On the Assimilation of Satellite Retrievals of Aerosol Optical Depth to Improve 0-48 h Air Quality Predictions Over the U.S.

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Outline

• Project goal and objectives

• Tasks:
  - Chemical data assimilation (Rajesh Kumar, NCAR)
  - Uncertainty quantification (Stefano Alessandrini, NCAR)
  - “Spreading technique” to generate 2D Maps (Irina Djalalova, NOAA/ESRL)
  - Transition to operations (Pius Lee, NOAA/ARL)
  - Socio-economic impact study (Jeff Lazo, NCAR)

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• Summary
Goal:

- National Oceanic and Atmospheric Administration (NOAA) / National Centers for Environmental Prediction (NCEP) air quality (AQ) forecasting system is a key tool for decision makers across the U.S. to protect the public from poor AQ.
- To enhance this decision-making activity this project aims to improve the accuracy of NOAA/NCEP short-term predictions of ground-level ozone ($O_3$) and particulate matter less than 2.5 µm in diameter ($PM_{2.5}$) and to provide reliable quantification of their uncertainty.

Objectives:

1. Improve initialization of NOAA/NCEP Environmental Protection Agency (EPA) Community Multiscale AQ (CMAQ) model through chemical data assimilation of satellite retrieval products and in-situ observations with the Community Gridpoint Statistical Interpolation (GSI) system.

2. Improve CMAQ prediction accuracy and reliably quantify its uncertainty with analog-based post-processing methods.
Air Quality Prediction System

NOAA/NCEP National Air Quality Forecast Capability (NAQFC) is based on the EPA Community Multiscale Air Quality (CMAQ) model

Present-study CMAQ set-up:
- CMAQ version: 5.1
- Resolution: 12 km²
- Emissions:
  - Anthropogenic: NEI 2011
  - Biogenic: Online (BEIS)
  - Fires: U.S. forest service
- IC: previous CMAQ run
- BC: Static
- Other configuration options are consistent with NAQFC
- Run period: 15 Jul – 14 Aug 2014
GSI/CMAQ Code Development

Note: this code will be shared with the community as part of the GSI software
24-h Assimilation Cycle

Tropospheric Emissions Monitoring of Pollution (TEMPO): NASA geostationary satellite that will provide high-spatial and temporal resolution of AOD retrievals. Launch in 2019 timeframe.
Background Error (BE) Statistics

• GEN_BE is used to calculate BE statistics
  – Different meteorology (i.e., forecasts initialized at 00z and 06z)
  – Different emissions

Perturbed emissions = NEI - Mean(NEI – E_i); i = 1, 2, 3, 4
AOD Results

MODIS AOD

CMAQ AOD (First Guess)

CMAQ (After First Outer loop)

CMAQ (After Second Outer loop)

AOD (550 nm)

0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50
Effect of AOD Assimilation on AOD Initialization

PDFs, 15 July to 14 August 2014, All AIRNow Stations

Obs   CMAQ bkg   CMAQ met_be   CMAQ met+emis_be
MODIS AOD is assimilated in CMAQ at 15, 18, and 21Z – The assimilation pushes the modeled state towards observed state at all the three times
**PM$_{2.5}$ Time Series at Assimilation Time**

15 July to 14 August 2014
Averaged over all AIRNow stations

- **15 Z**
- **18 Z**
- **21 Z**

<table>
<thead>
<tr>
<th>Time</th>
<th>PM$_{2.5}$ (µg m$^{-3}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 Z</td>
<td>Obs, CMAQ (bkg), CMAQ (met+emis_be)</td>
</tr>
<tr>
<td>18 Z</td>
<td>Obs, CMAQ bkg, CMAQ met+emis_be</td>
</tr>
<tr>
<td>21 Z</td>
<td>Obs, CMAQ met_be</td>
</tr>
</tbody>
</table>

Day Number: 195 to 225
Effect on Predictions

15 July to 14 August 2014
Averaged over all AIRNow stations

- PM$_{2.5}$ (μg m$^{-3}$)
- Temporal CC
- Gross Error (μg m$^{-3}$)
- RMSE (μg m$^{-3}$)
- Spatial CC
- Mean Bias (μg m$^{-3}$)
- RMSE$_b$ (μg m$^{-3}$)
- RMSE$_u$ (μg m$^{-3}$)

 UTC

Obs    CMAQ bkg    CMAQ met_be    CMAQ met+emis_be

NCAR/RAL – National Security Applications Program
Spatial differences in PM$_{2.5}$ Response to DA

- Nighttime overestimation in Group 1 and Group 2 even in the “bkg” run without assimilation
- Discrepancies in CMAQ relative to MODIS AOD are likely not representative of the discrepancies in CMAQ surface PM$_{2.5}$ at 29% of the AIRNow sites (Group 1)
- DA improves the initialization at 25% sites (Group 2) in the eastern US but then the model has a tendency to overestimate nighttime PM$_{2.5}$ levels
- The current DA system works very well to the western U.S. (Group 3)
Summary

We are improving NOAA/NCEP operational AQ predictions, by:

• Chemical data assimilation
  ✷ Improvements in AOD and PM$_{2.5}$ estimates
  ✷ However, forecast at times is degraded (e.g., eastern U.S.)

• Analog-based methods

• Ongoing socio-economic impact study to assess the value of improvements on end-user decision making process