THE MODELS-3 COMMUNITY MULTI-SCALE AIR QUALITY (CMAQ) MODEL: Linking with NWS Eta Model for Air Quality Forecasting

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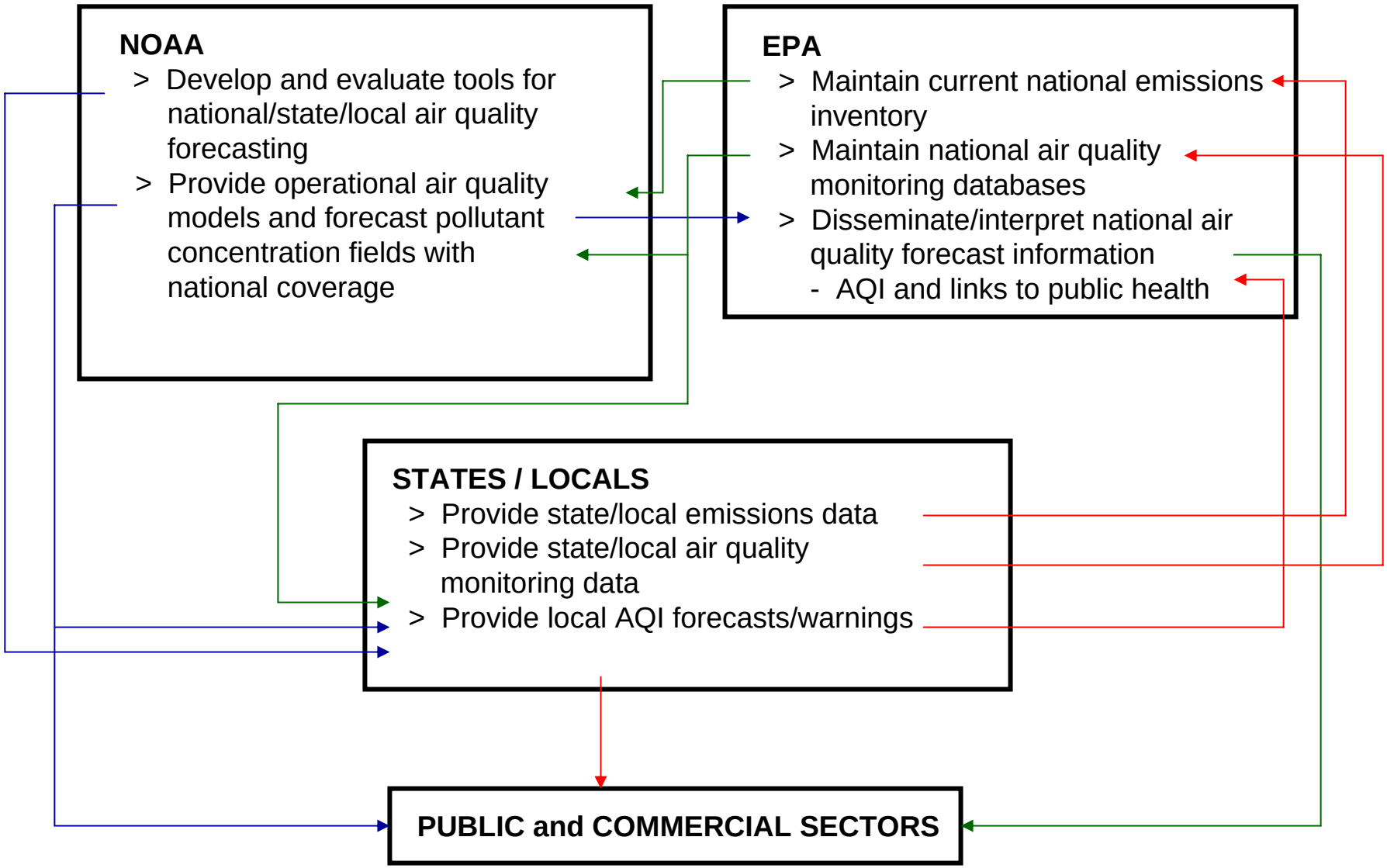
National Air Quality Forecasting *Background*

- Congressional interest
- H.R. 4 Energy Policy Act of 2002 (Senate Amendment) S. 517, SA 1383, Forecasts and Warnings: *"The Secretary of Commerce, through the Administrator of the National Oceanic and Atmospheric Administration, shall, in order of priority as listed in section (c) establish a program to provide operational air quality forecasts and warnings for specific regions of the United States…"*
- 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 (e.g., Canada, Australia, Spain) have existing AQ forecast capability
- NOAA-EPA Agreements
  - On May 6, 2003, DOC Deputy Secretary and EPA Administrator signed MOA on AQ forecasting

PARTNERSHIPS IN AIR QUALITY FORECASTING



CMAQ Assessment Model → CMAQ Forecast Model

- Increase computational speed
  - Decrease generality and flexibility
- Customize system architecture to NCEP IBM-SP
- Post-process Eta output for CMAQ input
- Streamline emissions processing
- Test new mass adjustment schemes in conjunction with Eta model adaptation
- Develop procedures for initial and boundary conditions for real-time runs

Computational Efficiencies

- Develop architecture where I/O overlaps computation
  - One processor handles output to disk
  - Many processors perform chemistry-transport kernel (CTK) computations
  - Synchronization mechanism - MPI communication
- Model runs in mode similar to Multiple Instruction-Multiple Data (MIMD)

- Domain decomposition
- New mass-adjustment scheme in CMAQ
  - Diagnoses vertical velocities to satisfy mass continuity
  - Based on work of R. Yamartino
- Other efficiencies
  - Smaller gas-phase mechanism (CB4)
  - Dropped transport of fast-reacting radical species
  - Disabled aerosols (for initial forecast version of CMAQ)
  - Eliminate some indirect addressing
  - Reordered some array arguments for cache efficiencies

Meteorological Processing

- Eta Model – 60 vertical layers; stepped-mountain vertical coordinate; Arakawa-E staggered grid; rotated latitude/longitude map; North America continental coverage

- CMAQ Model – 22 vertical layers; sigma-P vertical coordinate; Arakawa-C staggered grid; Lambert-conformal map; Northeastern U.S. coverage

- Interpolations needed in linkage
- Eta → Eta-Post → Product Generator → PREMAQ → CMAQ
- PREMAQ Processor
  - Equivalent to MCIP processor in standard CMAQ model system

AQ forecast modeling – emissions processing

- **Approach:** modify and streamline existing emission inventories and emission modeling systems used for EPA air quality analysis

- **Overall philosophy:** Simulate the complexities from significant source categories, and simplify processing when possible. Key complexities are in biogenic, mobile, and major power plants.

More efficient emissions processing:

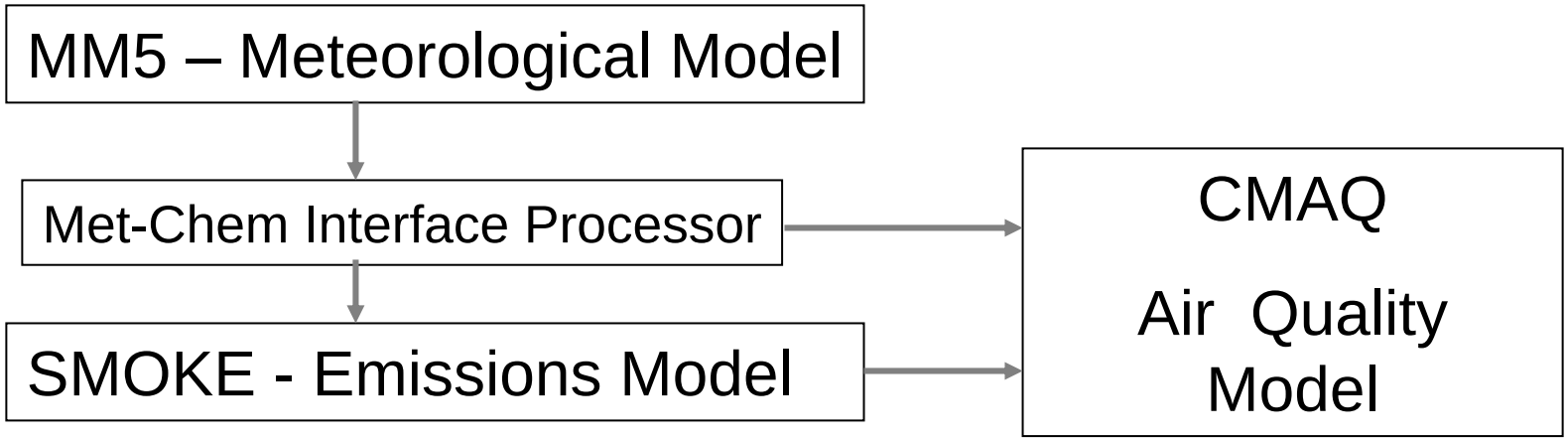
- Biogenic emissions
  - Streamline BEIS3 (hardwire the chemical speciation)
  - Identify and use appropriate met variables from ETA
  - Use vegetation fraction files to drive leaf biomass density
- Mobile emissions
  - Develop pre-calculated gridded emissions [hourly, day-of-week]
  - Develop simple temperature regressions to apply to pre-calculated emissions

- Major fossil-fuel power plants
  - Plume rise – meteorologically dependent
  - Include effects of current emissions control programs (SO_x, NO_x)
  - Try to link with daily forecasts of power generation; test and apply relationships and compare with CEM data (in future plans)

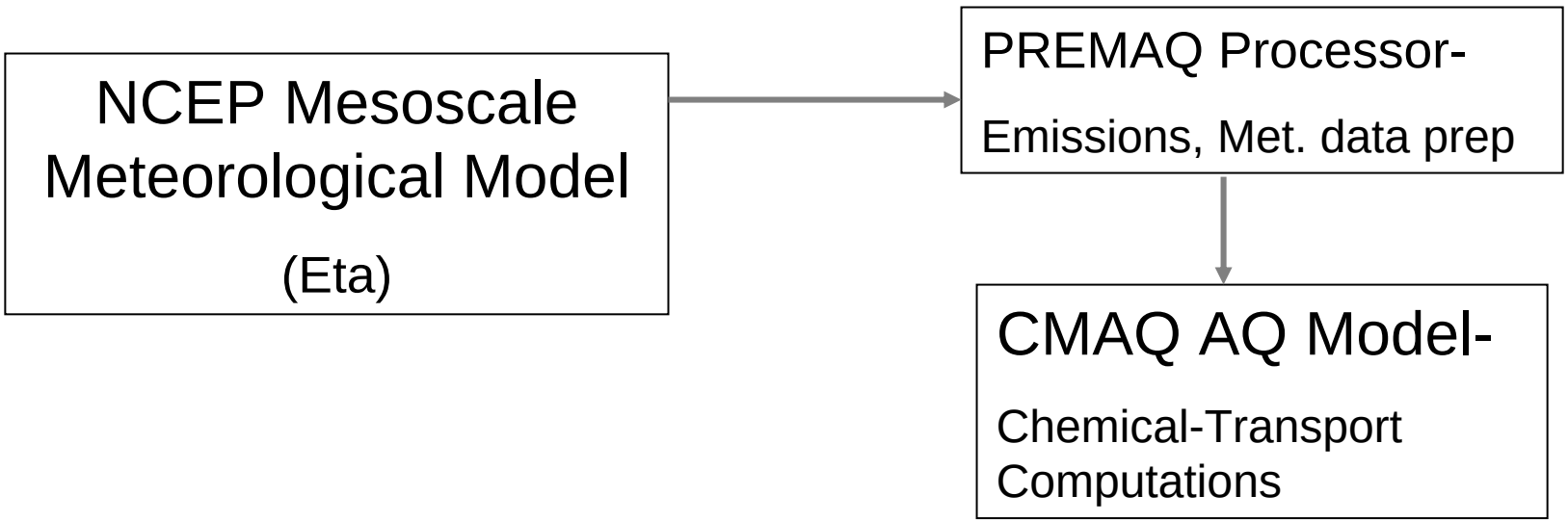
Initial and Boundary Conditions

- ICs
  - Model is initialized with concentrations from previous run (continuity with earlier run is maintained) – self-cycling
- BCs
  - 2003 season – lateral boundaries set to continental or maritime background profiles for all species; sfc ozone ~ 50 ppb
  - 2004 season – same, except ozone profiles obtained dynamically from Global Forecast Model/ Data Assimilation system

Current CMAQ Modeling System

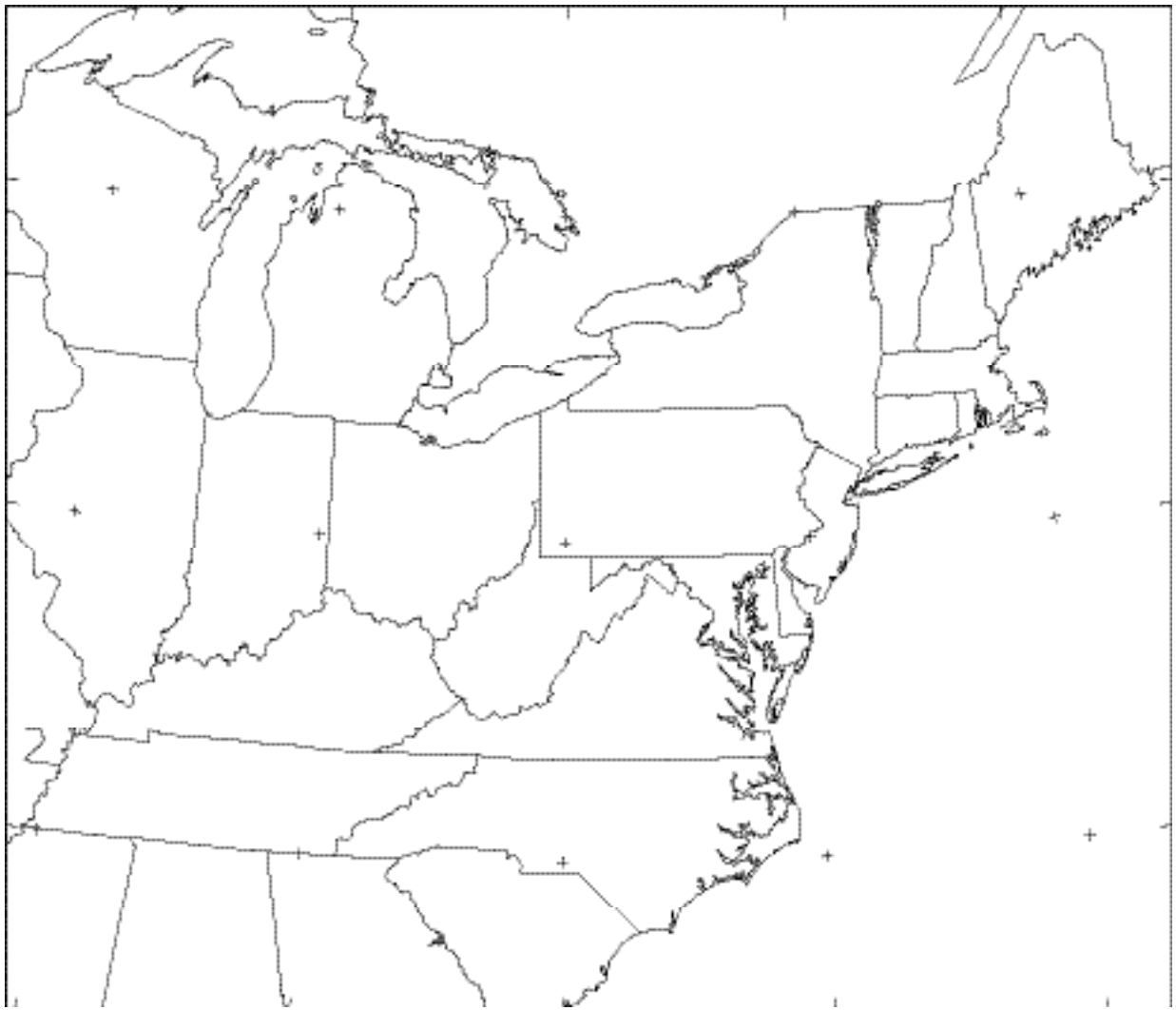


CMAQ Forecast System

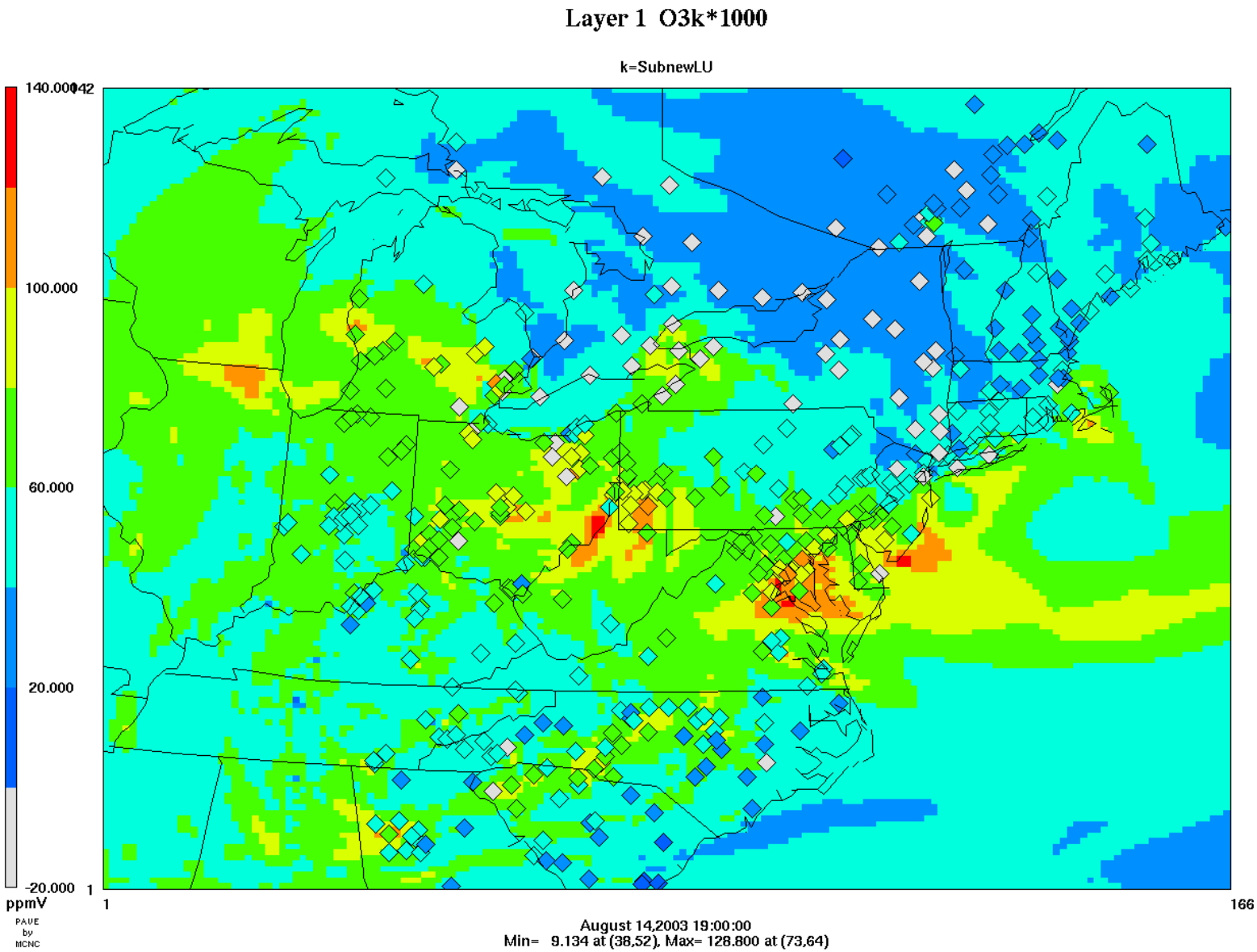


- Schedule
  - July-Sept. 2003 –Initial system tests at NOAA/NCEP during 2003 ozone season
    - Northeast US domain
    - 12km grid cells
    - 1-day forecast – O_3
  - October 2003-May 2004 – Refine system for NCEP operations
  - May 2004 – Begin operational real time test and evaluations at NOAA/NCEP
  - September 2004 – Initial operational Eta-CMAQ forecast system for Northeast US

AQF CMAQ Model Northeast Domain

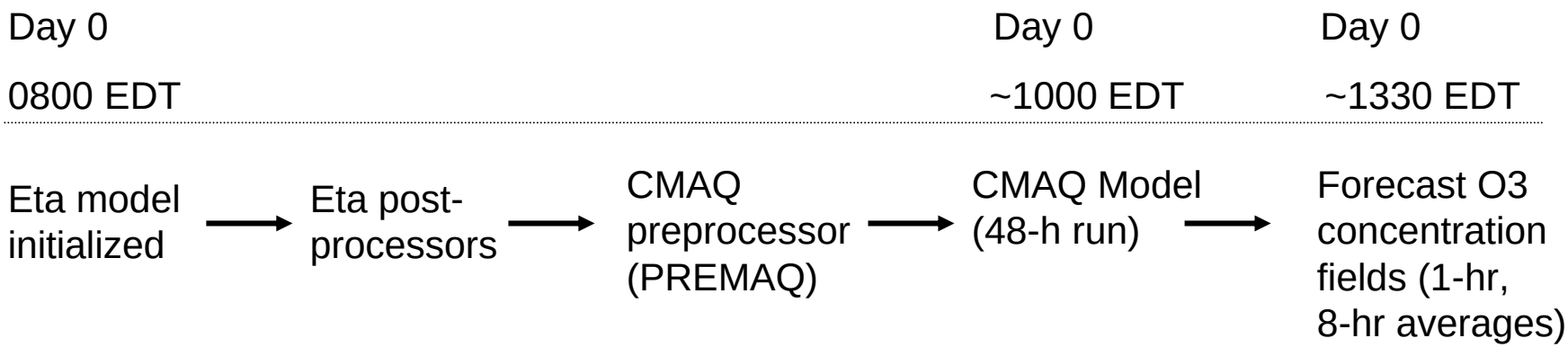


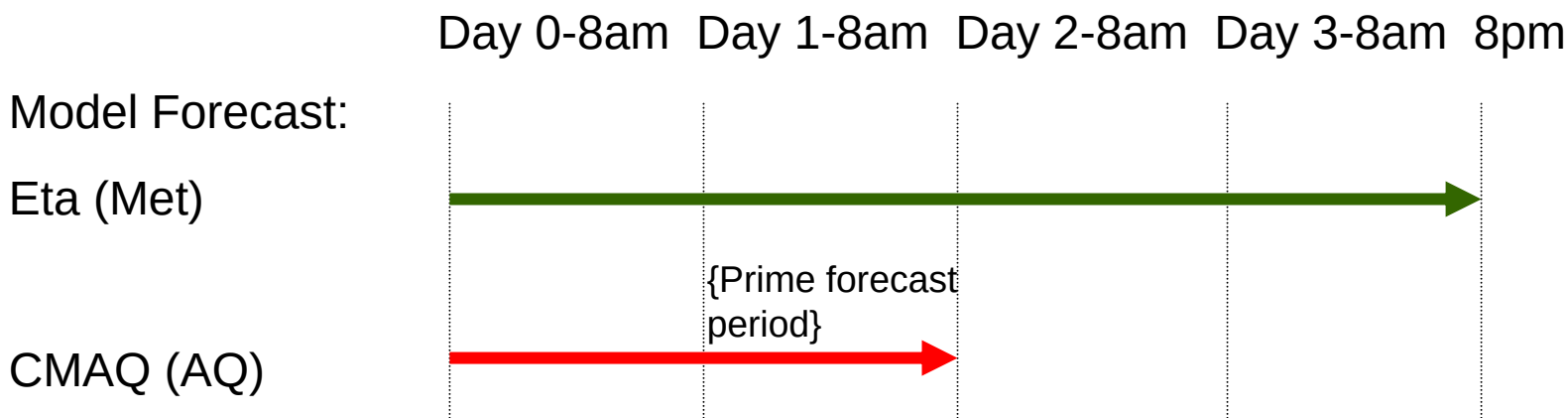
AQF Ozone – Aug 14, 2003



Anticipated Production Cycle

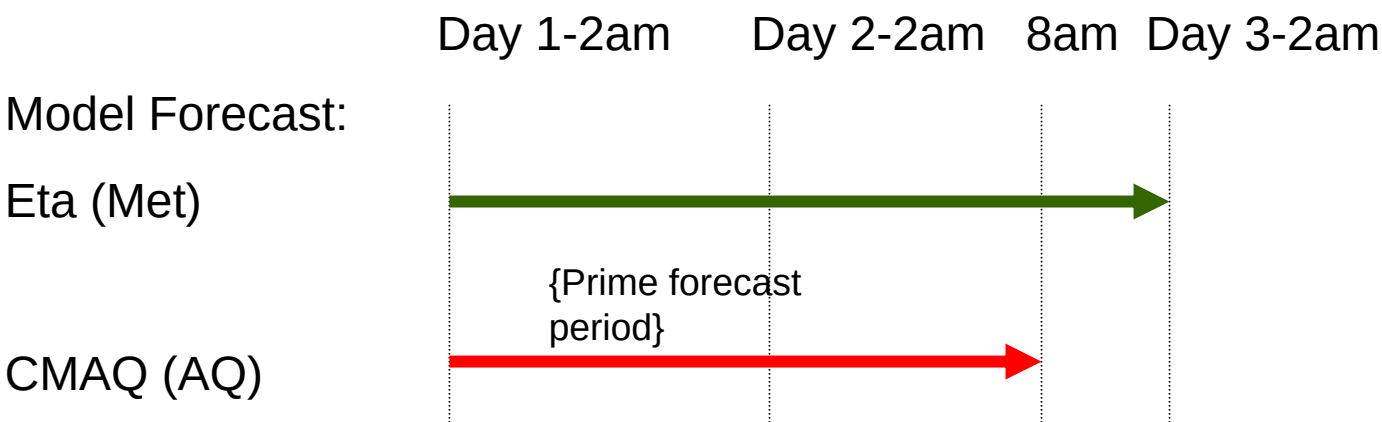
- First Forecast Run





- Second (updated) Forecast Run

Day 1			Day 1	Day 1
0200 EDT			~0400 EDT	~0730 EDT
Eta model initialized →	Eta post-processors →	CMAQ preprocessor (PREMAQ) →	CMAQ Model (30-h run) →	Forecast O3 concentration fields (1-hr, 8-hr averages)



Future Plans for Eta-CMAQ System

- Initial evaluation
  - August 6-16, 2002; Northeast U.S.
  - July-September 2003; Northeast U.S.
- Evaluation during 2004 Northeast field studies
- Over next 5 years:
  - Expansion of model domain to CONUS
  - Add PM2.5 simulation
  - Expansion from 1-day to 3-day forecasts
  - Transition from Eta to WRF met driver
- Move to “on-line” AQ forecast model – WRF/Chem

- Creation of CMAQ air quality forecast archive
  - Useful to EPA and states as a resource to drive urban scale SIP modeling for short- or long-term simulations
    - Meteorological data archive
    - Air quality forecast data archive
  - Developing climatologies of air quality over continental U.S.

- Analysis of CMAQ air quality forecast outputs
  - Assessing signals of emissions change on air quality
  - Evaluate NOx- and VOC-limited regions on a long-term basis
  - Couple air quality and health data to examine the inter-relationships