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Assessing the Anthropogenic Fugitive Dust Emission Inventory and Temporal Allocation using an Updated Speciation of Particulate Matter

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Office of Research and Development
National Exposure Research Laboratory,Atmospheric Modeling and Analysis Division

September 23, 2010

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Atmospheric Fine Particles are a health issue

- Health studies have shown a significant association between exposure to fine particles and adverse health effects
- Fine particles can aggravate heart and lung diseases and have been linked to effects such as: cardiovascular symptoms; cardiac arrhythmias; heart attacks; respiratory symptoms; asthma attacks; and bronchitis.
- 1997: EPA established National Ambient Air Quality Standards for $PM_{2.5}$
  - annual : 15 ug/m^3
  - 24 hours: 65 ug/m^3 (revised to 35 ug/m^3 in 2006)

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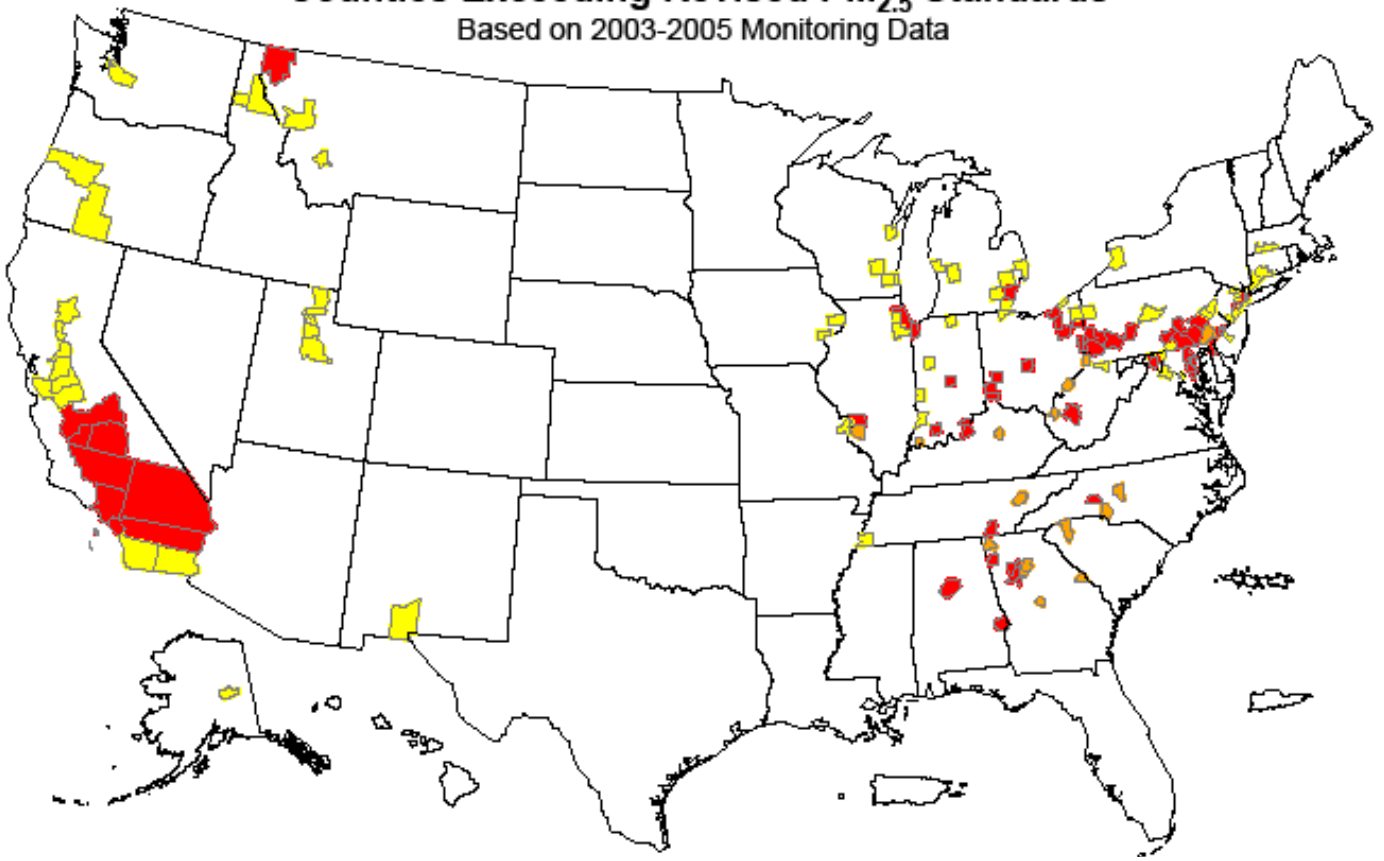
Counties Exceeding Revised $PM_{2.5}$ Standards

Based on 2003-2005 Monitoring Data



Legend

County with monitor exceeding:	Number of Counties
both annual (15 µg/m3) and 24-hour (35 µg/m3) $PM_{2.5}$ standards	56
ONLY the 24-hour $PM_{2.5}$ standard (35 µg/m3)	70
ONLY the annual $PM_{2.5}$ standard (15 µg/m3)	17
Total Counties Exceeding	**143**

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Problem: CMAQ overpredicted PM2.5 for January 2002 by a factor of 2

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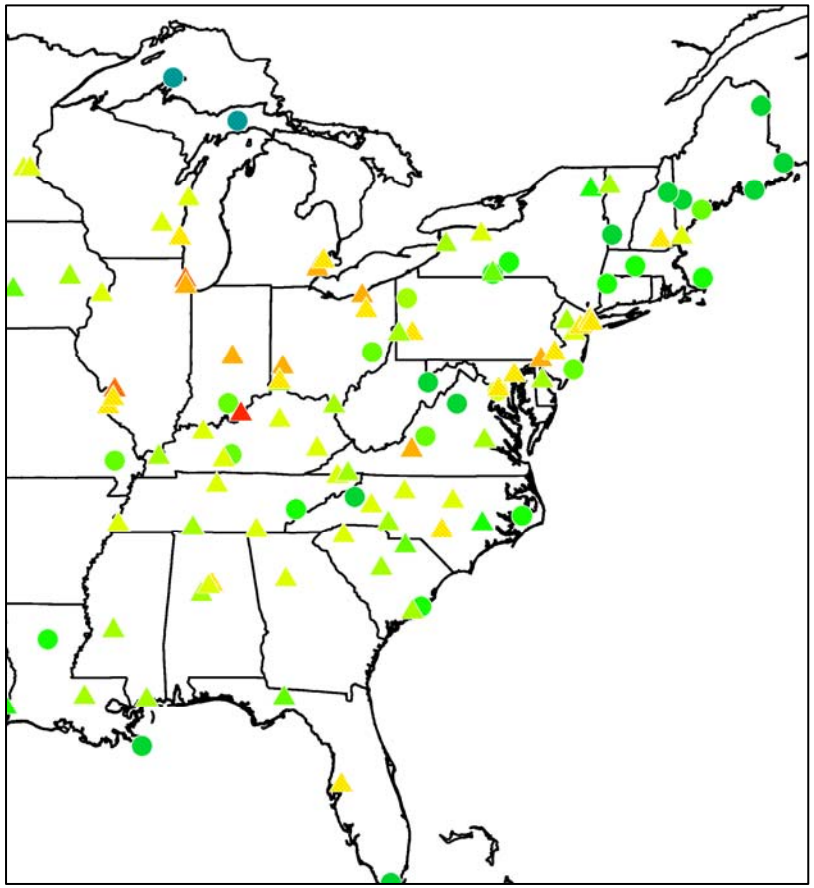
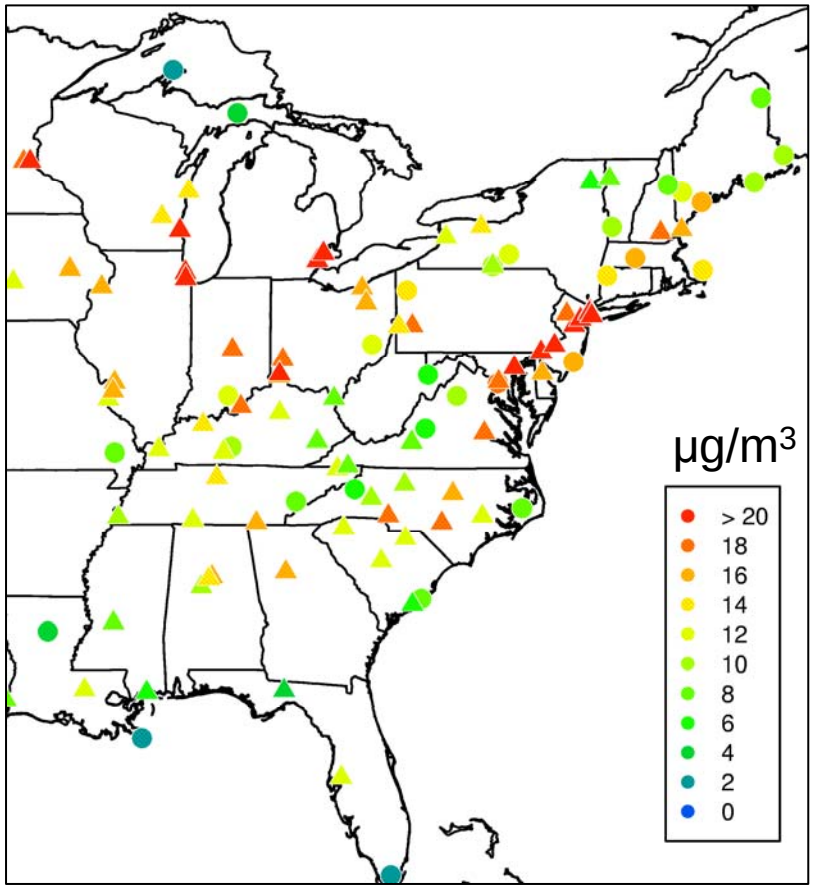
Observations (IMPROVE and CSN)



CMAQ



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How to improve and diagnose $PM_{2.5}$ emission estimates used in air quality modeling?

(1) Revise speciation profiles for PM-Other to diagnose bias

(2) Improve temporal allocation

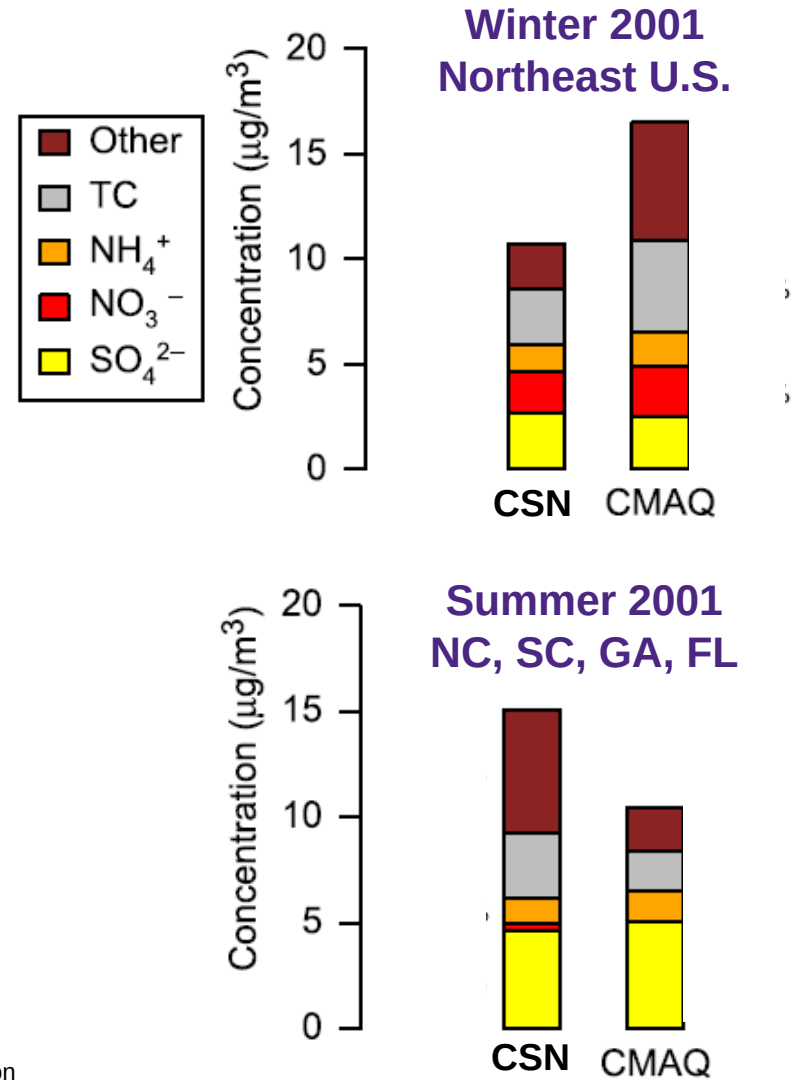
(3) Revise “transportable” fraction

(4) Adjust for meteorological effects

(5) Improve estimates for annual emissions

What is the source of the discrepancy between modeled and observed concentrations?

- Appel et al. (2008) evaluated CMAQ v4.5 across network of urban monitoring sites **Chemical Speciation Network (CSN)** in eastern U.S.
  - Examined the speciated contributions to $PM_{2.5}$
  - Stratified evaluation into 4 seasons and 4 geographic regions
- In 10 of 16 subsets, CMAQ's PM-Other exhibited largest compositional bias.
  - Positive bias in Winter & Fall
  - Negative bias in Summer



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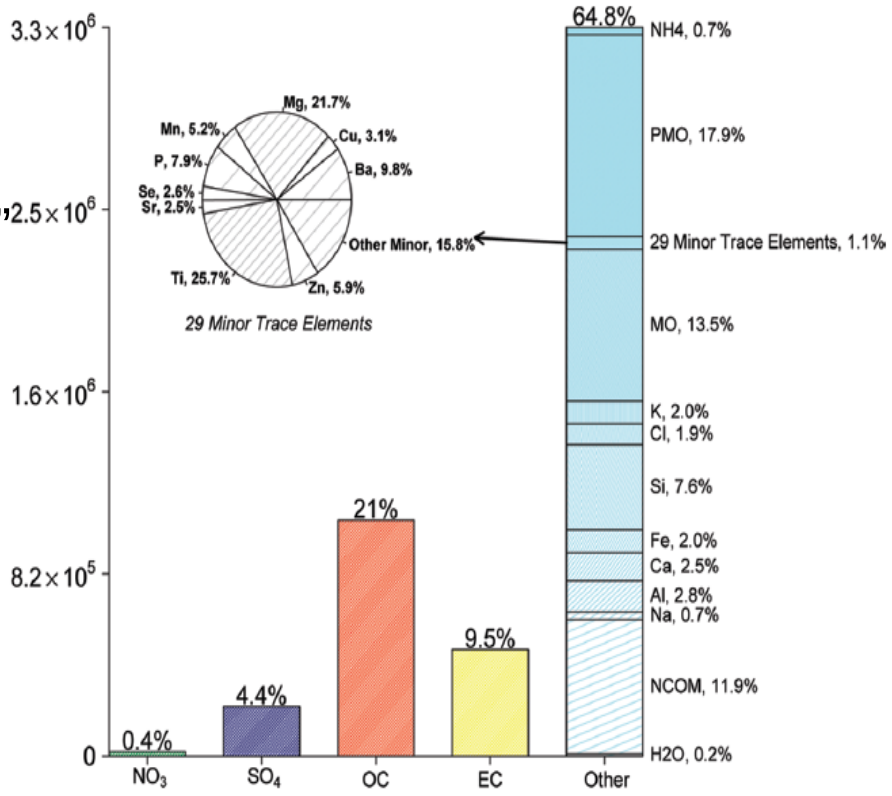
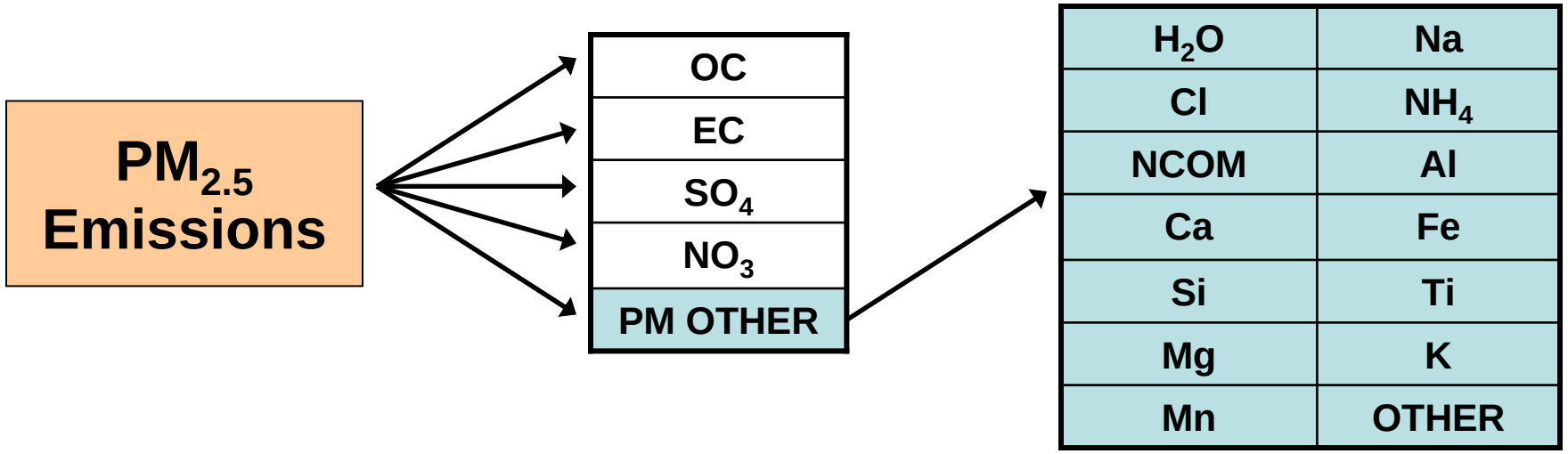
Revise speciation profiles for PM-Other to diagnose bias

- Traditionally, $PM_{2.5}$ in the inventory has been speciated into OC, EC, SO4, NO3, and "Other"
  - 65% of the Inventory falls in "Other"
- Reff et al. (*ES&T* 2009)
  - analyzed source characterization studies in the SPECIATE database
  - constructed emission inventory of trace elements, metal oxides, and non-carbon organic mass (NCOM)
  - reduced the unspeciated $PM_{2.5}$ mass from 65% to 18%



Revise speciation profiles for PM-Other to diagnose bias

- PM-other emissions were split in 14 species



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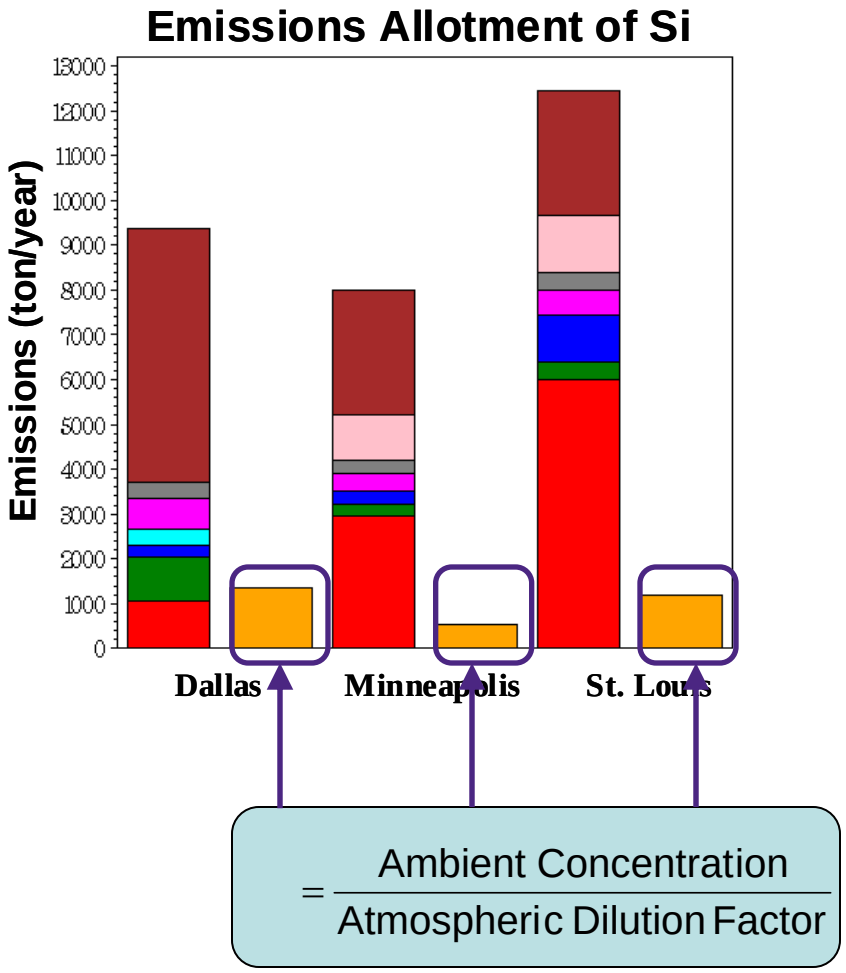
What is the major source of PM-Other?



- Comparisons of gridded inventory with CSN data from 21 cities reveals persistent positive biases in the emissions of
  - **Agricultural soil**
  - **Unpaved road dust**
- These sources fall in the National Emissions Inventory sector called anthropogenic fugitive dust

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Plot provided by A. Reff

Improve Temporal Allocation

- In the emissions processing, we apply temporal factors on a monthly, weekly, and diurnal basis.
- The monthly and weekly profiles generate flat temporal allocation throughout the year
- A review of the profiles suggests updating the temporal profiles to reflect activity associated with other parts of the Inventory will be more representative

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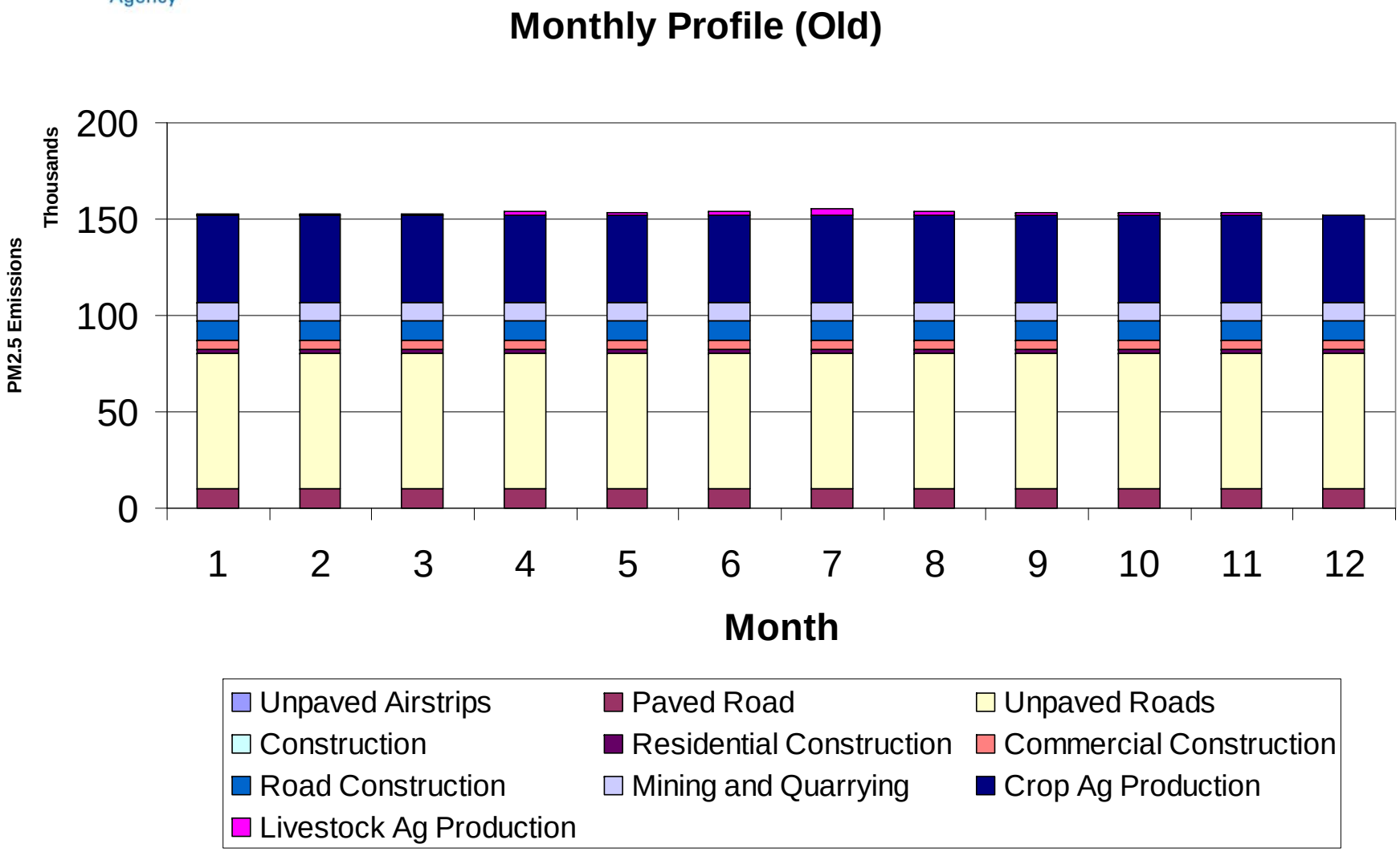
Improve Temporal Allocation

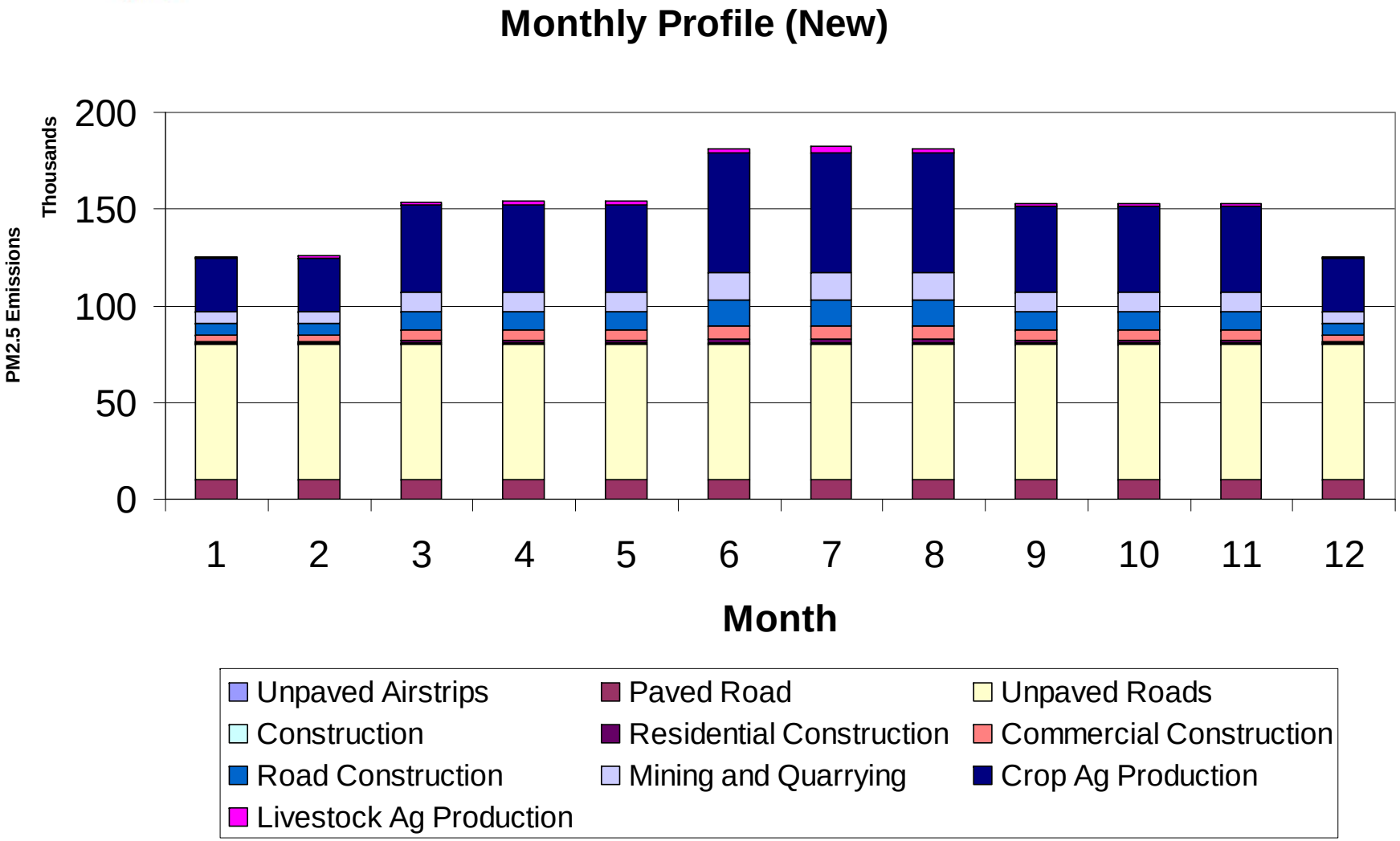
Changes made to the temporal allocation by source group:

- Paved & unpaved road dust: use profiles from on-road mobile activity (light duty gas vehicles) for all road types (except for industrial unpaved roads)
- Residential, commercial & road construction: use activity profile from non-road equipment
- Ag production – crops: use profile for non-road agriculture equipment

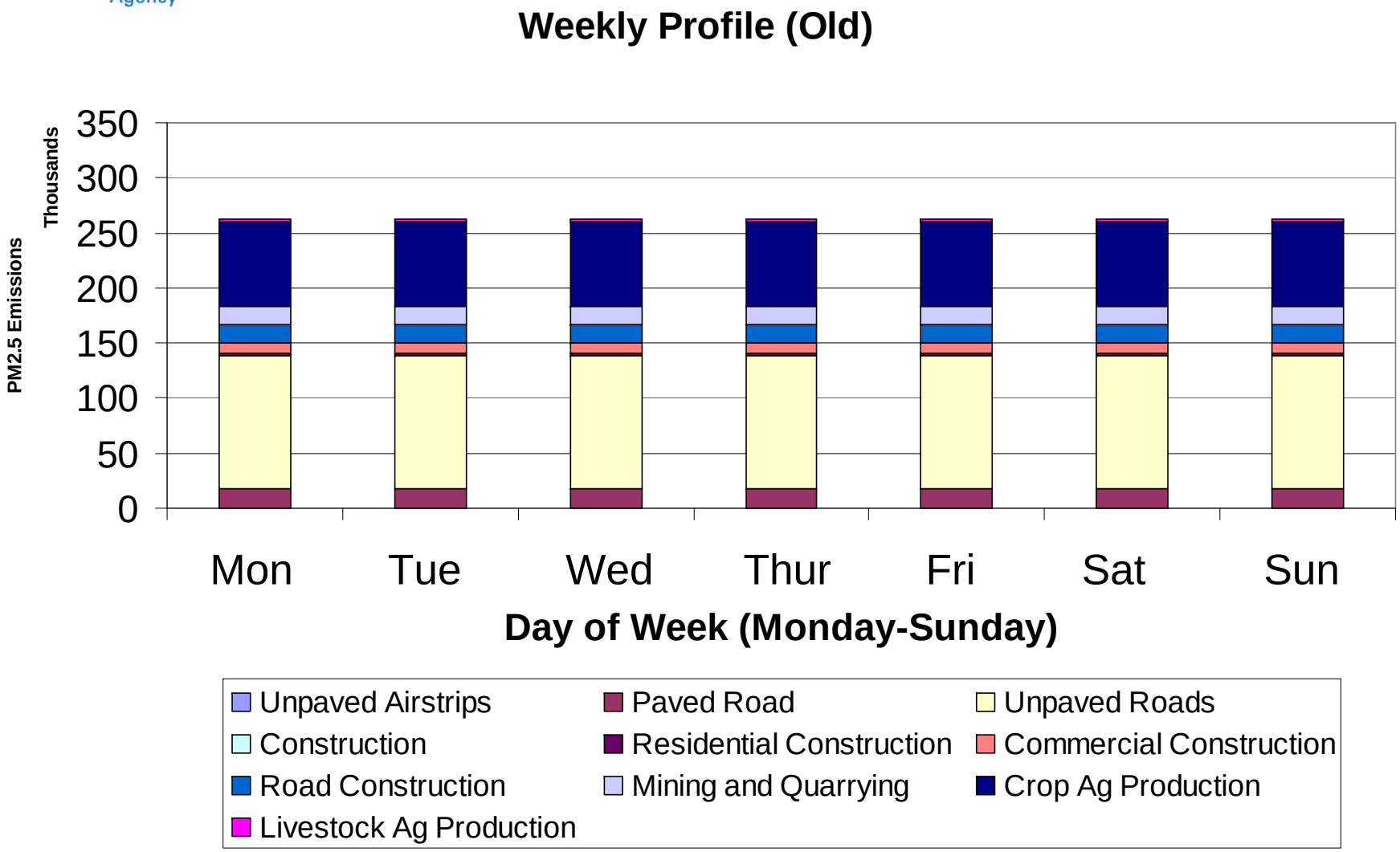
Old Temporal Allocation



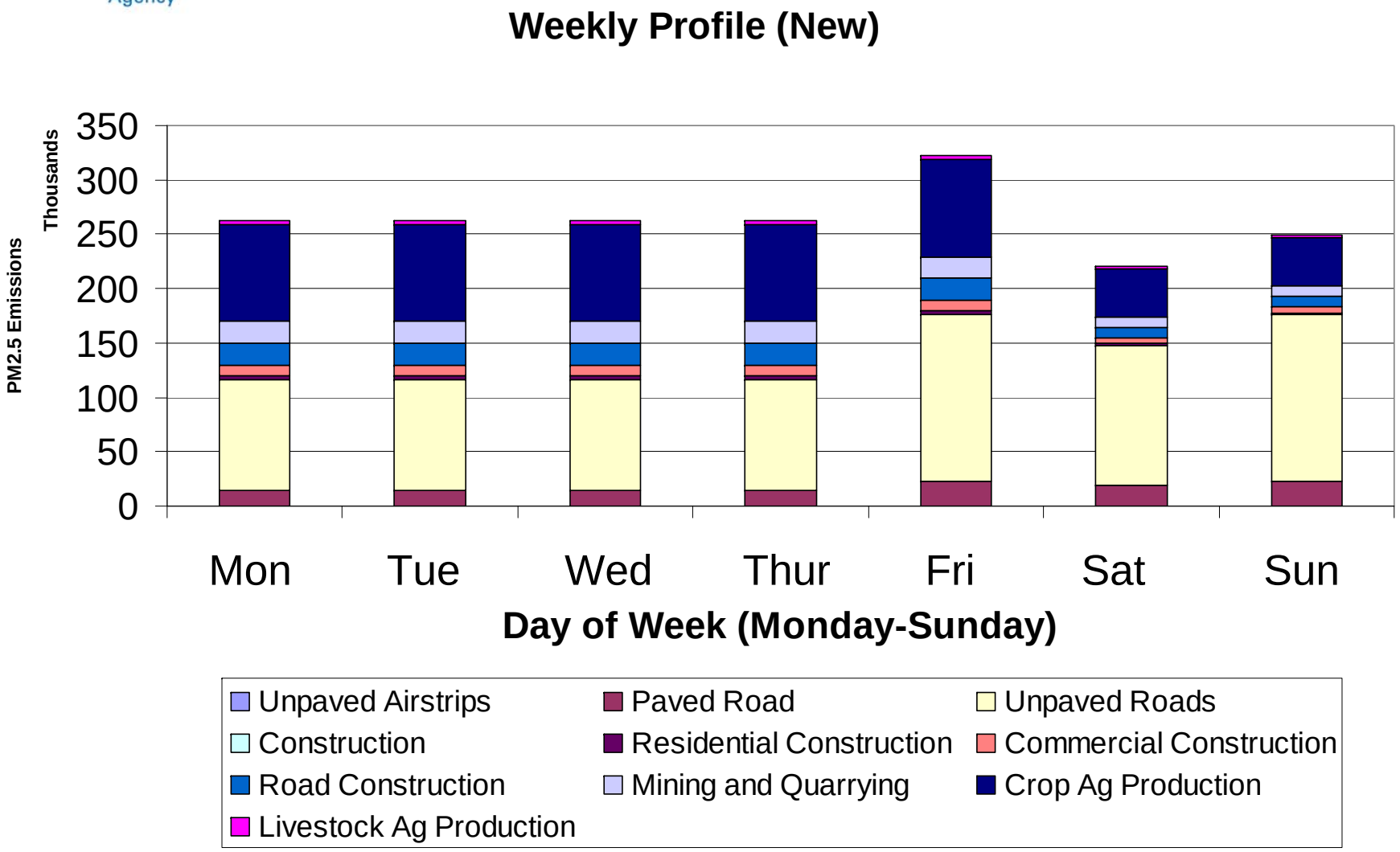
Improve Temporal Allocation



Old Temporal Allocation



Improve Temporal Allocation



Old Temporal Allocation

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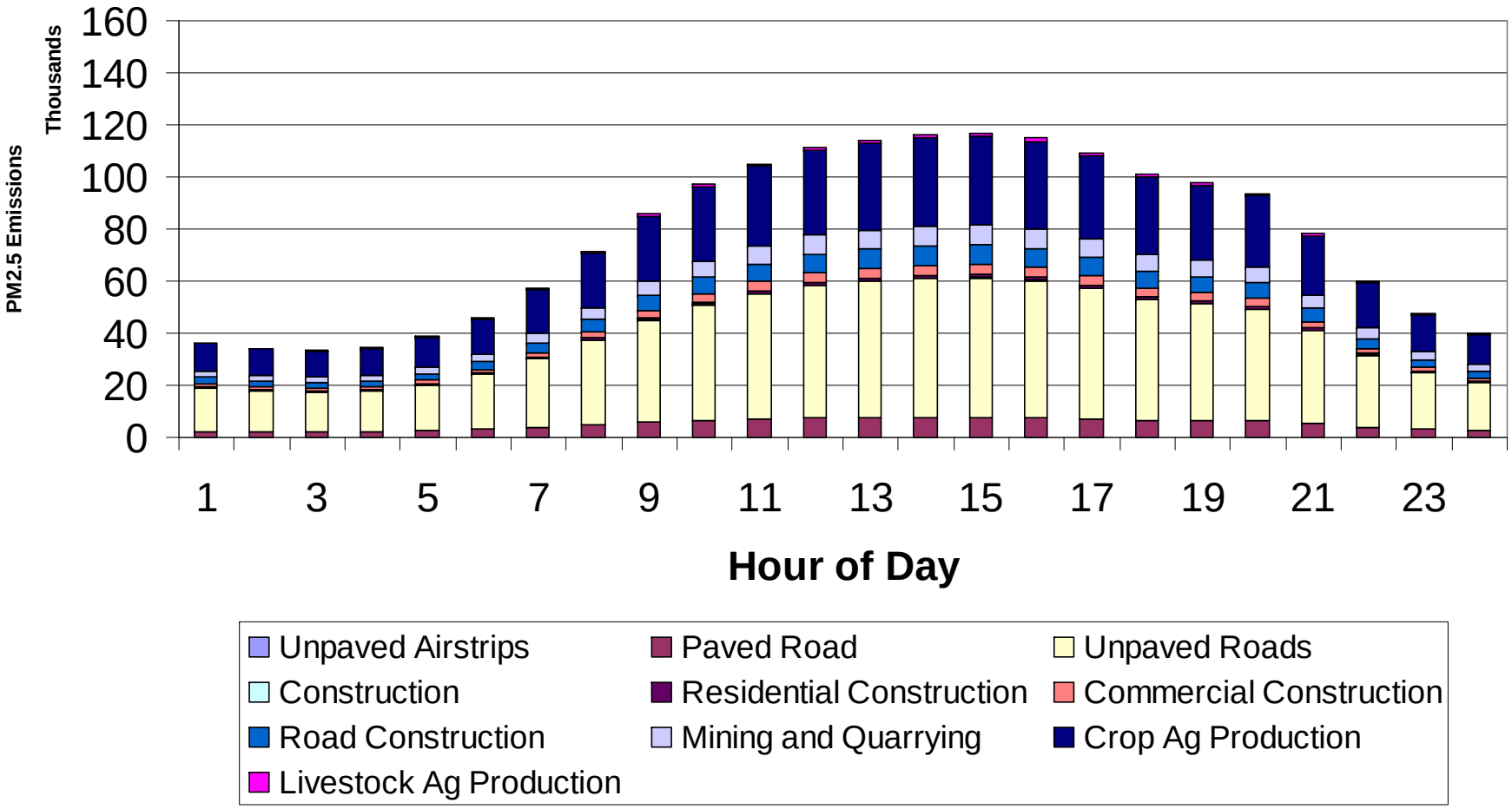
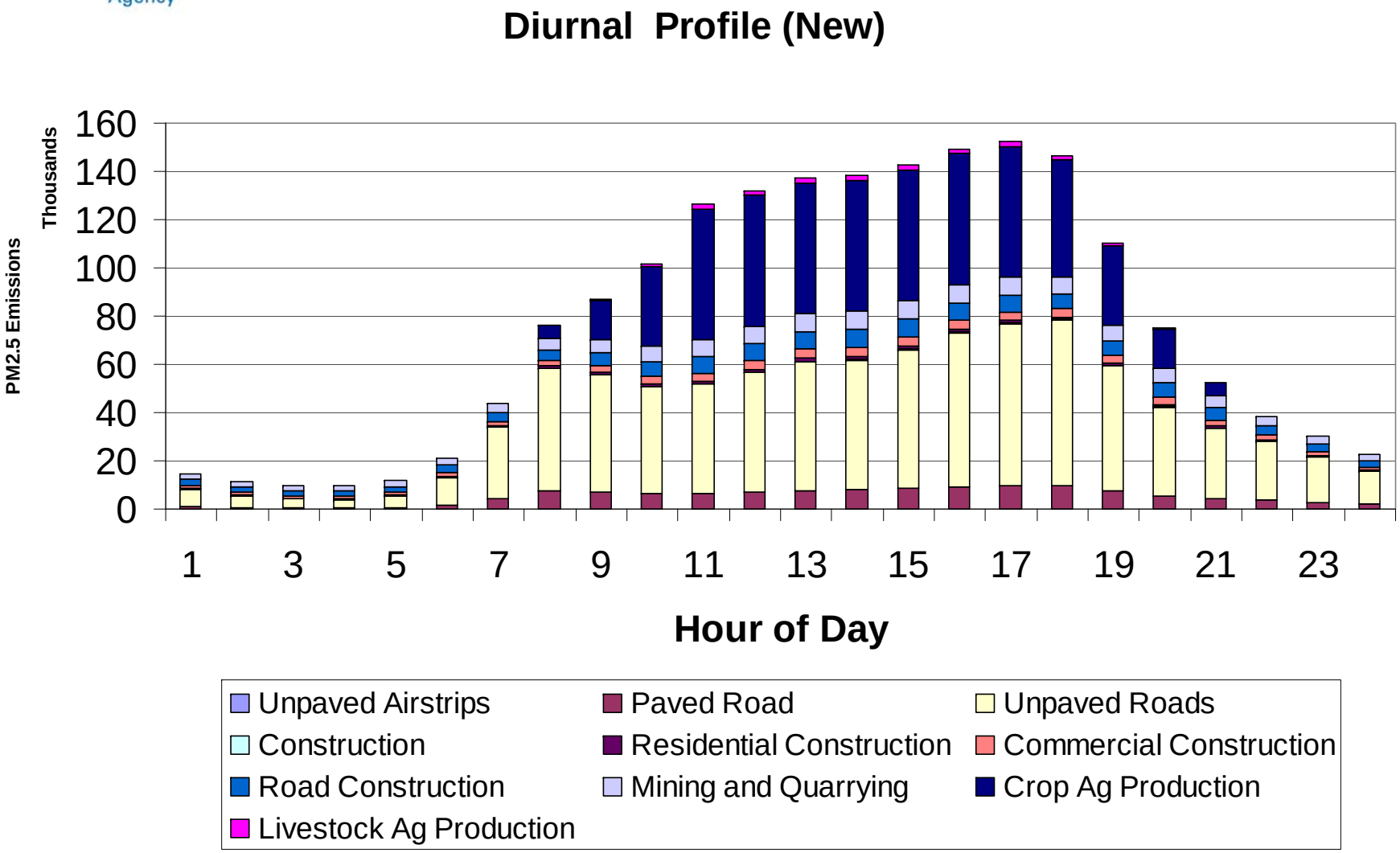
Diurnal Profile (Old)

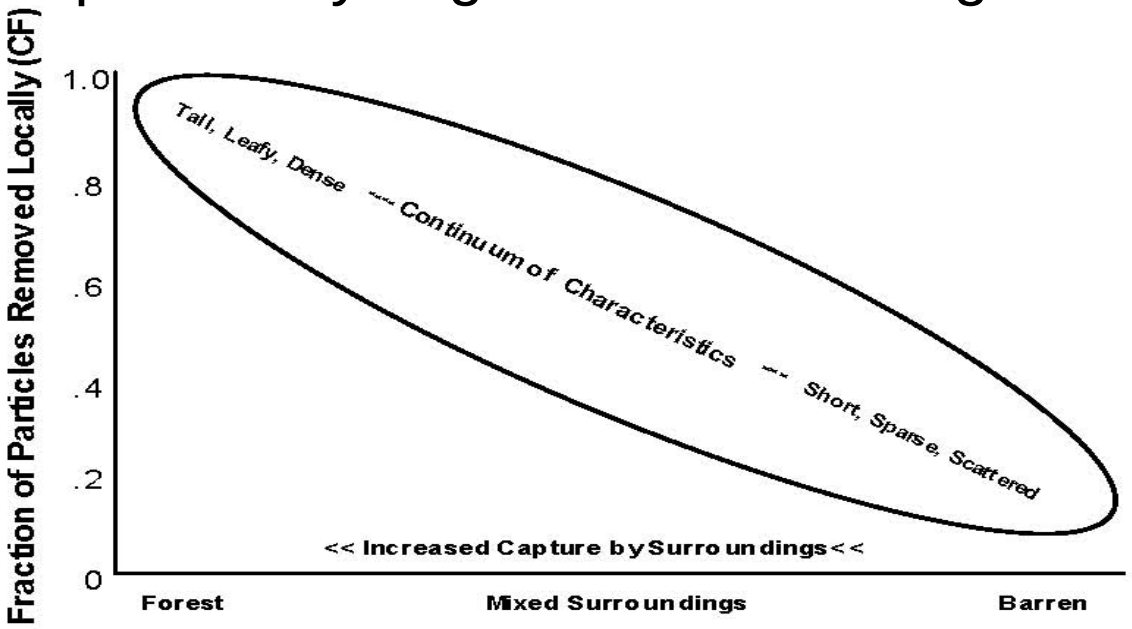


Improve Temporal Allocation



Revise "Transportable" Fraction

- Pace (2002, 2006) introduced a transportable fraction based on land use to estimate the fraction of dust that is not "captured" by vegetation or buildings



Conceptual Model – Near Source Capture of Dust Particles by Surface Cover

Revise “Transportable” Fraction

Land Use data divided into 5 groups with capture fraction for each type:

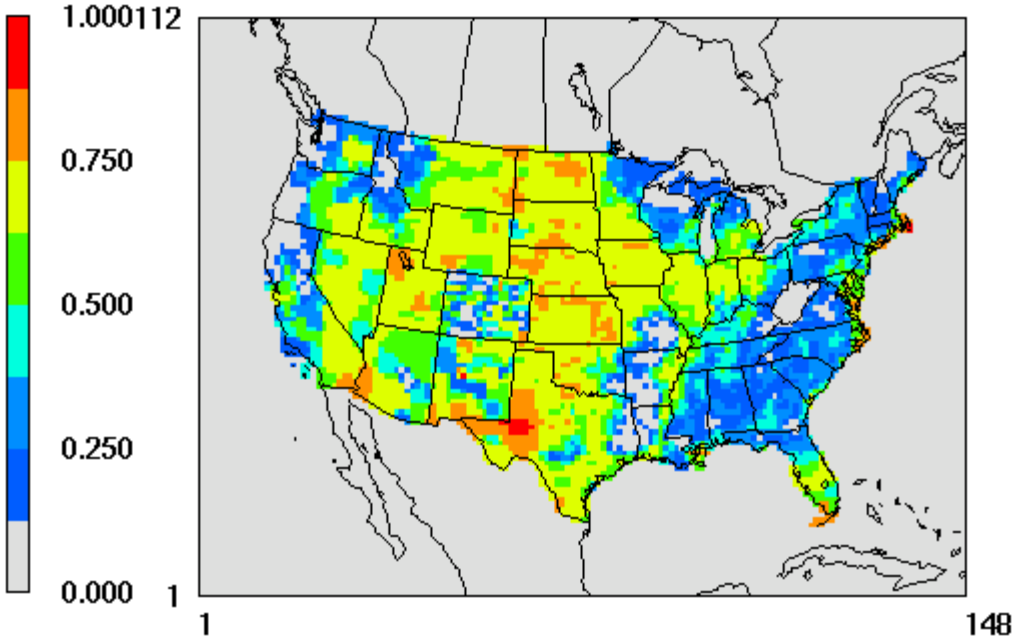
- barren &water
- agricultural
- grasses, scrub and sparsely wooded
- urban
- forested

Pace (2006): Based on county level data

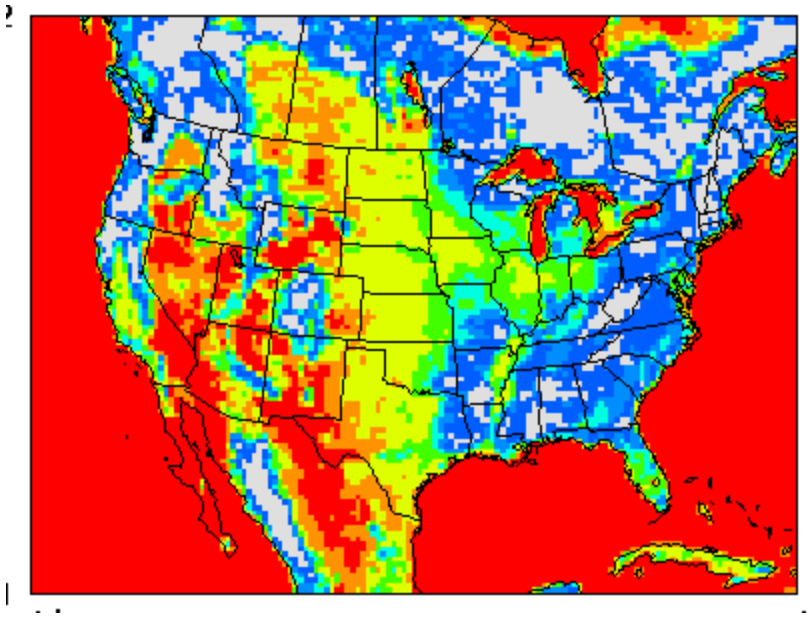
Revised: Based on 1km North America Land Use for biogenic emission estimates

Revise “Transportable” Fraction

Tom Pace (2006) Transportable Factor



Revised Method



How to Improve and Diagnose Fugitive Dust Emission Estimates used in Air Quality Modeling?

(1) Revise speciation profiles for PM-Other to diagnose bias

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(4) Adjust for meteorological effects

(5) Improve estimates for annual emissions

Done Underway

Updated Emissions were tested in a chemical transport model with this setup:

- CMAQ V4.7.1, 24 Layers
- MCIPv3.4beta3
- MM5 Meteorological Model
- 36km domain CONUS
- Updates to Emissions Processing to track Trace Metals in CMAQ
- January and July 2002, with 10 day spin-up (Dec 22-Dec 31 2001 and Jun 21-Jun 30, 2001)

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Three Models Runs

- BASECASE: No changes to temporal allocation or Transportable Fraction, but updated speciation
- NEW: Updates to temporal factors and revised transportable fraction
- NODUST: Removed all sources of fugitive dust

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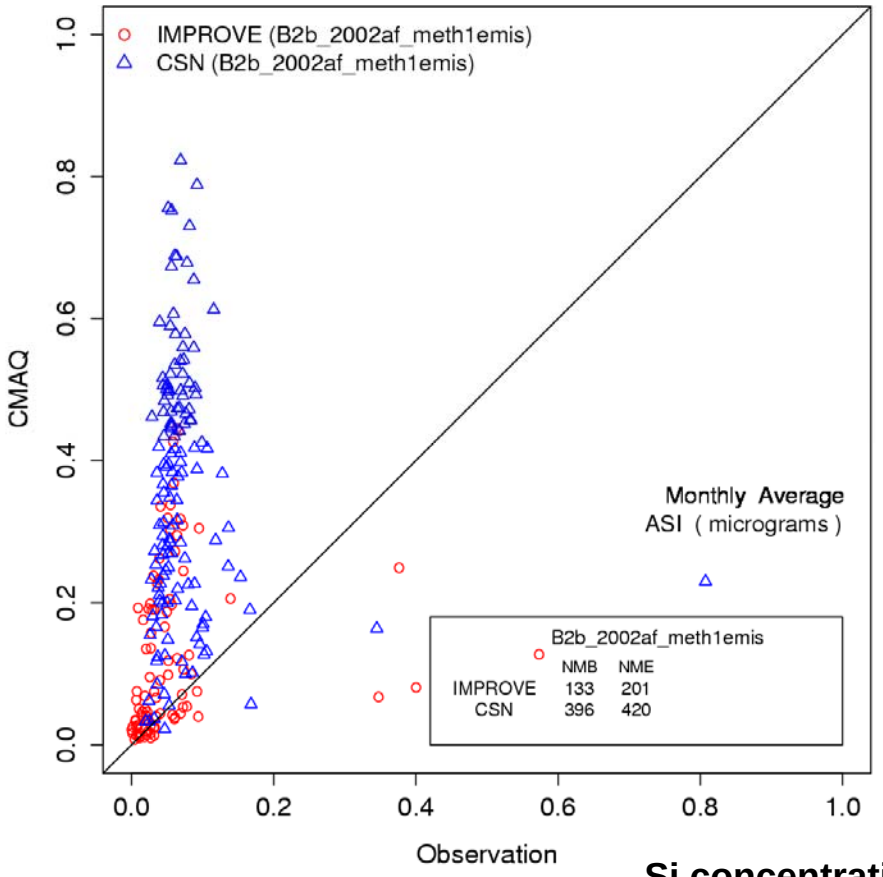
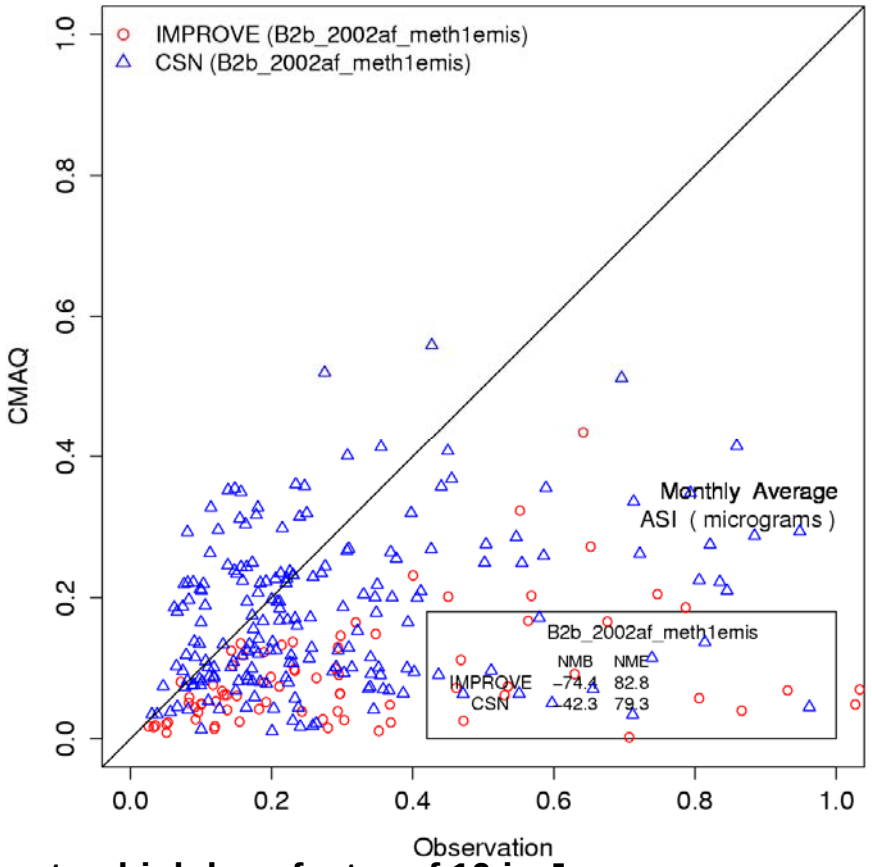
Basecase Evaluation – Silicon

monthly averages by site

January 2002



July 2002



Si concentrations are too high by a factor of 10 in January

Si concentrations are biased slightly low in July

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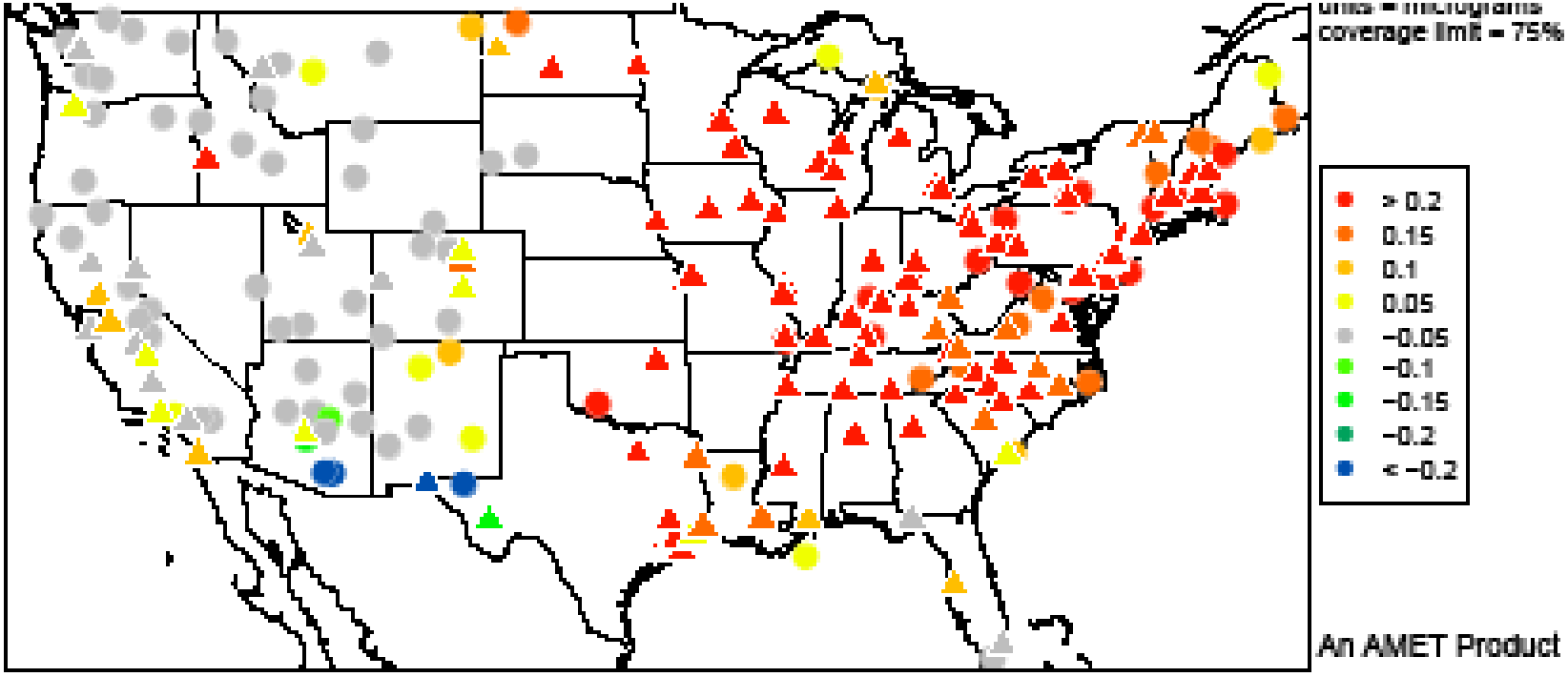
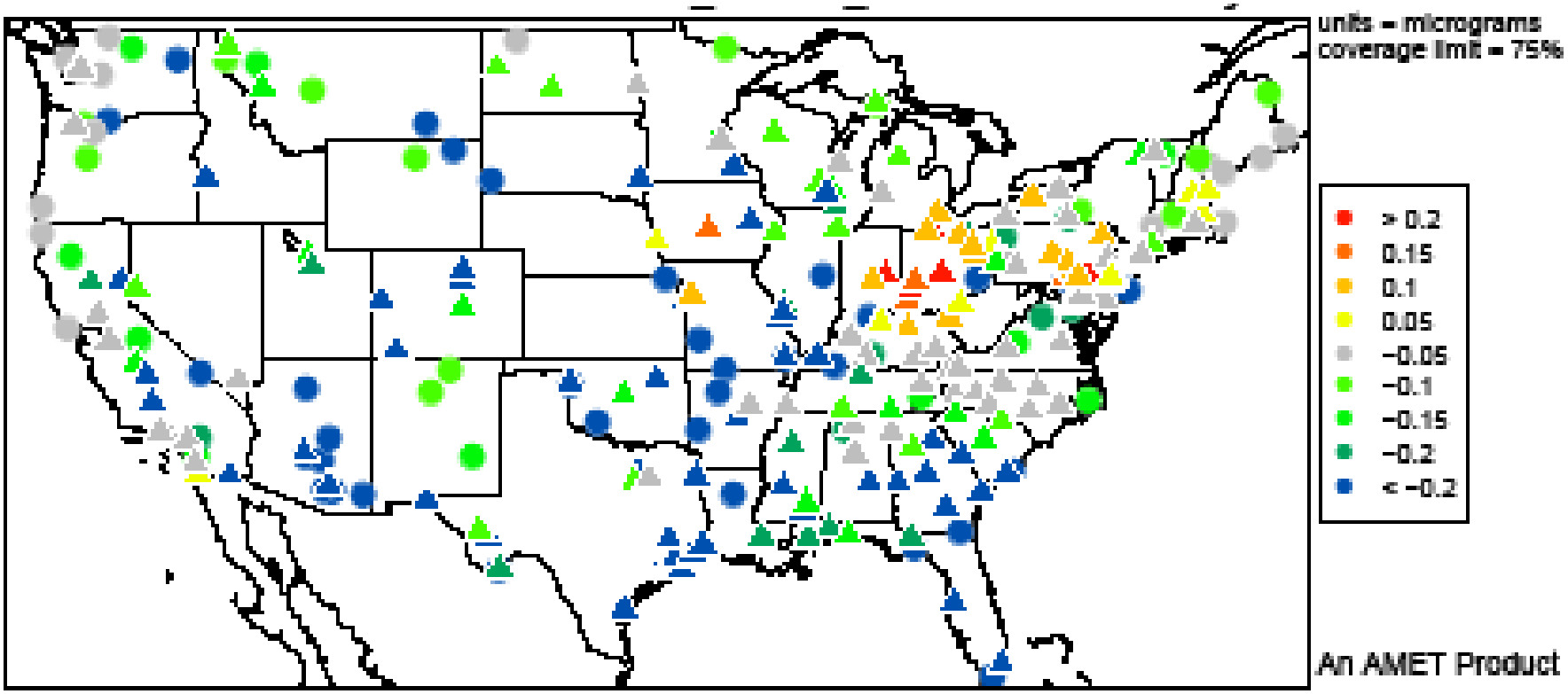
January basecase: Si is over-predicted in the Midwest and NE, but underpredicted in the SW and unbiased in the rest of the West



CIRCLE=IMPROVE; TRIANGLE=CSN;

July basecase: Si appears to have a slight negative bias nationwide except in the Ohio Valley – are coal emissions causing this?

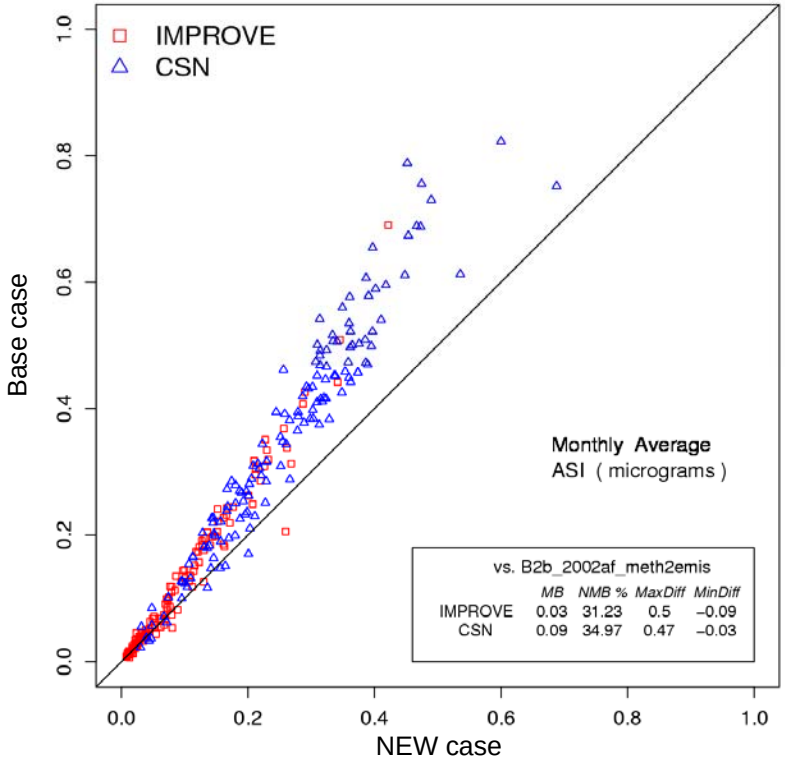


CIRCLE=IMPROVE; TRIANGLE=CSN;

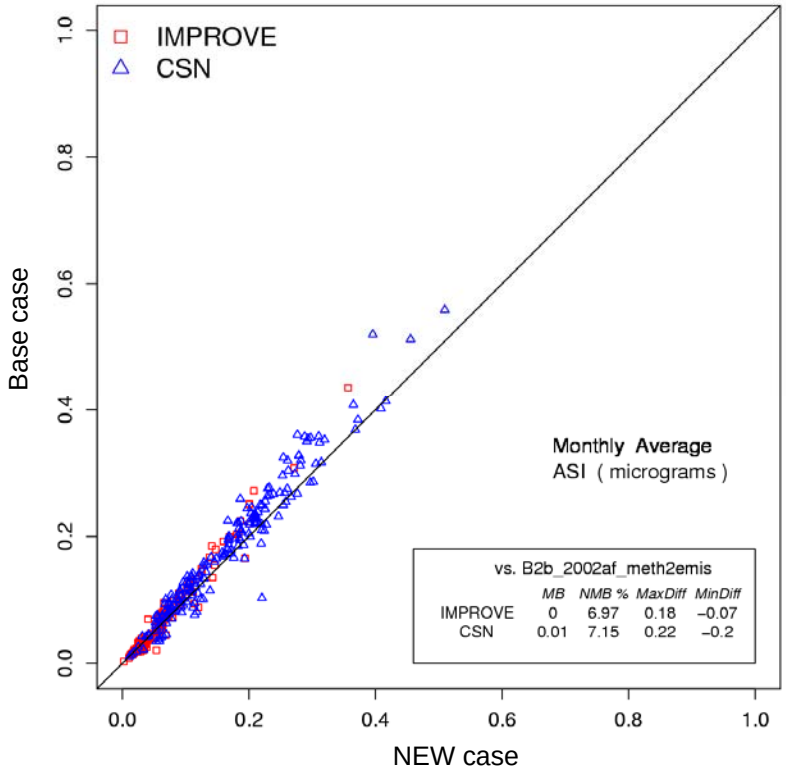
NEW Case

- New Model to Base Model Comparison
- New estimates lead to Si concentrations that are 30% lower in January and 7% lower in July

January 2002



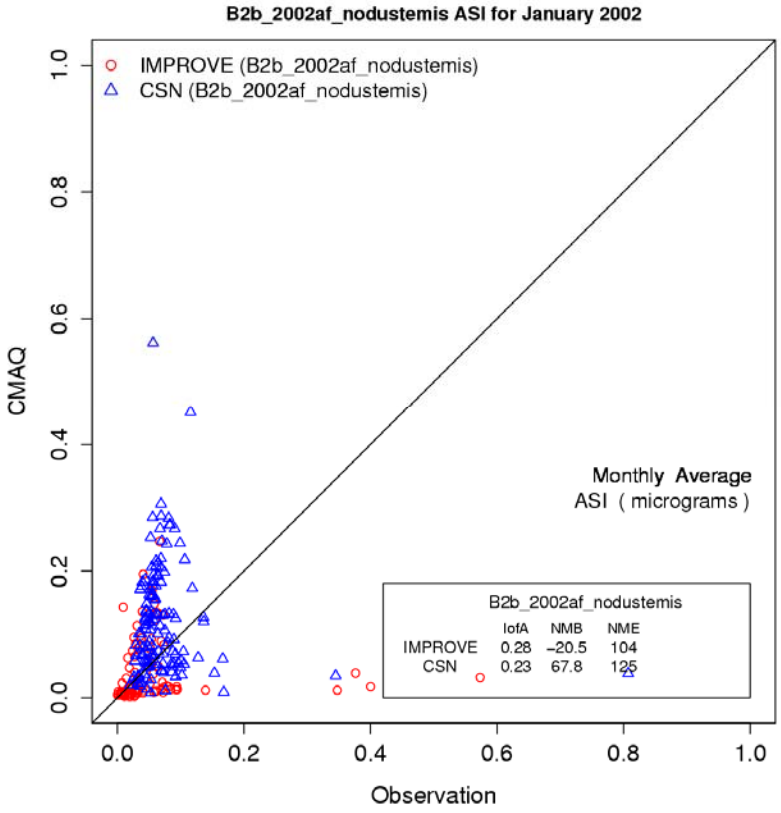
July 2002



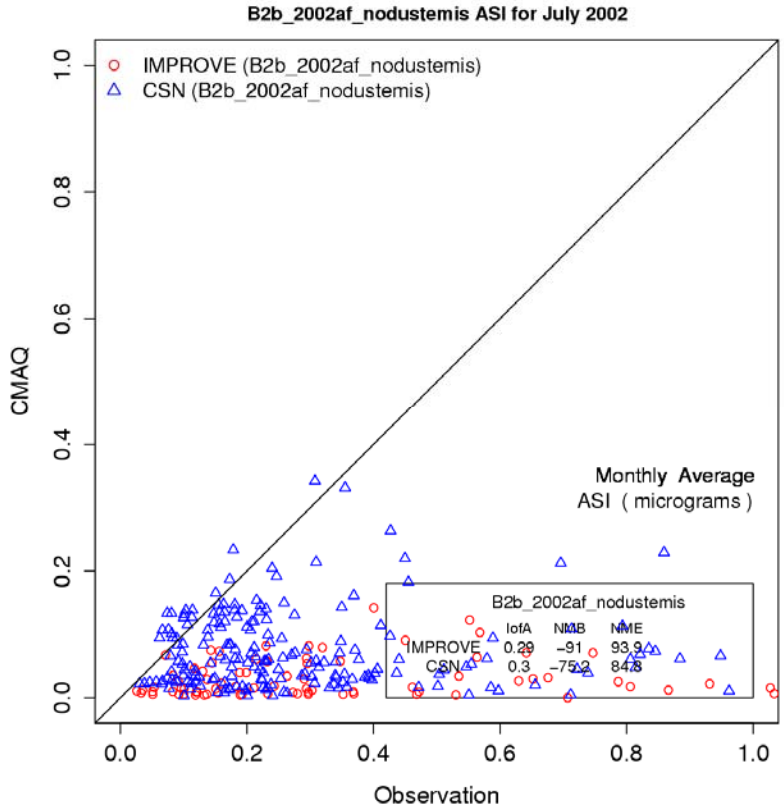
NODUST:

When we eliminate all dust emissions Si is still overestimated by a factor of 4 in January but under-estimated in July

January 2002

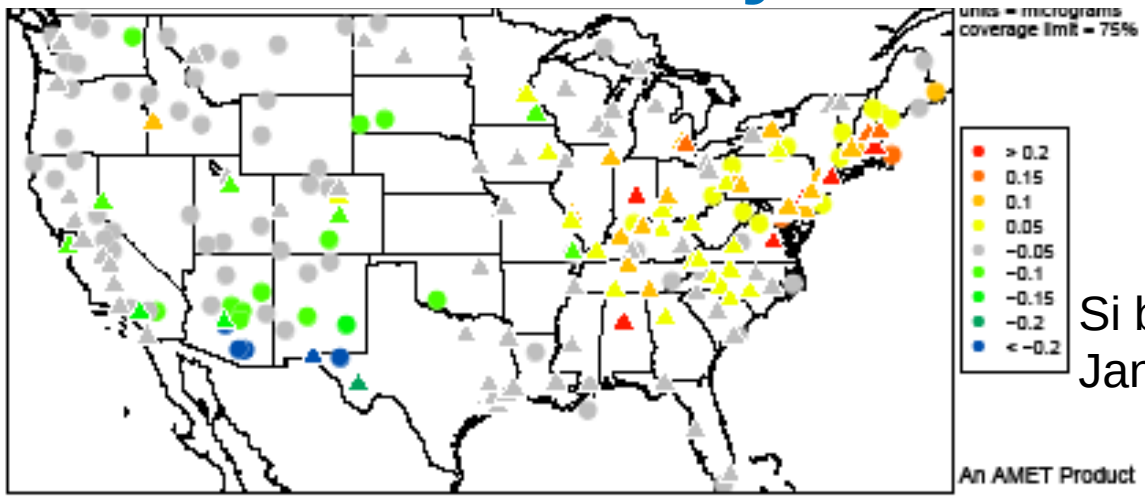


July 2002



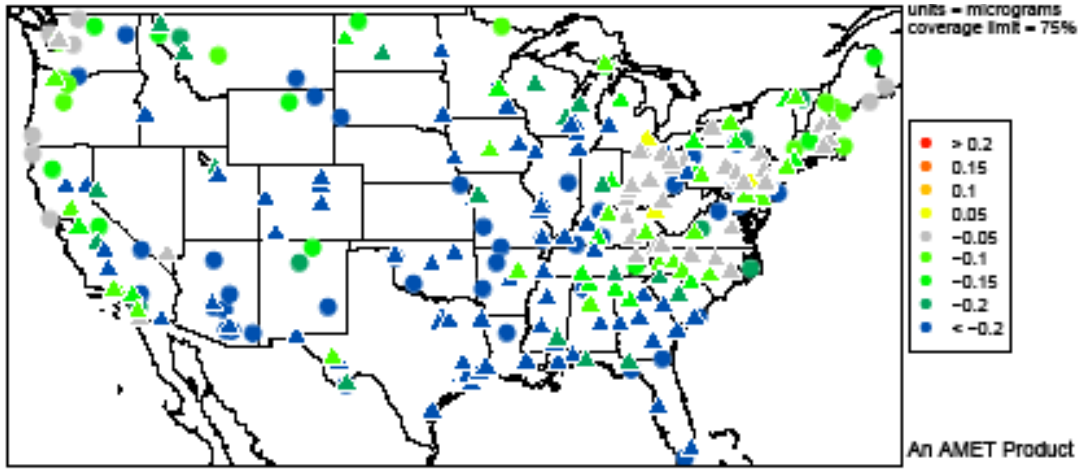
Silicon monthly averages by site

NODUST: the Si overprediction is only in the Eastern US



Si bias (µg/m^3) in January 2002

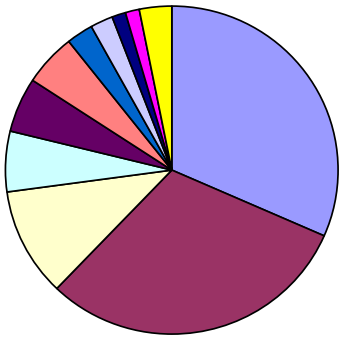
CIRCLE=IMPROVE; TRIANGLE=CSN;



Si bias (µg/m3) in July 2002

CIRCLE=IMPROVE; TRIANGLE=CSN;

$PM_{2.5}$ Silicon by Source



- Agriculture Production - Crops (DUST)
- Unpaved Roads (DUST)
- External Combustion Boilers;Electric Generation
- Paved Roads (DUST)
- Industrial Processes;Construction (DUST)
- Industrial Processes;Mining and Quarrying: (DUST)
- External Combustion Boilers;Industrial
- Stationary Source Fuel Combustion;Industrial
- Industrial Processes;Mineral Products
- Industrial Processes;Primary Metal Production
- Remaining

Summary and Conclusions

- CMAQ shows positive bias in winter and negative bias in summer for $PM_{2.5}$
- Agricultural sources, Unpaved roads, and Coal Combustion are responsible for most of the bias
- Improved temporal allocations and transportable fraction did not significantly resolve the high bias
- Improvement in the speciation of PM-other should enable diagnosis of problems and identification of solutions

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Future Work

- Reduce/eliminate fugitive emissions during snow and rain
- Compare model and observation with additional trace elements using the enhanced speciation for further diagnosis and analysis
- Re-examine the annual emission factors and speciation profiles for all anthropogenic fugitive dust and coal combustion source categories.
- Continue to improve PM2.5 characterization to enhance development of cost-effective control strategies.

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Acknowledgements

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- Adam Reff
- Computer Sciences Corporation
  - Charles Chang
  - Ryan Cleary
  - Lucille Bender
  - Nancy Hwang