# Use of Remote Sensing Air Quality Information in Regional Scale Air Pollution Modeling: Current Use and Requirements

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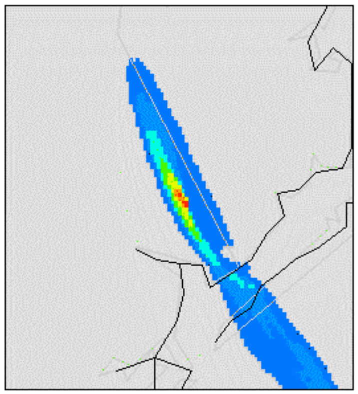
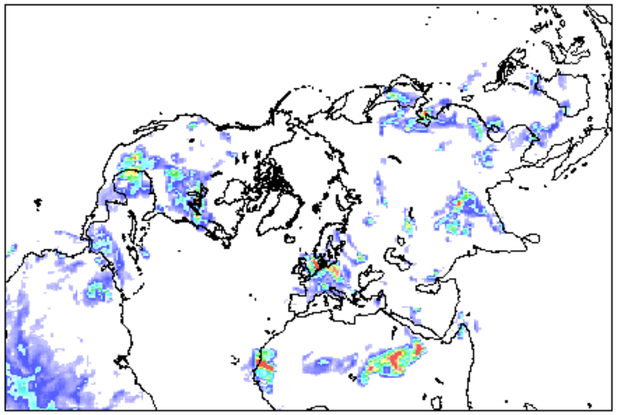
# Motivation

- Applications of regional AQ models are continuously being extended to address pollution phenomenon from local to hemispheric *spatial scales* over episodic to annual *time scales*





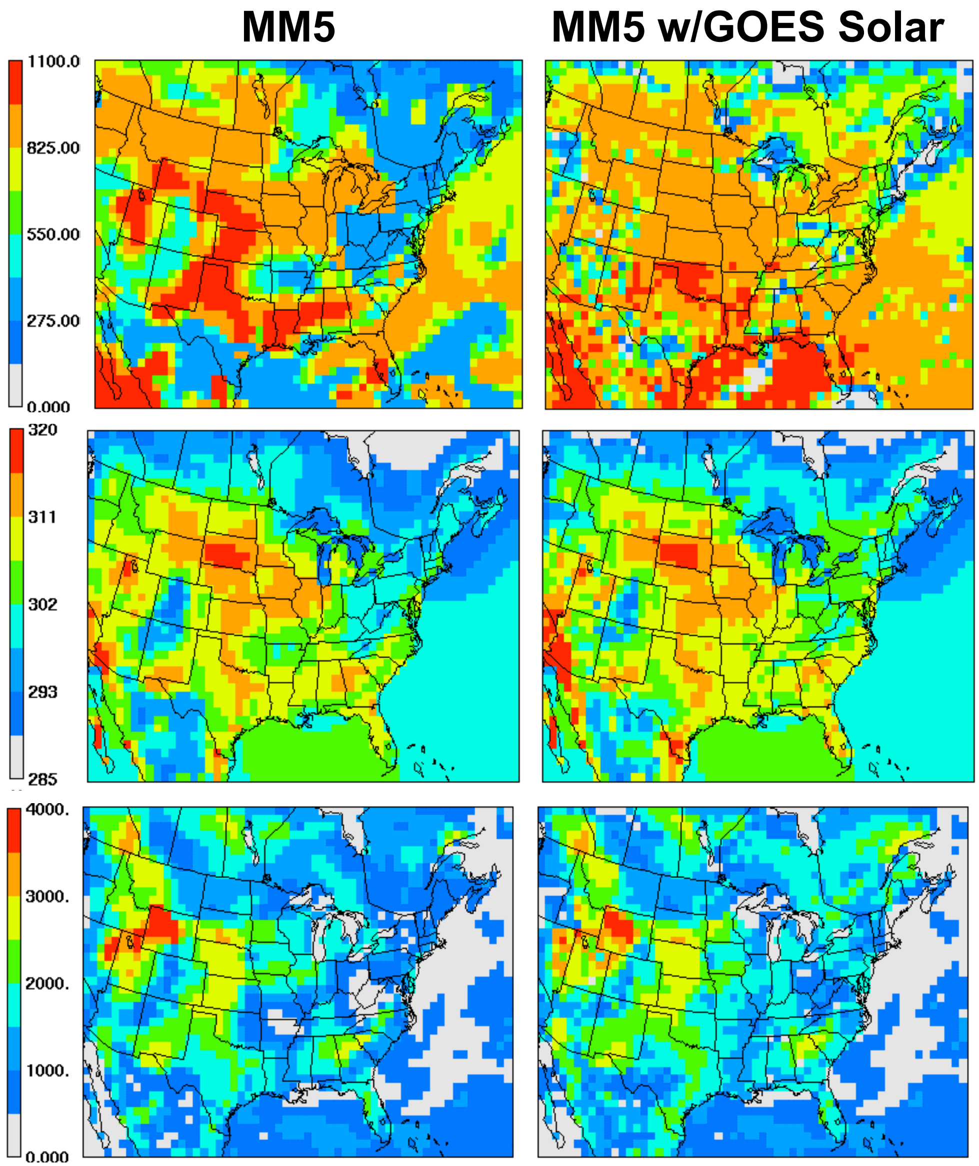
- The need to represent interactions between physical and chemical processes at these disparate spatial and temporal scales requires use of observational data beyond traditional surface networks

# *Use of Remote Sensing Information in Regional AQMs*

- Evaluation/Verification of model results
  - High spatial resolution over large geographic regions of remote sensing data is attractive
- Improve estimates of model parameters
  - Location and effects of clouds (e.g., photolysis)
  - Key meteorological parameters (e.g., PBL)
  - Lateral Boundary conditions (LRT effects)
  - Emissions (e.g, wildland fires, accountability)
- Chemical data assimilation
  - Improving short-term air quality forecasts
  - Identification of model deficiencies

# *Improving Key Meteorological Parameter Estimates*

Impact of assimilation of Solar Radiation from GOES (7/31/1988; 1900z)




**Surface Radiation (W/m$^2$)**

Large areas with reduced cloud effects

**Ground Temperature ($^o$K)**

Up to 6 $^o$K increase in surface temperature in affected areas

**PBL Height (m)**

Up to 1000m higher PBL in affected areas

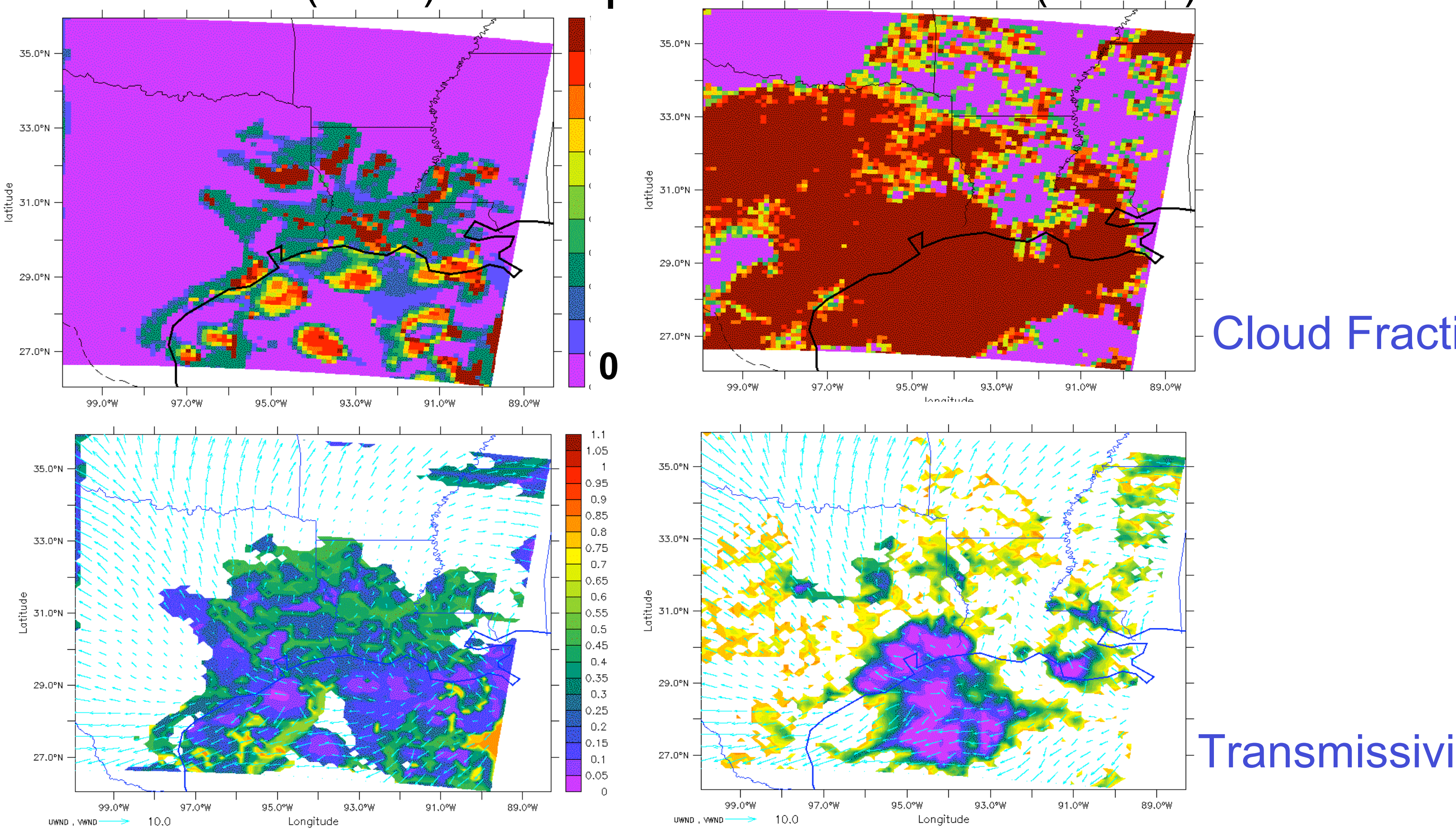
# *Improving Model Parameter Estimates*

## Photolysis attenuation by clouds

- $J = J_{clear}$ *f(transmissivity, fraction)*

Model (MM5)

Satellite Derived (GOES)

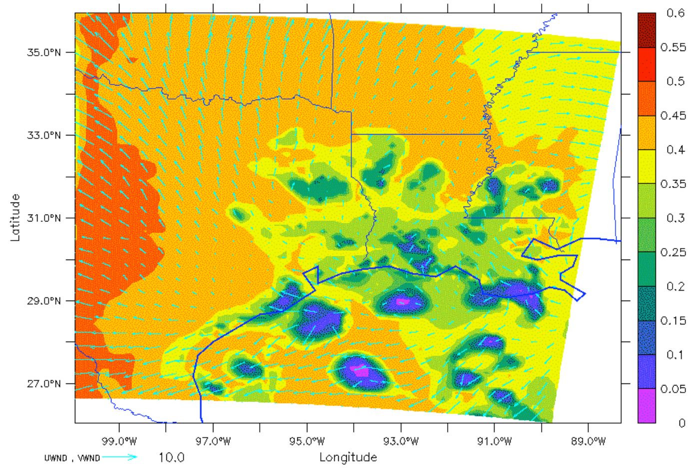



Cloud Fraction

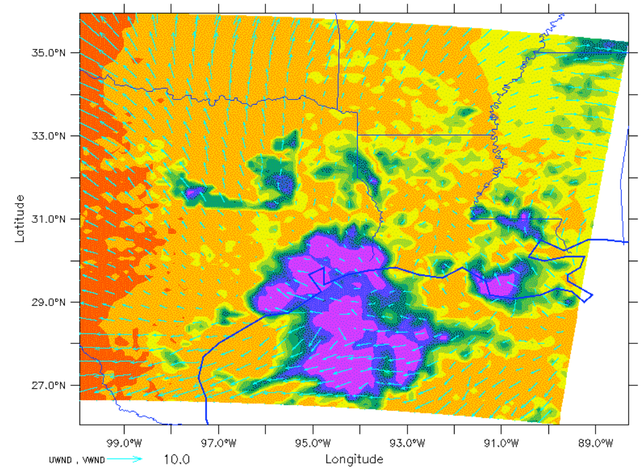
Transmissivity

# Photolysis attenuation by clouds: CMAQ (*contd.*)

Base

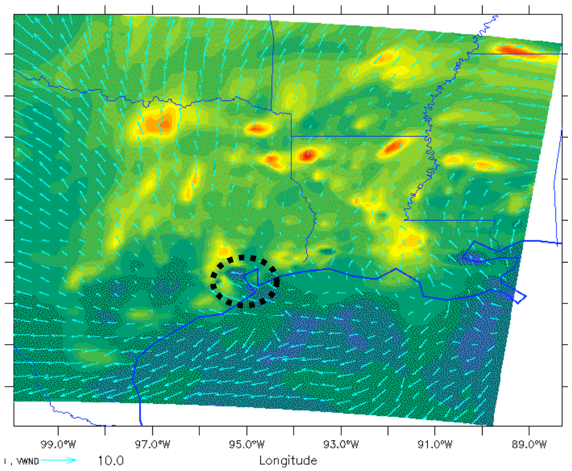



Satellite Based

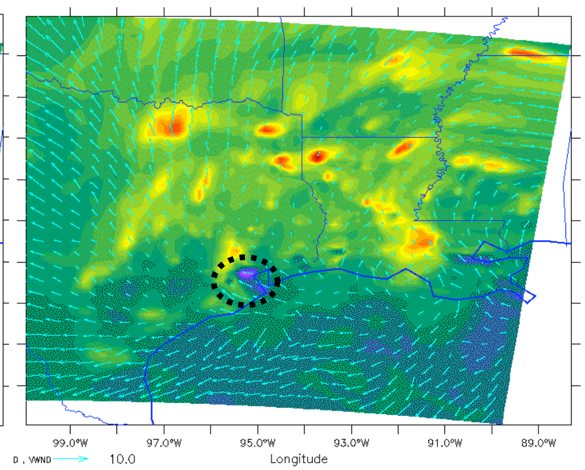



$JNO_2$ ($s^{-1}$)

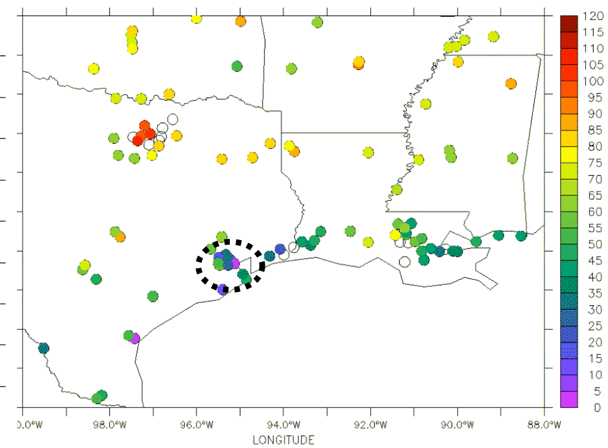
Base




Satellite Based




Observed




$O_3$

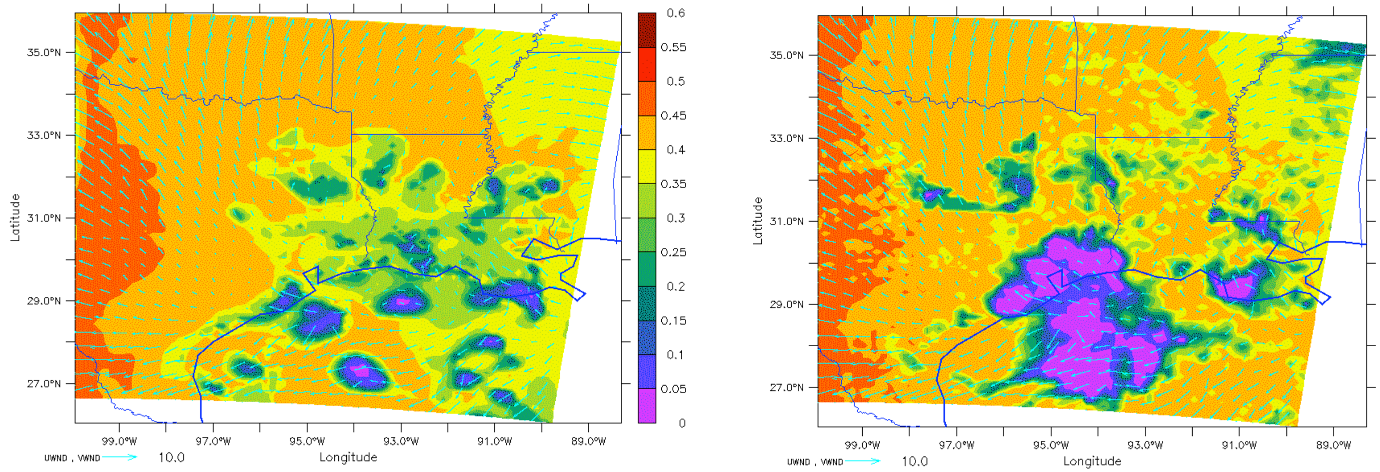
21Z on 8/24/2000

*Courtesy: A. Biazar, Univ. of Alabama*

# Photolysis attenuation by clouds: CMAQ (*contd.*)

Base

Satellite Based

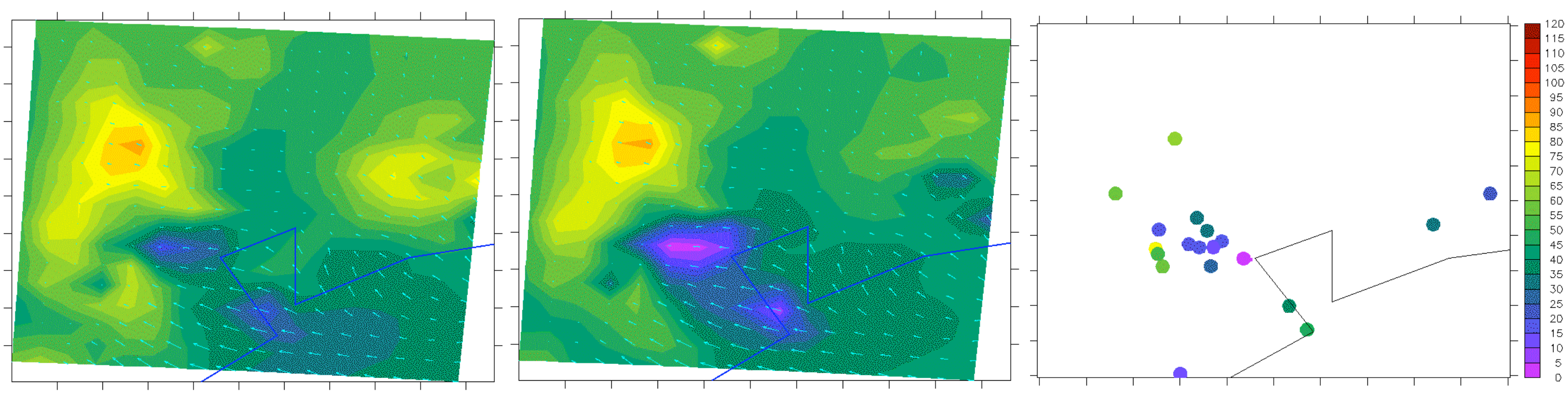



$JNO_2$ ($s^{-1}$)

Base

Satellite Based

Observed




$O_3$

21Z on 8/24/2000

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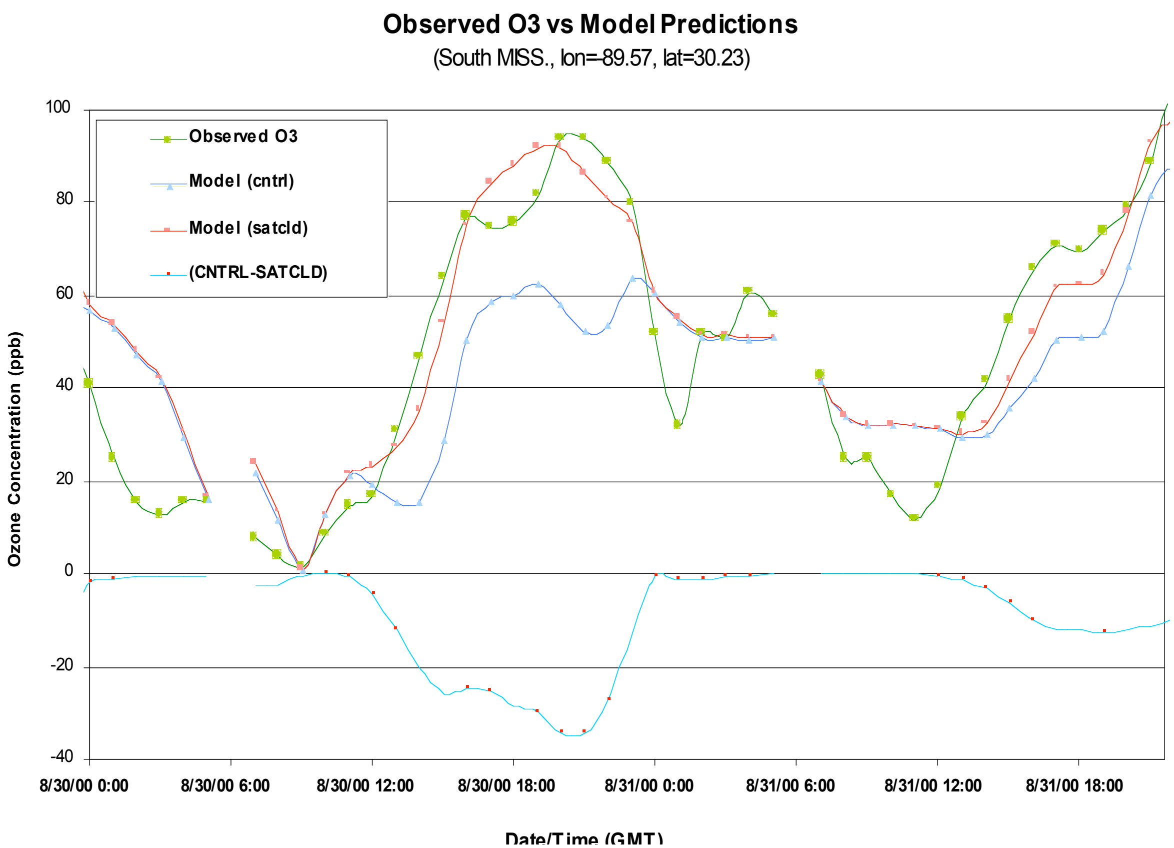
# Photolysis attenuation by clouds (*contd.*)

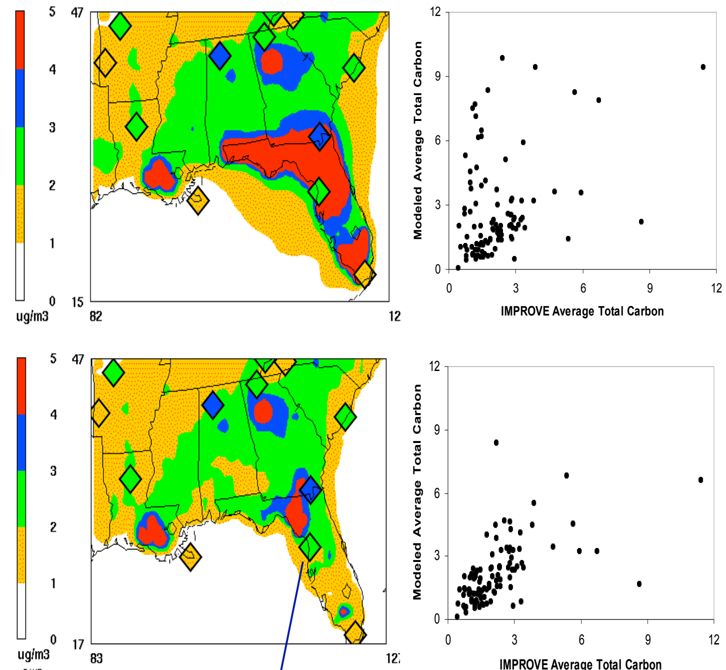



*Courtesy: A. Biazar, Univ. of Alabama*

# *Improving Model Parameter Estimates*
## Wildfire Emission Specification in CMAQ

- Spatial allocation of emissions based on forest surrogates leads to unrealistic spatial distributions

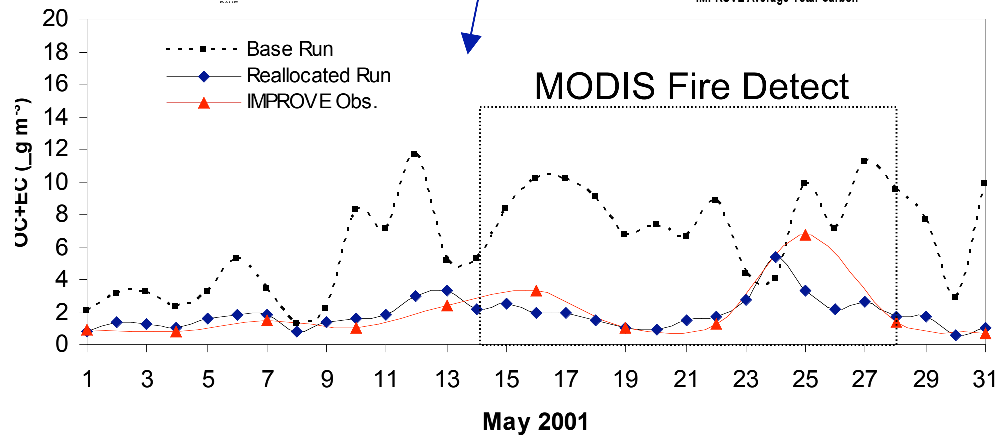
- Reallocate NEI prescribed and wildfire emissions using MODIS Rapid Response Fire pixel count




Base

Reallocated

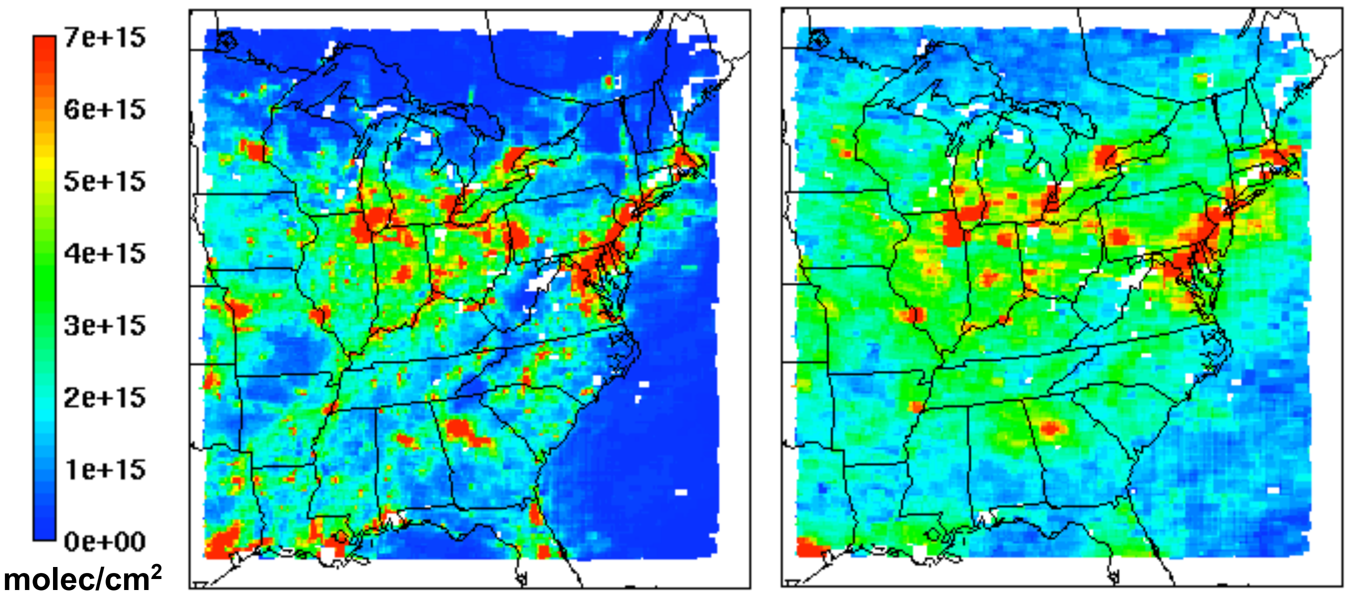
➡ Reallocation helps reduce bias and improves correlation in total carbon predictions



# *Evaluation of Modeled Spatial Distributions*

## $NO_2$ Columns: Summer 2004

CMAQ SCIAMACHY

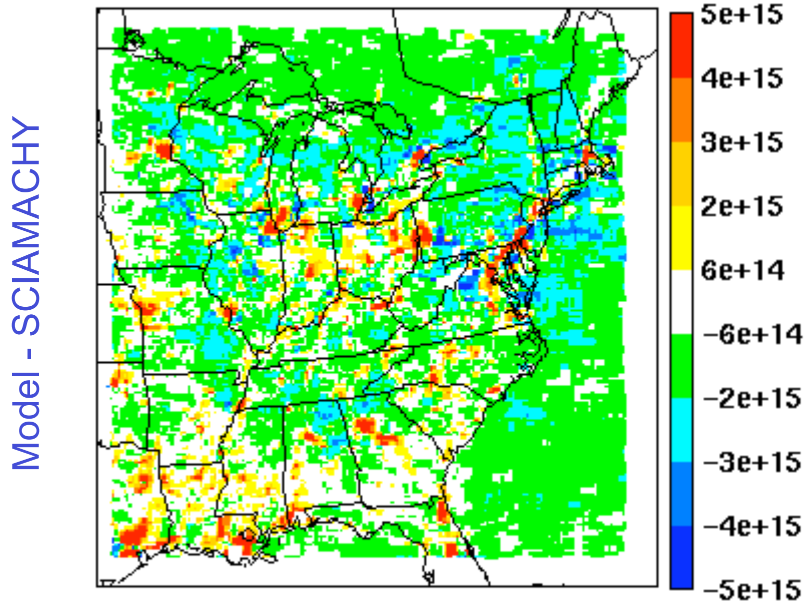


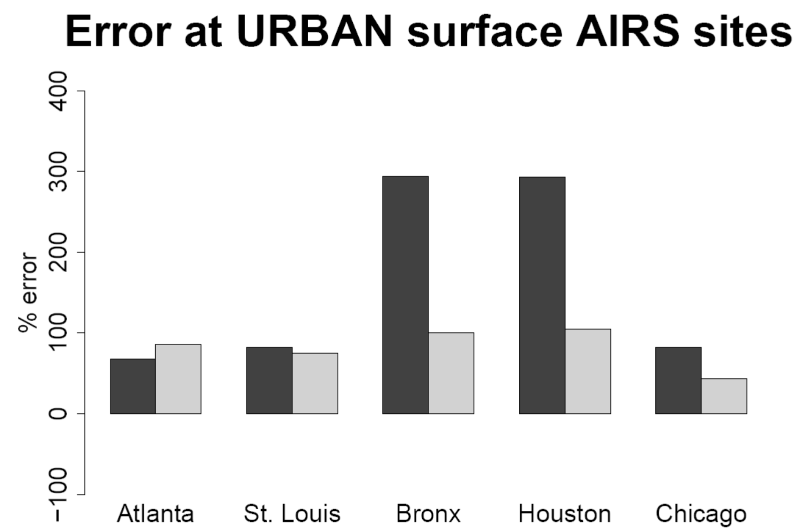

(*Courtesy: R. Martin*)

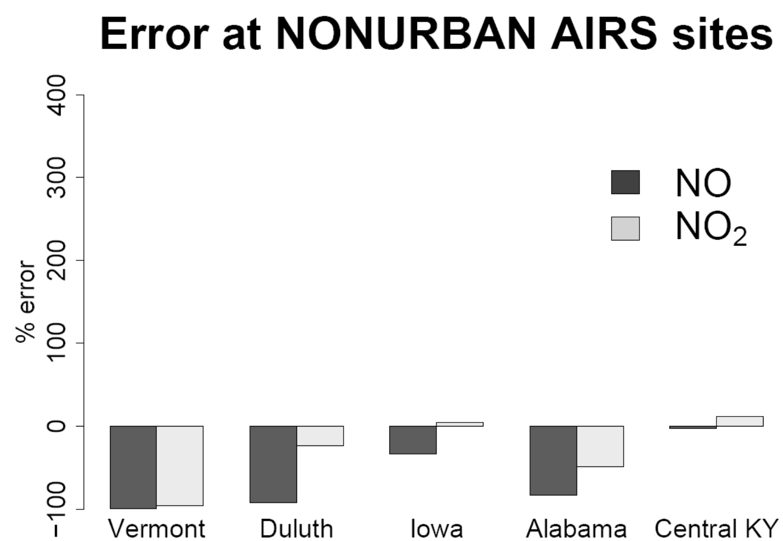
**On-going efforts**:

- Model Evaluation (2004)
- Test and Improve $NO_x$ Emission Inventories
- Accountability studies
  - Track impact of regulations on observed regional and local
- AQ over time using both model and observations

# *Evaluation of $NO_2$ Spatial Distributions (contd.)*




**Comparable spatial distributions**

**SCIAMACHY higher in rural areas**

- higher regional background
- missing source (lightning), or
- chemistry ($NO_x \rightarrow NO_y$) too rapid

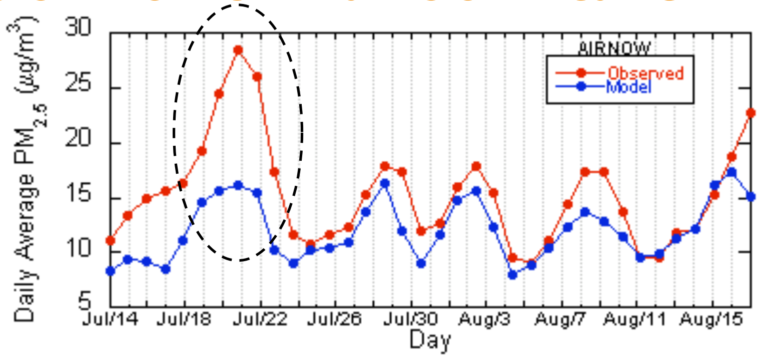
**CMAQ higher downwind of urban areas**

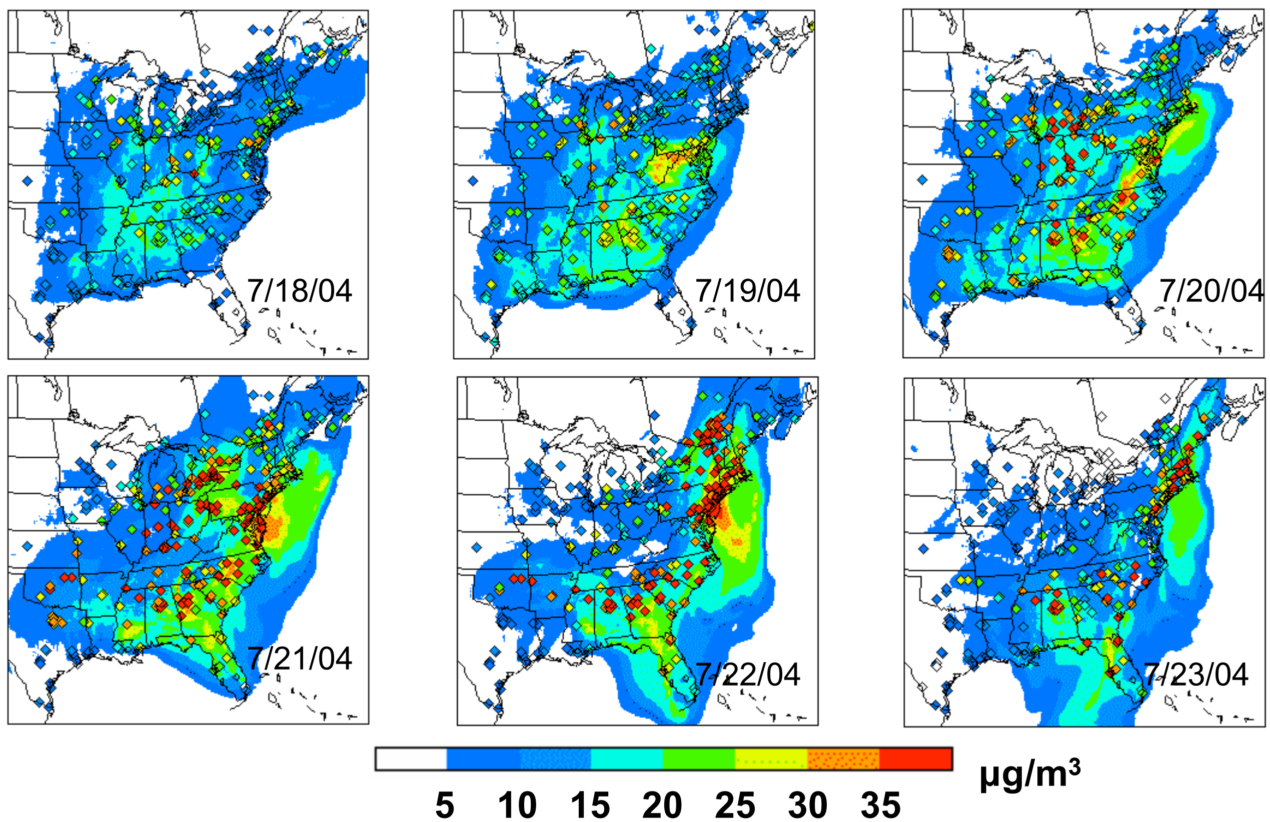
(e.g., Atlanta, St. Louis), Point sources

- Opposite trend compared to GEOS-CHEM (resolution/chemistry)
- air mass factor from GEOSCHEM ($NO_x$ lifetime difference due to resolution)

**Similar discrepancies at surface**

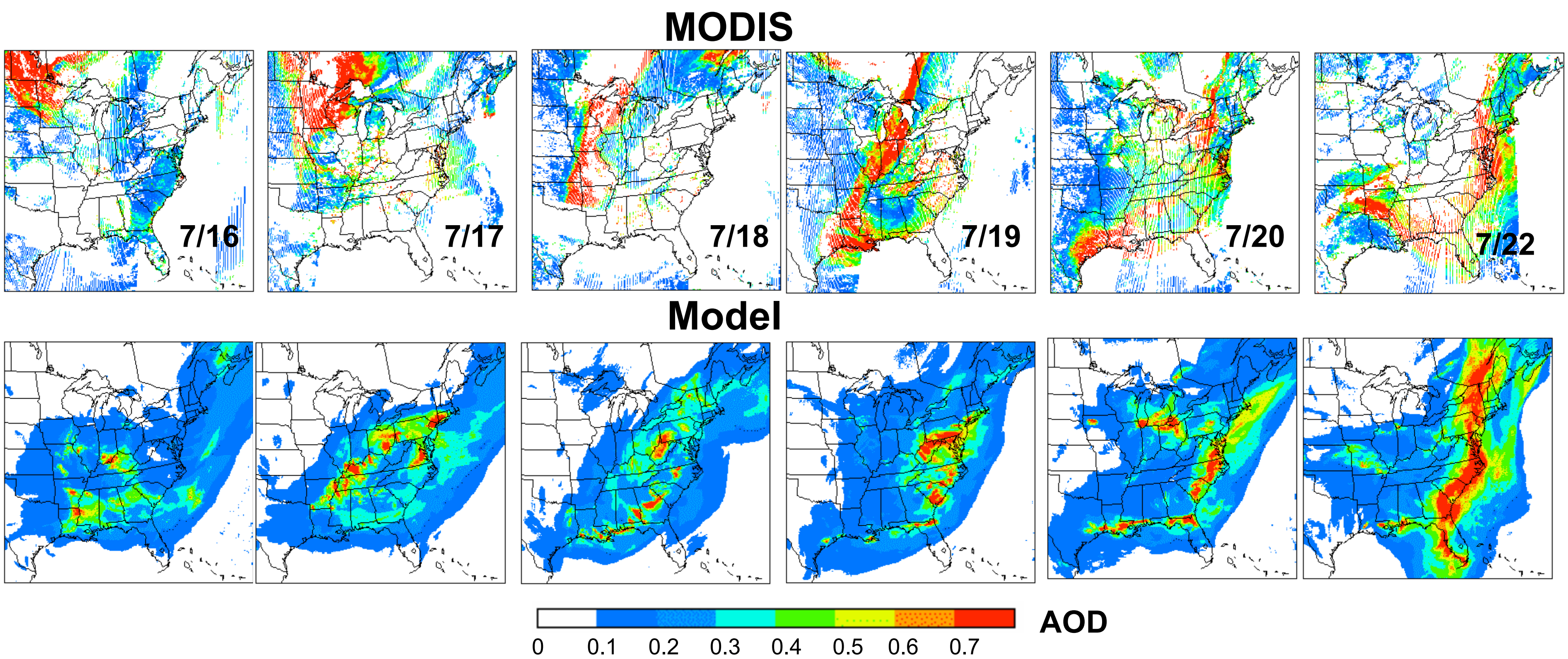
## *Diagnosing Model Performance: Eta-CMAQ $PM_{2.5}$ Forecasts*



# July 16-22, 2004: Evidence of Effects of Long Range Transport Originating from Outside the Modeled Domain

## Evolution of Model and Observed Aerosol Optical Depth

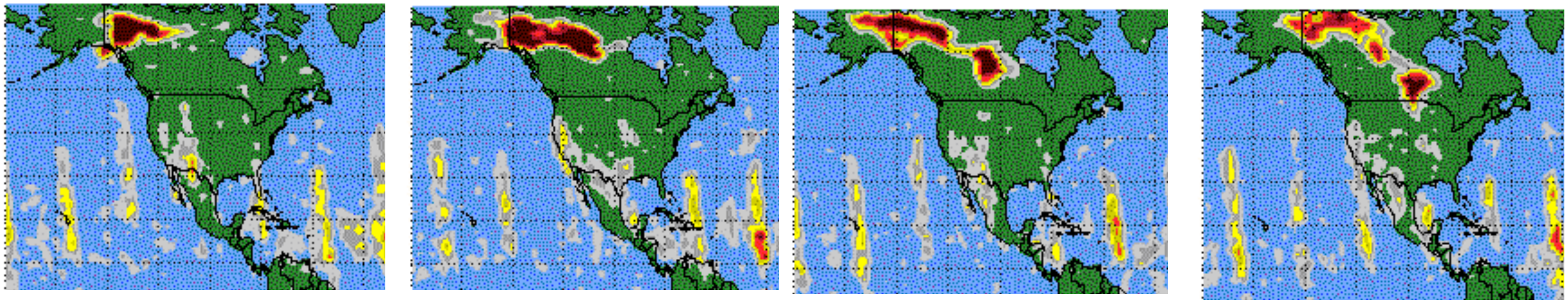



Transport from outside the domain influences observed PM concentrations which are grossly under-predicted during this period

- Model picks up spatial signatures ahead of the front
- Under predictions behind the front (due to LBCs)

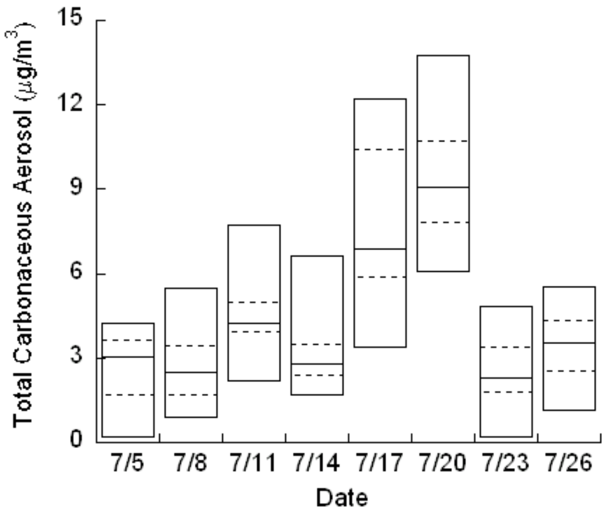
# Further Evidence

7/13/04 7/14/04 7/15/04 7/16/04




Goddard Space Flight Center

Long Range Transport of Alaskan Plume



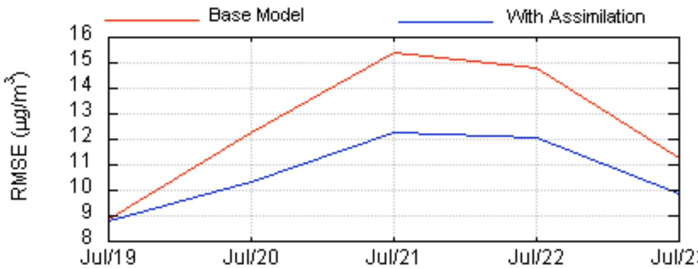

**Distribution of measured carbonaceous aerosol at STN sites within domain**

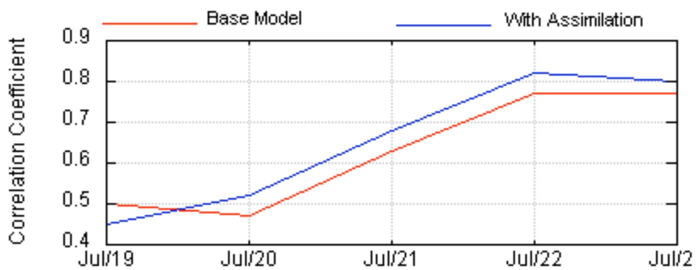
➡ Regional enhancement in TCM on July 17-20 suggests influence of wildfires on air masses advected into the domain

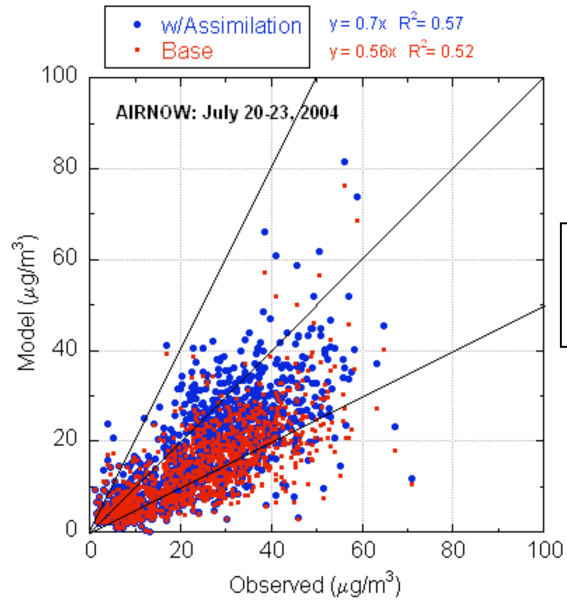
➡ ***Can AOD assimilation improve model PM forecast?***

# *MODIS AOD Assimilation: Impact on Surface $PM_{2.5}$ Model Performance*

**AIRNOW**
**July 19-23, 04**

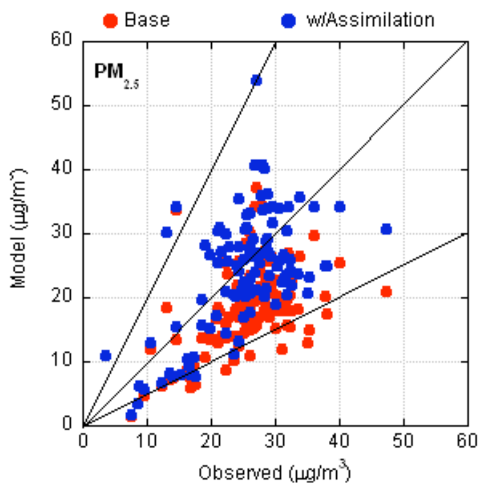


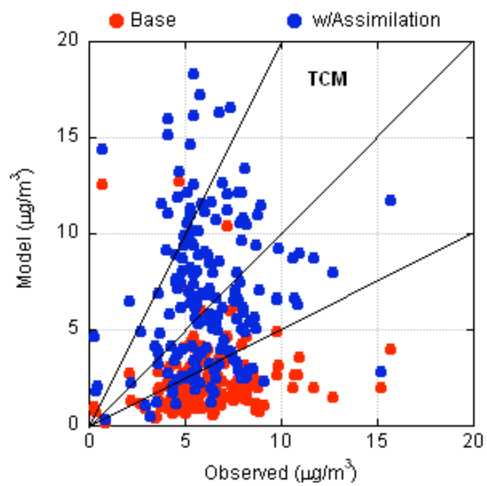



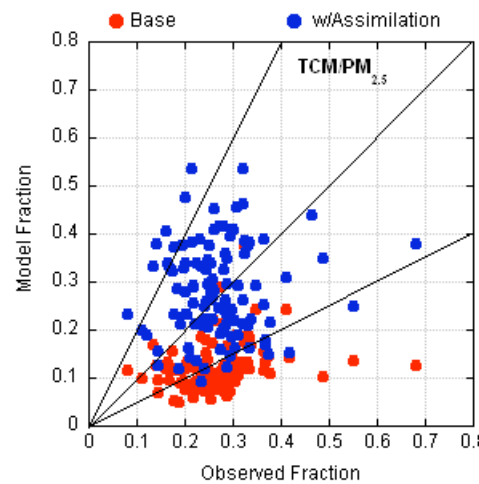




- **Reduced Bias/Error**
- **Improved Correlation**

**STN**
**July 20, 04**




**Domain median surface levels enhanced by 23 - 42% due to Alaskan fires on different days**

# Summary

- Air quality remote sensing data is useful for model evaluation and improvements
  - *What level of quantitative agreement is acceptable?*
  - Need for harmonization between assumptions used in retrieval and CTM process algorithms (e.g., AOD, $NO_2$ columns) for more rigorous quantitative use
- Potential for use in chemical data assimilation
  - Simultaneous information on multiple chemical species
  - Use in air quality forecasting would require availability in near real-time
- Columnar distributions are a good starting point, but there is a need for better vertical resolution
  - Discern between BL and FT
  - Help improve FT predictions in regional AQMs
    - Linking with global models that assimilate satellite data
    - Direct assimilation in regional AQMs

# *Acknowledgements*


- Collaborators:
  - Arastoo Biazar and Dick McNider
  - Randall Martin
  - James Szykman
  - Shobha Kondragunta

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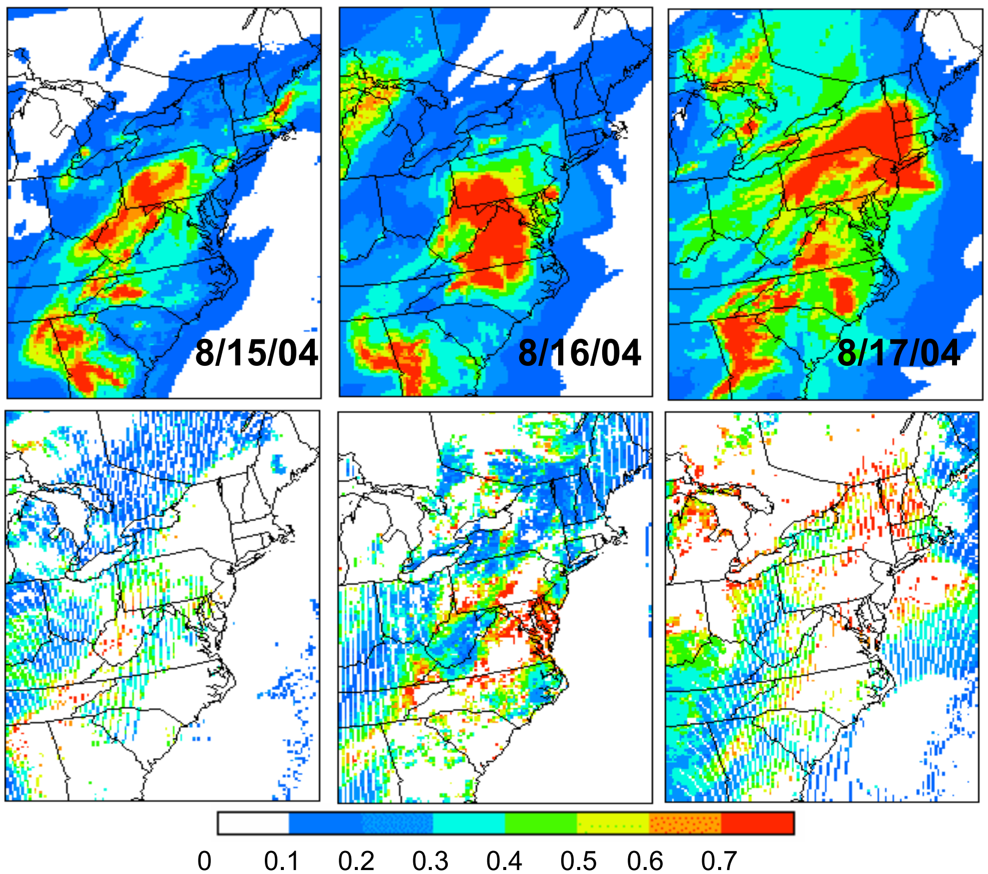
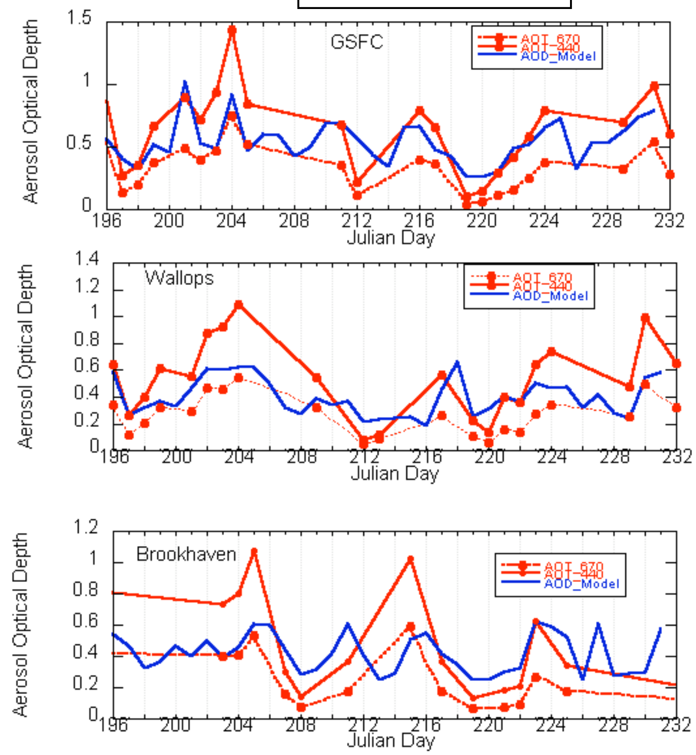
# Model and Observed Aerosol Optical Depths (AOD)

Model (top panels) MODIS (bottom panels)




AERONET




Modeled AOD at 550nm

AERONET Data at 440 and 670nm

Reasonable model simulation of spatial and temporal variability in AOD is possible

➡ ***Can AOD assimilation improve model PM forecasts?***