A New Way to Couple the CMAQ Model Using the National Unified Operational Prediction Capability (NUOPC) Framework

Barry Baker¹, Pius Lee¹, Daniel Tong¹,², Li Pan¹ and Youhua Tang¹

¹ National Oceanic and Atmospheric Administration
Air Resources Laboratory
College Park, MD 20740

² Cooperative Institute for Climate and Satellites
University of Maryland
College Park, MD 20740
Outline

- Overview of Community Multi-Scale Air Quality (CMAQ) model and current run options
- Discuss importance of coupling and drawbacks of the current system
- Introduce the National Unified Operational Prediction Capability (NUOPC) framework
- Show initial results
Current Flow diagram for CMAQ - Standalone

- CMAQ can currently run in a stand alone mode
- Requires that an emissions model (SMOKE) and meteorology model be run before CMAQ CCTM
Downside to Standalone – Power Spectra

- Standalone is limited by the amount of time between input meteorology. This is important in both horizontal and temporal scales.
- Increasing output times in the meteorology increases disk requirements considerably.

Figures from Grell et al. 2004, Geophysical Review Letters
Downside to Standalone – Vertical Profiles

Carbon Monoxide Mixing Ratio (ppb)

Ozone Mixing Ratio (ppb)

Figures from Grell et al. 2004, Geophysical Review Letters
Downside to Standalone - Review

• Must run one model first and then the air quality model
• Increasing the number of output times can significantly increase the amount of disk space required for a single run
• Updating the meteorology at hourly intervals (current operational status) severely limits the vertical variability need for chemical transport
• The need to increase horizontal resolution requires updating vertical profile more often – NCEP is moving from 12km -> 4km regional scales
• Simply increasing the amount of information to the chemical transport model can provide more realistic vertical profiles of atmospheric pollutants.
Current Coupling with CMAQ

• Currently CMAQ (v5.1) can only couple with WRF-ARW (v3.7)
• This is because it is hard coded to deal with communication and transfer of data.
• Limits the number of models that can be used and slows down development of the models
• CMAQ must run on the exact grid as WRF
Introducing NUOPC

NUOPC is designed to be a gateway for earth modeling systems. It provides a unified approach to numerical earth modeling systems including weather, ocean, hydrology, chemical, and space weather. Allows complex coupling of different systems for a complete earth system model and avoids duplication of efforts.

Advantages of NUOPC:

- Can couple with many different models; hydrology, land surface, ocean, etc.
- Can drive models with a single clock
- Allow advance coupling with time steps – will talk more about this later
- Defined coupling timestep at runtime.
- Individual models can run on separate grids
- Unified variable naming conventions
Introducing NUOPC

NUOPC is designed to be a gateway for earth modeling systems. It provides a unified approach to numerical earth modeling systems including weather, ocean, hydrology, chemical, and space weather. Allows complex coupling of different systems for a complete earth system model and avoids duplication of efforts.
NUOPC – A Single Model within Framework

Pure CMAQ FORTRAN Driver

- Initialize
- Run
- Finalize

NUOPC Application

NUOPC Driver

- Initialize MPI
- Register Components
- Advance Models

NUOPC Gridded Component

- Set Services
- Initialize (set grid and initialize model)
- Model Advance
- Finalize Model
NUOPC – Coupling with NMMB

NUOPC Application

NUOPC Driver
- Initialize MPI
- Register Components
- Advance Models

NMMB Gridded Component
- Set Services
- Initialize (set grid and initialize model)
- Model Advance
- Finalize Model

NMNM Model

Connector
- Handle the communication between models and grids

CMAQ Gridded Component
- Set Services
- Initialize (set grid and initialize model)
- Model Advance
- Finalize Model

CMAQ Model
NUOPC – Model Advance within NUOPC

**Driver:** SIMPLE EXPLICIT COUPLING

- **Model: ATM**
  - Initialization
  - Model Time: 0h, 6h, 12h, 18h

- **Model: OCN**
NUOPC – Model Advance within NUOPC

**Driver:** SIMPLE LEAP-FROG COUPLING

**Model:** ATM

**Model:** OCN

Model Time: 0h, 6h, 12h

Initialization
NUOPC – Model Advance within NUOPC

**Driver:** SIMPLE TWO TIMESCALE

- **Model:** ATM
- **Model:** OCN
- **Model:** RTM

Model Time:
- 0h
- 3h
- ...
- 21h
- 24h
- 27h

Initialization

- Fast
- Slow
NUOPC – 2D Re-Gridding between models

Surface Pressure

NMWB

CMAQ

Surface Pressure (mb)
NUOPC – Vertical Re-Gridding between models
Conclusion

- NUOPC allows us to work with any model compatible within its system
- Promotes the idea of a unified Earth system
- CMAQ has been restructured to be able to work within the confines of the NUOPC framework
- Currently information is able to be sent from NMMB $\rightarrow$ CMAQ. Feedback is not yet operational – future work
- Variables are re-gridded horizontally but not vertically due to the vertical coordinate systems
  - Vertical interpolation is done using $Ln(P)$
- With the CMAQ gridded component made flexibility to use different models (GFS, or WRF-ARW) are readily available with minimal effort.
CMAQ Modal Distribution

CMAQ Tri-Modal Representation of Mass

Mass Distribution

Diameter [μm]