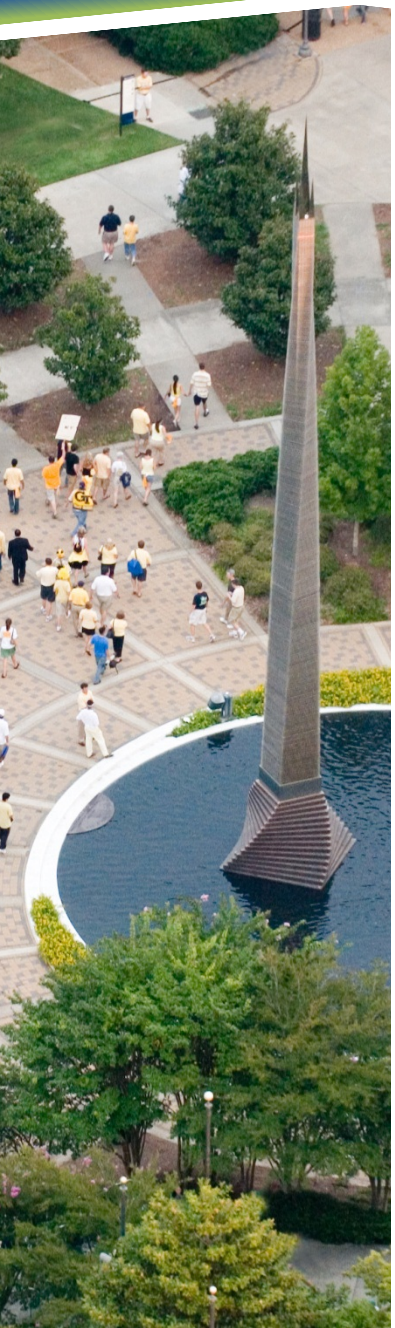


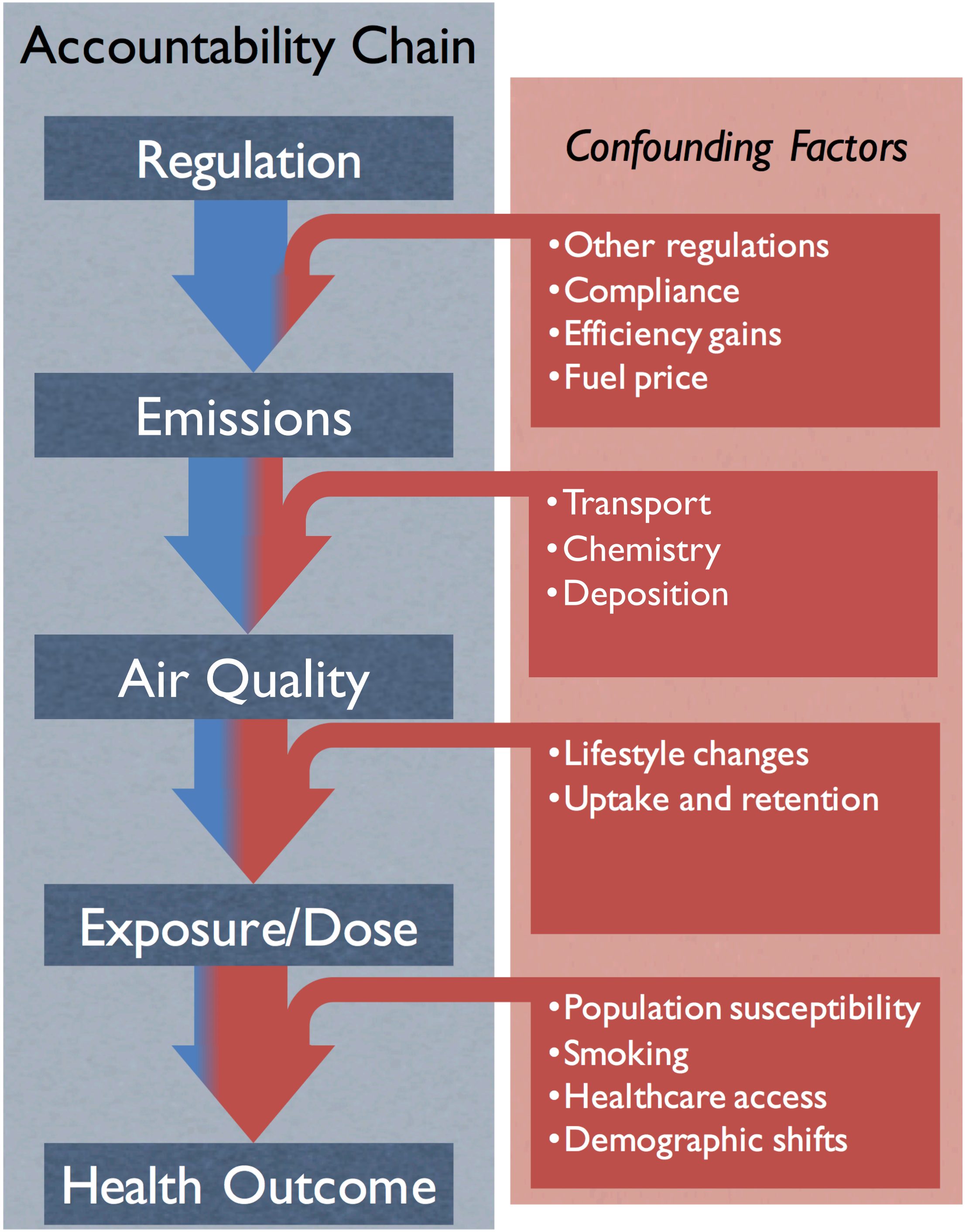
Dynamic analysis: assessing CMAQ’s ability to capture air quality trends over a time period of changing emissions

Cong Liu, Lucas Henneman,
Yongtao Hu, Abiola Lawal, Xinbei Guan,
James Mulholland, and Armistead Russell

CMAS Conference

Chapel Hill, North Carolina

26 October, 2016

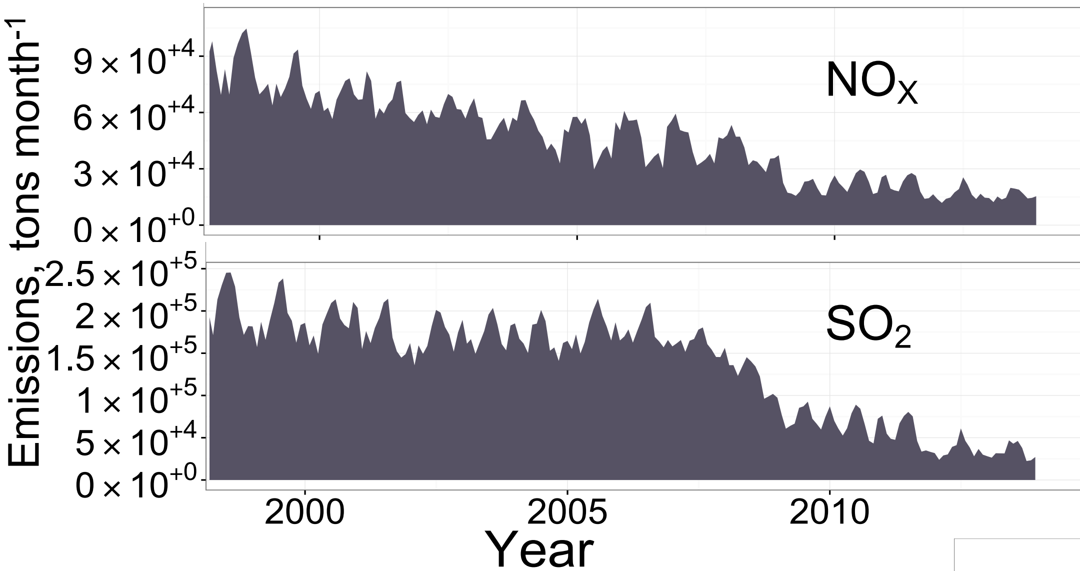


Air Pollution Accountability

- Seeks to quantify impacts of regulations on outcomes of interest
- Confounding variables obscure signal at each link
- Goal: Assess CMAQ's ability to capture air quality changes over period of changing emissions

Henneman et al. (2016), *JAWMA*

Substantial emissions reductions in multiple species from mobile and EGU sources



<u>Utility Emissions:</u>

90% decrease in NO_X & SO_2 in southeastern U.S.

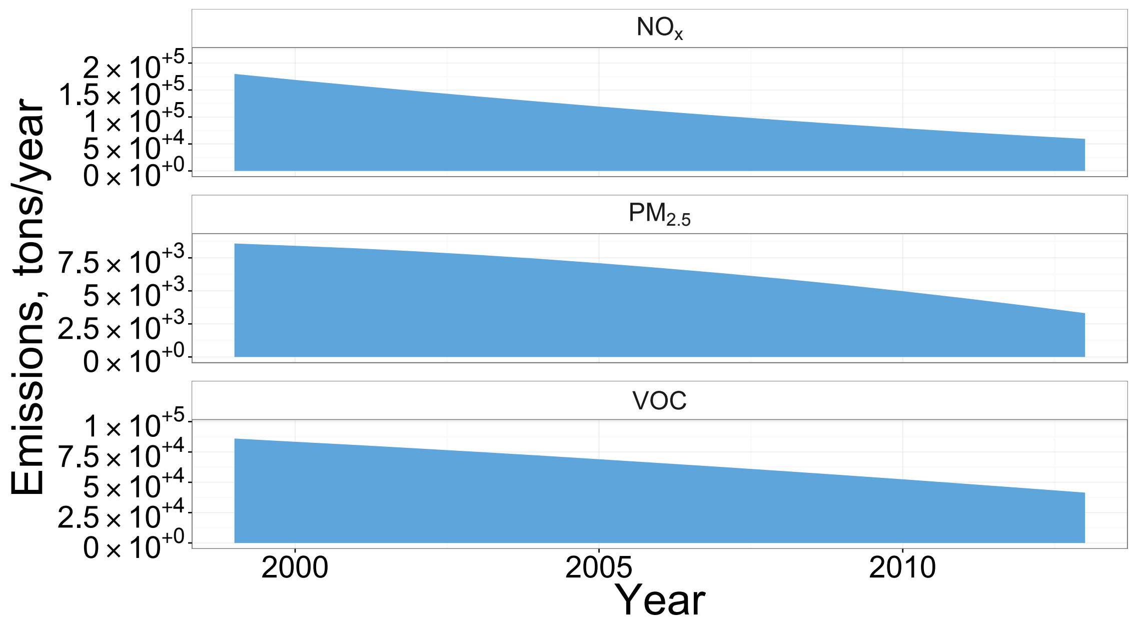
EPA Air Markets Program Data (2016)

<u>On-road Mobile Emissions:</u>

60-90% decrease in multiple pollutants* in Atlanta, GA

*NO_X, SO_2, $PM_{2.5}$, CO, VOC, EC, OC

Henneman et al. (in review)



CMAQ/SMOKE/WRF modeling system

Chemical Transport Model:

Community Multiscale Air Quality Model with the Decoupled Direct Method (**CMAQ-DDM, v5.0.2**) and *CB05tucl_ae6* mechanism

Emissions Model:

Sparse Matrix Operator Kernel Emissions (**SMOKE, v3.5.1**) Modeling System

2002 & 2011 NEIs

Meteorology Model:

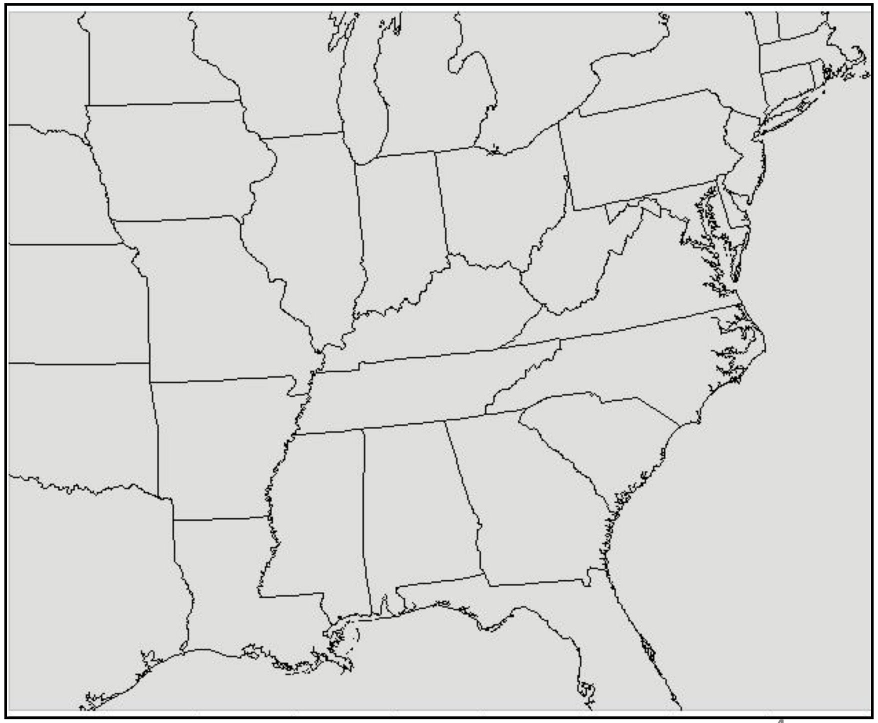
Weather Research and Forecasting (**WRF, v3.6.1**) Model

Domain:

Eastern US, 12km

201x162 horizontal grid

13 Vertical Layers



CMAQ/SMOKE/WRF modeling system

	Operational Evaluation	
	01E•01M	**11E•11M**
Emissions	2001	2011
Meteorology	2001	2011

How well does CMAQ capture observed air quality changes?

What caused the air quality changes?

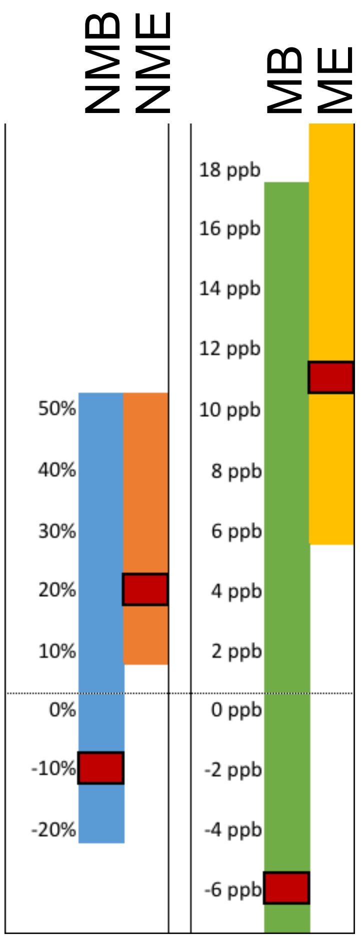
CMAQ-DDM/3D

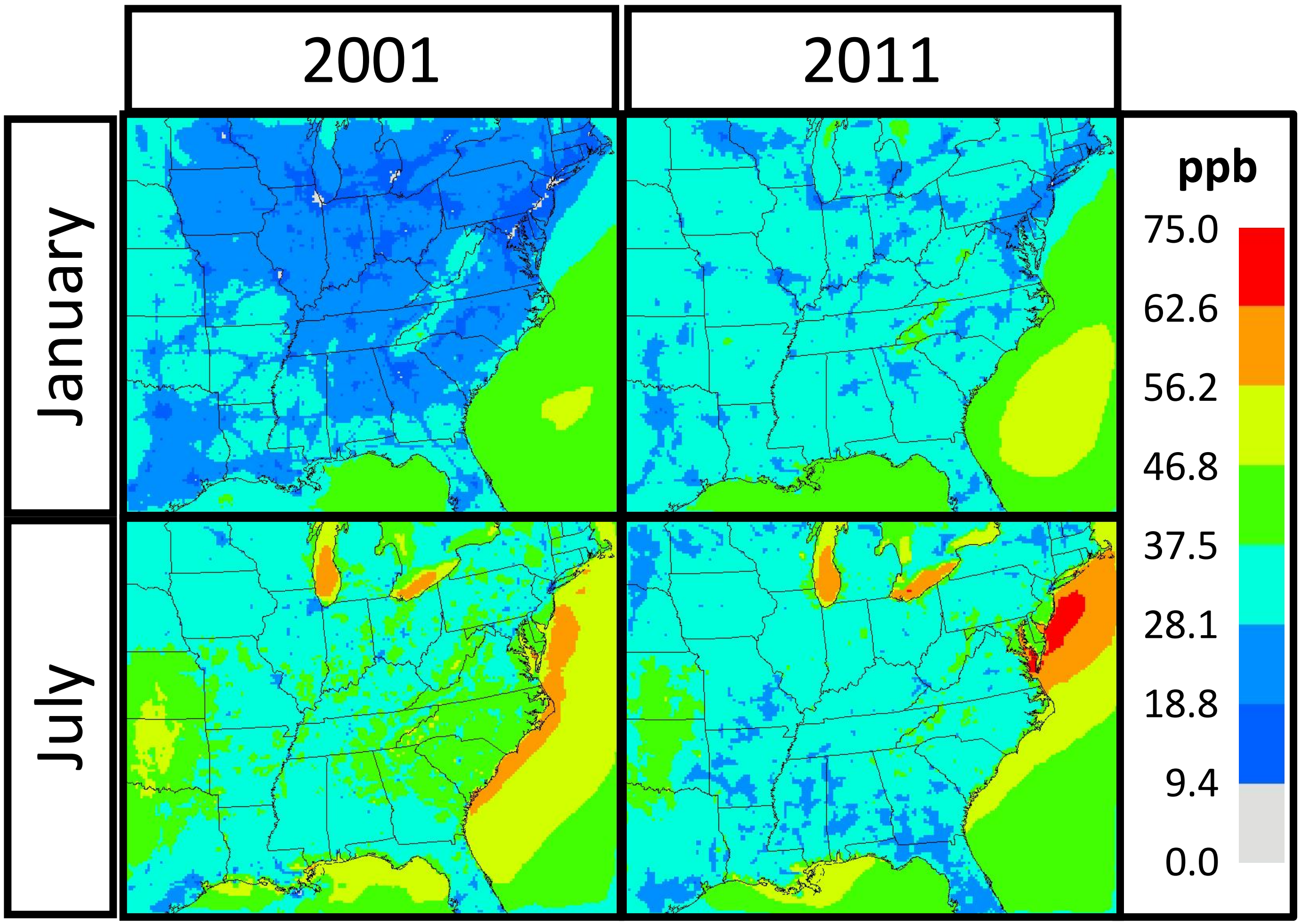
1. Concentration

2. Sensitivity

CMAQ-modeled changes 2001 vs. 2011: Summertime O_3 decreases, Wintertime O_3 increases

Model Evaluation





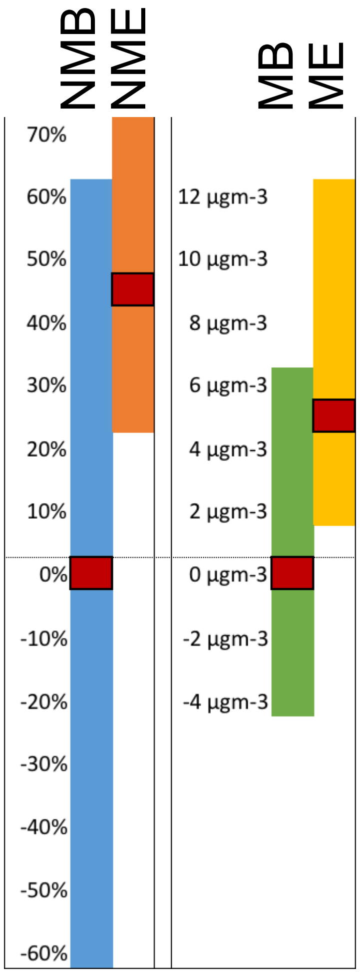
NMB: Normalized Mean Bias
NME: Normalized Mean Error

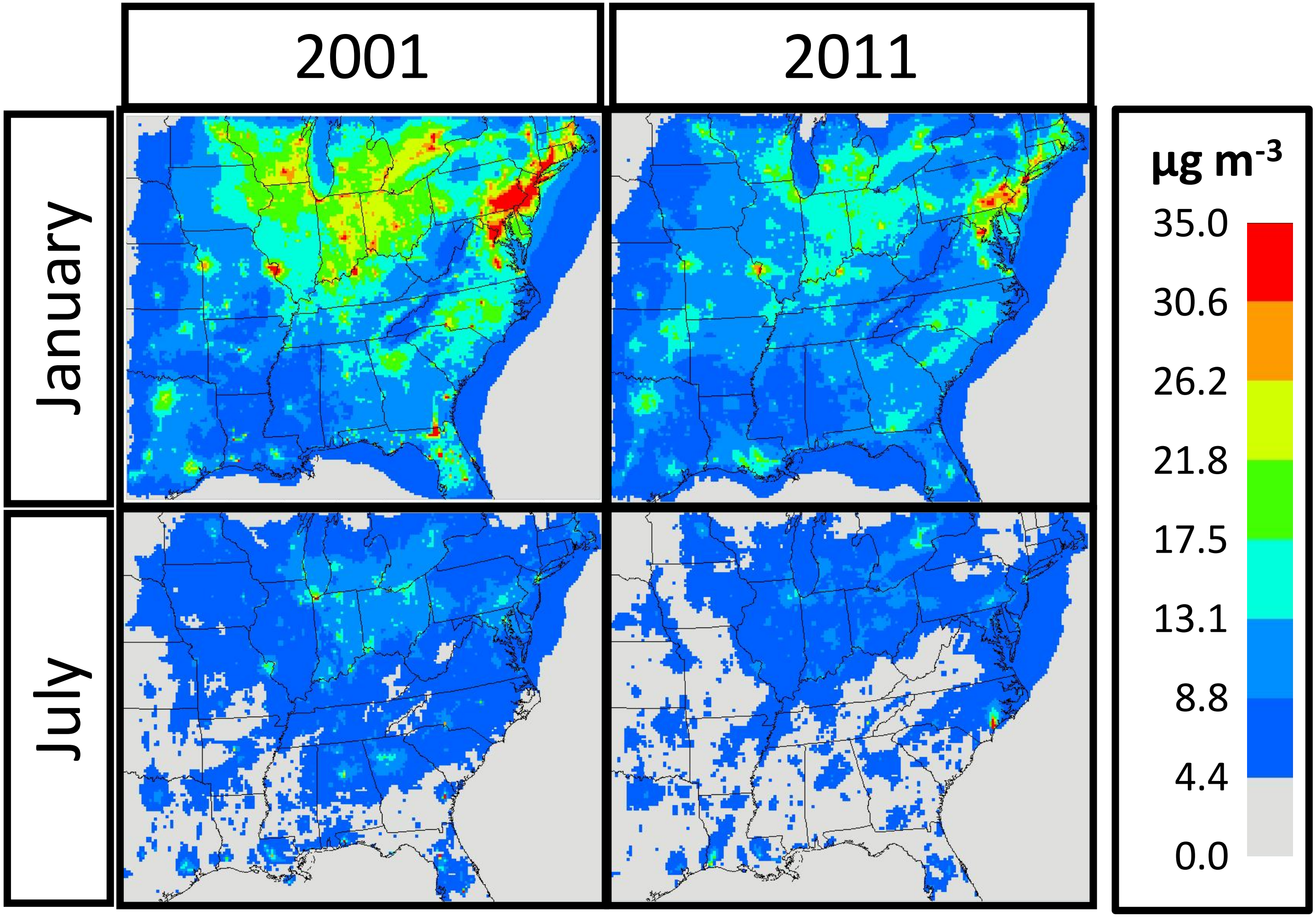
MB: Mean Bias
ME: Mean Error

Ranges (typical) from Simon et al. (2012)
Evaluation based on AQS (EPA)

CMAQ-modeled changes 2001 vs. 2011: $PM_{2.5}$ decreases in summer and winter

<u>Model Evaluation</u>





NMB: Normalized Mean Bias
NME: Normalized Mean Error

MB: Mean Bias
ME: Mean Error

Ranges (typical) from Simon et al. (2012)
Evaluation based on AQS (EPA)

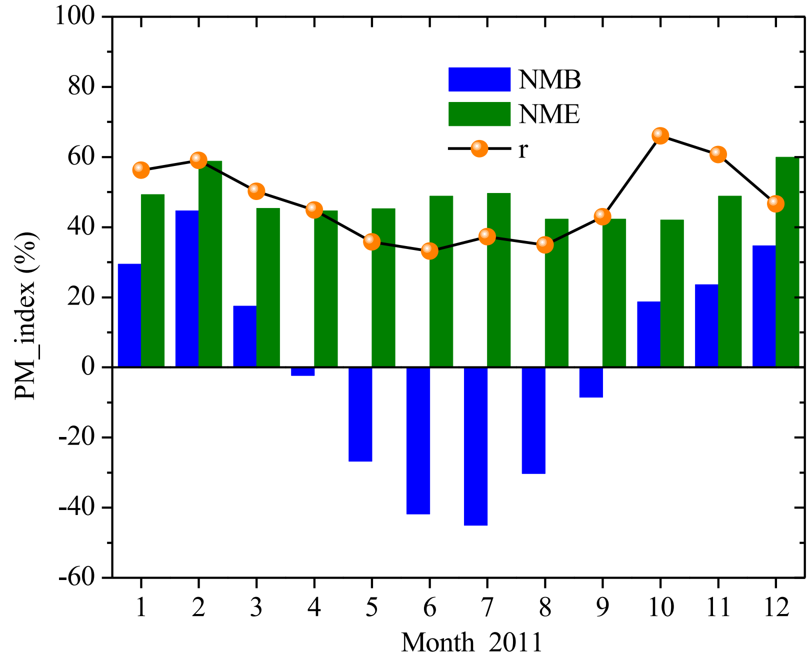
How well does CMAQ capture observed changes between 2001 and 2011?

Dynamic evaluation of $PM_{2.5}$ for Southeast: (AL, FL, GA, MS, NC, SC, TN)

	Observed	CMAQ
2001	13.9	10.7
2011	10.4	7.9
Difference	3.5	2.8

- CMAQ biased low in both years
- Slight under-prediction of change across years

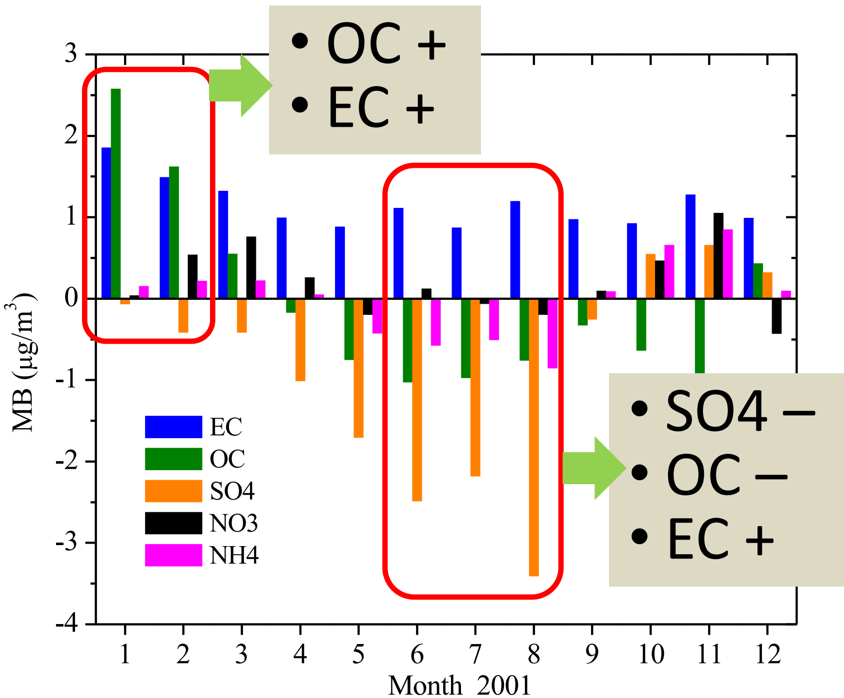
2011 $PM_{2.5}$ Monthly Evaluation



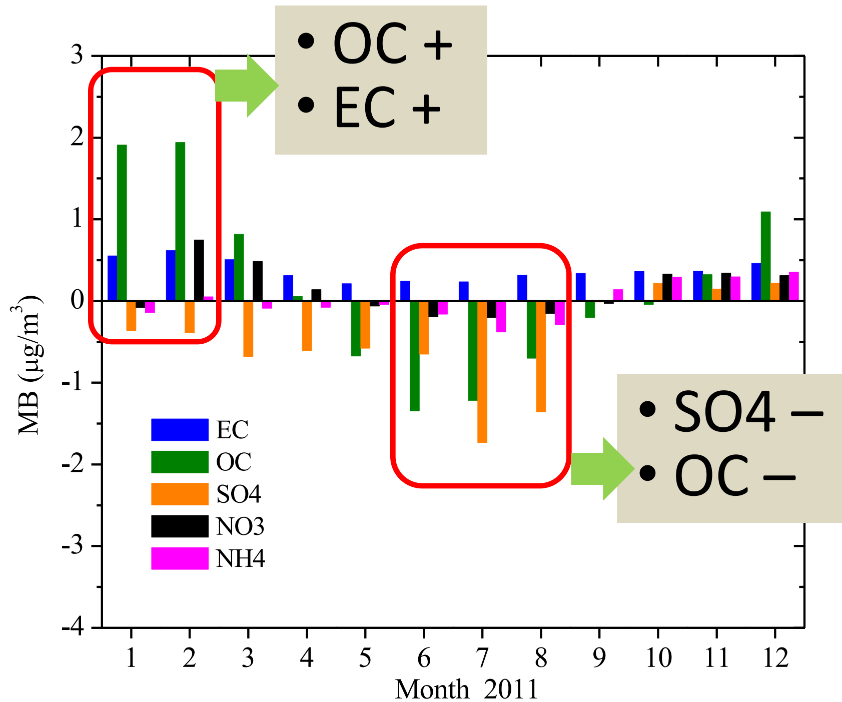
- Negative bias in the summertime, positive in the winter
- Model performs similarly in 2001 and 2011

Which species contribute most to bias?

Mean Bias (MB) can help answer: $MB = \frac{1}{N}\sum_{i=1}^{N}(C_m - C_o)$



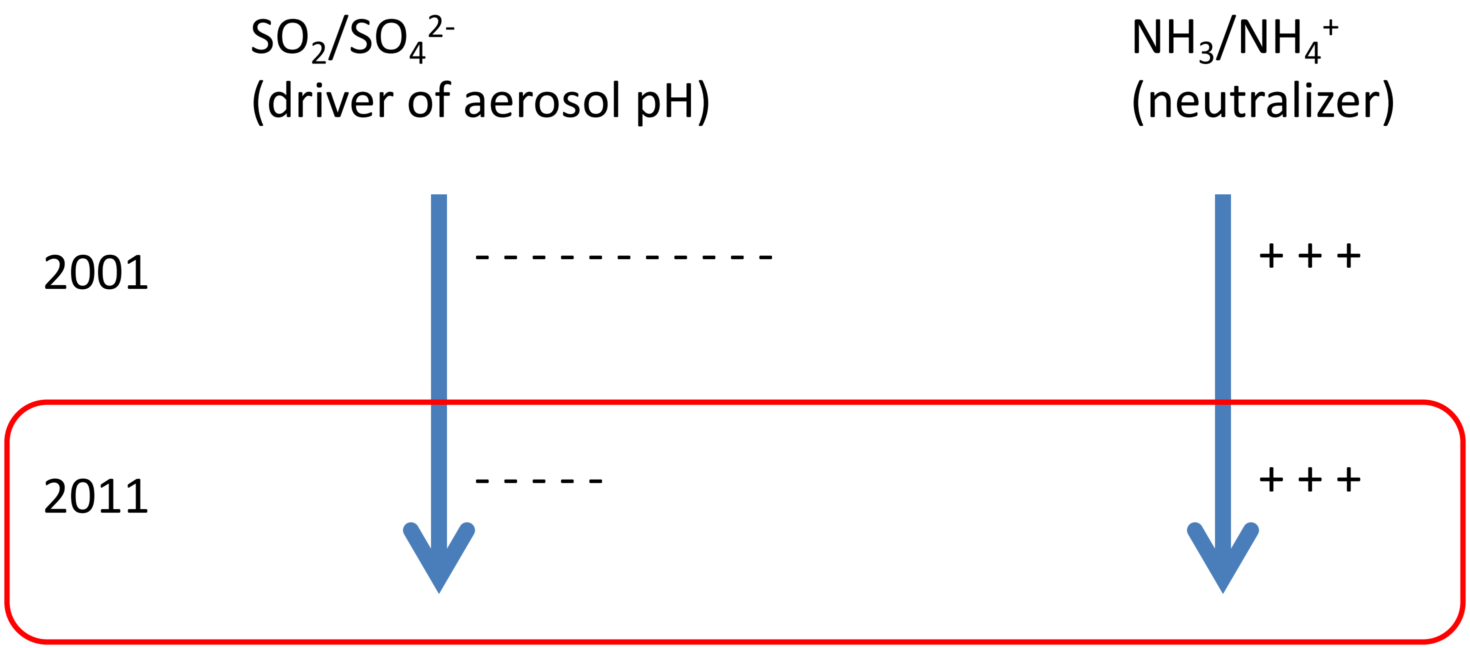
2001



2011

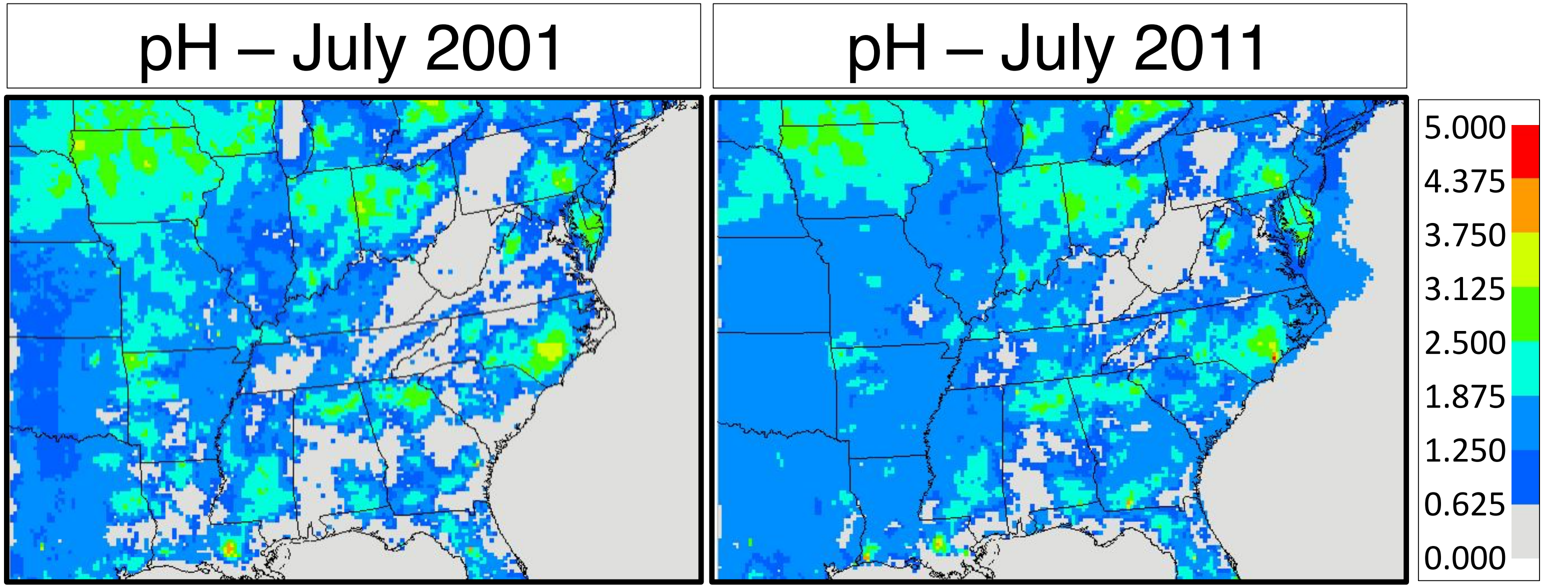
- Main contributors for Jun-Aug (-): sulfate and OC
- Main contributors for Dec-Feb (+): EC and OC

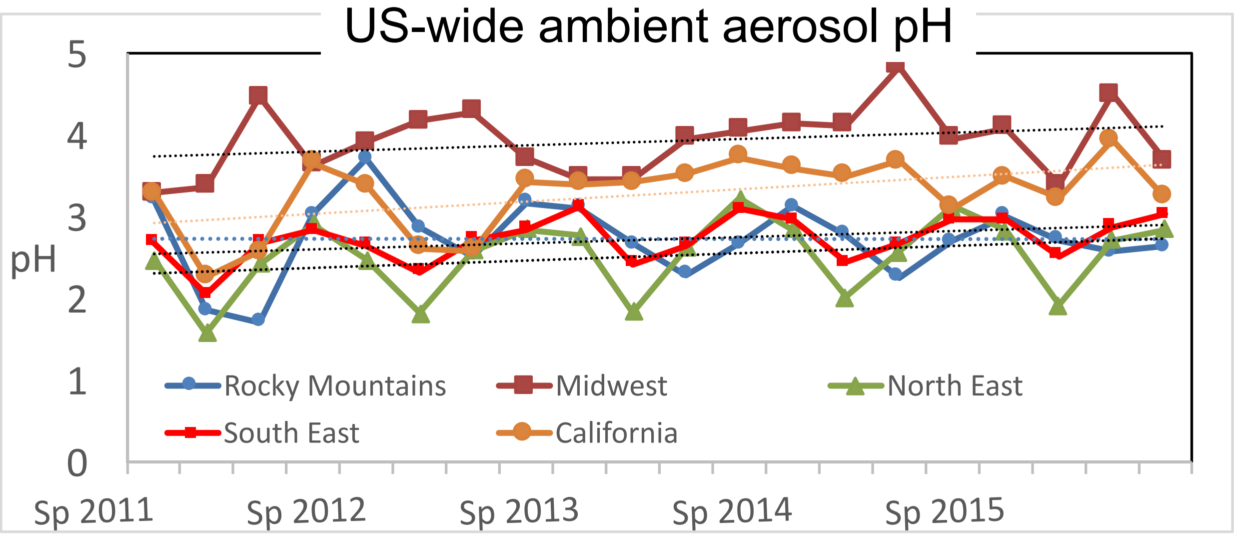
Aerosol pH conventional wisdom: decreased sulfate should lead to increased pH



- Conventional wisdom: aerosols are neutralized, pH should go up
- ISORROPIA used to calculate aerosol pH by using CMAQ modeled ion concentrations as inputs

Aerosol acidity: pH remains low across period of changing emissions



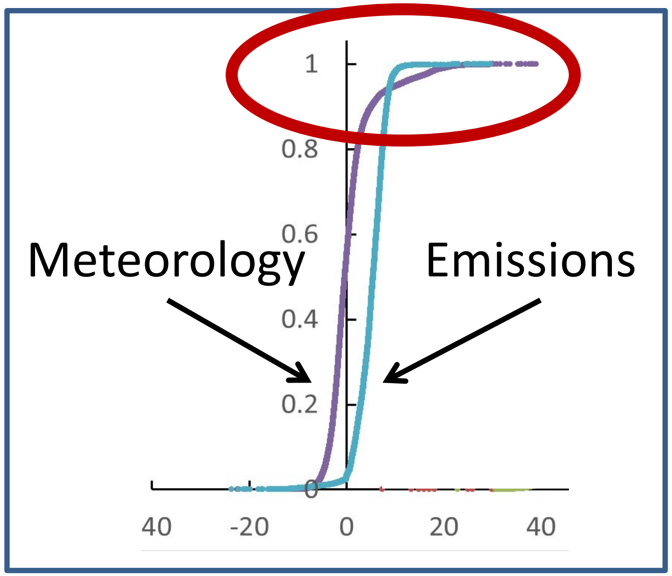


- CMAQ results consistent with observed changes in pH
- Nationwide, increases estimated at 0-5% yr^{-1}

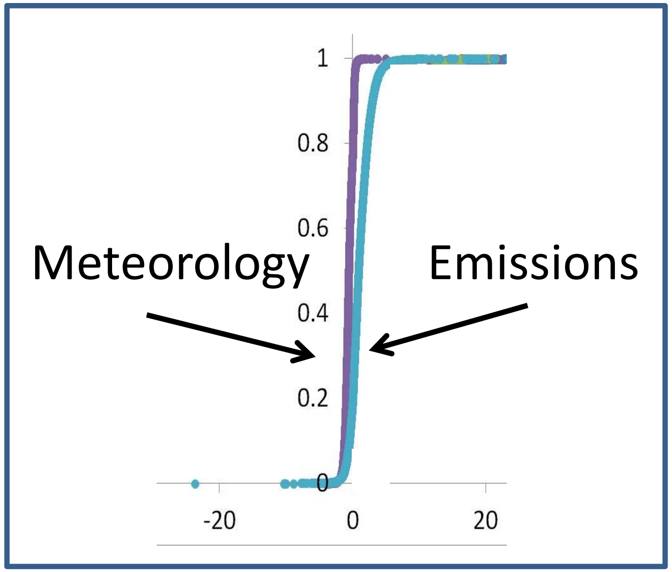
Guan et al., in preparation

Dynamic evaluation: separating impacts of emissions and meteorology using CDFs

Ozone



$PM_{2.5}$

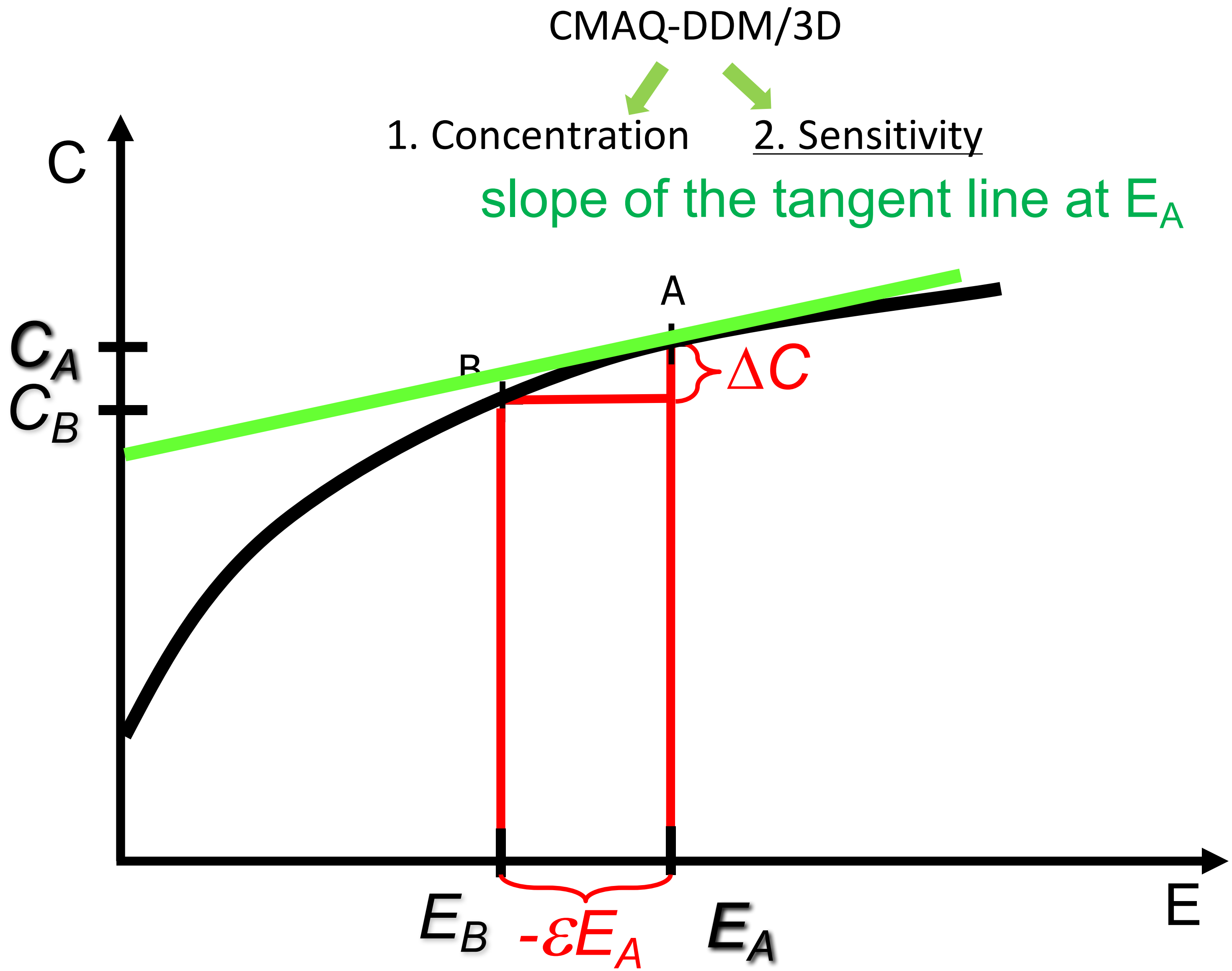


Emissions: 11E•01M – 01E•01M

Meteorological: 11E•11M – 11E•01M

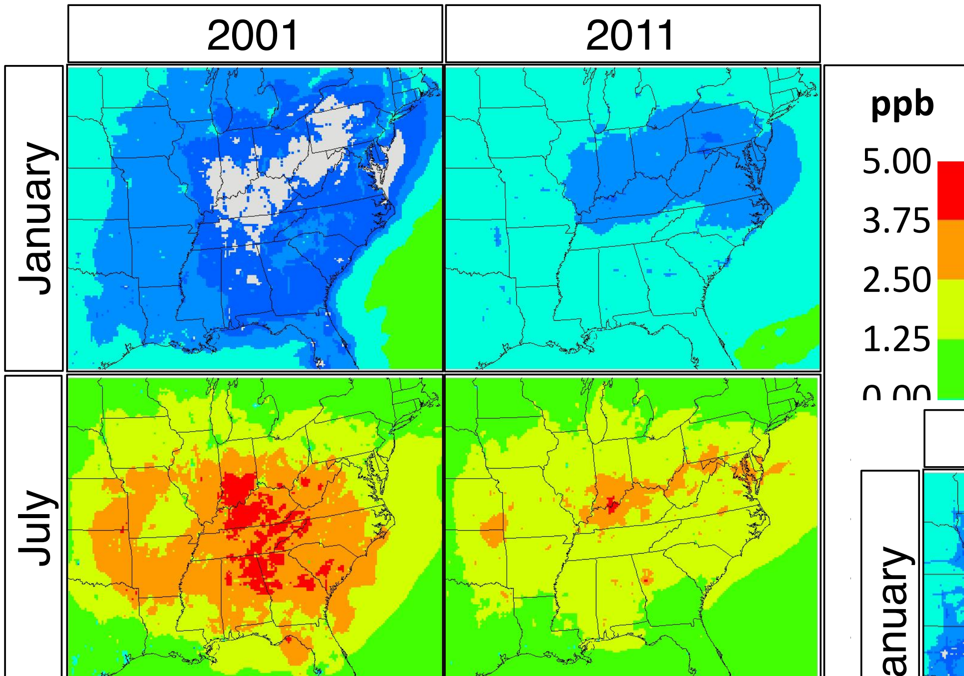
- Change in median ozone (5ppb) attributable to emissions changes
- Meteorology effects on 95th percentile larger than emissions: implications on compliance
- Impacts of emissions changes increase at higher percentiles

Sensitivity: 1st-order response of concentration to emission



Ozone sensitivities to EGU and on-road sources decrease

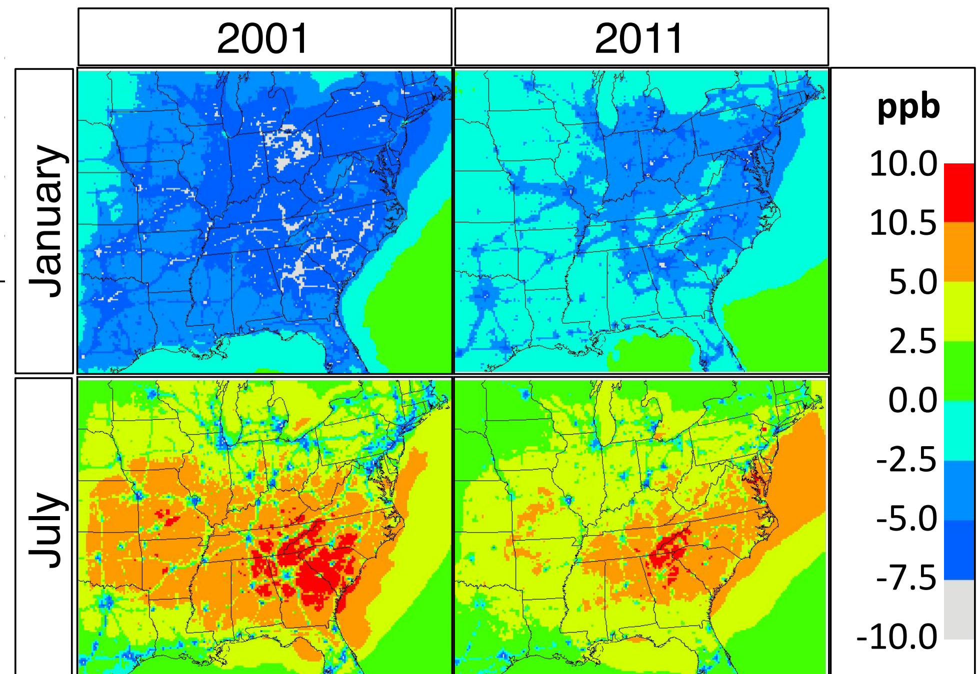
EGU sensitivities



- Sensitivities in both seasons trend to zero
- Summertime sensitivities around power plants remain important

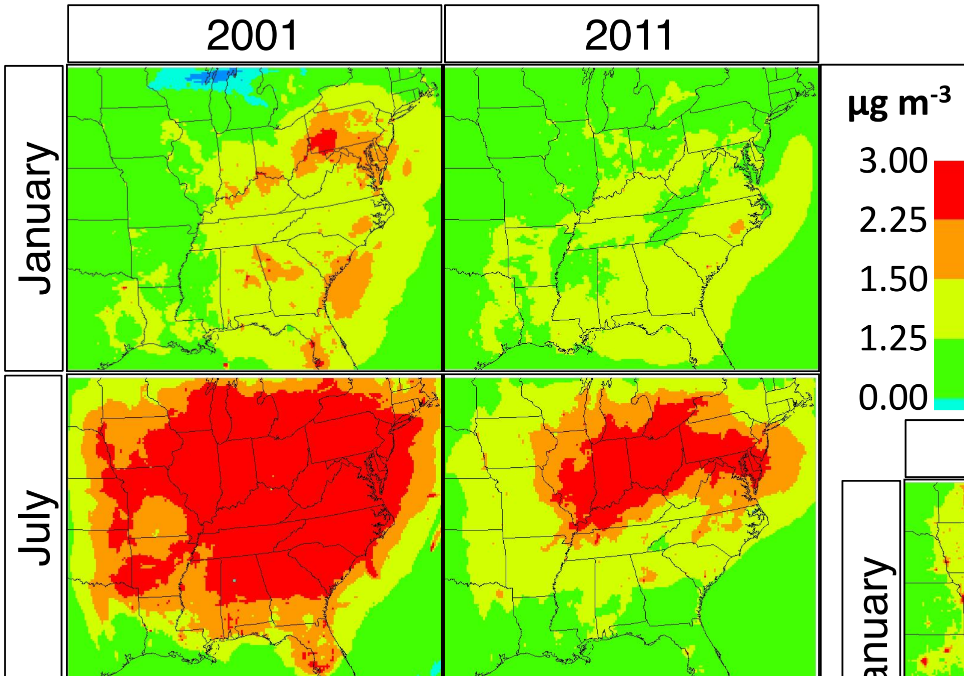
- Sensitivities in both seasons trend to zero
- Hot-spot remains in southeast

On-road sensitivities



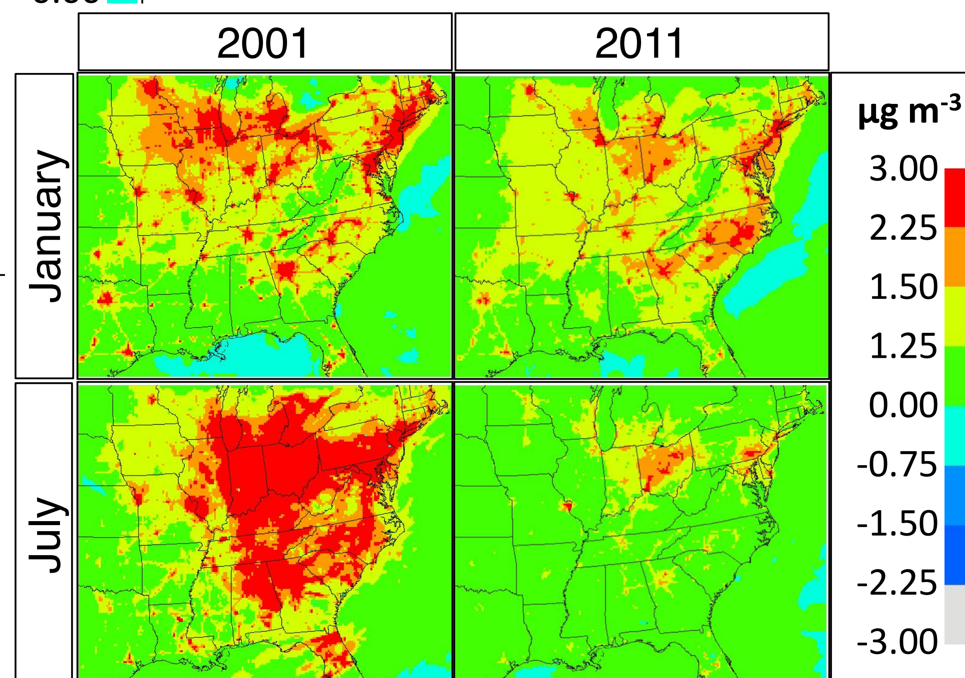
$PM_{2.5}$ sensitivities to EGU and on-road sources decrease

EGU sensitivities



- Sensitivities in both seasons decrease (larger change in winter
- Ohio River Valley and point sources remain important

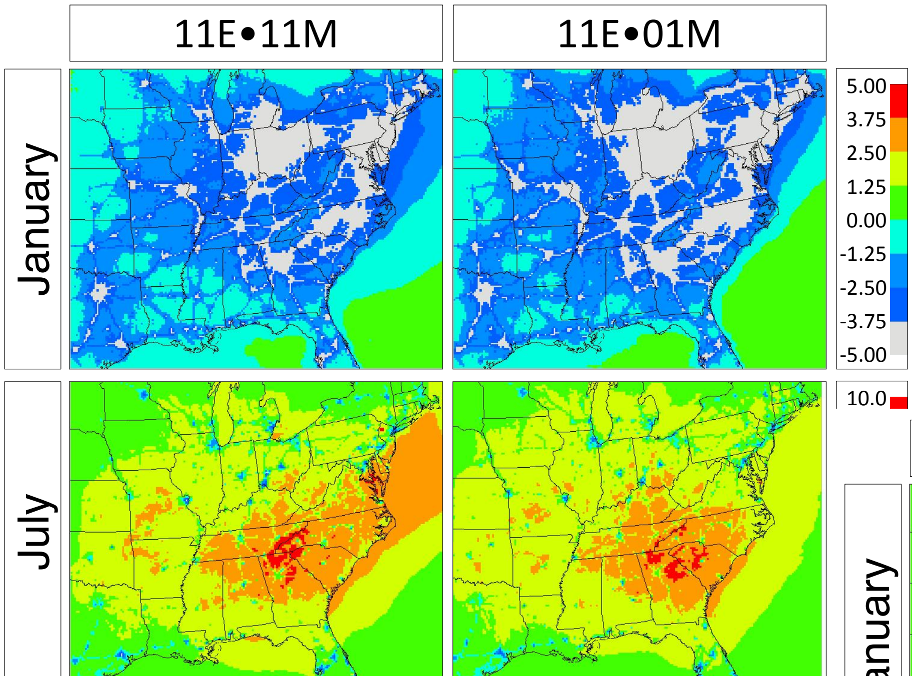
On-road sensitivities



- Sensitivities decrease across seasons
- In 2011, winter sensitivities larger than summer sensitivities

Meteorology has little effect on sensitivities

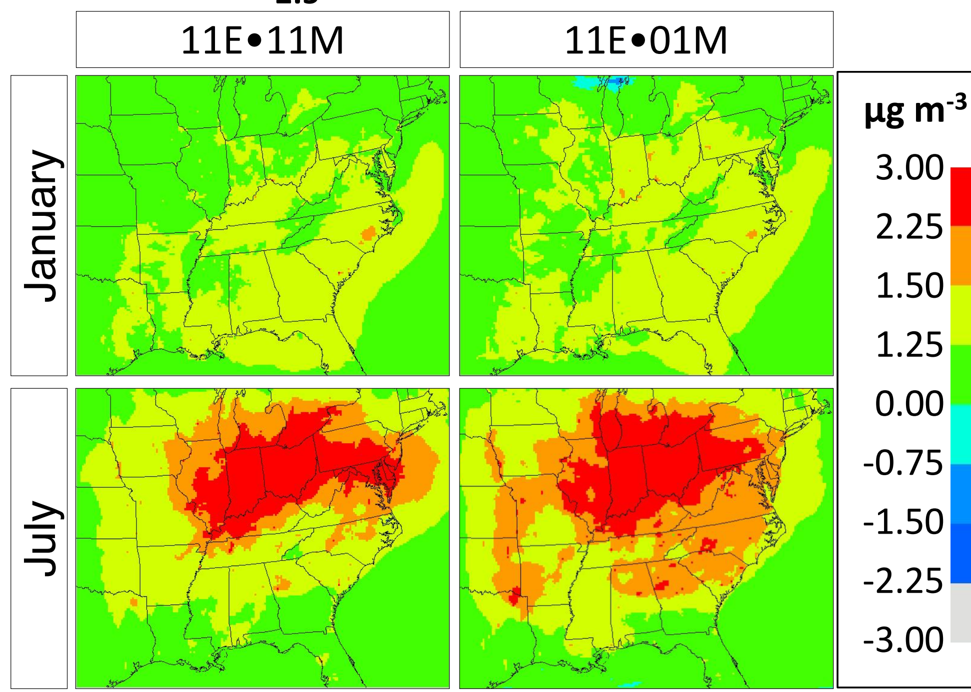
Ozone – On-road sensitivities



- Some differences in southeastern U.S.

- Little change attributable to meteorology

$PM_{2.5}$ – EGU sensitivities



Conclusions

- **Operational Evaluation**
  - CMAQ captures O_3 and $PM_{2.5}$ concentration changes, with different species dominating bias in different seasons
  - Sulfate and OC are the main contributors to bias in summer, and EC and OC in winter
  - Aerosols remain highly acidic, despite of significant reduction of SO_2 emissions
  - Sensitivity decreases from 2001 to 2011
- **Dynamic Evaluation**
  - Emissions drives concentration changes, though meteorology has larger effect on high O_3 days
  - Meteorology has little effect on sensitivity
  - Corroborates empirical evidence (Henneman et al., 2015)