



# **NOAA's National Air Quality Forecast Capability: Targets and Needs**

NOAA Chemical Modelling Workshop  
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# NOAA's National Air Quality Forecast Capability: Targets and Needs

- **Background on NOAA's AQ Forecast Capability**
- **Operational Perspectives**
  - *Links to Operational AQF capabilities*
  - *Links to NUOPC*
- **Recommendations**



# National Air Quality Forecast Capability

## *Current and Planned Capabilities*

### ***Near-term: 1-day forecast guidance for ozone and smoke***

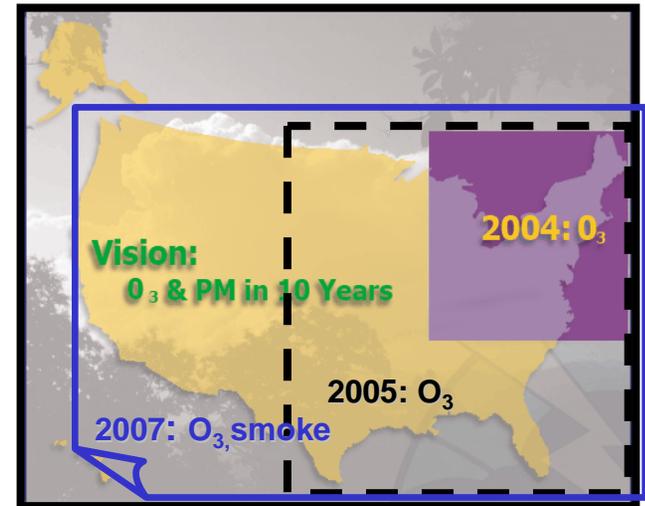
- Operational for Contiguous US (CONUS) as of September, 2007
- Nationwide by FY10

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

- Implement quantitative 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 Forecast Capability

## *End-to-End Operational Capability*

### **Model Components: Linked numerical prediction system**

Operationally integrated on NCEP's supercomputer

- *NCEP mesoscale NWP: WRF-NMM*
- *NOAA/EPA community model for AQ: CMAQ*

Observational Input:

- *NWS weather observations; NESDIS fire locations*
- *EPA emissions inventory*

### **Gridded forecast guidance products**

- *On NWS Telecommunications Gateway and EPA servers*
- *Updated 2x daily*

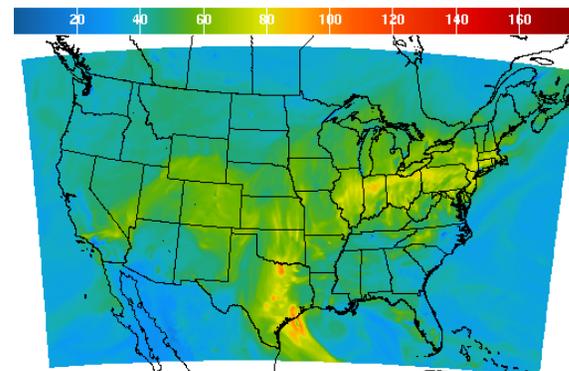
### **Verification basis**

EPA compilation:

- *Ground-level ozone observations*

### **Customer outreach/feedback**

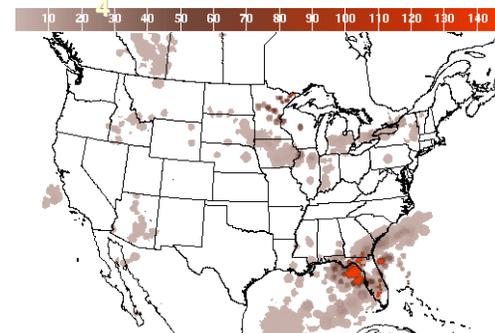
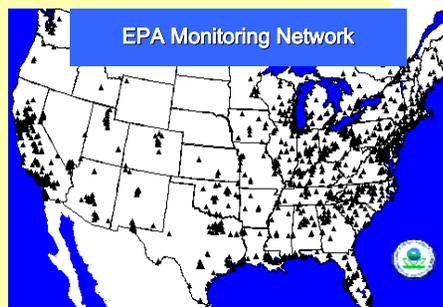
- *State & Local AQ forecasters coordinated with EPA*
- *Public and Private Sector AQ constituents*



1Hr Avg Ozone Concentration(PPB) Ending Thu Oct 04 2007 4PM EDT  
(Thu Oct 04 2007 20Z)



National Digital Guidance Database  
06z model run Graphic created-Oct 04 7:23AM EDT



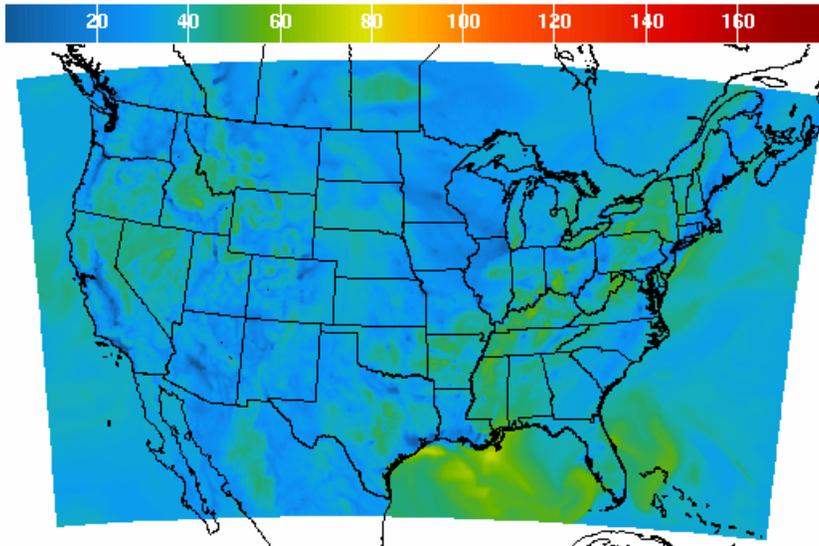
1Hr Surface Smoke (micrograms/m<sup>3</sup>) Fri May 11 2007 6PM EDT  
(Fri May 11 2007 22Z)

National Digital Guidance Database  
6z model run Graphic created-May 10 9:25AM EDT



# Operational AQ forecast guidance

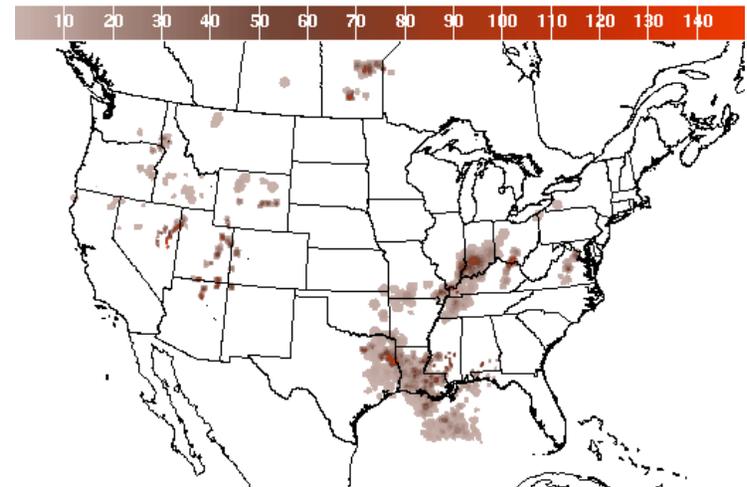
[www.weather.gov/aq](http://www.weather.gov/aq)



## CONUS Ozone

Expansion Implemented September, 2007

1Hr Avg Ozone Concentration(PPB) Ending Thu Sep 20 2007 10AM EDT  
(Thu Sep 20 2007 14Z)  
National Digital Guidance Database  
06z model run    Graphic created-Sep 20 7:23AM EDT



1Hr Surface Smoke (micrograms/m<sup>3</sup>) Thu Sep 20 2007 9AM EDT  
(Thu Sep 20 2007 13Z)  
National Digital Guidance Database  
6z model run    Graphic created-Sep 20 8:24AM EDT

**Smoke Products  
Implemented March, 2007**

Further information: [www.nws.noaa.gov/ost/air\\_quality](http://www.nws.noaa.gov/ost/air_quality)



# Transition to Operations: *Phased Development, Testing, Implementation*

## Phased Testing

**Research**  
**Does the science work?**

**Developmental Testing**  
**Does it work with operational systems?**

**Experimental Testing**  
**Does it meet deployment readiness criteria?**

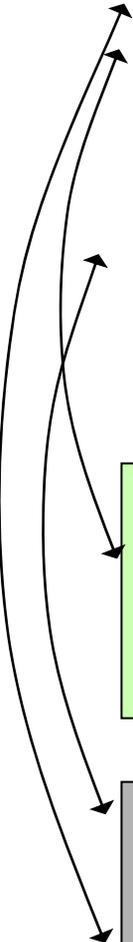
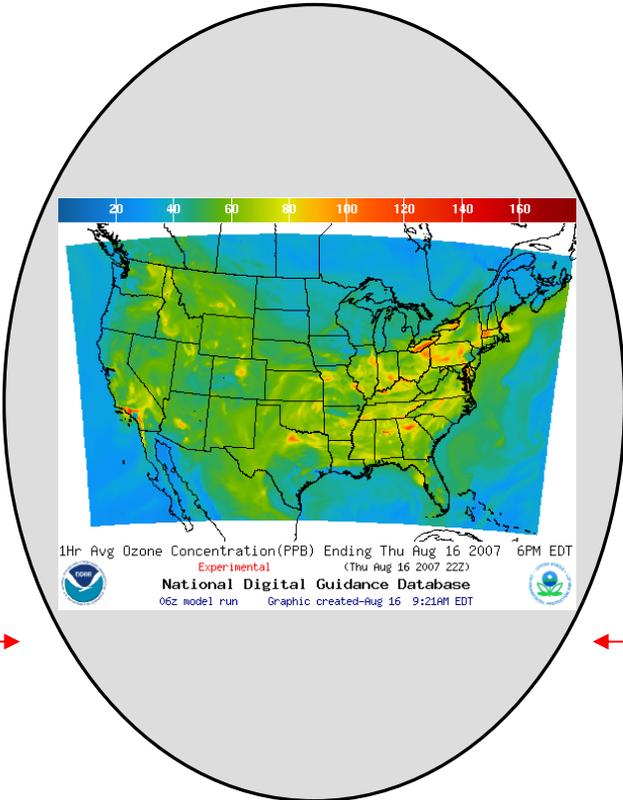
**Deploy into Operations**

**Key S&T Tests**  
***O<sub>3</sub> -- Summer 2007***

**More advanced PBL mixing in CMAQ (CB05)**

**PBL mixing (ACM2) in CMAQ, CA off-road emissions, dry deposition upgrades**

**NAM and emissions data updates; Plume rise correction**





# Operational Readiness Criteria Summary:

## *Example, Expanded Ozone Predictions*

<b>Criterion</b>	<b>Lead</b>	<b>Metric</b>	<b>Dates</b>	<b>Status <sup>2/07</sup></b>
<b>Objective Evaluation: Accuracy</b>	<b>NCEP</b>	<b>&gt; 90%</b>	<b>5/4/07 – 8/31/07</b>	<b>C</b>
<b>Subjective Feedback</b>	<b>OCWWS</b>	<b>Positive on balance</b>	<b>5/4/07 – 8/31/07</b>	<b>C</b>
<b>Production Readiness</b>	<b>OCIO, NCEP</b>			<b>C</b>
<b>On-time delivery</b>		<b>&gt; 95 %</b>	<b>5/4/07 –8/31/07</b>	<b>C</b>
<b>Back-up</b>		<b>In place</b>	<b>6/1/06</b>	<b>C</b>
<b>Data retention</b>		<b>In place</b>	<b>6/1/06</b>	<b>C</b>
<b>Near-real time verification*</b>	<b>NCEP</b>	<b>In place</b>	<b>6/1/06</b>	<b>C</b>
<b>Final go/no go decision</b>	<b>NWS</b>		<b>9/10/07</b>	<b>C</b>

\* NESDIS automated ( objective) product

**Key**

Complete	On schedule	At risk	Remedial Action Required
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# **Air Quality Forecasting**

## ***Goals and Status, October 2007***

### ***Purpose:***

- **Provide predictions of poor AQ with enough accuracy and lead time for people to take actions to limit adverse effects of poor AQ**

### ***Statement of Need, State/Local Air Quality Forecasters:***

- **Operational predictions of ground-level concentrations of ozone, PM and other pollutants of concern**
- **Hourly information, on 5-km grid resolution, updated twice each day**

### ***Objectives:***

- **National Forecast Capability for ozone (O<sub>3</sub>, particulate matter (PM<sub>2.5</sub>), and other pollutants of concern**
- **Target Full Operational Capability: O<sub>3</sub>, FY 10; PM<sub>2.5</sub>, FY15**

### ***Current Capabilities, October 2007***

- **Operational capabilities: Ozone and Smoke Predictions for CONUS**
- **Experimental capabilities (FY08): Ozone, smoke upgrades**
- **In development: Components for quantitative PM<sub>2.5</sub> prediction**



# **Operational Air Quality Forecasting:** ***Development of PM Forecast Capability*** ***CTM for regional AQF***

## ***Progress with ozone***

- **Mature technology; Gas-phase chemistry relatively well understood**
- **Pollutant emissions inventory successful for capturing daily chemical inputs important for O<sub>3</sub> prediction**

## ***PM: More challenging***

- **More complicated chemistry (approx 10X more species involved)**
- **Real-time source inputs (e.g. dust, fire) are significant additions to inventory-based emissions**
- **Longer atmospheric lifetimes of both primary and produced particles**
- **Reliable prototype model for PM and ozone not yet available**
- **AQ Program outlined a decision process for developing prototype model for combined PM and O<sub>3</sub>: CTM for regional AQF**



# Operational Air Quality Forecasting: *Key Technical Risks and Mitigation*

**Technical risks/mitigation for implementing full operational capabilities:**

<i>Technical Risk</i>	<i>Mitigation</i>
<i>Inaccurate estimates of chemical boundary conditions for US, based on climatology</i>	<i>Real-time, speciated chemical information from global-scale models</i>
<i>Inaccurate predictions of chemical species: ozone</i>	<i>Ongoing updates to pollutant emissions inventories from EPA on; continued monitoring of O3 prediction accuracy/verification</i>
<i>Inaccurate predictions of chemical species: PM2.5</i>	<i>For candidate models: monitoring of PM test-prediction accuracy/verification; continued development of missing or deficient components (dust, smoke, SOA, nitrates, sulfates....)</i>
<i>Inaccurate predictions of driving boundary-layer meteorological conditions</i>	<i>Closer coupling between weather and AQ modules; improvements ongoing in accuracy, resolution of NCEP's NAM</i>
<i>Run-time exceeds 2.5-hour prediction window and processor capacity</i>	<i>NOW: Adaptations/optimizations to CTMs for NCEP operational supercomputing environment  FUTURE: Closer coupling of meteorological and CTM modules; additional supercomputing processors for AQF</i>

**Mitigation involves:**

- Incorporation of improved CTM in global scale models
- Improved, more comprehensive CTM for regional AQF



# Air Quality Forecasting

## *AQ Model Decision Framework*

### *Purpose*

- Process for NOAA's AQ Program to select, from available approaches and components, those best suited for an operational quantitative forecast model for particulate matter (PM<sub>2.5</sub>)

### *Model Requirements*

- Timing: **NOAA's AQ Team**, to recommend to NWS a prototype AQ model in FY09 that is suitable to transition to operations by FY11.
- Prediction accuracy: must predict ozone with sufficient accuracy to meet existing performance measures and must also predict speciated PM2.5.
- Ownership: NOAA must have rights to review and modify source code for models and related processing programs.
- PM model run-time: PM predictions, including associated interface processors must run at NCEP in a 2.5-hour window on the supercomputer processors available for air quality operations.



# Air Quality Forecasting

## *AQ Model Decision Framework*

### ***Criteria for Evaluating Model Configuration Options***

#### ***Forecast/Analysis***

- Which approach provides the best forecast guidance for ozone and PM<sub>2.5</sub>?

#### ***Sustainability***

- Which approach best represents the current scientific understanding?
- Which approach provides the most flexibility for future improvements and extensions?

#### ***Compatibility***

- What are the computational requirements of each approach?
- How easy will the choice be to implement/integrate?

#### ***Efficiency***

- Which approach affords the best efficiency for software and model system maintenance, and integration with both regional and global applications?



# Air Quality Forecasting

## *AQ Model Decision Framework*

### **Decision Process**

- **Sequential, focusing earlier on the decisions that constrain successive choices.**
- **Decisions may be deferred if available information is inadequate, but efforts to resolve key uncertainties should be initiated.**
- **If prior decisions have led to an undesirable result, decisions may be revisited.**
- **NWS and OAR will work closely together to make decisions, in NOAA's AQ Matrix Program.**
  - *The line office with final authority for making decisions will depend on the phase of the project:*
    - **Specifying operational constraints for the system--Lead: NWS**
    - **Research that produces the prototype modeling system--Lead: OAR**
    - **Recommendation to NWS for prototype for initial operational capability (FY09Q3)--Lead: OAR**
    - **Transition of the prototype to operations--Lead: NWS**
    - **Operations--Lead: NWS**
  - *During the research phase the following process will be used*
    - **A technical team of OAR and NWS personnel selected by the management team will consider issues and make recommendations; may also include recommending new research activities to provide information required to reach a decision.**
    - **An OAR-led management team with members from both OAR and NWS will make decisions.**
    - **Periodically a peer panel composed of independent experts will conduct a scientific peer review of the research activities.**



# **Operational Perspectives:** ***NOAA's Atmospheric Chemistry Models Linkage to NUOPC***

**National Unified Operational Prediction Capability, the next-generation global weather forecast system, being planned:**

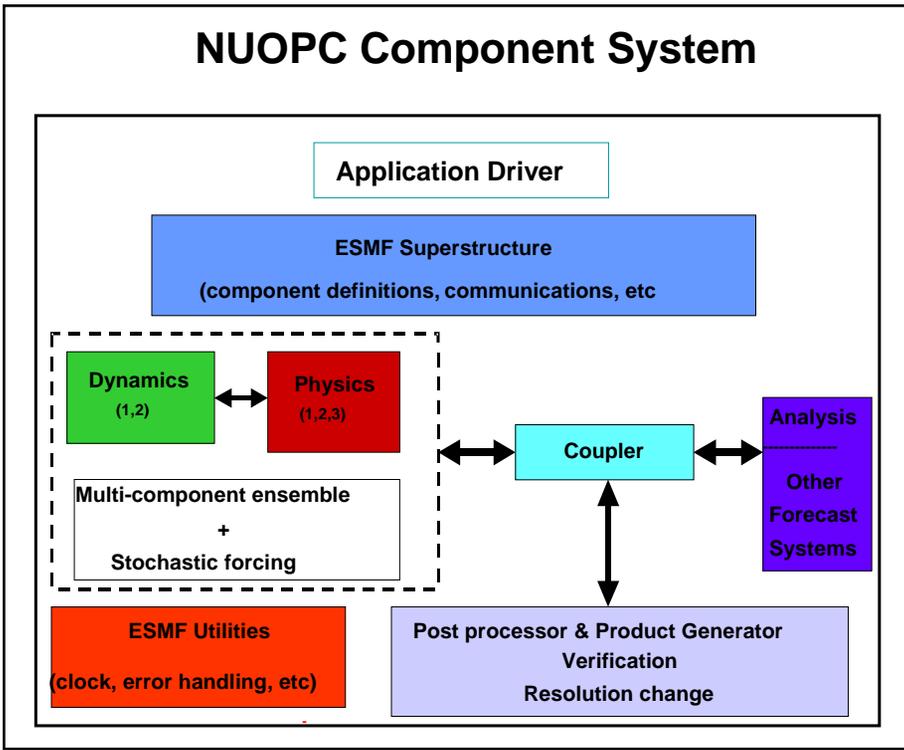
- **Tri-agency effort: NOAA, Navy, AirForce**
- **Framework to couple modules for data assimilation, dynamics, physics**
- **Aerosol module important for data assimilation; also dynamics, physics of NWP**

**NOAA's AQ Forecast capability requires chemical boundary conditions (BC):**

- **NUOPC could provide the required speciated chemistry for BC—especially critical for PM**



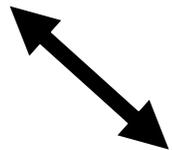
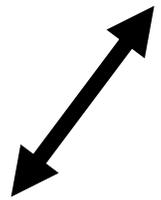
# NUOPC Vision: A National Global Modeling System (Slide courtesy F. Toepfer)



**Developmental Test Center**

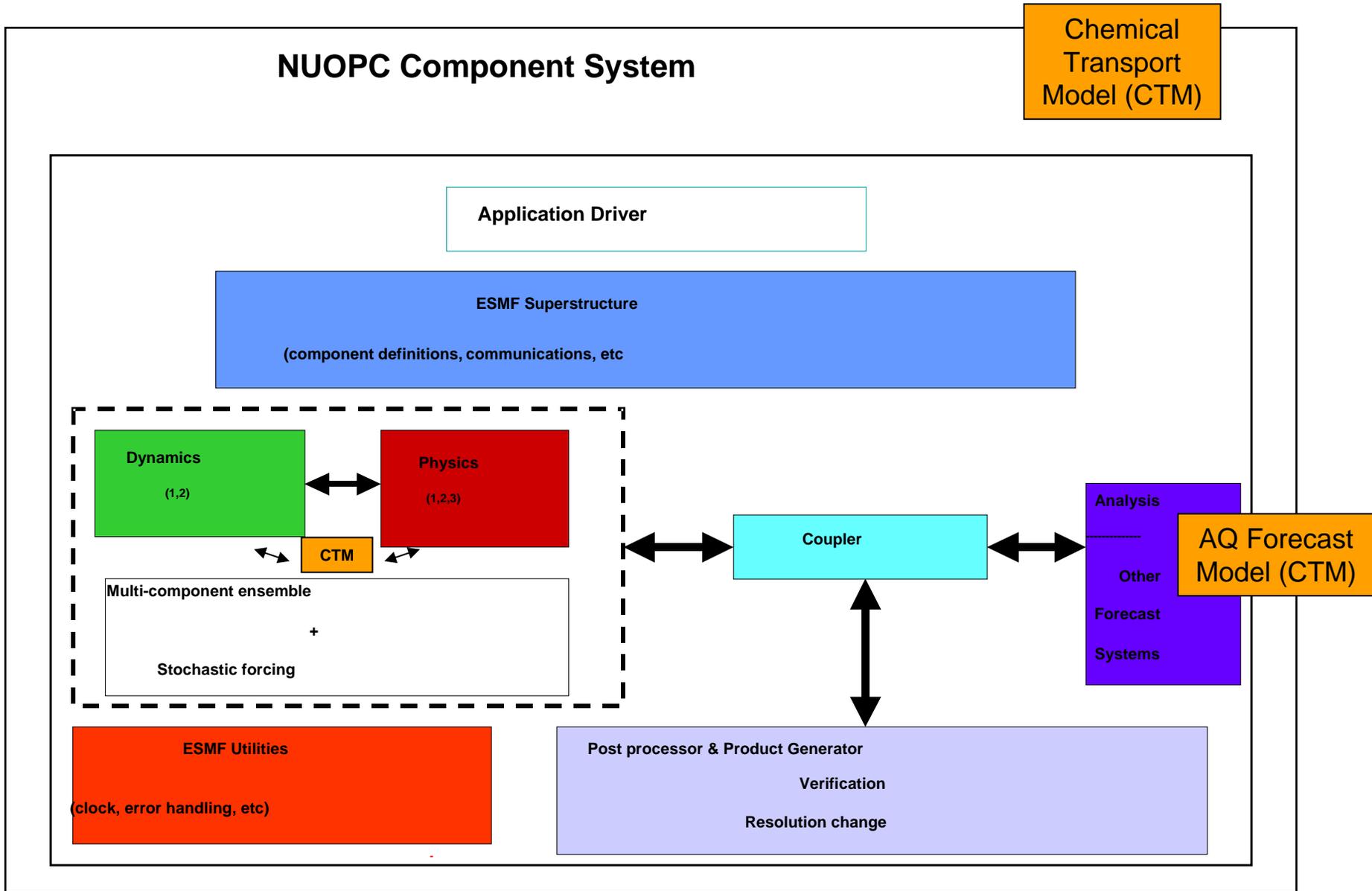


**Focused R & D**





# NUOPC Vision II: A National Global Modeling System





# **Operational Perspectives:** ***NOAA's Atmospheric Chemistry Models Linkage to NUOPC***

## **NUOPC**

- **CTM within NUOPC framework can provide source inputs, reactive transport, deposition for aerosols**
- **Tradeoffs between detailed, complex chemistry and large-scale total-aerosol impacts**

## **NAQFC:**

- **Consistent CTM approach in global and regional scales minimizes model-induced uncertainty for operational AQ forecasts.**
- **Possibility for streamlining a comprehensive CTM used in higher-scale regional AQF.**

**Recommendation: Next-generation global weather model (NUOPC) incorporates operational AQF CTM, streamlined as necessary**



# NOAA's Atmospheric Chemistry Models: *Research and Operational Capabilities*

- Many of the models were developed for specific research questions and/or applications
- Some are also used directly for operations or to improve NOAA operations
- **Links to operational capabilities speeds transition of Research to Operations:**
  - *Effectiveness for NOAA operations enhanced*
    - when user base includes both research and operations– e.g. CMAQ
    - when CTM includes NOAA operational input sources -- operational observational input streams, data assimilation, weather models.
  - *Effectiveness for NOAA research enhanced*
    - wider application, user bases increase rate of improvements

**Recommend: OAR and NWS work to increase linkage between research chemistry models and operational models**



# Operational Needs for AQF: *NOAA's Atmospheric Chemistry Models*

## **Global Aerosol Inputs:**

- **Real-time information on aerosol-forming emissions and processes that contribute to inputs to airborne PM in the US**
  - *Combines global real-time and episodic contributions, on species contributing to primary and secondary PM with available inventory and other data for the US*

## **Regional Chemical Transport Modules:**

- **Reliable, short-term prediction of ground-level PM and ozone**
  - *Hourly concentrations accurately predict thresholds used by AQ forecasters in issuing alerts*
  - *Onset, severity, duration of poor AQ episodes: forecasts accurately predict max values for day 2 and beyond*
- **Simulate processes for production, reactive transport, deposition on scale of mesoscale weather models (currently 12km; approaching 4 km in future)**
- **Incorporate chemical boundary conditions (BC) from global chemistry model**

## **Coupled to Operational NWP:**

- **Appropriate feedback between chemical and weather models**
- **Degree of coupling may be limited by timing (cannot add more than ~2 hrs to "off-line" meteorological forecast model production)**
- **Appropriate precision for reactive transport processes**
- **Options for probabilistic information/ensembles**

## **Effective, efficient use of operational supercomputing resources**

- **Modules for data assimilation and reactive chemical transport adaptable for use in both global and regional scales**
- **Interoperability of developmental modules with experimental and operational systems for accelerated transition of new S&T to operations**



# Recommendations

- **OAR/NESDIS and NWS work to increase linkage between research chemistry models and operational models**
- **Next-generation global weather model (NUOPC) integrates regional operational AQF CTM, streamlined as necessary**



# Acknowledgments: *AQF Implementation Team*

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**OST/MDL**

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*Outreach, Feedback*

*Data Communications*

*Dev. Verification*

*NDGD Product Development*

*Program Support*

*Product Archiving*

*NOAA AQ Matrix Manager*

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*\*Eric Rogers, \*Hui-Ya Chuang*

*Geoff Manikin*

*John Ward, Brent Gordon, Dave Michaud*

*\* Guest Contributors*

*EMC AQF model team leader*

*System design and implementation*

*PBL & Chem Verification*

*Regional testing*

*Global dust/smoke system DT&E*

*Global data assimilation and feedback testing (NASA, NESDIS)*

*WRF retrospective run*

*NAM products*

*Smoke Product testing and integration*

*NCO transition and systems testing*

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*CMAQ verification, PM testing*

*CMAQ diagnostic studies*

*PREMAQ development*

*CMAQ met processing development*

*Code optimization*

*Emissions processingOA*

*ASMD Science oversight*

*HYSPLIT adaptations*

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*Shobha Kondragunta, Jian Zeng*

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*Smoke Verification product development*

*HMS product integration with smoke forecast tool*

# National Air Quality Forecast Capability: Current NWS Operational Links: Ozone

