Support of AQ community by providing long term reanalysis Chemical fields through data assimilation – prototype & testing

- Air Resources Lab. Team : Pius Lee, Tianfeng Chai, Hyuncheol Kim, Daniel Tong and Li Pan
- GA Tech Team : Ted Russell, Yongtao Hu and Talat Odman
- Potential Clients : State Implementation Planners (DNR), Local and national AQ Forecasters (e.g. NCEP; USFS), ..., many more
Air Quality Reanalysis (*Translating Research to Services*)

Greg Carmichael + others

**Stand-up a demonstration of an operational AQ reanalysis**

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**Applications**

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+ State Implementation Plan Modeling
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AQAST 5th Semi-annual, June 4-6, 2013

12 km CMAQ Regional Assimilation
**Challenge:** Achieving A Closer Integration Of Observations And Models

http://acmg.seas.harvard.edu/aqast/members.html

Courtesy: Carmichael, Keynote speech

IWAQFR 2011, Nov 29 – Dec 1 2011, D.C.

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Goal: A user friendly downloadable archive

- This study aims to build a prototype

- User friendliness and reliability are keys to success: e.g.
Building a chemical reanalysis prototype & its testing: Incremental addition of ingesting observations

<table>
<thead>
<tr>
<th>Base</th>
<th>NMMB-CMAQ471; EPA 2012 aa mobile/area; 2011 CEM point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raqms</td>
<td>Dynamic BC</td>
</tr>
<tr>
<td>Fire</td>
<td>HMS (~7 satellites) wild fire</td>
</tr>
<tr>
<td>AOD-DA</td>
<td>IO method D.A. MODIS AOD</td>
</tr>
<tr>
<td>AIRNow PM</td>
<td>AIRNow ~ 300 monitors with hourly PM2.5 obs</td>
</tr>
</tbody>
</table>

CMAQ PM

MODIS

AIRNow
This is set up not ideal:
Working towards ingesting AIRNow 3 hourly, and 4 cycles per day.
O3 verification statistics over CONUS with NAM-CMAQ for August 1-5 2006. (Tang et al. 2008 Environ. Fluid Mech.)

<table>
<thead>
<tr>
<th>Case</th>
<th>Mean bias</th>
<th>Regression slope</th>
<th>Corr. Coef.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed LBC</td>
<td>8.0</td>
<td>0.887</td>
<td>0.714</td>
</tr>
<tr>
<td>GFS O3</td>
<td>9.2</td>
<td>0.935</td>
<td>0.714</td>
</tr>
<tr>
<td>MOZART</td>
<td>8.2</td>
<td>0.941</td>
<td>0.716</td>
</tr>
<tr>
<td>RAQMS</td>
<td>10.0</td>
<td>0.911</td>
<td>0.718</td>
</tr>
</tbody>
</table>
Emission should include Exo- and intra-domain wild fires

Agricultural burning prevails in the months of March and April in Mexico

HMS wildfire detections during Apr./2010
MODIS AOD Assimilation

\[ X^a = X^b + BH^T (HBH^T + O)^{-1} (Y - HX) \]

Difference map: Analysis minus Base
Methodology of OI: Take account for background input; Obs; and physical processes from model.
HMS detected large swath of smoke in EUS on July 2 2013.
Total AOD assimilation tests

Base case: CMAQ4.7.1 without any data assimilation
OI forecast: CMAQ results after assimilating previous day AOD observations
OI Analysis: CMAQ results after assimilating same day AOD, for next day forecast

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OI forecast:  CMAQ results after assimilating previous day AOD observations
OI Analysis:  CMAQ results after assimilating same day AOD, for next day forecast

Fine mode AOD assimilation

Total AOD assimilation

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CO (ppb) along the P3 Flight – July 2 2011: AOD_DA case vs. Obs
NO2 (ppb) along the P3 Flight – July 2 2011: AOD_DA case vs. Obs

NOy (ppb) along the P3 Flight – July 2 2011: AOD_DA case vs. Obs
GA Tech as end user of product of re-analysis fields

- **WRF 3.2.1 for meteorological fields**
  - NCEP North American Regional Reanalysis (NARR) 32-km resolution inputs
  - NCEP ADP surface and soundings observational data
  - MODIS landuse data for most recent land cover status
  - 3-D and surface nudging, Noah land-surface model

- **SMOKE 2.6 for CMAQ ready gridded emissions**
  - NEI inventory projected to 2011 using EGAS growth and existing control strategies
  - BEIS3 biogenic emissions based on BELD3 database
  - GOES biomass burning emissions:
    ftp://satepsanone.nesdis.noaa.gov/EPA/GBBEP/

- **CMAQ 4.6 revised to simulate gaseous and PM concentrations**
  - SAPRC99 mechanism, AERO4, ISORROPIA thermodynamic, Mass conservation,
  - Updated SOA module (Baek et. al. JGR 2011) for multi-generational oxidation of semi-volatile organic carbons

**DISCOVER-AQ**

GA_Tech

4 km

**IC/BC of Base and AOD_DA cases**
24 h PM2.5 on 07/02/2013 (a) Base, (b) AOD_DA for DISCOVER-AQ GA_Tech 4 km
24 h PM2.5 on 07/07/2013 (a) Base, (b) AOD_DA for DISCOVER-AQ GA_Tech 4 km
<table>
<thead>
<tr>
<th>Region</th>
<th>PM2.5 24h avg</th>
<th>Obs mean</th>
<th>Mean bias</th>
<th>RMSE</th>
<th>Corr. Coef.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CONUS</strong></td>
<td></td>
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<tr>
<td>Base</td>
<td>12.75</td>
<td>-4.55</td>
<td>7.92</td>
<td>0.55</td>
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<tr>
<td>RAQMS</td>
<td>12.75</td>
<td>-4.45</td>
<td>7.87</td>
<td>0.55</td>
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<tr>
<td>Fire</td>
<td>12.75</td>
<td>-4.33</td>
<td>7.80</td>
<td>0.55</td>
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<tr>
<td><strong>NE</strong></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Base</td>
<td>14.49</td>
<td>-4.07</td>
<td>6.63</td>
<td>0.64</td>
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<tr>
<td>RAQMS</td>
<td>14.49</td>
<td>-3.96</td>
<td>6.55</td>
<td>0.64</td>
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</tr>
<tr>
<td>Fire</td>
<td>14.49</td>
<td>-3.89</td>
<td>6.51</td>
<td>0.64</td>
<td></td>
</tr>
<tr>
<td><strong>DISCOVER-AQ</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GA_Tech 4 km</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Base</td>
<td>17.36</td>
<td>-5.88</td>
<td>22.50</td>
<td>0.40</td>
<td></td>
</tr>
<tr>
<td>With re-analysis field to derive LBC</td>
<td>14.49</td>
<td>-3.48</td>
<td>22.19</td>
<td>0.42</td>
<td></td>
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**AQAST leads:**

- Comprehensive
- Policy-relevant &
- State-of-science
- Long term
  Reanalysis product

**Observations**

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