Establishing **process-oriented** constraints on global models for ozone source attribution: Lessons from **GFDL-AM3**

**Meiyun Lin**
(Princeton University/GFDL)

Geophysical Fluid Dynamics Laboratory
GFDL AM3 Global Simulations for HTAP2

- **Horizontal and vertical resolution:**
  - C90 cube sphere grid, ~1.0x 1.25 degrees
  - 48 vertical levels, from surface to 86 km altitude

- **Using HTAPv2 anthropogenic emissions**
  - HTAP2 emissions and RETRO VOC speciation
  - HTAP2 aircraft emissions distributed vertically based on ratios in ACCMIP
  - Daily FINN fire emissions emitted at the model surface level
  - MEGAN v2.1 biogenic isoprene emissions

- **Interactive stratospheric & tropospheric chemistry**

- **Nudged to NCEP GFS winds**

- **Citations for model documentation**
  - Donner L. J. *et al.* [J. of climate, 2011]
  - Lin M.Y. *et al* [JGR2012a; JGR2012b; Nature Geosci, 2014]

http://data1.gfdl.noaa.gov/nomads/forms/HTAP2/AM3_HTAP2_MODEL_DESCRIPTION.pdf
GFDL AM3 for HTAP2 regional boundary conditions

- **Available at NOAA GFDL data portal:**
  http://data1.gfdl.noaa.gov/nomads/forms/HTAP2/

- **Relatively long-lived chemical species (3-hourly & 3-D output)**
  Ozone, CO, PAN, sulfate, nitrate, BC, OC, dust, NO, NO2, SO2, NH3, ethane, propane, acetone

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
<th>Get Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>BASE</td>
<td>Base emissions, methane=1798 ppb (2008-2013)</td>
<td><a href="#">get data</a></td>
</tr>
<tr>
<td>CH4INC</td>
<td>Base emissions, methane=2121 ppb (2008-2010)</td>
<td><a href="#">get data</a></td>
</tr>
<tr>
<td>GLOALL</td>
<td>20% decrease of all anthropogenic emissions globally</td>
<td><a href="#">get data</a></td>
</tr>
<tr>
<td>NAMALL</td>
<td>20% decrease of all anthropogenic emissions</td>
<td><a href="#">get data</a></td>
</tr>
<tr>
<td>EASALL</td>
<td>20% decrease of all anthropogenic emissions</td>
<td><a href="#">get data</a></td>
</tr>
<tr>
<td>EURALL</td>
<td>20% decrease of all anthropogenic emissions in HTAP2 Tier1 domain for Europe</td>
<td><a href="#">get data</a></td>
</tr>
</tbody>
</table>

*Known issues:* The response is noisy and lack of a coherent spatial pattern

*Contact:* [Meiyun.Lin@noaa.gov](mailto:Meiyun.Lin@noaa.gov) for authorization
Evaluation of GFDL AM3 with **EANET** observations

Mean surface ozone concentrations during April-June, 2010

Tappi, Japan[141.3W, 41.2N, 105m]

- BASE2009–2010
- OBS 2001–2007

Rishiri, Japan[141.2W, 45.1N, 40m]

- BASE2009–2010
- OBS 2001–2007
Evaluation of GFDL AM3 with EANET observations

Mean surface ozone concentrations during April-June, 2010

Oki, Japan [133.2W, 36.3N, 90m]

Sado-seki, Japan [138.4W, 38.2N, 110m]
Evaluation of GFDL AM3 with EANET observations

Mean surface ozone concentrations during April-June, 2010

Need measurement data in China for additional model evaluation!!
Evaluation of GFDL AM3 with CASTNET observations

Mean surface ozone concentrations during April-June, 2010

with NA anthropogenic emissions set to zero
Comparison of mean O$_3$ profiles with ozonesondes for April and May

- Hindcast simulations (1979-2012) with anthrop & wildfire emissions set to climatology

The GFDL AM3 model explains 50-90% of observed daily $O_3$ variability in Point Reyes sonde.

Cooper et al., 2011

Sonde
AM3/C180 (~50 km)
AM3/C48 (~200 km)

All sites: 40-90%

Evaluation of Source Attribution

- Deep STT
- Regional anthropogenic pollution
- Wildfires
### Simulating deep stratospheric intrusions: role of model resolution (May 28, 2010 example)

#### Sondes

<table>
<thead>
<tr>
<th>Altitude (km)</th>
<th>TH</th>
<th>SH</th>
<th>RY</th>
<th>PS</th>
<th>JT</th>
<th>SN</th>
<th>TH</th>
<th>SH</th>
<th>RY</th>
<th>PS</th>
<th>JT</th>
<th>SN</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 0.5° model better captures vertical structure
- 2° model reproduces the large-scale view (suitable for exploring IAV)

*Lin MY et al (JGR, 2012b)*: *Springtime high surface ozone events over the western US: Quantifying the role of stratospheric intrusions*
Attribution of WUS high-O$_3$ events: Observations

Anomallysely frequent high-O$_3$ events were measured in Apr-May 2012 (Lin et al., Nature Commun. 2015)

Attribution of WUS high-O$_3$ events: **GFDL AM3**

May 29, 2012 (Pollution)

Meiyun Lin et al (in prep, 2015)
Long-term trends in US surface ozone
Selection of model baseline to be more representative of observed conditions at WUS mountain sites

Problem:
- Model limitations in resolving observed baseline conditions
- Local pollution influence in the model grid perturbs the small baseline signal

Approach:
- Sample the model at site elevation
- Filter the model to remove the influence from fresh local pollution (i.e. removing data on days when N. American COt ≥ 33rd percentile)
Simulated ozone trends with/without selection of baseline conditions in the model

Lassen Volcanic NP (1.7 km, Mar-Apr-May)

Model surface

Model Baseline

Observed weaker variability in the 2000s attributed to BGO$_3$
**SPRING** U.S. surface $O_3$ trends: Do domestic NO$_x$ reductions work?

**Observed**  
**AM3 BASE**

MAM 1988-2012

MDA8 $O_3$ trends (ppb yr$^{-1}$)

Larger circles indicate statistically significant trends

WUS  
Model filtered to be more representative of observed conditions  
High background, thus little response to local NO$_x$ reductions
SUMMER U.S. surface O₃ trends: Do domestic NOₓ reductions work?

Observed

AM3 BASE

JJA 1988-2012

MDA8 O₃ trends (ppb yr⁻¹)

Larger circles indicate statistically significant trends

MY Lin, LW Horowitz, OR Cooper et al (in prep, 2015)
Some final thoughts on process-oriented model evaluation

- Leveraging high-quality observational constrains (e.g. daily ozonesondes, hourly meteorological parameters)
- Evaluating ability to quantitatively relate pollutant concentrations to their sources and transport on synoptic time scales
- Investigating ability to capture variability on daily to decadal time scales and from the regional to local scales
- Examining the full range of pollutant distribution (e.g. 95th, 75th, 50th, 25th, 5th)

→ Ensure an apple-to-apple comparison btw OBS and Models

Thank you!! (Meiyun.Lin@noaa.gov)