

US EPA ARCHIVE DOCUMENT

Black Carbon, Air Quality and Climate: From the Local to the Global Scale

Spyros Pandis

**Department of Chemical Engineering
Carnegie Mellon University**

The Team



Spyros Pandis



Allen Robinson



Neil Donahue



Peter Adams



Bernhard Vogel (KIT)

Objectives

- Develop size-resolved *number* emission inventories for BC-containing sources
- Evaluate and improve the existing mass inventories using a consistent definition of BC.
- Improve our understanding of the atmospheric processing of BC particles.
- Improve the ability of the existing regional models to simulate the BC mass and number concentrations

Objectives (continued)

- Quantify the contributions of the different BC source sectors (including long-range transport) to BC mass and number concentrations in the Eastern US.
- Quantify the contributions of the various source sectors to the effects of BC on climate.
- Elucidate the role of BC in local and regional meteorology, including temperature and the hydrological cycle.
- Quantify the effectiveness of various US and global strategies of reducing BC on BC mass and particle number concentrations, and radiative forcings.

Project Overview

- 1. Laboratory Studies**
 - Primary emissions characterization
 - Aging of primary emissions
- 2. Emission inventory development**
 - Source-resolved inventories
 - Inventories for number and sub-grid processing
- 3. Model extension**
 - Mixing state and optical properties
- 4. Black carbon and number concentrations**
- 5. Regional scale simulations**
- 6. Scenarios and controls**

BC Emissions, Chemical Aging, and Optical Properties

OA and BC Formation and Aging

Aethalometer



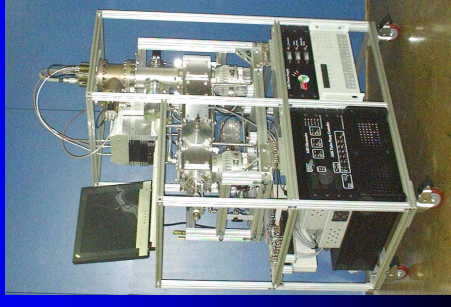
OA/BC from biomass burning



SP2



HR-AMS



Vehicle Testing in CARB Facility



Secondary aerosol production investigated with portable smog chamber

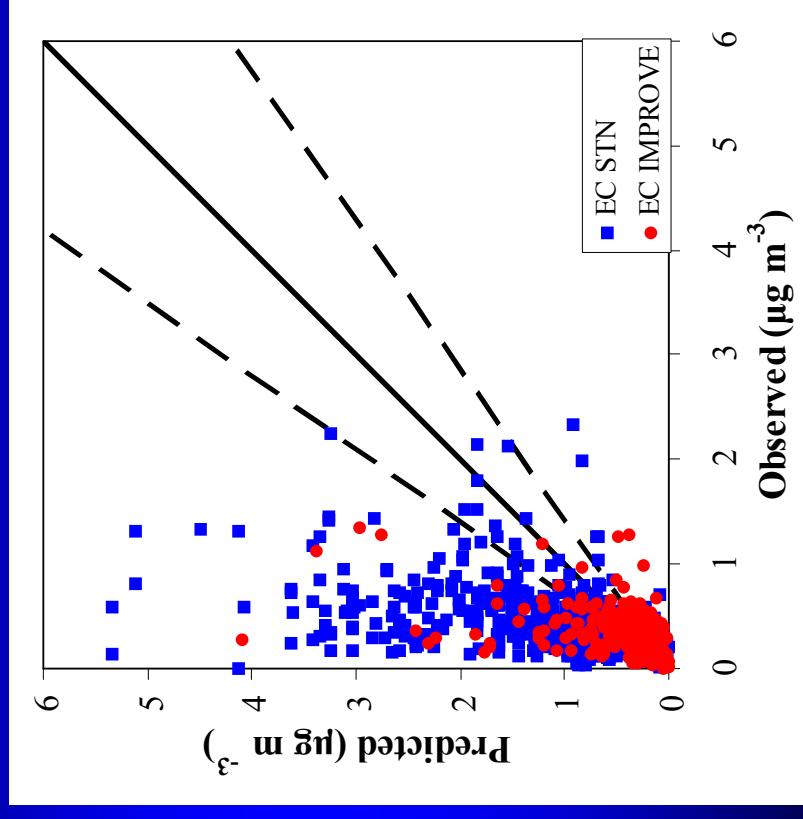
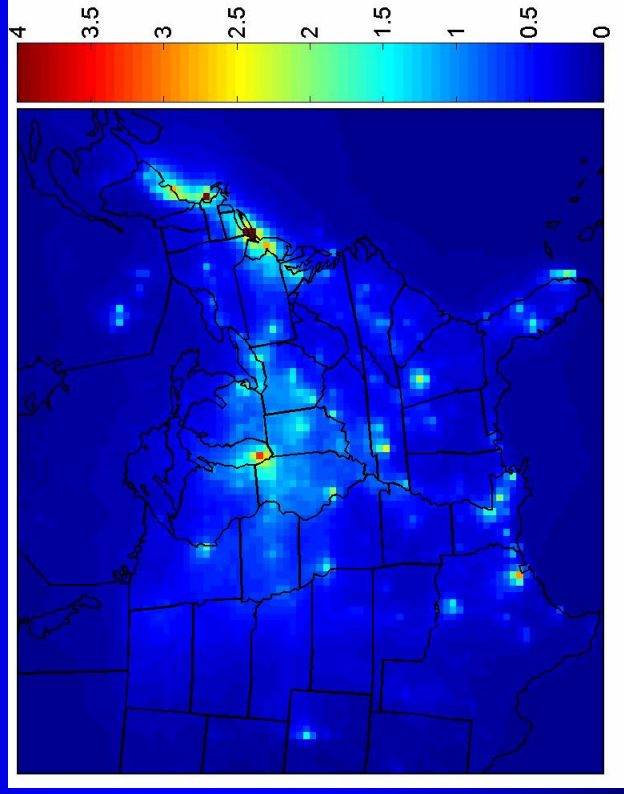
Carnegie Mellon

Airplane Engines



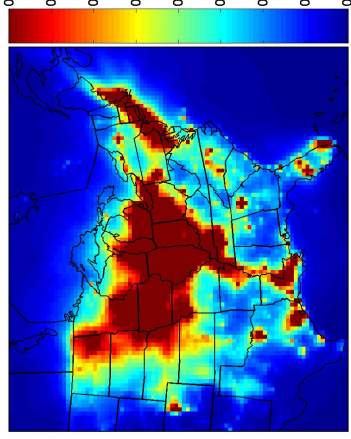
Black Carbon Emission Inventory PMCAMx Evaluation

Evaluation of PMCAMx: 2001 (Summer-Original Inventory)

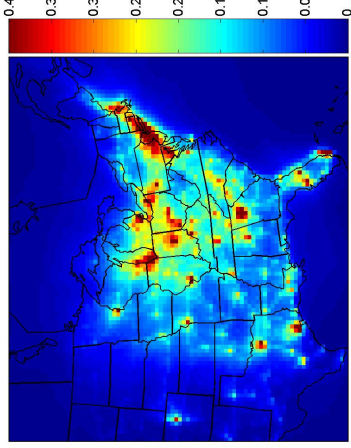


EC Source Contributions

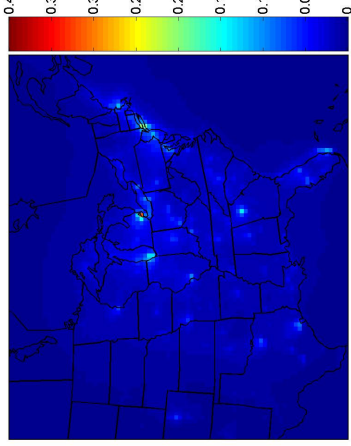
Off-road Diesel



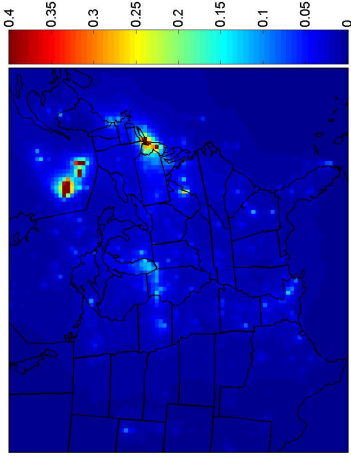
On-road Diesel



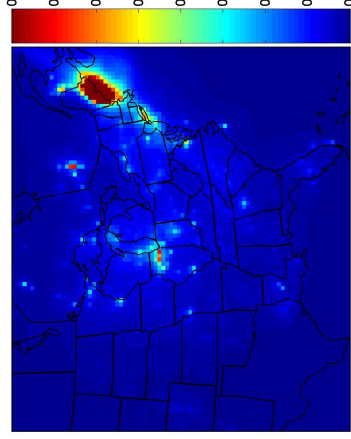
Gasoline



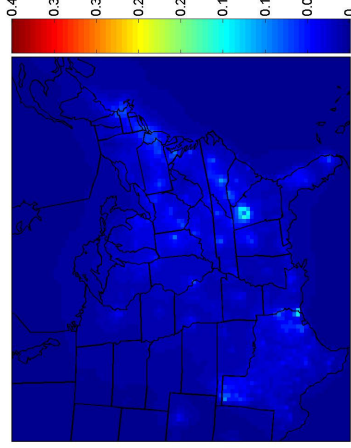
Other



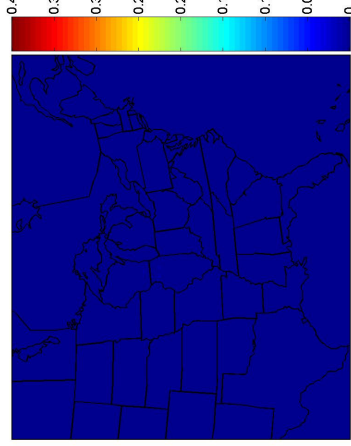
Wood



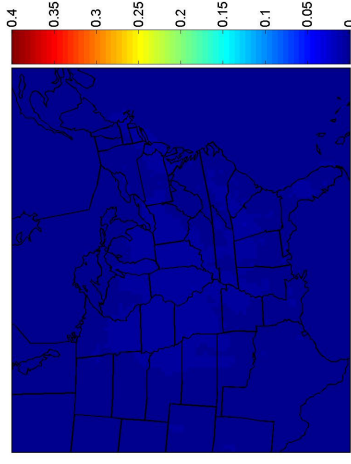
Biomass



Natural Gas

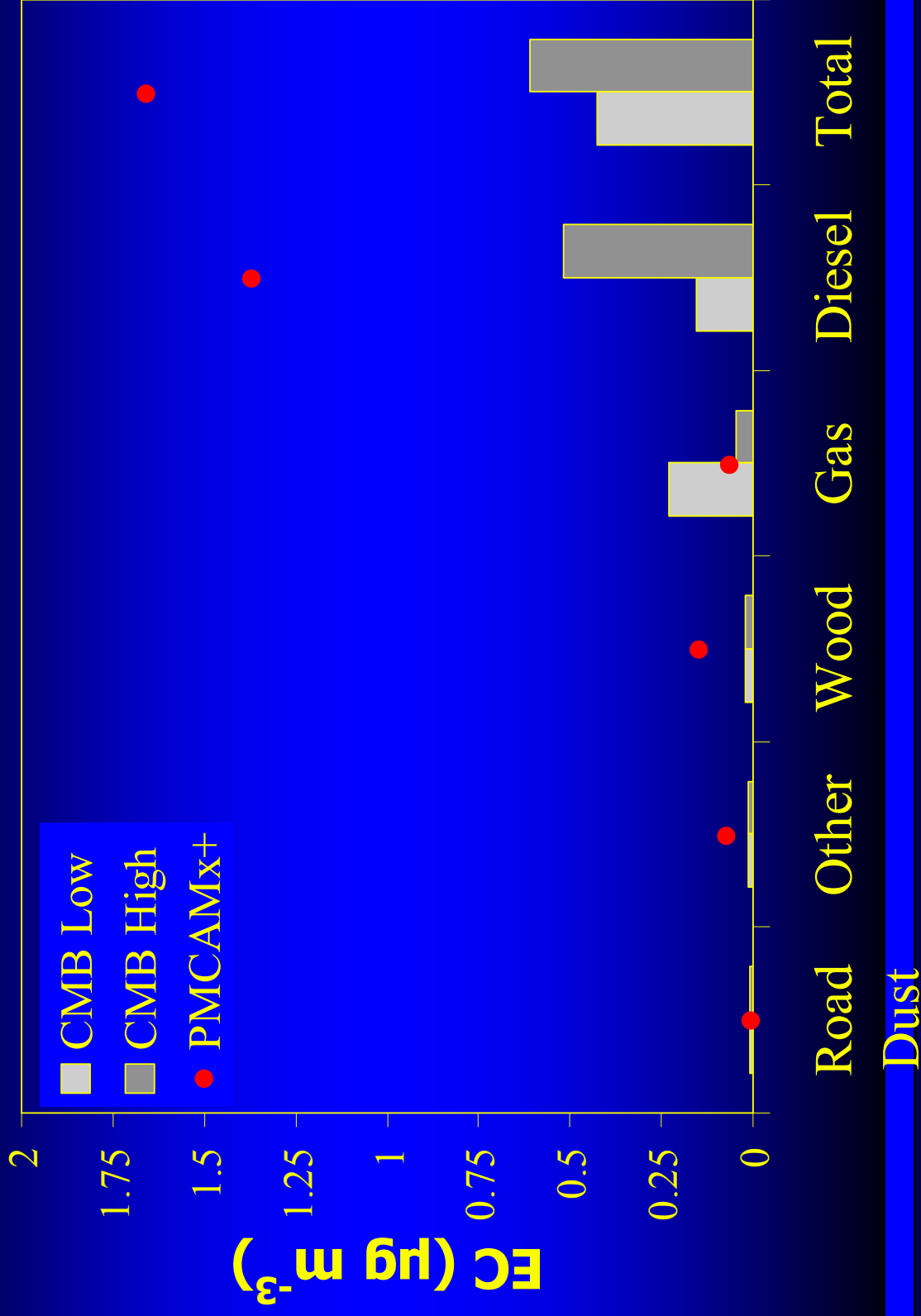


Road Dust

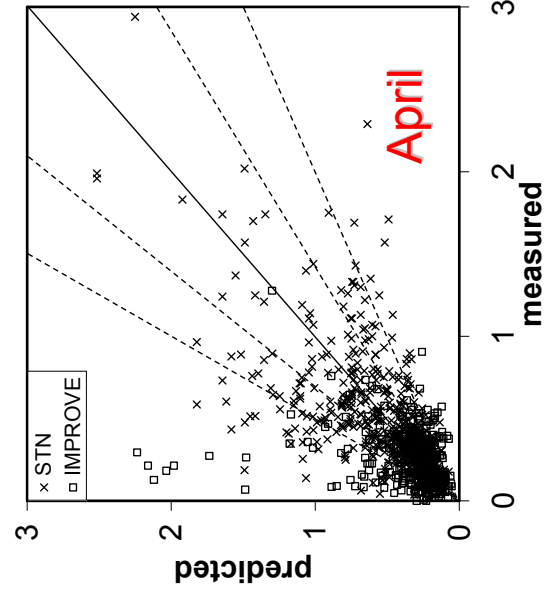
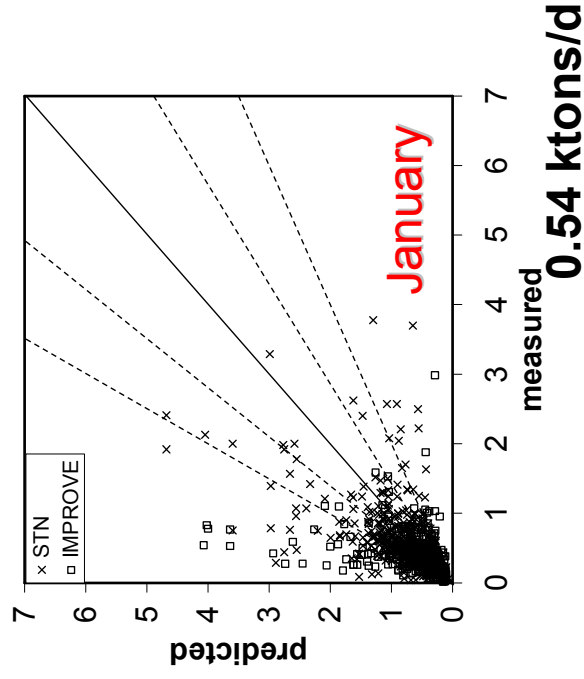
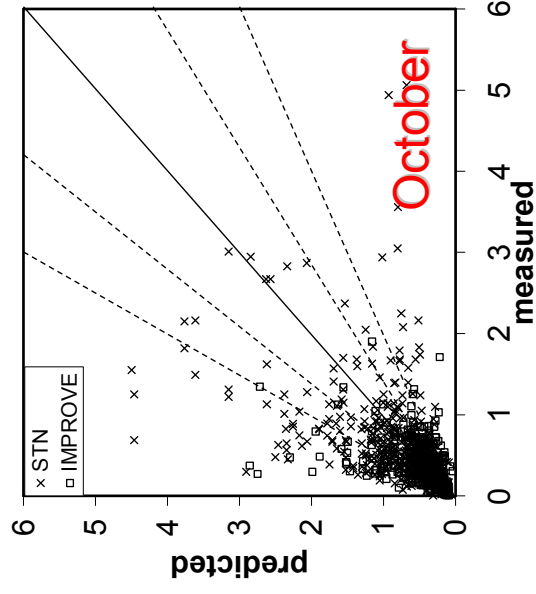
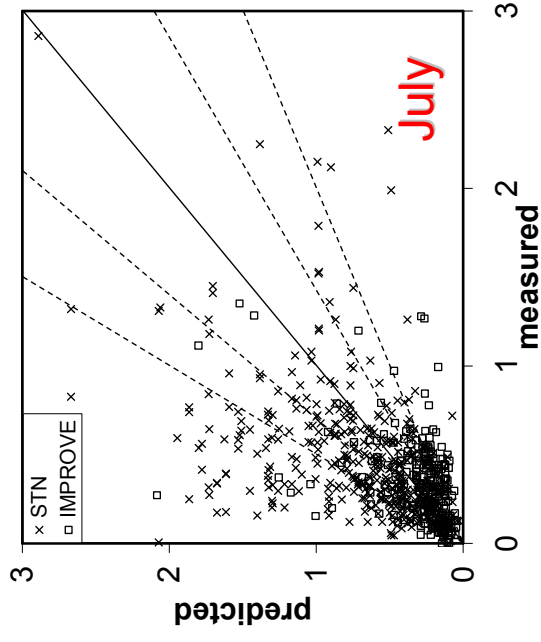


1.1 ktons/d (53% from off-road diesel)

EC in Pittsburgh: PMCAMx vs CMB



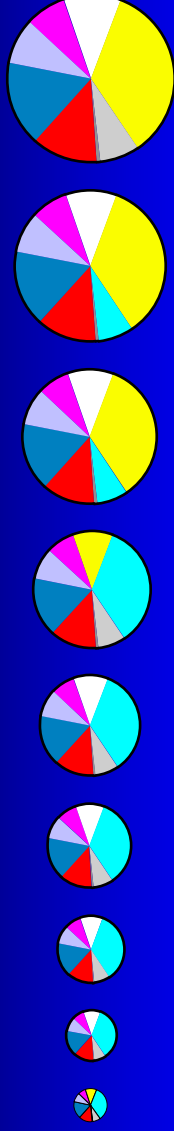
Improved 2001 EC Emissions



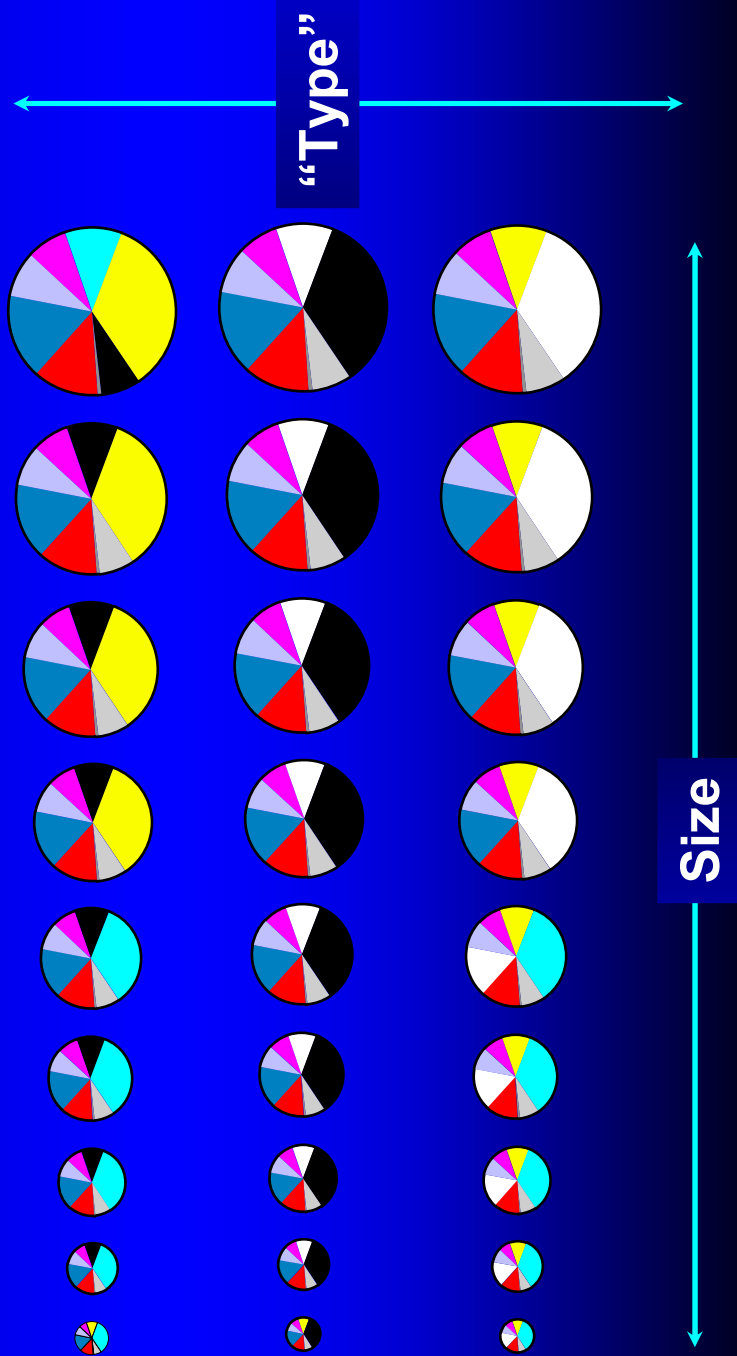
Improving Regional Scale BC Models

Relaxing the Internal Mixture Assumption

Internal
Mixture



External
Mixture

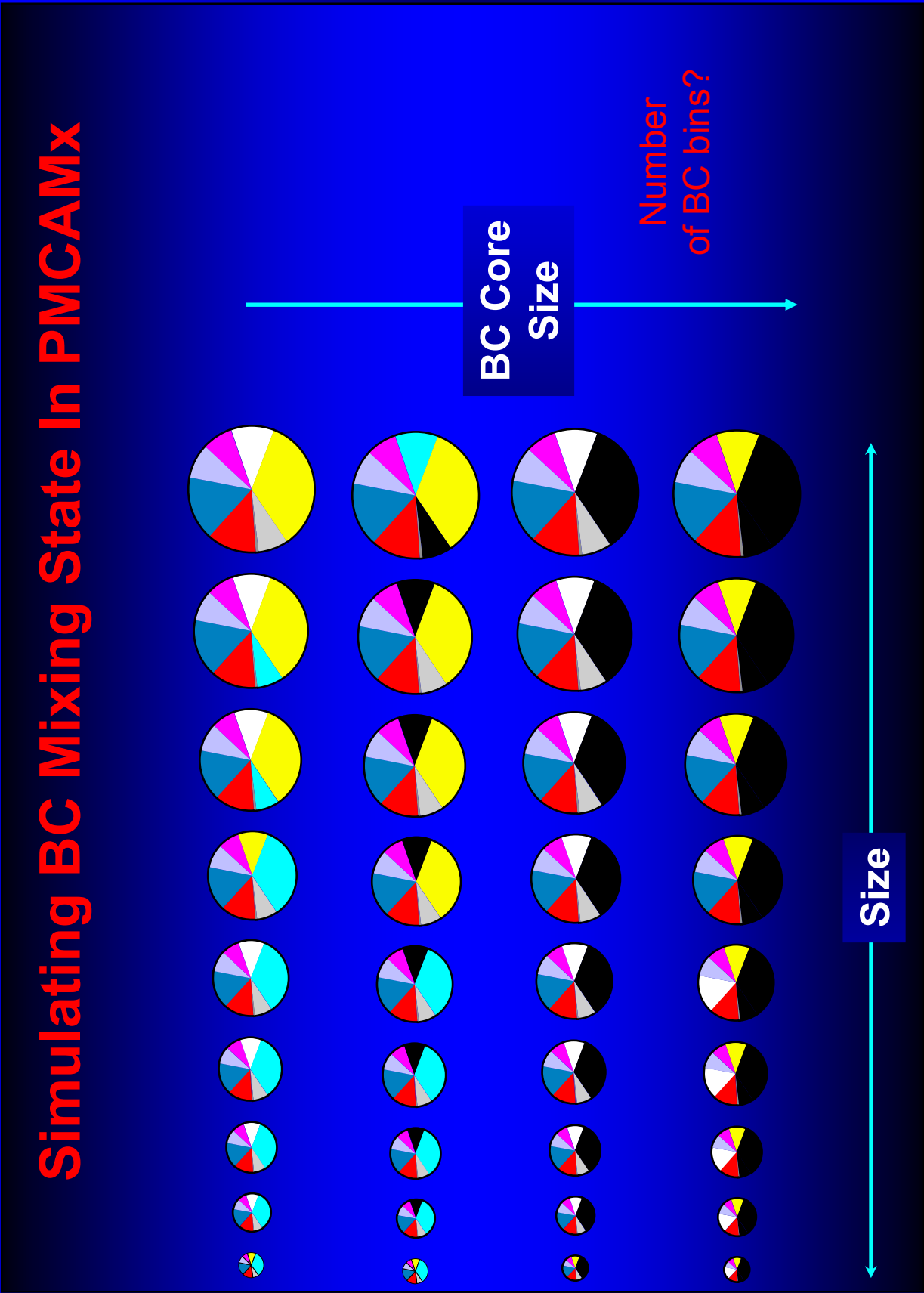


Simulating BC Mixing State In PMCAMx

BC Core Size

Number of BC bins?

Size



BC Core Size

Number of BC bins?

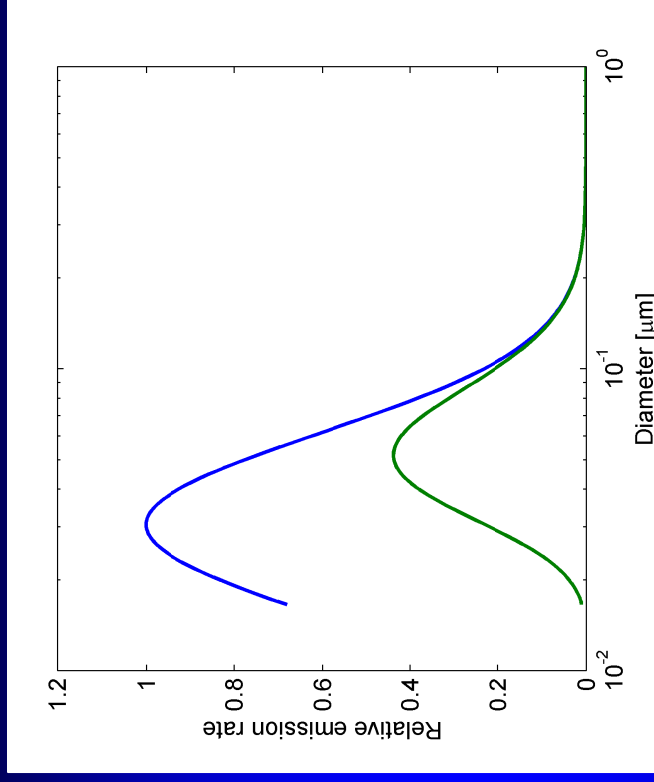
Size

BC and Aerosol Number Concentrations

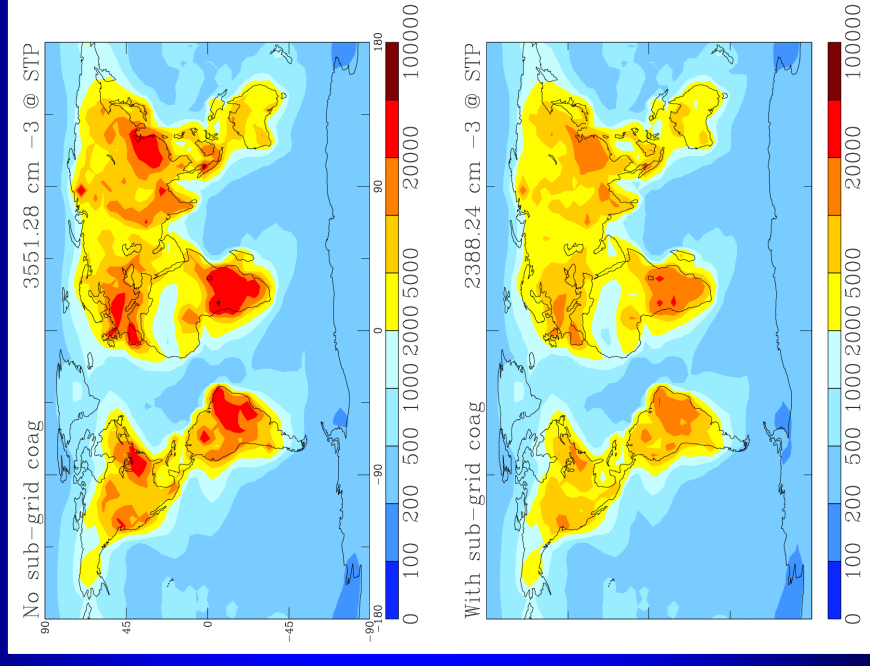
Parameterizing the effect of sub-grid scale aerosol dynamics on aerosol number emission rates

- Calculation of the probability that a given particle emitted inside the grid cell will survive and be available for transfer outside the cell.
 - function of the emitted particle size and the pre-existing aerosol size and the residence time in the grid cell.
- Net number of particles effectively emitted to the grid cell = size dependent emission rate in the inventory times this survival probability function.
- The method simultaneously conserves mass by adding the mass of particles lost by coagulation to the larger particle sizes.
- The approach is grid-size independent and can be used in models of all scales.

Test Results pre-processor

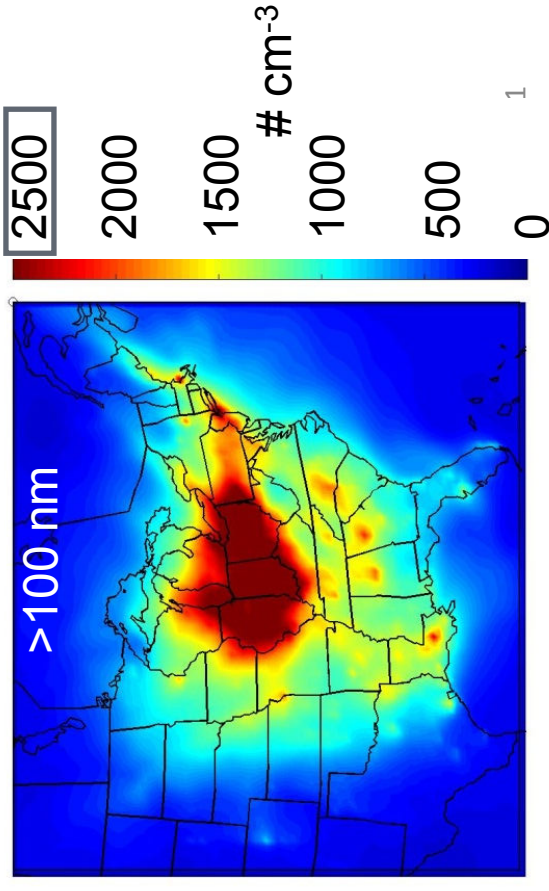
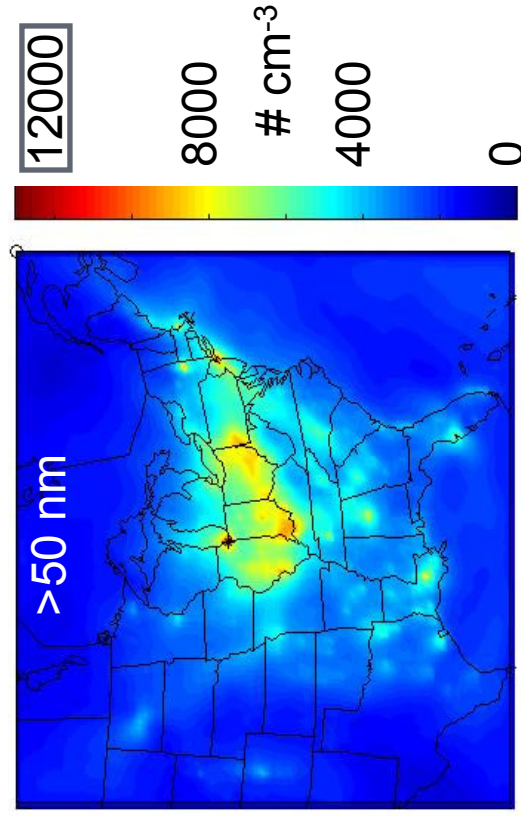
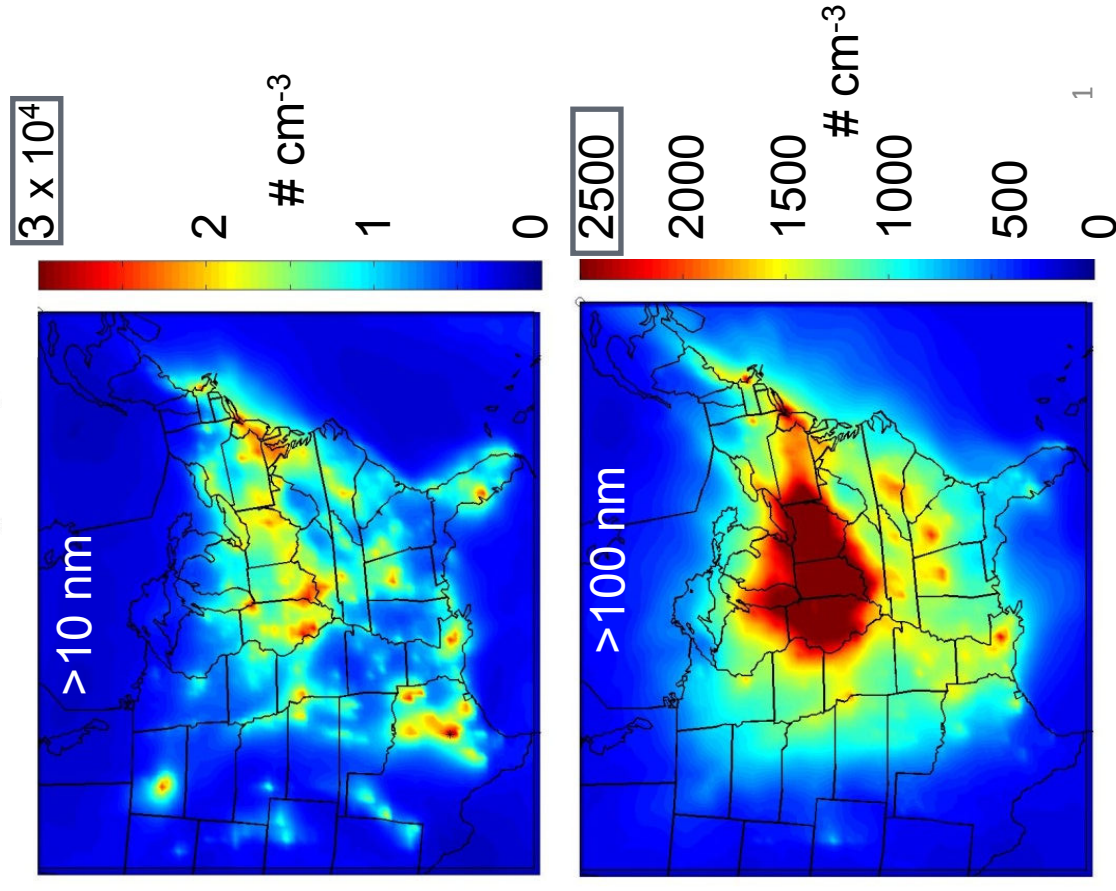
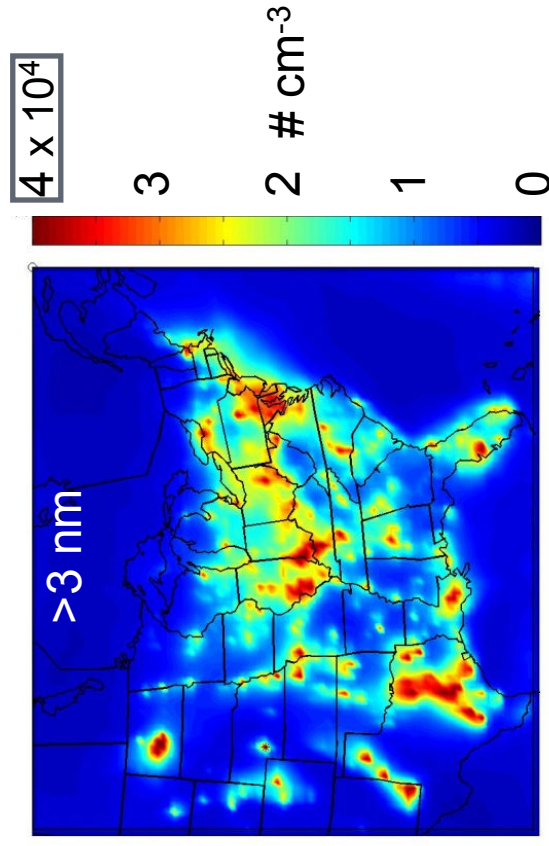


Total aerosol number (CN)  concentrations predicted for the surface layer of the model for summer months: without sub-grid coagulation (top) and with sub-grid coagulation (bottom).

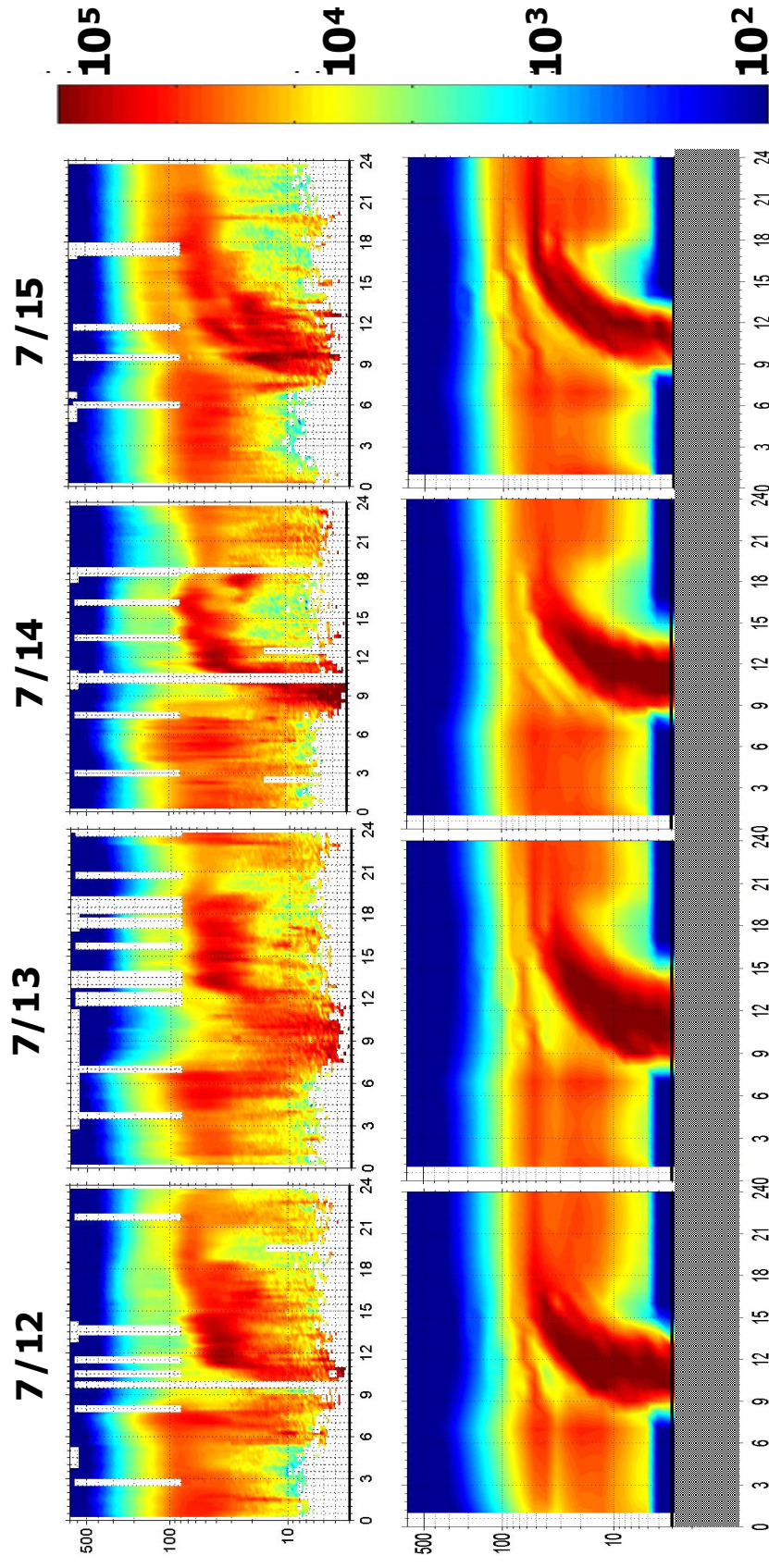


Predicted Total Number of Particles [cm^{-3}]

Summer

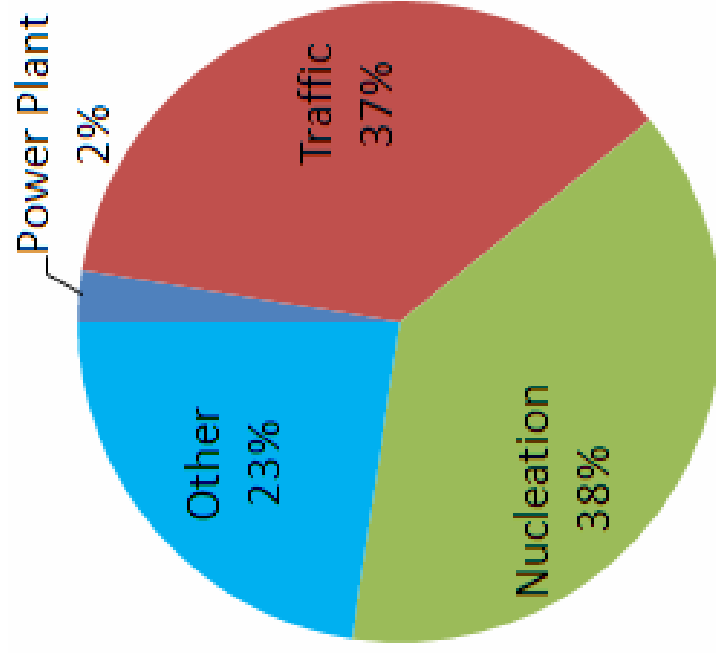


PMCAMx-UF Evaluation (Pittsburgh)



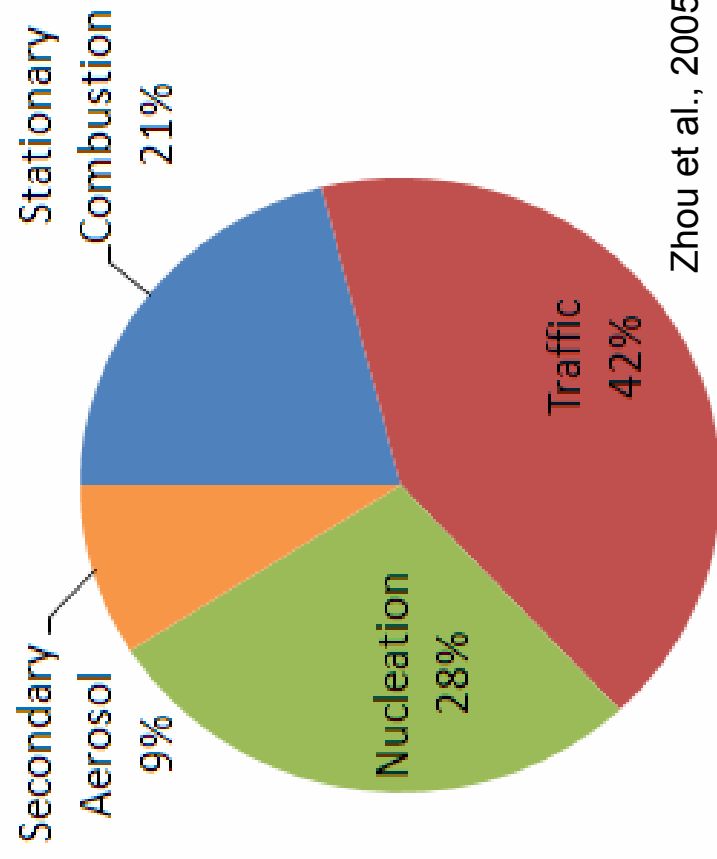
Sources of Measureable (>3 nm) Particle Number in Pittsburgh

Modeled



Predicted: 29,000 cm^{-3}

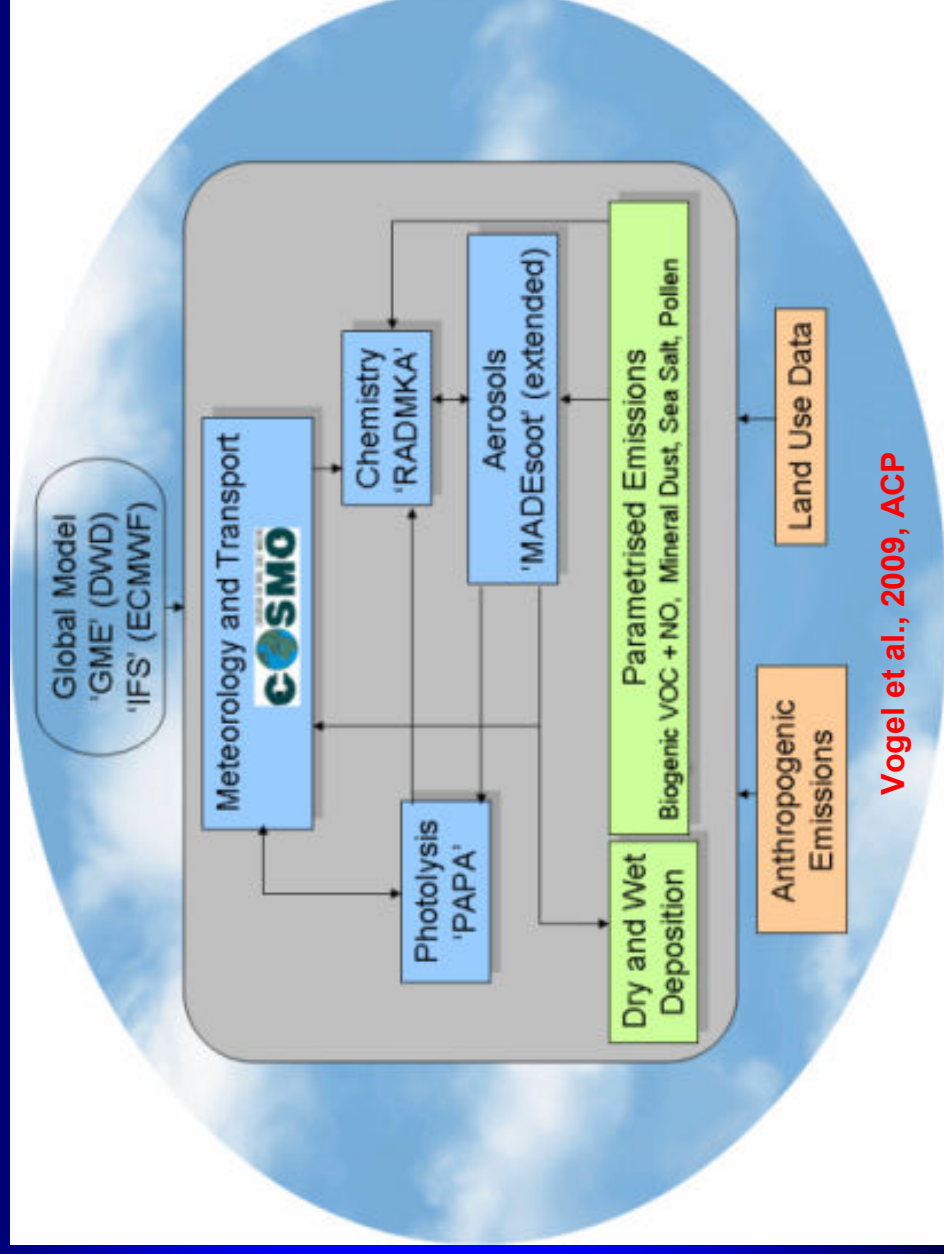
Calculated from Measurements



“Measured”: 26,000 cm^{-3}

BC Effects on Regional Meteorology

COSMO-ART: Aerosols and Reactive Trace gases

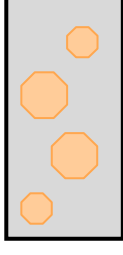


Vogel et al., 2009, ACP

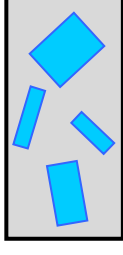
BC Modeling in COSMO-ART

Non-Interactive modes

3 Mineral dust modes

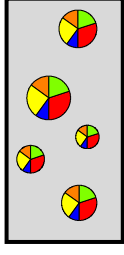


3 Sea salt modes



Interactive modes for SO_4^{2-} , NO_3^- , NH_4^+ , SOA, soot

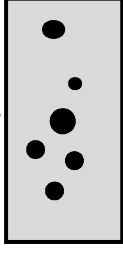
2 mixed modes without soot



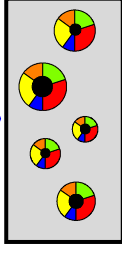
Gas phase chemistry



1 pure soot mode



2 mixed modes with soot



COSMO-ART Application in the Eastern US

- **Additional improvements of PM modules in COSMO-ART**
 - Emissions, optical properties
- **Three types simulations**
 - All processes active
 - Zero BC concentrations
 - Zero emissions of specific BC sources (including co-pollutants)
- **Effect of BC on regional meteorology (temperature and hydrological cycle)**
- **Regional indirect climate forcing**

Future Emission Scenarios and Mitigation Options

Source-Specific Emission Controls

- **Focus on US sources**
 - Additional scenarios for international BC emission changes
 - Use of GLSS/TOMAS for global scale simulations
- **Will quantify changes in:**
 - BC concentrations
 - PM_{2.5} concentrations
 - Ultrafine and total particle concentrations
 - Regional scale climate forcings

Project Overview

1. **Laboratory Studies**
 - Primary emissions characterization
 - Aging of primary emissions
2. **Emission inventory development**
 - Source-resolved inventories
 - Inventories for number and sub-grid processing
3. **CTM continued**
 - Mixing state and optical properties
4. **Black carbon mass and number concentrations**
5. **Regional scale simulations (chemistry and meteorology)**
6. **Scenarios and controls**

