# National Air Quality Forecast Capability: Progress Toward Initial Implementation

February 24, 2004

US EPA 2004 National Air Quality Conference

Paula M. Davidson

NWS Program Manager for Air Quality Forecasting

- *Background*

- *Planned Capabilities*

- *Progress in 2003*

- *February 2004 Status*

# National Air Quality Forecasting
## *Background*

## *Congressional Interest*

- H.R. 4 Energy Policy Act of 2002 (Senate Amendment)

## *NOAA-EPA Agreements*

- DOC Deputy Secretary and EPA Administrator signed MOU/MOA for AQ forecasting May 6, 2003

## *Constituent Interest*

- AQ managers, public health officials, private weather sector partners urge NOAA to provide AQ forecasts

## *Science is Mature*

- Ozone forecast models demonstrated in lab -- others in development
- Other nations (Canada, Australia) have existing AQ forecast capability

# National Air Quality Forecasting
## *Vision and Strategy*

## *Vision*

National Air Quality Forecast System which provides the US with ozone, particulate matter and other pollutant forecasts with enough accuracy and advance notice to take action to prevent or reduce adverse effects

## *Strategy*

Work with EPA, State and Local Air Quality agencies and private sector to develop end-to-end air quality forecast capability for the Nation

# National Air Quality Forecasting
## *Planned Capabilities*



**Initial: 1-day forecast guidance for ozone**

- **Develop and validate in Northeastern US by September, 2004**
- **Deploy Nationwide within 5 years**

**Intermediate (5-7 years):**

- **Develop and test capability to forecast particulate matter concentration**
  - *Particulate size $\leq$ 2.5 microns*

**Longer range (within 10 years):**

- **Extend air quality forecast range to 48-72 hours**
- **Include broader range of significant pollutants**

# National Air Quality Forecasting
## *Planned Initial Operating System*

## Linked numerical prediction system

### Operationally integrated on NCEP's supercomputer :

- *NCEP mesoscale NWP: Eta-12*
- *NOAA/EPA community model for AQ: CMAQ*

### Observational Input:

- *NWS weather observations*
- *EPA emissions inventory*

## Gridded forecast guidance products

### Delivered to NWS Telecommunications Gateway and EPA for users to pull

## Verification basis

### EPA ground-level ozone observations

## Customer outreach/feedback

### State & Local AQ forecasters coordinated with EPA

### Public and Private Sector AQ constituents
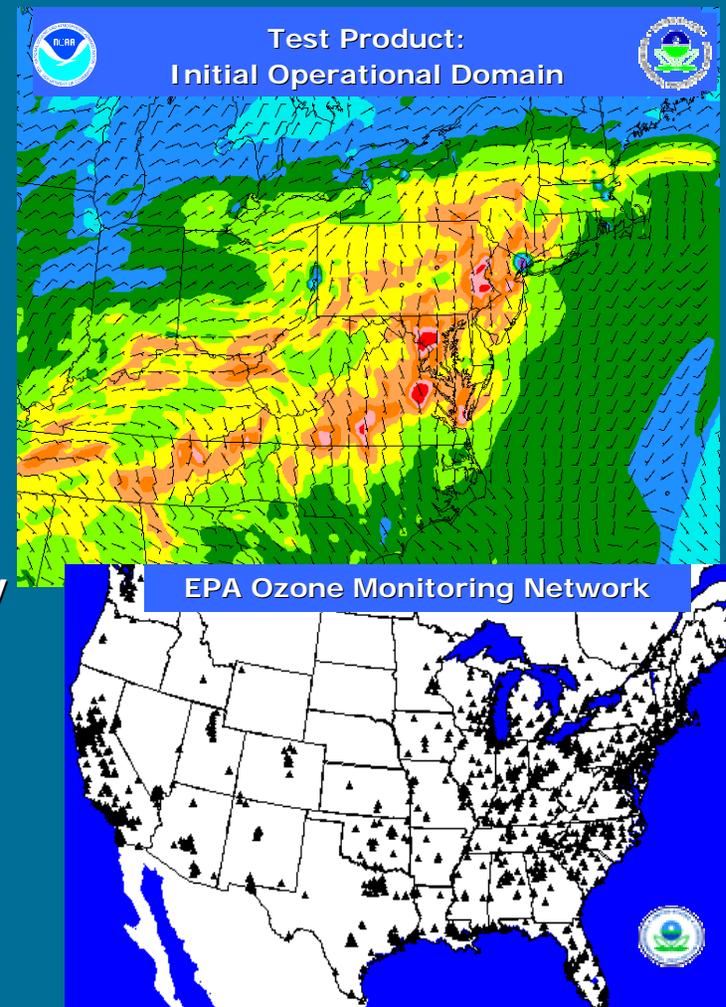


Test Product:
Initial Operational Domain



EPA Ozone Monitoring Network

NWP Model

Eta-12

**NOAA/NWS**

Weather Observations

AQ Module:
Emissions Preprocessor

PREMAQ

**NOAA/OAR** and **EPA/ORD**

EPA's National

Emissions Inventory:

**EPA/OAQPS**

AQ Module:
Air Quality Reactive Transport

CMAQ

**NOAA/OAR** and **EPA/ORD**

IT /Comms

**NOAA/NWS**

and

**EPA/OAQPS**
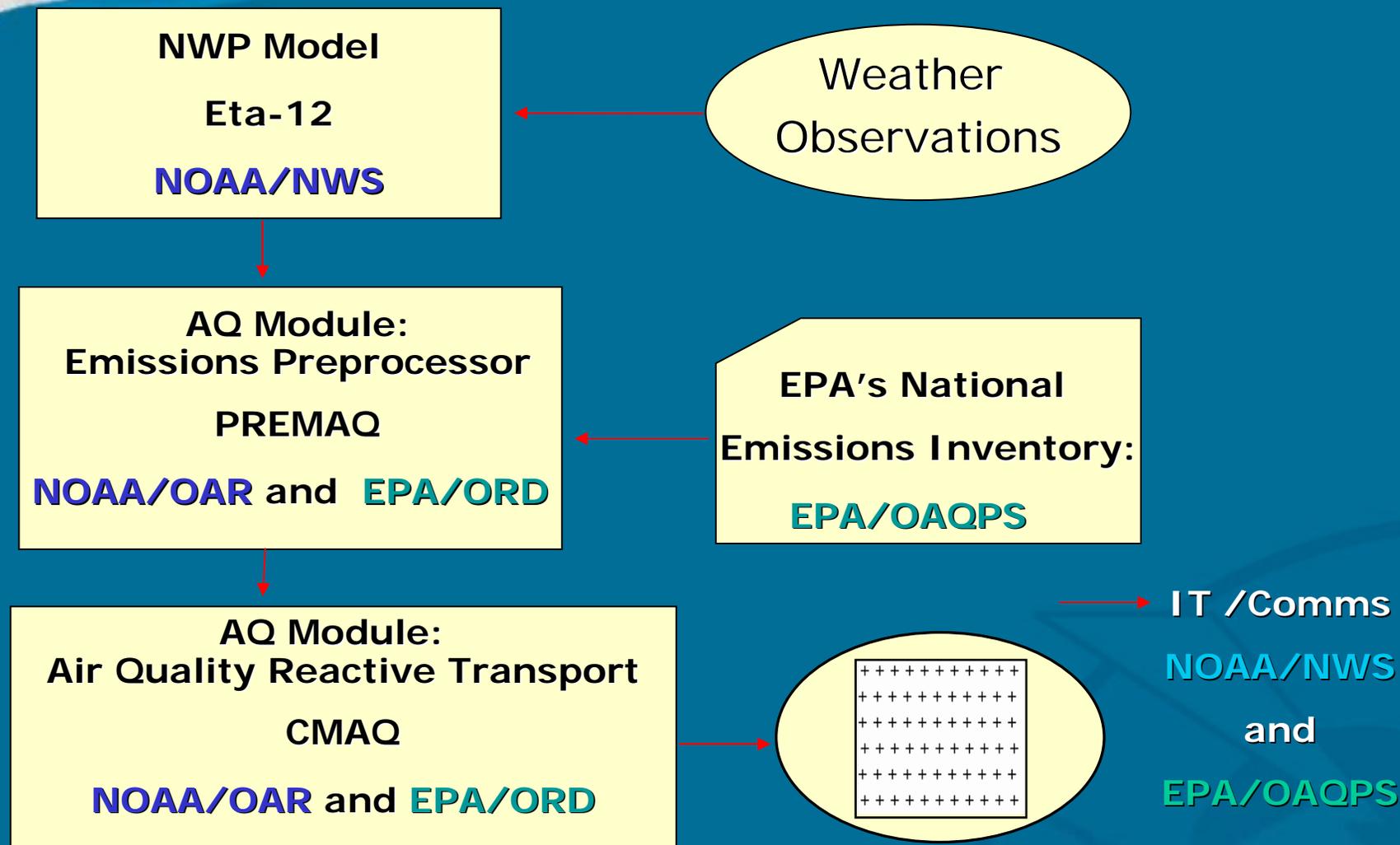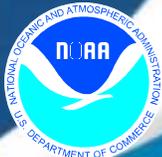
# Air Quality Forecasting
## *Key Model Components/Functions for Integrated Operational Forecast Guidance*

*Eta-12 NWP Output Parameters Driving AQ Prediction Models:*

- *Cloud cover, Temperature, Vertical temperature structure, Surface winds, Aloft winds*


- *Post-processor provides additional fields for AQ, including:*
  - **evapotranspiration, PBL height, land-use type, soil type, canopy conductance, canopy water**


- *Product Generator interpolates to grid structure for AQ modules:*
  - **22 sigma P-levels to 100 mb, Arakawa C**

# Air Quality Forecasting
## *Key Model Components/Functions for Integrated Operational Forecast Guidance*

*PREMAQ:*

- *Processes static and met-dependent emissions data*

*CMAQ:*

*Chemical Transport*

- Advection: Piecewise Parabolic method
- Vertical Diffusion:  Pleim-Xu PBL
- Horizontal Diffusion:   Eddy-diffusivity with Kh dependent on grid-size

- *Cloud processes:  Aqueous chemistry and sub-grid clouds from RADM*

- *Plume-in-Grid: OFF for this application*

- *Dry depositions:  M3dry-- Pleim-Xu method for deposition velocities*

- *Gas-Phase Chemistry Mechanisms:*

  - Smaller Carbon Bond 4; limited species
  - Chemical steady states

- *Gas-Phase Chemistry Solver:  Fast Hertel solver*
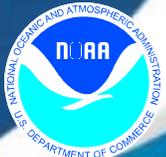
# Initial Operating Capability:
## EPA + NOAA IT Links

**EPA Data Management Center**

O₃ Movies/ Forecasts

**NOAA National Center for Environmental Prediction**

AQ Data from S/L Agencies

Weather Obs

EPA Emissions Inventory

**Commercial Weather Providers**

Data "pull"
Data "push"

Predicted Pollutant Concentration Fields

Ozone Levels 5
Tue 04:00 PM
WRAL_Final

Media

City-specific AQI forecasts

State/Local Air Agencies

Public
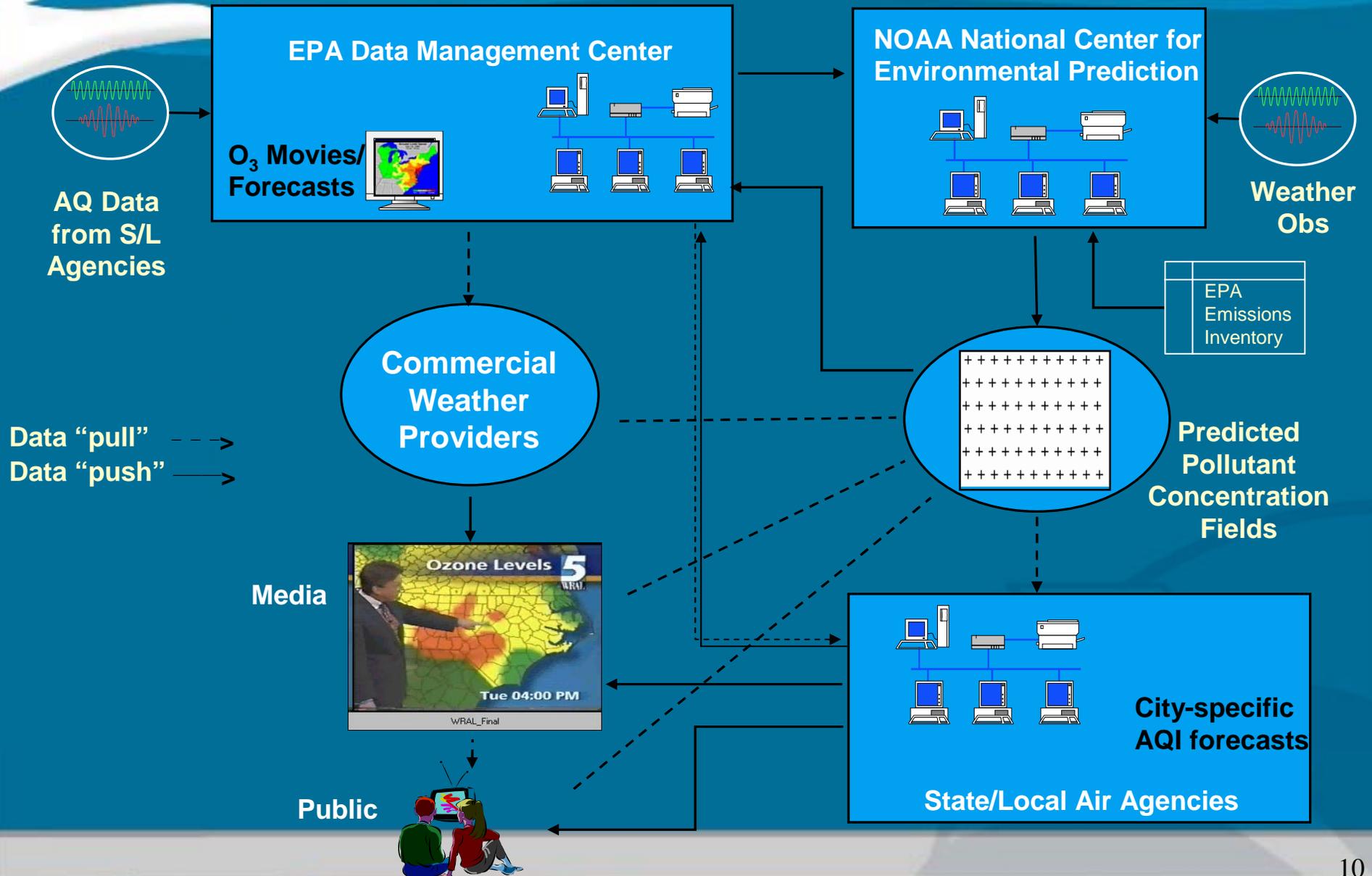
# Production Cycle

## 1-Day ozone forecasts: Target deployment 9/15/04 for NE US

1-hr and 8-hr avg $O_3$ levels: categories for EPA and in parts per billion (ppb) at NWS Gateway

## Delivered 2X daily:

Primary forecasts for following day: delivered by 1730 UTC valid for 24 hours through 4 UTC, day 2
Update forecasts for current day: delivered by 1300 UTC valid for 15 hours through 4 UTC, next day
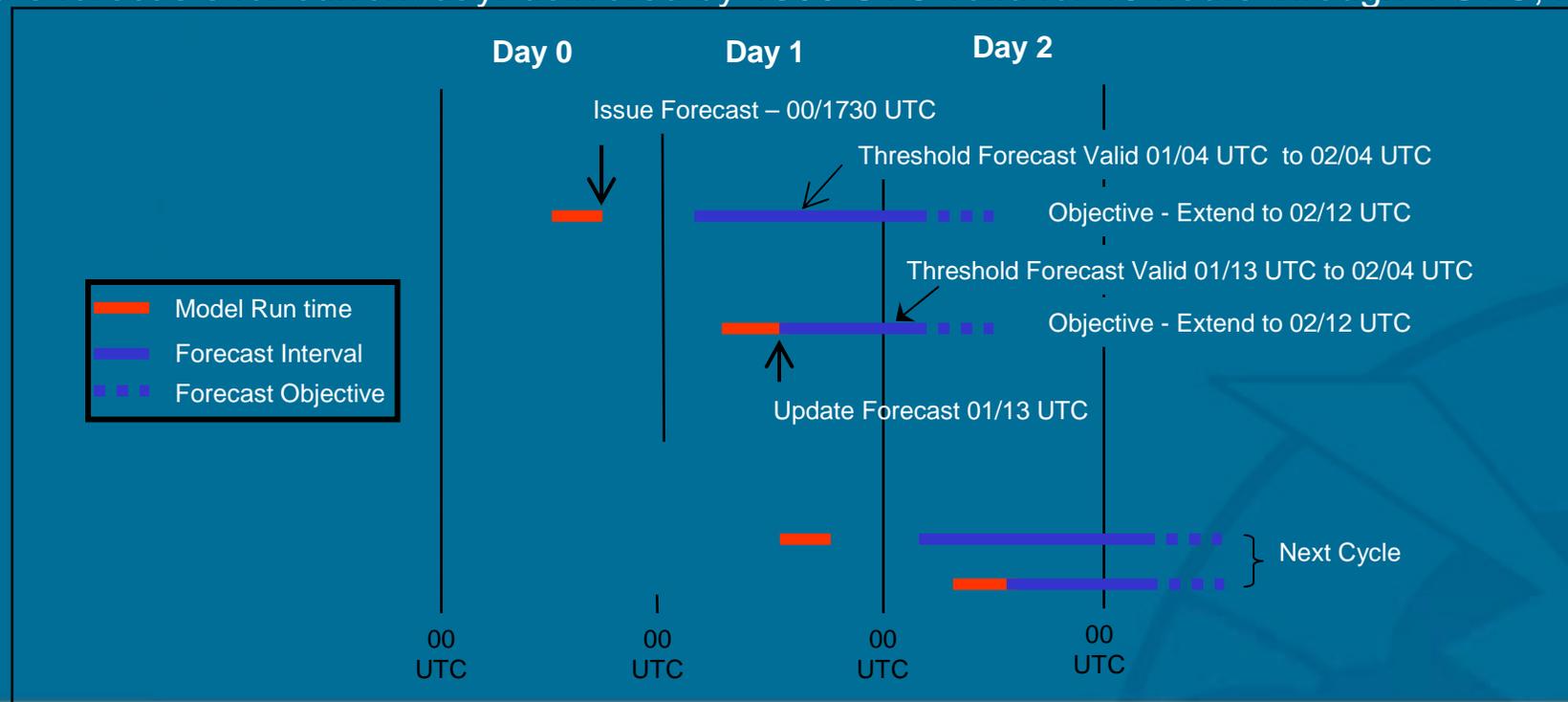


**Day 0**  **Day 1**  **Day 2**

Issue Forecast – 00/1730 UTC

Threshold Forecast Valid 01/04 UTC  to 02/04 UTC

Objective - Extend to 02/12 UTC

Threshold Forecast Valid 01/13 UTC to 02/04 UTC

Objective - Extend to 02/12 UTC

Model Run time
Forecast Interval
Forecast Objective

Update Forecast 01/13 UTC

Next Cycle

00 UTC     00 UTC     00 UTC     00 UTC

# Predicted Air Quality
## Ground-Level Ozone: 1-hr average



OZONE
(parts per billion)
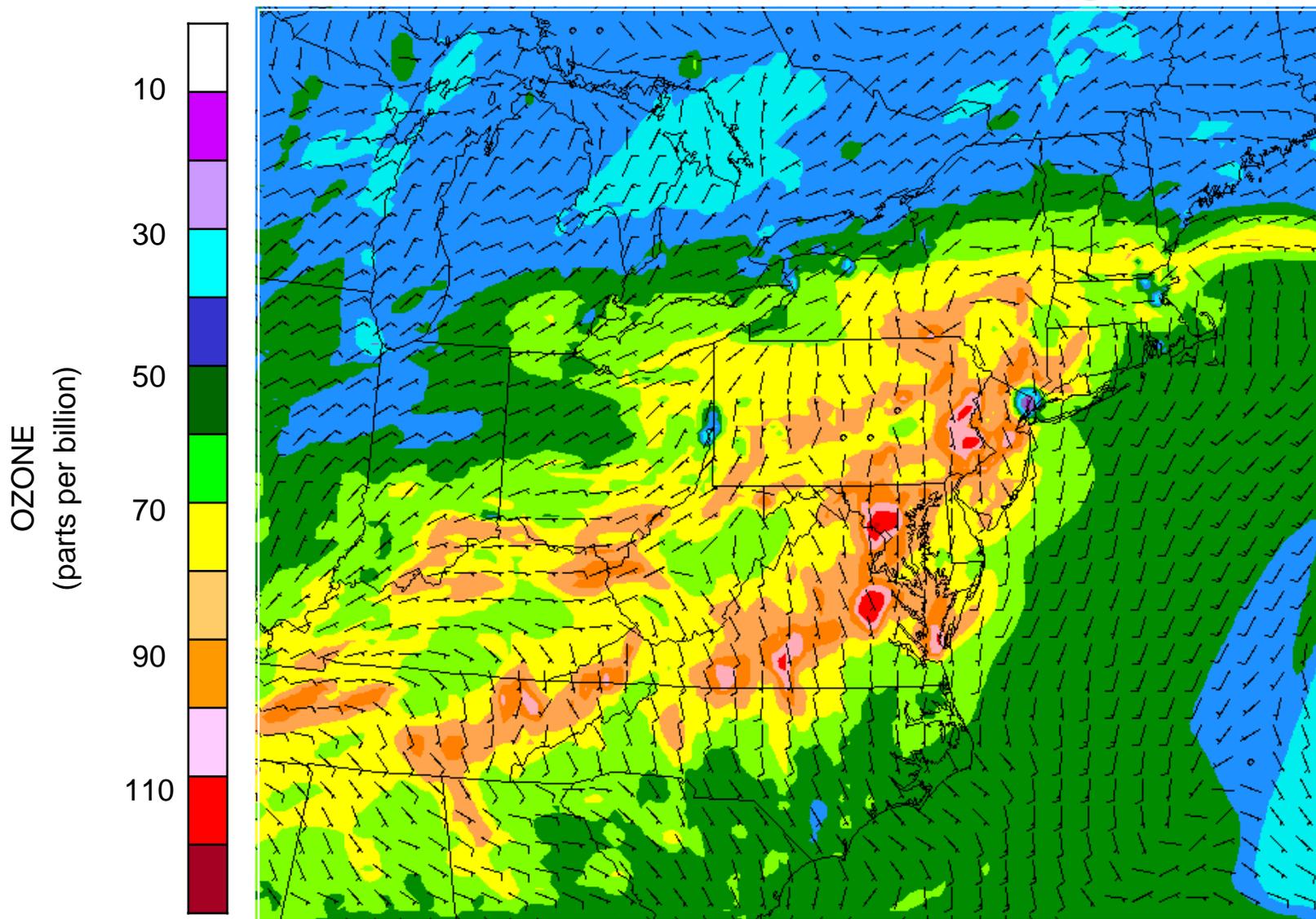
# National Air Quality Forecast Capability
## *Summary of Activities, FY03*

- Planned for operational production of AQ forecast guidance

- Developed an end-to-end integrated weather-air quality forecast capability

- Conducted real-time test runs through September

- Analyzed system performance & identified upgrades needed for pre-deployment testing in 2004

## NOAA & EPA Planning for IOC in NE US domain by 9/04.

- **Models integrated into 12UTC "primary" and 6UTC NCEP operational environment for twice daily test-runs**
  - *Eta-12 output tailored to drive CMAQ*
  - *CMAQ adapted to run in forecast mode & optimized to meet run-time window*
  - *Required HPCC hardware acquired and integrated into NCEP operations*
  - *NWS IT architecture and links to EPA in place*
  - *"morning update" (6UTC cycle) predictions added In August*
- **Developers and Focus group evaluated guidance**
  - *Verification system developed with EPA's compilation of real-time monitoring data*

# 2003 Testing

*Verification period: June 30-September 30, 2003*

- **Unusually good AQ in NE US; only a few days with poor AQ**

- **Systematic ozone overprediction identified**

- **Developers in OAR and MDL conducted objective evaluations of forecast guidance**

  - *comprehensive suite of diagnostic measures over entire domain*

- **Closer look: Focus group of state/local forecasters provided subjective feedback**

  - *daily feedback survey responses, monthly summaries*

  - *participated in workshop to synthesize review /feedback for test season*

  - *both "big picture" and community-specific: local performance tracked*

*Objective Measures:  Accuracy*

- **Systematic ozone overprediction identified**
  - *Systematic errors isolated in Eta-CMAQ linkage; account for majority of ozone overprediction  (McQueen et al.,2004; Eder et al., 2004)*

- **Biases for elevated terrain, urban areas, nighttime**
  - *Problems diagnosed and corrections implemented, Sept-Feb, 2004*

*Product utility*

- **Recommendations for formats, display**
- **Recommendations for additional guidance products**

## *Performance targets:*

- **critical level "hit accuracy" > 90%**
- **forecast guidance provided on schedule > 95%**

## *Test Performance:*

☺ **Accuracy. Exceedances extremely rare in 2003. 1-hr average "hit" accuracy > 90%**

- *Systematic overprediction of ozone levels: room for improvement. Diurnal cycle: overnight minima not low enough*

- *8- hr average "hit" accuracy > 80%*

✓ **On time. Model system runs reliably, on-time delivery by early August**

# Model Corrections & Upgrades:
## *Advances to 2003 Developmental Capability*

**HYPOTHESES**

- PBL mixing insufficient?
- Photolysis overpredicted?
- Emissions?
- Ozone Boundary Conditions?
- Eta-CMAQ coupling?

## IMPROVEMENTS:

**Eta-CMAQ Linkage Corrections:**

- Land-use error.   Reduces Overprediction
- Temperature interpolation error.   Reduces Overprediction

**Ozone boundary Conditions**

- Static values replaced with (lower) values from satellite-based msmt. Reduces overprediction

**PBL upgrades in Eta-12. Fall and Spring bundles. Impact TBD**

**Still undergoing testing:**

- Emissions upgrades,  vertical mixing  and turbulence parameterization impacts

# Analysis of 2003 Testing
## *Additional Feedback:  Product Utility*

### *Do guidance products help AQ forecasters?*

- **Focus group:  (Ryan, et al. AMS 2004 J2.13)**
  - *Rapid progress in developmental production and reliability encouraging*
  - *Guidance useful input for forecasts; knowledge of biases also helpful*
  - *Location of ozone "hot spots" well forecast*
  - *Accuracy notable for some communities, e.g. Phila*

### *Recommended improvements:  (Focus group workshop, 9/03)*

- **More graphical, interoperable guidance products:  weather elements overlayable with AQF guidance**
  - *NWS initiating hosting guidance with NDFD-like technology for graphical, interoperable, user-pulled interface*

- **Provide statistical bias correction for forecast guidance**
  - *NWS adds investigation of statistical post-processing techniques to planned R&D*

# National Air Quality Forecasting
## *Review, Feedback and Customer Input*

**Science Reviews:  Combined CMAQ – Eta Model System**

- **System Design Reviews:  Initial (Feb, 2003); 2004 Upgrades (Oct, 2003)**

- **Evaluation/verification of Summer 2003 testing**

- **Conference presentations (AMS, AWMA, CMAS, EPA Science Forum)**

**USWRP AQ Workshops: Nov, 2001; May, 2003**

**Focus Group Input/ Feedback:**

- **State & Local AQ forecasters provide subjective evaluation of guidance utility**

- **Summer 2003 weekly, monthly with summary workshop**

**Constituent Input:**

- **NOAA round-table meetings**

- **EPA National Air Quality Conference (annual)**

# Traditional NWS Operational Cycle



Observe → Process → Product & Services (Central Guidance → Local Offices) → Distribute & Respond
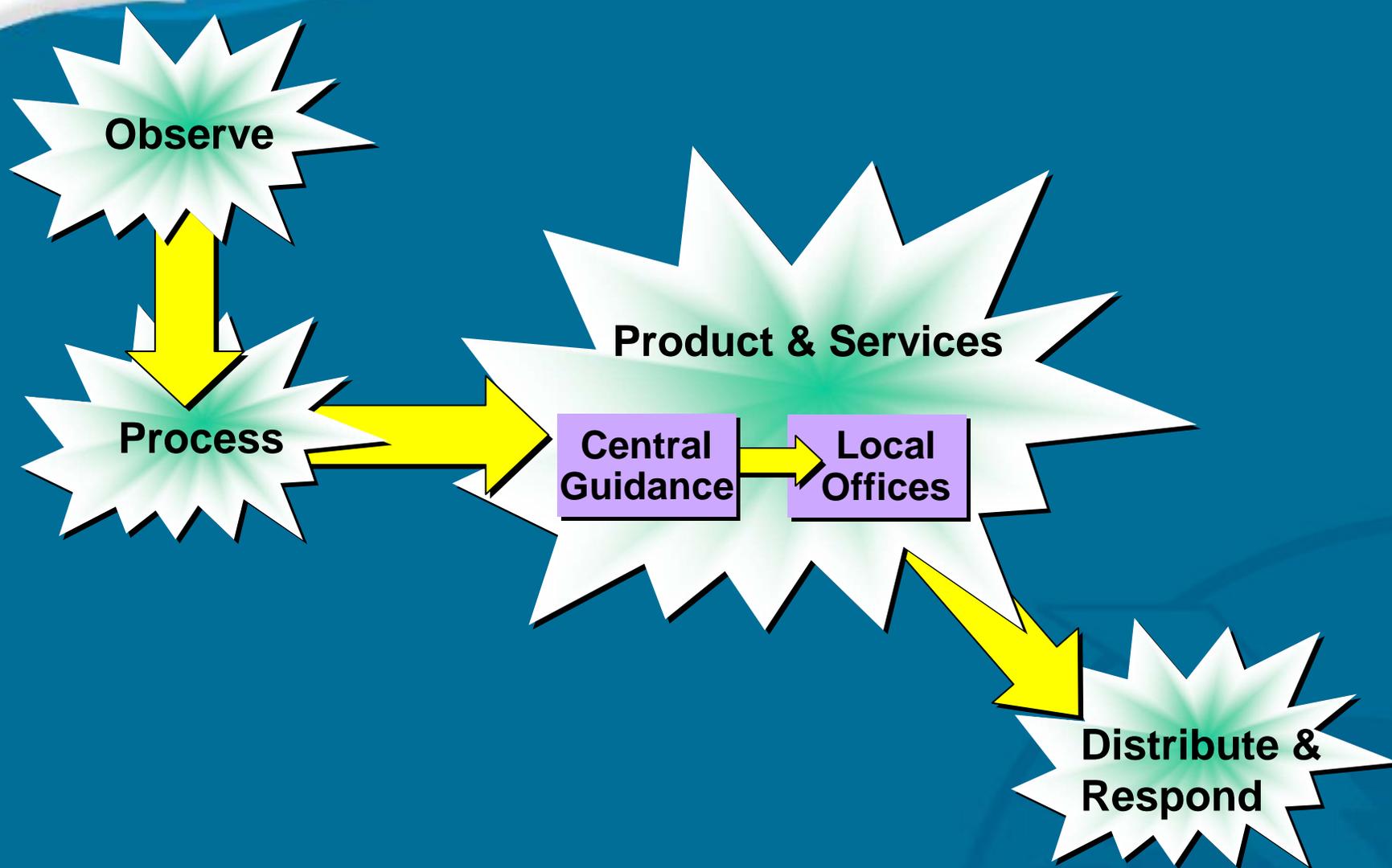
# Air Quality Operational Cycle

**Observe**

**Process**

**NWS & EPA Products and Services**

Model Guidance & Monitoring Data

**State and Local Air Quality Forecasters**

**Distribute & Respond**

22
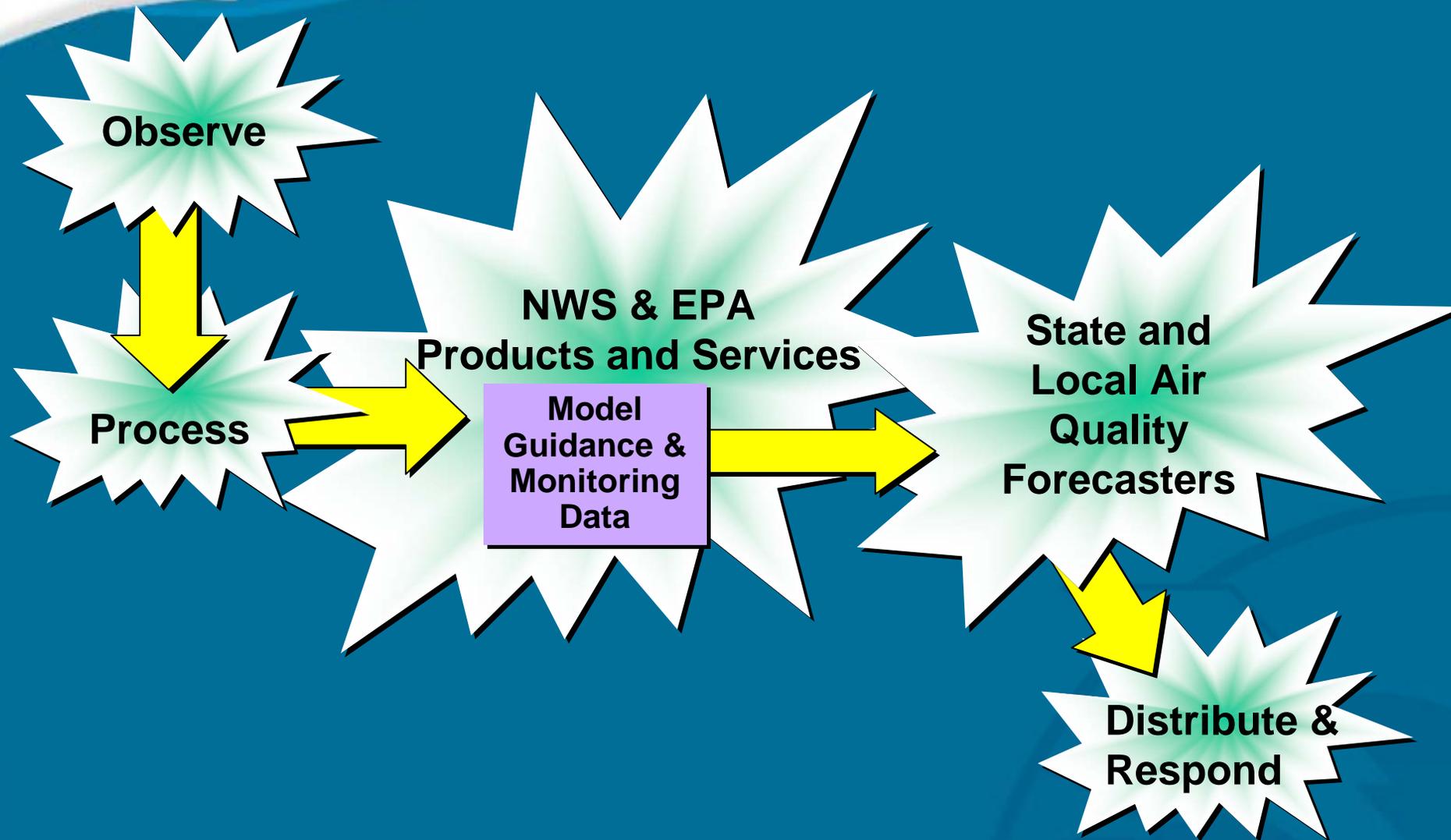
# AQ Forecast Capabilities:
## *Today and Tomorrow*

| | Current AQ Alerts | NAQF Initial Operational Capability: September, 2004 | NAQF Capability: 10-Year Vision |
|---|---|---|---|
| **Purpose**: Limit adverse effects of poor AQ, by providing | Next-day warnings for large cities | State-of-the-science ozone forecast guidance to: <br> - assist state / local AQ forecasters <br> - assist people at risk from poor AQ | State-of-the-science ozone and particulates forecast guidance to: <br> - assist state / local AQ forecasters <br> - assist people at risk from poor AQ |
| **Products** | Daily AQ alerts; predicted AQ Index (AQI) category | Predicted hourly pollutant concentrations -- digital and graphical formats | Predicted hourly air pollutant concentrations -- state-of-the-art formats |
| **Coverage** | Approximately 300 cities | Entire Northeast United States | Nationwide |
| **Pollutants Forecast** | AQI (ozone-based); some cities include particulates | Ground-level ozone | Ground level ozone, particulate matter, possibly others |
| **Forecast Period** | Next-day; also through weekends | Forecast guidance issued through midnight next day | Forecast guidance extended to 2 days or beyond |
| **Spacial Resolution** | Alerts are community-wide; little/no other spacial information | 12 kilometer grid for Northeast U.S | 2.5 kilometer grid for Nation |
| **Temporal Resolution** | Daily | 1-hr and 8-hr averages each hour throughout the forecast period | 1-hr and 8-hr averages each hour throughout the forecast period |

**The National AQF Capability to provide**
- **Improved basis for AQ alerts**
- **AQ information for people at risk**

***FY 04 Activities:  Preparing for Real-Time Testing & Evaluation   in Summer 2004 and deployment by September, 2004***

- *Upgrades underway to incorporate feedback, improve accuracy for RTT&E in 2004*
  - **Improve vertical mixing, boundary conditions**
  - **Systematic corrections to Eta-CMAQ linkage**
  - **Retrospective testing with episodes of poor AQ (2002) and good AQ (2003)**
- *Guidance products both digital and graphical:  available experimentally beginning in June, 2004*
- *Operational "go/no go" decision for IOC in September, 2004*

***Beyond Initial Operating Capability***

- *Developmental testing of expanded domain to begin over summer*
- *Research in progress for extending capability to particulates*

# National Air Quality Forecast Capability

## Lives & property at risk from poor AQ

- **Congress directs NOAA to provide AQF operationally**
- **Constituents & partners work with NOAA to significantly advance science in AQ forecasts**

  - EPA, State and Local agencies share data, guidance
  - AQ prediction now linked to NOAA's weather prediction system

## NOAA to produce AQ Forecast guidance 2X daily

- **Numerical prediction of ground-level ozone**
- **Gridded (12km), hour-by-hour through next day**

## Phased Deployment

- **September, 2004: Northeastern US, next-day, ozone**
- **5 years: Nationwide coverage; begin particulates forecasts**
- **10 years: Extend forecasts to 2 days+; add additional pollutants**

**Predicted Air Quality**
**Ground-Level Ozone: 1-hr average**

**Test Product: Initial Operational Domain**

Further information  http://www.nws.noaa.gov/ost/air_quality
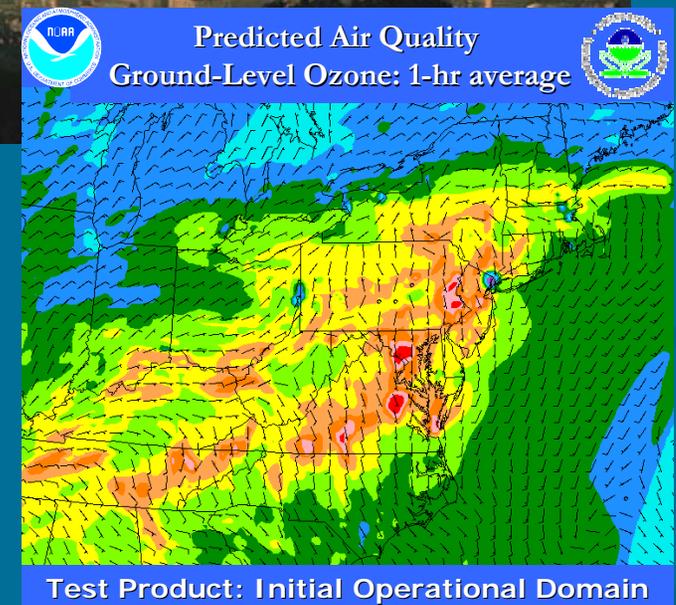
# National Air Quality Forecast Capability
## *Implementation Team*

## *Special Thanks To:*

| | |
|---|---|
| *Jim Meagher* | *Air Quality Matrix Manager* |
| *Nelson Seaman* | *Science Advisor* |
| *Ken Schere and RTP research group at NOAA/EPA/ORD* | *CMAQ Adaptation* |
| *Paul Stokols* | *Services Lead* |
| *Jeff McQueen, Pius Lee, Marina Tsidulko, John Ward et al. at NWS/NCEP* | *Model Adaptation/ Integration at NCEP* |
| *Ken Carey* | *AQF Program Administration Support* |
| *Pai-Yei Whung* | *NOAA/OAR AQF Research Lead* |
| *Fred Branski, Allen Darling et al. at NWS/TOC* | *NWS IT/Comms Infrastructure* |
| *Dave Rowson; Chet Wayland, et al. at EPA/Airnow* | *EPA-NOAA Coordination* |
| *Jon Adkins* | *IT Architecture Support* |
| *Wil Shaffer, Paul Dallavalle et al. at OST/MDL and Brian Eder, et al. at NOAA/EPA/ORD* | *Verification Statistics* |

# BACK-UP

# Partnerships in Air Quality Forecasting

**NOAA**
> Develop and evaluate tools for national/state/local air quality forecasting
> Provide operational air quality models and forecast pollutant concentration fields with national coverage

**EPA**
> Maintain current national emissions inventory
> Maintain national air quality monitoring databases
> Disseminate/interpret national air quality forecast information
  - AQI and links to public health

**STATES / LOCALS**
> Provide state/local emissions data
> Provide state/local air quality monitoring data
> Provide local AQI forecasts/warnings

**PUBLIC and COMMERCIAL SECTORS**

28

# National Digital Forecast Database

- **Seamless Digital Forecast Mosaic**

- **Each Forecast Parameter Will be Available Out to 7 Days for Viewing on the NDFD Website**

- **Offices' Digital Data Will be Available in Compressed Packets for Download by Private Vendors or the Media**

- **Nationwide Data available on experimental basis**





SURFACE DEWPOINT (DEG F) ANALYSIS FOR 20011127/1700 UTC
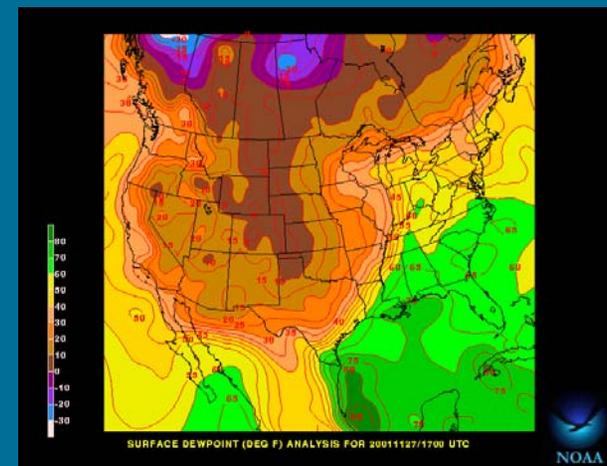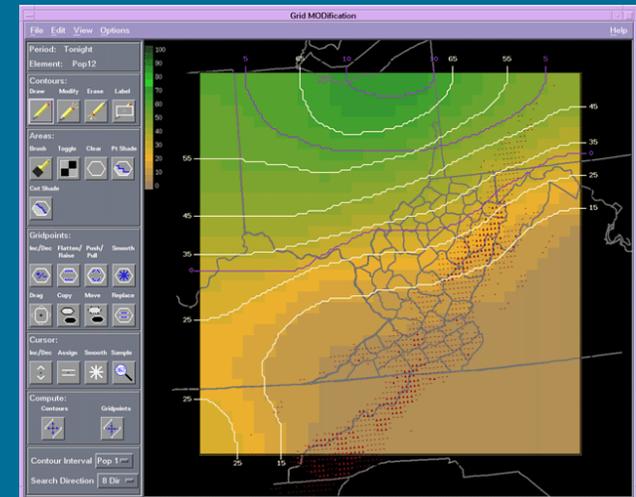
# National Digital Forecast Database Gives Customers What They Want
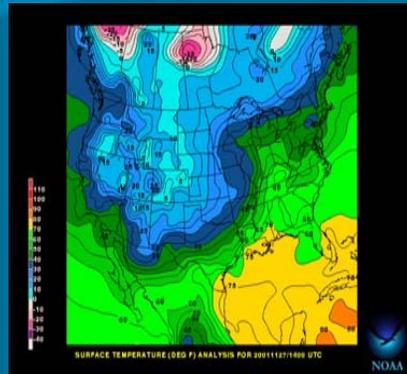


*The public, emergency managers and city planners use WWW. graphic products for detailed forecasts*

**Different Products for Different Customers**
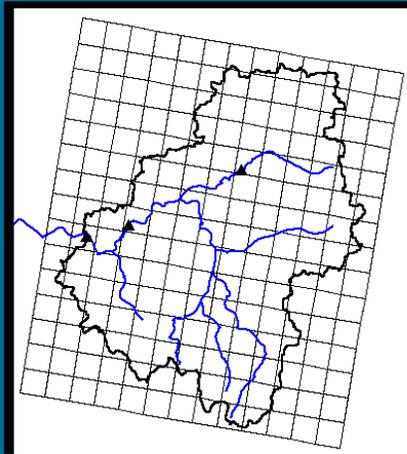


*Commercial weather companies & emergency managers use grids to generate tailored products*

TODAY...RAIN LIKELY. SNOW LIKELY ABOVE 2500 FEET. SNOW ACCUMULATION BY LATE AFTERNOON 1 TO 2 INCHES ABOVE 2500 FEET. COLDER WITH HIGHS 35 TO 40. SOUTHEAST WIND 5 TO 10 MPH SHIFTING TO THE SOUTHWESTEARLY THIS AFTERNOON. CHANCE OF PRECIPITATION 70%.

*Radio stations & public read text forecasts*

- ✓ **More weather data**
- ✓ **Higher resolution forecasts**
- ✓ **Visual displays of probability**
- ✓ **User-defined products create business opportunities**
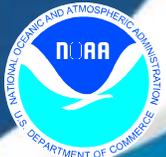
# Initial Operating System
## *Status: Development, Testing, Integration*

| Task | Lead | Dates | Status 1/04 |
|------|------|-------|-------------|
| **Model Development** | **NOAA/NWS and NOAA/EPA/ORD** | *09/02 – 05/03* | C |
| **Model Upgrades** | **NOAA/NWS and NOAA/EPA/ORD** | *10/03 – 05/04* | G |
| **Acquire/implement IT Resources** | **NOAA/NWS** | *02/03 – 09/03* | C |
| **Model Integration** | **NOAA/NWS and NOAA/EPA/ORD** | *04/03-06/03* | C |
| **Model Testing/optimization** | **NOAA/NWS** | *06/03 – 09/04* | G |
| **Experimental products** | | *06/04 – 09/04* | G |
| **Final go/no go decision** | | *09/04* | G |
| **Develop/implement required verification** | **NOAA/NWS and NOAA/EPA/ORD** | *10/02 – 06/04* | G |
| **Develop required product archiving** | **NOAA/NWS** | *04/03 -- 09/04* | G |

**Key**  | **Complete** | **On schedule** | **At risk** | **Remedial Action Required**