Annual Model Simulations and Evaluation of Particulate Matter at 36-km and 12-km Grid Resolutions

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  - Co-Authors: Carey Jang, Norm Possiel, Pat Dolwick, Brian Timin, Tom Braverman, Marc Houyoux, and Tyler Fox
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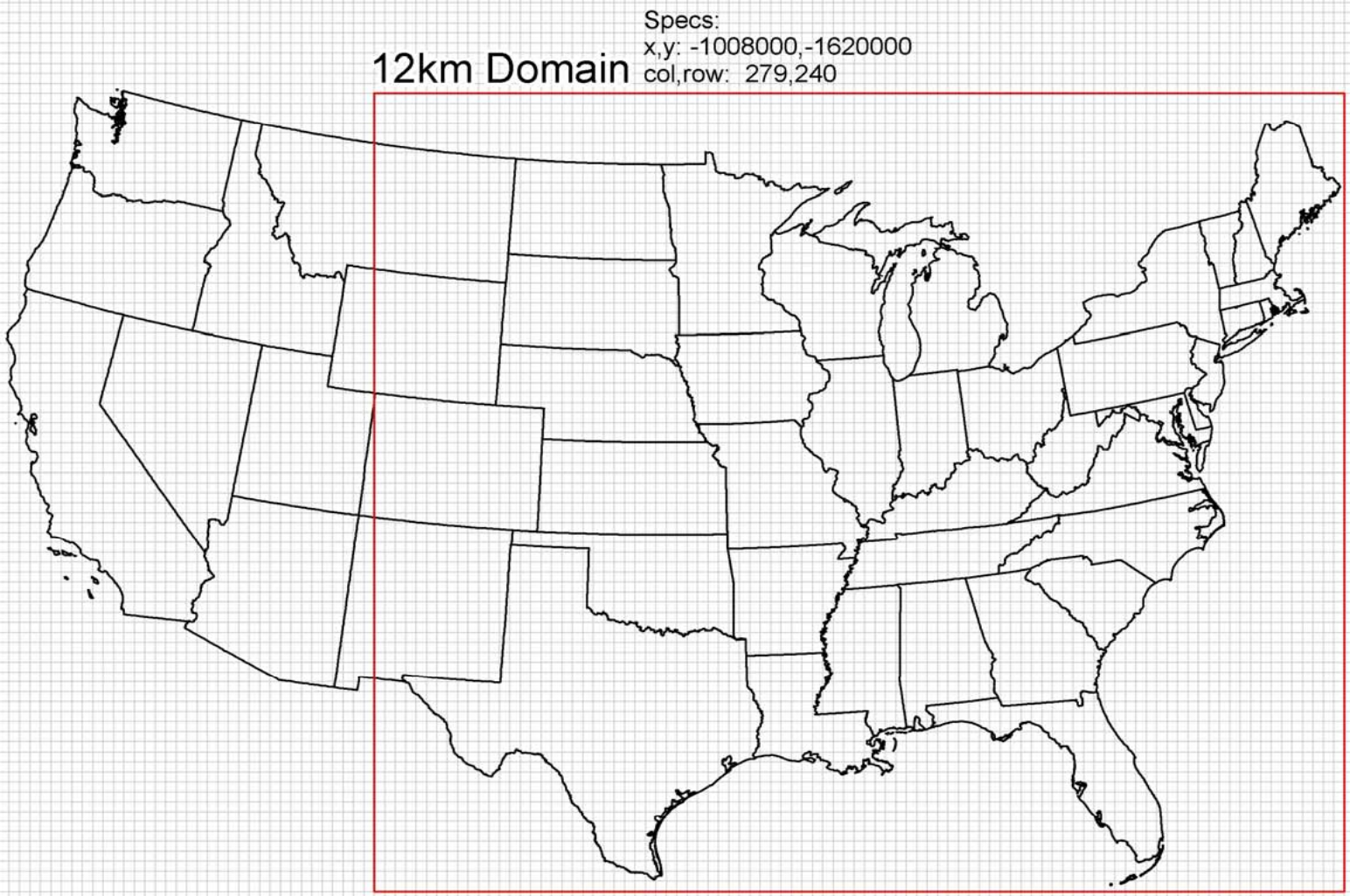
Overview

- **Purpose**
  - Evaluation/comparison of 2001 annual CMAQ model simulations at 36-km and 12-km grid resolution focusing on:
    - Case study analysis of Sulfate PM predictions
- **Background**
  - As part of a collaborative effort involving OAQPS (AQMG & EIG) and ORD (ASMD) this CMAQ comparative evaluation for 2001 has led to:
    - Improve the science in CMAQ
    - Investigate model performance at finer (12-km) resolution
    - Develop meteorological and emissions data for 2001 at 36-km & 12-km
    - Develop boundary conditions from a global chemistry / transport model for continental U.S. modeling

Configuration of Model Platform

- Model version:
  - CMAQ Version 4.4
- Model domain:
  - Continental U.S., 148 x 112 at 36-km resolution
  - Eastern U.S., 279 x 240 at 12-km resolution
  - Lambert Conformal map projection
  - 14 vertical layers
- Model inputs:
  - Meteorological data: MM-5 v3.6.1 (36-km); MM-5 v3.6.3 (12-km); MCIP v2.3 (36-km & 12-km)
  - Anthropogenic emissions based on NEI 1999 projected to 2001 (SMOKE), Biogenic emissions based on BEIS 3.13
  - BCs/ICs nested from a global chemistry model (GEOS-CHEM)

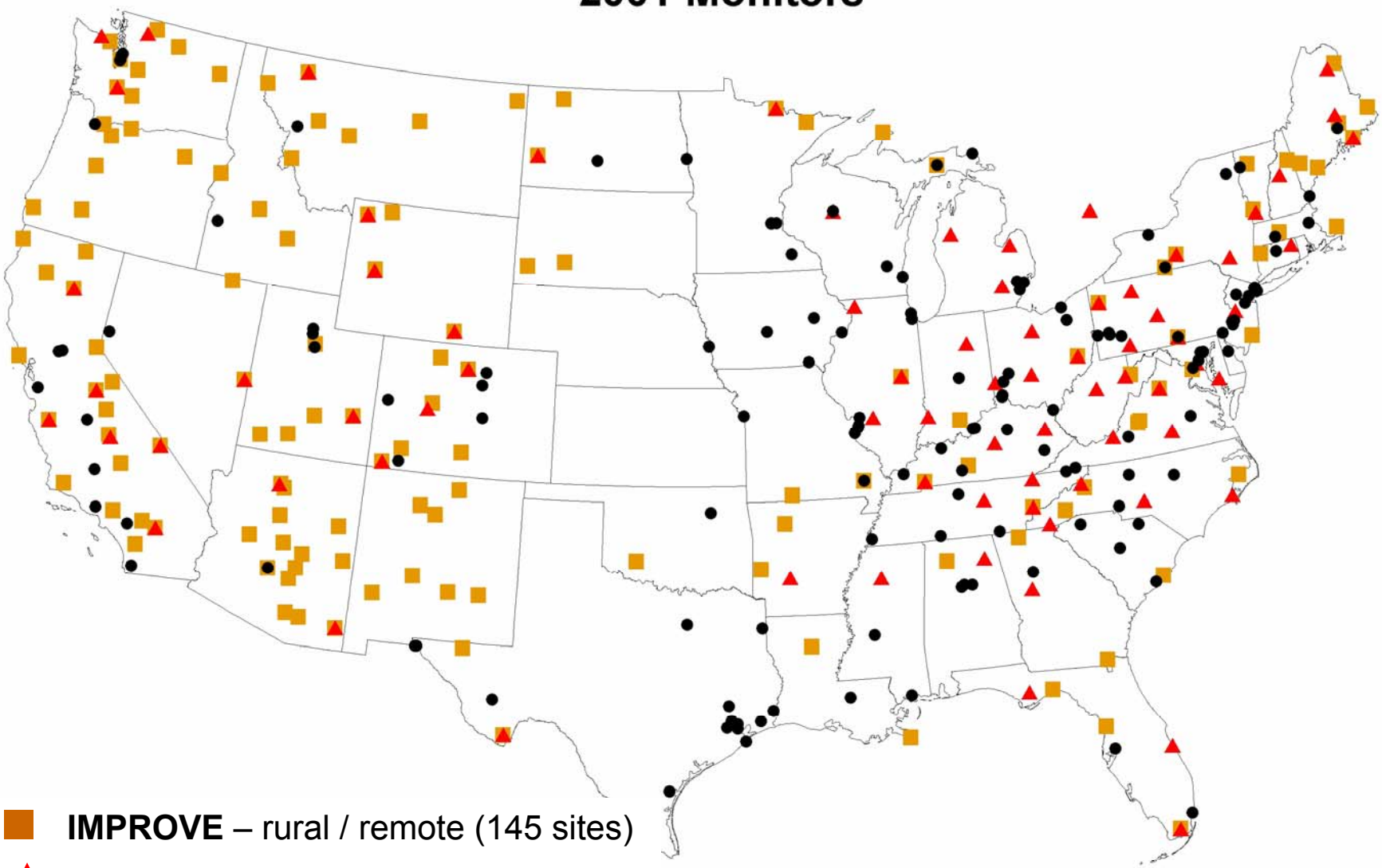
36km Domain



Components of Model Performance

- Relative performance across model applications
- Predictions of $PM_{2.5}$ component species from 36-km & 12-km model grid resolutions versus ambient data
  - STN – urban
  - CASTNet – rural / suburban
  - IMPROVE – rural / remote
- Case study - compared SO_4 & NO_3 species
  - Nitrate PM – January
  - Sulfate PM – July

2001 Monitors



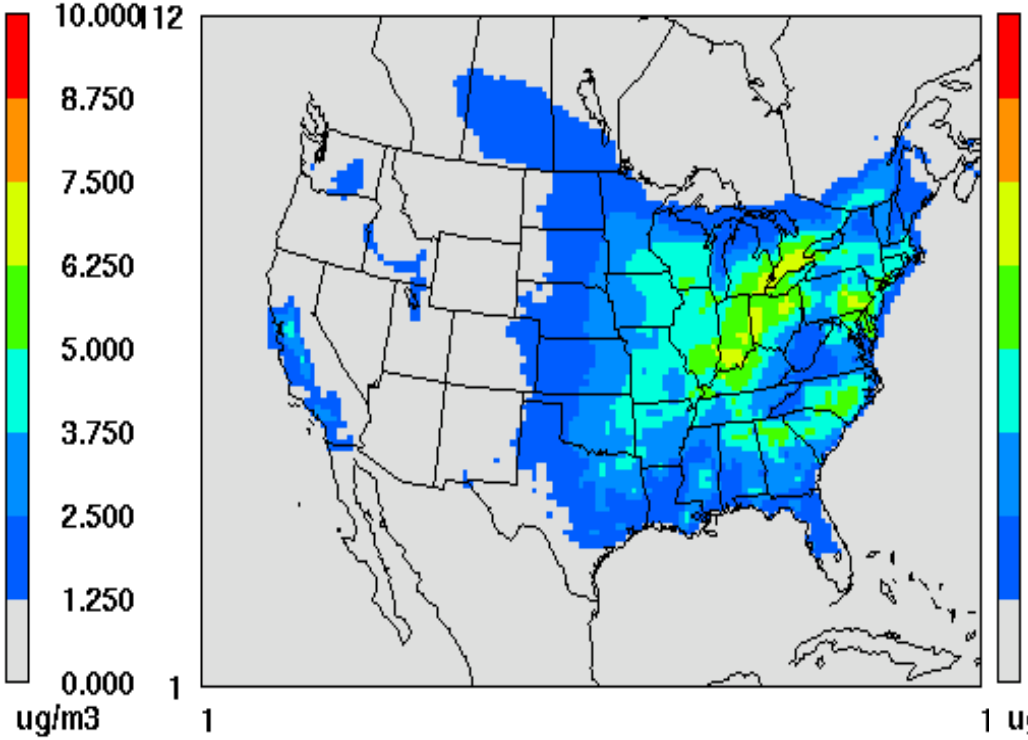
IMPROVE – rural / remote (145 sites)

CASTNet – rural / suburban (83 sites)

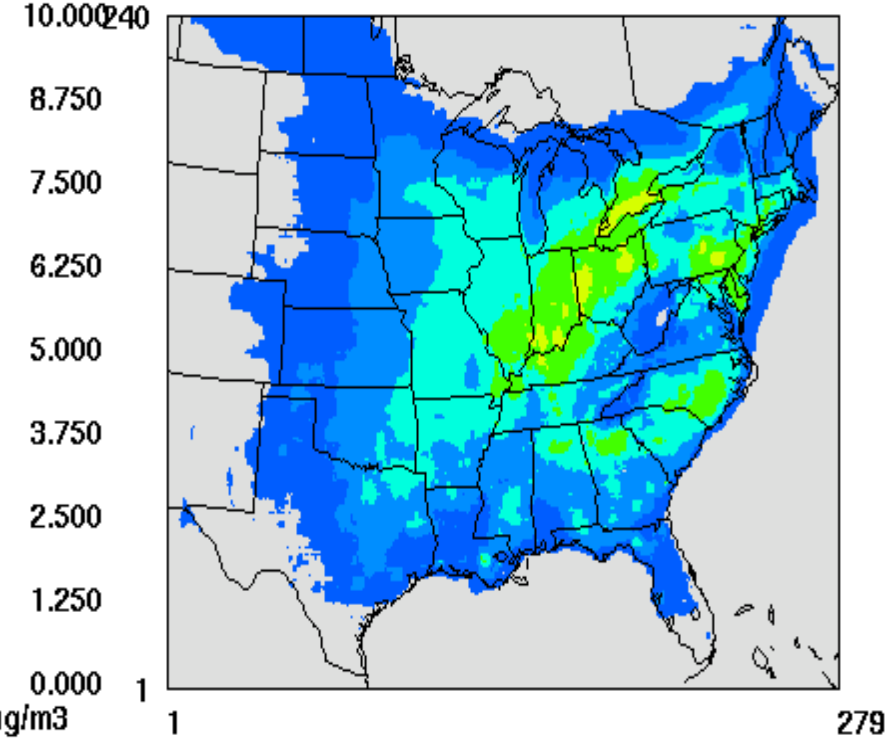
STN – urban (139 sites)

January - Nitrate PM ($\mu g/m^3$)

36-km

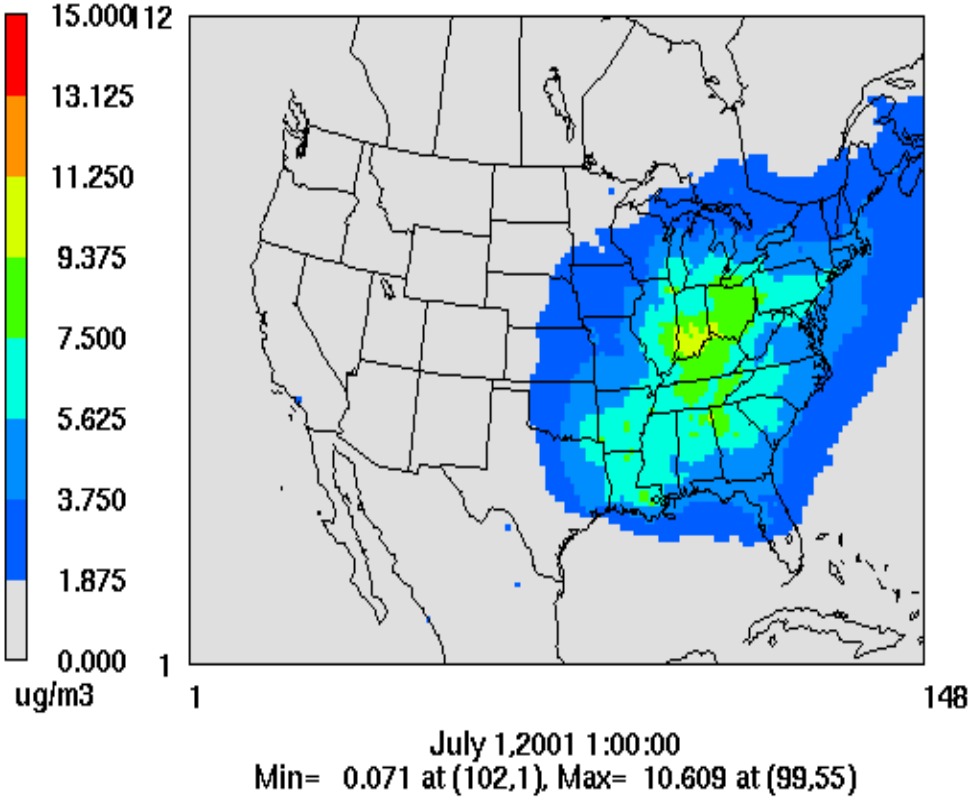


12-km

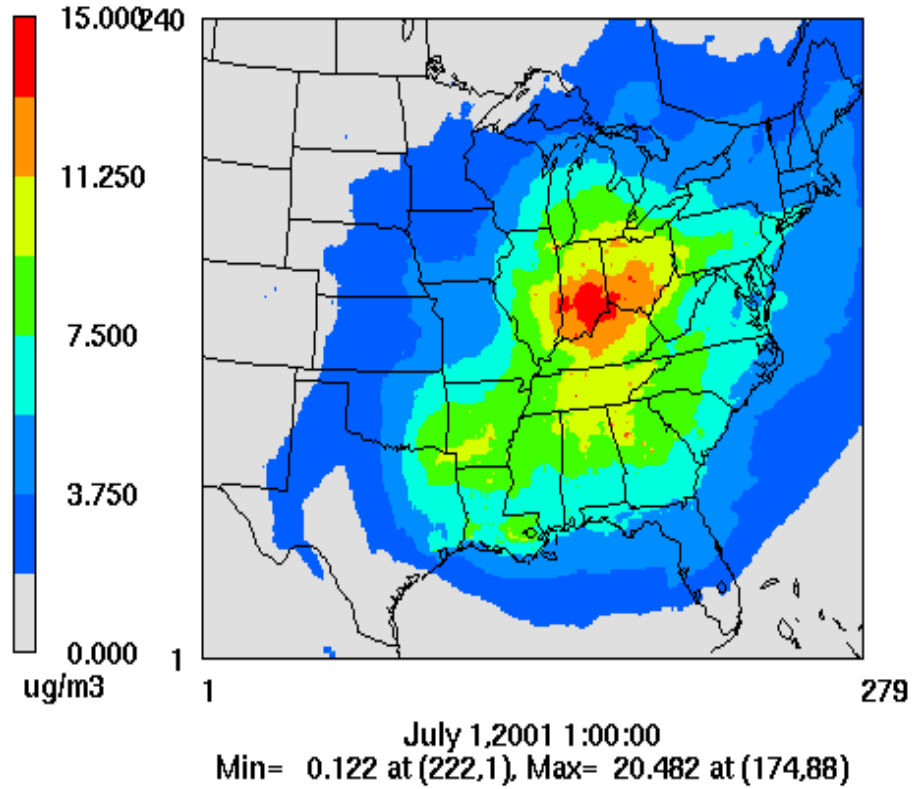


July - Sulfate PM ($\mu g/m^3$)

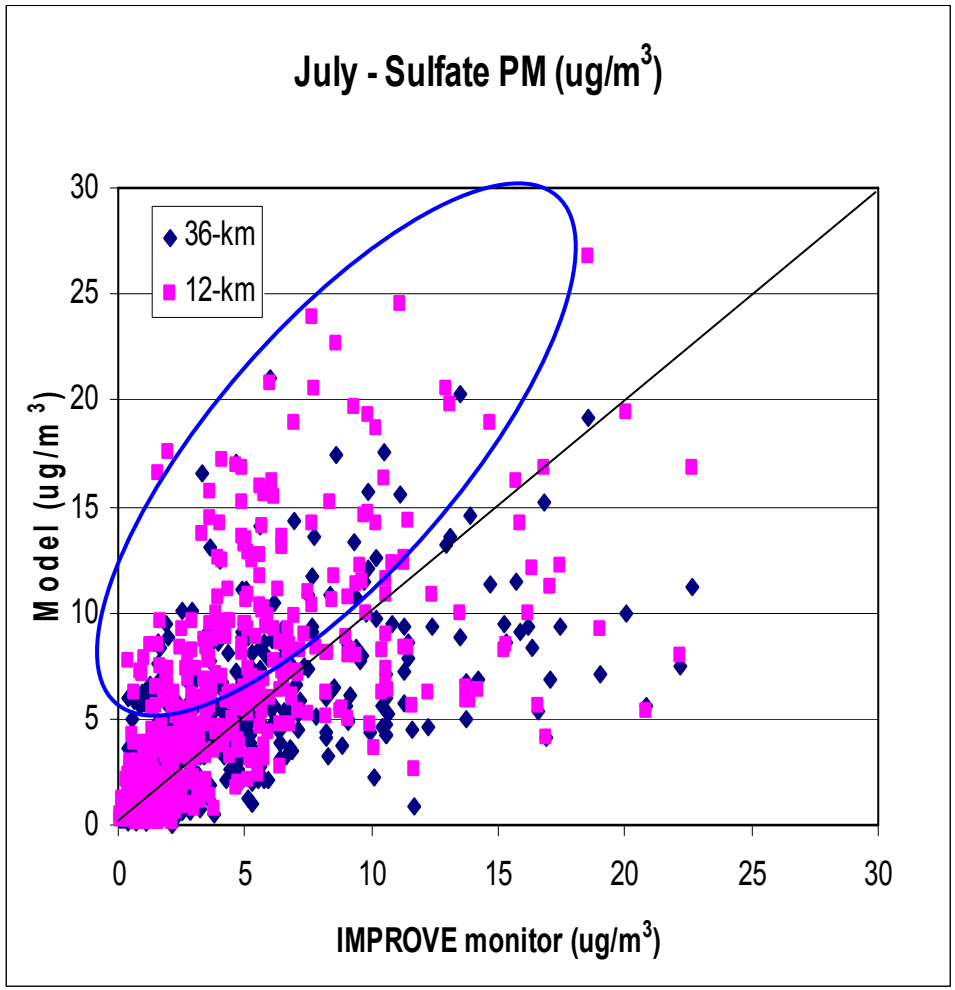
36-km

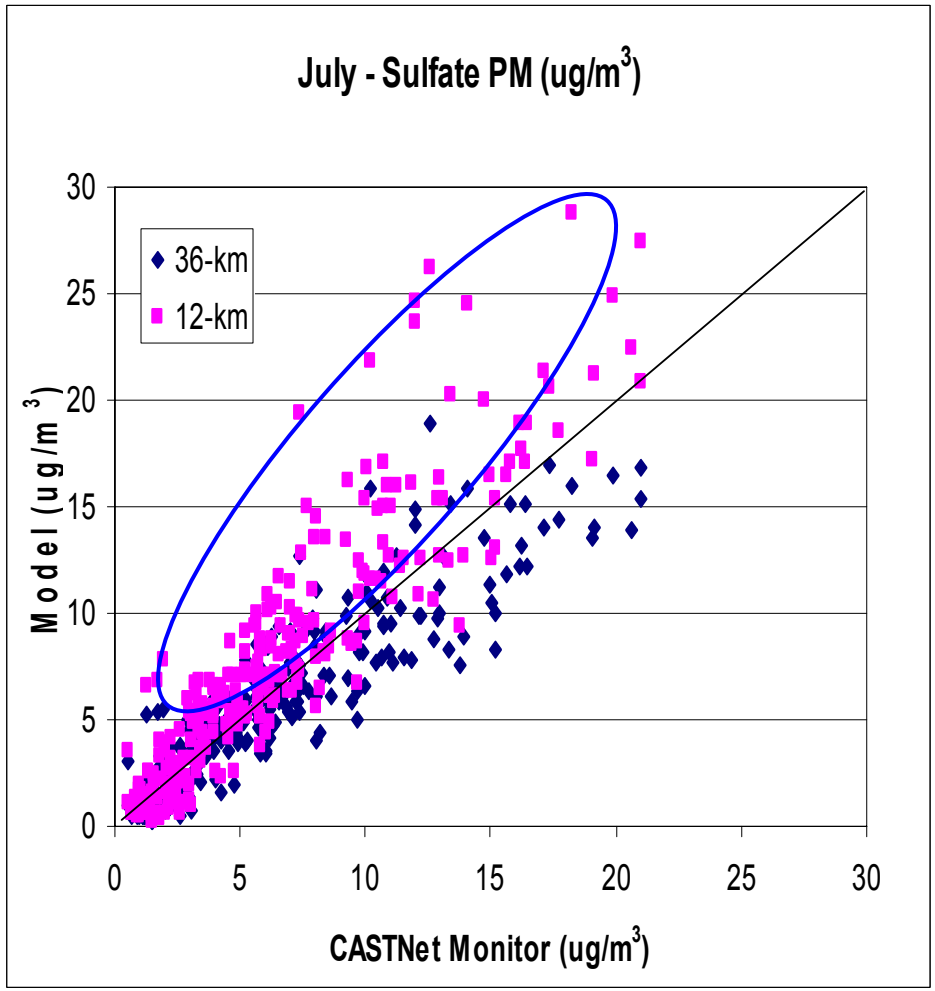


12-km



SO_4 Observations vs. Model 36-km & 12-km July 2001





Issues examined
(differences among grid resolutions)

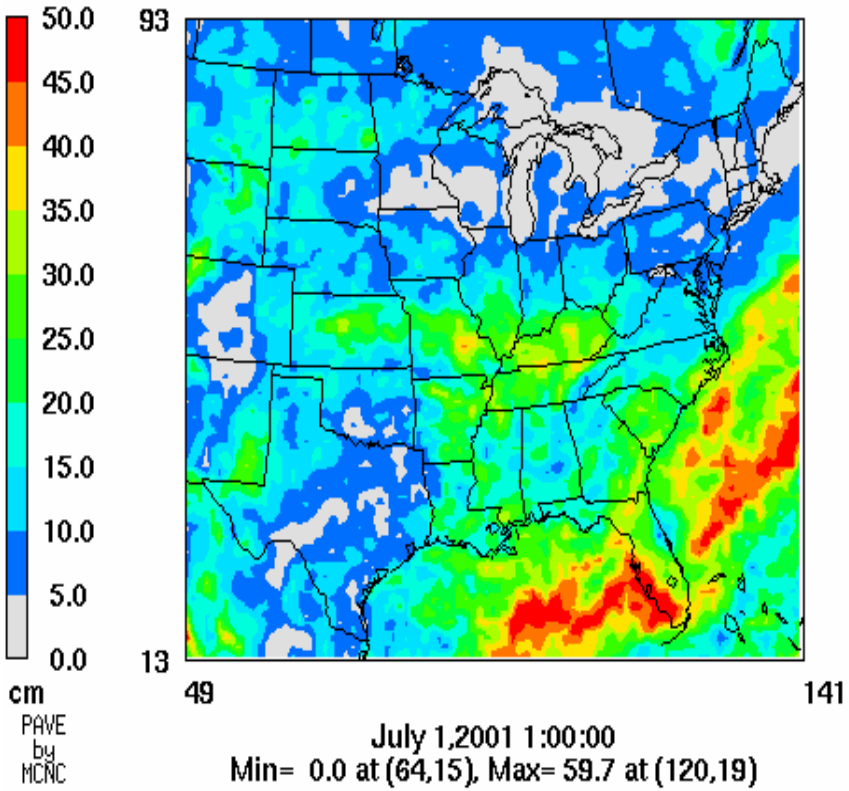
- Why is summer SO_4 different between 36-km & 12-km?
  - used post-processing technique to evaluate/compare 36-km vs.12-km model results

1. Emissions inputs

2. Meteorology (processes) inputs:
   - Cloud processes
   - Precipitation
   - Wet deposition

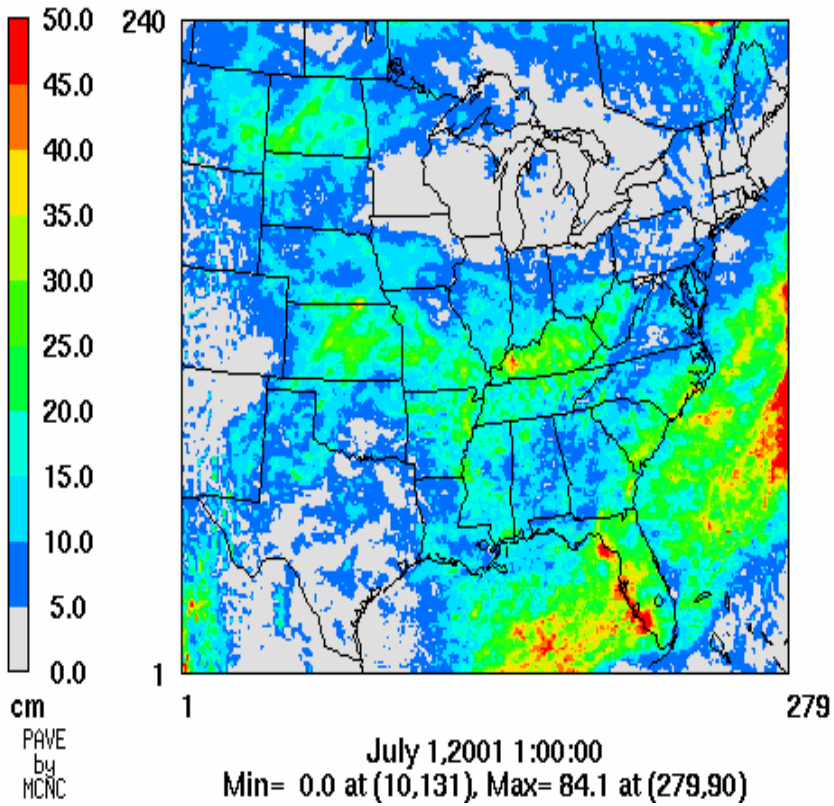
July - Precipitation (cm)

36-km



Bias ≈ +50%

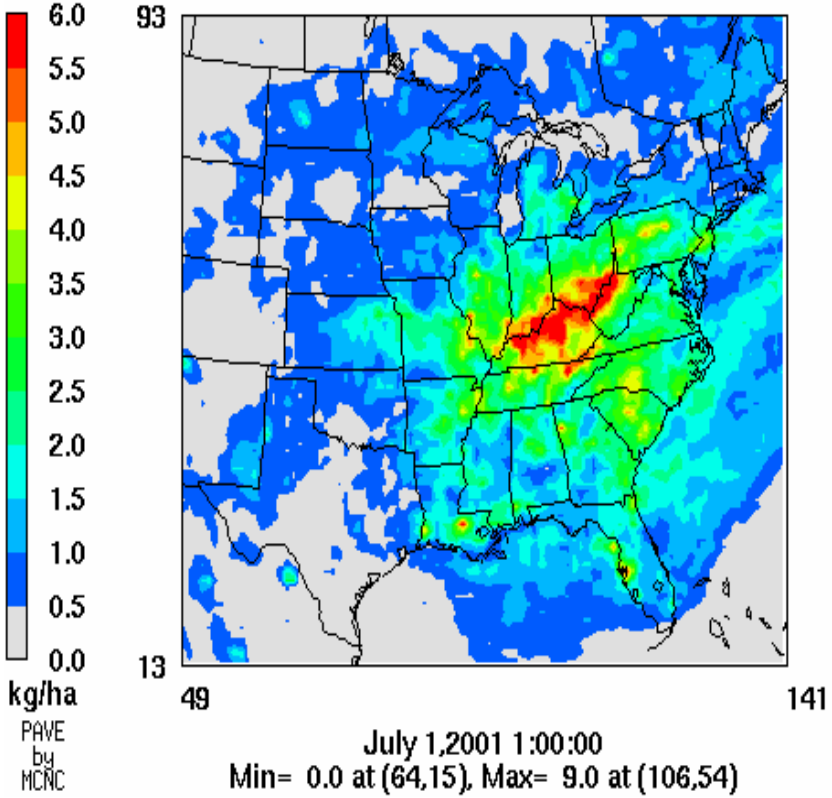
12-km



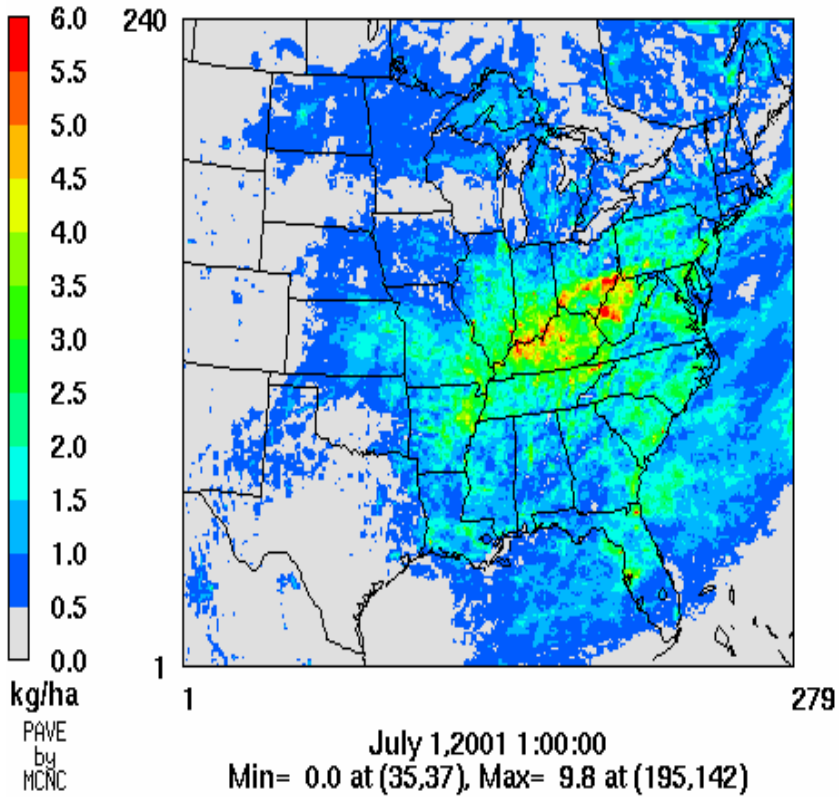
Bias ≈ +25%

July - Sulfate Wet Deposition (kg/Ha)

36-km

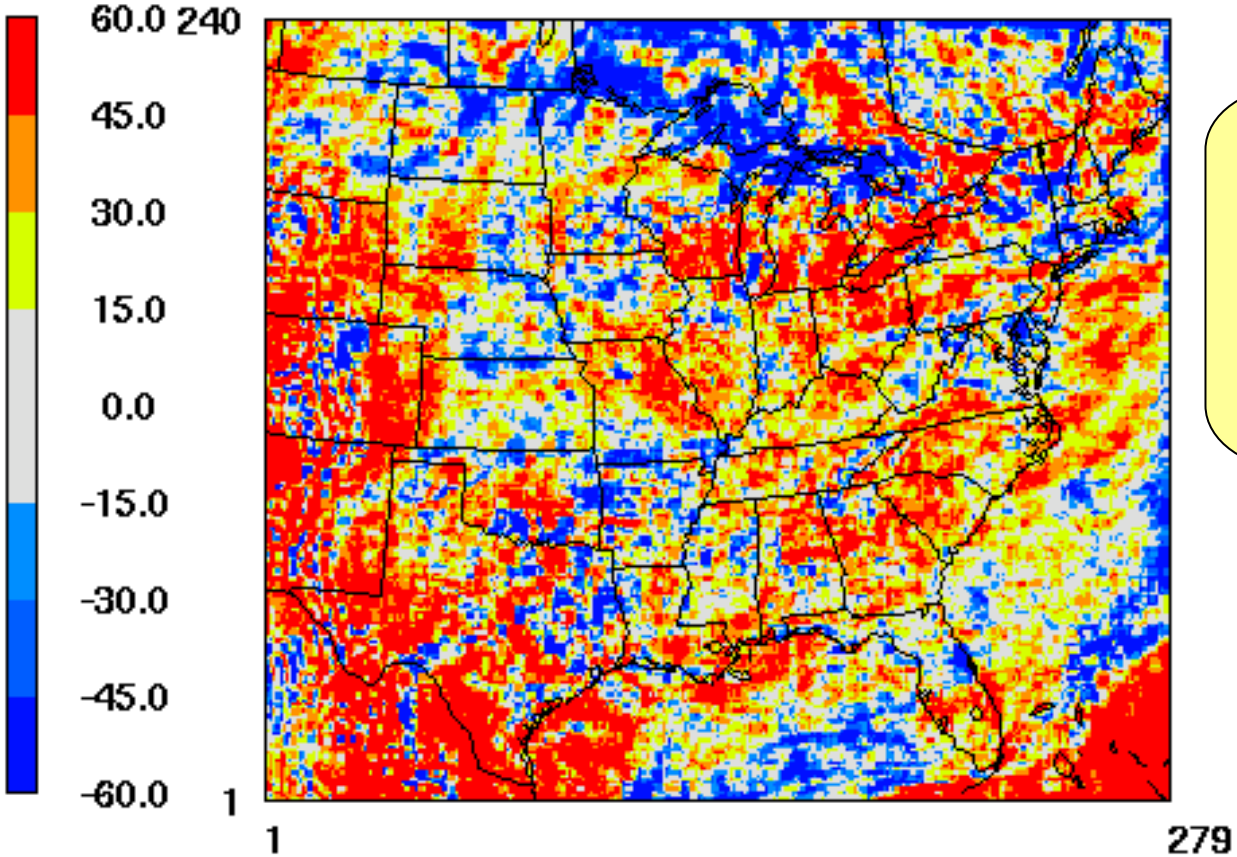


12-km



July - Wet Sulfate Deposition

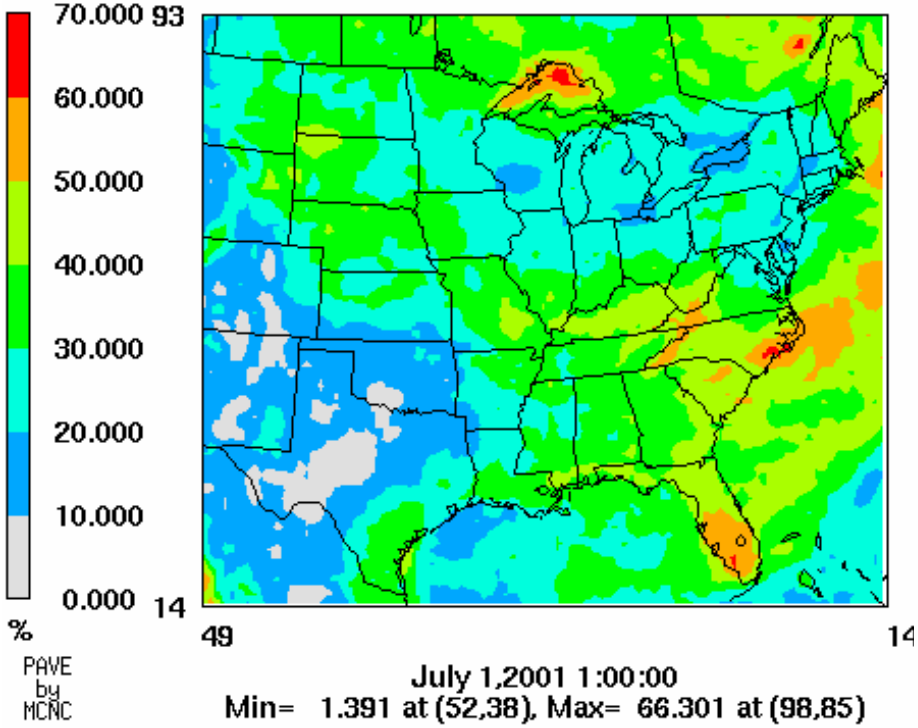
% Change between 36-km & 12-km



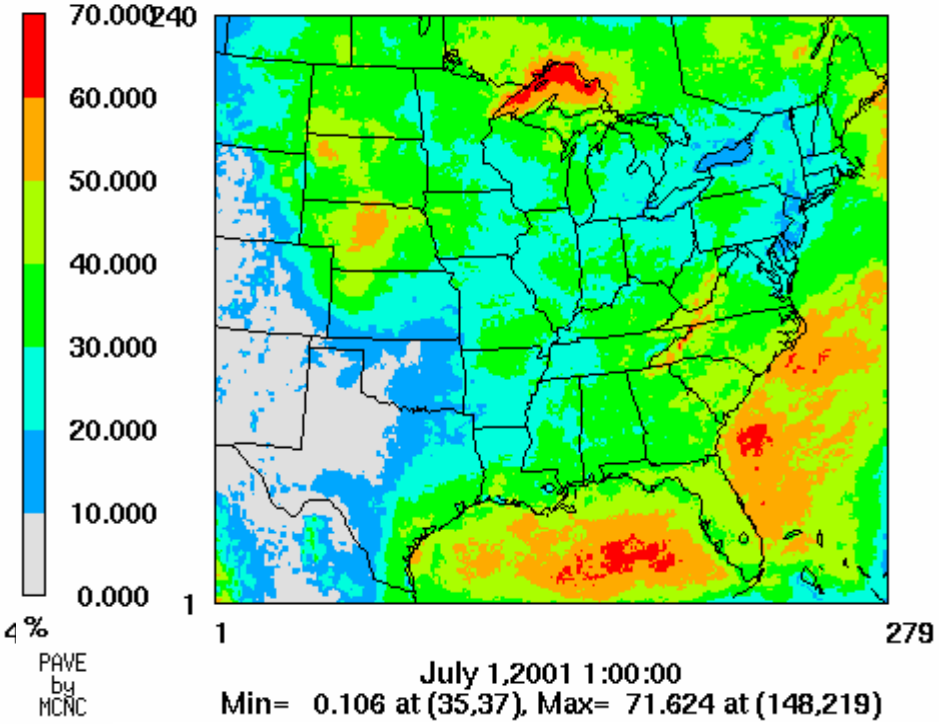
Wet SO_4 deposition – greater at 36-km; removing more SO_4 in 36-km → therefore less SO_4 ambient concs.

July - CMAQ Total Cloud Cover (%)

36-km



12-km

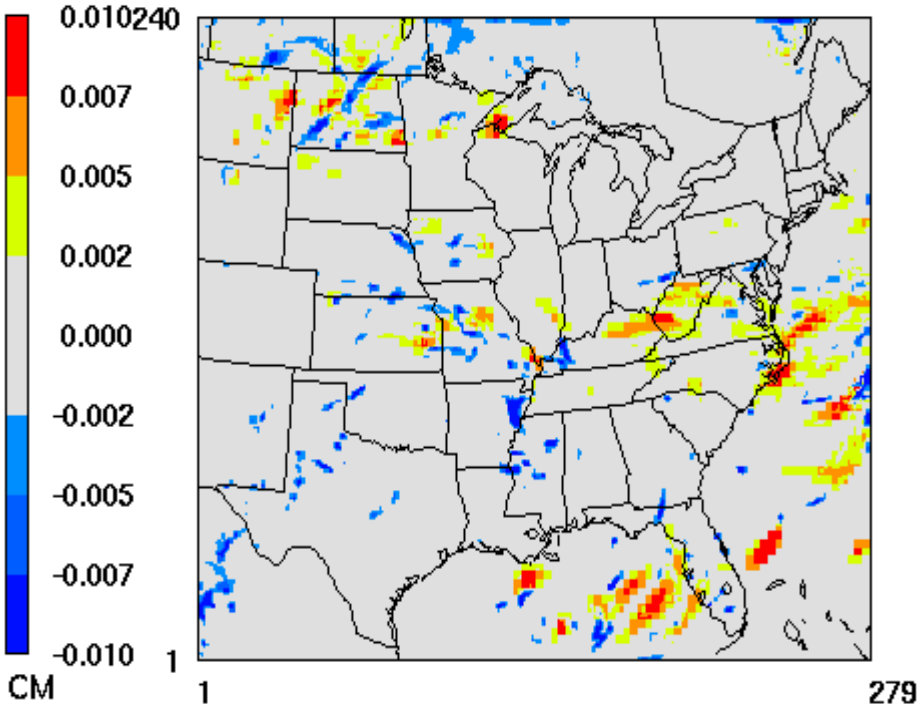


More cloud fraction cover in 36-km – potential for producing more aqueous phase SO_4.

Total Cloud Cover – used for aqueous phase chemistry, i.e. aqueous oxidation of SO_2 to SO_4.

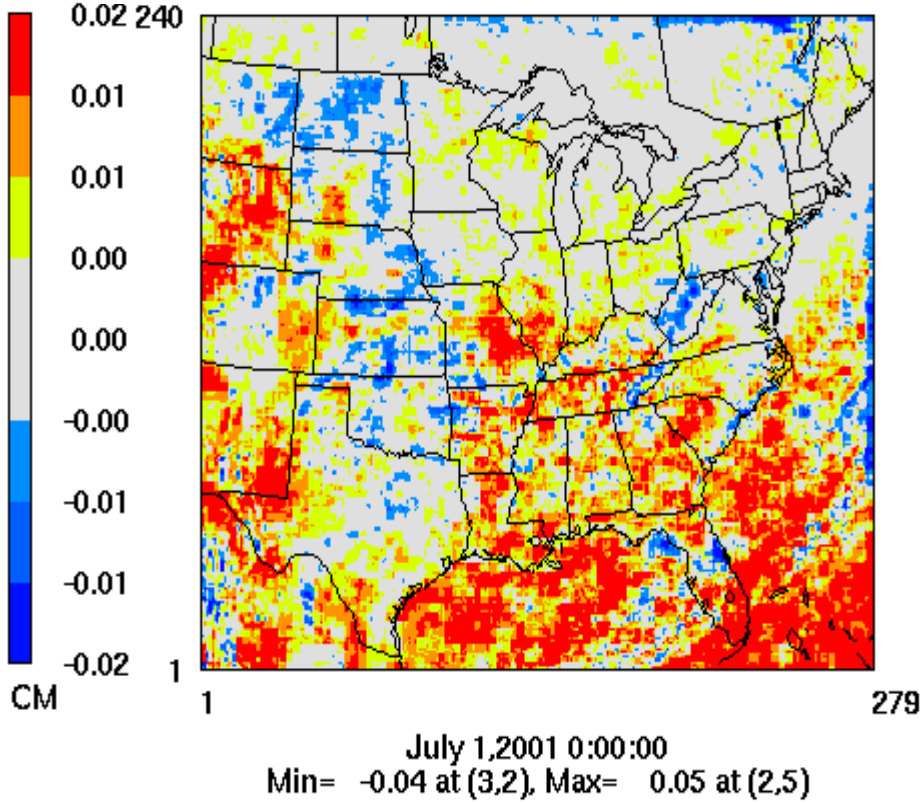
July - Resolved Clouds & Sub-grid Clouds

Δ Rn (36km - 12km)



Resolved clouds (Non-convective precipitation)- negligible differences between 36-km & 12-km.

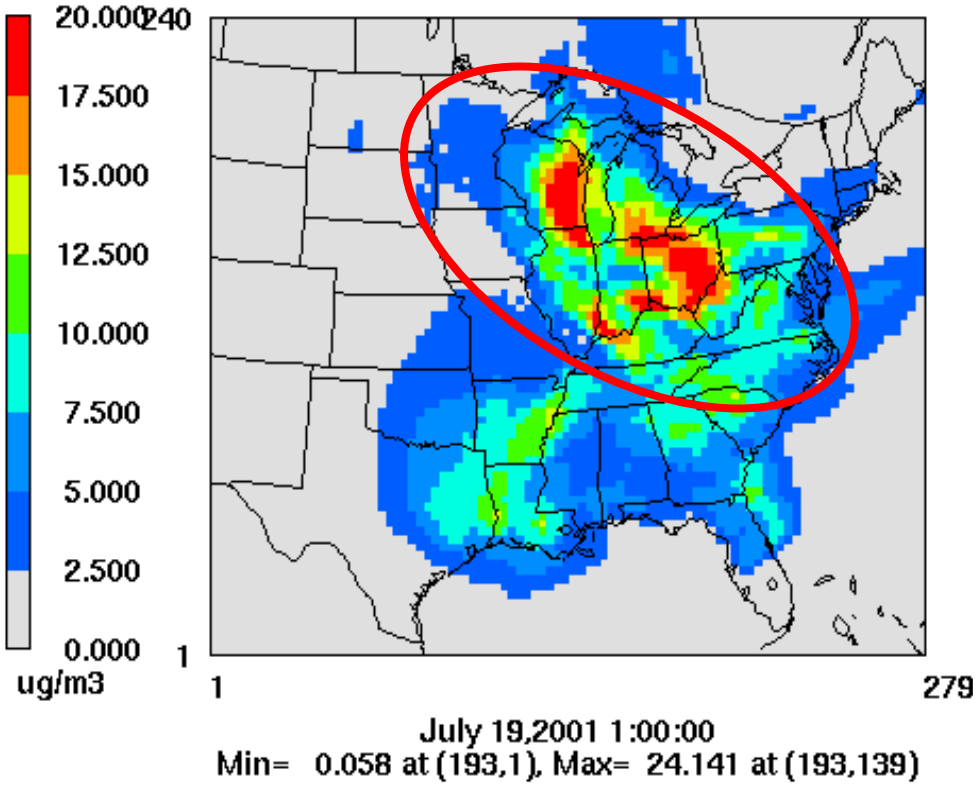
Δ Rc (36km - 12km)



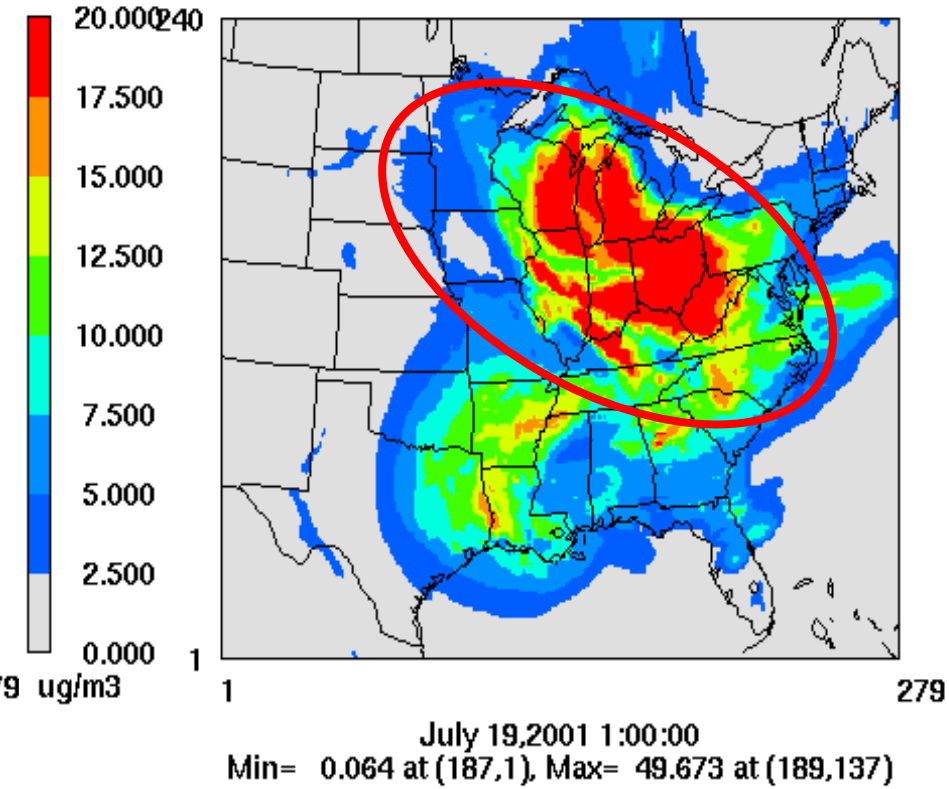
More sub-grid clouds (convective precipitation) in the 36-km.

Sulfate PM ($\mu g/m^3$): July 19th

36-km

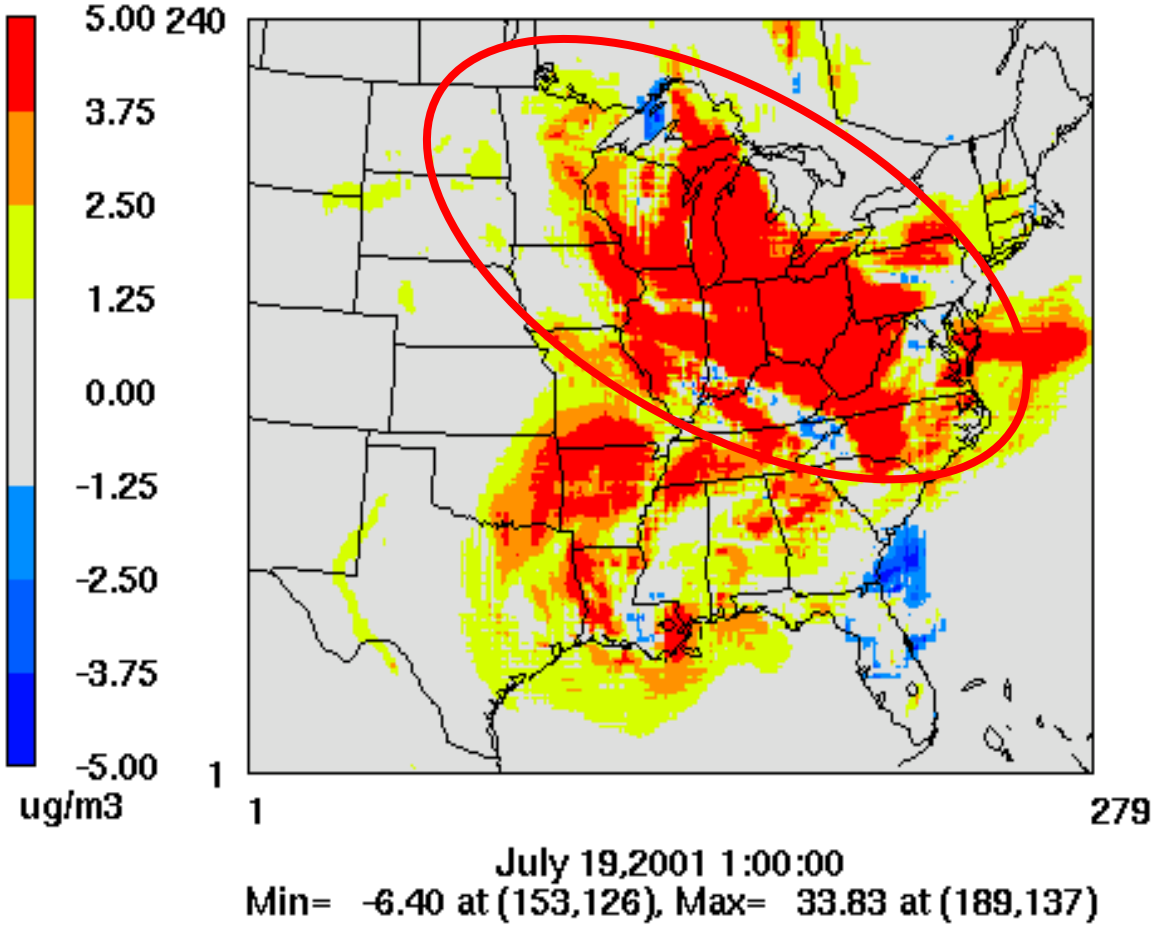


12-km

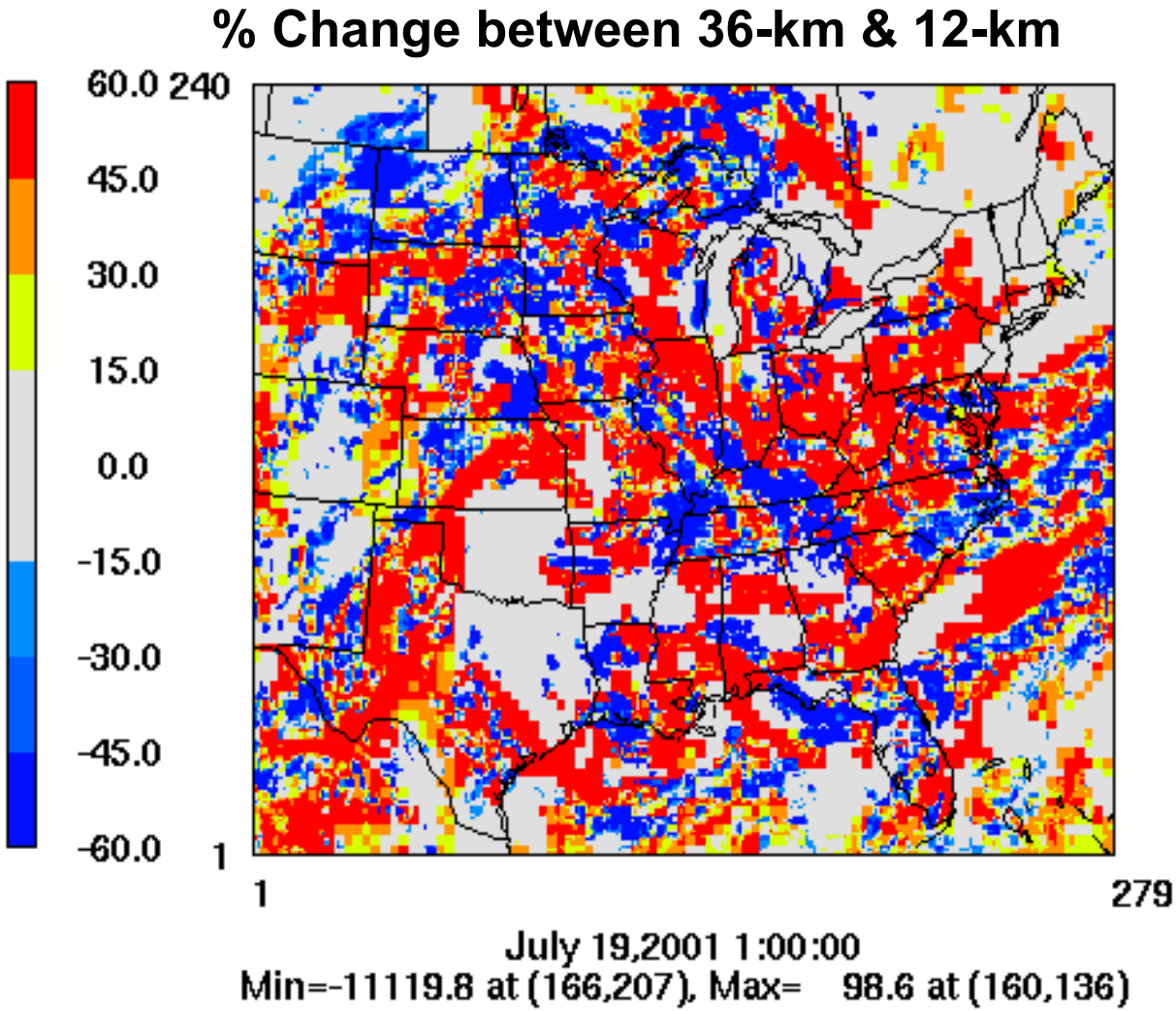


Δ Sulfate PM ($\mu g/m^3$): July 19th

(12km - 36km)



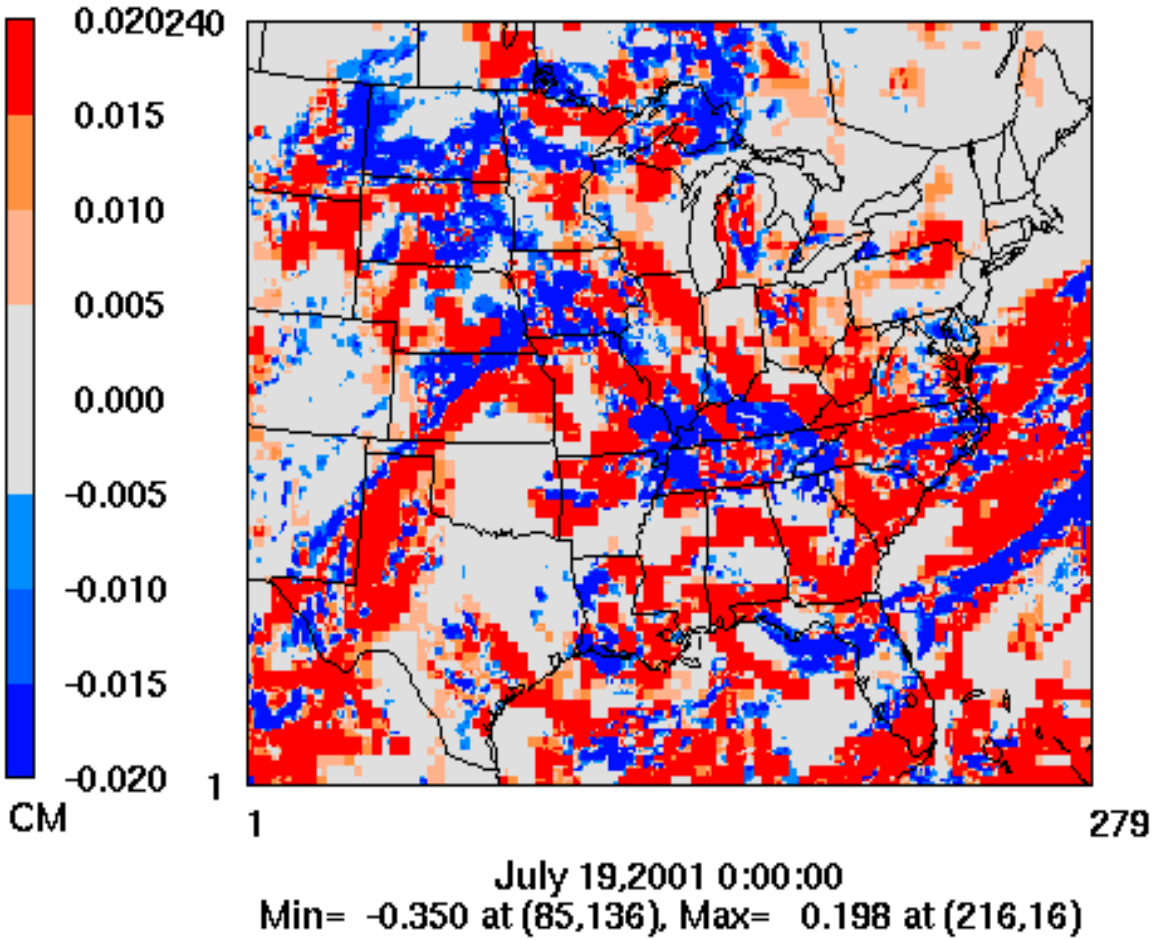
Wet Sulfate Deposition: July 19th



Wet SO_4 deposition– greater at 36-km; removing more SO_4 in 36-km → therefore less [SO_4].

Sub-grid Clouds: July 19th

Δ Convective Precipitation
(36km - 12km)



More sub-grid clouds (convective precipitation) in the 36-km.

Summary

- Annual CMAQ simulations showed comparable $PM_{2.5}$ species between 36-km & 12-km resolution; except for summer sulfate which was notably higher in 12-km modeling.

- CMAQ modeling was sensitive to differences of meteorological (MM5) inputs used for the 12-km grid resolution (more convection enhancing precipitation) due to:
  - Cloud processes
  - Precipitation
  - Wet deposition

- Summer wet deposition in 12-km modeling was lower due to lower precipitation amounts at 12-km, resulting in less deposition and therefore greater sulfate PM concentrations.

- This case study helped inform CMAQ developers on issues addressing:
  - Grid resolution
  - Meteorological modeling
  - Chemical transport model (CMAQ)

CMAQ Improvements

- This case study:
  - Led to a rapid incorporation of the ACM cloud model (from the forecast model into the community version of the model)
    - Added new sub-grid cloud mixing algorithm/module
  - Re-examination of the aerosol dry deposition algorithm and model updates
  - Inclusion of extra cloud variables into the cloud diagnostics file

	RMSE (%)		NMB (%)		NME (%)	
	v4.4	v4.5	v4.4	v4.5	v4.4	v4.5
IMPROVE	3.23	2.53	26.69	2.92	41.64	32.85
STN	4.14	3.39	28.71	13.83	52.3	44.48
CASTNet	2.60	1.74	21.10	0.59	27.36	19.03

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