Air Quality Reanalysis
(Translating research to service)

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Yesterday talks:
Duncan, Streets et al.
Pfister, Cohan, Henze et al.

Posters:
Hyer, Lamsal et al.

- Constrained Satellite Products
- Global Assimilation
- Satellite Products

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

+ AQ Assessments
+ State Implementation Plan Modeling
+ Rapid deployment of on-demand rapid-response forecasting; e.g., new fuel type, etc.
+ Health Impacts assessments
+ Demonstration of the impact of observations on AQ distributions
+ Ingestion of new AQAST products into operations

AQAST-8 Dec 2-4, 2014, Atlanta, GA
Goal: A user friendly downloadable archive

- This study aims to build a prototype
- User friendliness and reliability are keys to success: e.g.
Applications of Reanalysis

1. Ozone – modeled (~ 3 yr data lag) & monitor (~ 1 yr data lag), both from EPA
2. PM2.5 mass - modeled (~ 3 yr data lag) & monitor (~ 1 yr data lag), both from EPA
3. Air Toxics - benzene, formaldehyde, modeled from EPA, 2005 only (NATA)

Reanalysis would be able to provide PM2.5 speciation data with national coverage at county level, which are highly valuable for health effects studies
Cloud-obs Photolysis rates

**GOES-MCIP INTERFACE**
Cloud transmissivity (calculated from satellite retrieved cloud albedo), cloud top pressure, and cloud fraction are prepared for input to MCIP

**MODIFIED MCIP**
GOES retrievals replaces MM5 cloud information being passed to CMAQ. Cloud fraction, transmissivity, cloud base and top heights are passed to CMAQ.

**PHOT in CMAQ**
In subroutine PHOT, clear sky photolysis rates will be adjusted for cloud cover based on GOES cloud fraction and cloud transmissivity information.

Interpolated in between.

AQAST-8 Dec 2-4, 2014, Atlanta, GA
MODIS AOD & AIRNow PM$_{2.5}$ assimilated
For initial condition adjustment

MODIS AOD (Terra and Aqua)

AIRNOW PM$_{2.5}$, PM$_{10}$, Ozone
Analysis field Verification: AIRNOW $O_3$ & PM$_{2.5}$ over CONUS

hourly $O_3$ (nsite=1427)

- obs
- L42-Fire1-OL4
- L42-Fire1
- L42-RAQMS

hourly PM$_{2.5}$ (nsite=816)

- obs
- L42-Fire1-OL4
- L42-Fire1
- L42-RAQMS

- SO$_4^{2-}$, Criegee
- Kim et al., crustal element, pH
- SOA
- Small fires

Fire-work
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 & PM species
- SAPRC99 mechanism, AERO4, ISORROPIA thermodynamic, Mass conservation,
- Updated SOA module (Baek et. al. JGR 2011) for multi-generational oxidation of semi-volatile organic carbons

Analysis fields as IC and forecast with Total AOD Assimilation basis for LBCs
Analysis field Verification: AIRNOW $O_3$ & PM$_{2.5}$ over BW SIP
### CONUS

<table>
<thead>
<tr>
<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>L42</td>
<td>12.3</td>
<td>-7.7</td>
<td>10.4</td>
<td>0.4</td>
</tr>
<tr>
<td>L42RAQMS</td>
<td>12.3</td>
<td>-5.4</td>
<td>8.5</td>
<td>0.5</td>
</tr>
<tr>
<td>L42-Fire1</td>
<td>12.3</td>
<td>-7.6</td>
<td>10.6</td>
<td>0.3</td>
</tr>
<tr>
<td>L42-Fire1-OI4</td>
<td>12.3</td>
<td>-1.11</td>
<td>6.65</td>
<td>0.61</td>
</tr>
</tbody>
</table>

### DISCOVER-AQ

**Application of analysis field for State Implementation Planning**

<table>
<thead>
<tr>
<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>Base</td>
<td>19.8</td>
<td>-0.67</td>
<td>24.18</td>
<td>0.49</td>
</tr>
<tr>
<td>With L42-Fire1-OI4 field to derive LBC</td>
<td>19.8</td>
<td>1.15</td>
<td>5.79</td>
<td>0.53</td>
</tr>
</tbody>
</table>
ANs – Alkyl Nitrates (NTRx)
Essex Site

PNs – Peroxyacyl Nitrates (PAN, PANx, OPAN, MPAN)
Padonia Site


Courtesy D. Schwede and D. Luecken, CMAS Oct 27-29, 2014; hinted help is on the way
The July – August 2014 DISCOVER-AQ and FRAPPÉ Field Campaigns in the Front Range Region of Colorado: Summary of Experiment Design and Preliminary Findings

Ken Pickering, NASA Goddard
James Crawford, NASA Langley
Frank Flocke, NCAR
Gabriele Pfister, NCAR
Pius Lee, NOAA/ARL
Melanie Follette-Cook, GESTAR

The DISCOVER-AQ and FRAPPÉ Observation Teams
July 22 is one of two days exceeding the NAAQS for O3 during campaign.
<table>
<thead>
<tr>
<th></th>
<th>Overall</th>
<th>PBL</th>
<th>FT</th>
</tr>
</thead>
<tbody>
<tr>
<td>O₃</td>
<td>Day before</td>
<td>Same Day</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>-0.45%</td>
<td>0.93%</td>
<td>1.72%</td>
</tr>
<tr>
<td>NO₂</td>
<td>Same day</td>
<td>Same day</td>
<td>Same day</td>
</tr>
<tr>
<td></td>
<td>-24.76%</td>
<td>0.86%</td>
<td>-59.76%</td>
</tr>
<tr>
<td>CO</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>4.12%</td>
<td>7.49%</td>
<td>2.14%</td>
</tr>
<tr>
<td>HCHO</td>
<td>Day before</td>
<td>Day before</td>
<td>Day before</td>
</tr>
<tr>
<td></td>
<td>32.13%</td>
<td>-14.44%</td>
<td>52.40%</td>
</tr>
</tbody>
</table>

\[\rightarrow\] indicates that the difference between forecasts was less than 1%

Courtesy: Pickering, 13th CMAS

AQAST-8 Dec 2-4, 2014, Atlanta, GA
• Cressman successive correction scheme
• Two passes reducing radius of influence
  – 1\textsuperscript{st} pass: $R_0 = 4$ grid-length (48 km)
  – 2\textsuperscript{nd} pass: $R_0 = 2$ grid-length (24 km)
Push towards higher resolution at NCEP

<table>
<thead>
<tr>
<th>product</th>
<th>Targeted next</th>
<th>date</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>GFS</td>
<td>T878L64 ~ 22km</td>
<td>April 2014</td>
<td></td>
</tr>
<tr>
<td>GDAS</td>
<td>T574 Enkr/GSI ~ 27 km</td>
<td>April 2014</td>
<td></td>
</tr>
<tr>
<td>GEFS</td>
<td>T382L64 ~ 35 km</td>
<td>April 2014</td>
<td>~30 members</td>
</tr>
<tr>
<td>NAM</td>
<td>12 km North America</td>
<td>Already in place</td>
<td></td>
</tr>
<tr>
<td>NAM</td>
<td>3 km CONUS nest</td>
<td>July 2014</td>
<td></td>
</tr>
<tr>
<td>NAM</td>
<td>On demand basis 1.3 km limited domain</td>
<td>Already in place</td>
<td>Fire weather</td>
</tr>
</tbody>
</table>

Poster: A. Davis
L. Cordero et al.
M. Friberg
Y. Zhou
H. Qu
J. Moulinho
Configured forward-model **vertical structure** mimicking that of GFS

The analysis forward model is **tested** and used to generate July 2011 analysis fields. They were delivered to: Prof. Russ Dickerson for SIP for MDE, and Prof. Mike Newchurch for verification with Lidar data

**Data Set assimilated:** RAQMS (MLS, OMI O3, MODIS AOD); HMS Fire; GOES cloud fraction for photolytic rate correction; MODIS AOD; AIRNow O₃, PM₂.₅

July 2011 analysis fields was used by Georgia Tech for a 14-day SIP simulation and showed significant improvement in RMSE

**DISCOVER-AQ** related lessons-learned that can help this project:
- Flight transects to help fine tune vertical structure
- Collaborated with NESDIS to use analysis field to initialize forecast

**Next sets:** Fire-work, lightning NOx; OMI SO2; PAR adjustment by retrievals

Verification to include data from O₃ lidar network & AERONET

Transition assimilation codes to GSI-based

Production mode generation of analysis field for 2010

Application and development of end-users:
- Health impact studies (Lee and Liu 2014, *IJER & Public Health*)
- HTAP tasks
- Outreach: Hosted in RSIG and NOAA forecasting sites

*Anonymous* [ftp://ftp.arl.noaa.gov]; RSIG (Szykman et al.)
EXTRA SLIDES

Contact:
Pius.Lee@noaa.gov
http://www.arl.noaa.gov/
Thank you for voicing support to NAQFC

“I am writing to comment on the Proposed Termination of NWS Ozone Air Quality Predictions … The NAQFC is the only numerical forecast model that is available every day, is fully documented, accessible for evaluation, and shows good forecast skill. It should be retained”. (November 1 2012, Bill Ryan, PSU)

On “The proposal to shelve the $5.4 million National Air Quality Forecasting Capability in March has drawn protests from public health officials…” (January 26 2013, Dan Vergano, USA Today)

The Maryland Department of the Environment (MDE) hereby submits these comments on the proposal of the National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) to terminate the National Air Quality Forecast Capability (NAQFC) ozone and fine particle pollution (PM$_{2.5}$) models. Maryland urges NWS to reconsider its proposed termination of the NAQFC models. Since 2004, NAQFC has worked toward developing and improving its air quality models to support the air quality scientific community. MDE provides the official air quality forecasts for ground-level ozone and PM$_{2.5}$ for Maryland residents. In doing so, MDE meteorologists frequently utilize NAQFC model guidance as an important resource when preparing the State’s official air quality forecasts.
July 2011 Analysis field delivered to Dickerson et al. for SIP;
and to Newchurch et al. for verification with Lidar data
Typically good correlation between surface PM$_{2.5}$ and AOD retrieved by MODIS

MODIS (Moderate Resolution Imaging Spectroradiometer) AOD

- Orbit: 705 km, 10:30 a.m. descending node (Terra) or 1:30 p.m. ascending node (Aqua)
- Swath Dimensions: 2330 km (cross track) by 10 km (along track at nadir)
- Spatial Resolution: 250 m (bands 1-2), 500 m (bands 3-7), 1000 m (bands 8-36)

http://terra.nasa.gov/About/

National correlation map between AIRNow measurement and MODIS AOD

Courtesy: NESDIS

AQAST-8 Dec 2-4, 2014, Atlanta, GA
Optimal Interpolation (OI)


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

- Obs far away (beyond background error correlation length scale) have no effect in the analysis.
- Injection of Obs through OI takes place at 1800 UTC daily.