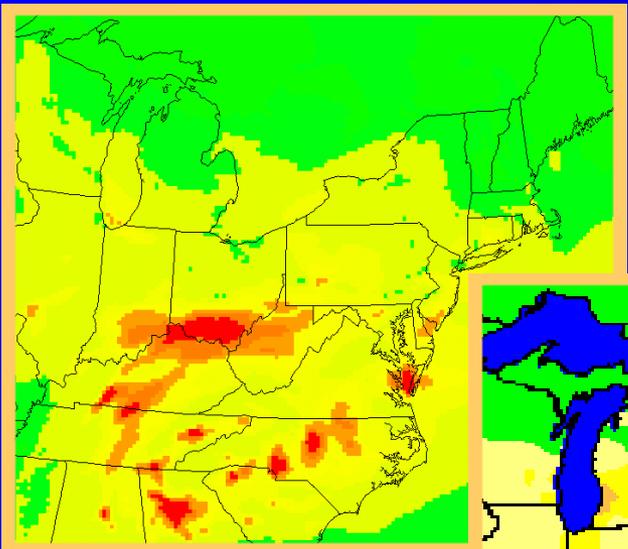


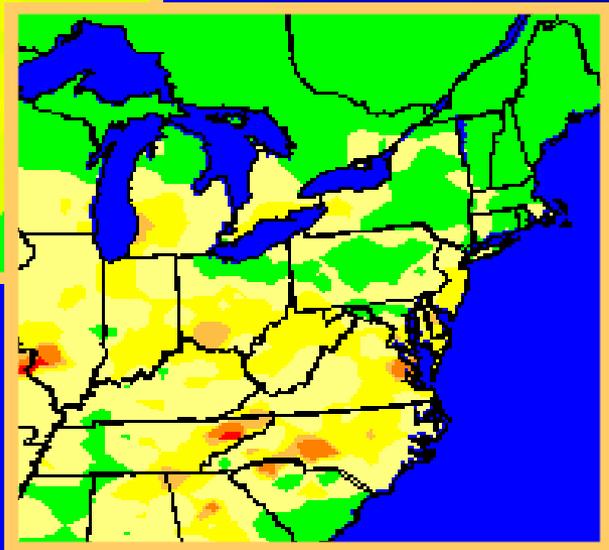


AN EVALUATION OF THE ETA-CMAQ AIR QUALITY FORECAST MODEL AS PART OF NOAA'S NATIONAL PROGRAM

CMAQ



AIRNOW



August 26, 2003

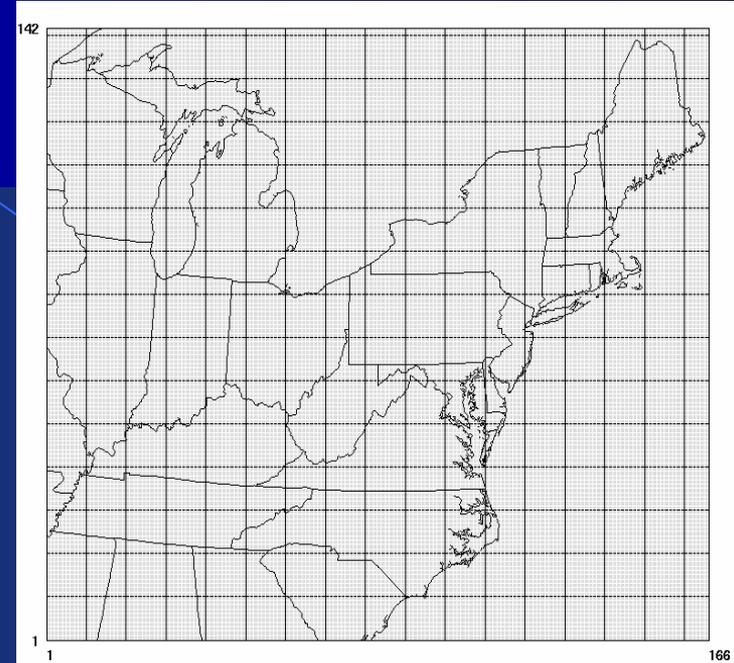
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Daiwen Kang *
Ken Schere *
Jonathan Pleim *

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Air Resources Laboratory, NOAA

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RTP, NC 27711



Domain



Forecast Configuration

- Eta Meteorology
- CBIV Mechanism
- SMOKE Emissions (*Offline*)
- 12 km grid resolution
- 22 Vertical Layers
- 48 Hr. Forecast (12Z Init.)

Simulation Periods

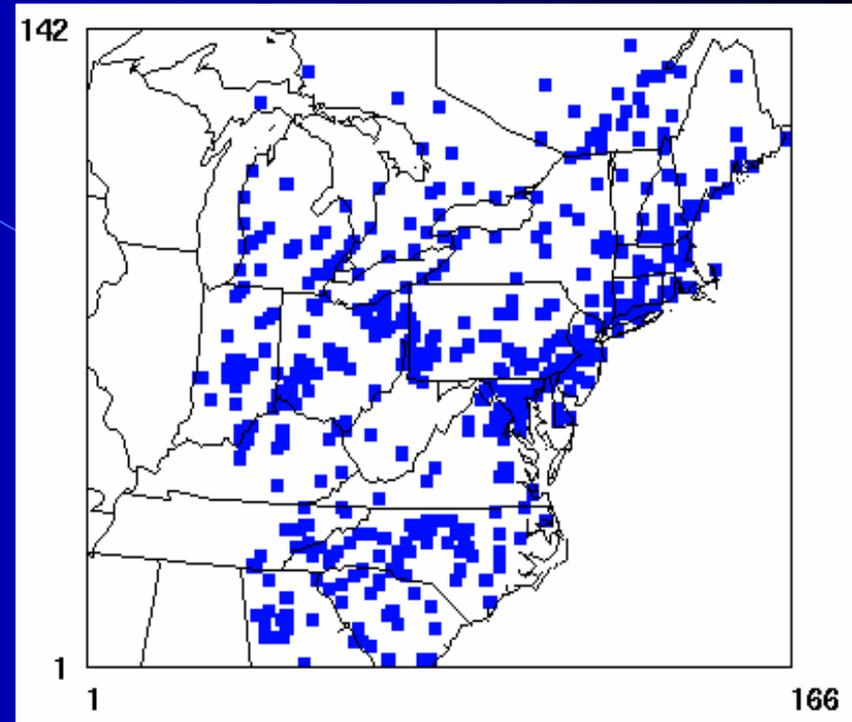
- 7 July – 30 September, 2003
- 12 – 19 August (Rerun with changes)

This evaluation used:

Hourly O₃ concentrations (ppb)
from EPA's AIRNOW network

521 stations

7 July - 30 September



A suite of statistical metrics for both:

discrete forecasts and categorical forecasts

for the:

hourly, maximum 1-hour, maximum 8-hour O₃ simulations

Two Forecast / Evaluation Types

- **Discrete Forecasts**

[Observed] *versus* [Forecast]

- **Category Forecasts** (Two Category)

Observed Exceedances, Non-Exceedances
versus
Forecast Exceedances, Non-Exceedances

Discrete Forecast / Evaluation

Statistics

- Summary
- Regression
- Biases

$$MB = \frac{1}{N} \sum_{i=1}^N (\text{Model} - \text{Obs})$$

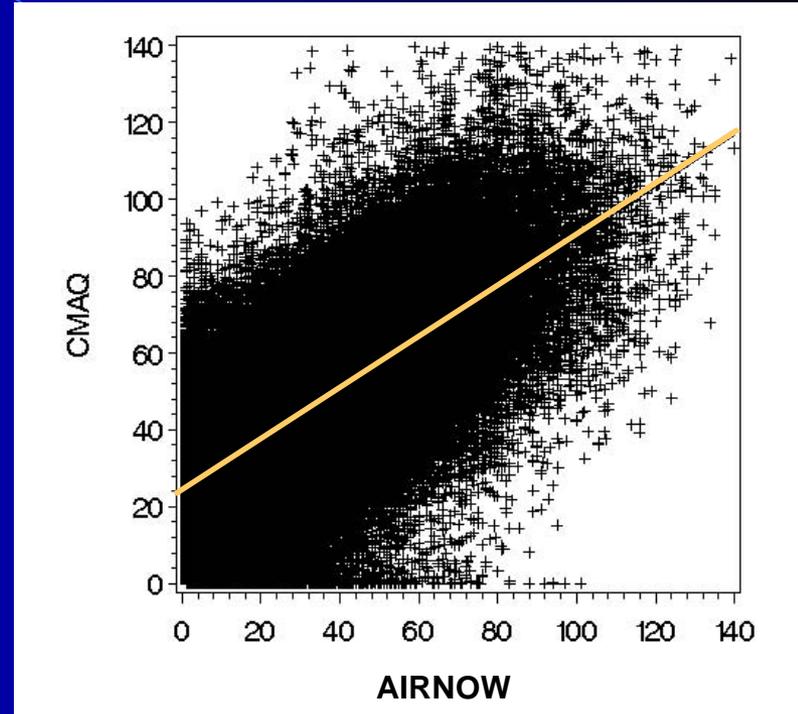
$$NMB = \frac{\sum_{i=1}^N (\text{Model} - \text{Obs})}{\sum_{i=1}^N (\text{Obs})} \cdot 100\%$$

- Errors

$$RMSE = \left(\frac{1}{N} \sum_{i=1}^N (\text{Model} - \text{Obs})^2 \right)^{0.5}$$

$$NME = \frac{\sum_{i=1}^N |\text{Model} - \text{Obs}|}{\sum_{i=1}^N (\text{Obs})} \cdot 100\%$$

[Observed] versus [Forecast]



Category Forecast / Evaluation

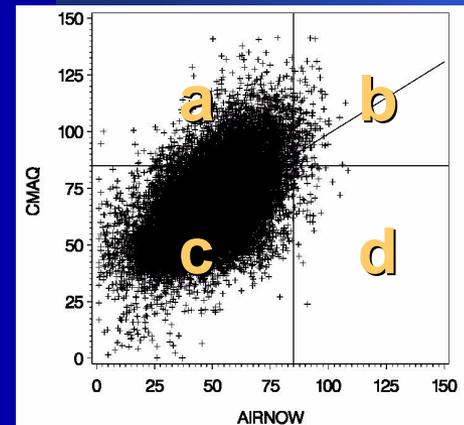
- Two Category Forecasts

Observed Exceedances, Non-Exceedances

versus

Forecast Exceedances, Non-Exceedances

Forecast Exceedance	Yes	a	b
	No	c	d
		No	Yes
		Observed Exceedance	

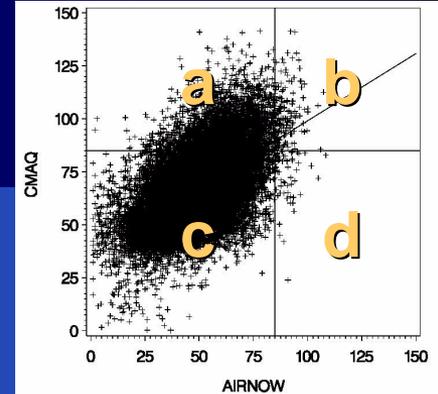


Category Forecast

Accuracy

Percent of forecasts that correctly predict event or non-event.

$$A = \left(\frac{b + c}{a + b + c + d} \right) \cdot 100\%$$



Bias

Indicates if forecasts are under-predicted (false negatives) or over-predicted (false positives)

$$B = \left(\frac{a + b}{b + d} \right)$$

False Alarm Rate

Percent of times a forecast of high ozone did not occur

$$FAR = \left(\frac{a}{a + b} \right) \cdot 100\%$$

Category Forecast

Critical Success Index

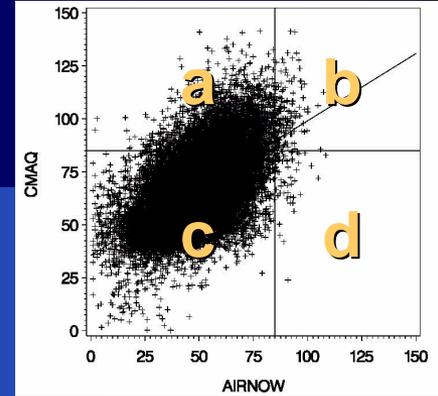
How well the high ozone events were predicted.

$$\text{CSI} = \left(\frac{b}{a + b + d} \right) \cdot 100\%$$

Probability Of Detection

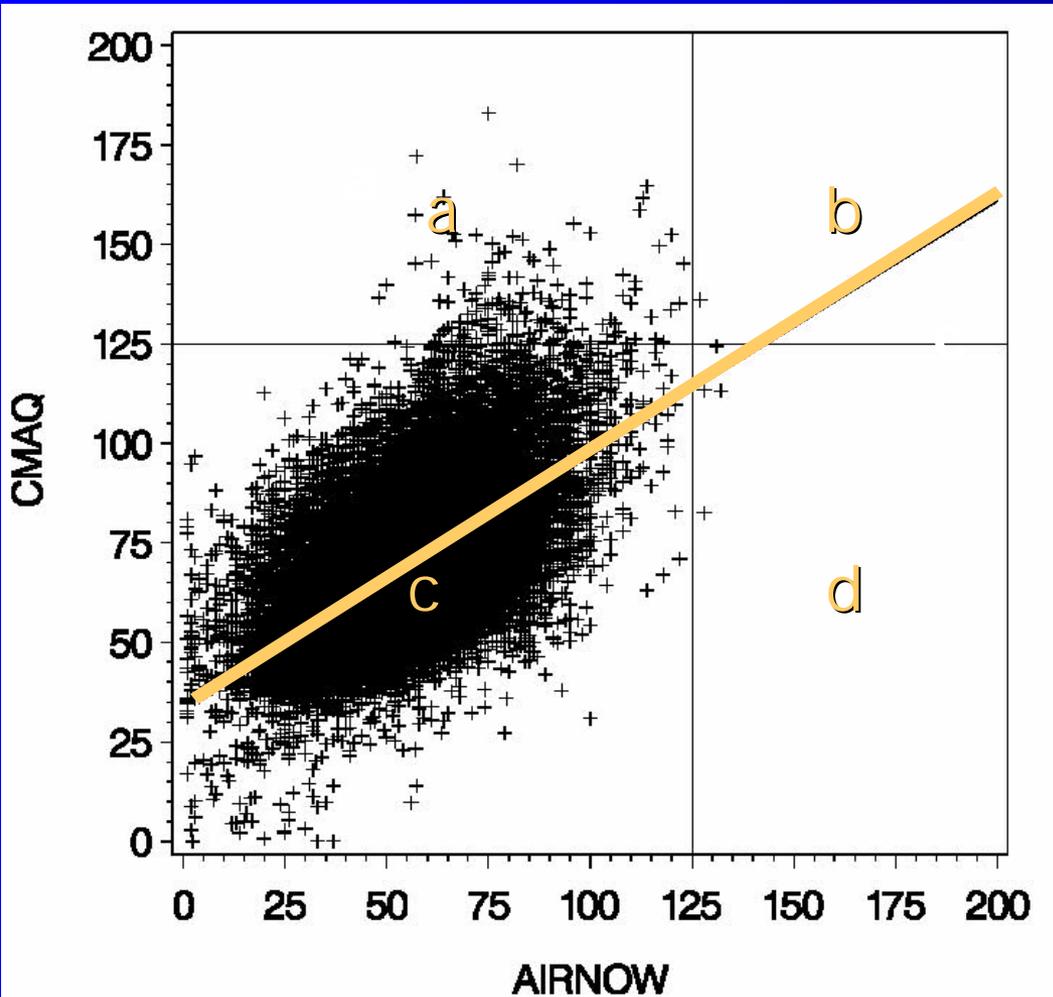
Ability to predict high ozone events

$$\text{POD} = \left(\frac{b}{b + d} \right) \cdot 100\%$$



Max. 1-hour O₃

$$\text{CMAQ} = 34.5 + 0.63(\text{AIRNOW})$$



7 July – 30 September

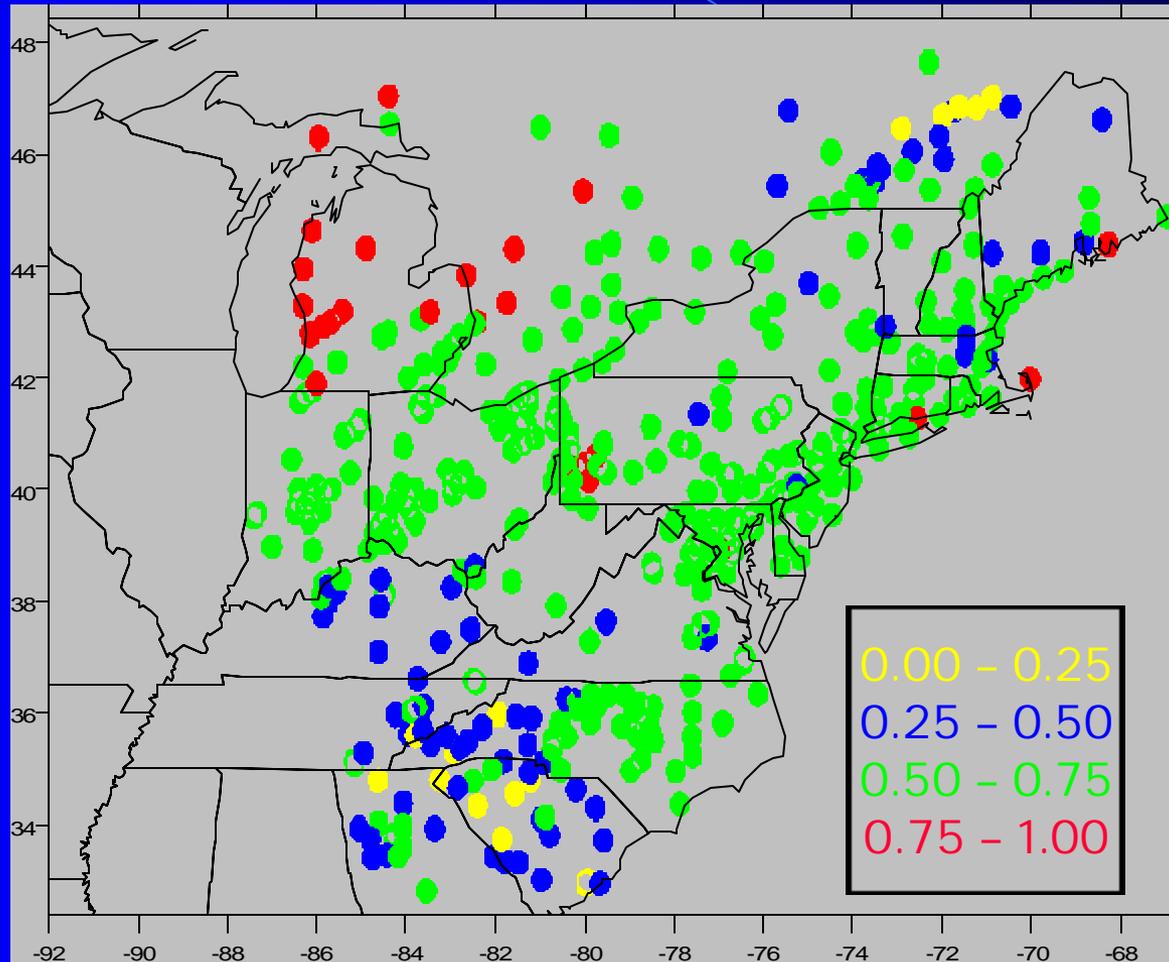
a= 155
b= 1
c= 36,837
d= 5
n= 36,998

Max. 1- hour O₃

	Summary Statistics		Discrete Evaluation		Categorical Evaluation	
[ppb]	CMAQ	AIRNOW	CMAQ = 34.5 + 0.63 (AIRNOW)		Ozone \$125 ppb	
Mean	68.1	53.1	r	0.62	A	99.6%
SD	17.3	16.7	N	36,814	B	26.0
CV	25.3	31.5				
Max	182.9	132	BIASES			
95 th	99.2	81	MB	15.0	FAR	99.4%
75 th	78.7	65	NMB	28.2%	CSI	0.6%
50 th	66.0	53				
25 th	55.6	41	ERRORS			
5 th	44.2	27	RMSE	21.1	POD	16.7%
Min	0	1	NME	32.2%		

Spatial Evaluation

Max. 1-hour O₃
Correlation



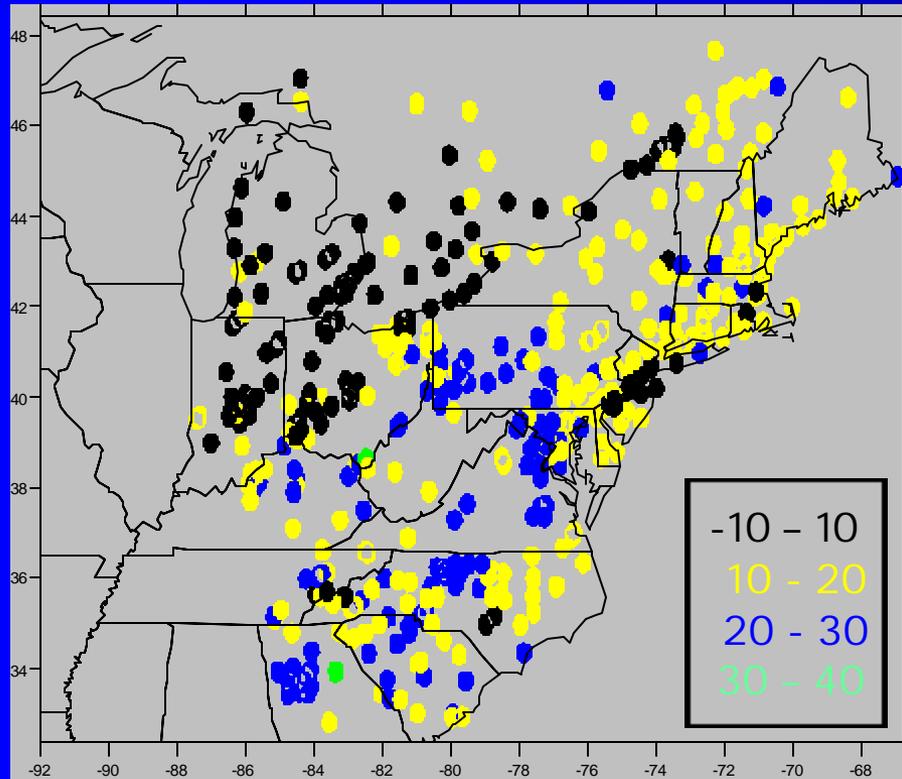
Overall Mean Correlation = 0.62

Spatial Evaluation

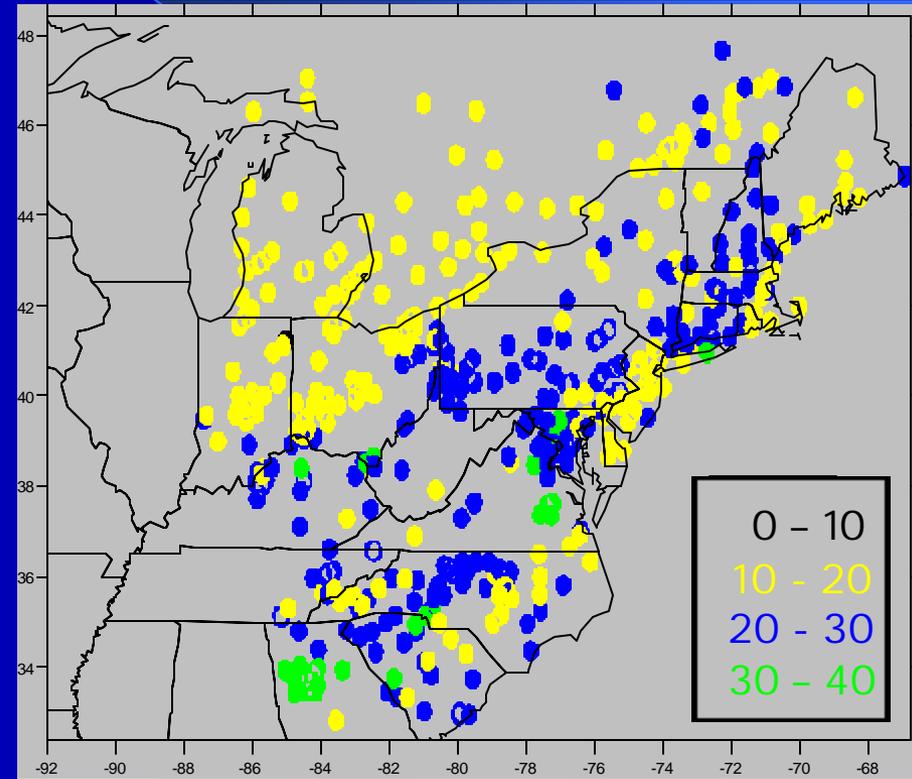
Max. 1 - hour O_3

Mean Bias

RMSE



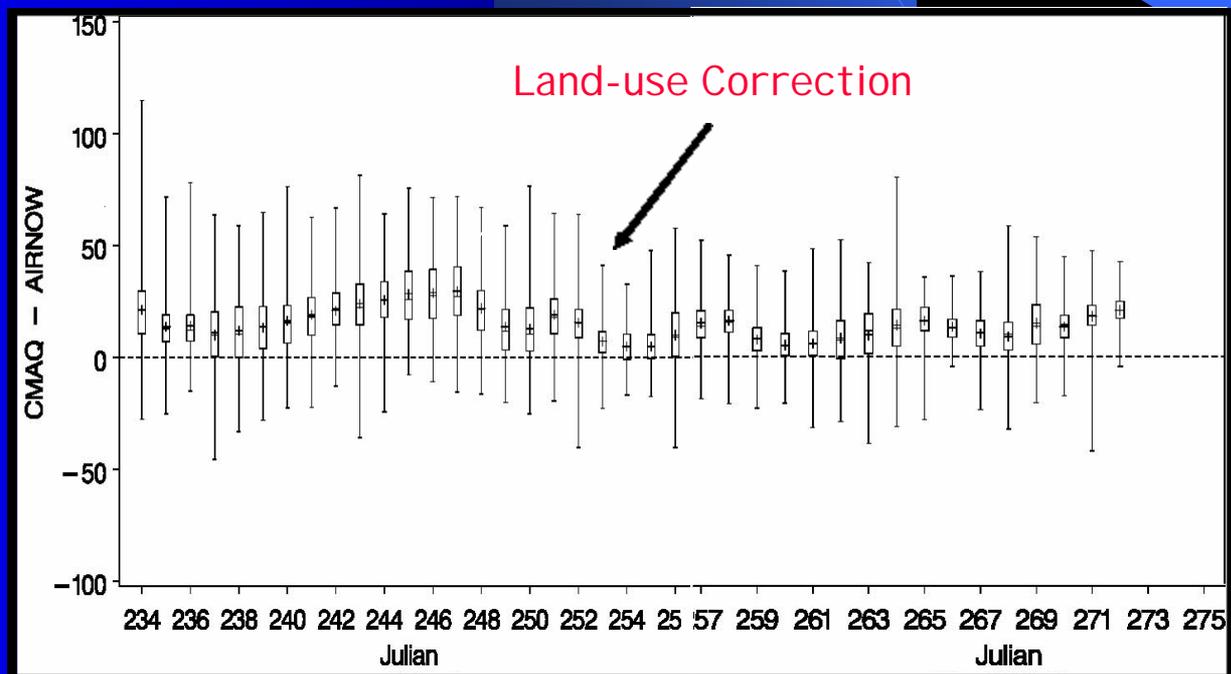
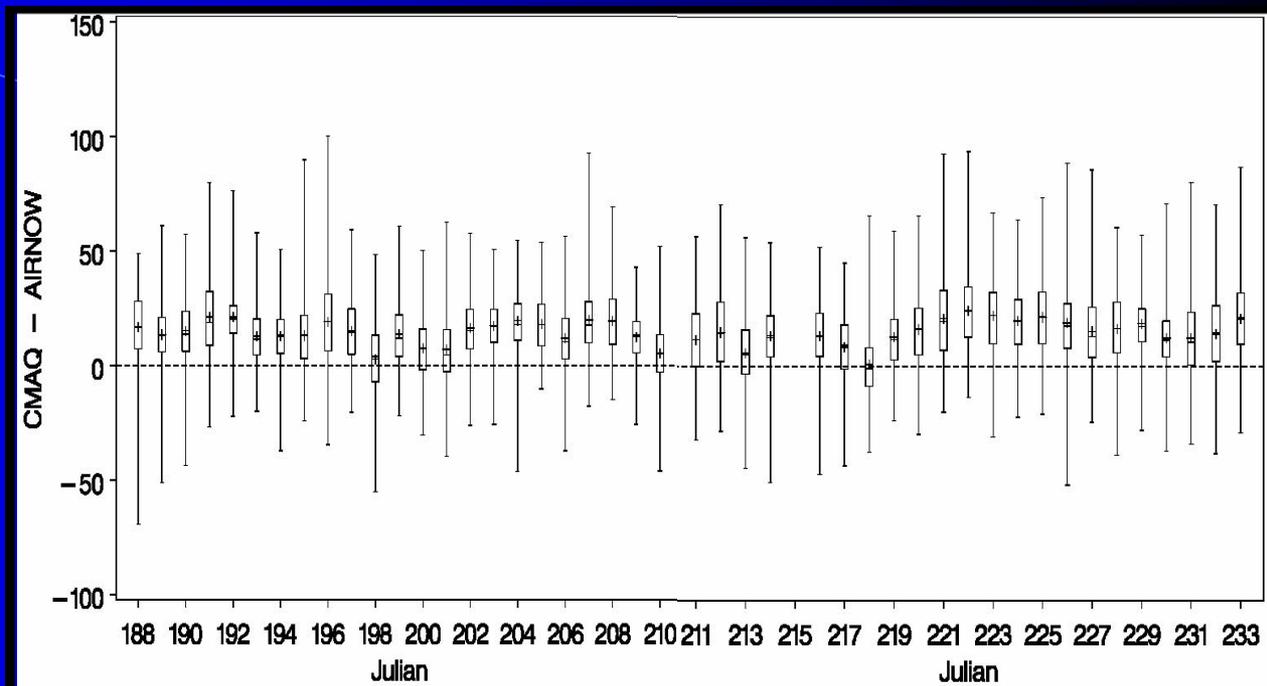
Overall Mean Bias = 15.0 ppb



Overall Mean RMSE = 21.1 ppb

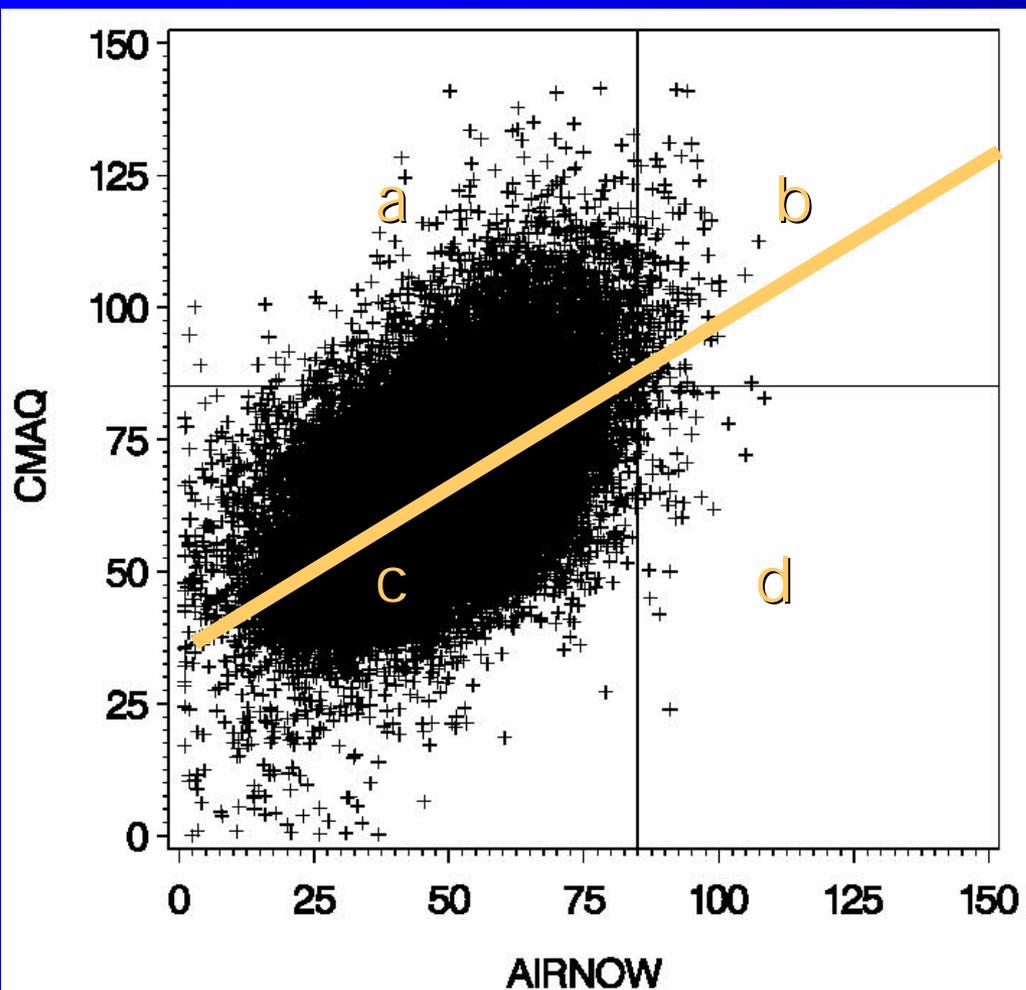
Temporal Evaluation

– Max. 1 hour O₃



Max. 8-hour O₃

$$\text{CMAQ} = 35.1 + 0.62(\text{AIRNOW})$$



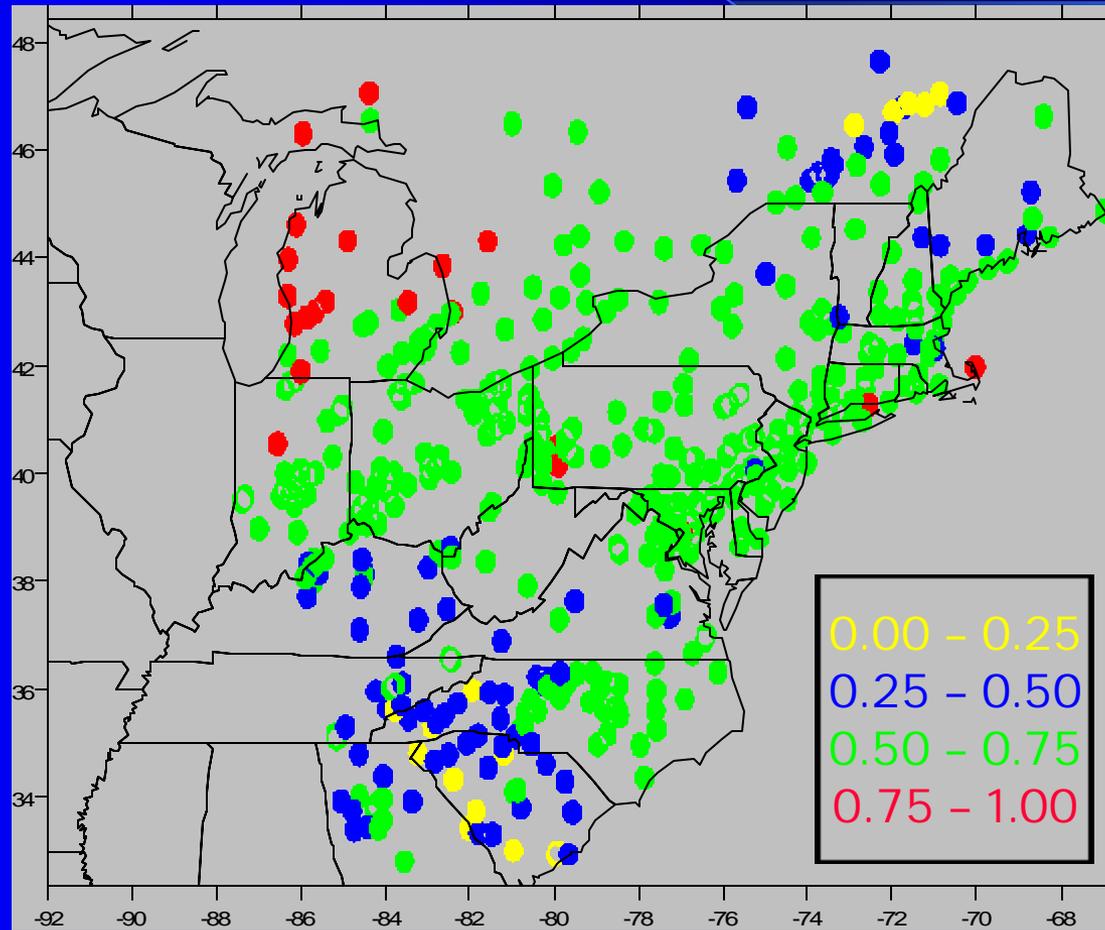
a= 3276
b= 149
c= 20,979
d= 65
n= 24,469

Max. 8- hour O₃

	Summary Statistics		Discrete Evaluation		Categorical Evaluation	
[ppb]	CMAQ	AIRNOW	CMAQ = 35.1 + 0.62 (AIRNOW)		Ozone \$85 ppb	
Mean	64.0	46.7	r	0.59	A	89.6%
SD	15.8	15.0	n	36,998	B	10.3
CV	24.6%	32.2%				
Max	162.2	108.4	BIASES			
95 th	92.1	71.6	MB	17.4	FAR	96.0%
75 th	73.9	57.2	NMB	37.3%	CSI	3.7%
50 th	62.2	46.1				
25 th	52.6	35.7	ERRORS			
5 th	42.1	23.3	RMSE	22.2	POD	41.0%
Min	0	1	NME	39.9%		

Spatial Evaluation

Max. 8- hour O₃ Correlation



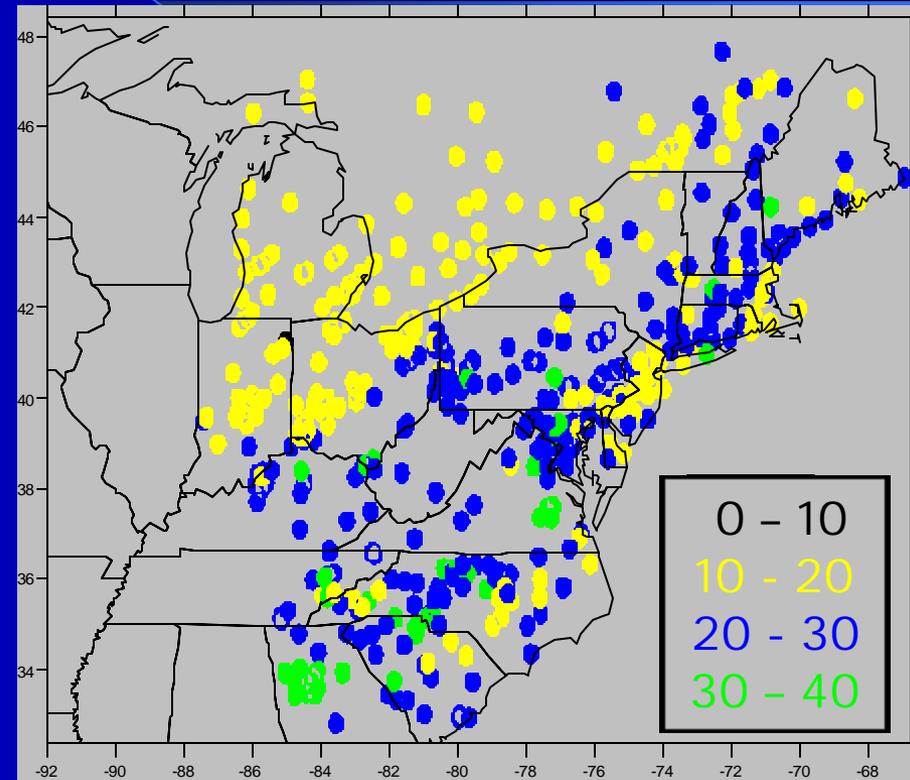
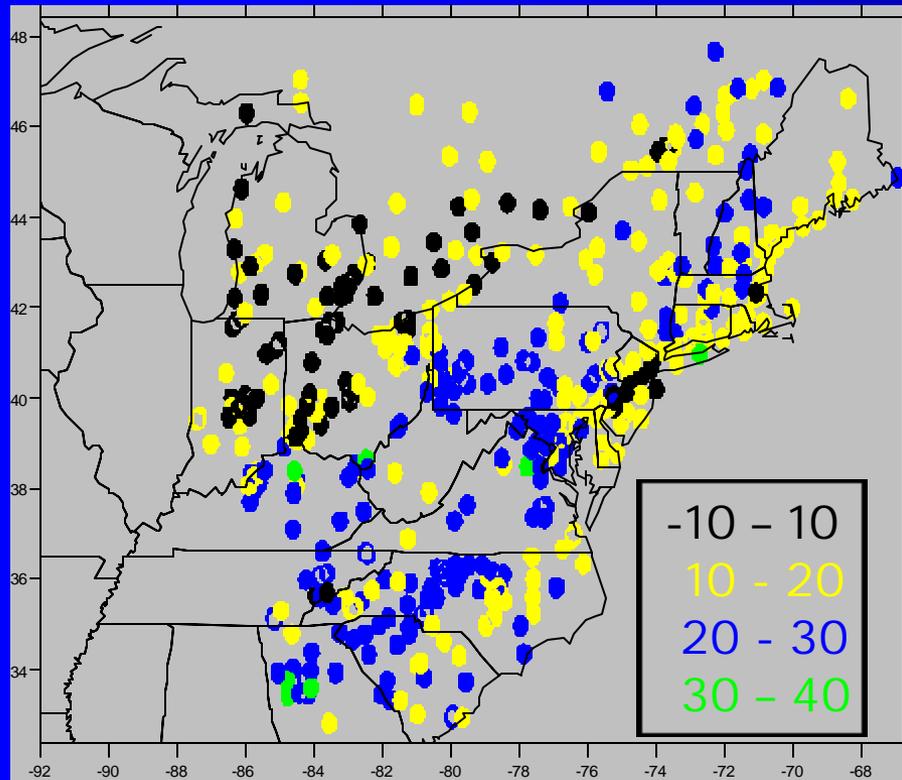
Overall Mean Correlation = 0.59

Spatial Evaluation

Max. 8 - hour O_3

Mean Bias

RMSE

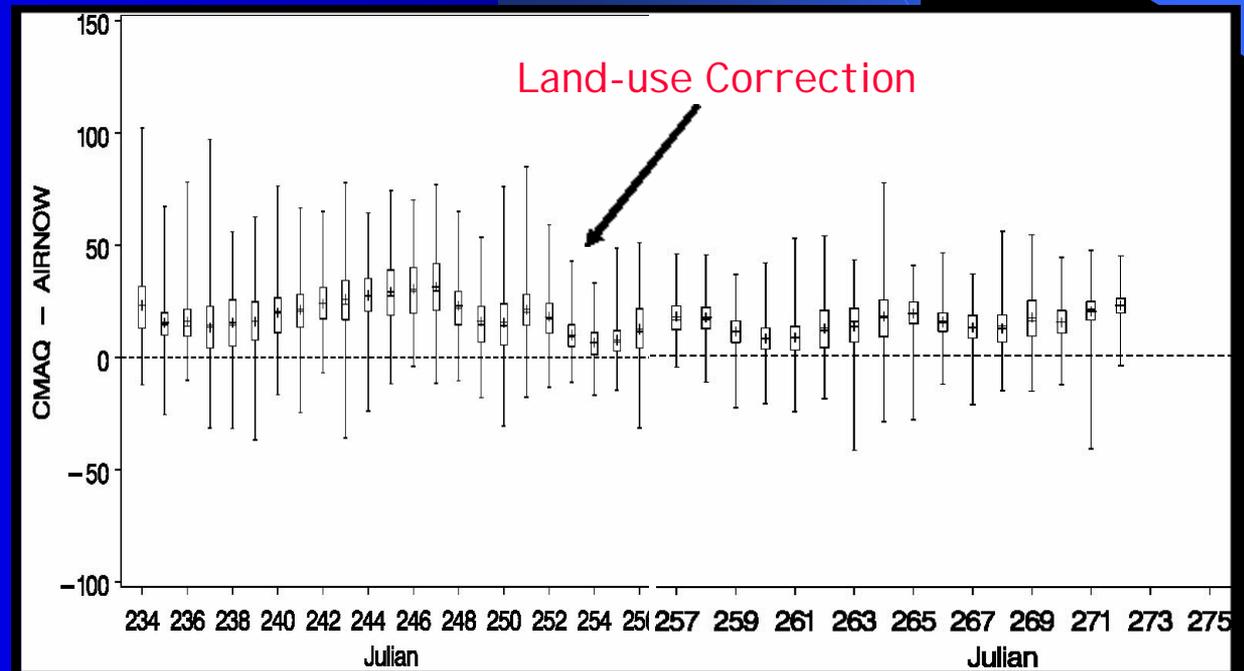
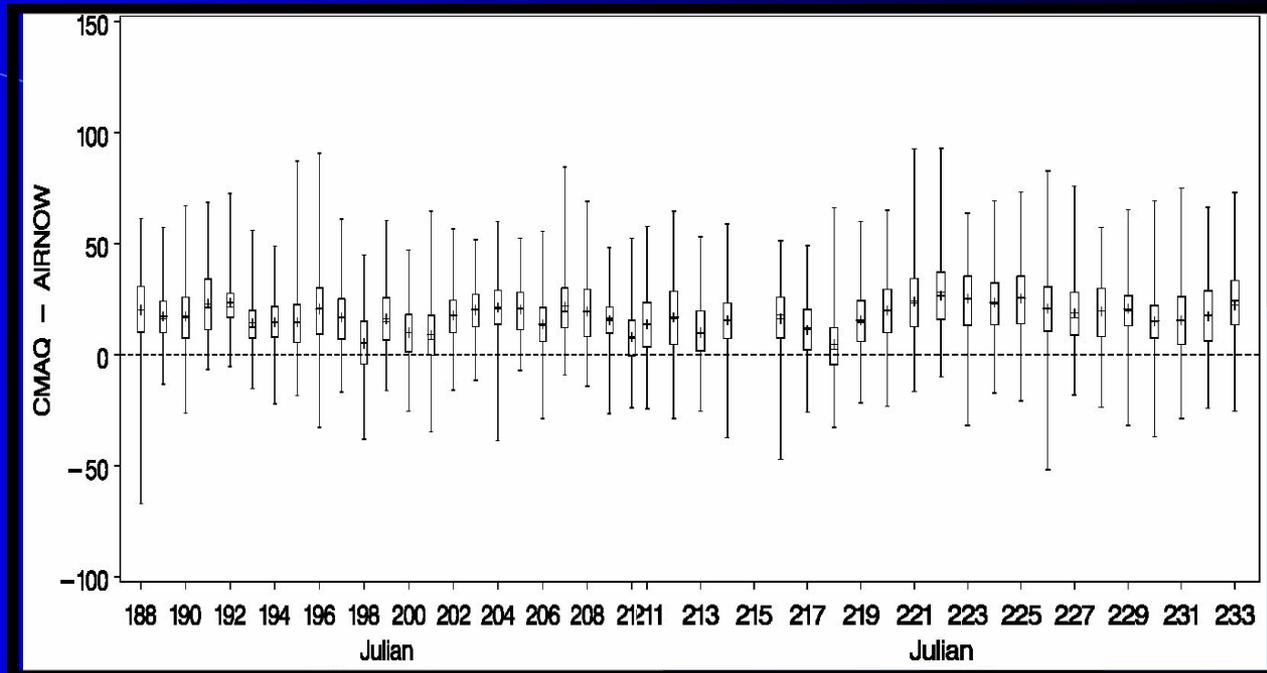


Overall Mean Bias = 17.4 ppb

Overall Mean RMSE = 22.2 ppb

Temporal Evaluation

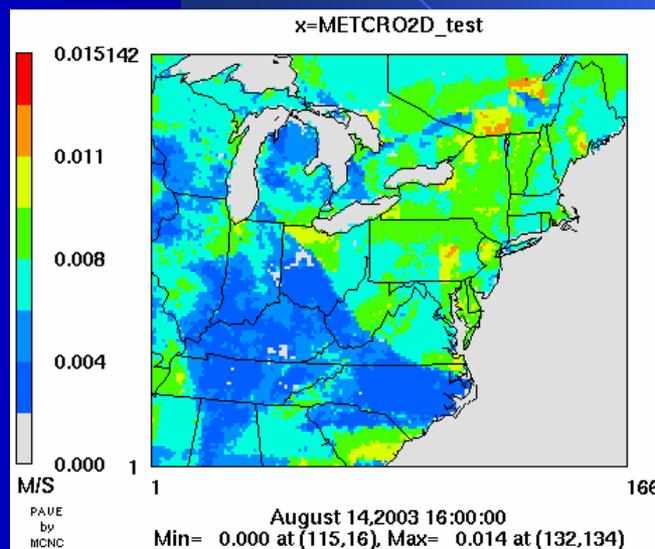
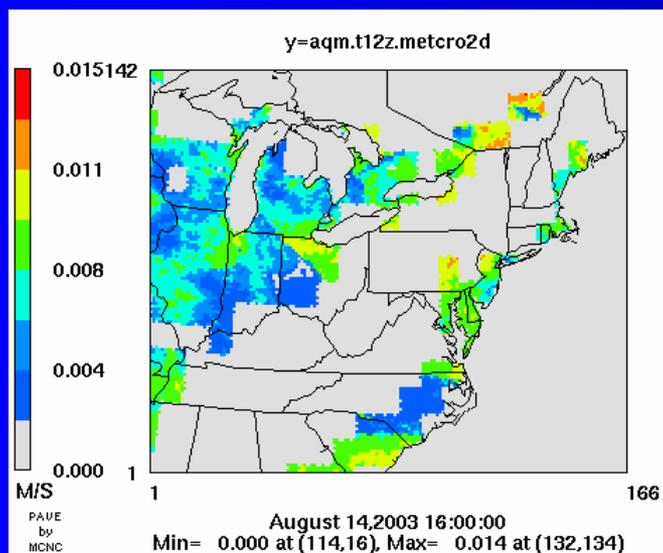
– Max. 8 hour O_3



Land-Use Error

Land-use fields associated with Eta were being post-processed incorrectly.
As a result:

- Most of the domain was classified as water.
- Dry deposition was greatly under simulated



This error was discovered/corrected on Sept. 9th.

- An eight day period (12-19 August) was re-simulated.
- Positive biases were cut in half, errors reduced also.

CMAQ Updates

The latest version of CMAQ was released in the Fall of 2003

featured numerous changes:

- updated science
 - efficiency enhancements
 - bug fixes
 - *new boundary conditions*
 - *new K_z values*
-
- An eight day period (12-19 August) was re-simulated
 - Positive biases were almost eliminated
 - Errors were also reduced

Comparison Between Initial, Corrected and Updated Simulations

August 12 –19 2003

Max. 1 - hour O₃

Run	r	MB (ppb)	NMB (%)	RMSE (ppb)	NME (%)
Initial Simulation	0.64	16.2	27.5	23.0	31.7
Corrected Land-Use	0.66	7.6	13.0	16.6	21.7
Updated CMAQ	0.63	0.6	1.0	13.9	17.8

Max. 8 - hour O₃

Run	r	MB (ppb)	NMB (%)	RMSE (ppb)	NME (%)
Initial Simulation	0.62	19.2	37.2	24.6	39.9
Corrected Land-Use	0.64	10.4	20.1	17.1	26.3
Updated CMAQ	0.62	3.9	7.4	13.0	19.2

Summary

The Eta-CMAQ modeling system performed *reasonably well*, in this, its first attempt at forecasting ozone concentrations.

An error was discovered in Eta's post processed land-use designation that resulted in the:

- under-estimation of dry deposition
- over-simulation of concentrations

Once corrected, the positive biases and errors were greatly reduced when the model was re-run for an eight day period.

A newer version of CMAQ, released in the fall of 2003, included changes that further reduced the positive bias and errors when the model was re-run for an eight day period.

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