The impact of observational nudging and nesting on the simulated meteorology and ozone concentrations from WRF-CMAQ during the DISCOVER-AQ 2013 Texas Campaign

Xiangshang Li, Yunsoo Choi, Beata Czader
Earth and Atmospheric Sciences
University of Houston

07/21/2014
DISCOVER-AQ Simulation

- September 2013
- Four complete set of WRF-SMOKE-CMAQ simulations; new model version and 2008 inventory

<table>
<thead>
<tr>
<th>WRF Cases</th>
<th>Type</th>
<th># of Domains</th>
<th>Input Analysis Data</th>
<th>FDDA Obs-Nudging</th>
</tr>
</thead>
<tbody>
<tr>
<td>AQF</td>
<td>Forecast</td>
<td>1</td>
<td>NAM forecast</td>
<td>N/A</td>
</tr>
<tr>
<td>NARR</td>
<td>Analysis</td>
<td>1</td>
<td>NARR analysis</td>
<td>Off</td>
</tr>
<tr>
<td>NARR-OA</td>
<td>Analysis</td>
<td>1</td>
<td>NARR analysis</td>
<td>On</td>
</tr>
<tr>
<td>NARR-Y2D</td>
<td>Analysis</td>
<td>2</td>
<td>NARR analysis</td>
<td>On</td>
</tr>
</tbody>
</table>

- Detailed analyses
  - By Period (three 10-day period)
  - Variables
    - Meteorology: T/U/V/CFRAC/CLDT/TEMP2/PBL
    - Chemistry: Ozone/NO/NO$_2$/NOx/Isoprene etc
DISCOVER-AQ Simulation
DISCOVER-AQ Simulation

• Analyses
  – Various satellite cloud, radar images and weather charts
  – Hourly precipitation data
  – Full statistics (CORR, IOA, MB, MAE etc) for major variables (T/U/V/O₃/NO/NO₂/NOx)
    • Daily
    • By site
    • Day-time
    • Night-time
  – Spatial and time-series plots
  – High ozone episode due to front passage (09/25-09/26)
  – Inland and coastal sites
  – Background ozone
  – Bogus thunderstorms
Satellite Visible – 20130925_11 CST

Radar – 20130925_11 CST
Ozone at La Porte

Wind shift on 20130925
11 sites at Houston
09/25 high ozone

Wind shift brings pollutants back from Galveston Bay
Model missed the high ozone around La Porte

High ozone

Bay breeze fully developed
Land/Sea/Bay breeze etc

- Land breeze and sea/bay breeze
- Local wind reversal, convergence
- Small-scale phenomenon, short life time, a few hours
- Occurs when large scale forcing is absent -> prone to high ozone
- Extremely important for simulating high ozone episode
- Hard for WRF to replicate
Observation nudging

- FDDA is one of the most important components in modern NWP models
- Model performance gain is substantial while cost is relatively low
- Nudging is a FDDA method to push (or nudge) model values toward observation.
  - Grid nudging uses analysis input (‘met emulate’ files from WPS)
  - Obs-nudging uses observation data (OBS_DOMAIN files from WRF-OBSGRID)
- Obs-nudging is performed every 3 hours, just like the grid nudging

Improvement of IOA: Wind (U and V) 10-14%; Temperature 9%
Improvement significant
WRF Obs nudging – op. flow chart

WRF simulation paradigm

WPS (namelist.wps)
- geogrid.exe (static data ➔ geo_em_d0*)
- ungrib.exe (NAM, GFS, NARR data + VTABLE ➔ FILE*)
- geogrid.exe (FILE* ➔ geo_em*) ➔ met_em*

Download MADIS data
- run_get_madis (csh script)
  ➔ METAR, CAP, NPN, RAOB
- obj_madis.pro ➔ obs*.little_r.format

OBSGRID (namelist.oa)
- obsgrid.exe ➔ mteoa_sm*
  OBS_DOMAIN1*
  wrffdda_d0*
  (lump all time steps together using combine_obspro)

WRF (namelist.input)
1) Initialization – generate IC/BC for WRF
   real.exe ➔ wrfbdy_d0*
   wrfinput_d0*
   wrffdda_d0*

2) WRF simulation
   wrf.exe ➔ wrfout_d01*

3) Nestdown – IC/BC for fine domain using coarse output
   ndown.exe ➔ wrfinput_d02
   wrfbdy_d02

Nudging options & inputs
- none: only need wrfinput_d01 & wrfbdy_d01
- grid nudging: grid_fdda = 1, wrfbbda_d01
- sfc nudging: grid_sfdda = 1, wrfsfdda_d01
- obs nudging: obs_nudge_opt = 1, OBS_DOMAIN101
OA did not solve the problem for 09/25
Current work: Enhanced obs nudging

• In 09-25, last nudging is performed at 9 CST, yet baybreeze onset is at 10 CST
  – From 10 to 13 CST, there is only one nudging done at 12 CST -> Not enough push to ‘bend’ model!

• Possible solution
  – Increase the obs nudging frequency to hourly!
    • Data available, already preprocessed
    • WRF does not support it
  – Can we still do it?
    • Actively working on it!
      – First task (modify OBSGRID code) done!
      – On 2nd task (modify WRF)