Atmospheric Aerosol Source-Receptor Relationships: The Role of Coal-Fired Power Plants

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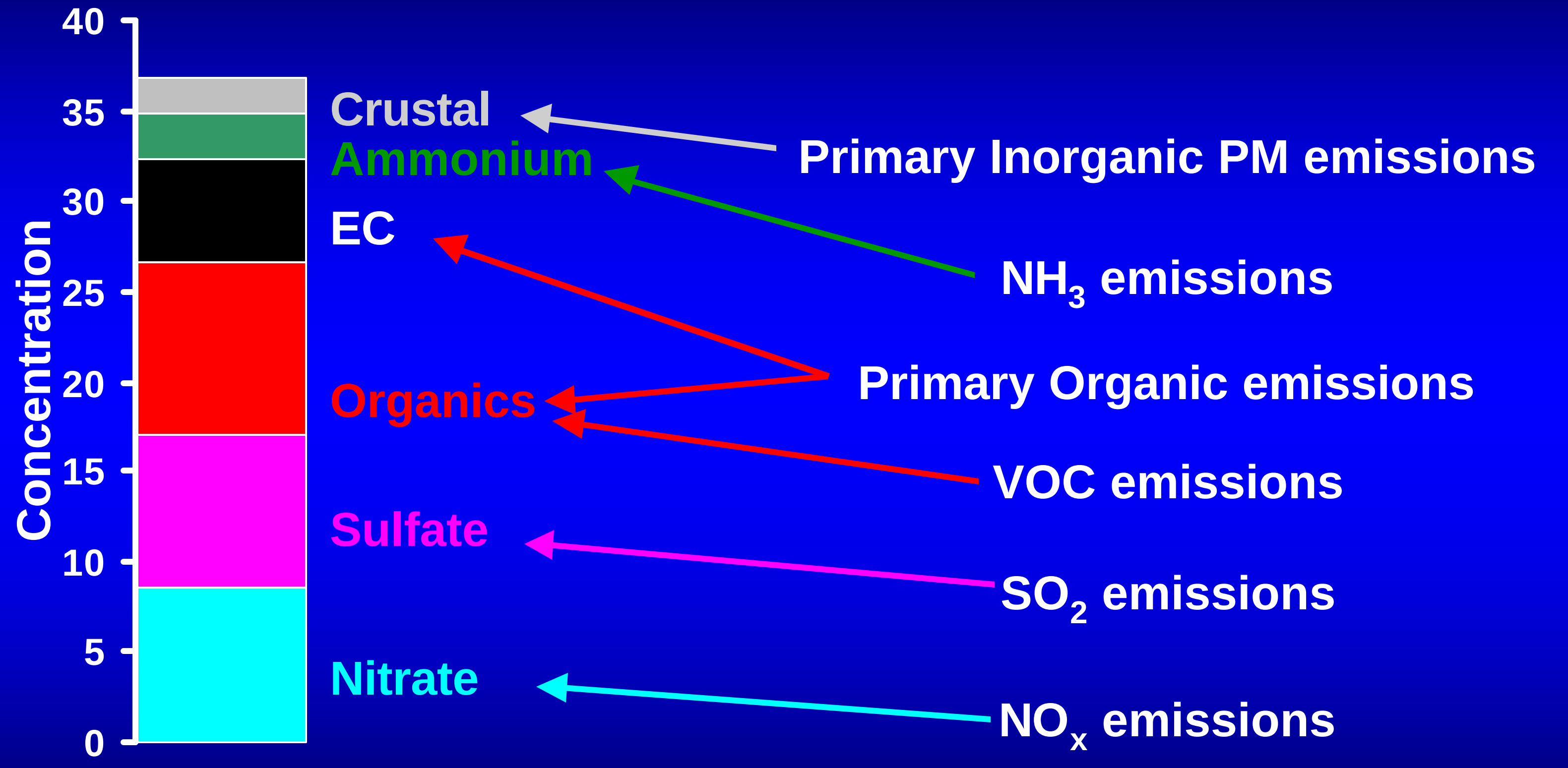
Atmospheric Particulate Matter

PM-2.5 Standard Promulgated in 1997

Design of efficient and effective control strategies requires understanding:

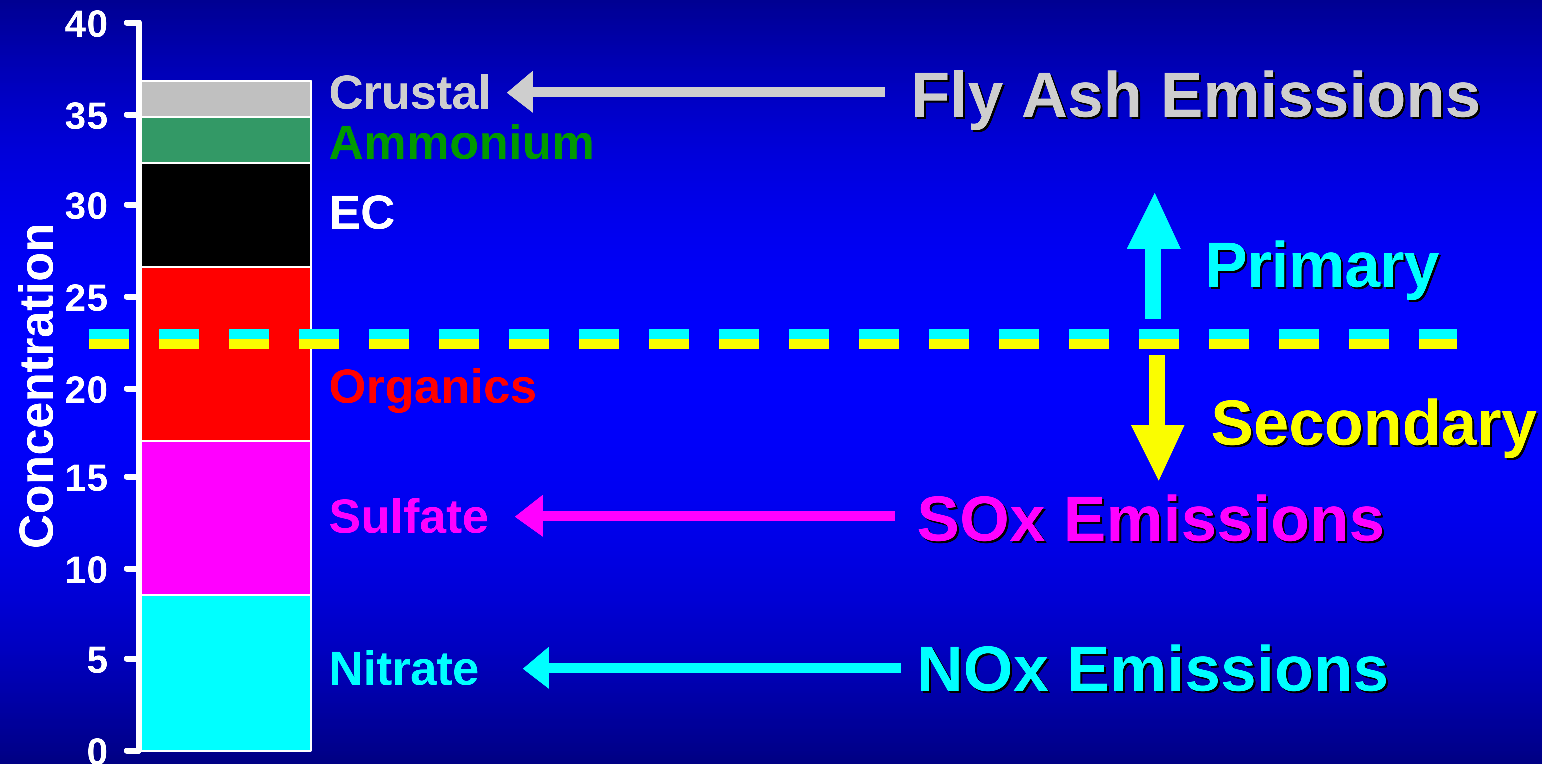
- What PM component(s) cause adverse health effects
- The contribution of various sources to current PM levels
- How PM concentrations respond to emission changes of a given source or sources

Sources of Fine PM and Their Precursors



PM-2.5 Composition during the Winter of 1999 in Philadelphia

Coal-Fired Power Plants and PM-2.5



PM-2.5 Composition during the Winter of 1999 in Philadelphia

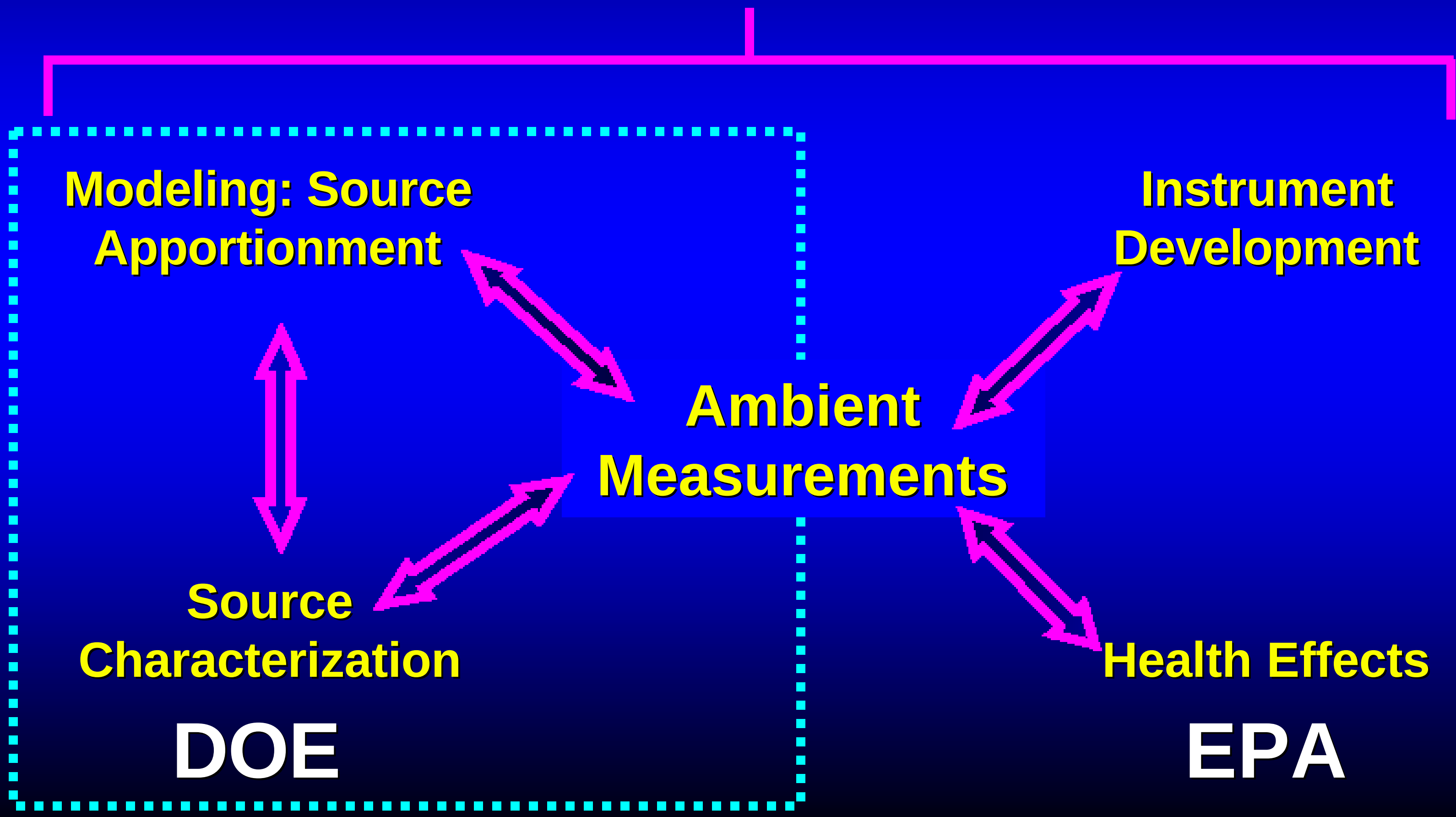
Objectives of the Pittsburgh Air Quality Study

- Characterize PM and its sources in the Pittsburgh area
- Quantify the impact of the various sources (transportation, power plants, biogenic, etc.) to the PM concentrations in the area
- Improve our understanding of the responses of PM to changes in emissions
- Develop and evaluate the next generation of atmospheric PM monitoring techniques (real time single particle measurements, ultrafine PM, organics, continuous, etc.)
- Elucidate the links between PM and health
- Quantify the relationship between indoor and outdoor concentrations

See homer.cheme.cmu.edu

The Pittsburgh Air Quality Study (PAQS)

OBJECTIVES & HYPOTHESES



Current Team Members

- **S. Pandis, C. Davidson, A. Robinson, N. Donahue [CMU]** (NSM distributions, ions, metals, ozone, NOx, HNO_3, NH_3, VOCs, size-resolved measurements)
- **A. Wexler, [U.C. Davis]** (Single particle mass spectrometry, organic aerosols)
- **M. Johnston [U. Delaware]** (Single particle mass spectrometry, organic aerosols)
- **W. Rogge [Florida Int.]** (Organic speciation)
- **B. Turpin [Rutgers]** (OC/EC, FTIR, organic characterization)
- **S. Hering [Aerosol Dynamics]** (Semi-continuous nitrate, sulfate, carbon)
- **D. Eatough [BYU]** (Organic/Inorganic sampling)
- **J. Ondov [U. Maryland]** (Semi-continuous metals)
- **S. Buckley [U. Maryland]** (Single-Particle metals metals)
- **M. Hernandez [U. Colorado]** (Bioaerosols)
- **J. Collett [Colorado State]** (Peroxides, fogwater)
- **U. Baltensperger [Paul Sherrer Inst.]** (Surface area)
- **K. Christ [Ohio U.]** (Satellite sites, data management)
- **G. Cassucio [RJ Lee Group]** (Morphology, coarse single particle analysis)
- **J. Kahl [U. Wisconsin]** (Meteorology)
- **P. Hopke [Clarkson]** (Source-receptor relationships)
- **L. Barrie [PNNL]** (Organics)
- **C. White [DOE-NETL]** (Organics)

Support

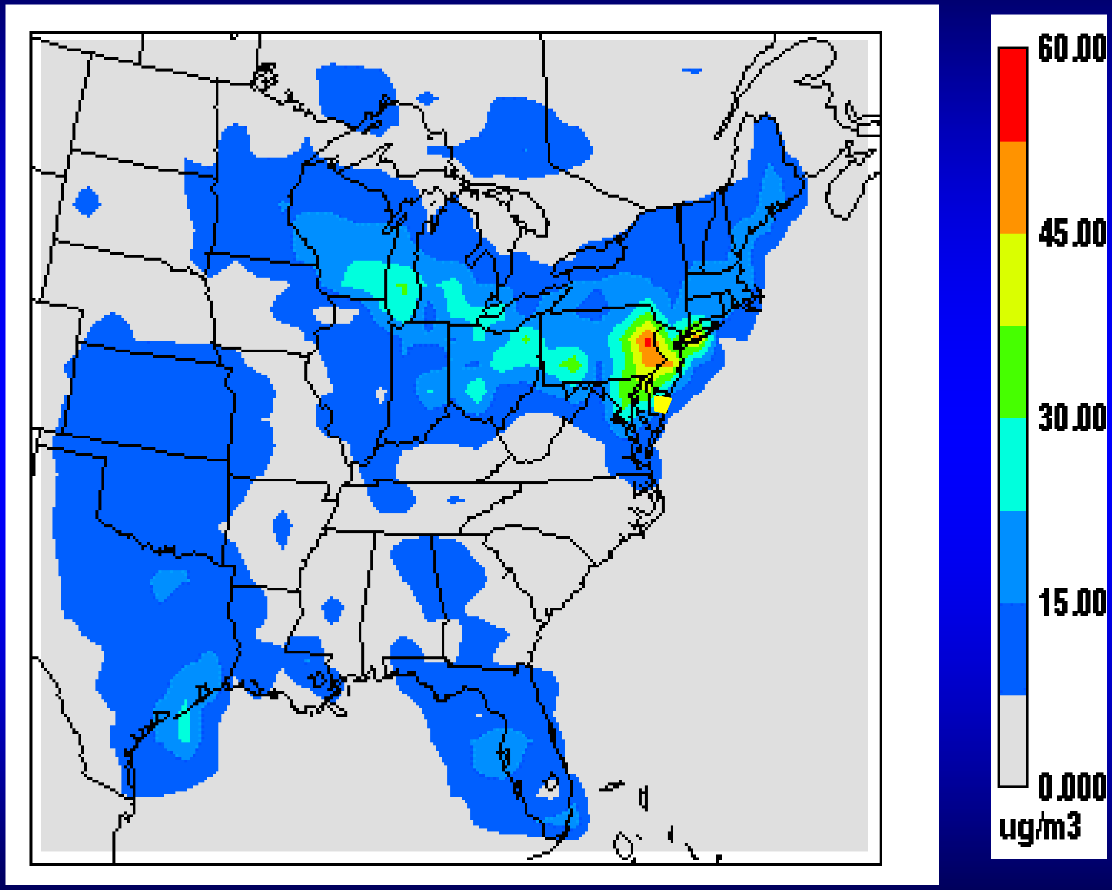
Direct:

- DOE (45%)
- EPA (45%)
- Carnegie Mellon University and others (10%)

Indirect:

- EPA speciation network
- Allegheny County Health Department
- Pennsylvania DEP
- Ohio EPA
- West Virginia EPA

Why Pittsburgh?



Predicted $PM_{2.5}$ Aerosol for the Eastern US ***(July 10, 1995)***

Ambient Measurements

Objectives:

- Examine Atmospheric Process
- Evaluate Deterministic Air Quality Models
- Statistical Source-Apportionment
- Examine Health Effects
- Indoor-outdoor relationships

Baseline Ambient Measurements

May 01–Oct 02 (18 months)

Almost continuous:

- Number distribution (3 nm -10 mm)
- Surface area
- TEOM PM mass
- OC/EC
- Sulfate/nitrate/carbon
- Single particle size composition
- Gases (O_3, NO_x, CO, SO_2)
- Meteorology, Visibility

Daily averages:

- PM_x Mass
- $PM_{2.5}$ Composition
- PM_{10} Composition
- Gases (VOCs, HNO_3, NH_3)
- Bioaerosols
- Hydrogen and organic peroxides

Other:

- Organic speciation (2 weeks)
- Cloud-fog composition

Intensive Ambient Measurements

Three Intensive Sampling Periods

- July 2001
- January 2002
- October 2002

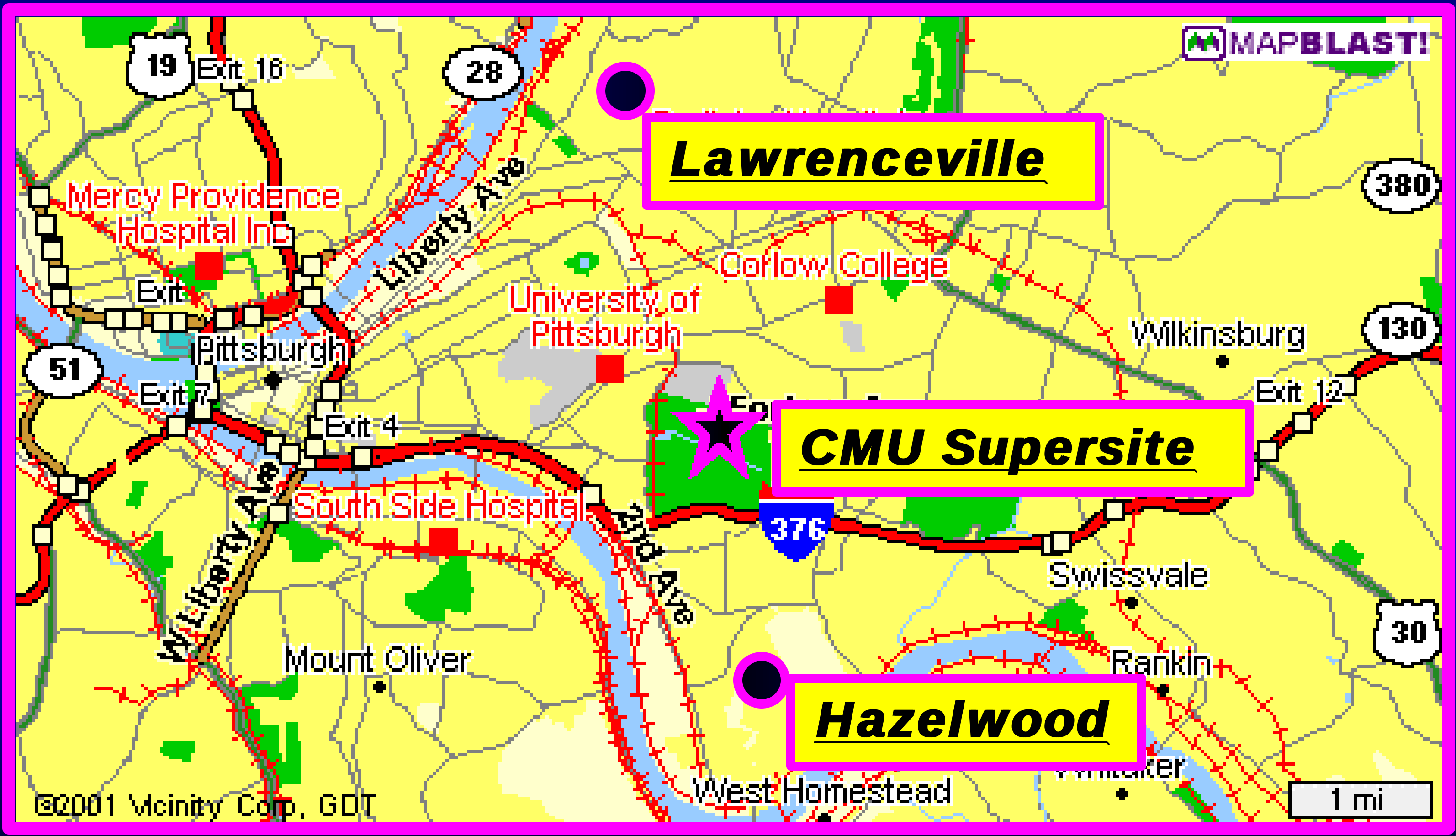
Increased frequency of all measurements

- **PLUS:** Size-resolved composition, PC-BOSS, FTIR, Organic Partitioning, Semi-continuous metals, LIBS, TDMA-RSMSII, CCN measurements, etc.

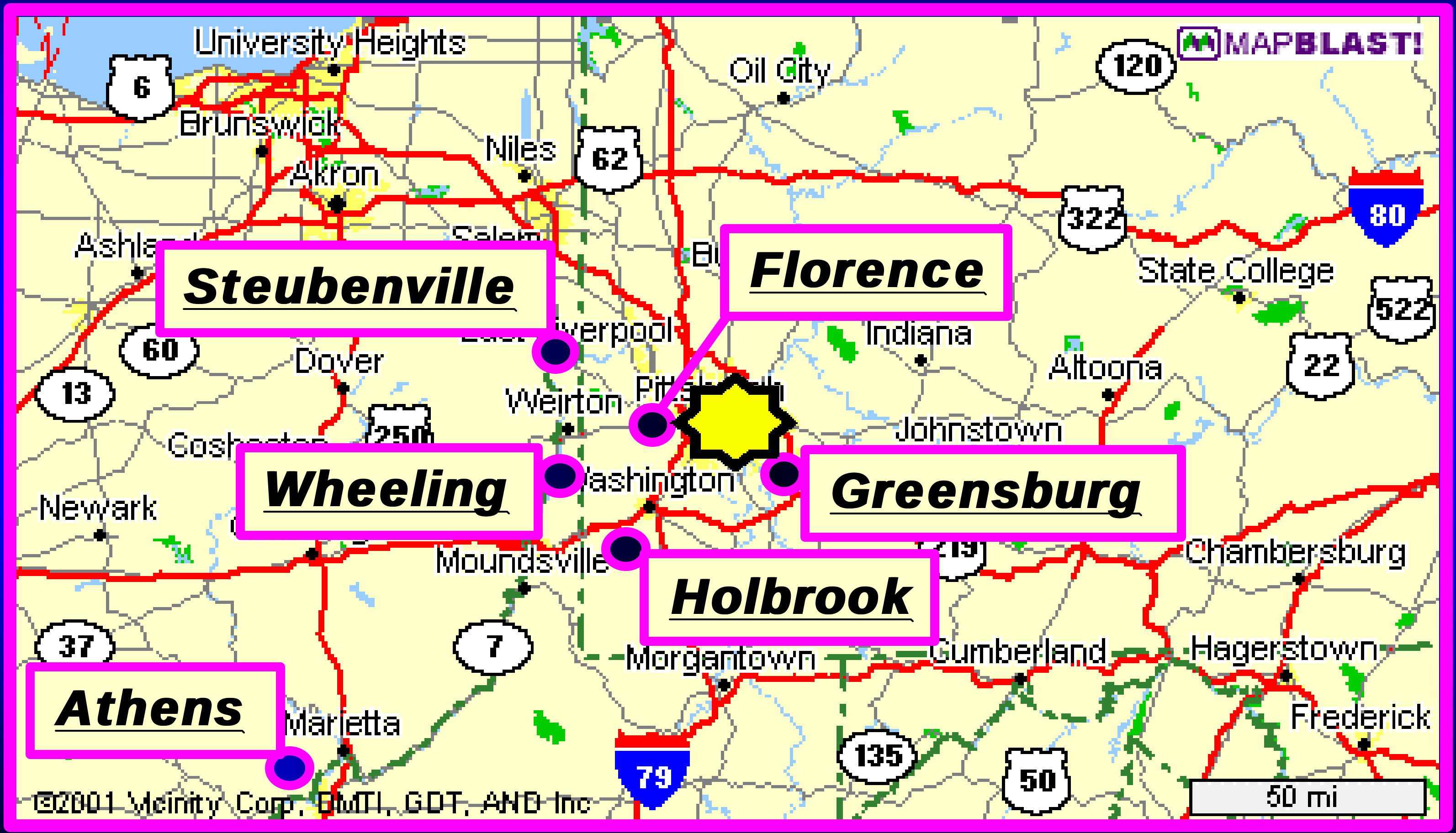
Coordination with Other Studies

- DOE
- EPA Supersite
- Other

Sites in the City of Pittsburgh



Remote Satellite Sites



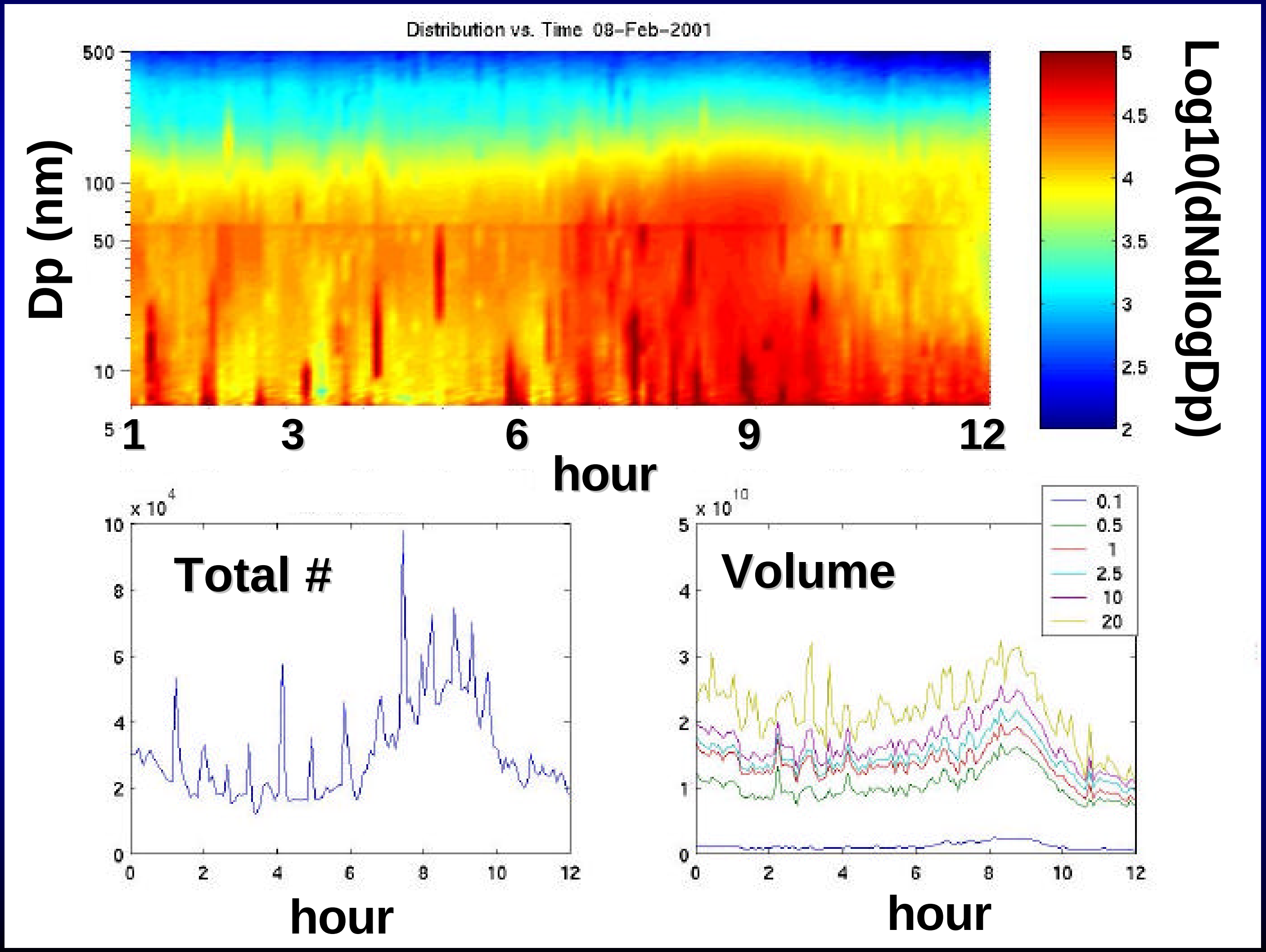
Supersite Location: Carnegie Mellon University

Location of Central Supersite

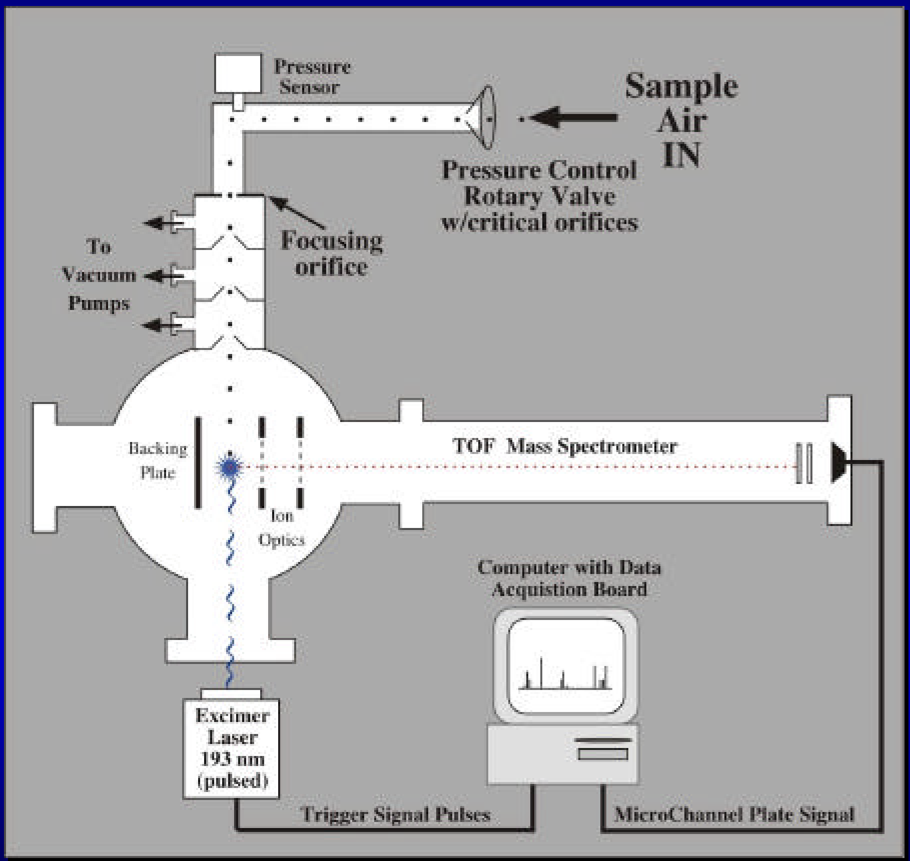
Advanced Ambient Measurements

- Continuous Size Distributions
- Single Particle Characterization
  - Single Particle Mass Spectrometry
  - Laser Induced Breakdown Spectroscopy
- Semi-Continuous Metals
- Semi-Continuous OC/EC
- Semi-Continuous Nitrate, Sulfate, and Carbon
- Continuous Particle Surface Area
- Organics Speciation

Continuous Measurements of Particle Size Distributions



On-Line Single Particle Measurement
(size and composition)



Three Instruments:

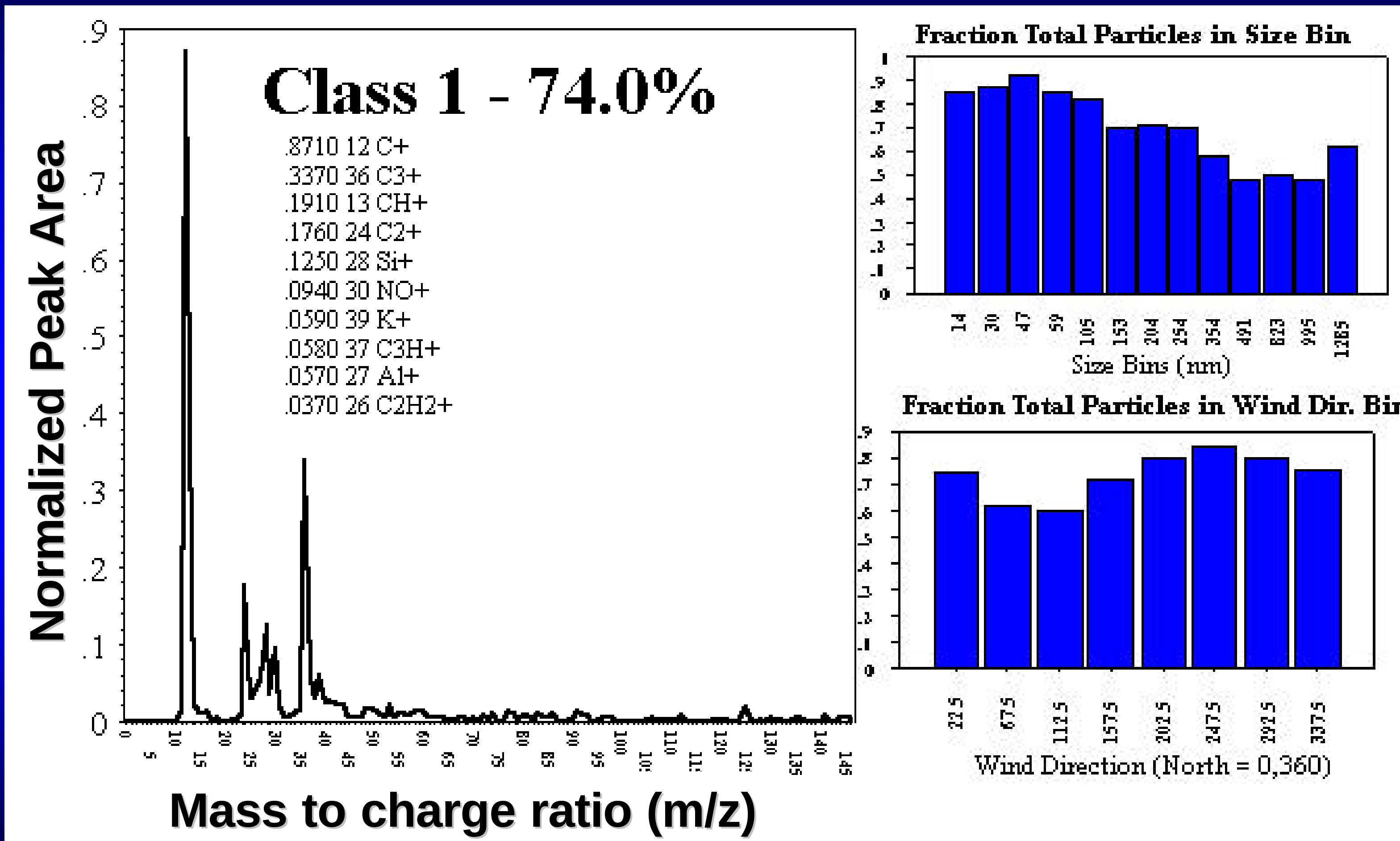
- RSMS-III - Wexler (UC Davis)
- APS-IMS - Johnston (U. Del.)
- LIBS – Buckley (U. Maryland)

Applications:

- Ambient measurements
- Source characterization
- Advanced source apportionment

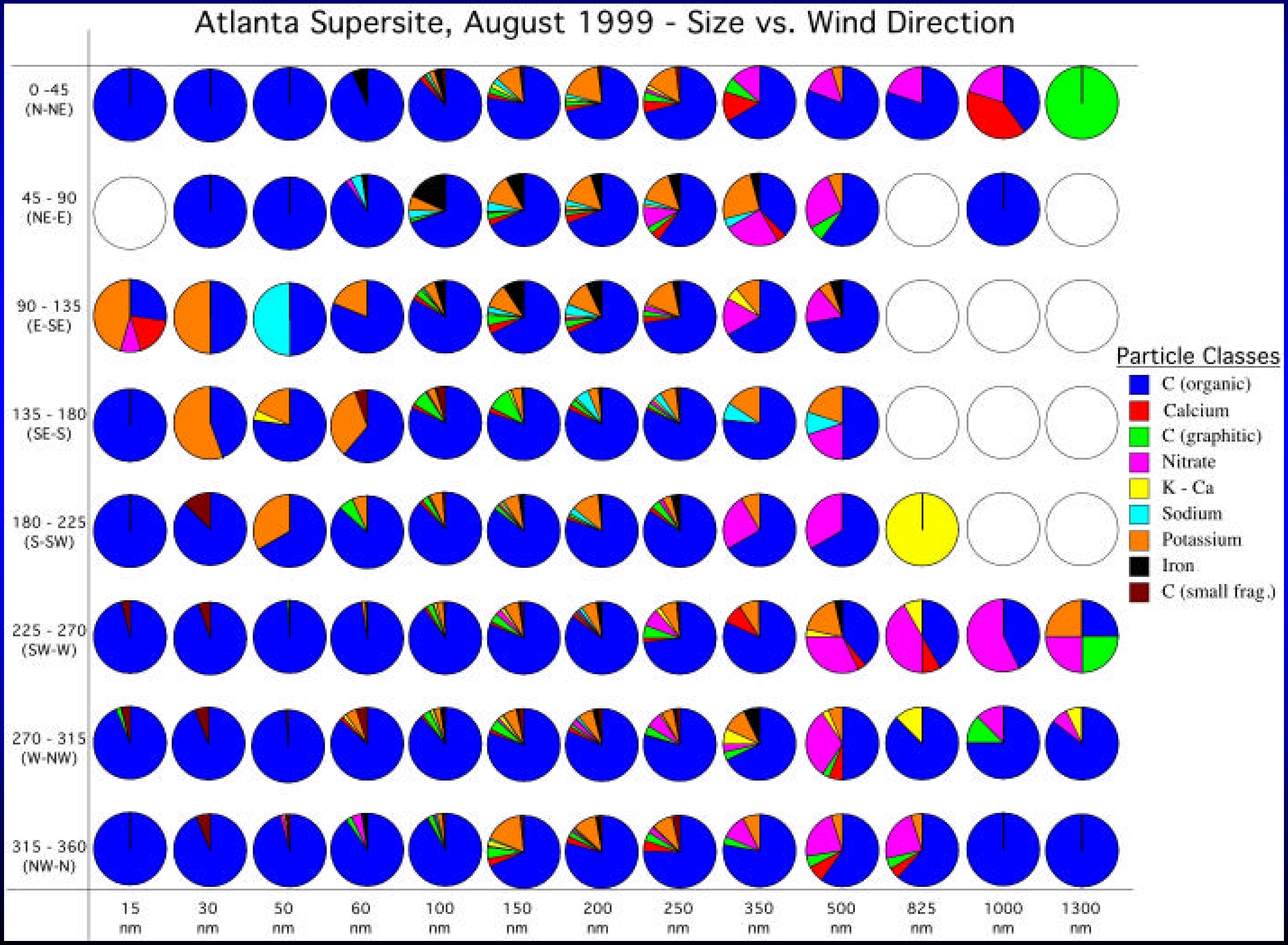
RSMS – Single Particle Mass Spectrometer
PI: Wexler

Single Particle Classification

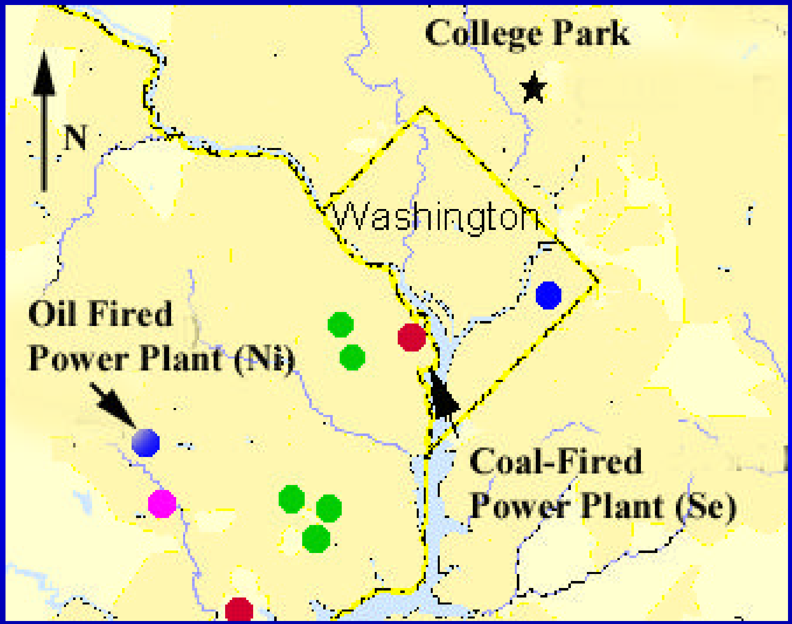


Most prevalent particle class in Atlanta August 1999. (PI Wexler)

Size and Composition Classes in Atlanta August 1999

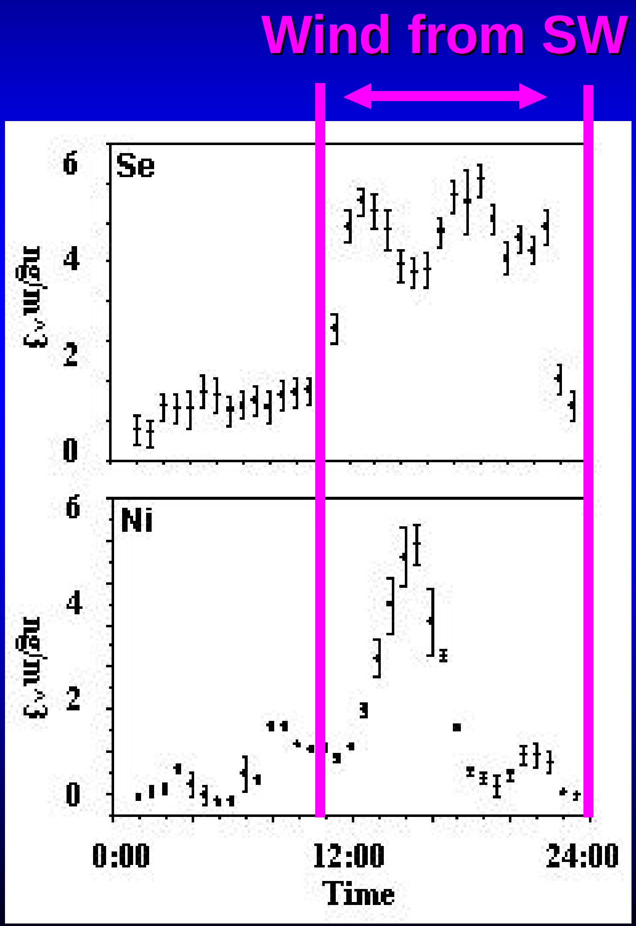


Semi-continuous metals measurements allow identification of individual sources

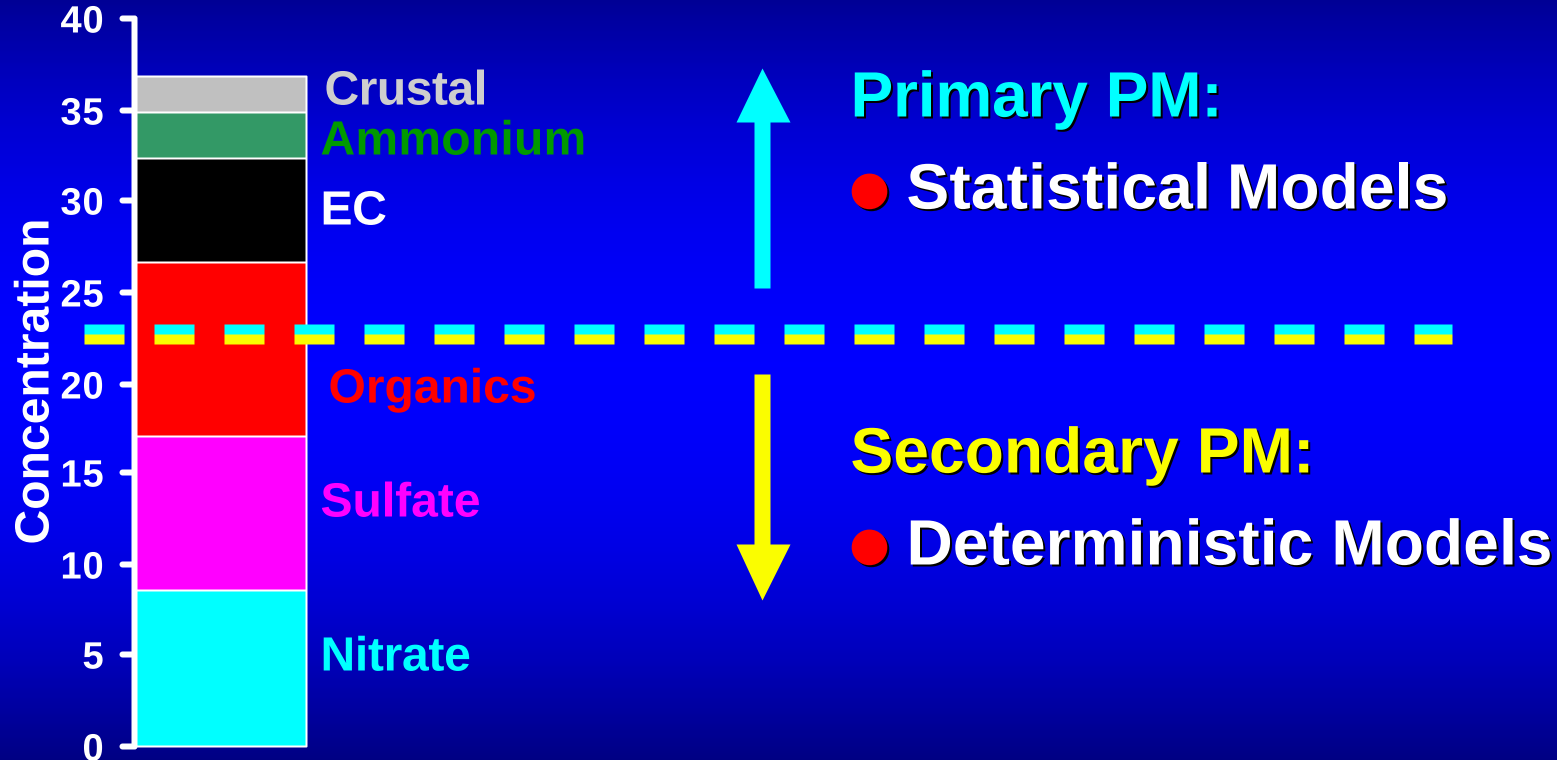


Measurements of Se & Ni in College Park, MD

PI: John Ondov

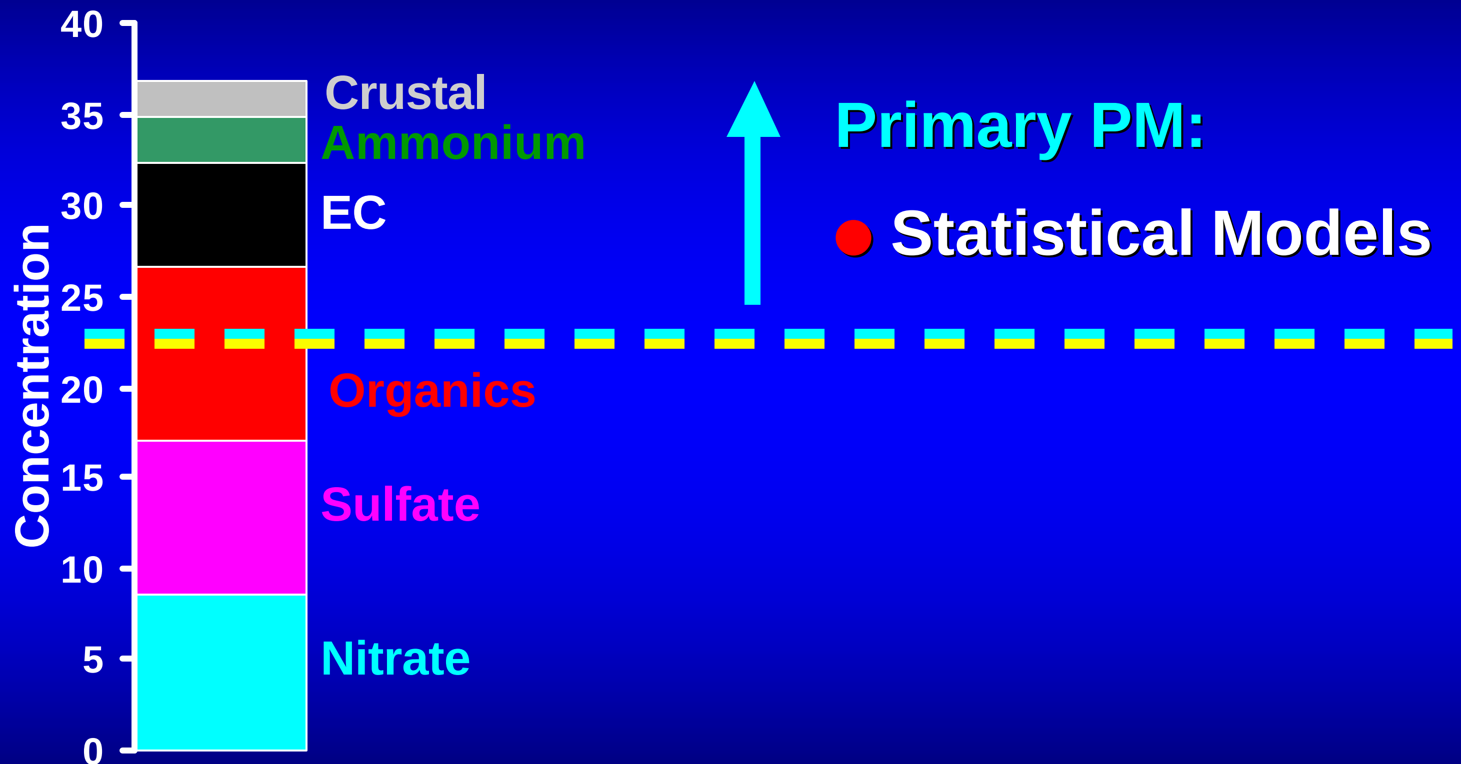


Source Apportionment of Primary vs. Secondary PM



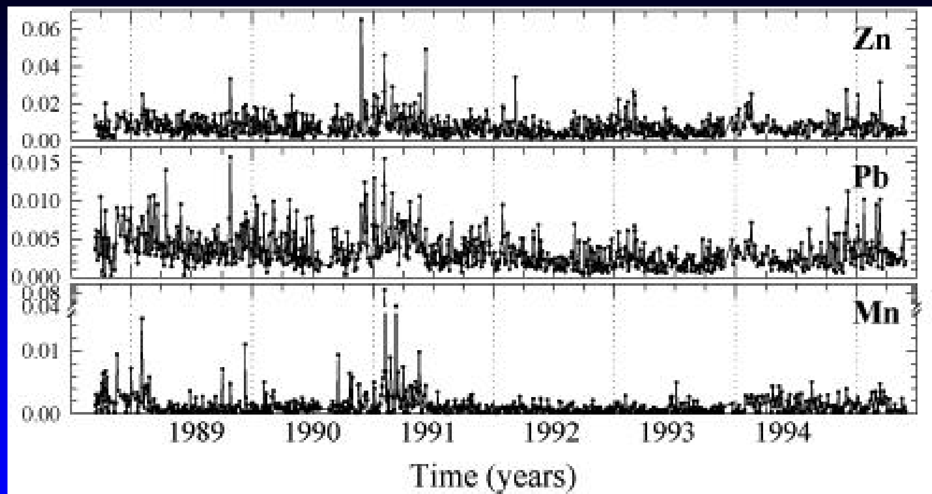
PM-2.5 Composition during the Winter of 1999 in Philadelphia

Statistical Source-Apportionment for Primary PM-2.5



PM-2.5 Composition during the Winter of 1999 in Philadelphia

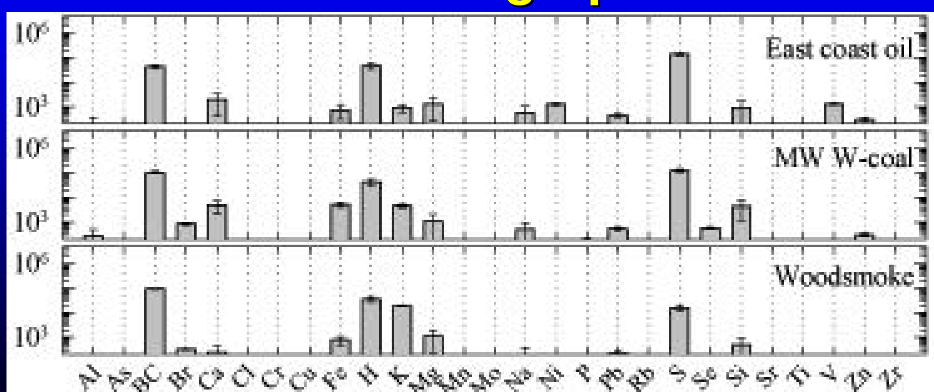
Traditional Statistical Source Apportionment

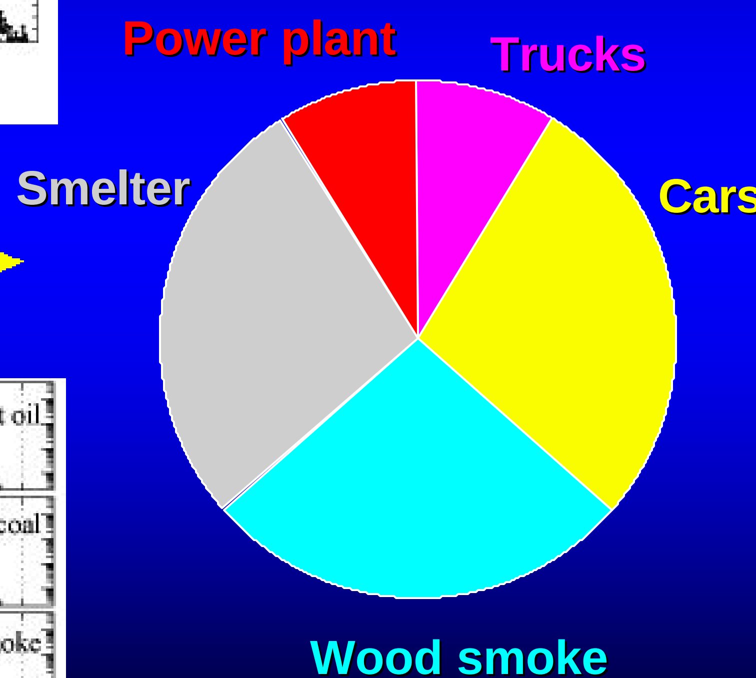


Ambient Data

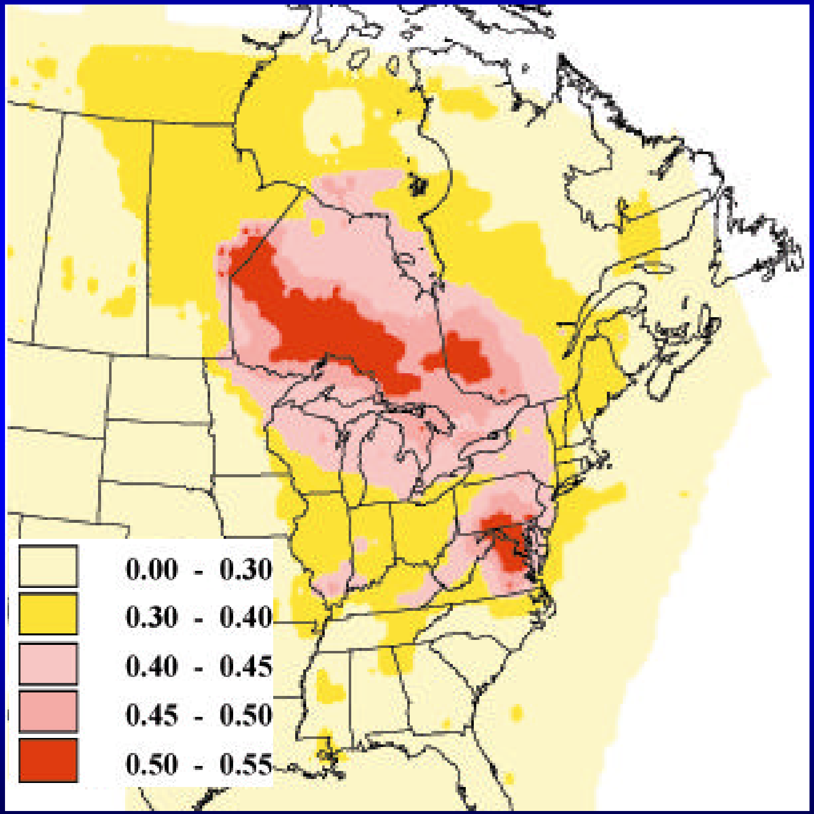
+

Source Fingerprints





Advanced Statistical Source Apportionment



Combining PM and meteorology data allows identification of source regions.

PI: P. Hopke

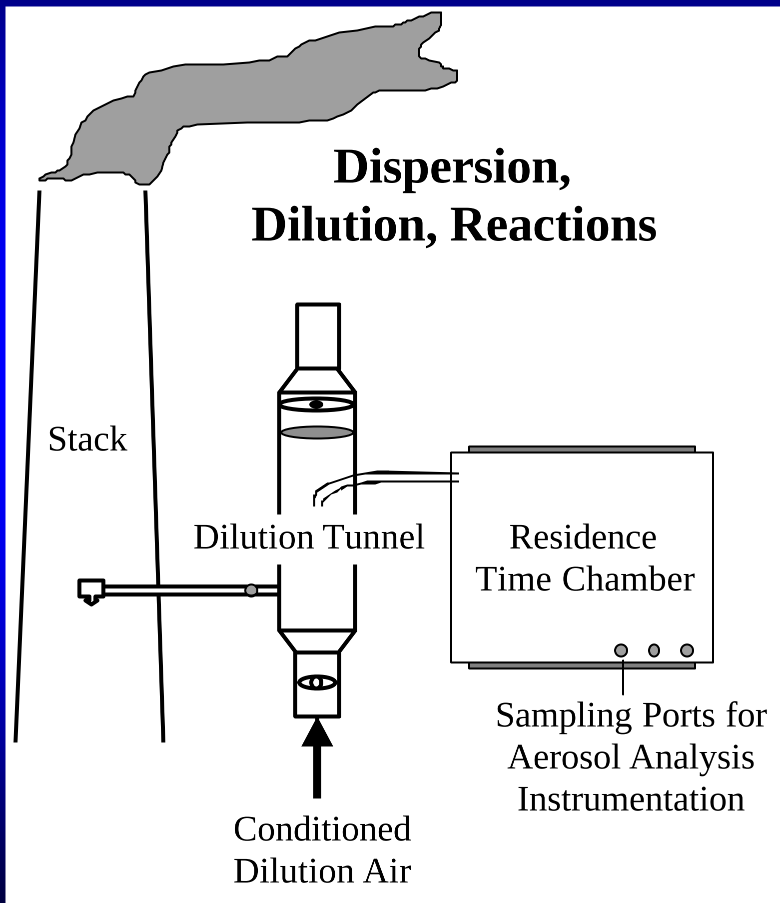
Source regions for As in Underhill, VT

Source Characterization

Objectives:

- Update source fingerprints for CMB
  - Steel industry
  - Coal fired boilers
  - Mobile sources
  - Wood burning
- Advanced source characterization
  - Organics
  - Single Particle

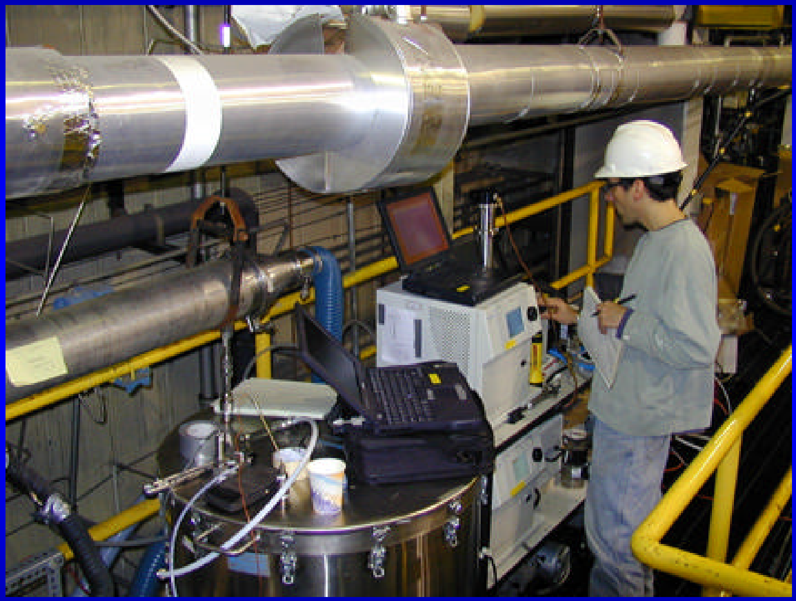
Dilution Sampling: Organic PM Emissions From Combustion Systems



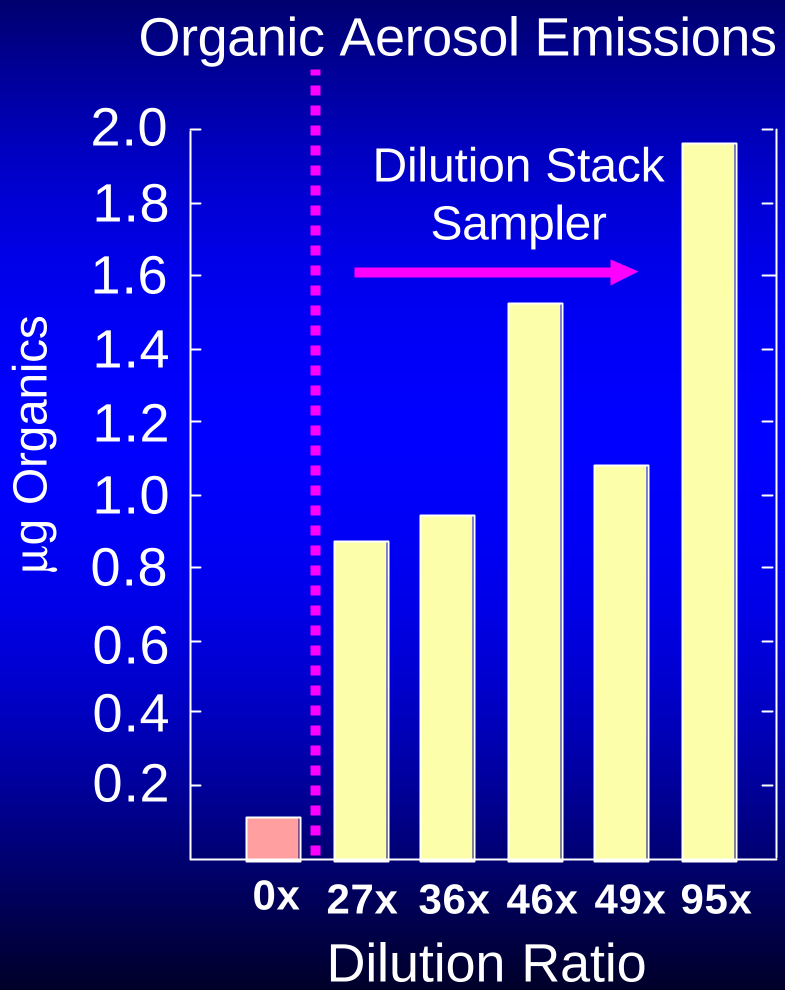
Schematic of Portable Dilution Sampler

- Plume processes effect volatile PM emissions
- Organic fingerprints for source apportionment
- Characterization of sources with single particle instruments

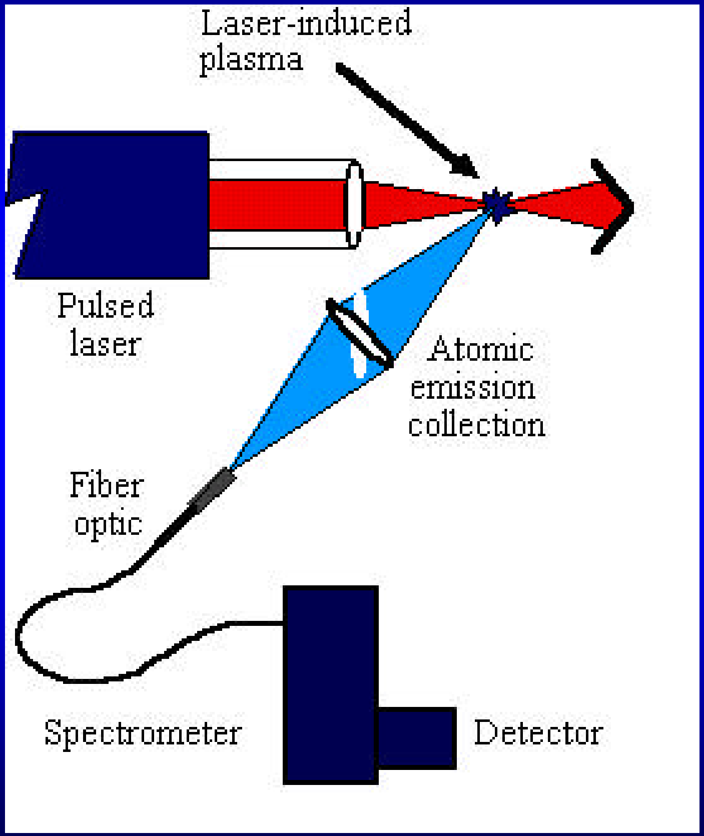
Dilution Effects Emissions



Dilution sampling on a pilot-scale combustor



Single Particle Source Characterization



Objective: Combining single particle ambient and source data may allow source apportionment on a **particle by particle** basis.

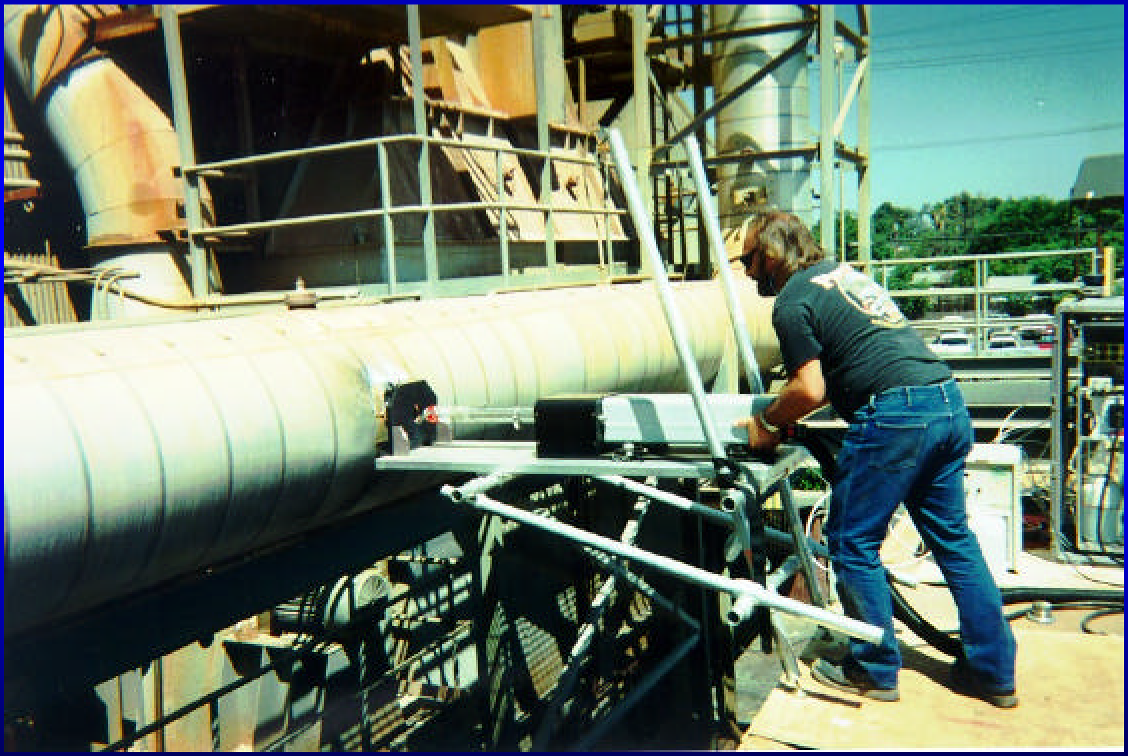
Two Systems:

APS-IMS - Johnston (U. Del.)

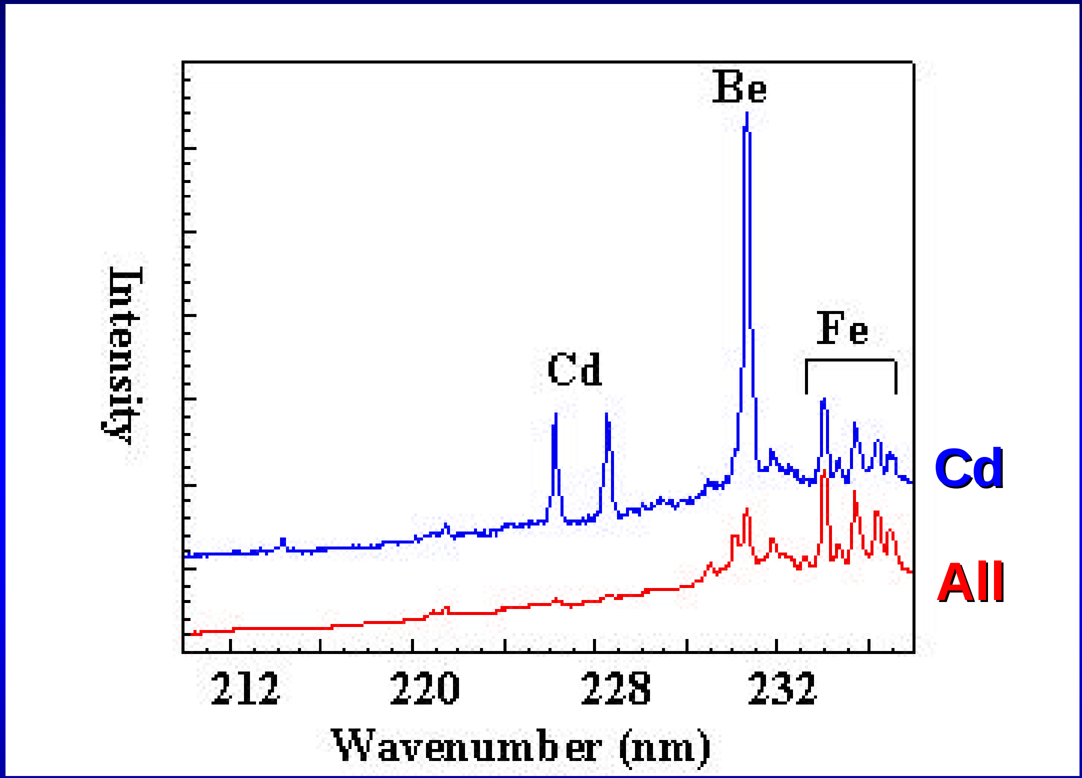
LIBS – Buckley (U. Maryland)

LIBS: Single Particle Metals Data

LIBS system deployed at Gallo Glass Furnace #1.

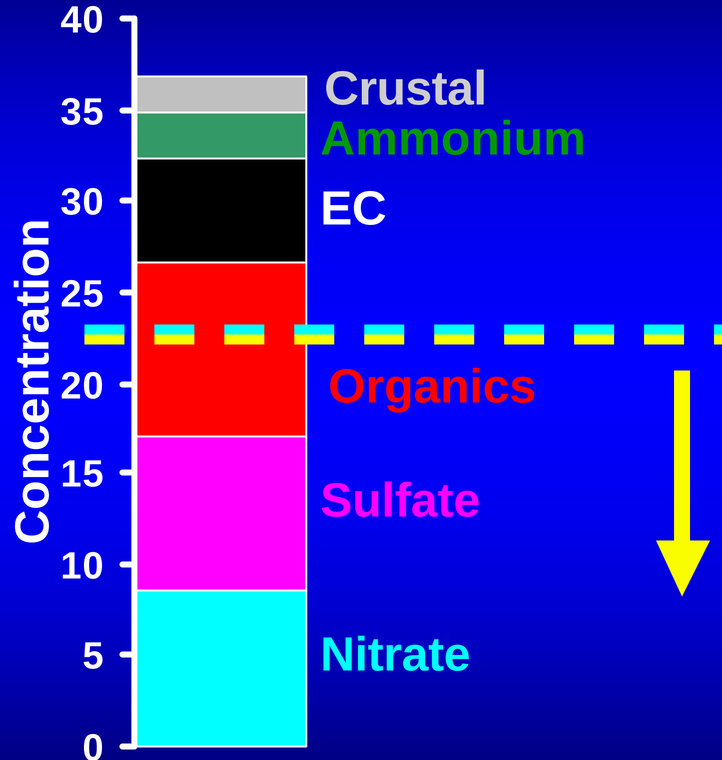


Single Particle Source Apportionment



LIBS provides elemental composition of particle. Associations between elementals potentially allow source identification on a single particle basis. PI: Buckley

Deterministic Modeling to Apportion Secondary PM

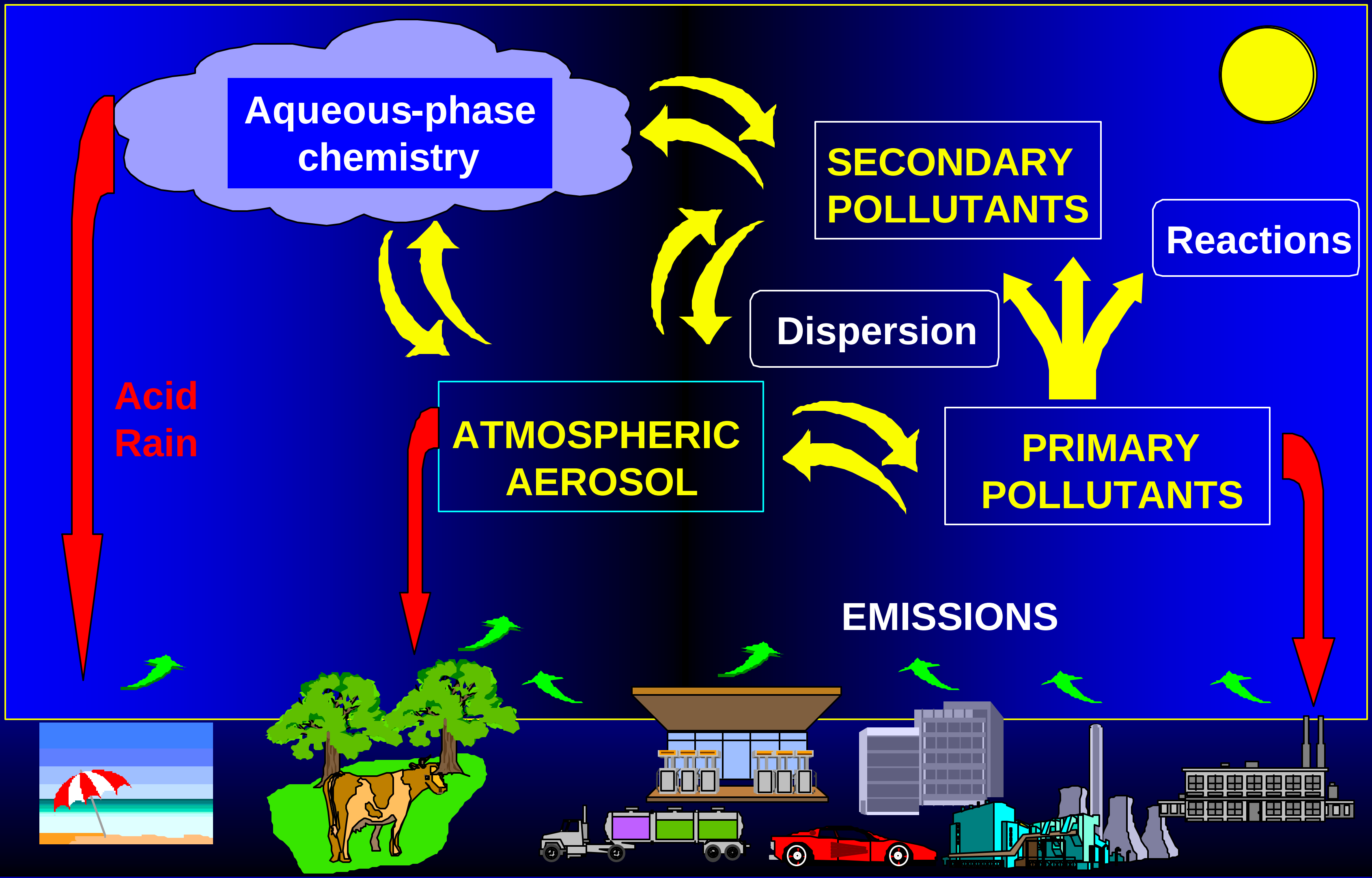


Secondary PM:

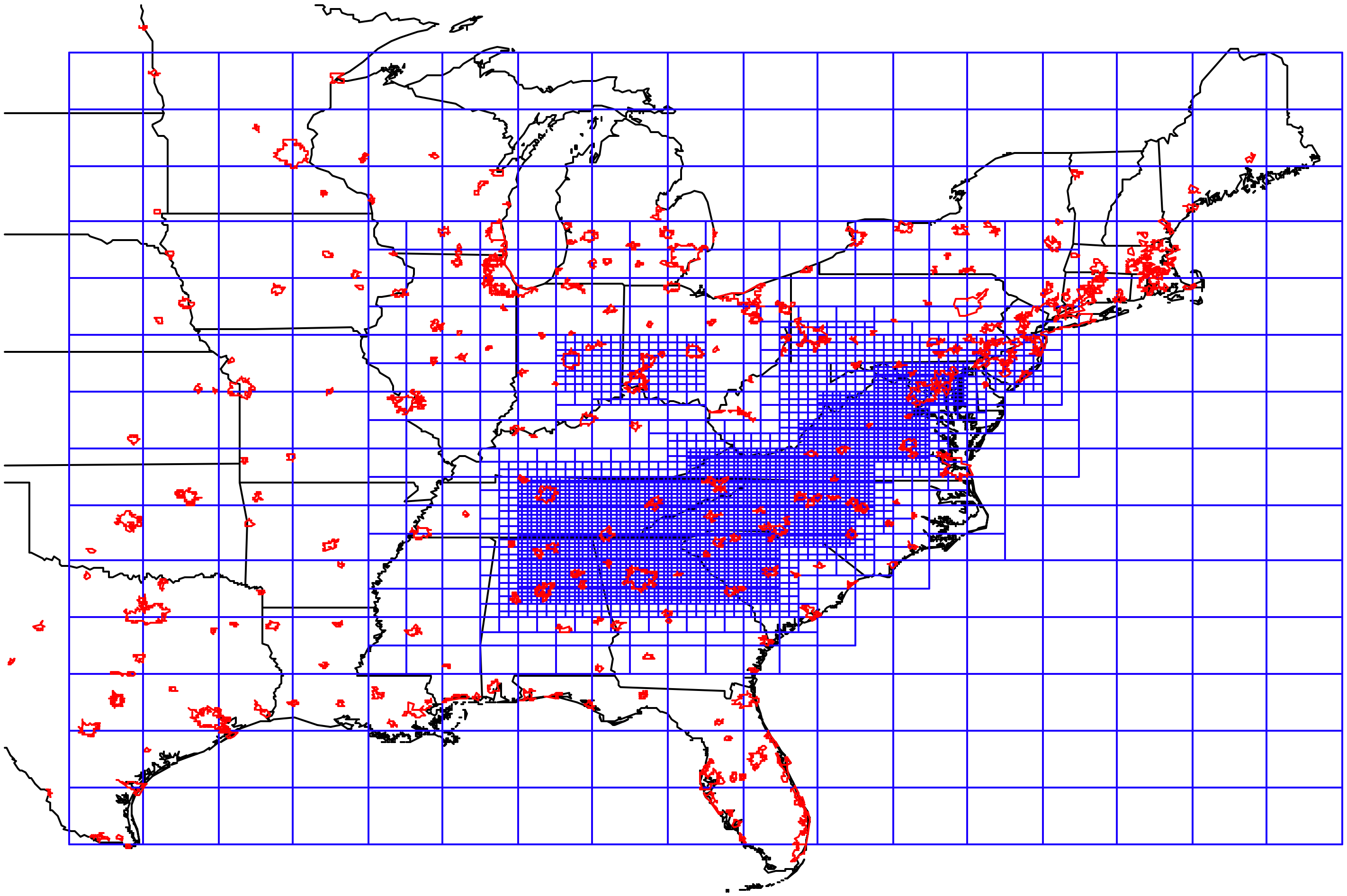
- Deterministic Models

PM-2.5 Composition during the Winter of 1999 in Philadelphia

Atmospheric processes and PM-2.5

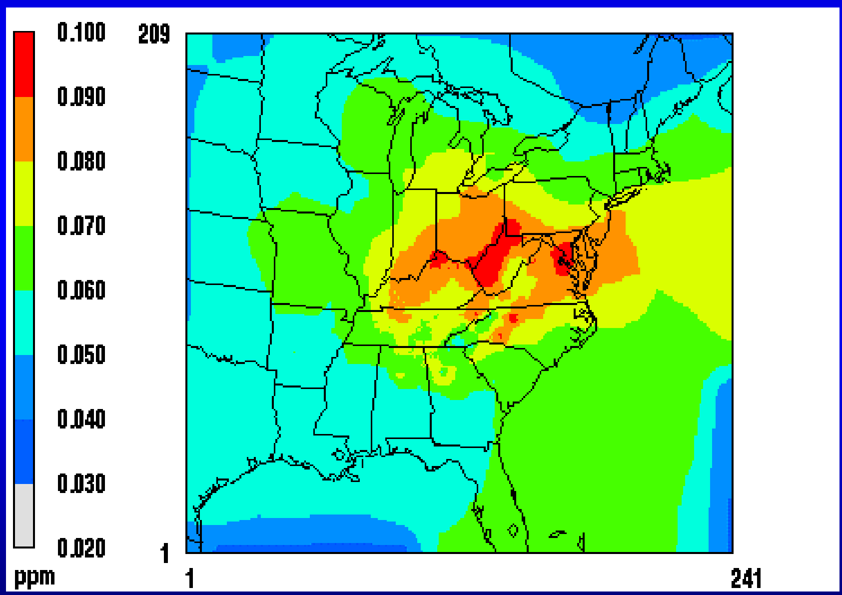


Grid to model PM in the Eastern US

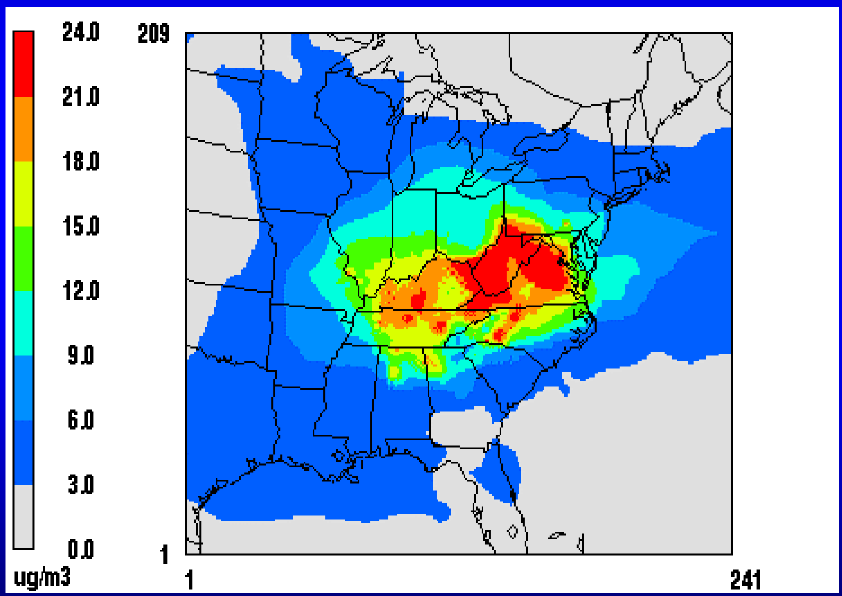


Predicted Ozone and Sulfate
July 15, 1995 (2:00 p.m.)

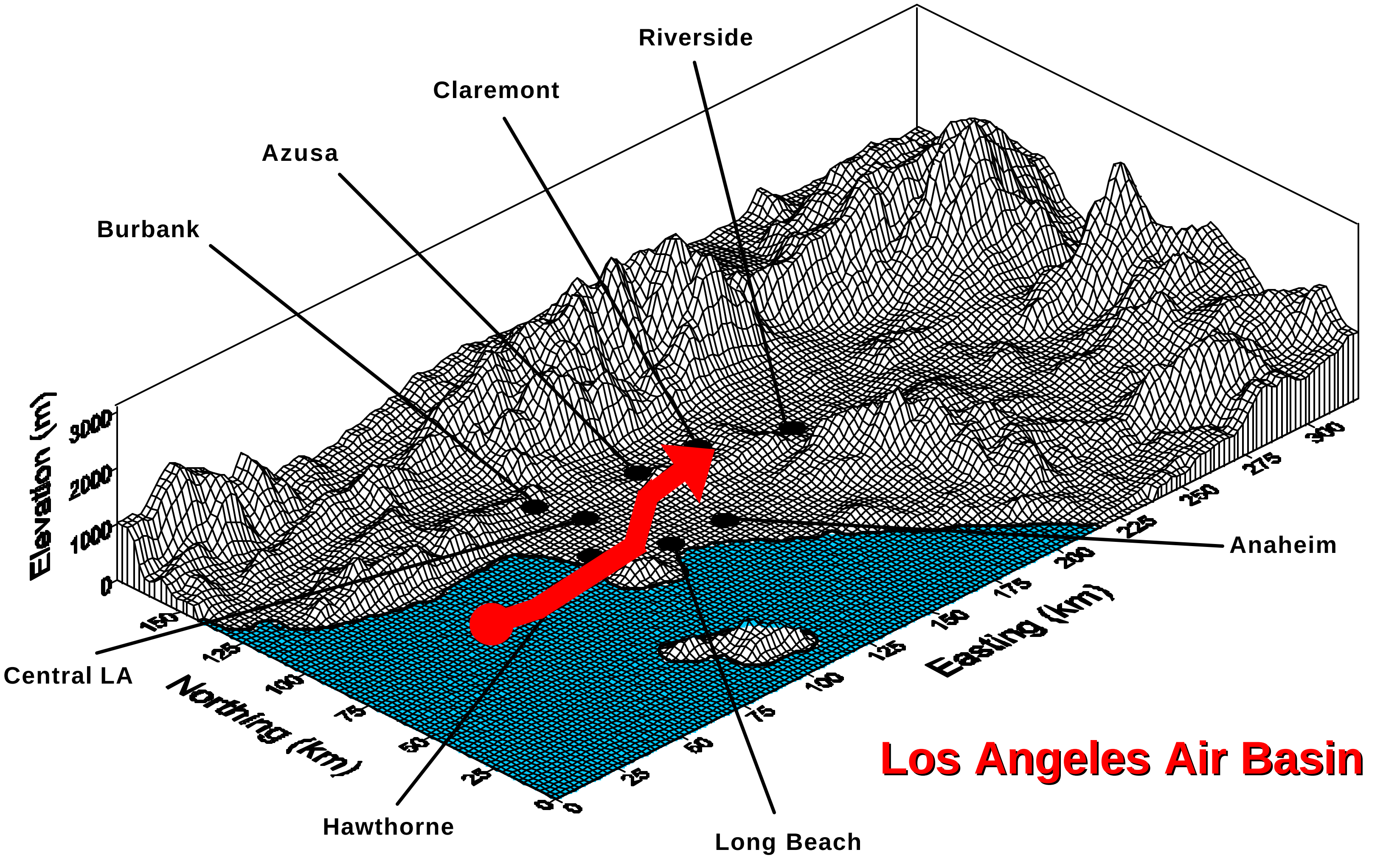
OZONE



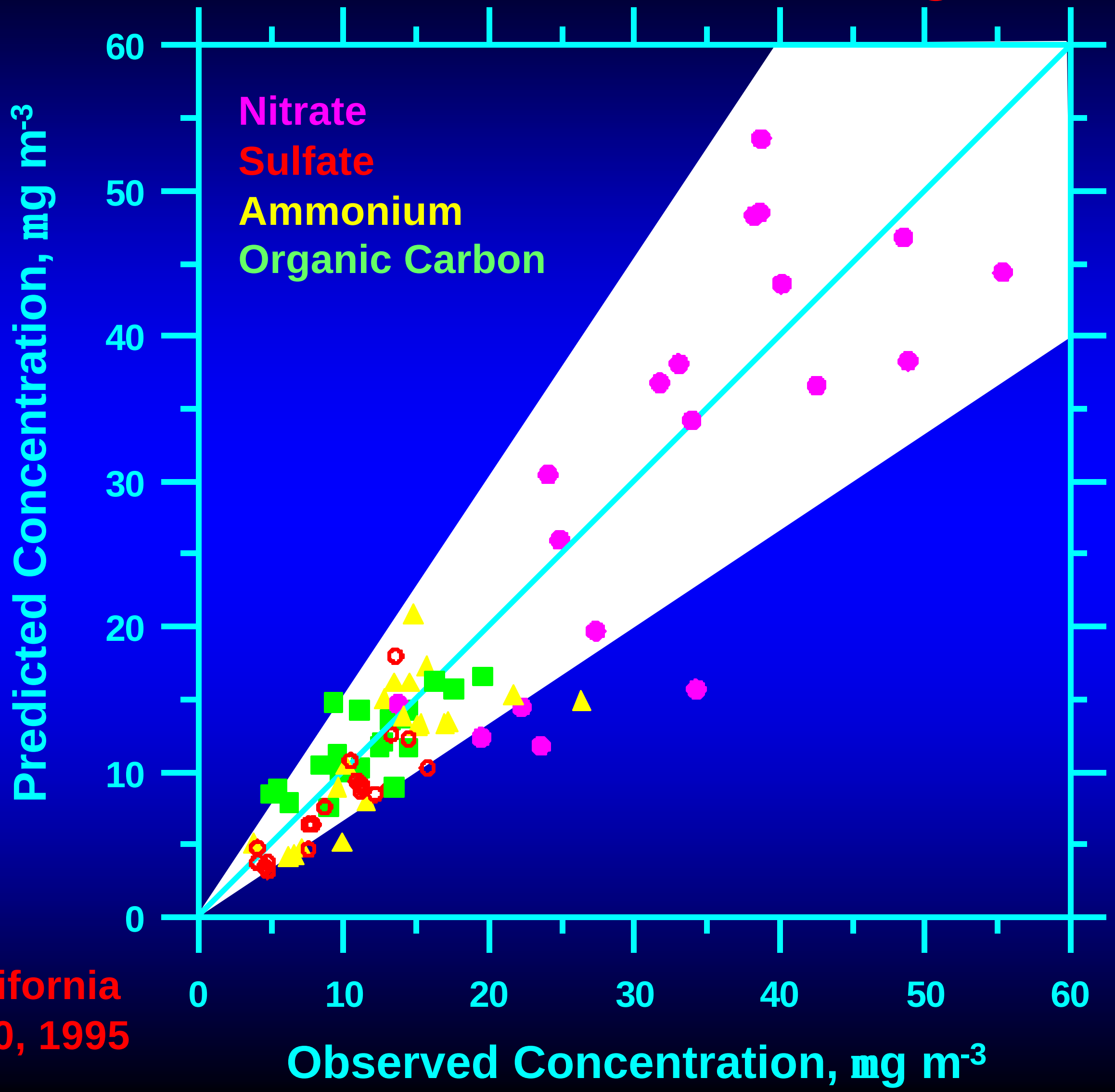
SULFATE



Model Evaluation

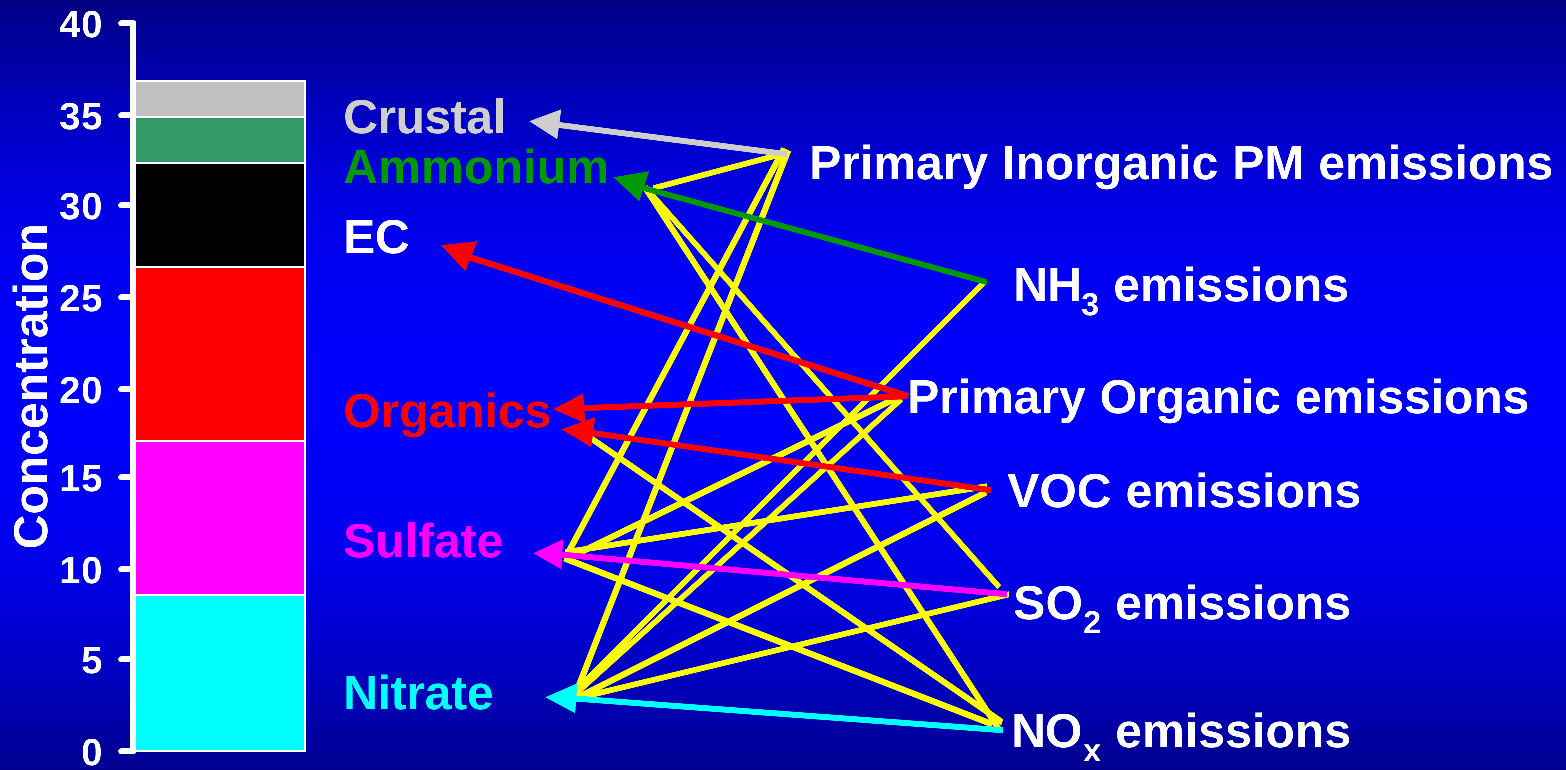


Model Performance in Los Angeles, CA



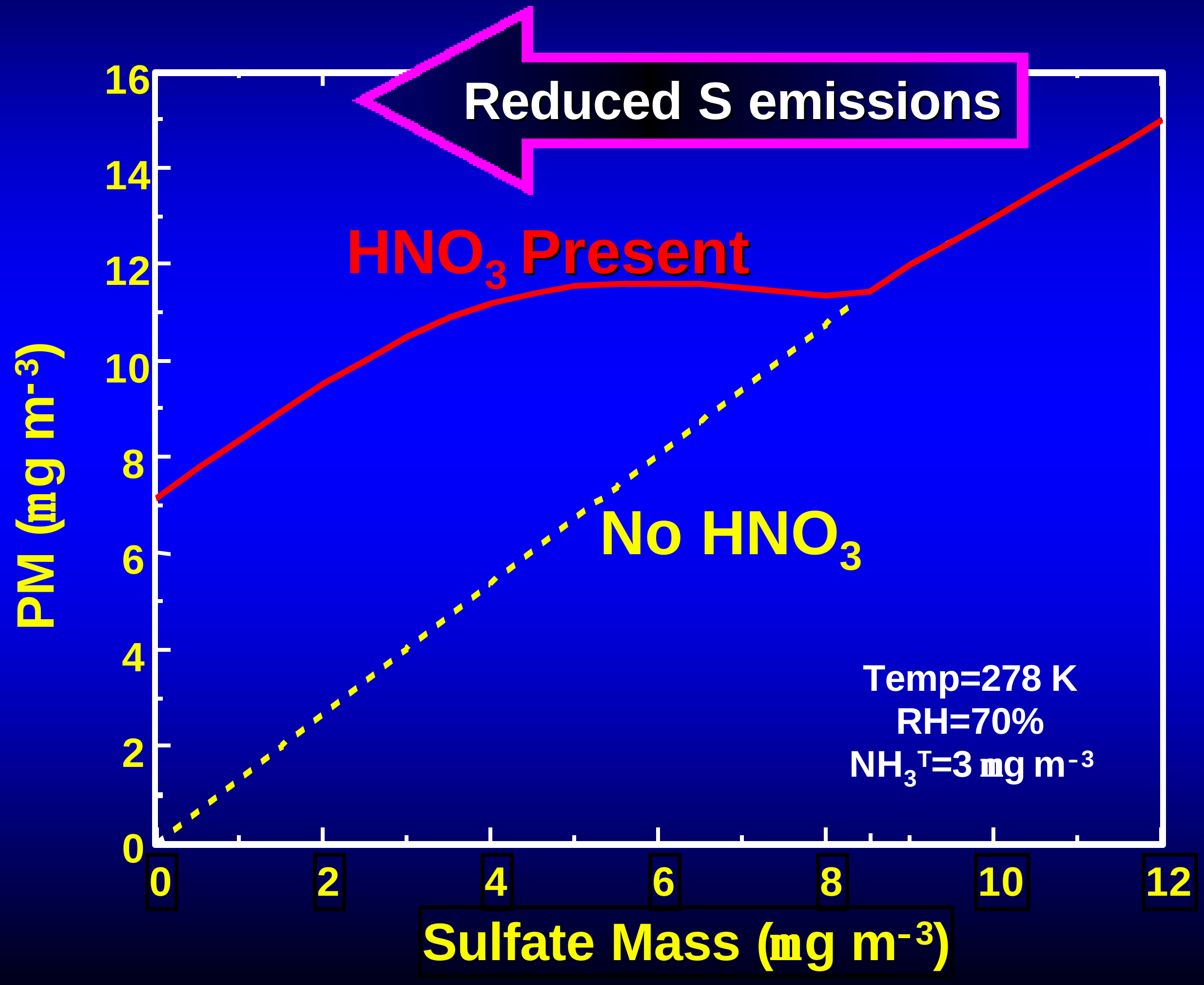
UAM-AERO
Southern California
October 17-20, 1995
Multiple sites

The Source-Receptor Challenge: Interactions between Fine PM and Their Precursors

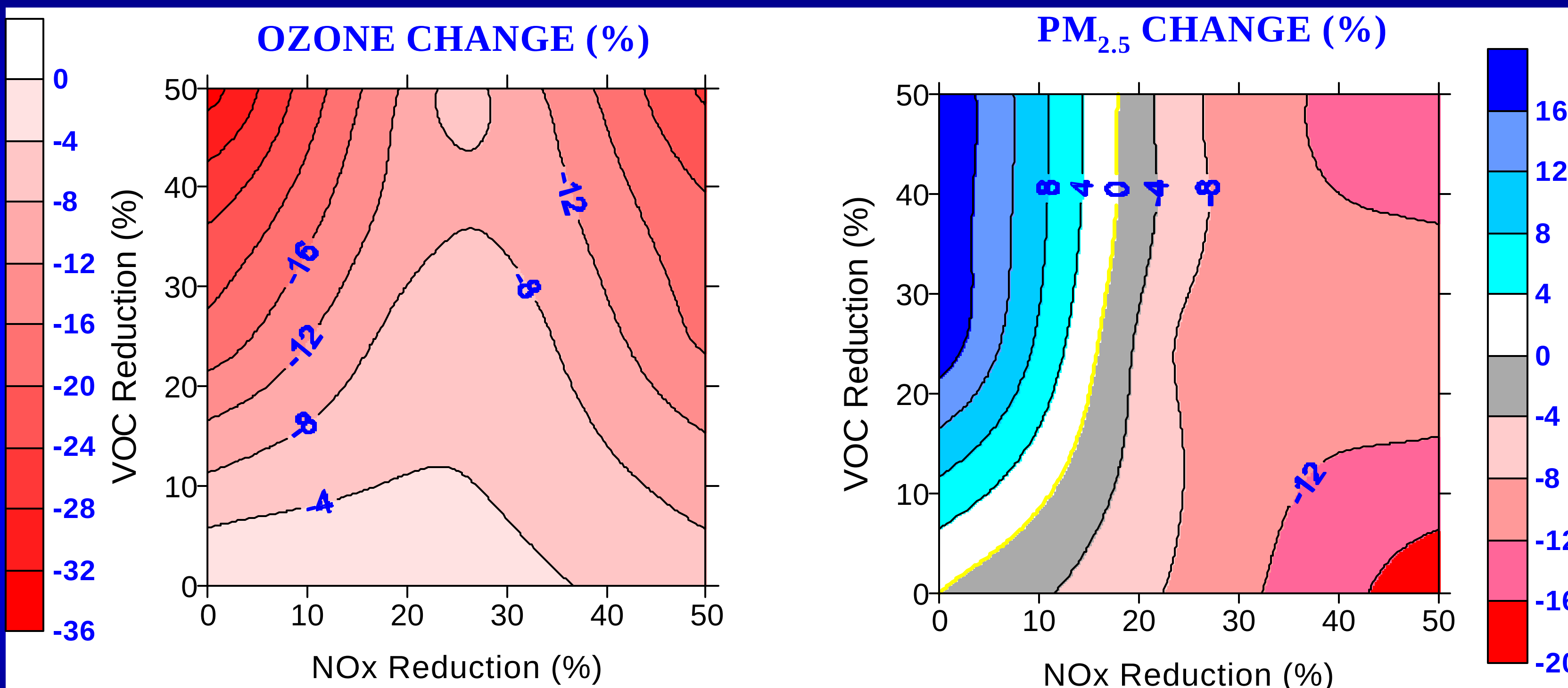


PM-2.5 Composition during the Winter of 1999 in Philadelphia

Nonlinear interactions determine effect of Sulfur controls on PM levels



Response of Ozone and $PM_{2.5}$ Concentrations to VOC and NO_x controls in L.A.



Fine PM can increase for significant reductions of VOC emissions if NOx is not reduced too (formation of additional nitric acid)

Results and Expected Benefits

- Comprehensive characterization of PM in Pittsburgh region
- Development of database for evaluation of air quality models
- Updated fingerprints for critical sources
- Development of next generation of source apportionment techniques
- Quantify the contribution of coal-fired power plants to primary and secondary PM
- Evaluation of emission control strategies

PM Characteristics and Health

- Total number (N)
- Total surface area (S)
- PM_x, $PM_{2.5}$, PM_{10}, $PM_{x\text{-}y}$
- Metals (Fe, Mn, etc.)
- Sulfate ($PM_{2.5}$, PM_{10})
- Nitrate ($PM_{2.5}$, PM_{10})
- OC ($PM_{2.5}$, PM_{10})
- EC ($PM_{2.5}$, PM_{10})
- Acidity
- Bioaerosols
- Polar Organics
- Non-polar organics
- Specific organic classes
- Hydrogen and organic peroxides
- Total soluble $PM_{2.5}$, PM_{10}
- Specific sources (diesel or gasoline combustion, power plants,…)
- Gas-phase co-pollutants (CO, O_3, NO_x, SO_2, etc.)
- Combinations of the above

Epidemiology-Indoor Pollution

EPIDEMIOLOGY (Samet, Johns Hopkins)

- Collection of mortality and morbidity data from emergency rooms in Oakland
- Use of time-series analysis relating the PM measurements to the health effects
- Coordination with Baltimore Supersite using common measurements
- Complimentary panel study of susceptible populations (children with asthma, chronic obstructive pulmonary disease, and ischemic heart disease).

INDOOR POLLUTION (Sextro, LBNL)

- Indoor measurements in Pittsburgh houses
- Testing of models