NCEP Air Quality Forecast System
Upgrades for the Summer 2005

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NOAA/ARL and EPA/ASMD
Forecast Domains (2005)

1. Eta-CMAQ
2. WRF-CMAQ

CONUS “5x” Domain

Northeast Domain

East “3x” Domain

- 259 grid cells
- 268 grid cells
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 emissions
- **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 O₃ & 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

<table>
<thead>
<tr>
<th>Current Capability</th>
<th>Met Model (Eta, WRF/NMM)</th>
<th>AQ Model (CMAQ)</th>
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<tr>
<td><strong>Core/Dynamics</strong></td>
<td>Rotated Arakawa E grid</td>
<td>Arakawa C Grid</td>
</tr>
<tr>
<td><strong>Clouds</strong></td>
<td>Full Ferrier Cloud Microphysics</td>
<td>Eta cloud water for aqueous chemistry</td>
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<td><strong>Convective mixing</strong></td>
<td>Betts-Miller Janjic</td>
<td><em>Entrainment from top turned off</em></td>
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<tr>
<td><strong>Radiation</strong></td>
<td>GFS*</td>
<td><em>Derived from Eta RH for photolysis</em></td>
</tr>
<tr>
<td><strong>PBL</strong></td>
<td>Mellor-Yamada TKE</td>
<td>Eta PBL hgt for Pleim-Xiu 1st order K</td>
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<tr>
<td><strong>Land Surface</strong></td>
<td>NOAH common</td>
<td>Eta canopy conductance terms for Pleim-Xiu LSM</td>
</tr>
<tr>
<td>Run</td>
<td>NAM-CMAQ (3x, Conus)</td>
<td>WRF-CMAQ</td>
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<tr>
<td>Domain</td>
<td>Interp to CMAQ C grid</td>
<td>Common Rotated E grid</td>
</tr>
<tr>
<td>Vertical Coordinate</td>
<td>Interpolate to CMAQ σ</td>
<td>Common WRF/NMM σ-P</td>
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<tr>
<td>Photolysis</td>
<td>Surface Eta Radiative Scaling</td>
<td>3-D Radiative fluxes</td>
</tr>
<tr>
<td>PBL</td>
<td>Eta PBL height into P-X</td>
<td>NAM TKE/Kh to drive mixing</td>
</tr>
<tr>
<td>Clouds Aqueous Mixing</td>
<td>Eta cloud water, Eta convective cloud base/top</td>
<td>NAM cloud water, graupel &amp; ice Axisymmetric Convective Model (ACM) mixing extended for conv.</td>
</tr>
<tr>
<td>LBCs</td>
<td>GFS above 6 km, Static below</td>
<td>GFS above 6 km, static below Higher top, improved vertical resolution near tropopause</td>
</tr>
</tbody>
</table>
NAM Verification
August 2004

Temperature

Downward SW
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

- **12Z July 16, 2004 – 12Z July 25, 2004**
- **12Z August 4, 2004 – 12Z August 13, 2004**
- **12Z August 8, 2002 – 12Z August 20, 2002**
Max 8-hr $O_3$ Mean Bias Spatial Distribution: July 21, 2004

2004 Base

S0

S1

S3

S5
Slight tendency to under-predict

O3 increased regionally,
Over-predict at low range
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.
<table>
<thead>
<tr>
<th>Run</th>
<th>Today</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>Sept</th>
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<tbody>
<tr>
<td><strong>Operational</strong></td>
<td>NE U.S</td>
<td>East U.S</td>
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<tr>
<td><strong>Experimental</strong></td>
<td>East U.S.</td>
<td>CONUS (Eta)</td>
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<tr>
<td><strong>Developmental (EMC)</strong></td>
<td>CONUS (Eta)</td>
<td>CONUS (WRF)</td>
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<tr>
<td><strong>Research (EMC)</strong></td>
<td>PM East US</td>
<td>PM East US (WRF)</td>
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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/ precursors (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
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 precursers 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, aqueous 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

<table>
<thead>
<tr>
<th>Run</th>
<th>To EMC</th>
<th>To NCO</th>
<th>Real-time runs</th>
</tr>
</thead>
</table>
| **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  
*If WRF/NMM is running real time* | 7/15/05         | 9/15/05         |
| **Research**  
(Aerosols)             | Real-time:  
Winter 05  
Retrospect:  
Summer 05 |  |  |
| **Fire Smoke**  
(Hysplit-I)            | 12/31/04        | 2/1/05          | 3/1/05         |
| **Bluesky-hysplit-II** | 3/1/05          | 5/15/05         | 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

Observed Wind Profiles

Model ETA/CMAQ_12km Ozone Profiles

NOAH/CTL Surface Chemistry

ADI
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

[Map of the United States with various data markers and a bar graph showing the number of 8-hour average exceedances forecasted and observed from 07/23/2004 to 07/29/2004.]

Ozone Exceedances
Eight Hour Average, Threshold = 85 ppb
Midnight To Midnight EDT 06/04/2004
3X Model Data