# NCEP Air Quality Forecast System Upgrades for the Summer 2005

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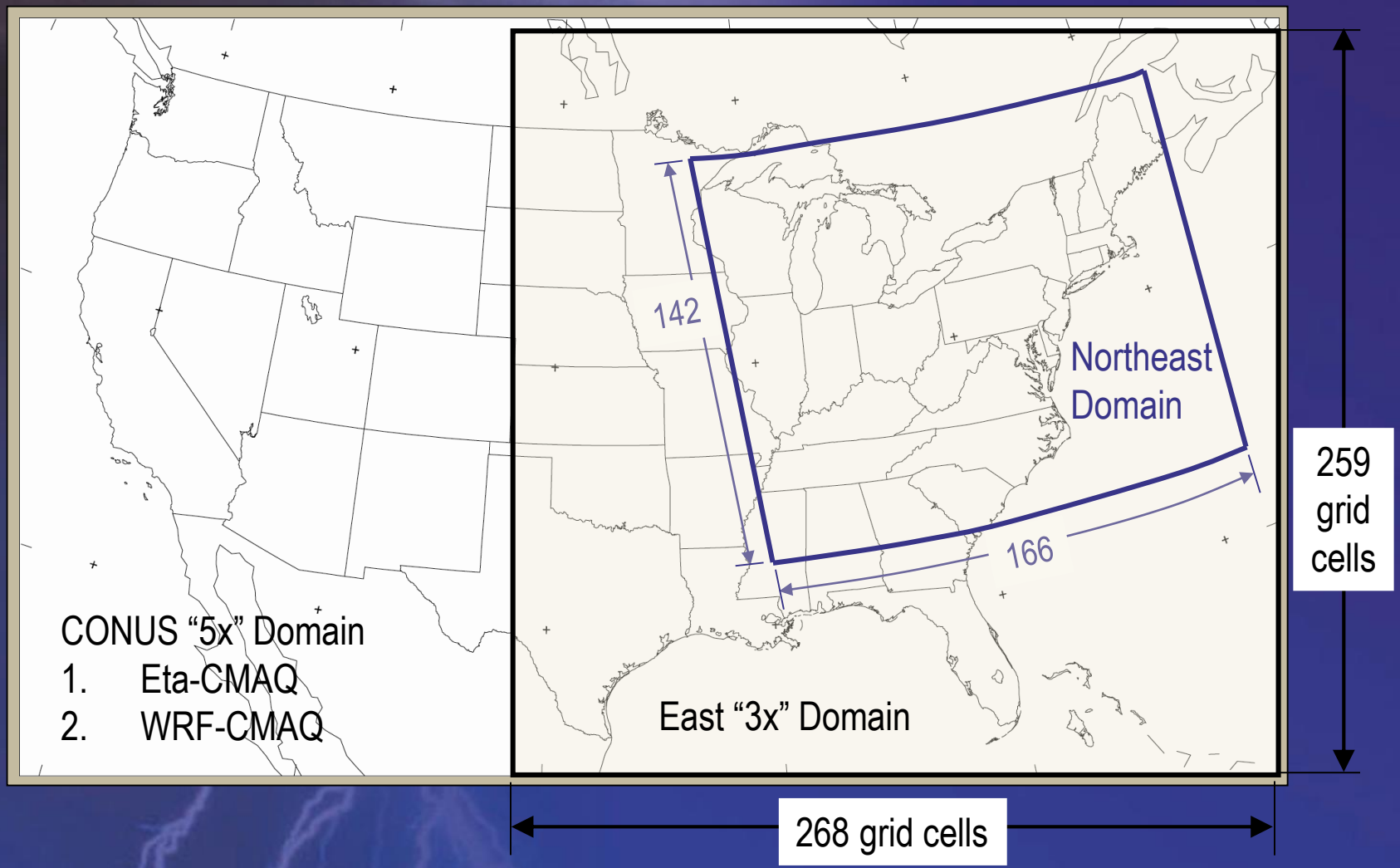
***NOAA/ARL and EPA/ASMD***

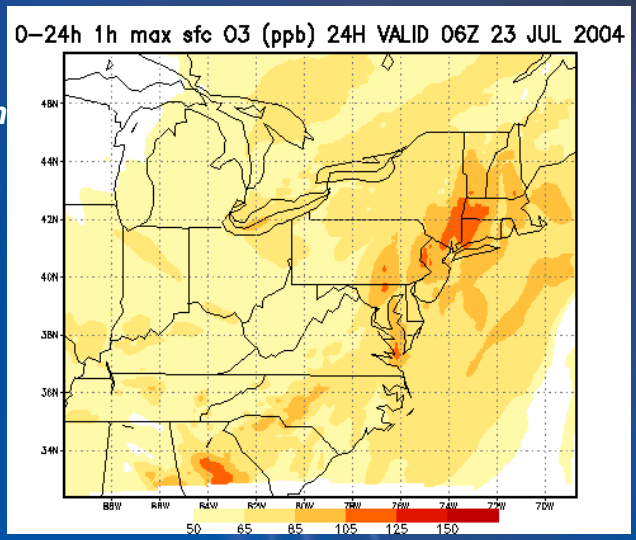
# Forecast Domains (2005)



# Upgraded Air Quality Forecasting Configuration for Operational NE US Domain

- ***NE Domain*: 48 hour forecasts of ozone ($O_3$) : 06 and 12 UTC runs**
- **12 km 166x142x22 top at 100 mb**
- **Optimized PREMAQ/CMAQ codes**
- **New NAM landuse definitions for deposition effects**
- **Updated emissions inventories:**
  - **Project 2002 point and area source inventories for 2005**
  - **Updated Mobile Emissions using MOBILE6 inventory**
    - ***Simplified Temperature dependency on mobile em***
- ***Real-time Verification***
  - ***BUFR O3 and CMAQ output evaluated***

  ***with VSDB/FVS system***

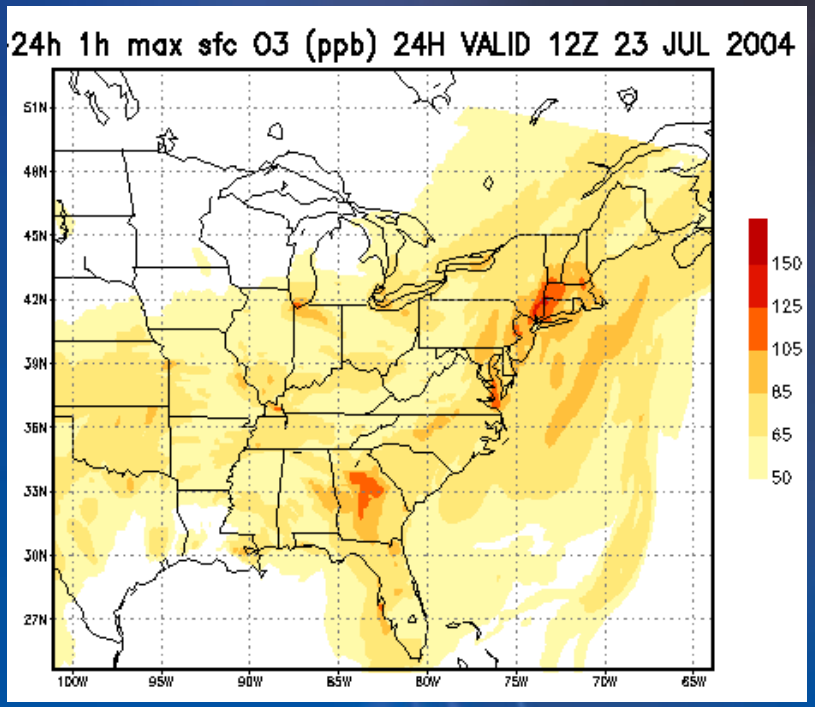


# Current Air Quality Forecasting
# *Experimental Expanded* Domain Configuration

- ***Eastern US*** **: 48 hour forecasts of ozone ($O_3$) : 06 and 12 UTC runs**
  - ***3x expanded domain*** **(East of Rockies, 268x259x22) run in parallel**
  - **Same Configuration as NE US Run except:**
    - **Convective Cloud Mixing from cloud top = 0**
  - **Additional processors (~65) used**

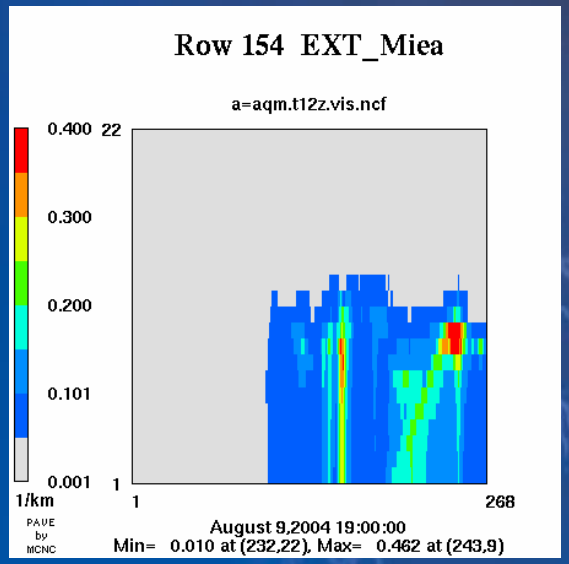
**on Production machine**

- **12 z Available by 16:10 UTC**



# Current Air Quality Forecasting *Research Aerosol* Domain Configuration

- ***Eastern US*** **: 24 hour forecasts of $O_3$ & Aerosols: 12 UTC run only**
  - **Same system as operational except**
    - ***3x expanded domain*** **(East of Rockies) run**
    - ***24 hr cycling***
    - ***33 processors on Development Machine (less (less reliability, 8x5)***
  - **Available by 21 UTC**



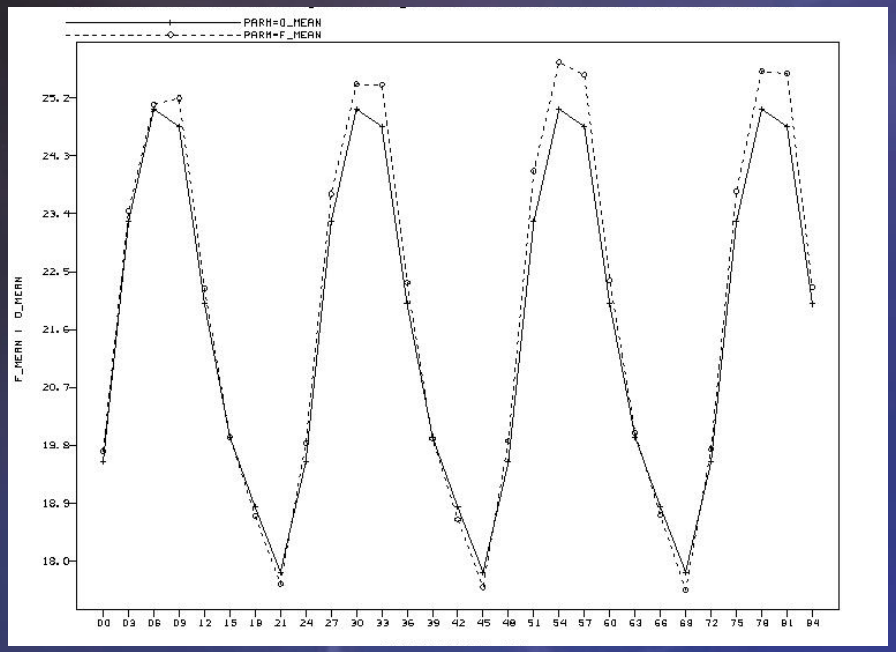
# Current Physics Coupling w/ NCEP NAM

| Current Capability | Met Model (Eta, WRF/NMM) | AQ Model (CMAQ) |
|---|---|---|
| ***Core/Dynamics*** | Rotated Arakawa E grid | Arakawa C Grid |
| ***Clouds*** | Full Ferrier Cloud Microphysics | Eta cloud water for aqueous chemistry |
| ***Convective mixing*** | Betts-Miller Janjic | *Entrainment from top turned off* |
| ***Radiation*** | GFS* | *Derived from Eta RH for photolysis* |
| ***PBL*** | Mellor-Yamada TKE | Eta PBL hgt for Pleim-Xiu 1st order K |
| ***Land Surface*** | NOAH common | Eta canopy conductance terms for Pleim-Xiu LSM |

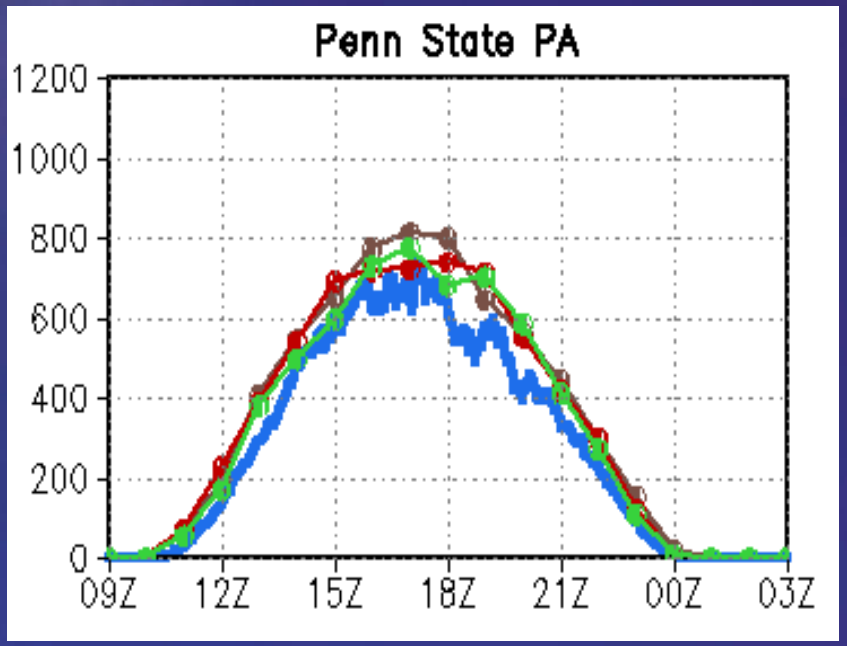
# Coupling Developments

| Run | NAM-CMAQ (3x,Conus) | WRF-CMAQ |
|---|---|---|
| Domain | Interp to CMAQ C grid | *Common Rotated E grid* |
| Vertical Coordinate | Interpolate to CMAQ σ | *Common WRF/NMM σ-P* |
| Photolysis | *Surface Eta Radiative Scaling* | *3-D Radiative fluxes* |
| PBL | Eta PBL height into P-X | *NAM TKE/Kh to drive mixing* |
| Clouds Aqueous<br>Mixing | Eta cloud water<br>*Eta convective cloud base/top* | *NAM cloud water,graupel & ice*<br>*Axisymetric Convective Model (ACM) mixing extended for conv.* |
| LBCs | *GFS above 6 km*<br>*Static below* | *GFS above 6 km, static below*<br>*Higher top, improved vertical resolution near tropopause* |

# NAM Verification
# August 2004

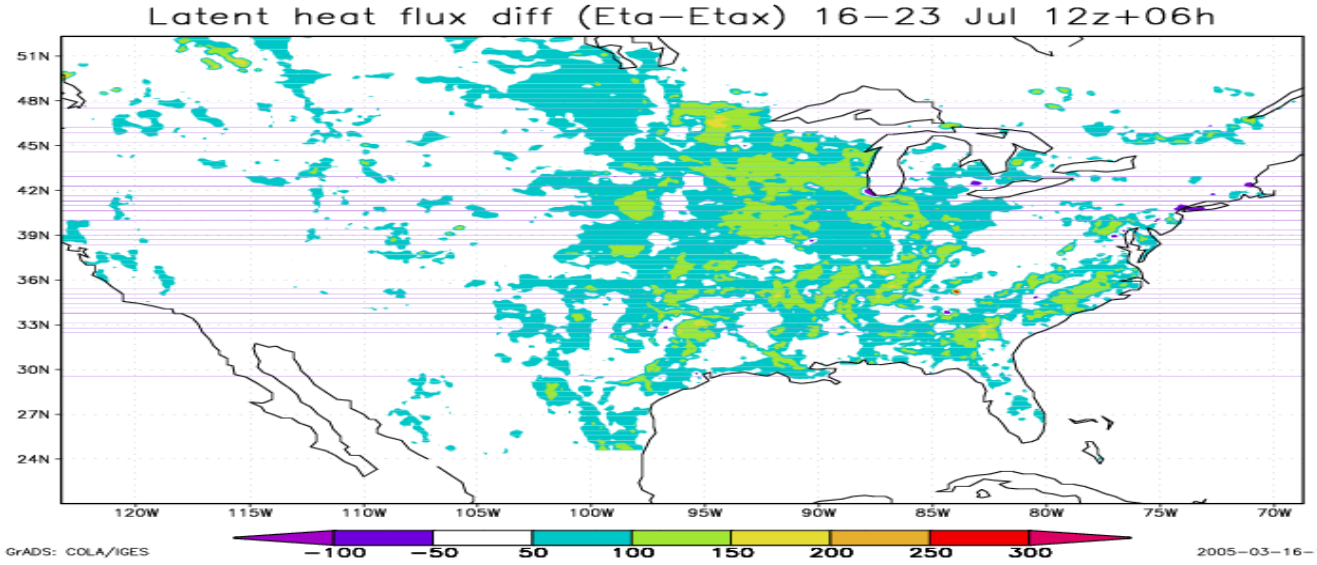



Temperature

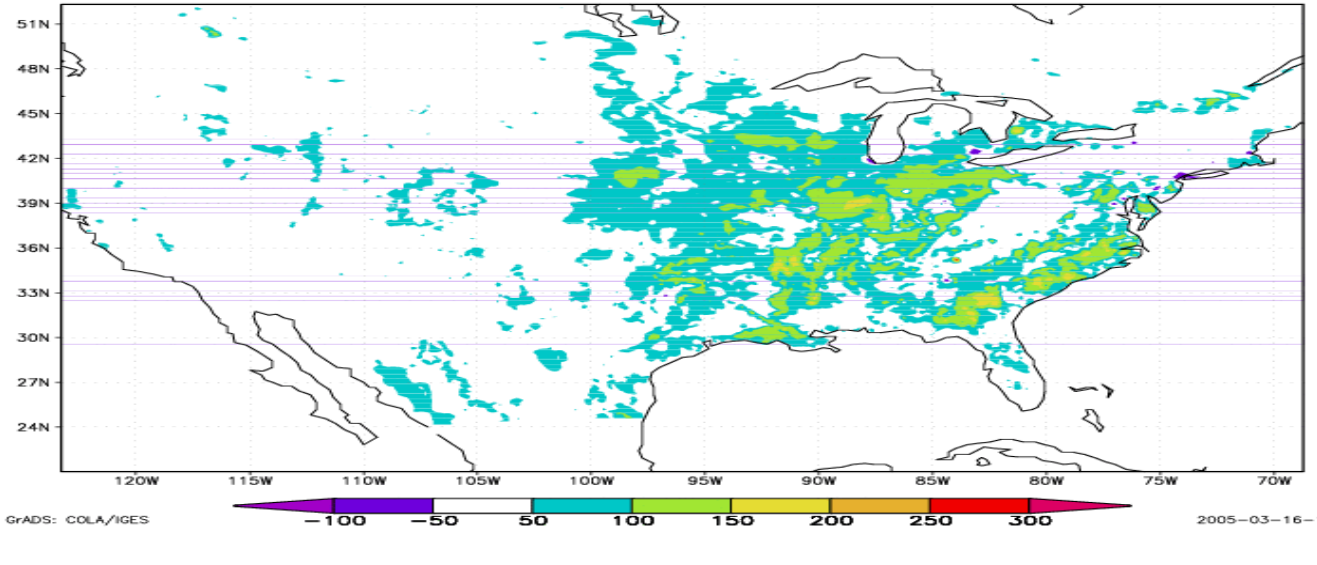



Downward SW

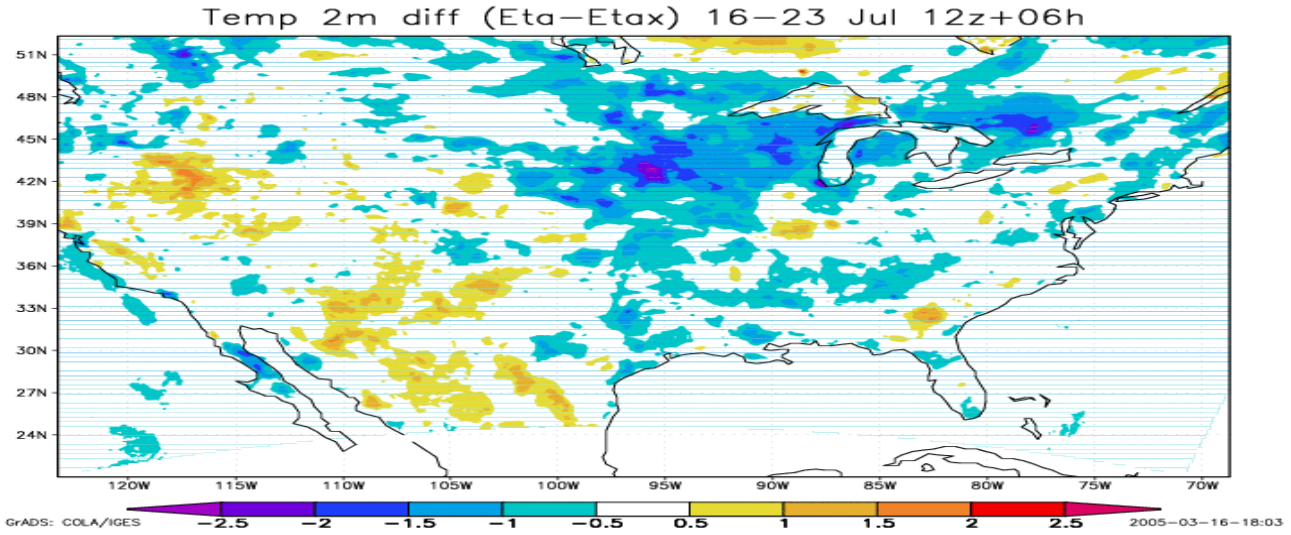
July 16-23



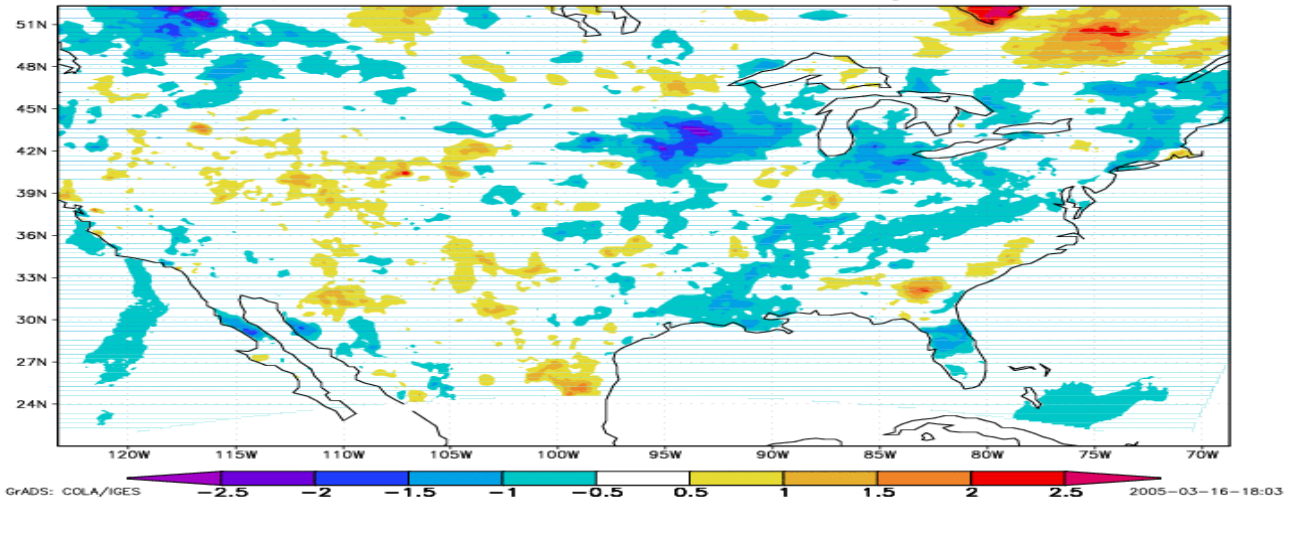

Aug 4-11



July 16-23




Aug 4-11



# RETROSPECTIVE TESTING

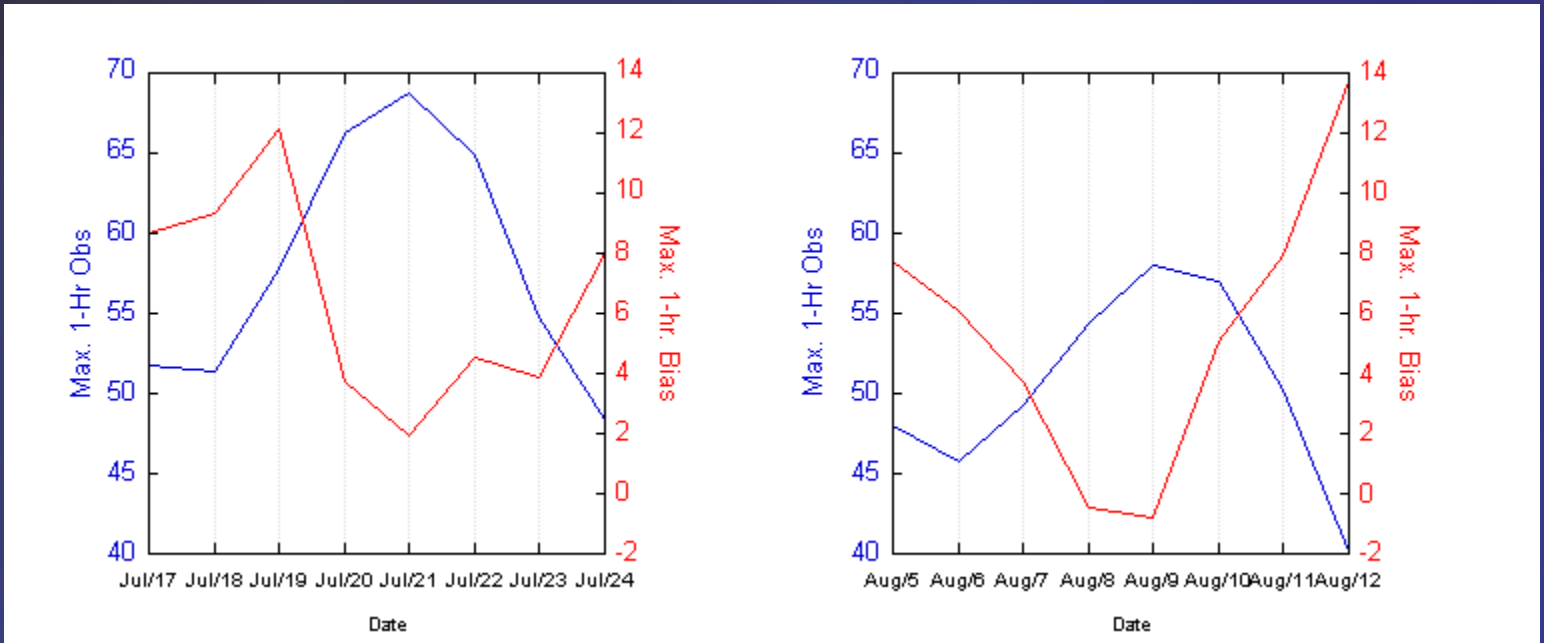
**Runs: P. Lee, M. Tsidulko**

**Analysis: R. Mathur, D. Kang, J. Pleim,…**

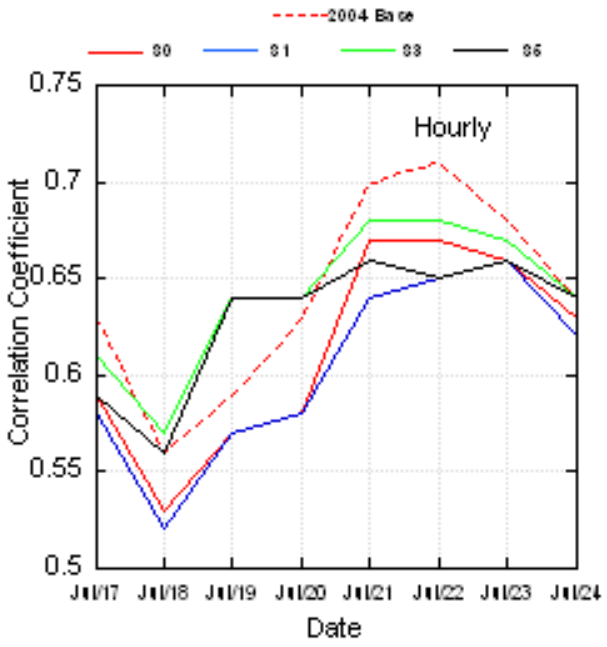
- 2004 Base: **2004 Operational run**
- S0: **Reflects changes due to Eta-X**
- S1: **S0 + photolysis attenuation based on Eta radiation fields**
- S3: **S0 + Mixing from above clouds turned-off**
- S5: **S1+S3**

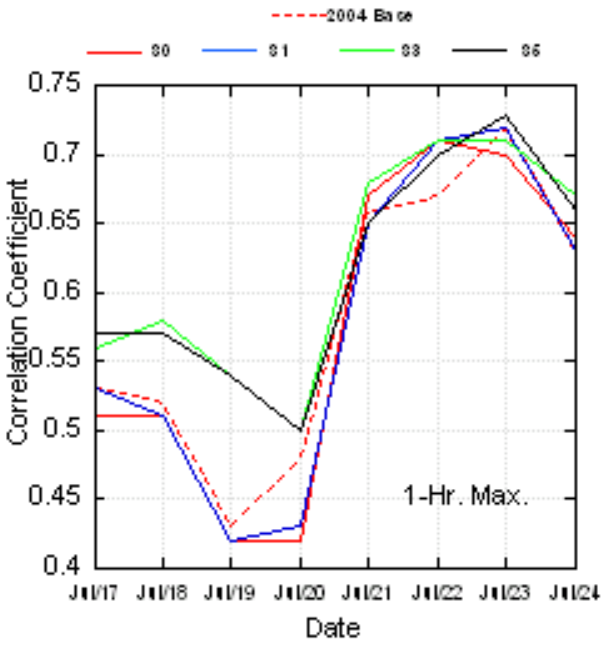
# Analysis Time Periods

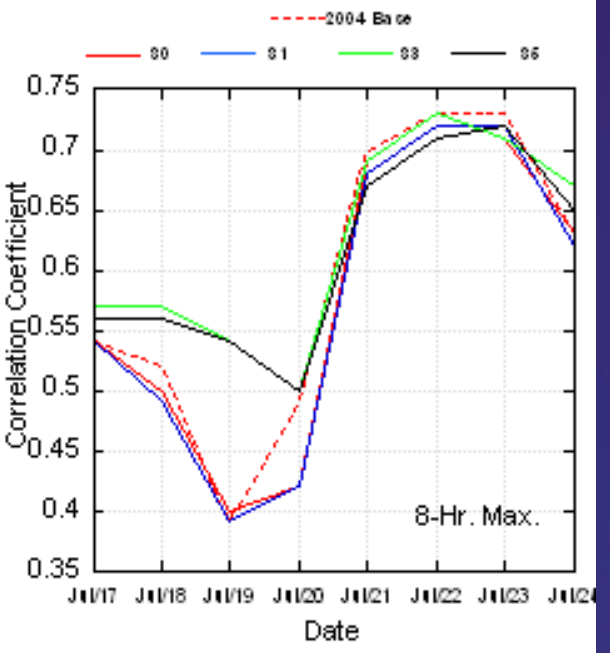
- Time Periods
  - ***12Z July 16, 2004 – 12Z July 25, 2004***
  - ***12Z August 4, 2004 – 12Z August 13, 2004***
  - ***12Z August 8, 2002 – 12Z August 20, 2002***

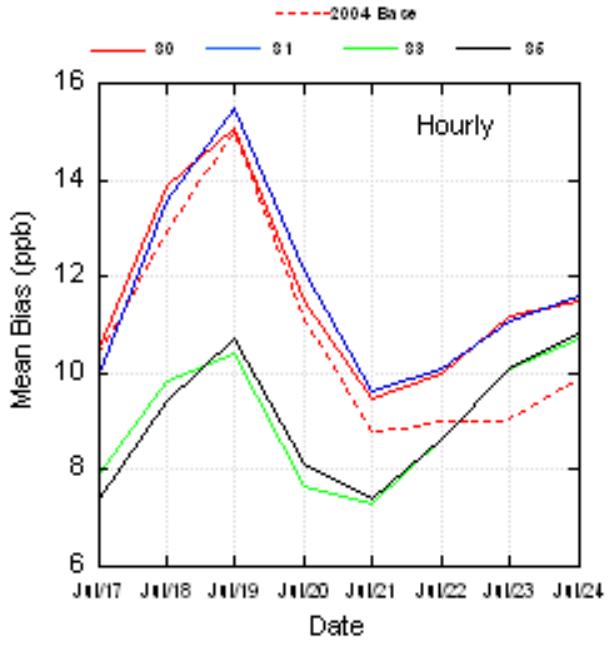


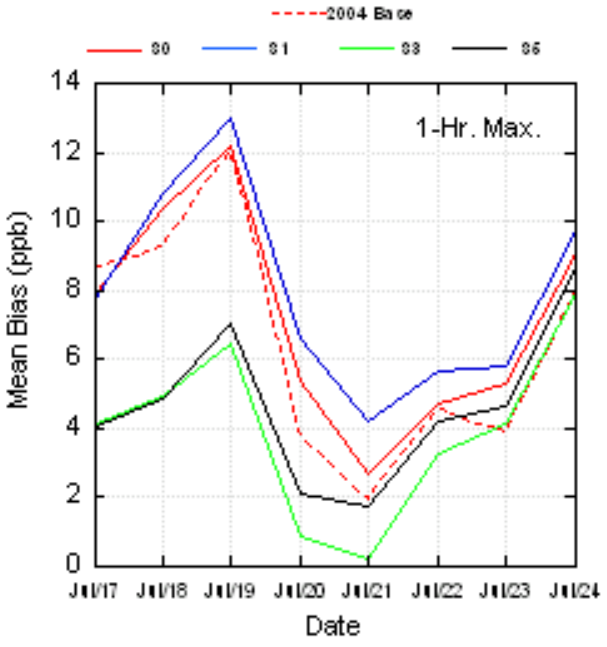
# July Case

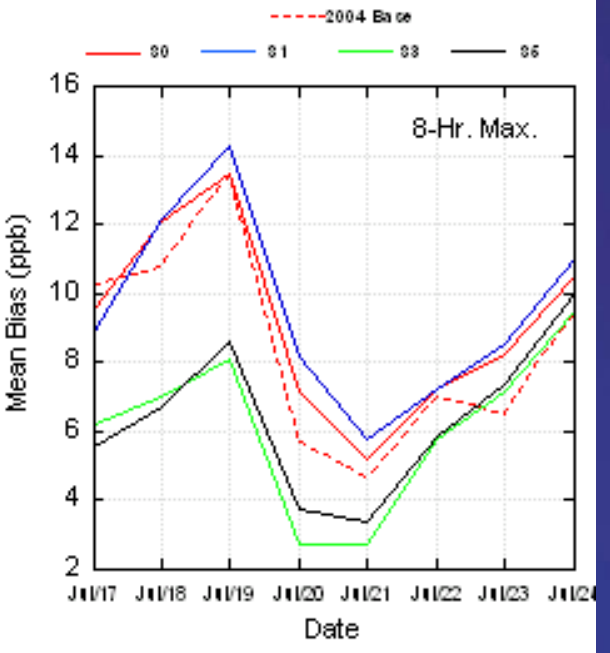

2004 Base
S0
S1
S3
S6
Hourly
Correlation Coefficient
0.75
0.7
0.65
0.6
0.55
0.5
Jul/17
Jul/18
Jul/19
Jul/20
Jul/21
Jul/22
Jul/23
Jul/24
Date


2004 Base
S0
S1
S3
S6
1-Hr. Max.
Correlation Coefficient
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
Jul/17
Jul/18
Jul/19
Jul/20
Jul/21
Jul/22
Jul/23
Jul/24
Date


2004 Base
S0
S1
S3
S6
8-Hr. Max.
Correlation Coefficient
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
Jul/17
Jul/18
Jul/19
Jul/20
Jul/21
Jul/22
Jul/23
Jul/24
Date

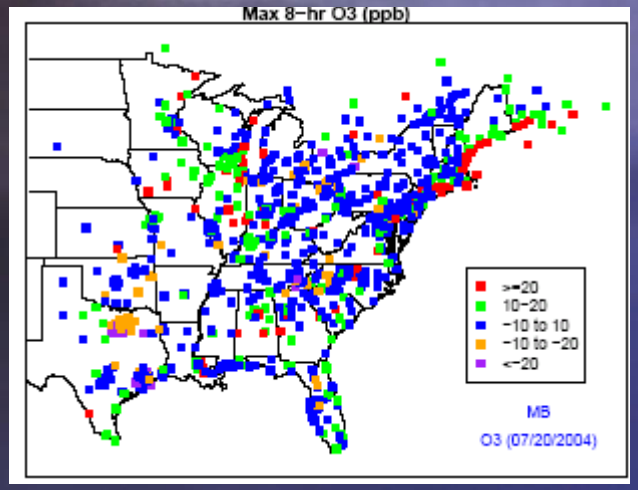

2004 Base
S0
S1
S3
S6
Hourly
Mean Bias (ppb)
16
14
12
10
8
6
Jul/17
Jul/18
Jul/19
Jul/20
Jul/21
Jul/22
Jul/23
Jul/24
Date


2004 Base
S0
S1
S3
S6
1-Hr. Max.
Mean Bias (ppb)
14
12
10
8
6
4
2
0
Jul/17
Jul/18
Jul/19
Jul/20
Jul/21
Jul/22
Jul/23
Jul/24
Date

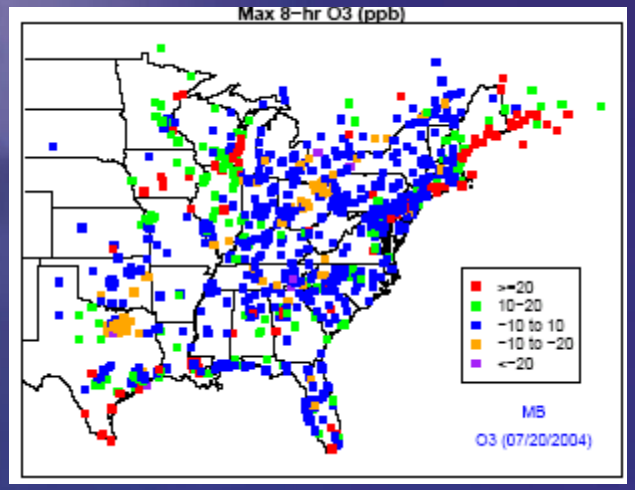

2004 Base
S0
S1
S3
S6
8-Hr. Max.
Mean Bias (ppb)
16
14
12
10
8
6
4
2
Jul/17
Jul/18
Jul/19
Jul/20
Jul/21
Jul/22
Jul/23
Jul/24
Date

# Max 8-hr $O_3$ Mean Bias Spatial Distribution: July 21, 2004

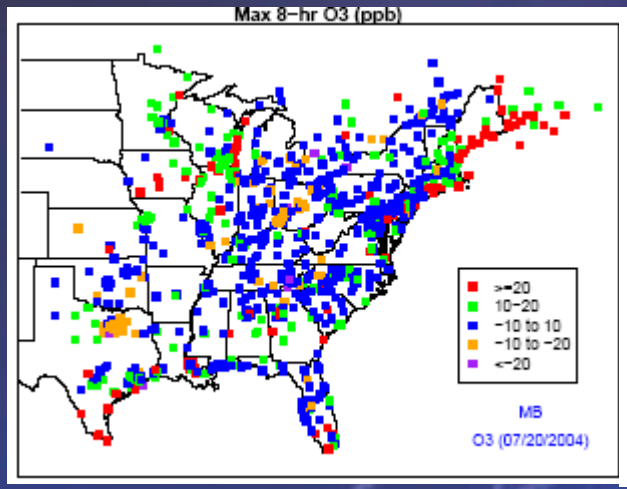
2004 Base



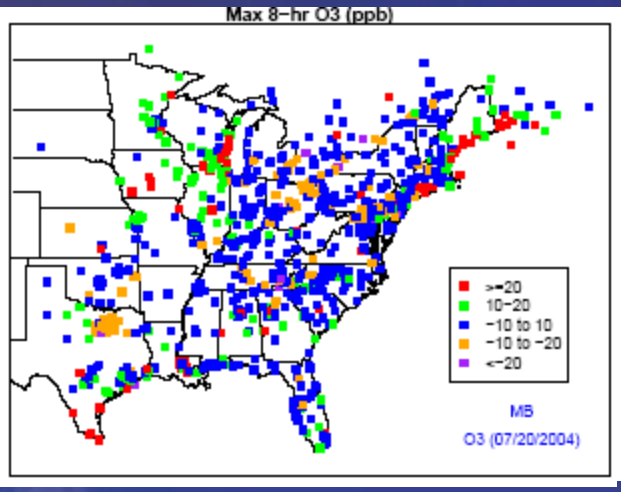

S0



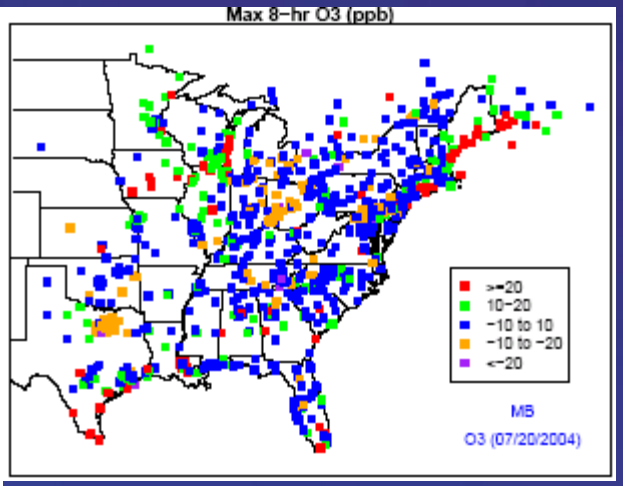

S1




S3

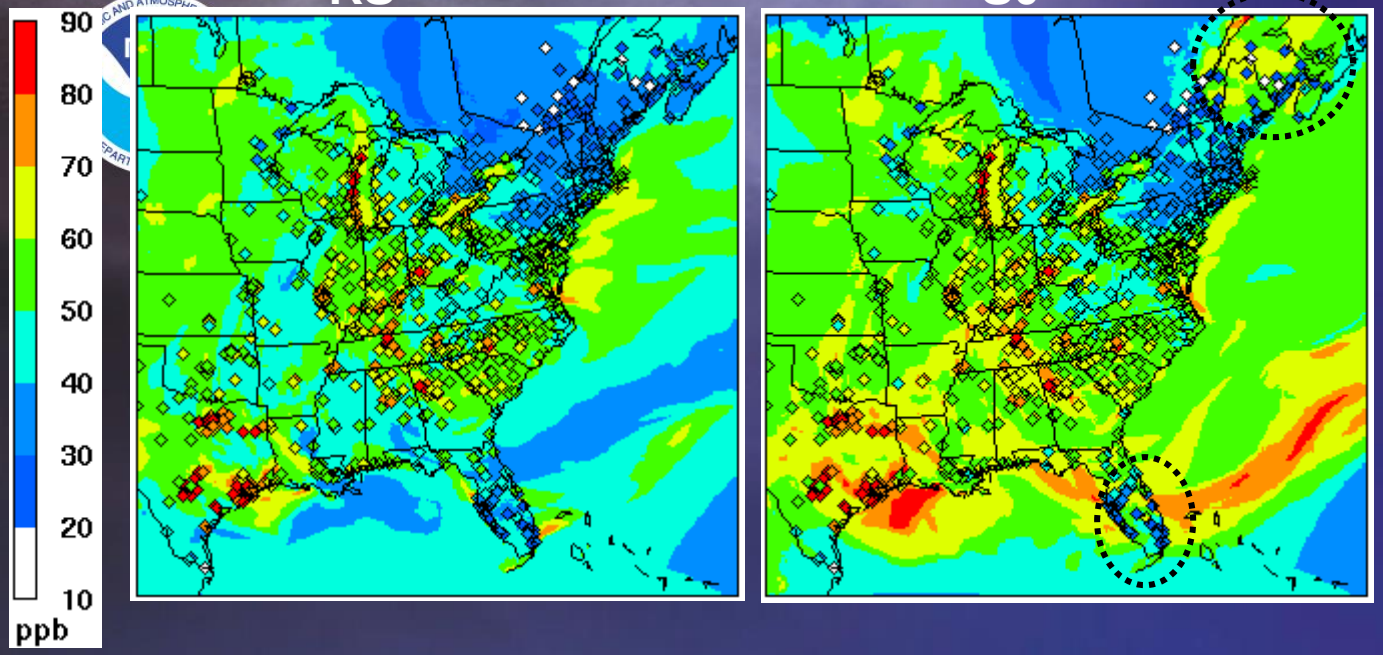



S5

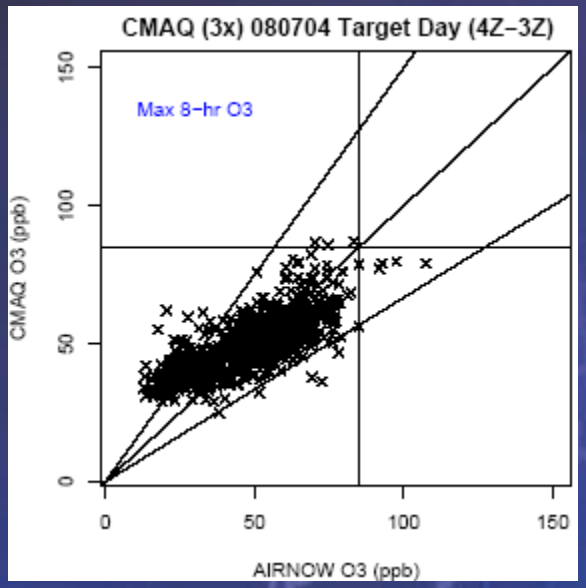


RS

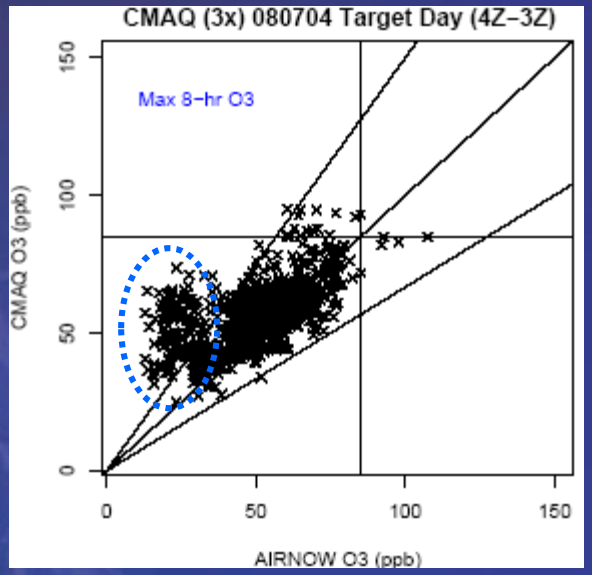
S0




Max. 8-Hr. $O_3$
August 8, 2004

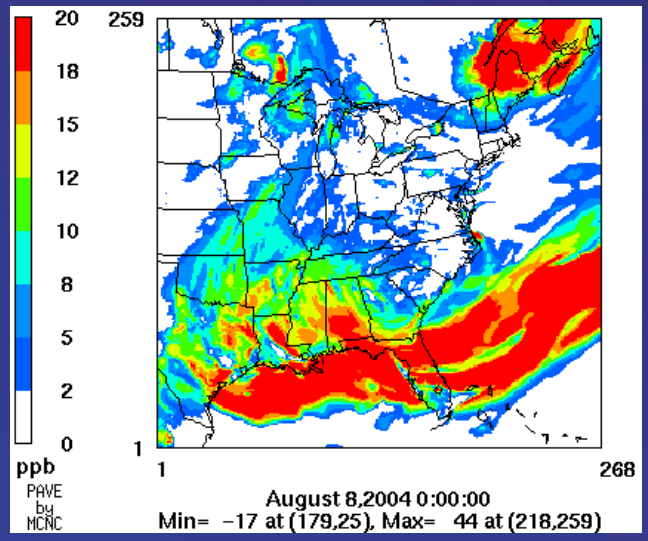



Slight tendency to under-predict




O3 increased regionally,
Over-predict at low range

S0-RS



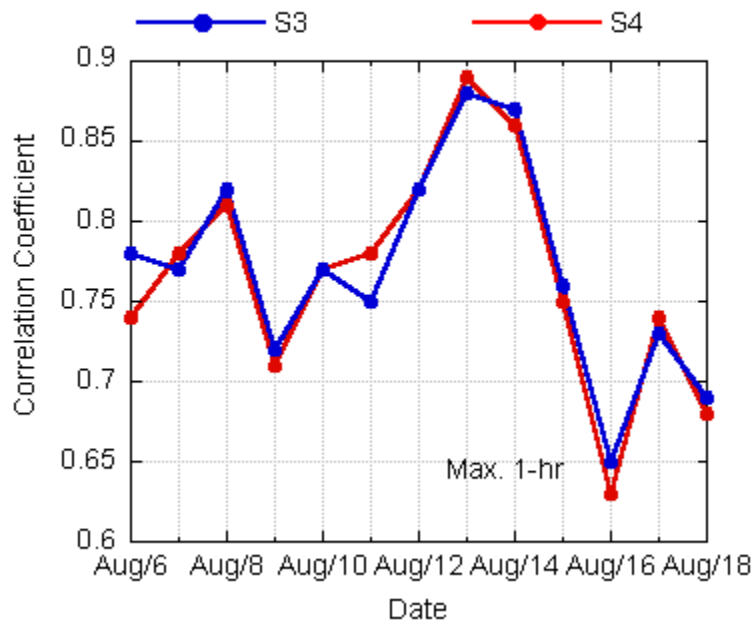
# Performance Summary for 2002 Retrospectives

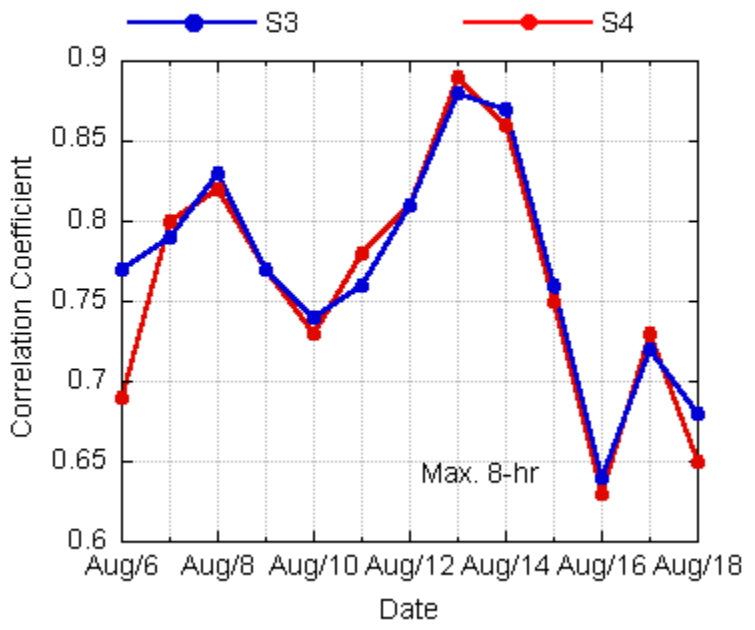
## Comparison of S3 and S4 CMAQ Configuration

**S0**: Reflects changes due to Eta-X
**S1**: S0 + photolysis attenuation based on Eta radiation fields
**S2**: S0 + ACM-type cloud mixing
**S3**: S0 + Mixing from above clouds turned-off
**S4**: S1+S2
**S5**: S1+S3

# Performance Summary: August 6-18, 2002

**Max. 1-Hr.** **Max. 8-Hr.**



# NCEP AQ Runs

| Run | Today | June | July | August | Sept |
|---|---|---|---|---|---|
| Operational | NE U.S → | | East U.S → | | |
| Experimental | East U.S. → | | | CONUS (Eta) | |
| Development al (EMC) | | CONUS (Eta) → | | CONUS (WRF) | |
| Research (EMC) | PM East US → | | | PM East US (WRF) | |

# Developmental Testing
## *WRF-CMAQ (East U.S)*

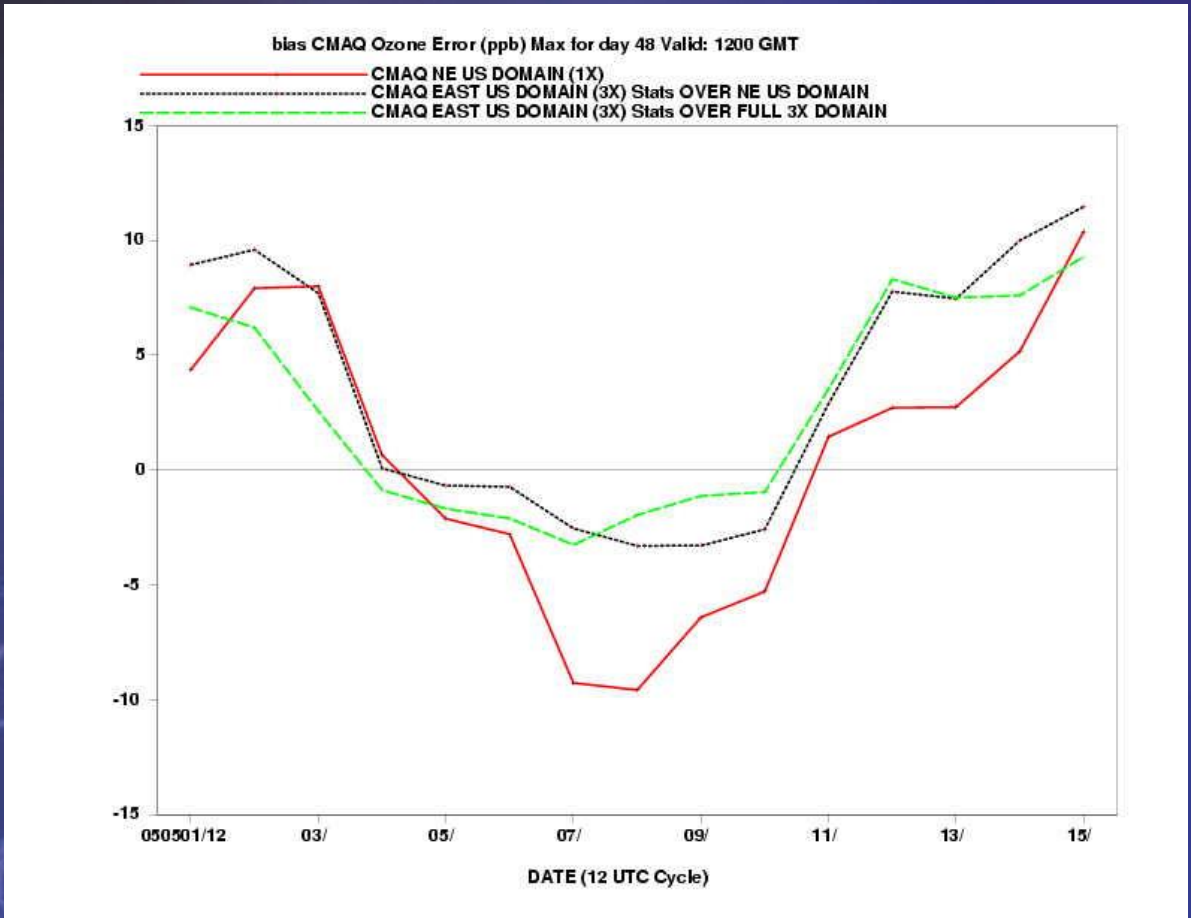
- **WRF/NMM tests**
  - ***Test common vertical Sigma coordinate***
  - ***Test common horizontal rotated E grid coordinate***
- **Improved Radiation Coupling for Photolysis**
  - ***Sfc and 3d radiative fluxes***
- **Improved Cloud Coupling for cloud mixing & aqueous chemistry**
- **Improved PBL coupling for mixing**
- **Improved Emissions**
- **Improved LBCs**
  - ***Improved vertical resolution near tropopause***
  - ***Raised CMAQ model top***
- **Full bundle tests**

# Verification Tasks

- **Implement near real-time ozone FVS verification system at NCO:**
  - ***Statistics for RMSE, Bias, Correlations for full and sub regions***
  - ***Contingency stats: Accuracy, POD, FAR, CSI, Threat scores for hrly, 8hrly, daily max***
- **Detailed evaluations of Eta/WRF met. forecasts**
  - ***Compare ozone errors with Temperature, RH, winds, PBL height, cloud cover, sfc flux errors***
- **Explore additional mesonets**
  - ***Ozone: rural networks(ETOS…)***
  - ***Aerosols: AIRNOW, AERONET, IMPROVE, CASTNET?***
  - ***Lidars: REALM***
  - ***Satellite case studies for CMAQ-aerosols :***
    - **GASP, MODIS, AURA/OMI&TESS**

# FVS O3 Real-Time Verification

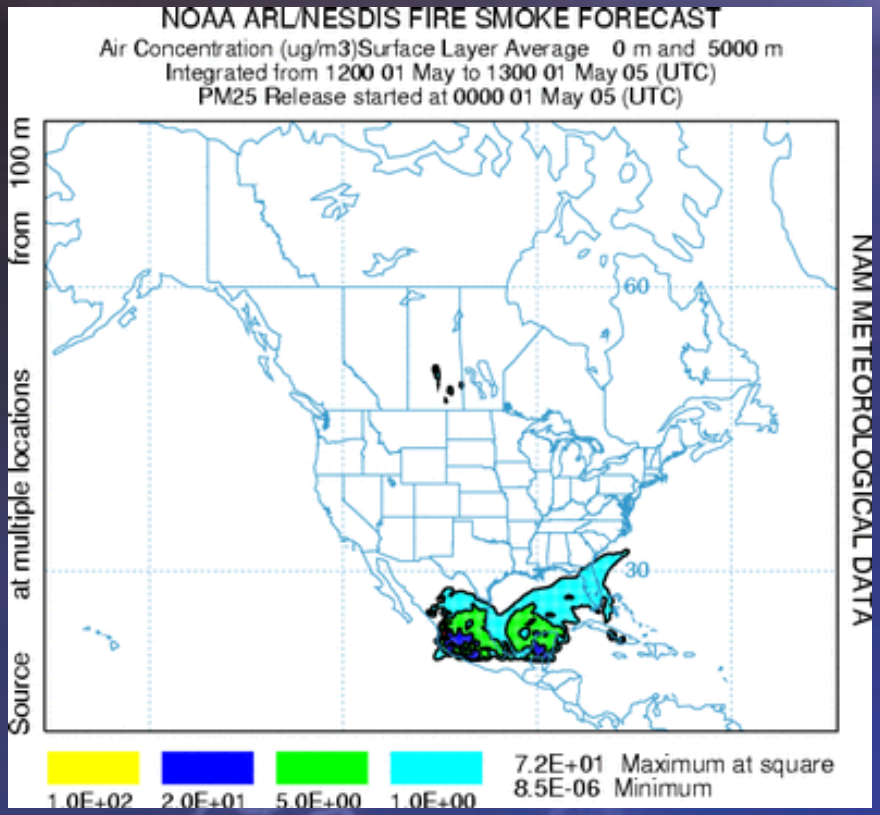
## Daily Maximum Ozone Bias



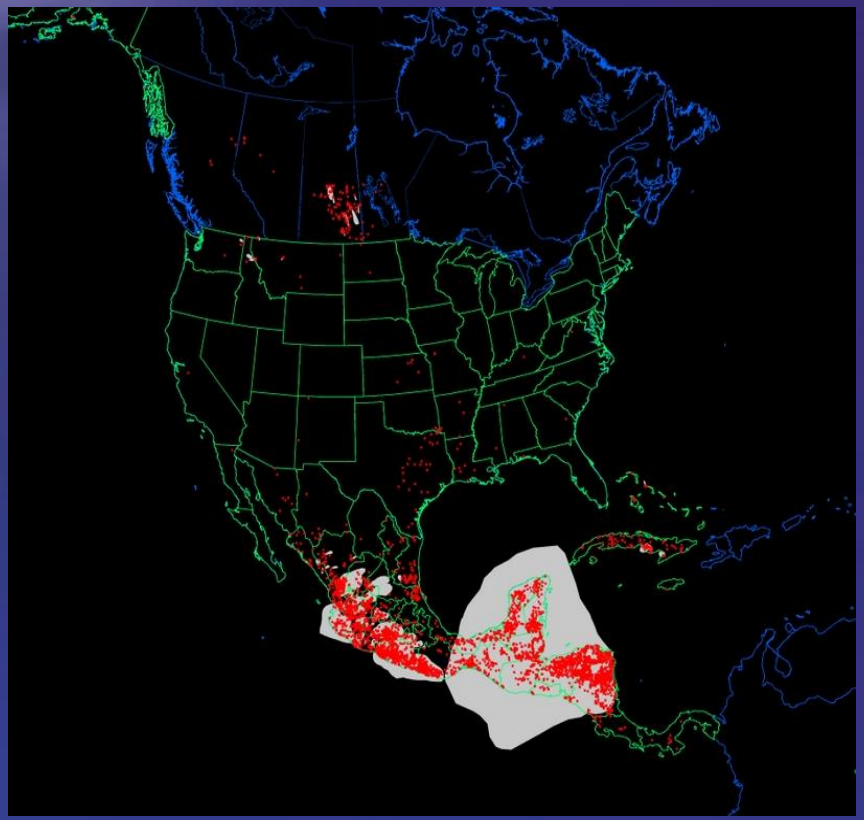
# *Hysplit fire smoke*

- **Jan. 2005**
  - ***Upgraded Hysplit for volcanic ash, radiological releases***
  - ***web visualization***
- **Sept. 2005**
  - ***Hysplit smoke w/ NESDIS HMS source locations retrospective & real-time tests***
  - ***USFS smoke emission system (w/o NetCDF)***
  - ***Retrospective tests***
  - ***Real-time parallel tests***
  - ***GASP, MODIS  AOD verification performed by NESDIS***

# *Hysplit fire smoke verification*




1 hr avg PM2.5 conc
0-5000 m



NESDIS Fire Location and
Visible Plume

# Data Assimilation/Global System Tasks

- **CMAQ data assimilation:**
  - ***Plan for surface ozone assimilation***
  - ***Correlate sfc ozone w/ precursers (Nox VOCs)***

- **GFS: Improved chemistry for regional LBCs**
  - ***Ozone:***
    - **Include tropospheric product/loss rate terms**
    - **Test reduced ozone chemistry (U.Wisc-RAQMS)**
    - **Begin testing assimilation of AURA/OMI**
    - **CMAQ LBC impact studies**
  - ***Aerosols:***
    - **Include NASA-GOCART reduced biomass burning/dust and emission processes**
    - **Begin testing assimilation of MODIS & AURA/TESS**
    - **CMAQ LBC impact studies**

# Summary

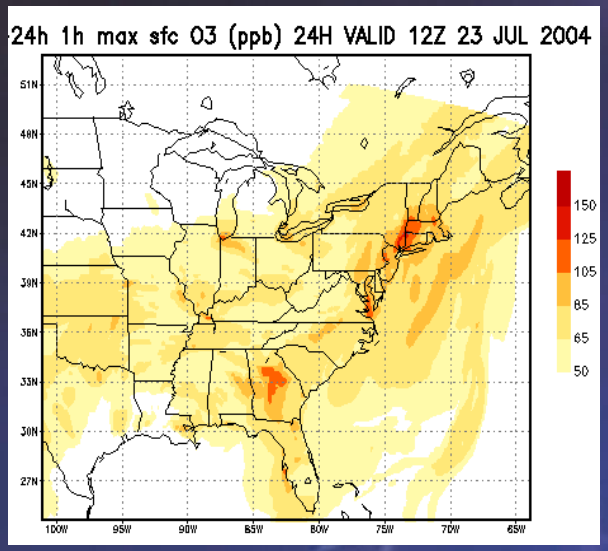
- ***Retrospective and real-time results show improvements***
  - **Mean daytime bias reduced from ~17 to 5 ppb**
  - **Mean daytime rmse reduced from  22.8 to 14.5 ppb**
  - **However, still general overprediction in day, poorer performance at night,**
  - **Temporary Fix of over-mixing from downward entrainment of strat(gfs) ozone**
- ***FY05 Focus***
  - **Improved dynamics/physics coupling**
  - **Begin assimilation**
  - **Improve verification**

# BACKUPS

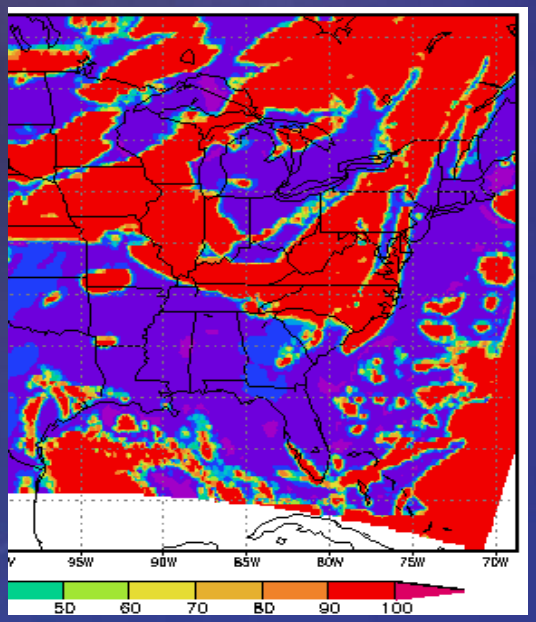
# Air Quality Forecasting
# User Access

- ***NE, and East Domain :***
  - **Public: NDGD and TOC ftp server**
    - ***Surface ozone predictions***
  - **State Forecasters: HPC web site**
    - ***Sfc O3 & met plots***
    - ***Daily (2pm) conference calls***
    - ***HPC forecasters trained***
- ***Experimental Domain (Conus & WRF O3):***
  - **Focus group: EMC web site**
    - ***Expanded met plots (pbl hgt, sw rad, ventilation index….)***
    - ***Sfc & upper level O3 and precurser plots (NOx, NOy,CO,SO2)***
- ***Research (Aerosols)***
  - **Sfc PM, AOT**

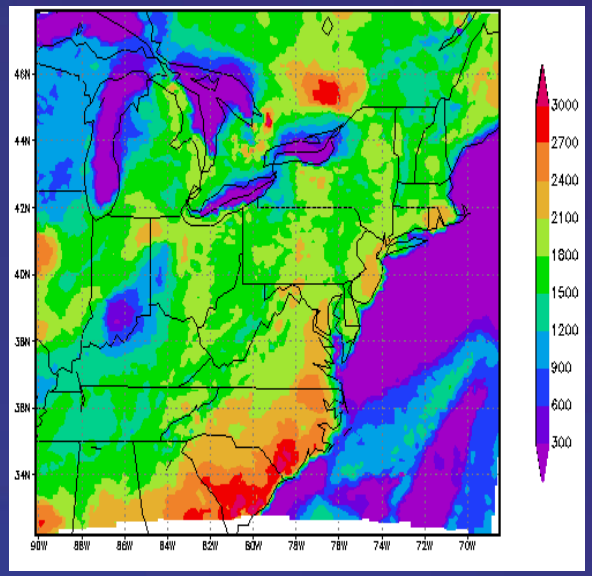
# NCEP Graphical Products




Predicted Sfc Ozone
(1, 8h, max)




Eta cloud cover



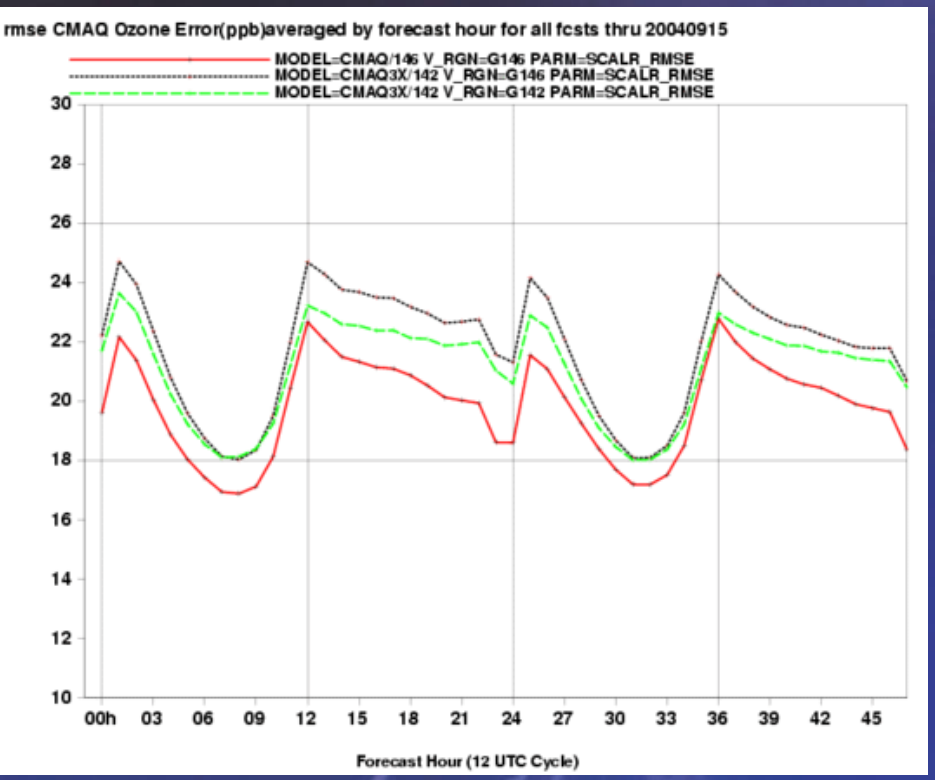

Eta PBL hgt

# Potential short-term collaboration projects

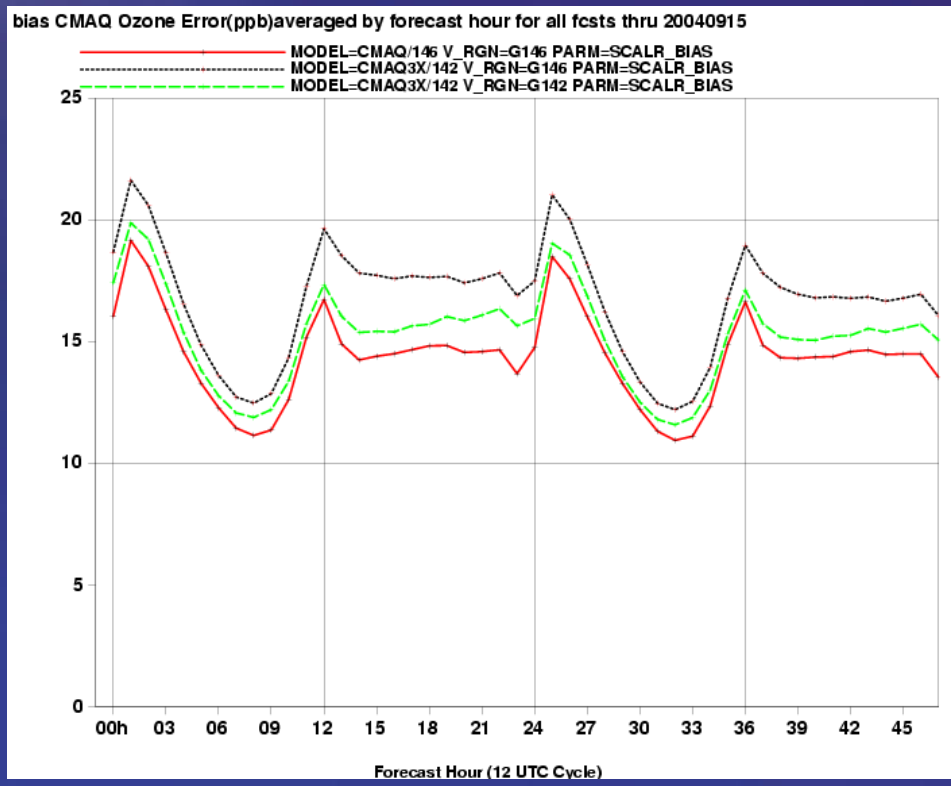
- **Evaluation of NCEP WRF-CMAQ ozone & aerosol simulations**
  - ***Experimental & rural obs networks (eg: ETOS, AERONET, REALM lidar network)***
  - ***GOES/MODIS satellite evaluation***
- **Assimilation of AIRNOW ozone data into CMAQ initial conditions**
- **Improved cloud mixing, aqueos chemistry PBL coupling with WRF-CMAQ**
- **Testing of WRF-Chem on-line system to offline WRF-CMAQ forecasts**

# Real-Time Verification

## *EMC FVS time-series binned by FHR*



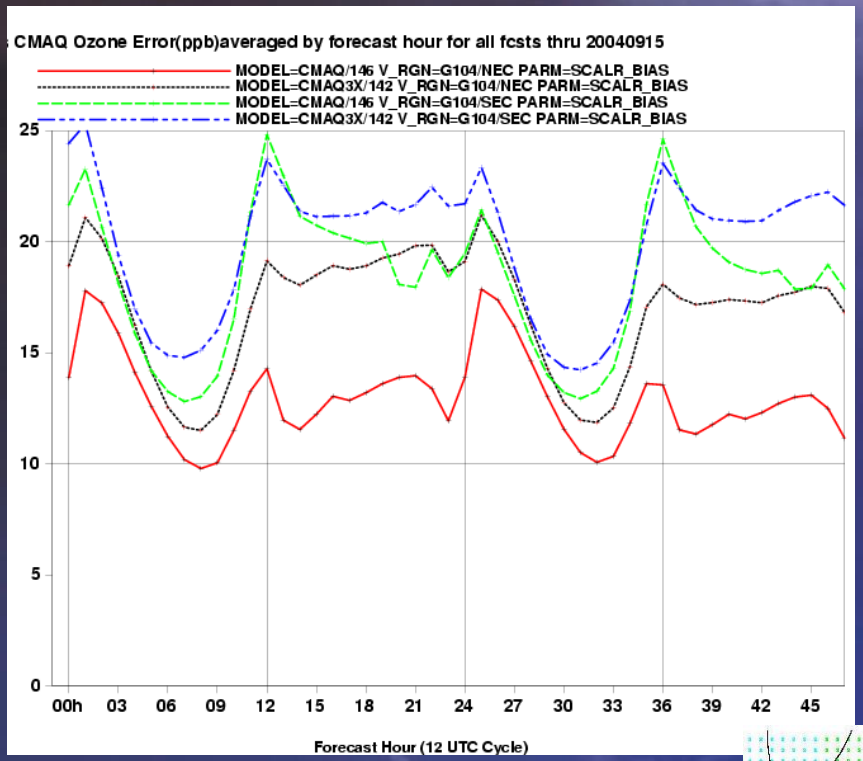

RMSE

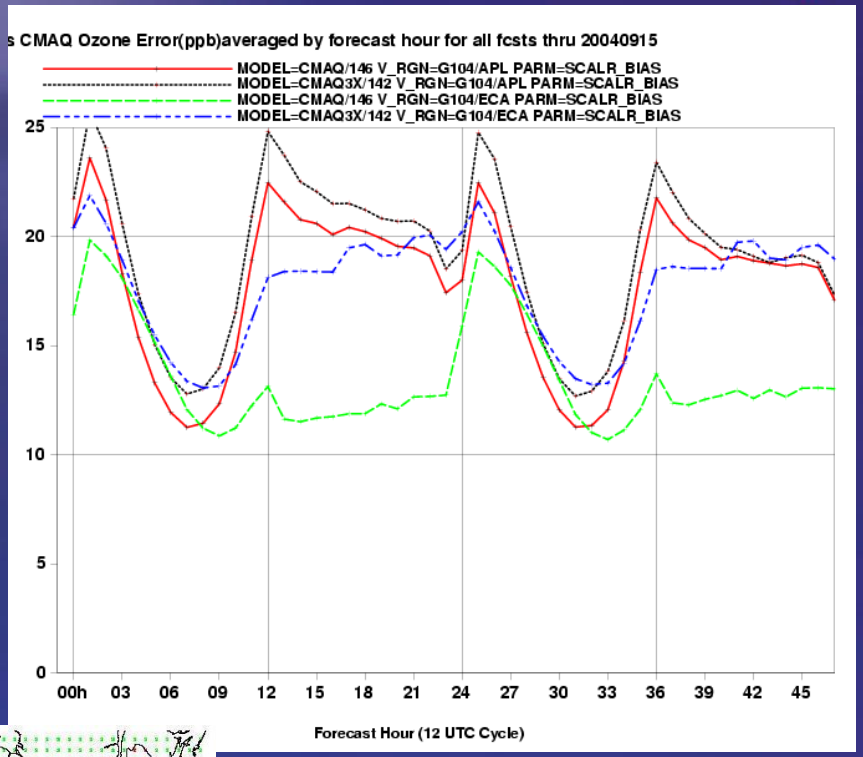



Bias

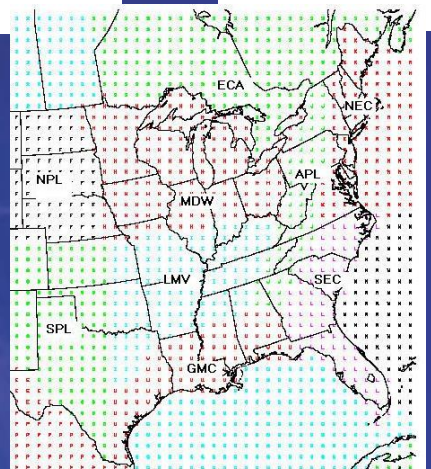
# Real-Time Verification

## *EMC FVS forecast by sub-region*




BIAS 1x vs 3x
NE, SE US




BIAS 1x vs 3x
E. Canada, APL US

# Retrospective Tests
## *Eta-CMAQ (East U.S)*

- **Upgraded Eta Met. Driver tests (S0)**
  - ***1 km NOAH Landuse, soils***
  - ***Improved cloud-radiation effects***
  - ***2 mb top, improved precip assimilation***
- **Improved Radiation Coupling for Photolysis (S2)**
  - ***Sfc radiation flux scaling***

- **Improved Cloud Coupling for cloud mixing *and aqueous chemistry?***
  - ***Use graupal, ice fields for aqueous***
  - ***Use convective cloud base/top for mixing***
- **Improved PBL coupling for mixing**
  - ***Use 3-D TKE Kh fields***
- **Improved Emissions**
- **Improved LBCs**
- **Full bundle tests**
- **Begin Real-time Parallels**

# Operational Requirements

**Driven by NCEP Operational Meteorological Model (Eta-12 and WRF/NMM)**

- **I/O Formats:**
  - ***Only machine binary, GRIB and BUFR, disk space limitations***
- **Time Requirement:**
  - ***12 Z 48 hour forecast available by 17:25 Z (1:25 pm EDT)***
  - ***06 Z 48 hour forecast available by 13:00 Z ( 9 am EDT)***
  - ***65 IBM Power 4 procs available***
  - ***12 Z start after Eta is complete (14:30 Z)***
- **Robustness:**
  - ***Thoroughly tested & evaluated with retrospective and real-time experimental runs***
  - ***Available to NWS Gateway, NDGD: 99% reliability, 24x7 NCEP support***
  - ***Accuracy: 90% exceedence hit rate***

# Summer 05 Planned NCEP Runs

| Run | To EMC | To NCO | Real-time runs |
|---|---|---|---|
| Operational (3x East U.S.) | 2/1/05 | 3/15/05 | 5/1/05 |
| Experimental (CONUS U.S.) | 3/15/05 | 5/1/05 | 6/1/05 |
| Developmental (CONUS-WRF) | 6/1/05<br>*If WRF/NMM is running realtime* | 7/15/05 | 9/15/05 |
| Research (Aerosols) | Real-time: Winter 05<br>Retrospect: Summer 05 | | |
| Fire Smoke (Hysplit-I)<br>Bluesky-hysplit-II | 12/31/04<br>3/1/05 | 2/1/05<br>5/15/05 | 3/1/05<br>7/1/05 |

# Air Quality Forecasting
# 2004 Verification (1x and 3x)

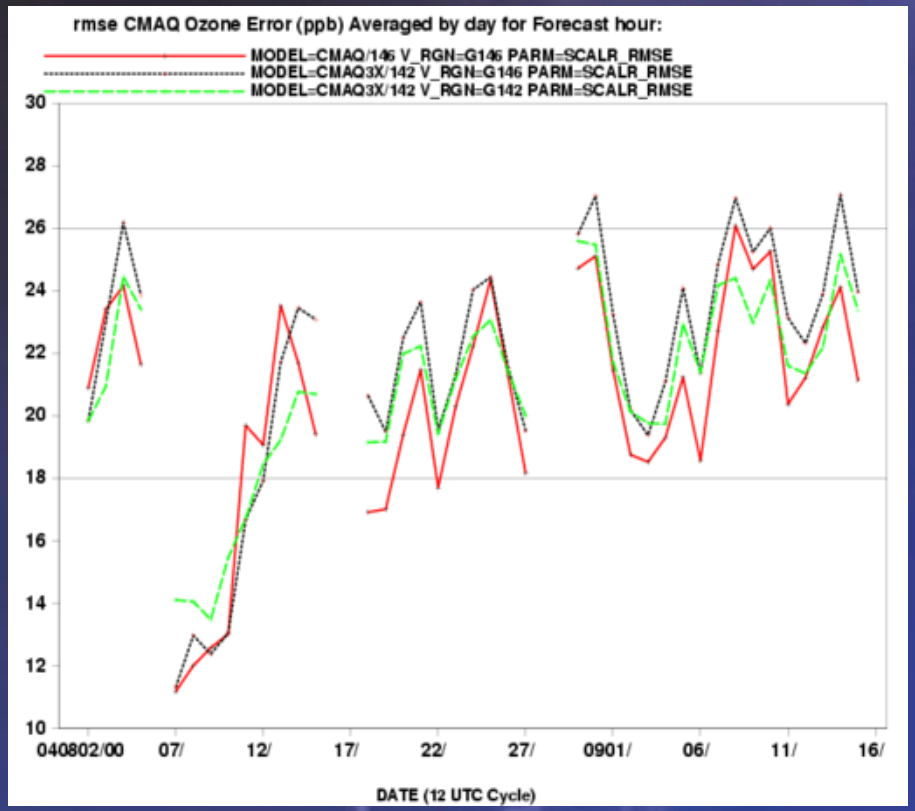
- ***NCEP EMC FVS System :***
  - **1 and 8 hour O3 averages**
  - **RMSE, Bias, STD, correlation coefficients Time series by fhr and day, subregion**
    - ***using EPA AIRNOW O3 network began 7/12/04***
  - **FHO contingency exceedence stats (POD, FAR, threat scores)**
    - ***Began 8/1/04***
- ***NWS/MDL***
  - **Daily Spatial obs vs predicted exceedence maps**
  - **Contingency exceedence stats since June 1**
- ***NOAA/OAR/EPA***
  - **Retrospective evaluations (8/12-19, 2003)**
  - **RT:Similar Stats except stations averaged over CMAQ grid points**
- ***ICARRT web page: sfc & UL ozone timeseries vs observations***

# Implementation Tasks

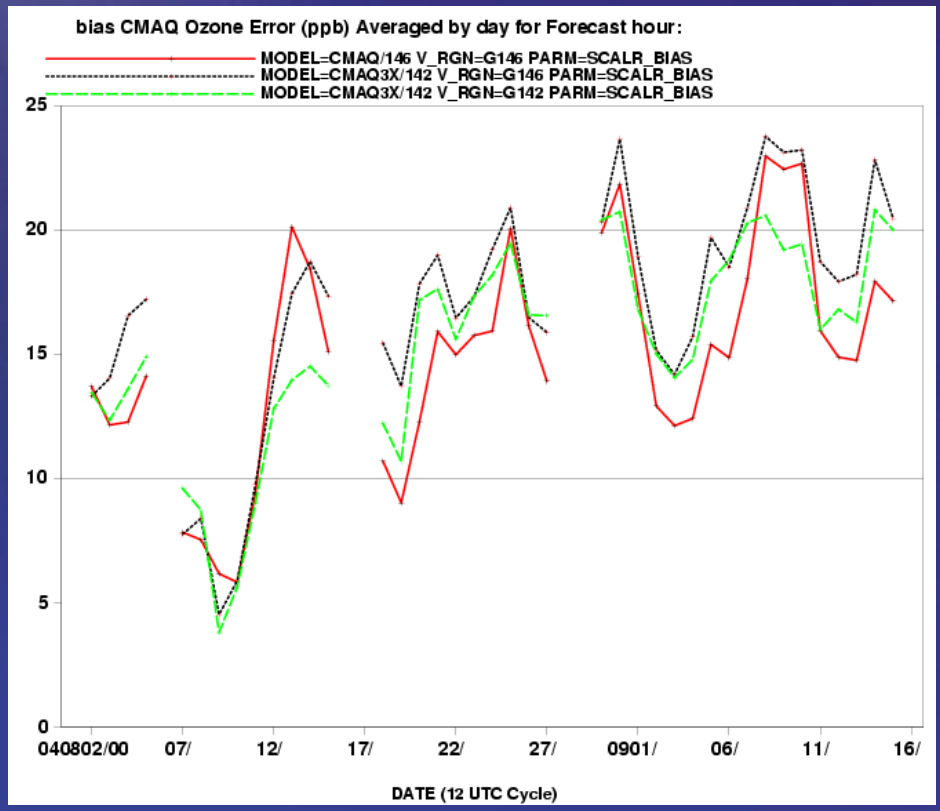
- **Transfer parallel experimental system to Operations:**
  - ***Complete agreed upon Charter w/ NCO***
  - ***Provide additional Eta/WRF fields from Postprocessors***
  - **** Transfer upgraded CMAQ to EMC***
  - ***Add internal documentation, refine scripts, adjust IO & dataset names***
  - ***Support GRIB2 hrly gridded outputs***
  - ***Perform 2002/2004 retrospective tests w/ upgraded Eta or WRF***
  - ***Perform real-time parallels w/ updated emissions files***
  - ***System evaluation against AIRNOW w NCEP FVS***
  - ***Prepare estimates of cpu/disk resources for NCO***
  - ***Prepare Job Implementation Form (JIFs) requests to NCO:***
  - ***Send out Change Notices, update web page change logs***
- **Maintain/improve operational graphics, verification plot web pages**
  - ***May require additional output to GRIB files***

# Real-Time Verification

## *EMC FVS 36 h forecast time-series by day*

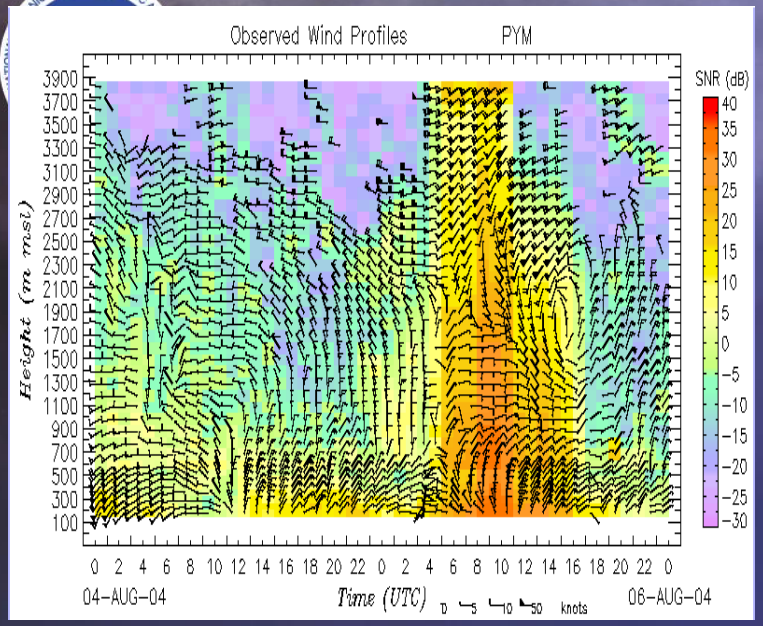


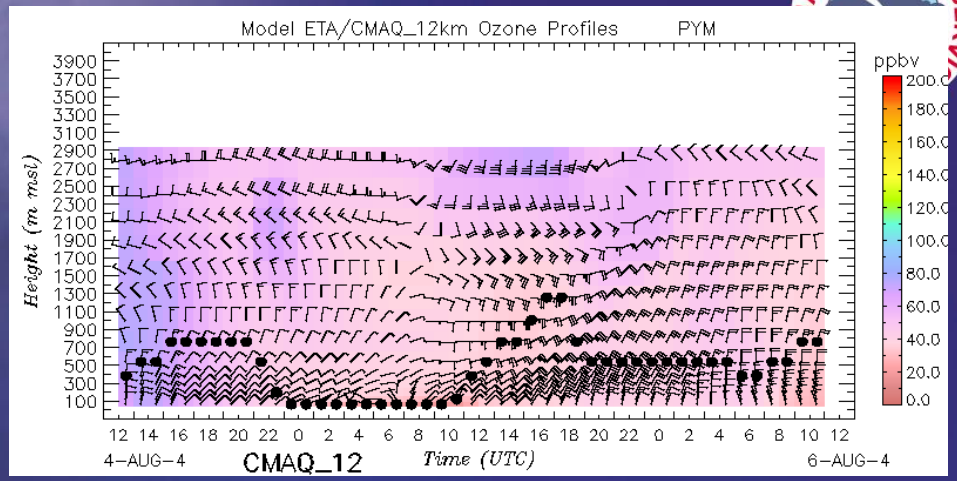

RMSE

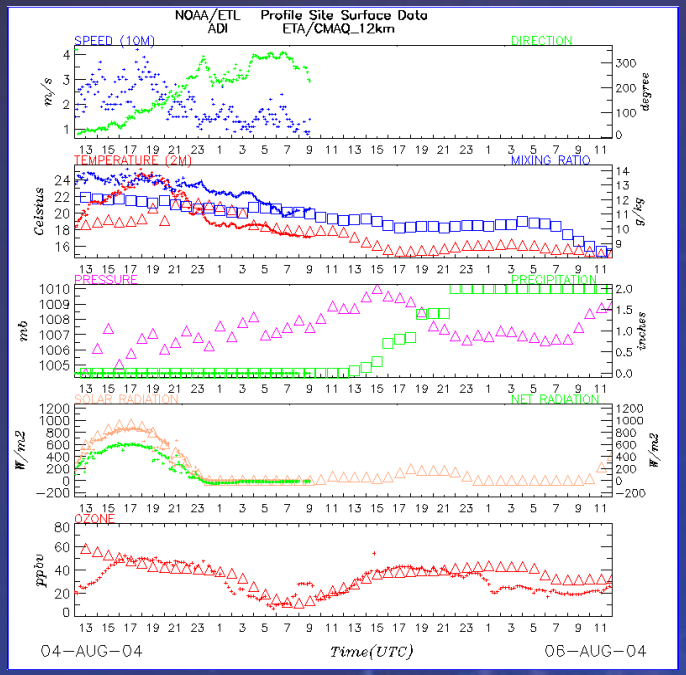


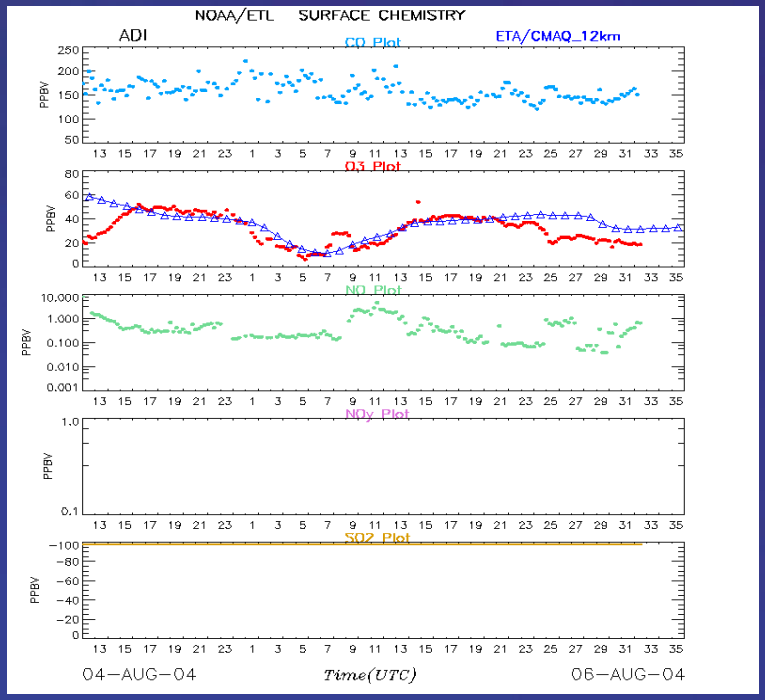

Bias

# ICARRT Evaluation



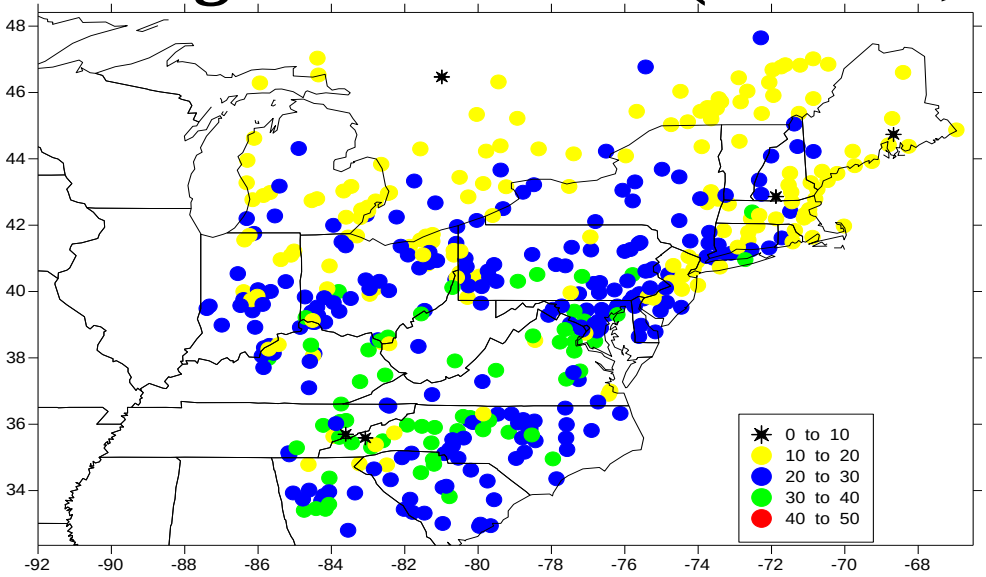



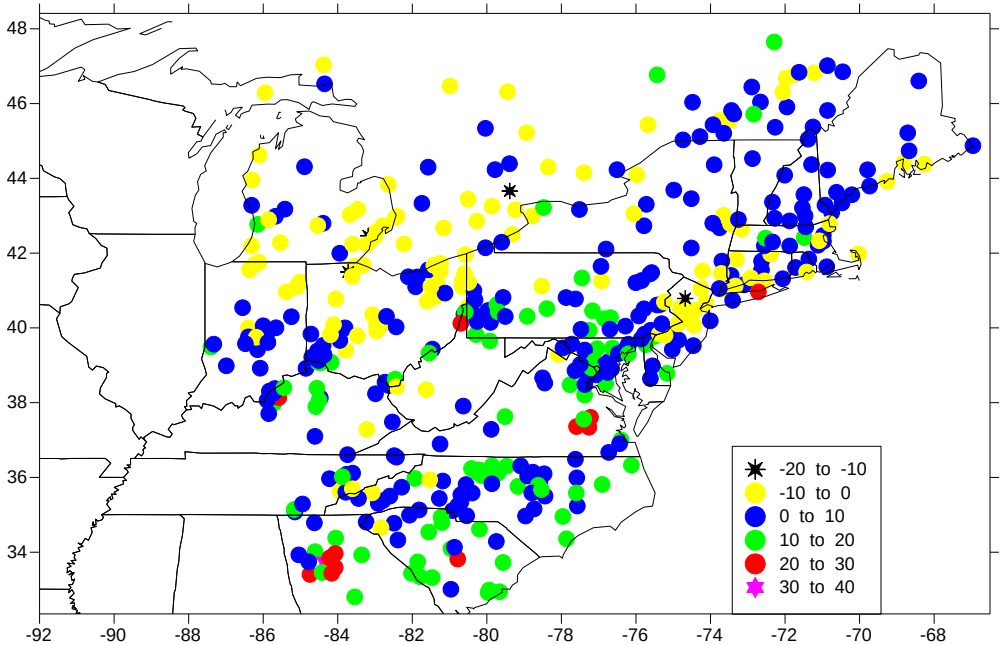



# NE DOMAIN Retros. Evaluation

## 1 Hr Avg ozone Errors (8/12-19, 2003)




RMSE




Mean Bias

# Real-Time Verification

## *NWS MDL Evaluation*

Predicted vs Obs Exceedence