Evaluation of 2006 Air Quality Forecasting in Georgia

Talat Odman , Yongtao Hu, Ted Russell
School of Civil & Environmental Engineering

Michael Chang, Carlos Cardelino
School of Earth and Atmospheric Sciences

Georgia Institute of Technology
Atlanta, Georgia

5th Annual CMAS Conference
October 17, 2006

Air Quality Forecasting

- There is an increasing interest in day-to-day variation of air quality
  - Public becoming more health conscious
  - Local authorities looking for short-term management strategies
- Forecasts are produced using various techniques
  - Persistence
  - Climatology
  - Statistical Regression
  - Close Neighbor
  - Decision Tree
  - 3-D Air Quality Models

Air Quality Forecasting in Atlanta

- Ozone forecasting since 1996 Olympic Games
- Panel of experts get together and issue a forecast for next day
  - Ozone Alerts
- One of the methods used is 3-D AQM
  - Urban Airshed Model (UAM)
  - Diagnostic Meteorology
  - Constant Emissions
  - Arguably first in the U.S. but now mostly outdated
- Last year, $PM_{2.5}$ forecasting started
- Forecasts being extended to other cities in Georgia
  - Macon (~150 km South of Atlanta)
- Our operation started May 1st, 2006

Some Other 3-D Forecasting Efforts in the U.S.

- NOAA/EPA
  - Eta-CMAQ modeling system
  - 12-km resolution over Southeastern U.S.
- BAMS
  - MM5-MAQSIP-RT modeling system
- NCAR/NOAA
  - WRF-Chem modeling system
- UH/Texas A&M
  - MM5-CMAQ modeling system

Goal of our Operation

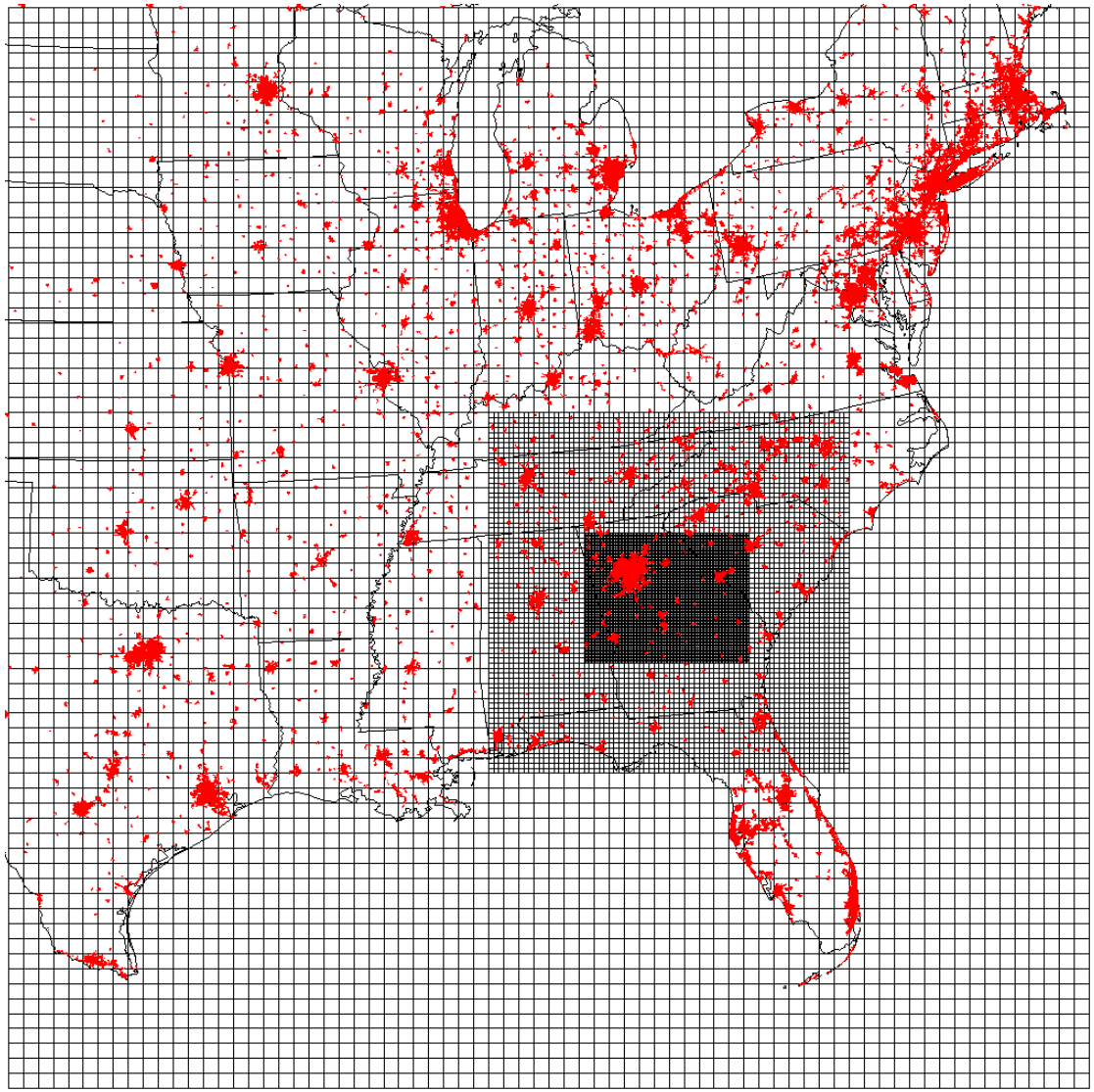
- To provide accurate, "fine-scale", local forecasts sufficiently in advance for planning purposes
- NOAA/EPA's target is to issue nationwide 2-day forecasts with 2.5-km resolution in 10 years.
  - Davidson, P. M. et al., "National Air Quality Forecasting Capability," February 14, 2005.
- We want to get there (and go beyond) locally much faster.
  - Longer periods
  - Finer resolution (~1 km)
  - Viability of control strategies to avoid bad episodes

Our Modeling System

- WRF for meteorology
  - Driven by NAM (formerly Eta)
  - 3 ½ -day NAM forecasts available every 6 hours (00, 06, 12, 18Z)
- SMOKE for emissions
- CMAQ for chemistry and transport
  - Currently using standard version 4.5
  - Will activate our special additions soon
    - Variable Time Step (Banff)
    - Direct Decoupled Method (DDM) (Istanbul)
    - Adaptive Grid (Boulder & Louvain-la-Neuve)

Modeling Domain and Grids

- Three grids:
  - 36-km (72x72)
  - 12-km (72x72)
  - 4-km (99x78)
- Horizontal domains are slightly larger for WRF
- 34 vertical layers used in WRF
- 13 layers in CMAQ

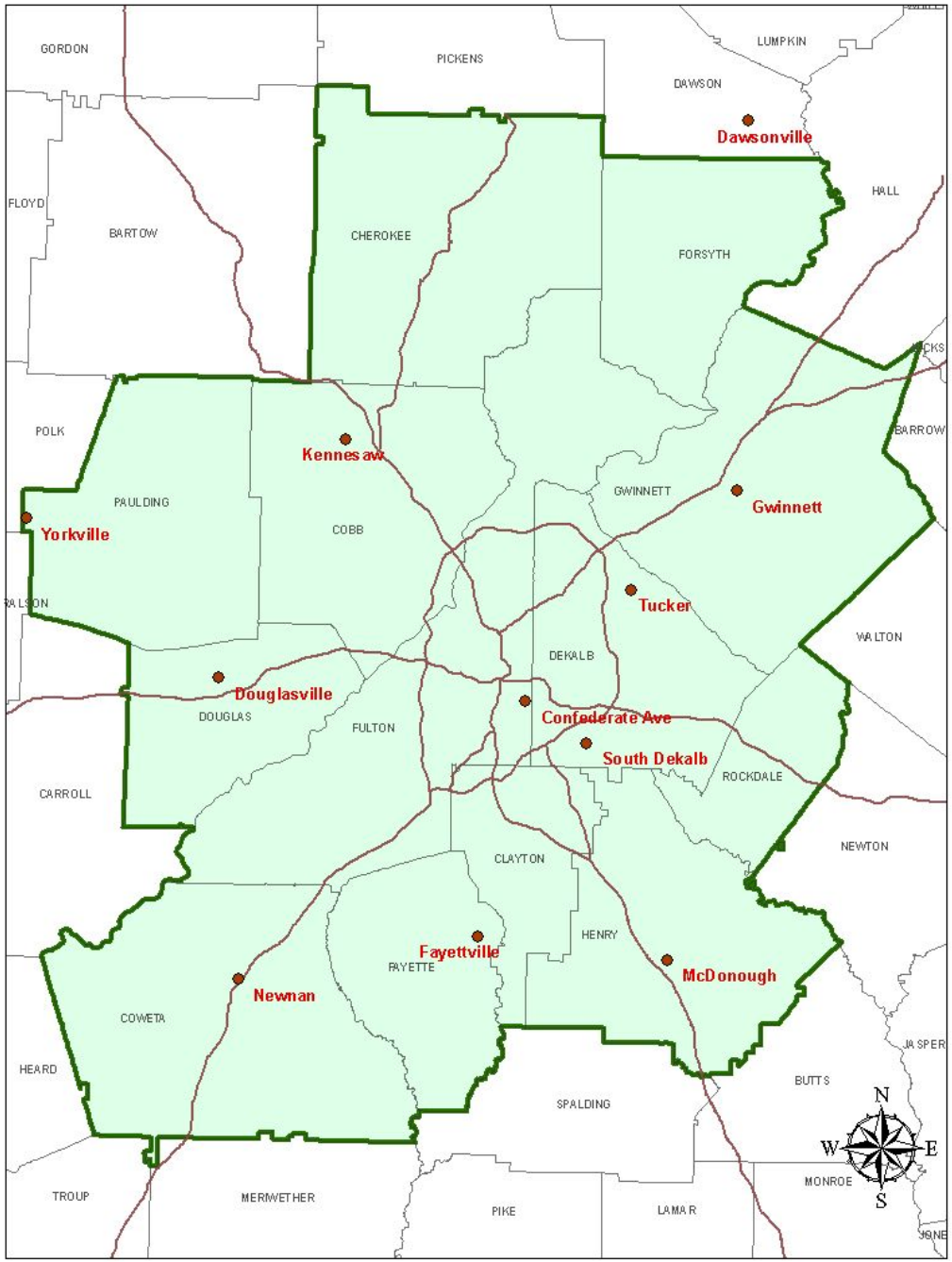


Operation 2006

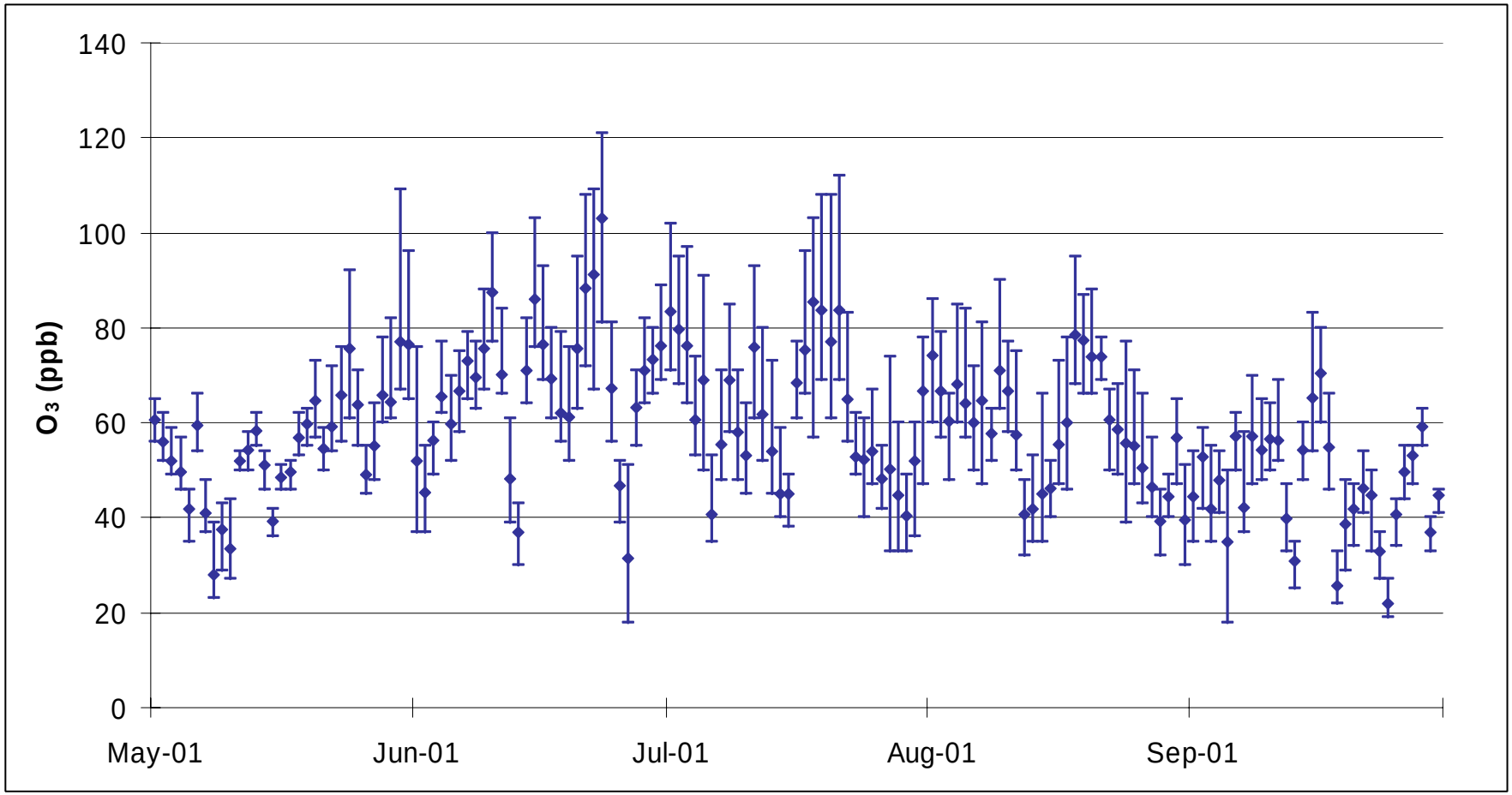
- Must issue tomorrow's forecast by 10 a.m. today
  - Operation starts 2 ½ days in advance (Wednesday's by Sunday night)
- We simulate:
  - 3 days over the 36-km grid using 00Z NAM, IC from previous cycle (warm start) and "clean" BC
  - 2 ½ days over the 12-km grid using 12Z NAM and IC/BC from 36-km
  - 24 hours over the 4-km using 12Z NAM and IC/BC from 12-km
  - Add 4 hours to all durations for time difference
- Mostly automated
  - 1 person
  - and 6 CPUs
- The product is a 24-hr ozone and $PM_{2.5}$ forecast once per day

Emissions Forecasting

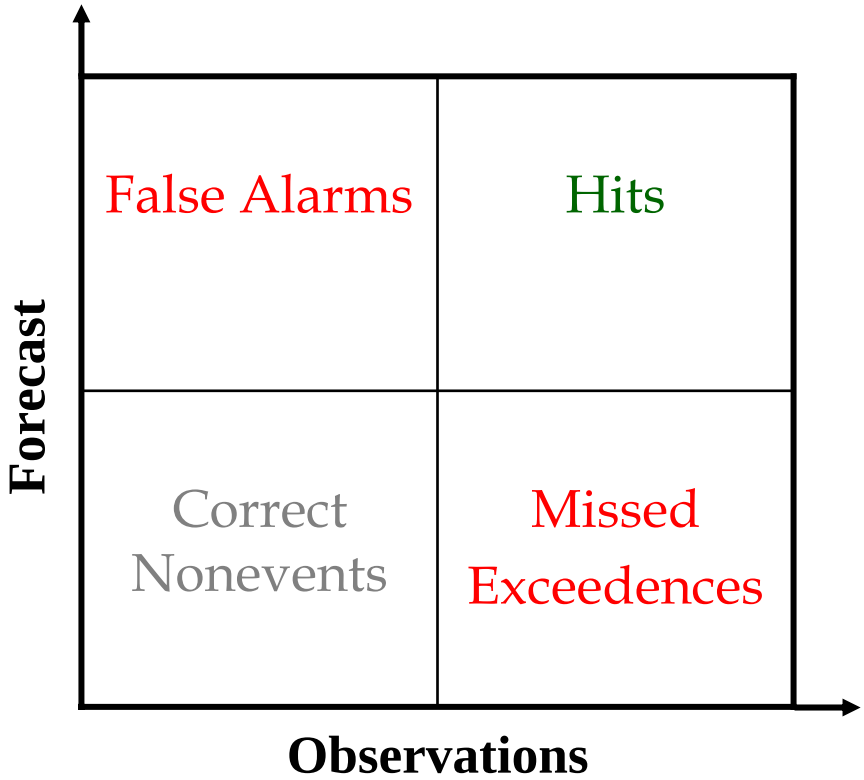
- Our goal is to use most up-to-date emissions inventories
- We projected the NEI-2002 emissions to 2006 using growth and control factors
  - EGAS model
  - NO_x SIP controls
- We use monthly-averaged data for major point sources and wild-land fires
- We forecast mobile emissions
  - Emission factors use the episode (3, 2 ½ or 1 day) average temperature
- We forecast biogenic emissions using summertime leaf indexes


GORDON
PICKENS
LUMPKIN
DAWSON
Dawsonville
HALL
FLOYD
BARTOW
CHEROKEE
FORSYTH
POLK
Kennesaw
BARROW
PAULDING
GWINNETT
Gwinnett
Yorkville
COBB
Tucker
WALTON
DEKALB
Douglasville
DOUGLAS
FULTON
Confederate Ave
South Dekalb
ROCKDALE
CARROLL
NEWTON
CLAYTON
HENRY
Fayettville
FAYETTE
McDonough
Newnan
COWETA
HEARD
BUTTS
SPALDING
N
W
E
S
MONROE
TROUP
MERIWETHER
PIKE
LAMAR

O_3 in Metro Atlanta: Summer of 2006



Performance Metrics

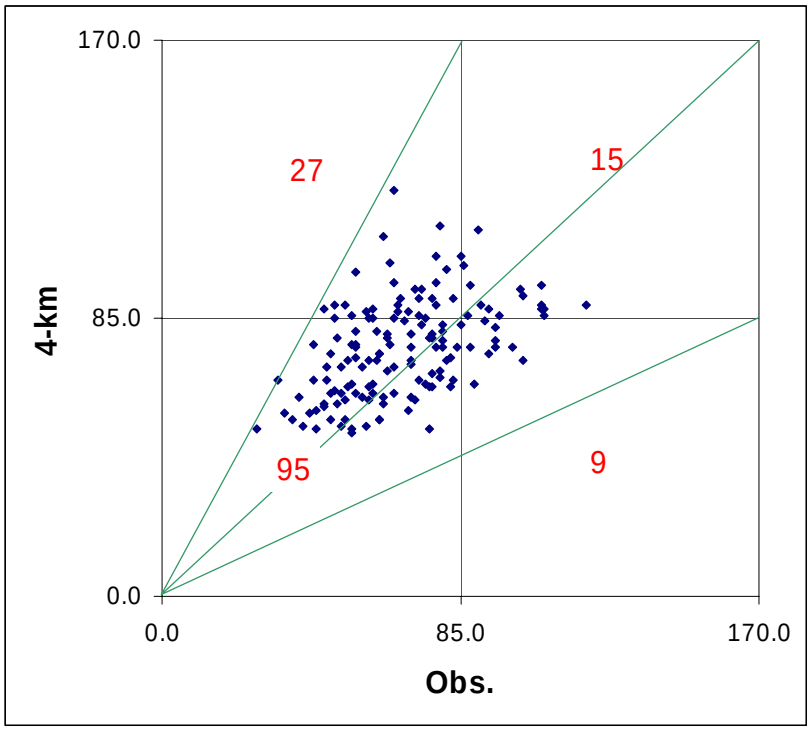


$$\text{NMB} = \frac{1}{N}\sum_{k=1}^{N}\frac{c_k^m - c_k^o}{c_k^o}$$

$$\text{NME} = \frac{1}{N}\sum_{k=1}^{N}\frac{\left|c_k^m - c_k^o\right|}{c_k^o}$$

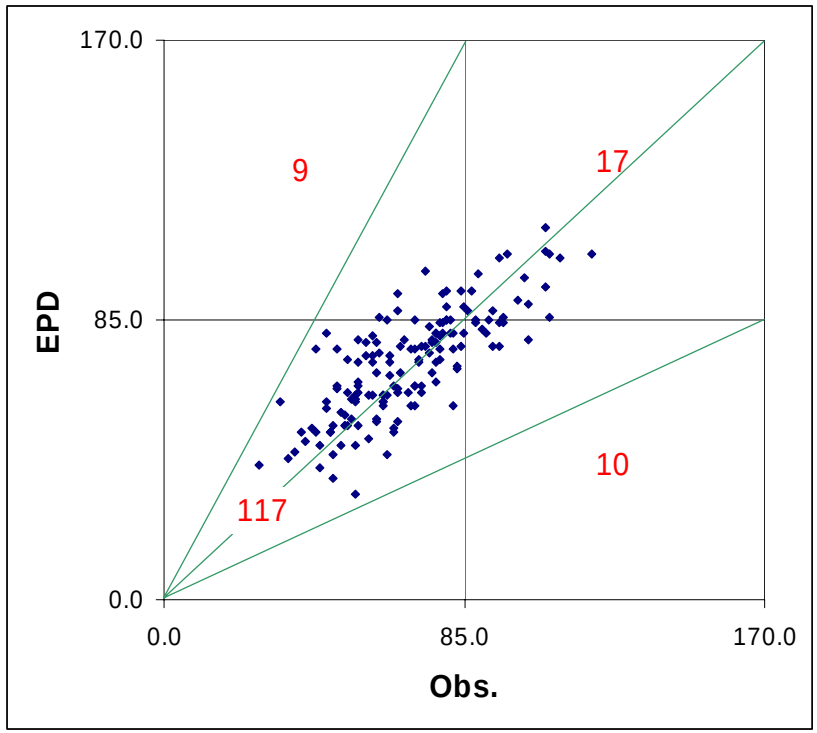
Categorical O_3 Performance

Our 4-km Forecast



MNB	11%
MNE	29%

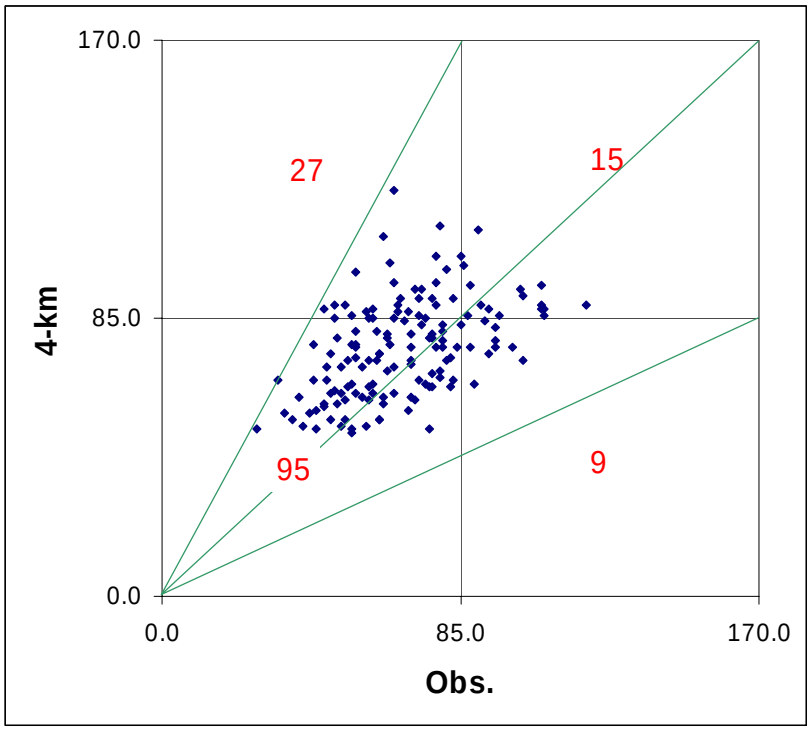
EPD Ensemble Forecast



MNB	6.2%
MNE	15%

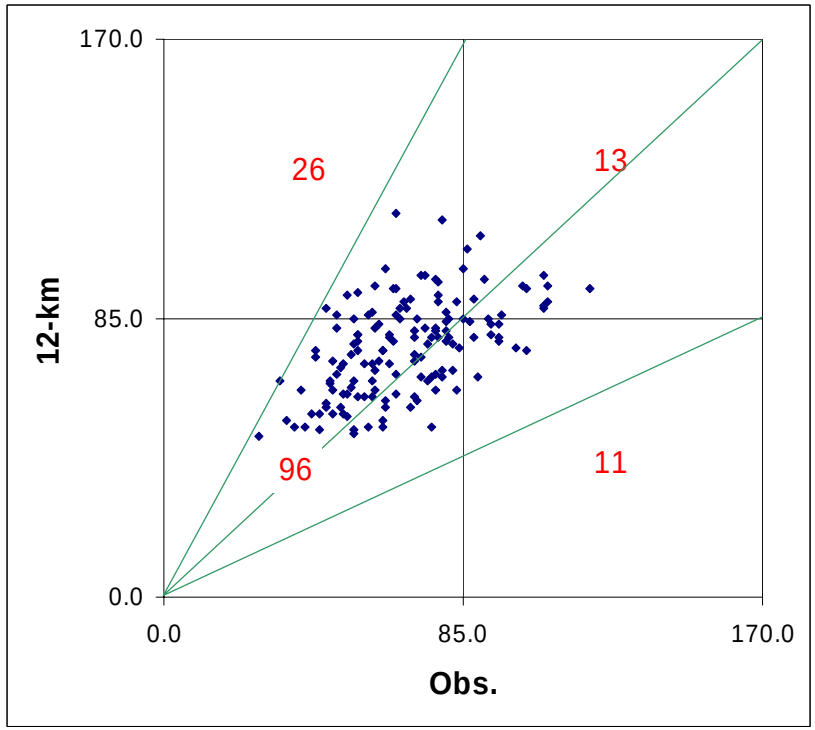
Categorical O_3 Performance

Our 4-km Forecast



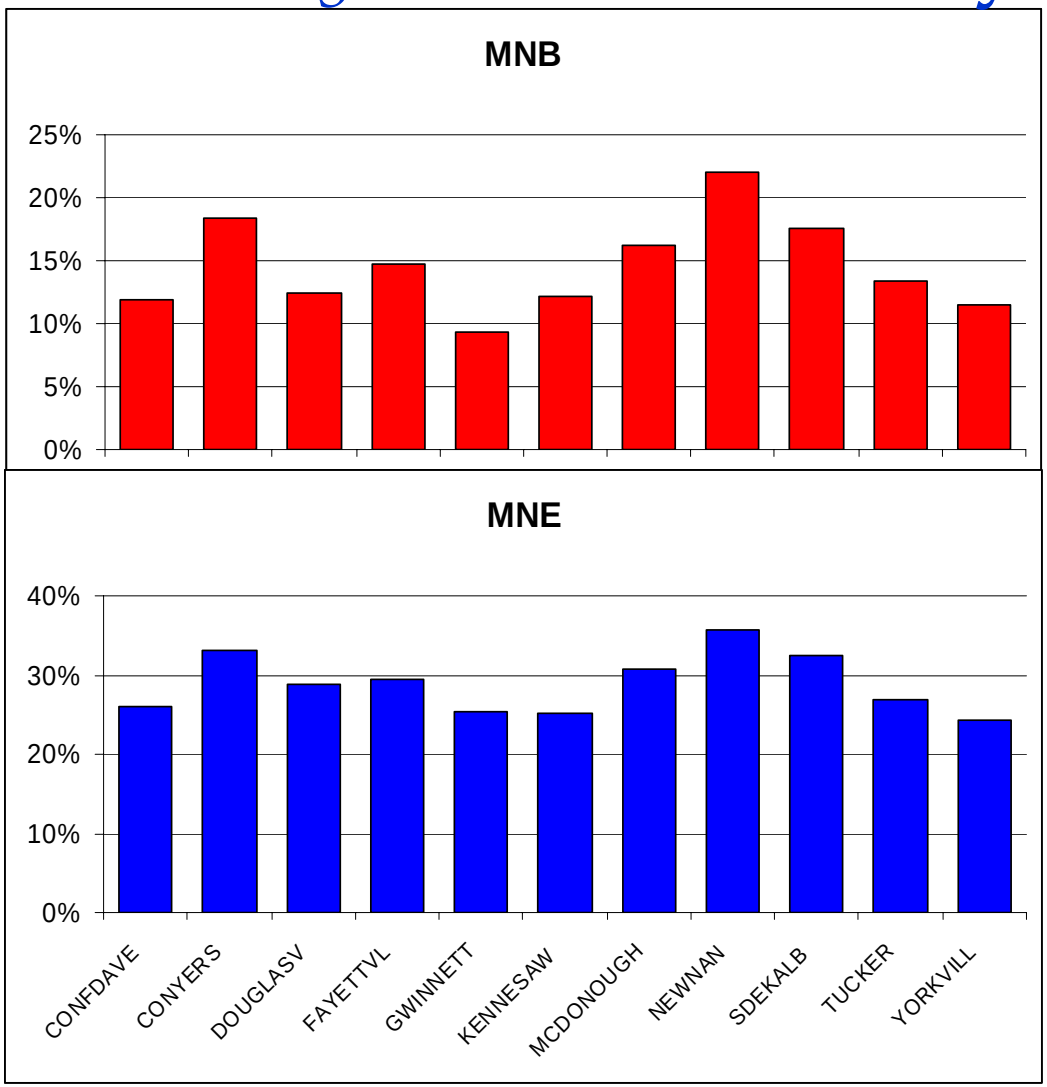
MNB	10.9%
MNE	28.6%

Our 12-km Forecast



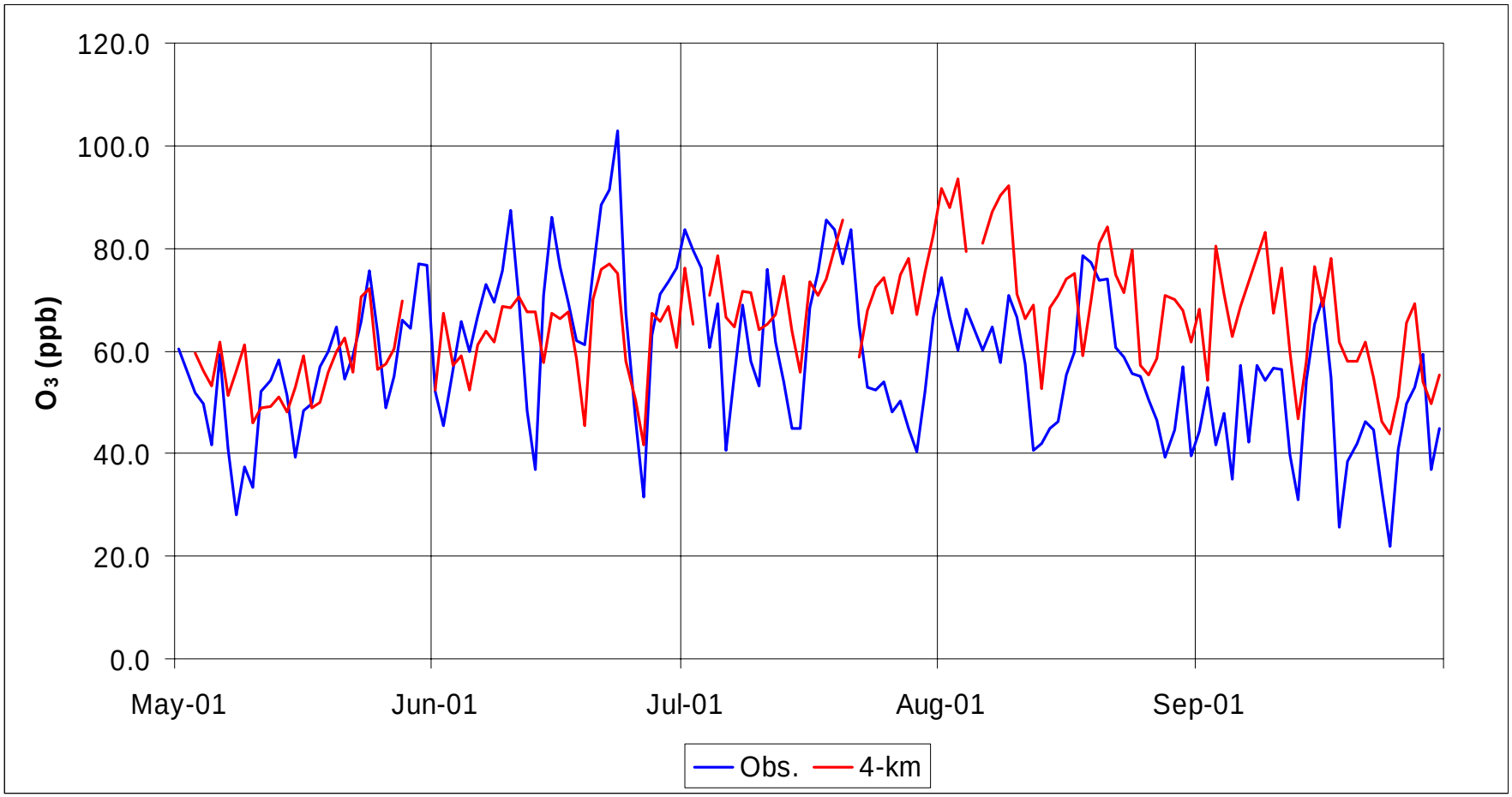
MNB	11.1%
MNE	28.0%

O_3 Bias & Error by Site

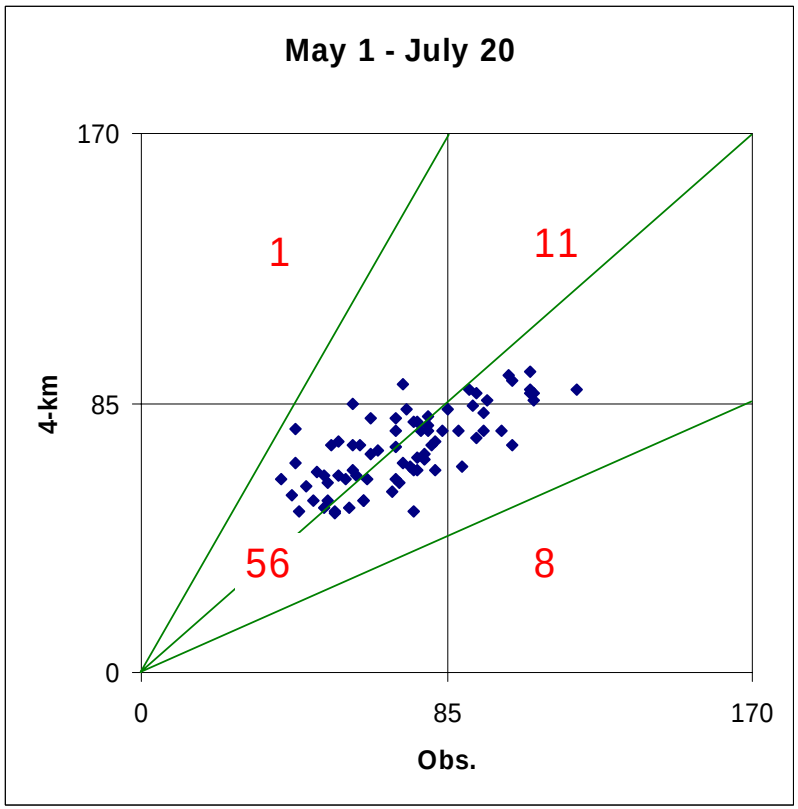


MNB	15%
MNE	31%

Forecasted vs. Observed O_3

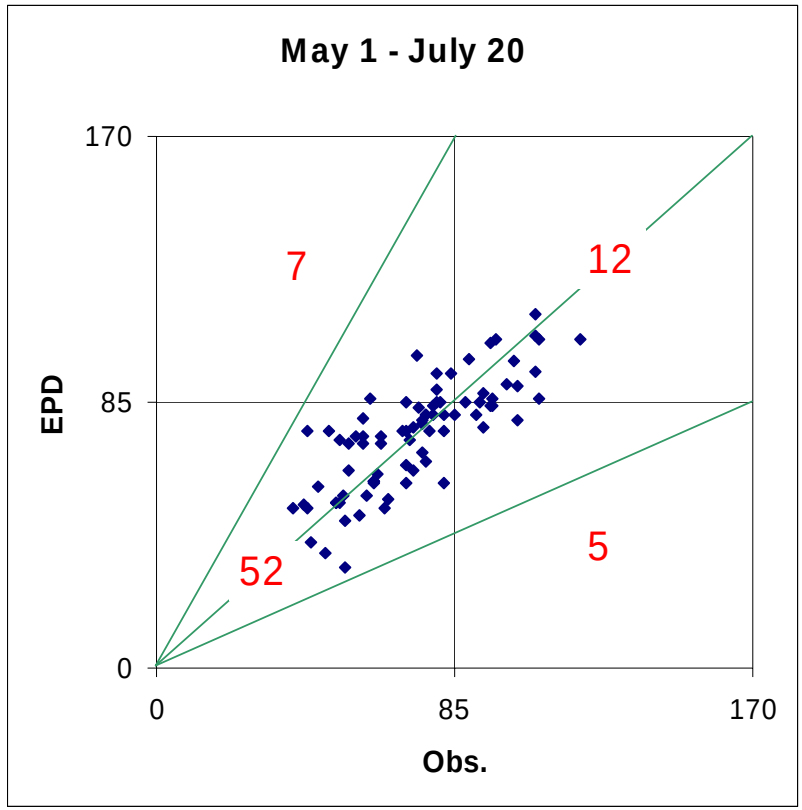


Our 4-km Forecast

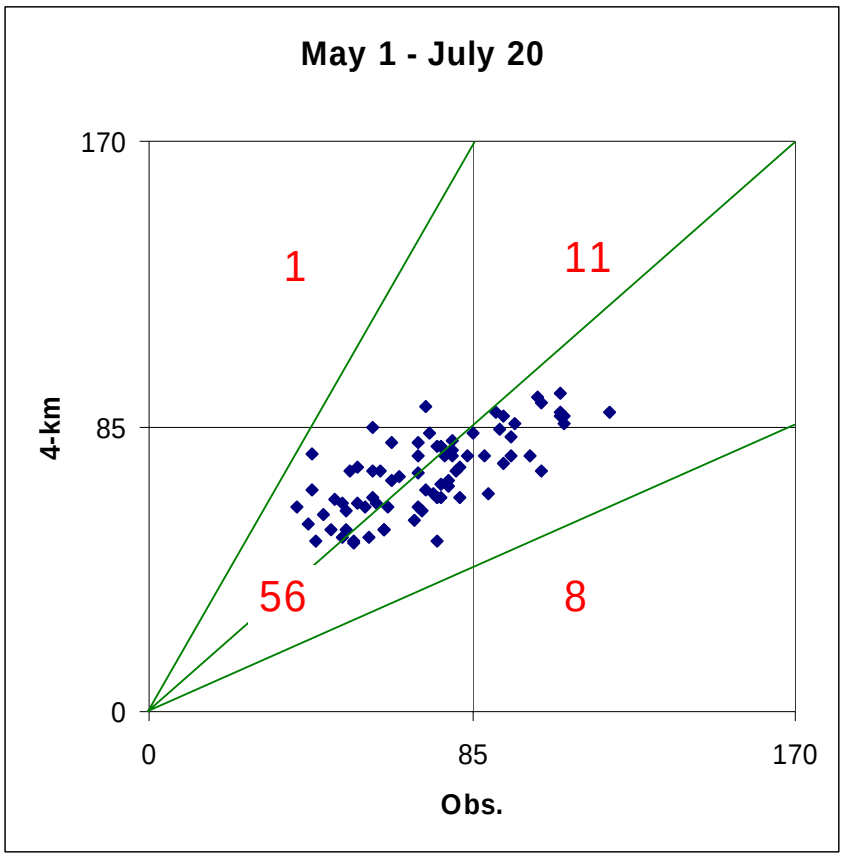


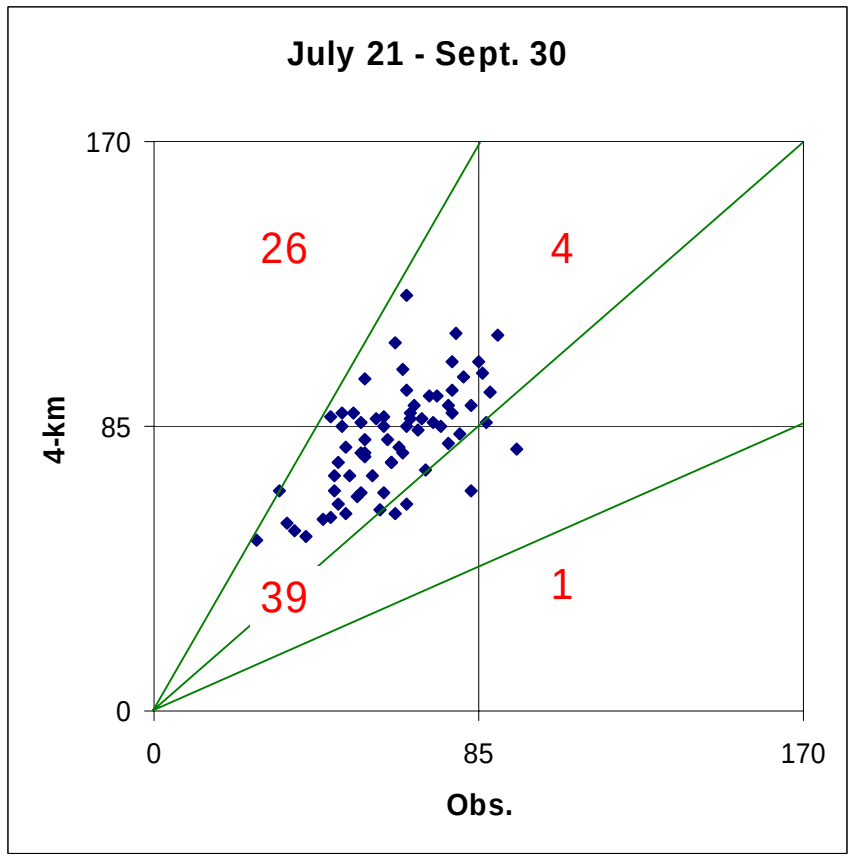
MNB	-0.4%
MNE	23%

EPD Ensemble Forecast



MNB	3.3%
MNE	14%



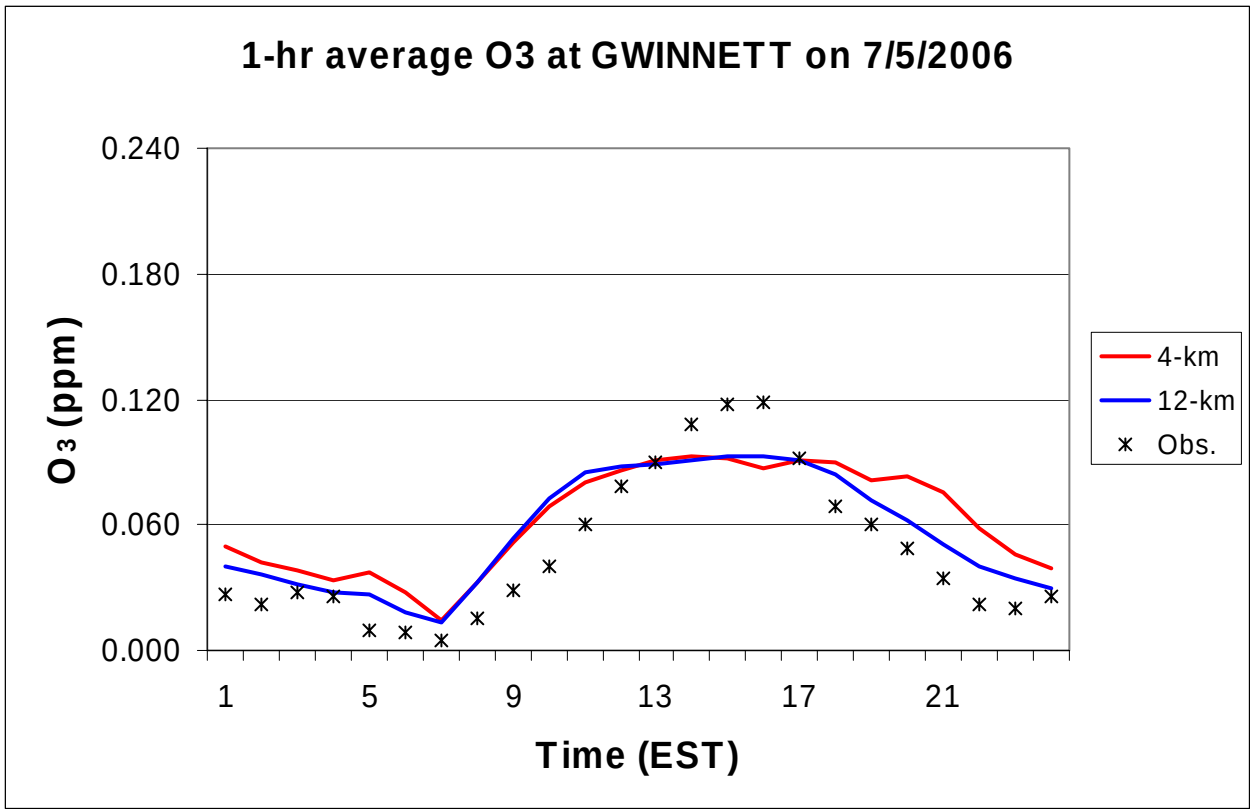


MNB	-0.4%
MNE	23%

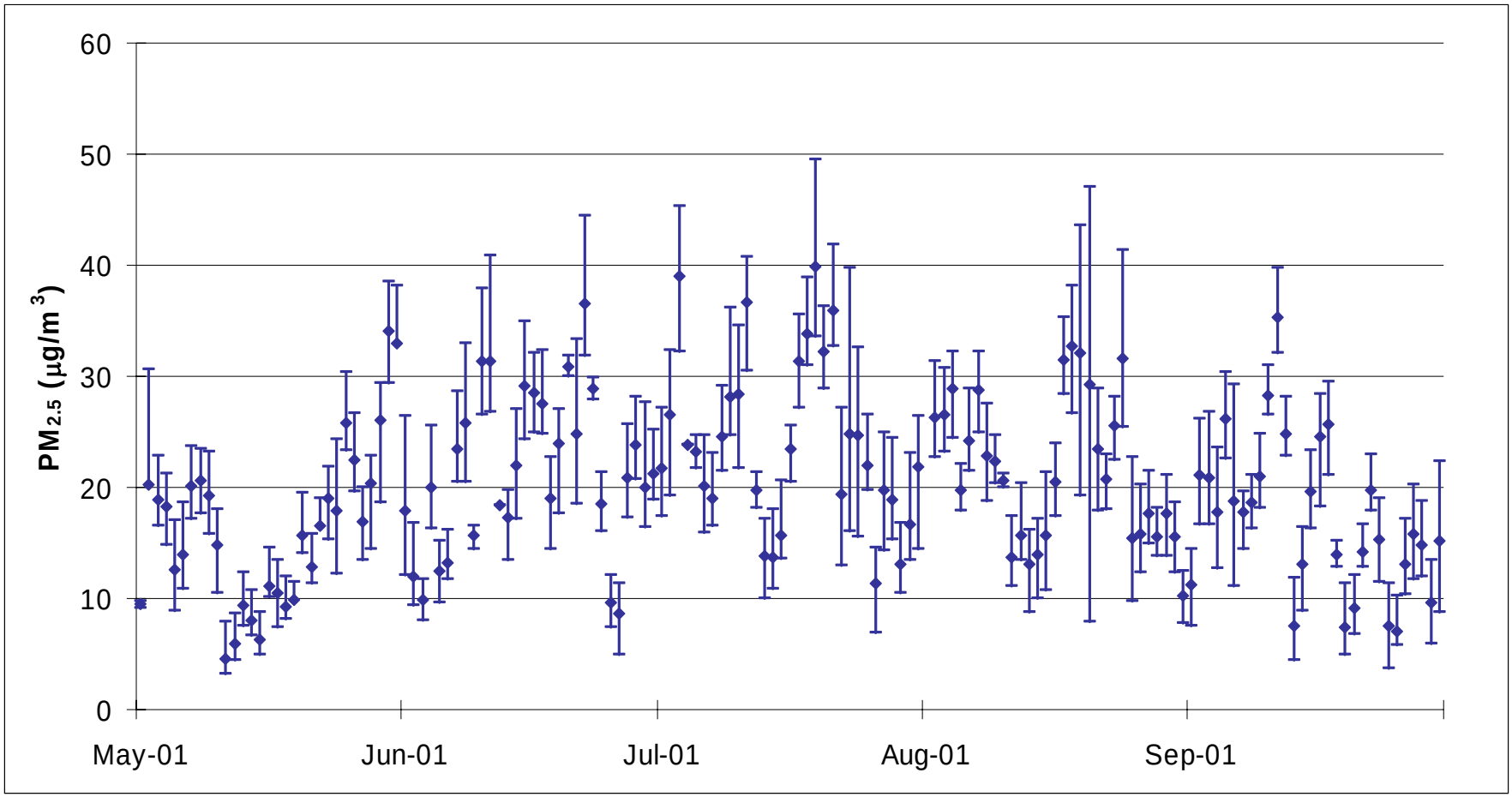
MNB	32%
MNE	40%

O_3 at Gwinnett on July 5, 2006

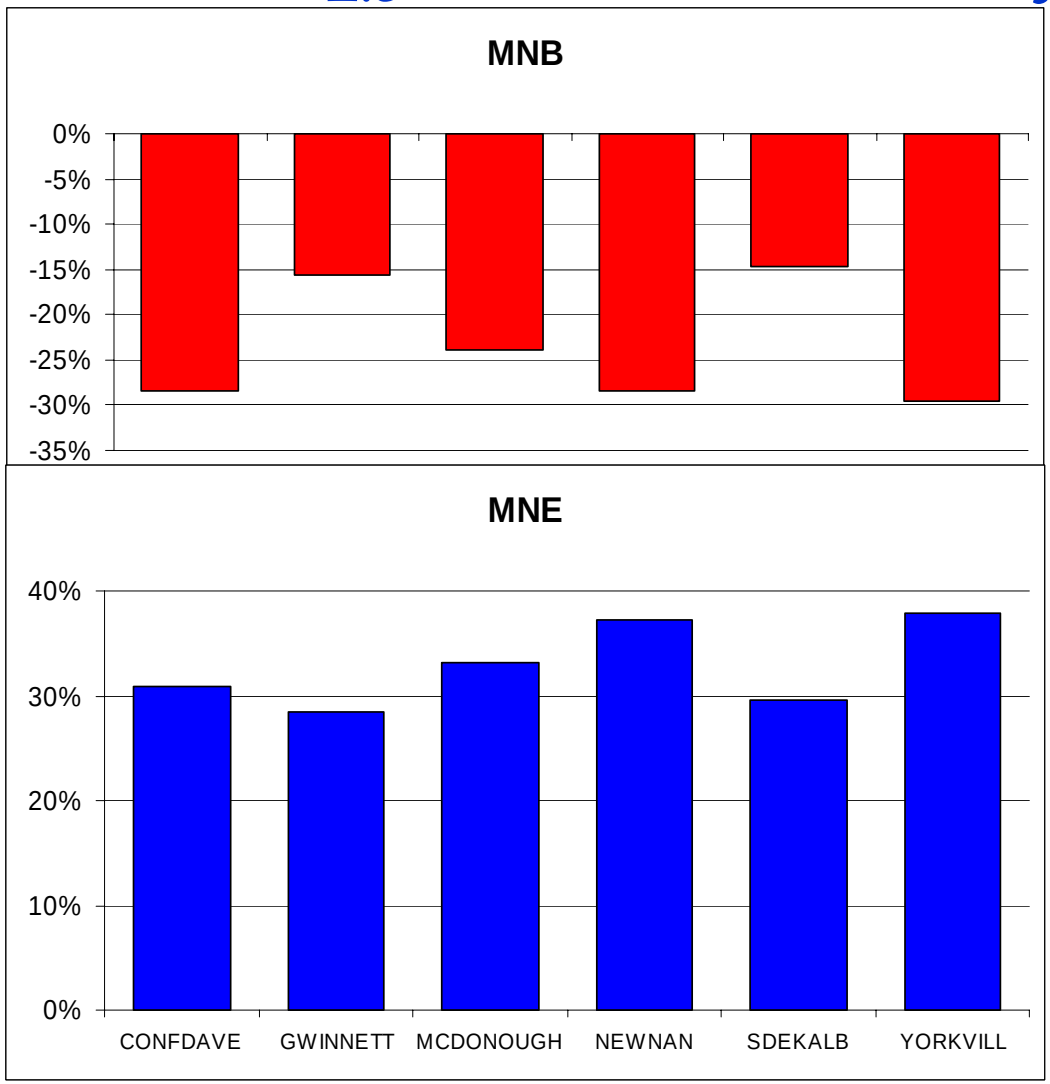
- Obs. 8-hr: 91 ppb 4-km 8-hr : 89 ppb



$PM_{2.5}$ in Metro Atlanta: Summer of 2006

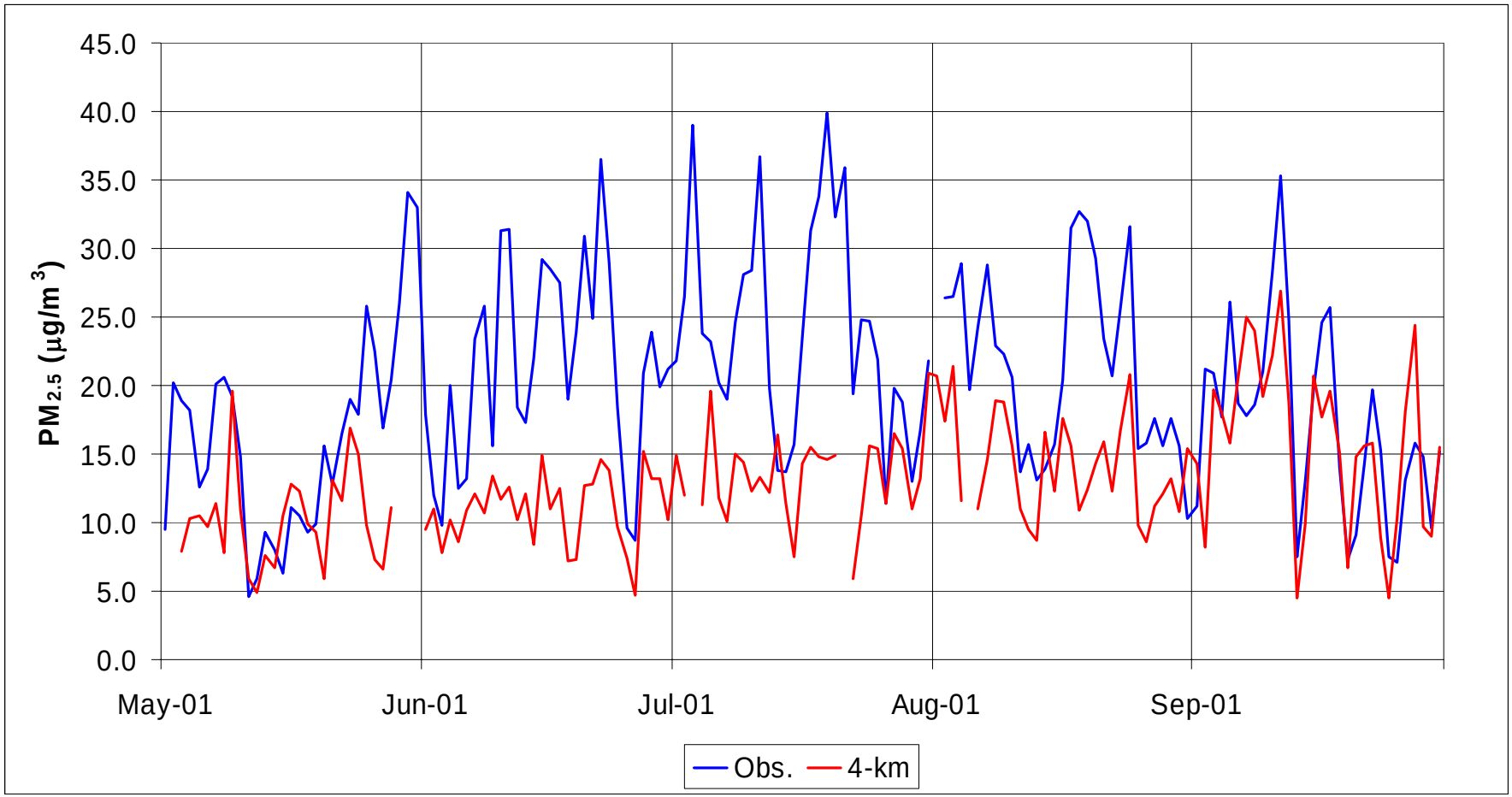


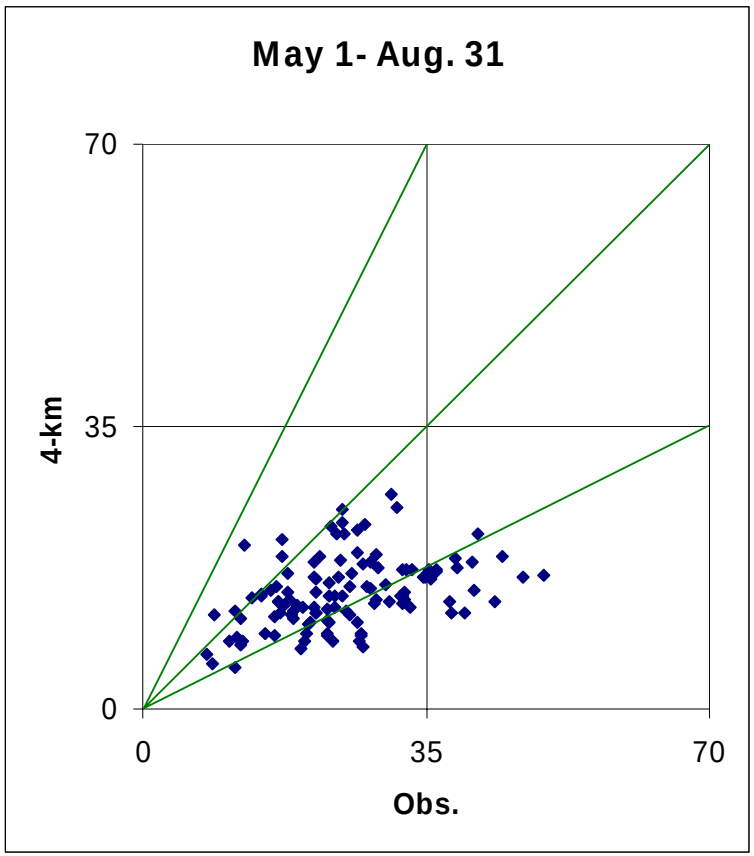
$PM_{2.5}$ Bias & Error by Site



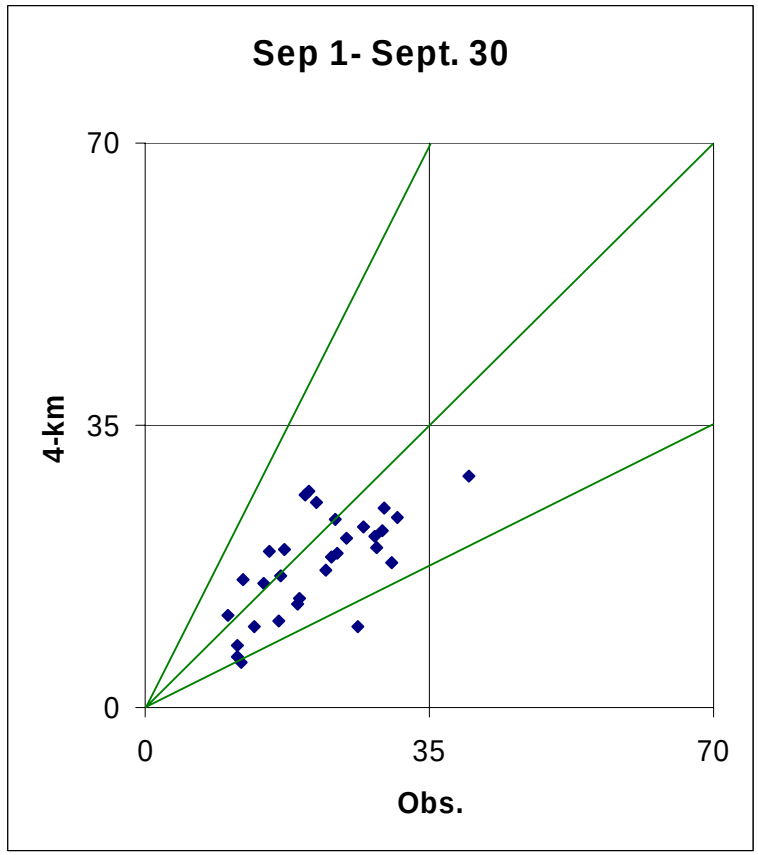
MNB	-31%
MNE	38%

Forecasted vs. Observed $PM_{2.5}$





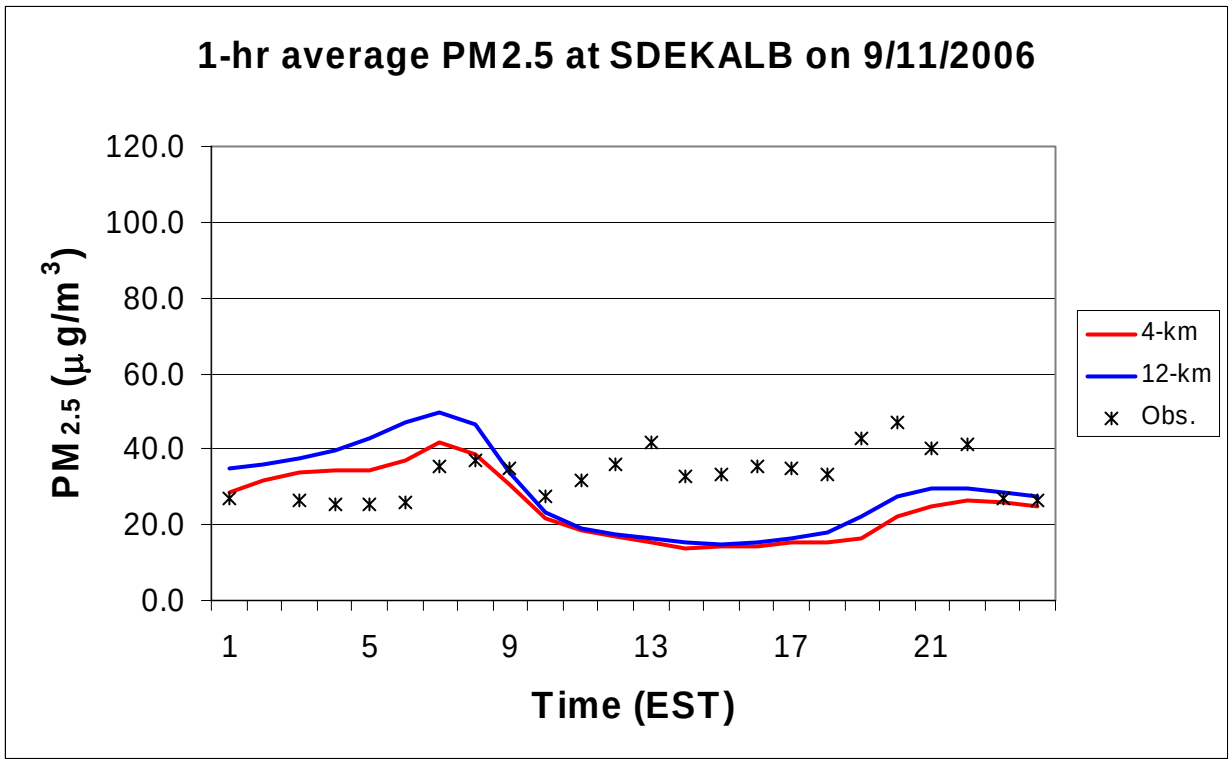
MNB	-38%
MNE	41%



MNB	-4%
MNE	26%

$PM_{2.5}$ at South Dekalb on Sep. 11, 2006

- Obs. 24-hr: 32.6 μg/m^3 4-km 24-hr : 28.7 μg/m^3



Conclusion

- A "fine-scale" forecasting operation using 3-D models started in Georgia on May 1st, 2006.
- The spatial variability in O_3 and $PM_{2.5}$ in Atlanta shows there is a need for fine-scale models
- 4-km forecast is slightly more accurate than the 12-km forecast
- Some sites are better than others. This is more so for PM2.5
- Ozone forecasts were generally accurate until mid-July.
- Over predictions were dominant afterwards
  - No bias and 20% error to 30 bias and 40% error
  - Diurnal changes are somewhat captured; daily peaks generally underestimated
  - The spatial variability is underestimated.
- $PM_{2.5}$ is harder to predict
  - Generally underestimated May-August
  - 20-40% error (peak)
  - Daily $R^2 < 0.4$
  - Some afternoon peaks are missed
- Ensemble O_3 forecast by Georgia EPD was more successful

Next Steps

- Continue the operation
  - Extend the domain of coverage
  - Increase the resolution
  - Elongate the forecasting period
  - Issue daily updates
  - Improve accuracy

- Link the forecast to health-effects studies:
  - Study the impacts on asthmatic children
  - Build a data archive for long-term exposure studies

- Forecast the effectiveness of short-term local control strategies
  - Predict the impacts of predetermined strategies

Acknowledgement

This research is supported by:

- Georgia Department of Natural Resources
- Air Resources Engineering Center at Georgia Tech