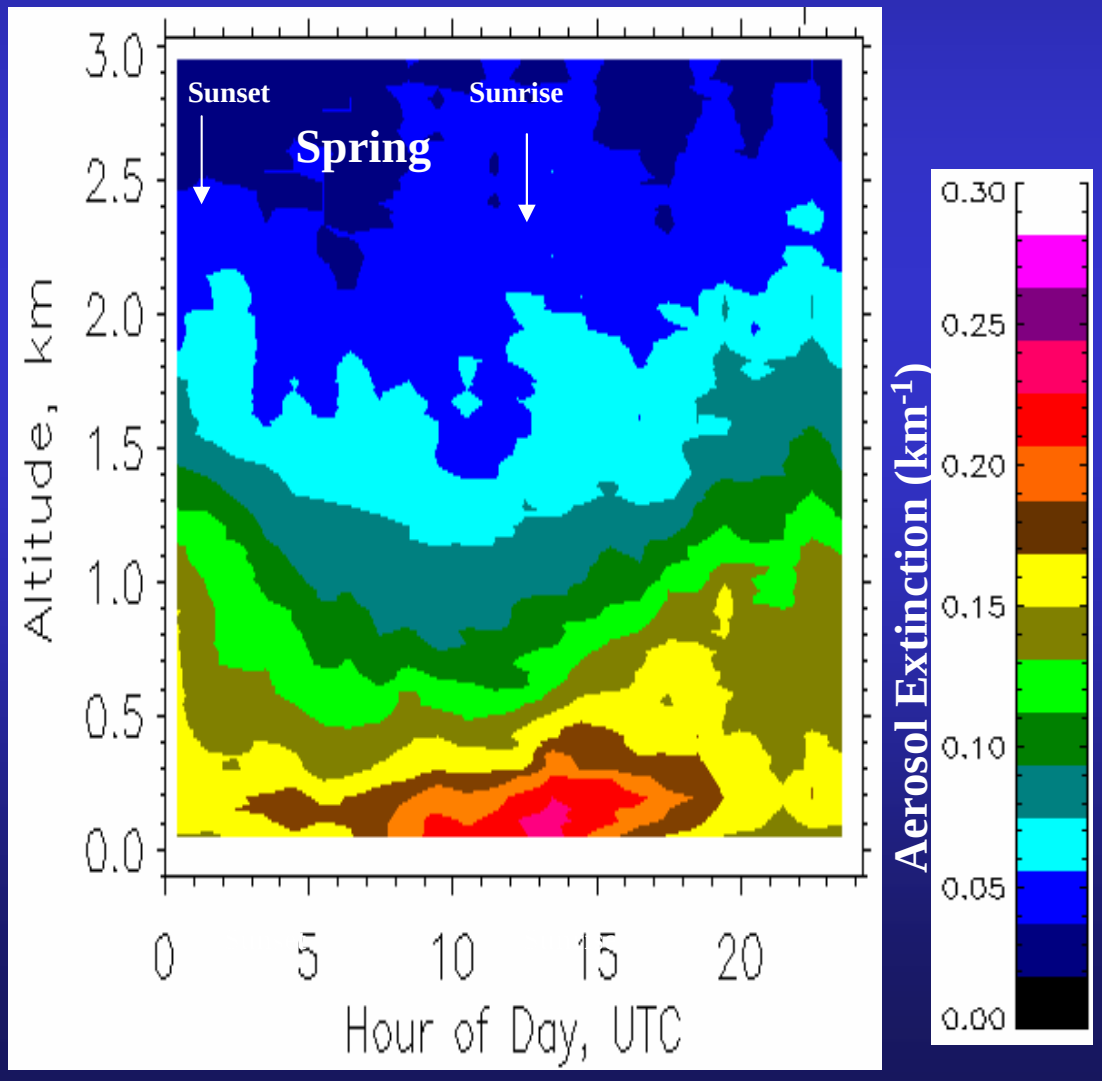


Single Scattering Albedo (550 nm)

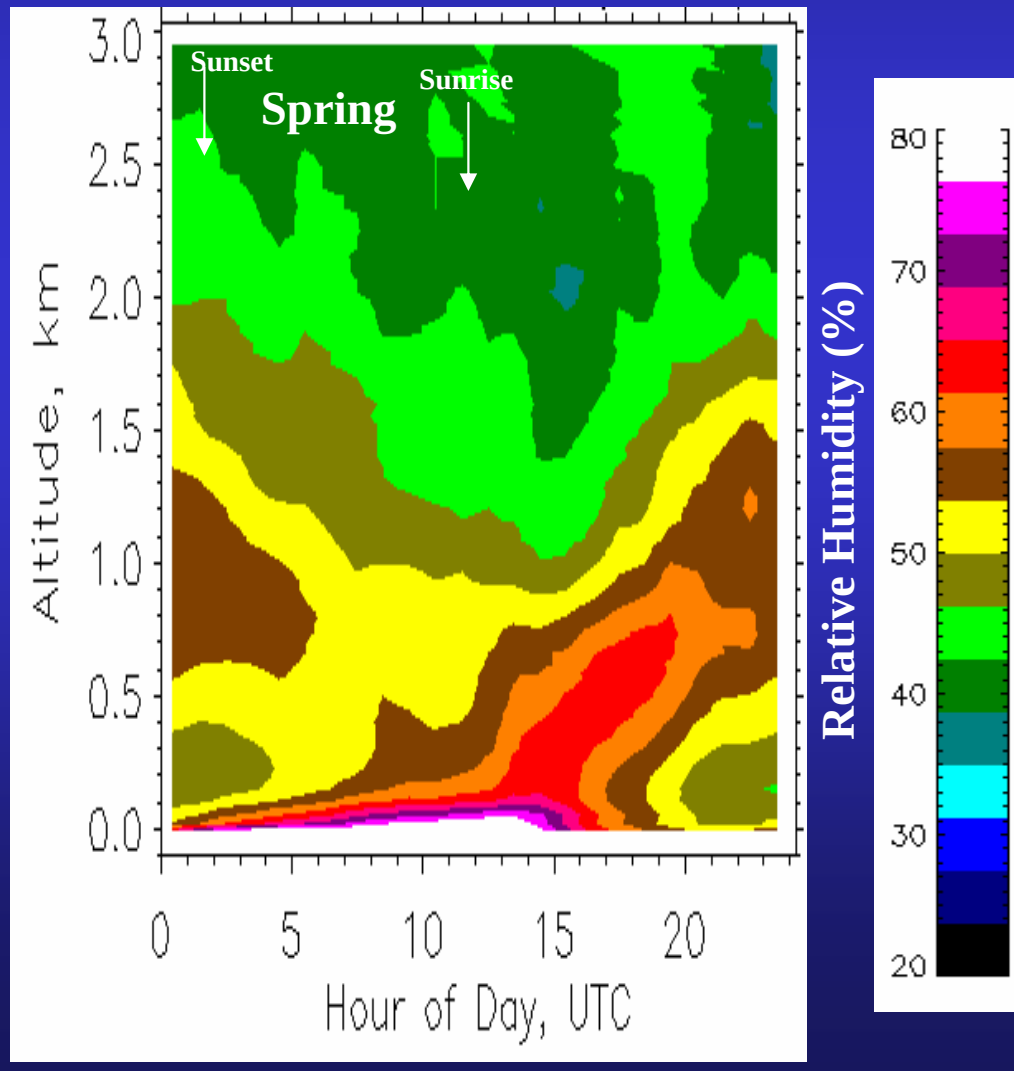
Correlation between Aerosol Extinction and Relative Humidity

- CARL aerosol extinction profiles averaged over 946 days (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

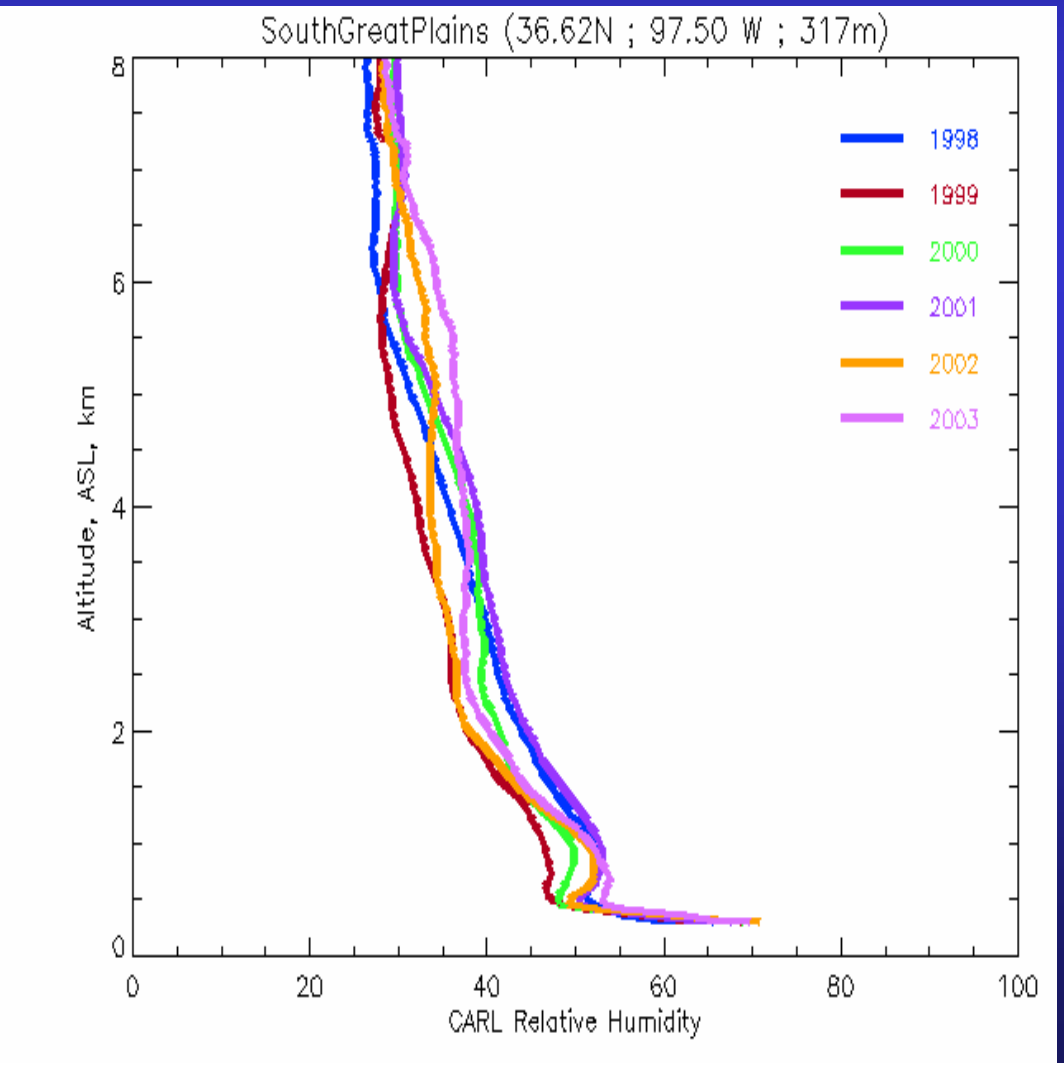


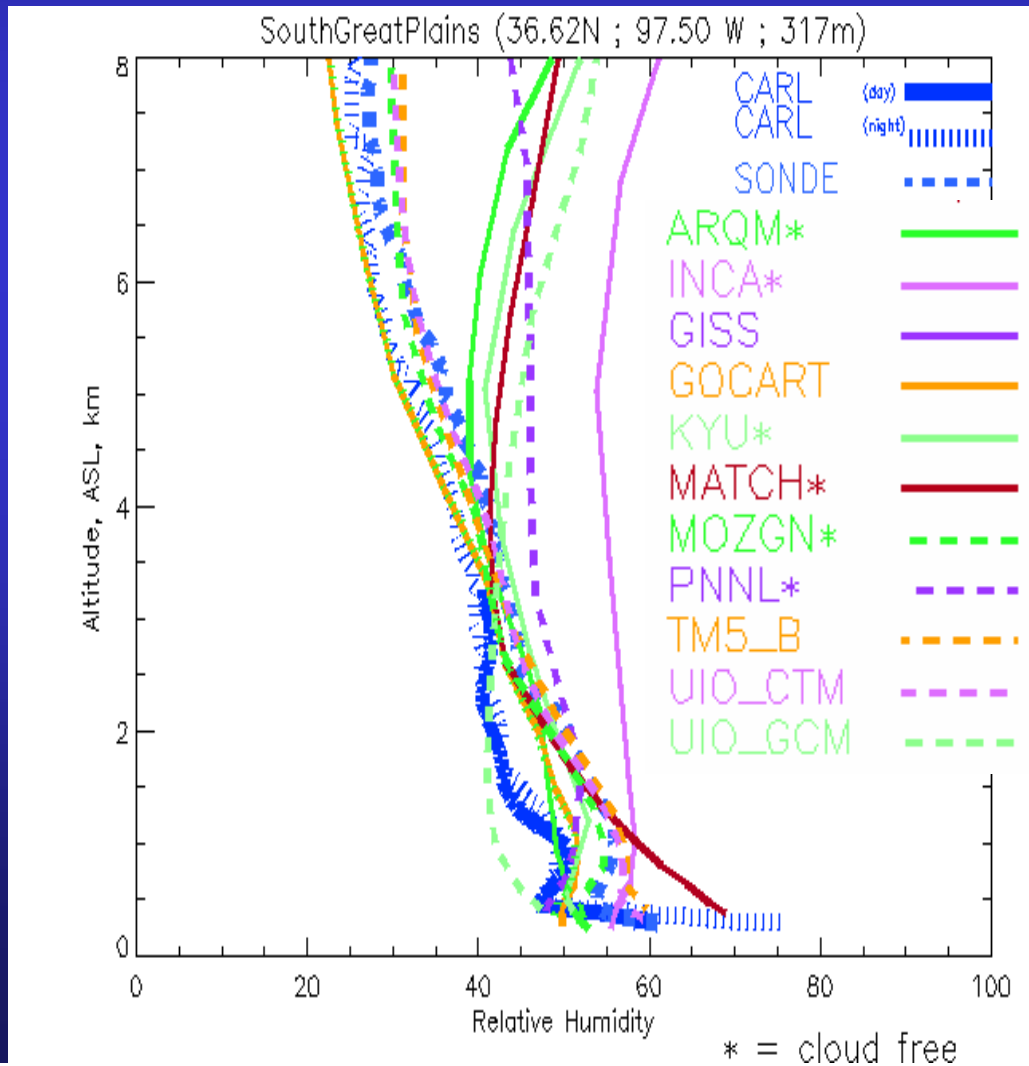
Relative Humidity



Relative Humidity Profile Comparisons

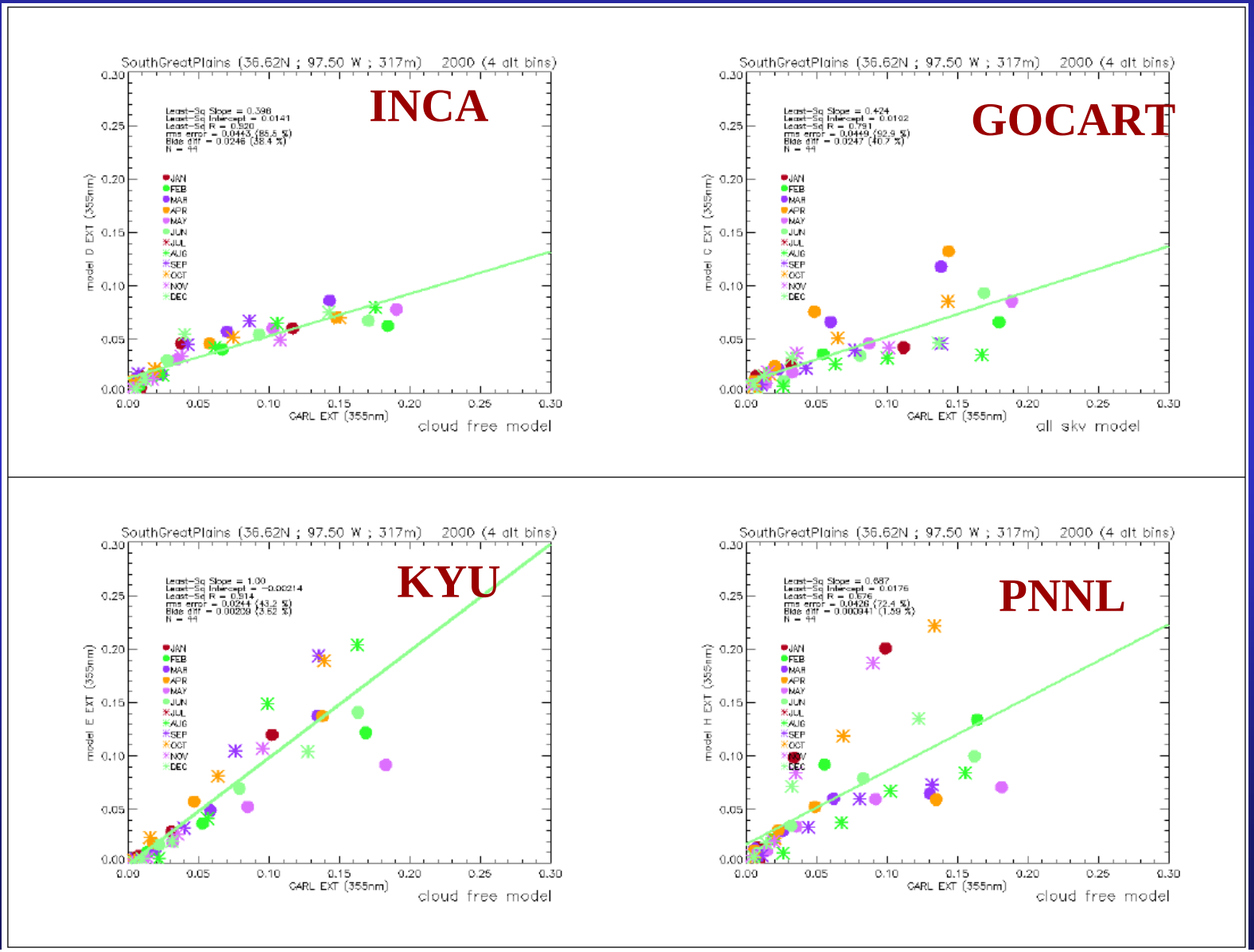
- CARL integrated water vapor measurements calibrated to match microwave radiometer total column water
- CARL water vapor measurements acquired during clear skies and so annual average slightly drier than radiosonde average





Aerosol Extinction Regression Results

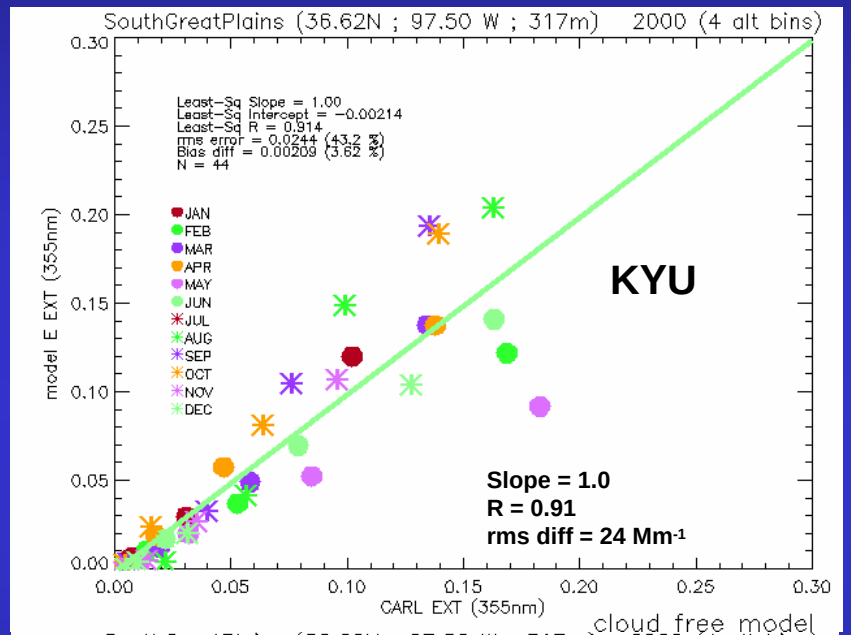
- Regressions computed using monthly averages from 0-8 km
- Slopes 0.4-1.0, indicative of differences in the lowest few km
- Correlation coefficients 0.7-0.9; Bias differences 0-30 Mm^{-1}

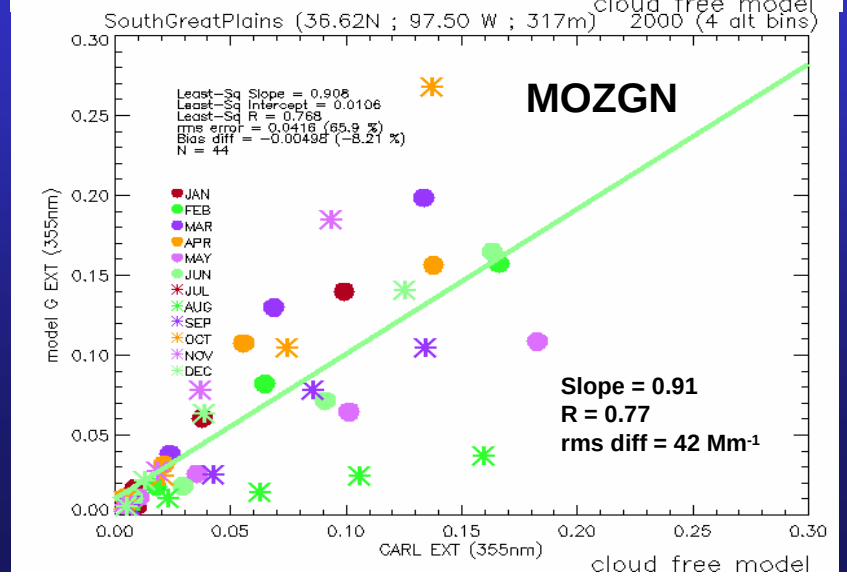


Aerosol Extinction Regression Results

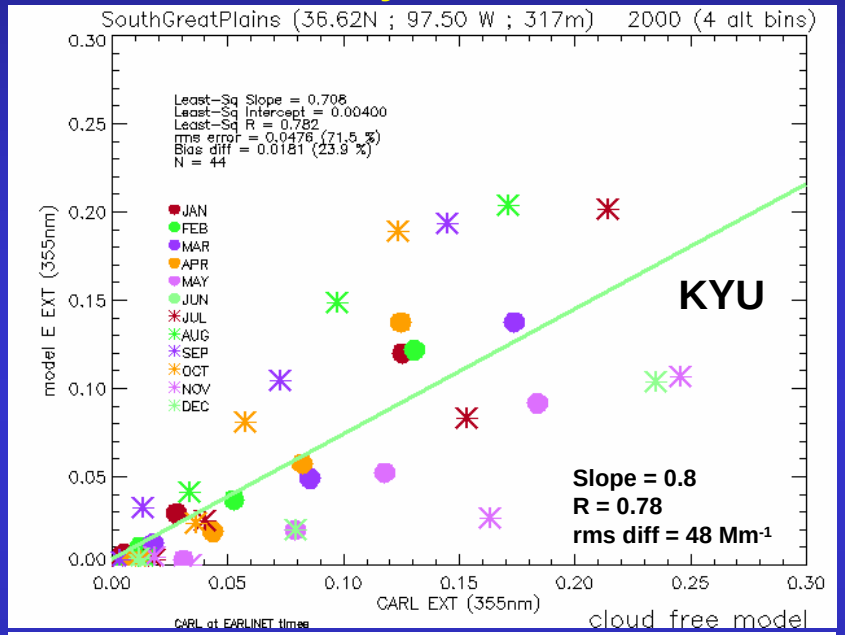
- Regressions computed using monthly averages from 0-8 km
- Using data at all times and not just at EARLINET times, reduces bias errors, increases correlation, and increases slopes

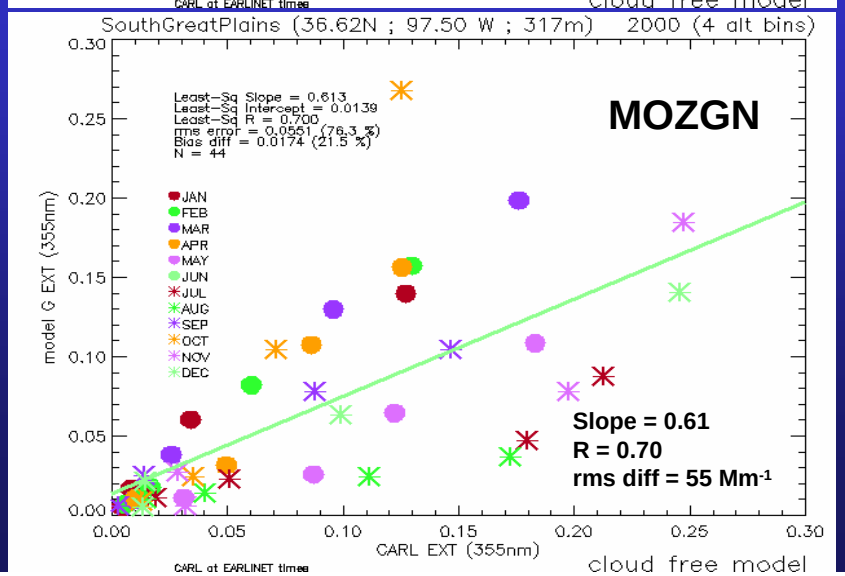
CARL data at all times





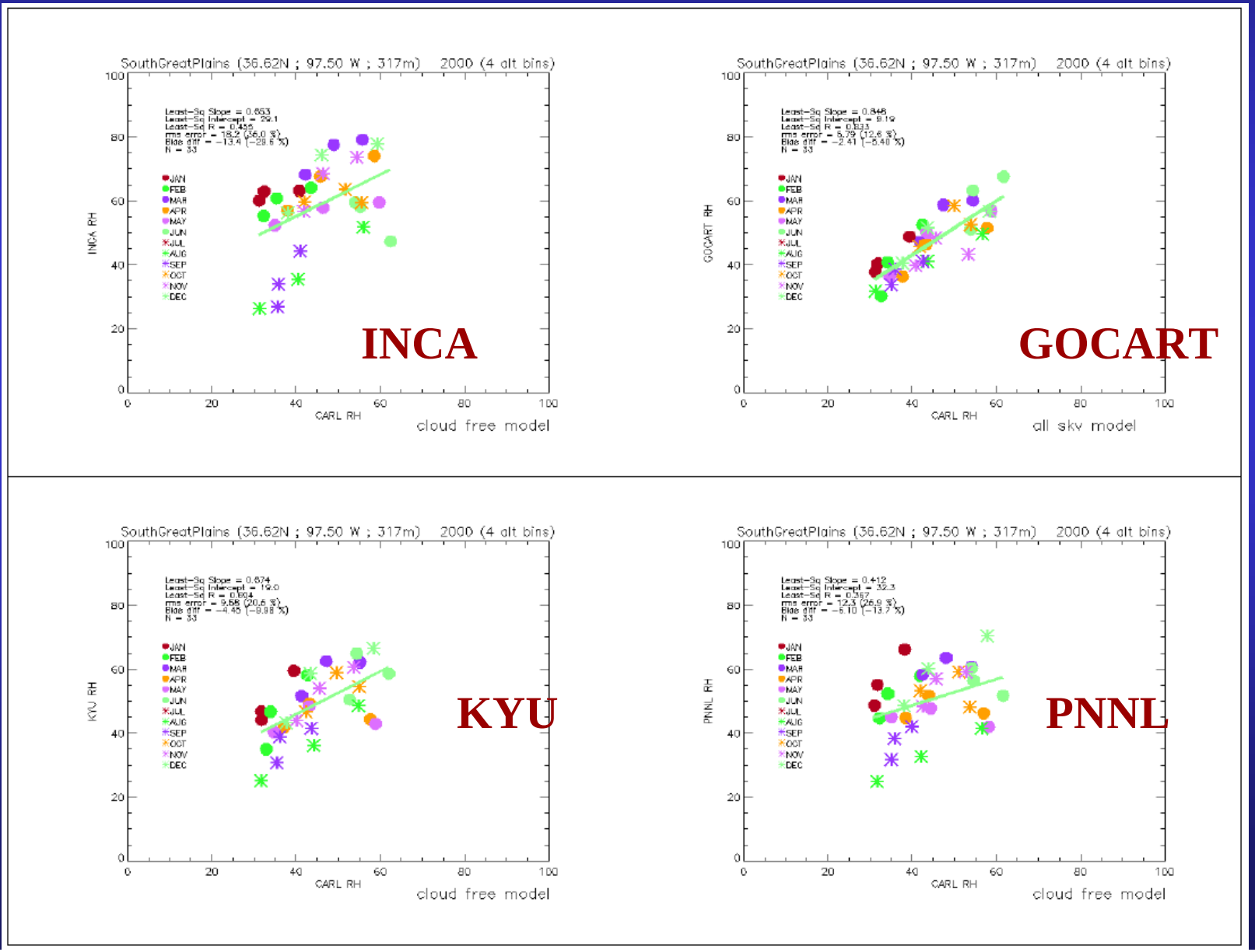
CARL data only at EARLINET times





Relative Humidity Regression Results

- Regressions computed using monthly averages from 0-3 km
- Slopes 0.6-1.0; Correlation coefficients 0.4-0.8; Bias differences 4-8 %



Future

- Would like to continue with additional models - CAM3, GEOS 3, …
- Look at higher temporal resolution – diurnal cycle
- Global – CALIPSO !!