Air Quality II

PARTICLES OF DIFFERENCE

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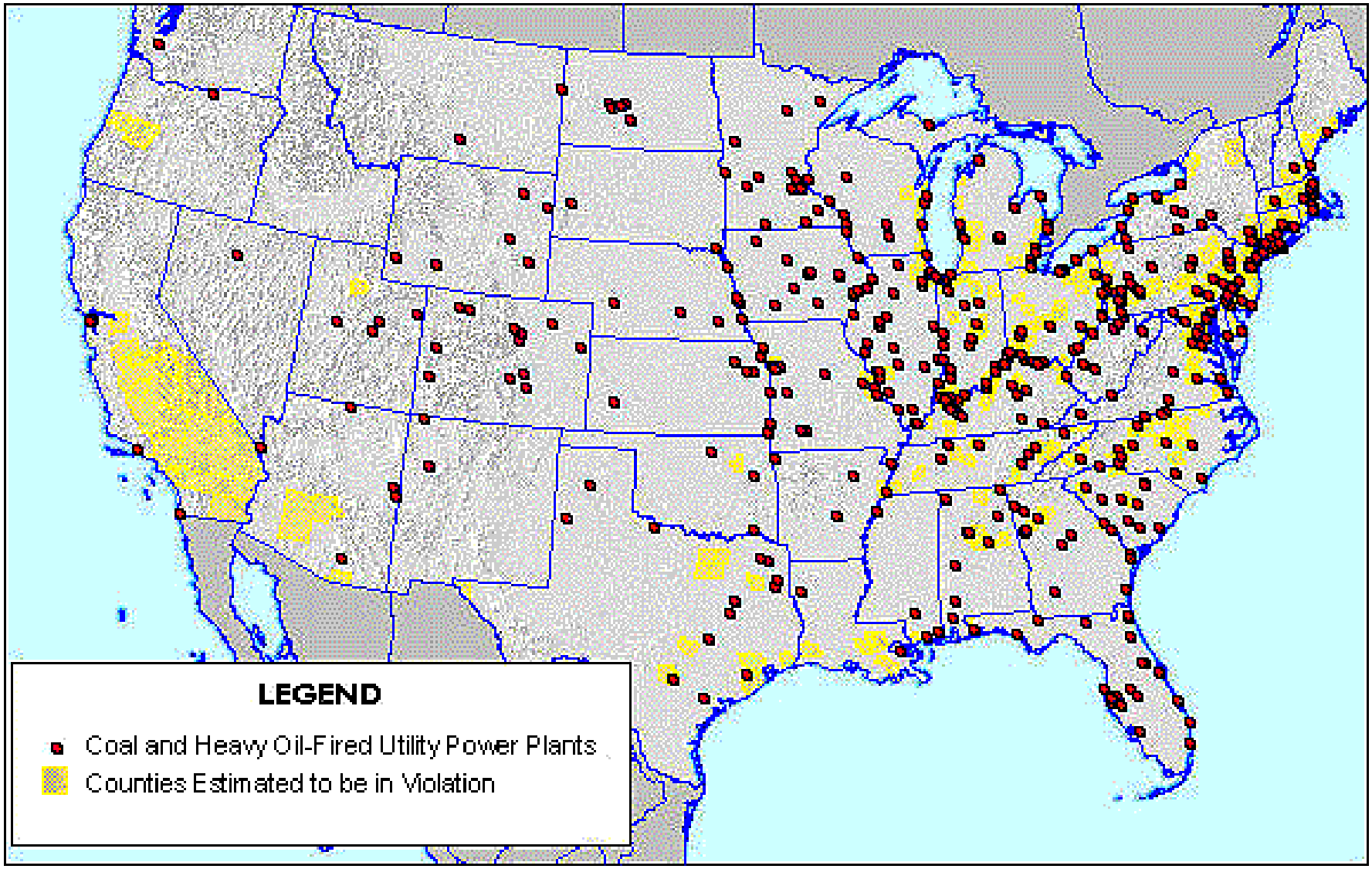
The PM-2.5 Problem

Reduce aerosol mass concentration to achieve a specified target value over some averaging time.

Additionally...

Aerosols play important roles in visibility impairment, wet and dry deposition, and climate modification.

Locations of Coal-Fired and Heavy Oil-Fired Plants Relative to Potential Non-Attainment Counties



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Solving the PM-2.5 Problem...

Roll back emissions of aerosols or precursor gases.

What substances or mix of substances?

Where? How far away?

Multiple strategies will work at a given location.

Devise effective and efficient strategies based on...

Cost

Energy efficiency

Equity

...requires scientific understanding

Aerosols are heterogeneous in many dimensions...

(Not just mass loading)

Location

2 and 3 Dimensions

Time, at a given location

Seasonal, daily, sub-daily

Composition

Bulk, as a function of particle size, particle to particle, within individual particles

Size distribution

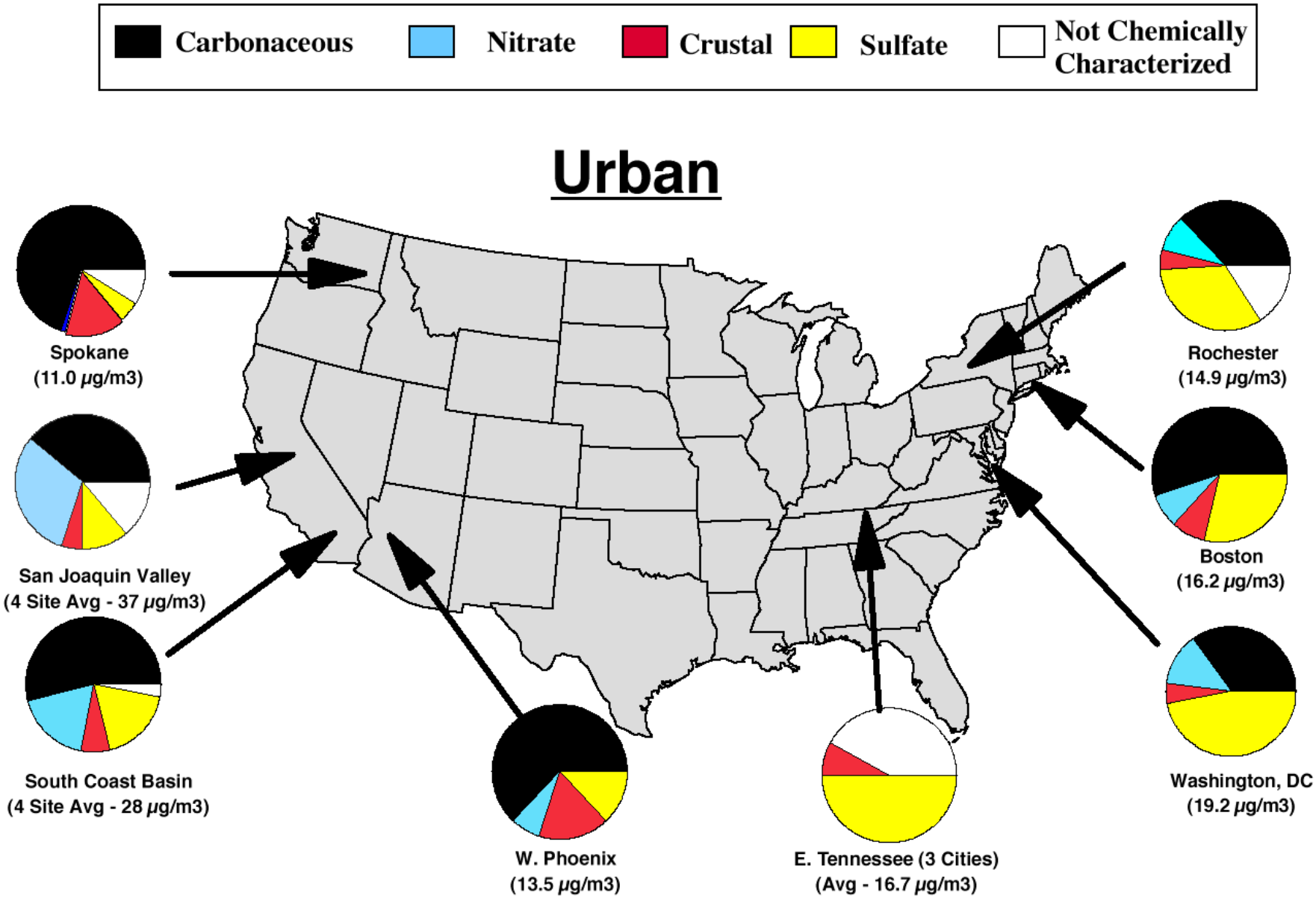
Mass or number as a function of size

Shape

Spherical drops, crystalline, chain aggregates ...

This heterogeneity is key to understanding

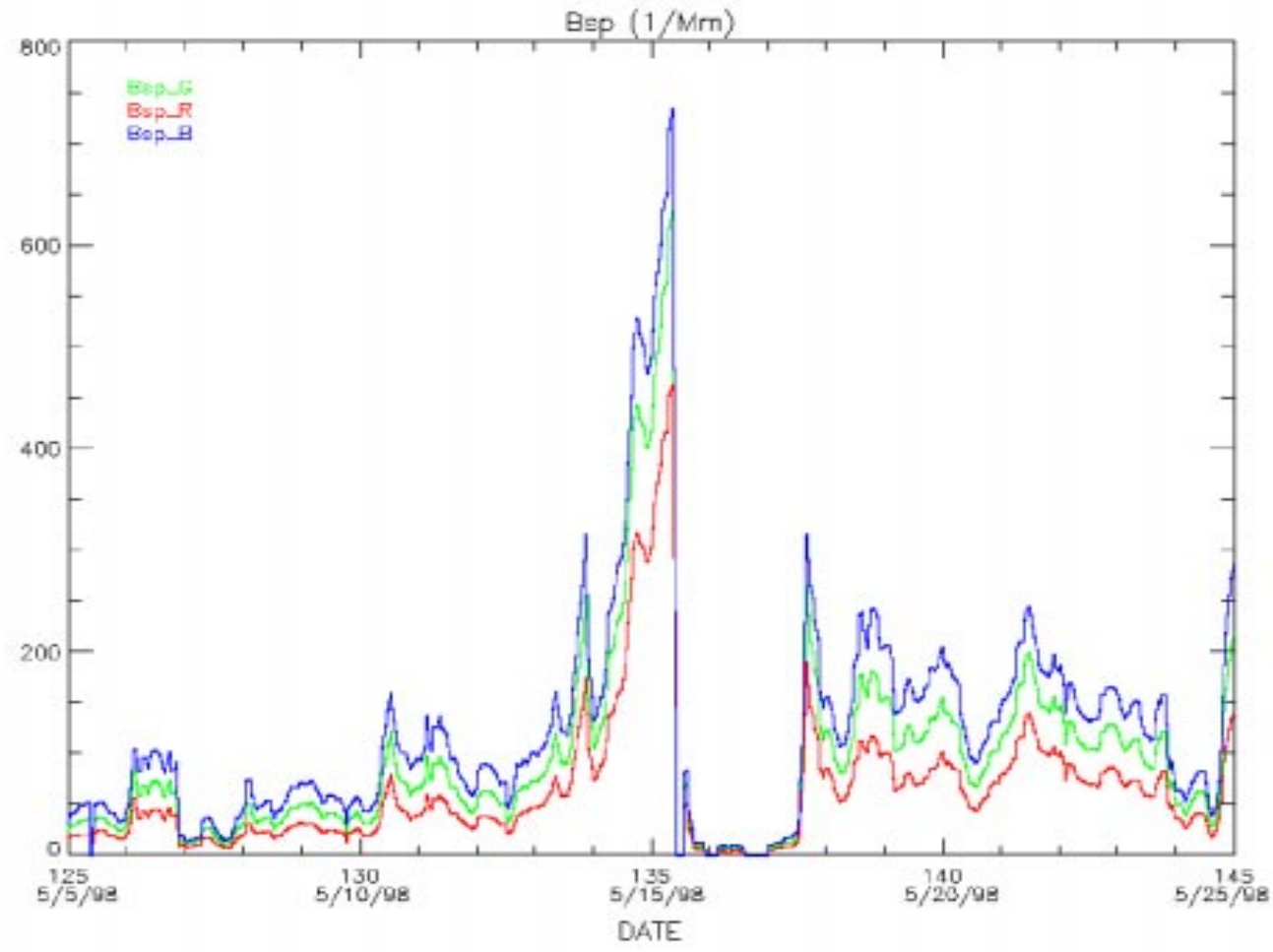
DEPENDENCE OF AEROSOL COMPOSITION ON LOCATION



EPA, *National Air Quality and Emissions Trends Report, 1997*, 1998

INFLUENCE OF LONG-RANGE TRANSPORT ON AEROSOL LOADING

Aerosol Light Scattering Coefficient in North Central Oklahoma

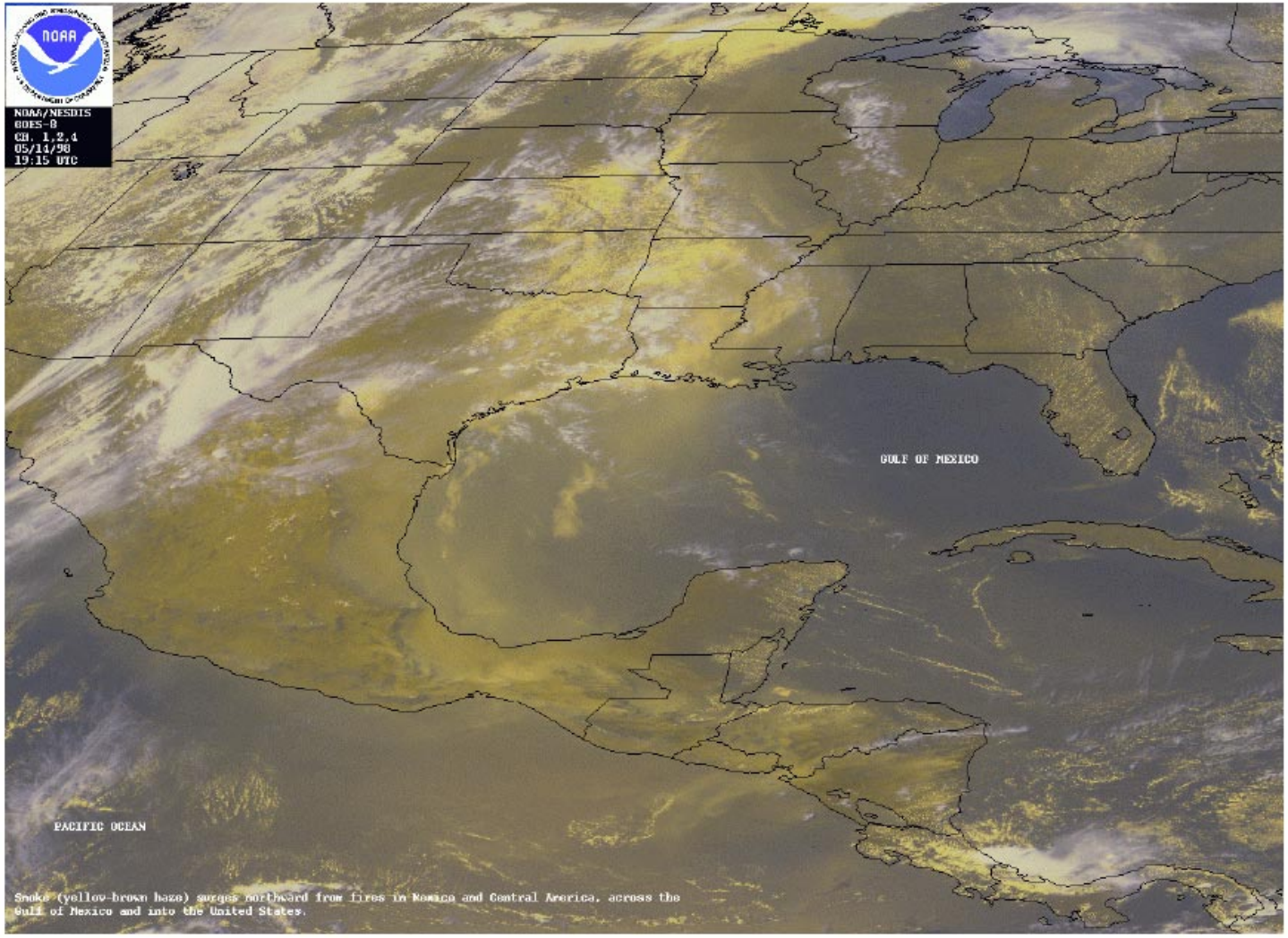


For mass scattering efficiency 10 m^2 g^{-1}, light scattering coefficient 600 Mm^{-1} corresponds to mass concentration of 60 µg m^{-3}.

DOE Atmospheric Radiation Measurement Program

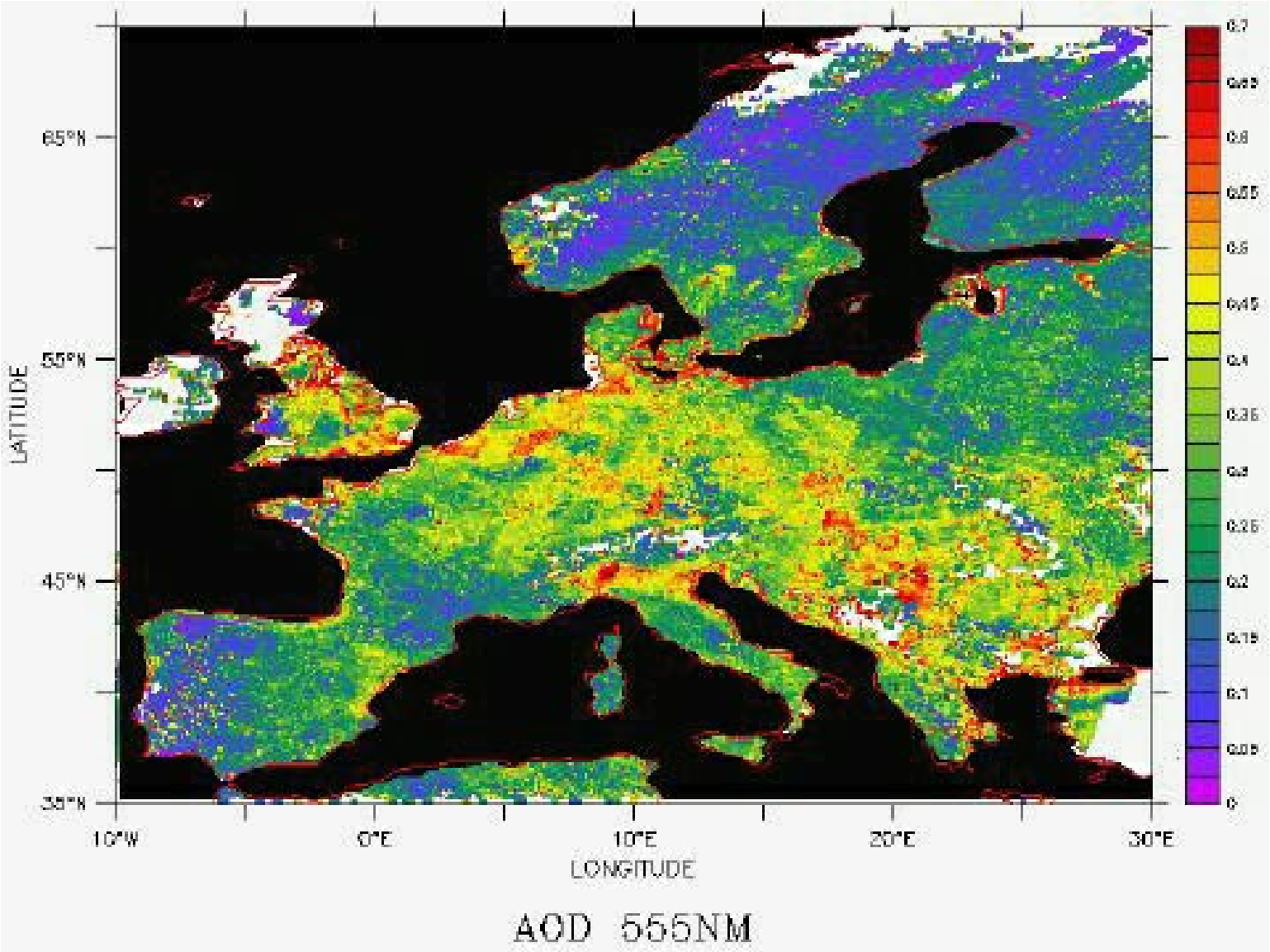
INFLUENCE OF LONG-RANGE TRANSPORT ON AEROSOL LOADING

Central American Forest Fire Plume over U.S. Great Plains
1998-05-14 19:15 UTC



Smoke (yellow-brown haze) is transported northward across Gulf of Mexico

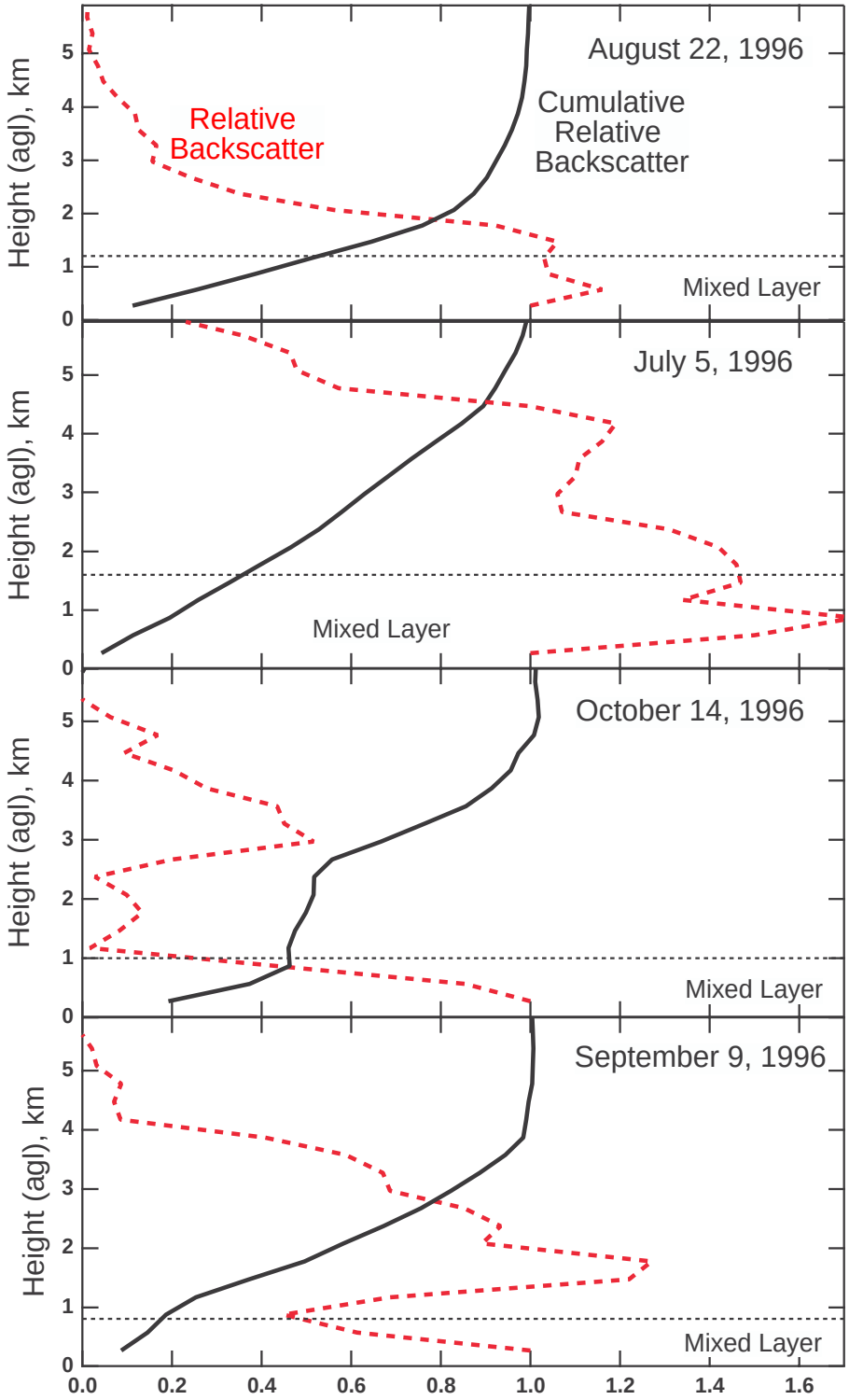
AEROSOL OPTICAL DEPTH OVER EUROPE
ATSR data for August 1997
Average of 10-15 retrievals at 0.1˚ resolution



Gonzalez, Veefkind & de Leeuw, Geophys. Res. Lett., 2000

AEROSOL VERTICAL DISTRIBUTION

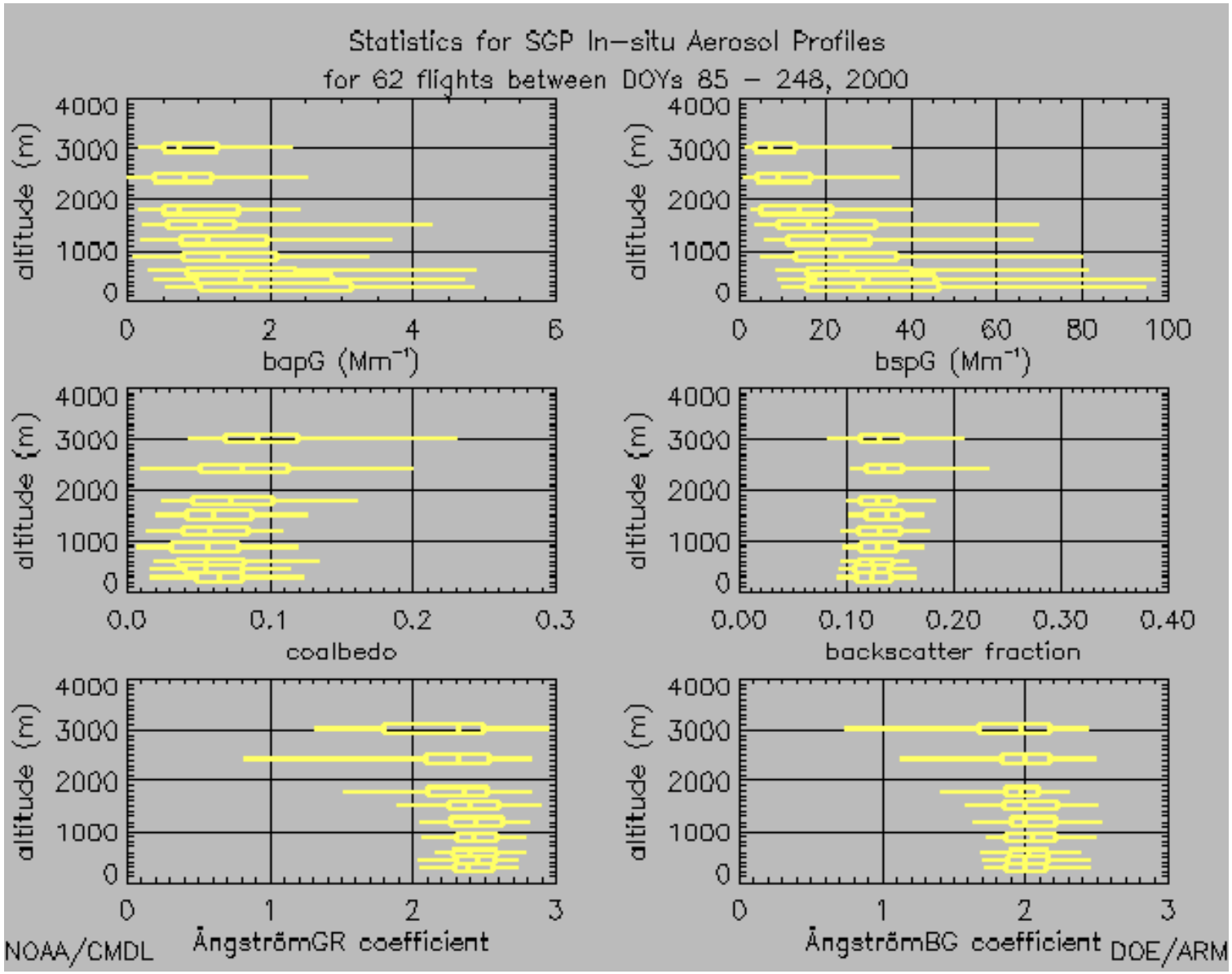
Aerosol Lidar Backscatter on Cloud-Free Days
North Central Oklahoma



Bergin, Schwartz, Halthore, Ogren & Hlavka (2000)

STATISTICS OF VERTICAL DISTRIBUTIONS OF AEROSOL PROPERTIES

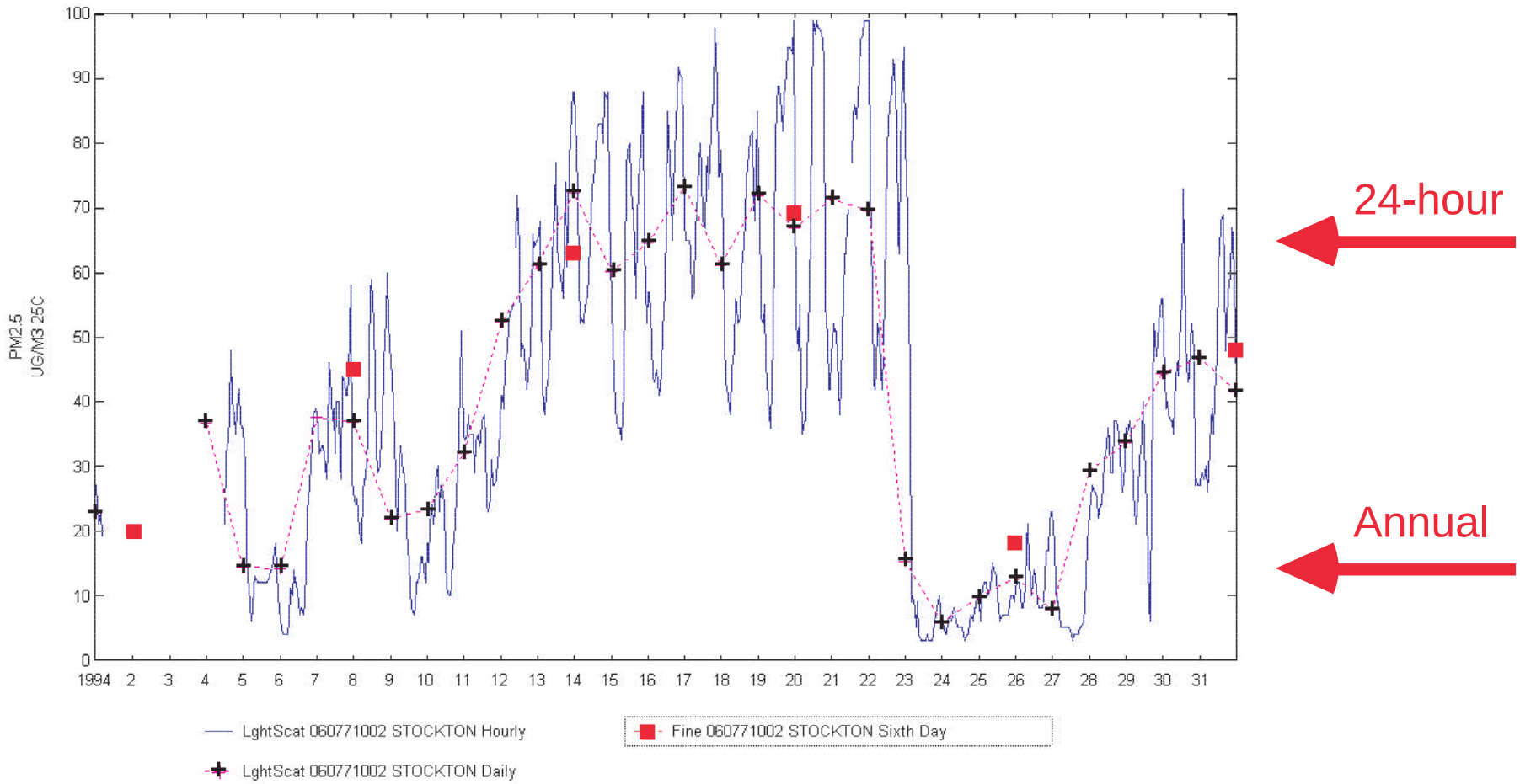
North Central Oklahoma



J. Ogren, NOAA CMDL

TIME SERIES OF LIGHT SCATTERING COEFFICIENT AND FINE PARTICLE MASS

STOCKTON CA

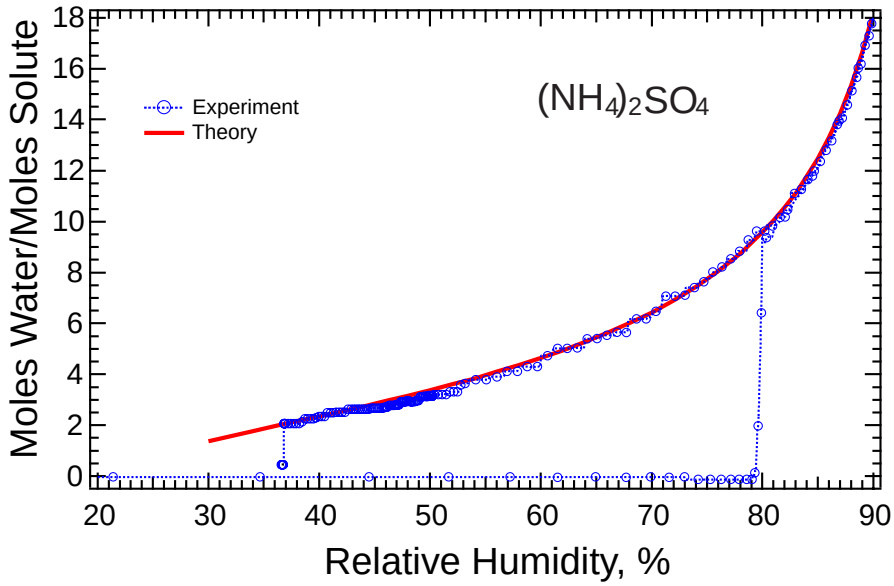


Husar, 1997

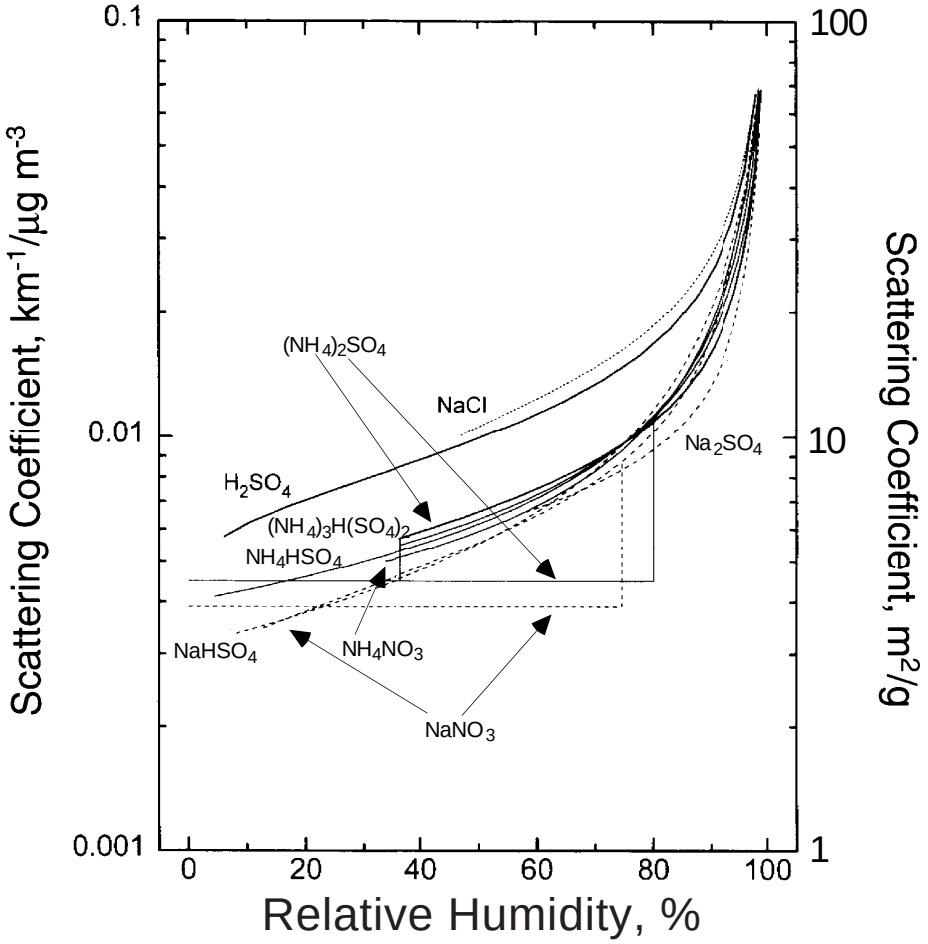
Time series of light scattering coefficient is scaled to fine particle mass by daily averages.

WATER UPTAKE AND LIGHT SCATTERING COEFFICIENT

Dependence on Relative Humidity



D. Imre, T. Onasch, BNL

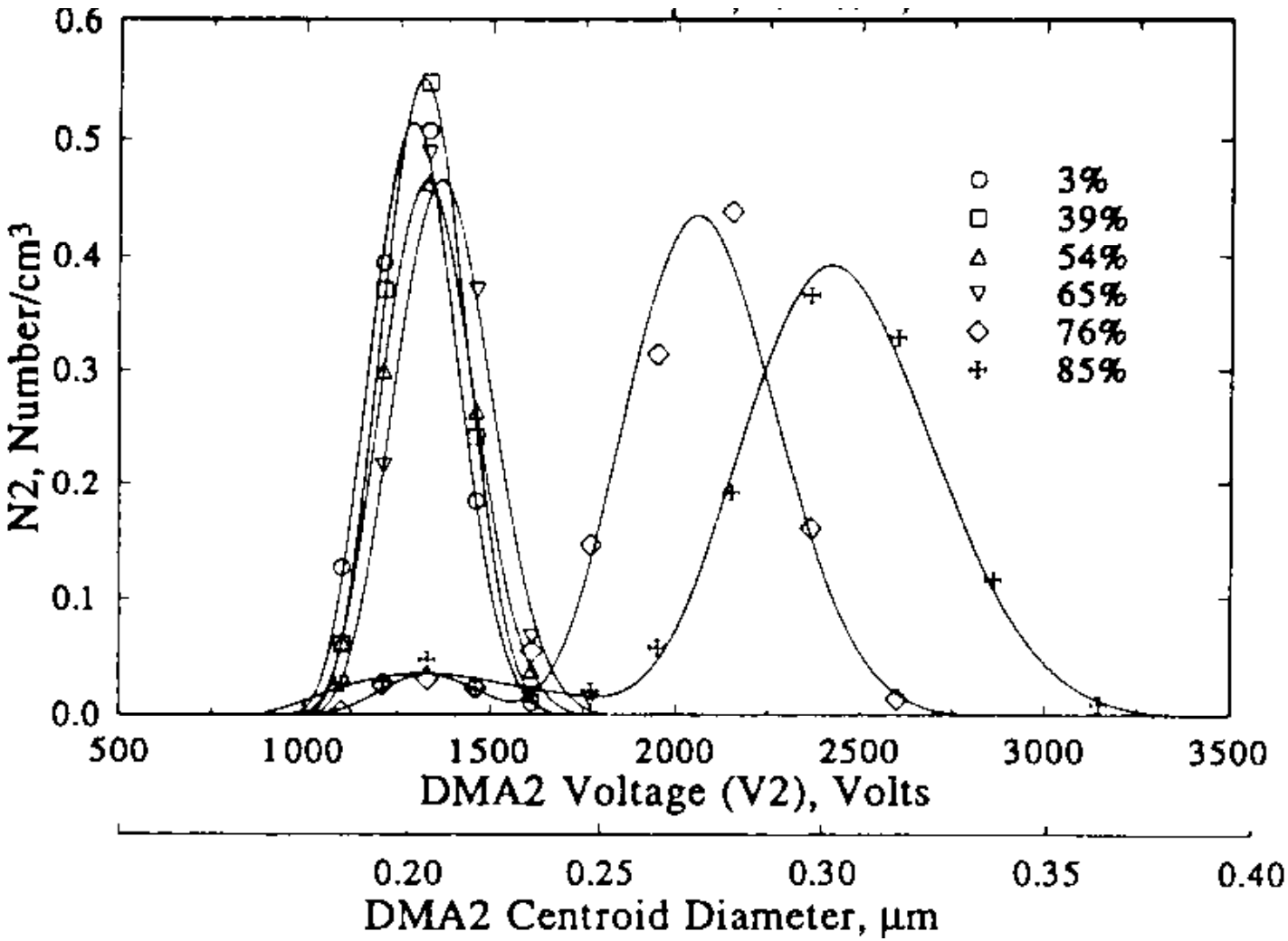


Lognormal, D_g = 0.3 µm; σ_g = 1.5; Tang, JGR, 1996

DIFFERENTIAL HUMIDITY RESPONSE WITHIN AEROSOL

First analyzer, low RH; Second analyzer variable RH

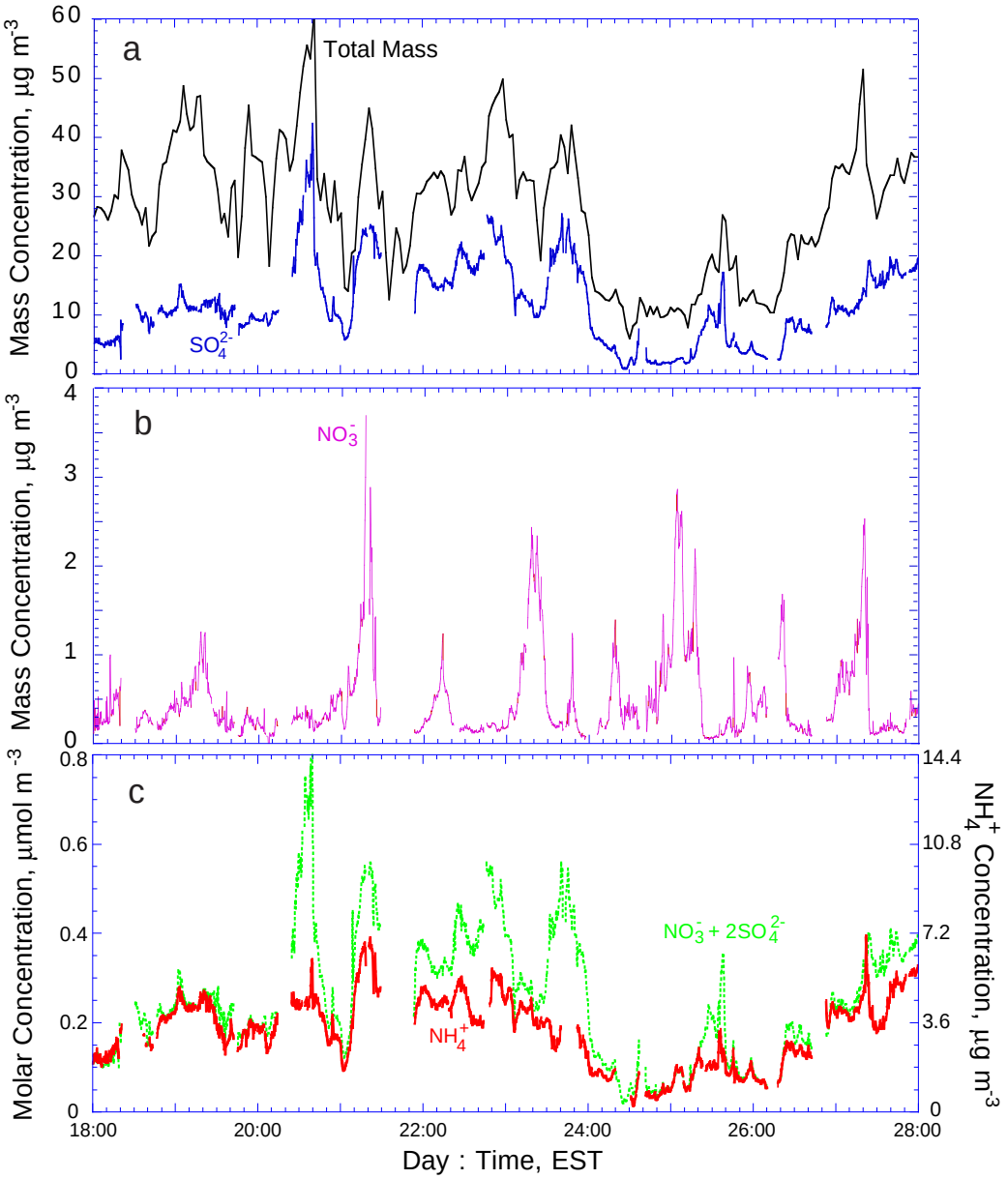
Hopi Point, Grand Canyon, Arizona, March 1, 1990, 14:15



Zhang, McMurry et al. (1993)

TIME-DEPENDENT PARTICLE COMPOSITION

Atlanta GA, Summer 1999



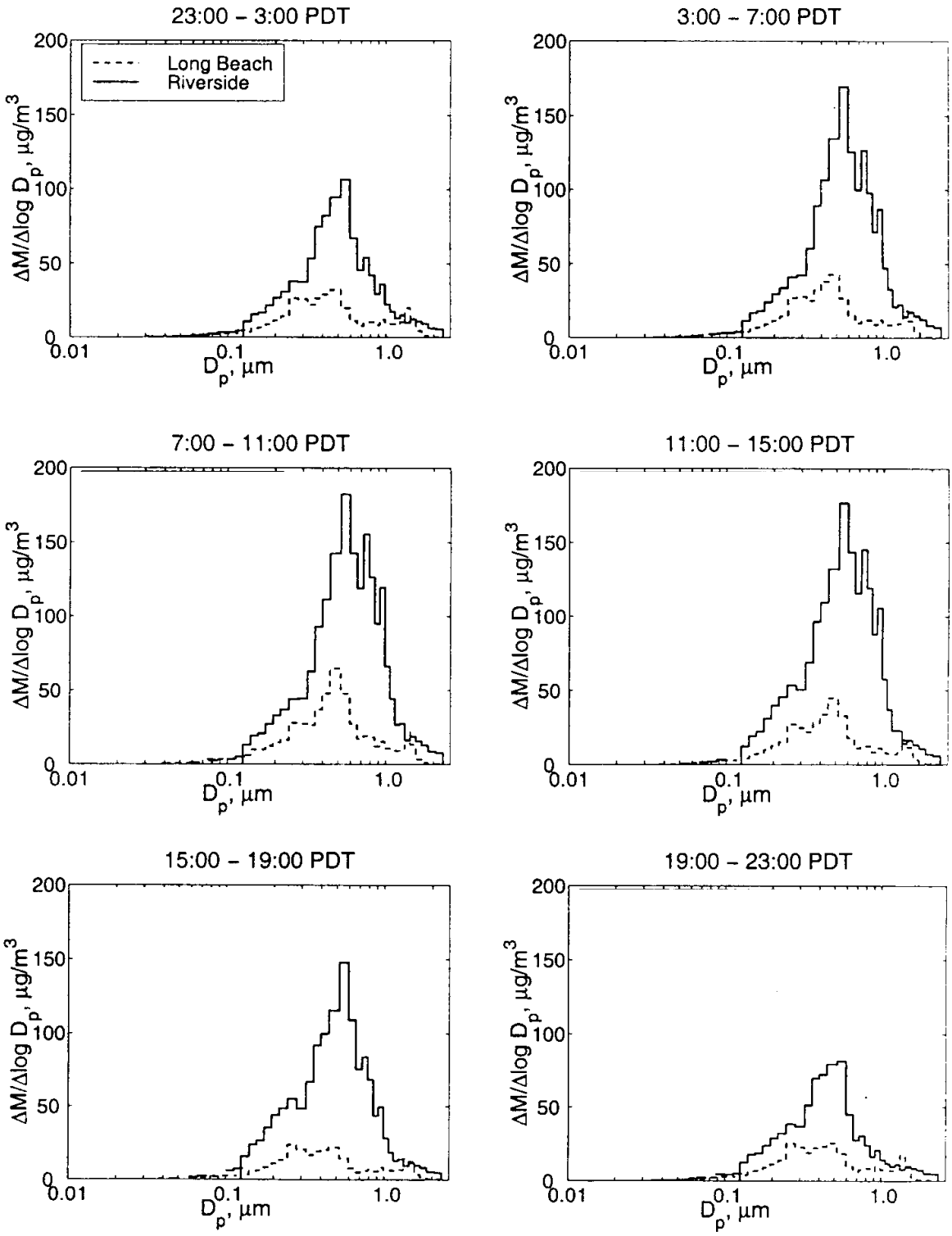
Y.-N. Lee, BNL; R. Weber, GaTech

- Rapid (sub-daily) variation of aerosol components.
- Lack of correlation of several aerosol components.
- Varying extent of neutralization of acid by ammonia.
- Correlation of sulfate concentration with total aerosol mass.

Such information is not available with conventional filter sampling.

REGIONAL AND DIURNAL DIFFERENCES IN AEROSOL LOADING AND SIZE

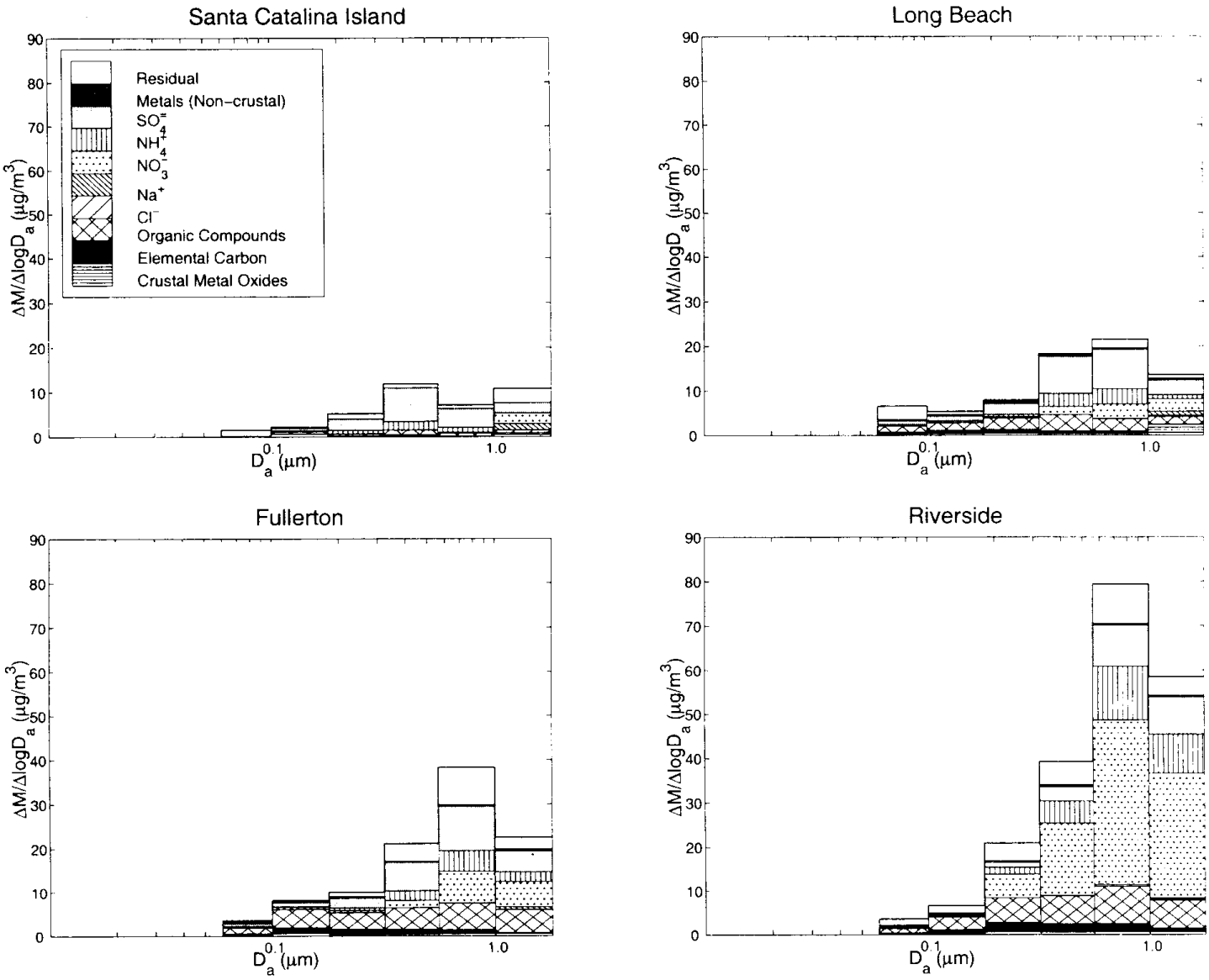
Composite of 4-hr samples over 9 days, September-October, 1996



Hughes, Cass, Prather et al. (1999)

REGIONAL DIFFERENCES IN AEROSOL LOADING, COMPOSITION, AND SIZE

Composite of 4-hr samples on several days, September-October, 1996

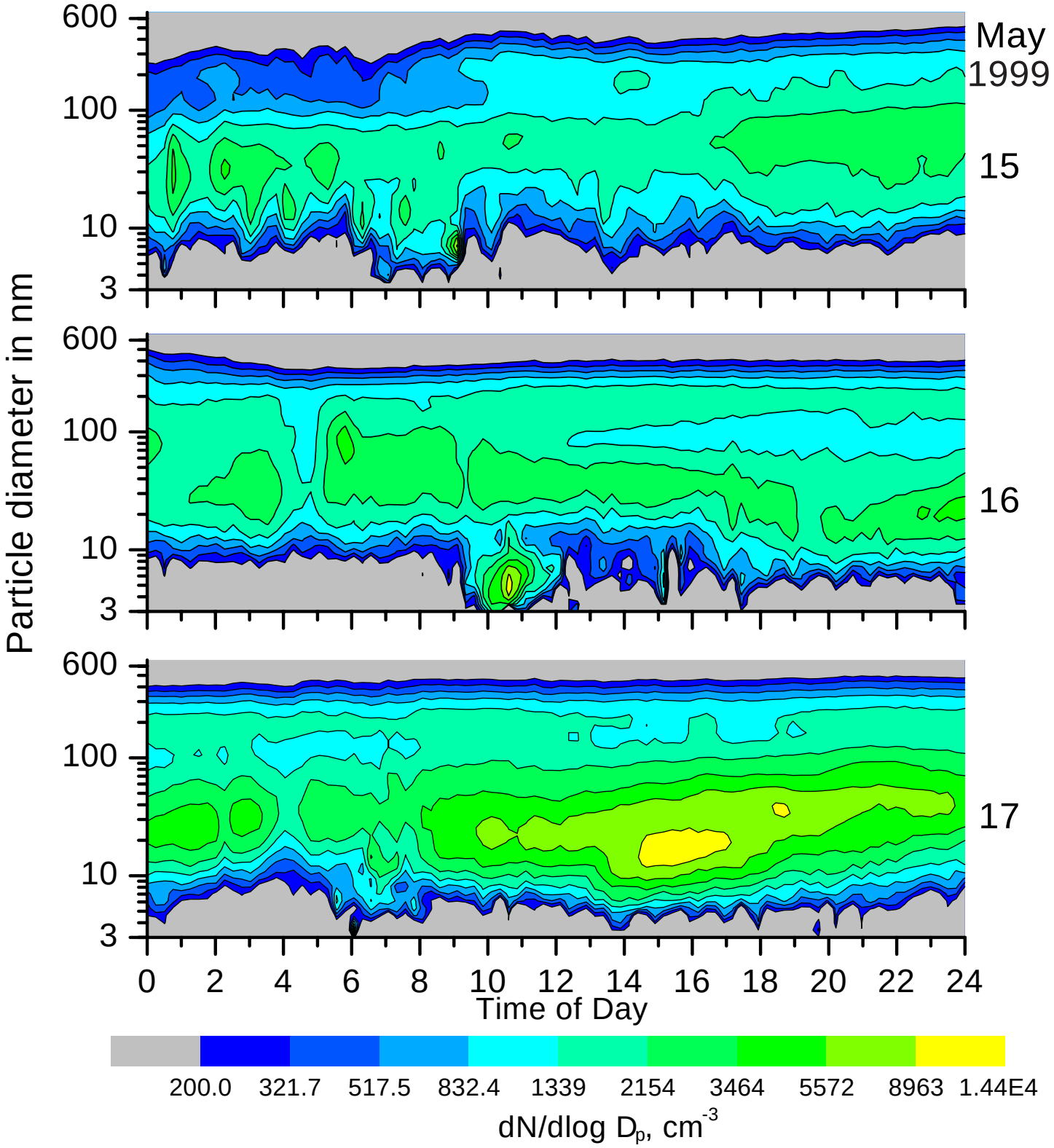


Hughes, Cass, Prather et al. (1999)

TIME DEPENDENT PARTICLE SIZE DISTRIBUTION

Differential Mobility Analyzer, Low Relative Humidity

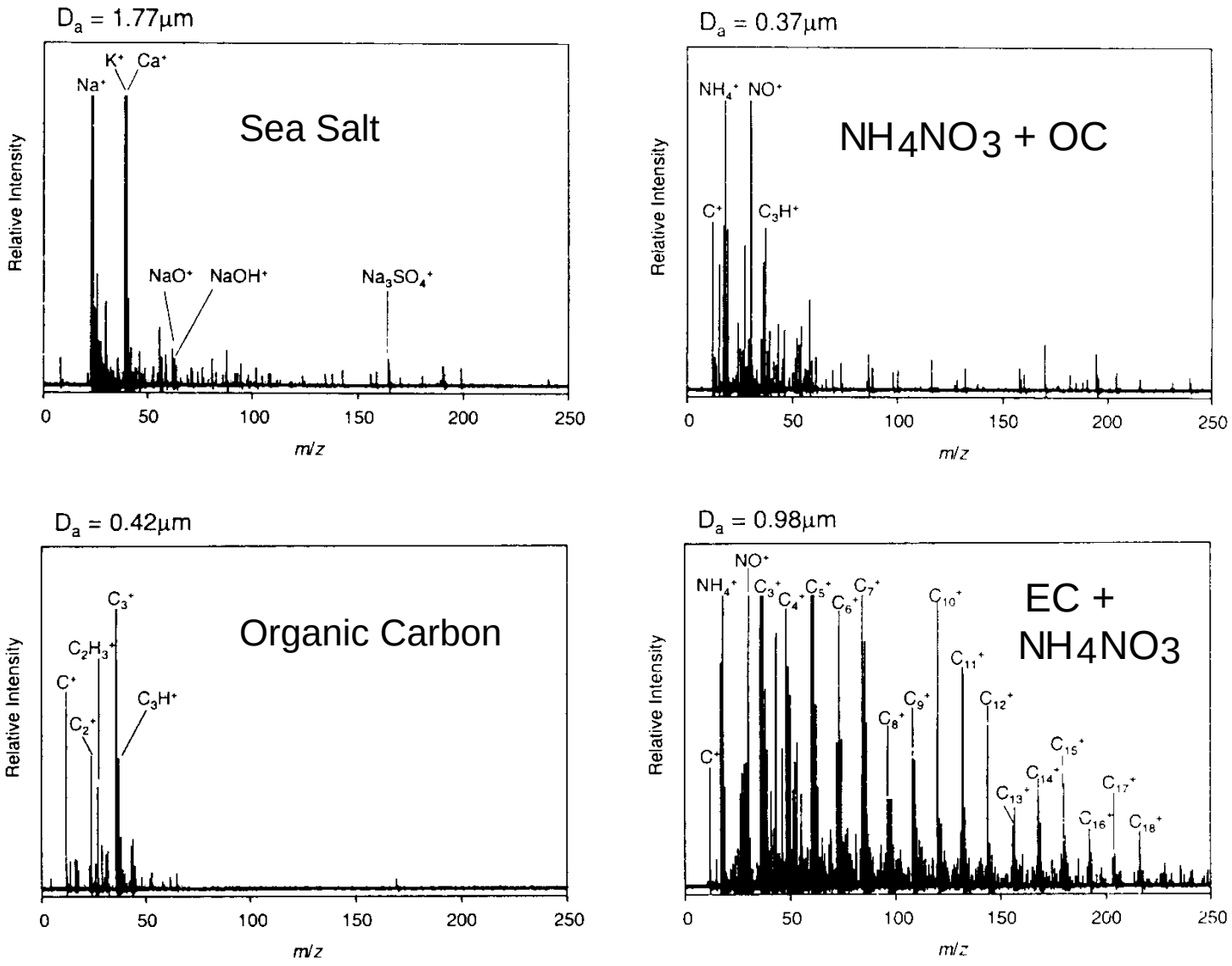
Rural Germany, May, 1999. Time Resolution 10 min



W. Birmili (IFT, Leipzig)

PARTICLE-TO-PARTICLE COMPOSITION DIFFERENCES

Time-of flight mass spectra of individual particles, South Coast, CA, September-October, 1996

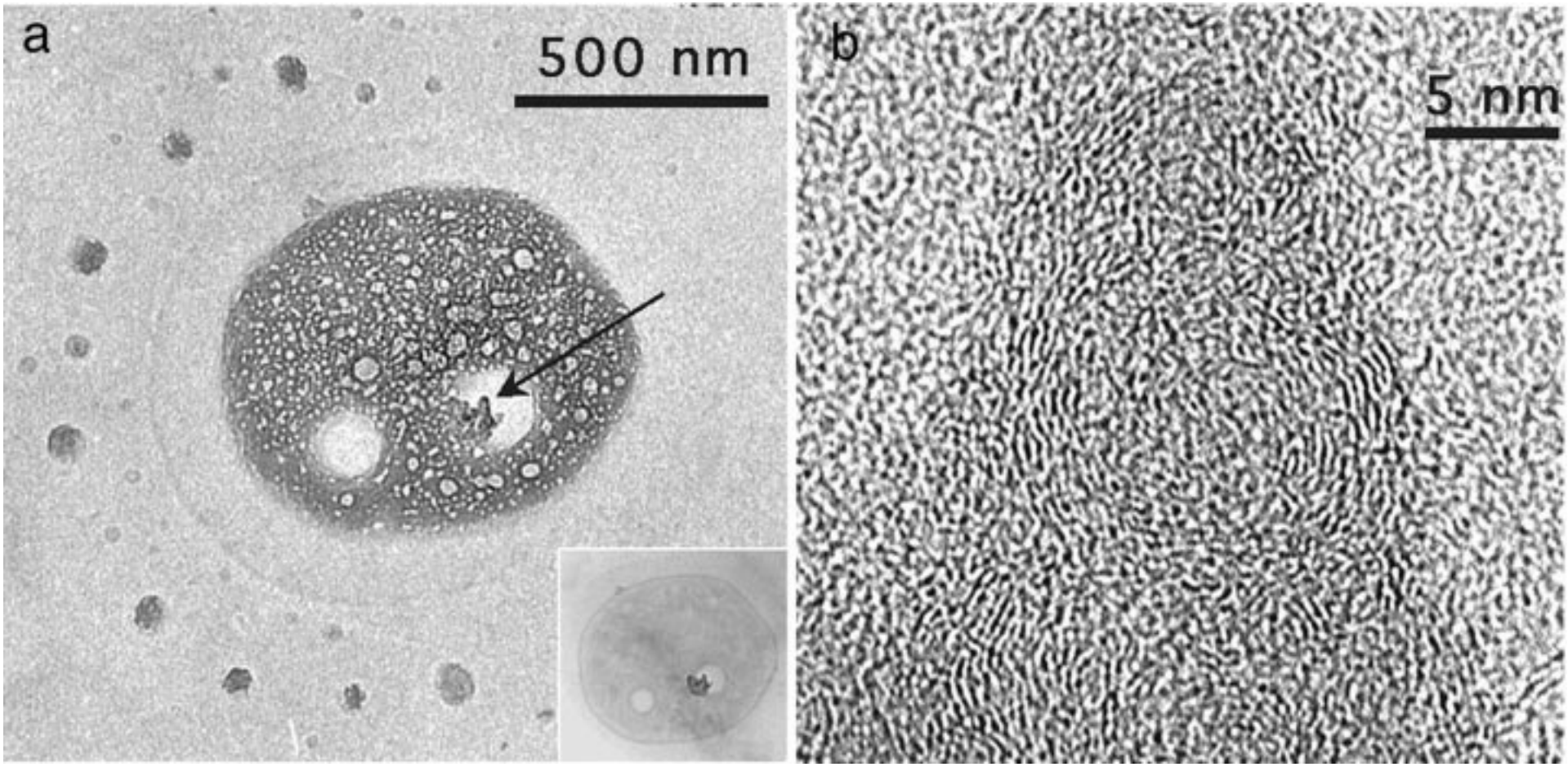


Hughes, Cass, Prather et al. (1999)

TRANSMISSION ELECTRON MICROGRAPH OF INDIVIDUAL PARTICLE

Soot inclusion in single particle consisting mainly of $(NH_4)_2SO_4$

Unpolluted air near Tasmania.



Buseck and Pósfai (1999)

MODELING EVOLUTION OF AEROSOL LOADING AND PROPERTIES
Moment-based representation of aerosol microphysics

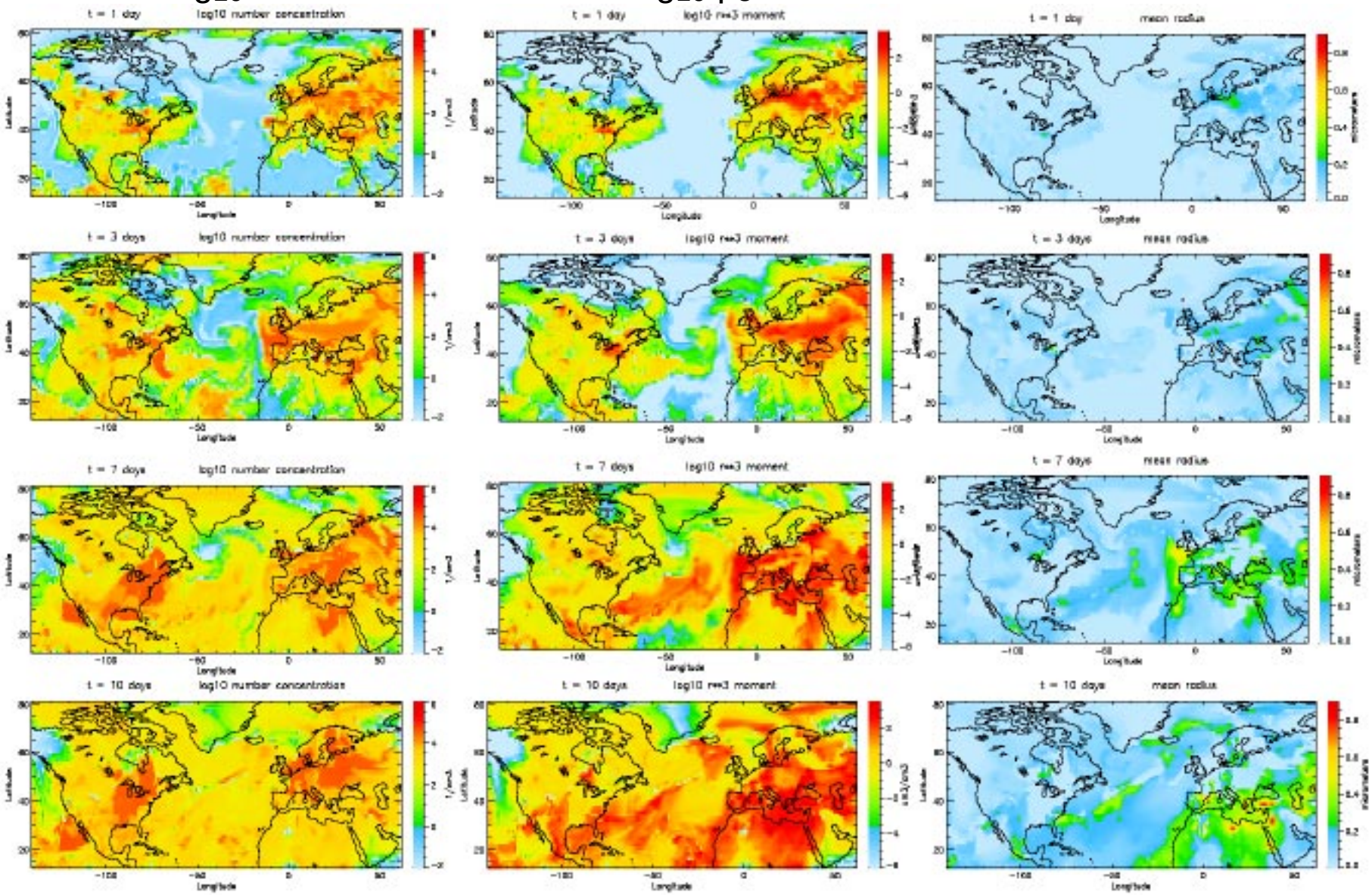
Day | Log_{10} N | Log_{10} μ_3 | Mean Radius

1

3

7

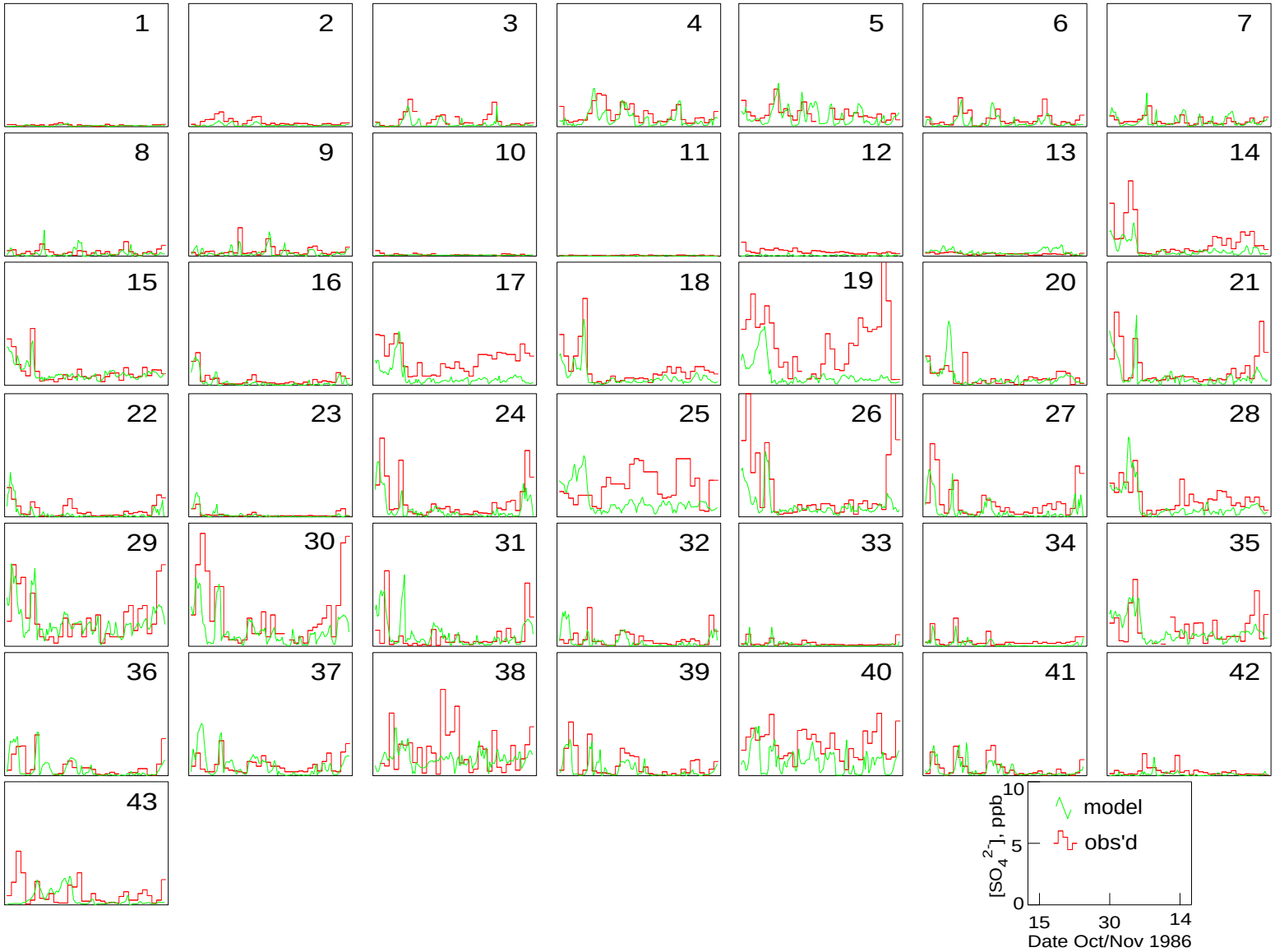
10



Wright, McGraw, Benkovitz & Schwartz (2000)

MODEL EVALUATION

Comparison of measured and modeled sulfate concentrations
Model is driven by observation-derived meteorological data



Benkovitz, Schwartz et al. (1994)

Observational requirements

Provide the understanding *necessary to represent aerosol loading and composition in chemical transport models.*

Provide an ***observational basis for present aerosol loading and composition and their spatial and temporal distribution****.*

Provide an observational data base to permit ***evaluation of models****:*

- *Mass concentration*
- *Composition (as a function of size; homogeneity vs. heterogeneity)*
- *Physical properties (size distribution and its RH-dependence, non-sphericity...)*
- *Optical properties including wavelength dependence*
- *Vertical and geographical distribution of all the above*

Not at all places and times, but at sufficient, and sufficiently diverse, locations and times as to provide required confidence in models.

Research approaches

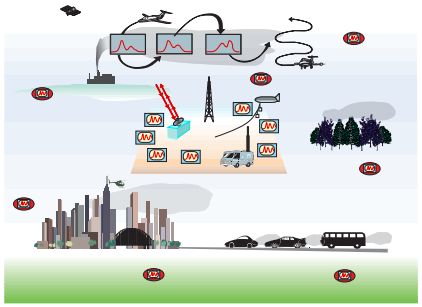
Approach	*LongTerm vs. Campaign*	*Global vs. Local*	*Aggregate vs. Detailed*
Satellite remote sensing	LT	G	A
Ground-based remote sensing	LT	L	A
Ground-based in-situ composition, physical, optical properties	LT, **C**	L	D
Aircraft remote sensing	**C**	L	A
Aircraft in-situ composition, physical, optical properties	**C**	L	D

Intensive campaigns are required to exploit aerosol heterogeneity to provide process-level understanding and to test model-based representations.

Looking to the Future...

DOE-SC-XXXX

Tropospheric Aerosol Program



Preliminary Program Plan

June 1999

U. S. Department of Energy
Office of Science
Office of Biological and Environmental Research
Environmental Sciences Division