WRF “Obs-nudging” Updates, Verification and Plans for the Future Developments


National Center for Atmospheric Research, Boulder, CO, USA

Lili Lei, Aijun Deng and Dave Stauffer

Department of Meteorology, Pennsylvania State University, College Station, PA, USA

Thanks to the numerous modelers, engineers, forecasters, and managements at Dugway Proving Ground, Utah, and the National Center for Atmospheric Research at Boulder, Colorado.
Overview

- WRF3.0 “obs-nudging” features and updates
- An introduction to Ensemble-RTFDDA
- “Obs-nudging” study with E-RTFDDA outputs
  - MM5 versus WRF
  - NAM versus GFS
  - Impact of physics schemes and other model uncertainties
- Comparison of WRF “obs-nudging” with community MM5 through a controlled case study
- Plans and on-going developments
Features of Obs-nudging in WRF3.0

- Assimilate T, U, V and RH from any platforms
- Use different data weight algorithms for vertical profile-type data, point-wise upper-air observations, and surface observations
- Many built-in physically-based spatial weight constraints

**New in WRF3.0:**

- Assimilate different data for nested domains
- Permit domain-dependent influence radii and time windows, besides nudging coefficients
- Double-scan (mimic successive correction OA)
- Code/namelist/printout cleaning and adjustments
- Bug fixes and more
E-RTFDDA: an Ensemble of “Obs-nudging”
### Description of 30 Members of DPG E-RTFDDA

<table>
<thead>
<tr>
<th>E#</th>
<th>LBC</th>
<th>WRF Members (15)</th>
<th>E#</th>
<th>LBC</th>
<th>MM5 Members (15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NAM</td>
<td>Control: WRF baseline physics</td>
<td>16</td>
<td>NAM</td>
<td>Control: MM5 baseline physics</td>
</tr>
<tr>
<td>2</td>
<td>GFS</td>
<td>Control: WRF baseline physics</td>
<td>17</td>
<td>GFS</td>
<td>Control: MM5 baseline physics</td>
</tr>
<tr>
<td>3</td>
<td>NAM</td>
<td>SLAB land surface</td>
<td>18</td>
<td>NAM</td>
<td>Simple cloud-effect radiation</td>
</tr>
<tr>
<td>4</td>
<td>NAM</td>
<td>MYJ PBL</td>
<td>19</td>
<td>NAM</td>
<td>ETA TKE PBL</td>
</tr>
<tr>
<td>5</td>
<td>NAM</td>
<td>MYJ PBL + GD Cumulus</td>
<td>20</td>
<td>NAM</td>
<td>Kain-Fritsch cumulus</td>
</tr>
<tr>
<td>6</td>
<td>NAM</td>
<td>WMS6 microphysics</td>
<td>21</td>
<td>NAM</td>
<td>Goddard microphysics</td>
</tr>
<tr>
<td>7</td>
<td>NAM</td>
<td>GD cumulus</td>
<td>22</td>
<td>GFS</td>
<td>Betts-Miller cumulus</td>
</tr>
<tr>
<td>8</td>
<td>GFS</td>
<td>Thomason microphysics</td>
<td>23</td>
<td>GFS</td>
<td>Reisner 3-ice microphysics</td>
</tr>
<tr>
<td>9</td>
<td>GFS</td>
<td>MYJ PBL + WMS5 microphysics</td>
<td>24</td>
<td>GFS</td>
<td>CCM2 radiation</td>
</tr>
<tr>
<td>10</td>
<td>GFS</td>
<td>MYJ PBL</td>
<td>25</td>
<td>GFS</td>
<td>GFS LBC Phase-uncertainty 1</td>
</tr>
<tr>
<td>11</td>
<td>GFS</td>
<td>MYJ PBL + GD Cumulus</td>
<td>26</td>
<td>GFS</td>
<td>Symmetric perturb to Member 25</td>
</tr>
<tr>
<td>12</td>
<td>GFS</td>
<td>BMJ cumulus</td>
<td>27</td>
<td>GFS</td>
<td>GFS LBC Phase-uncertainty 2</td>
</tr>
<tr>
<td>13</td>
<td>GFS</td>
<td>BMJ cumulus in 3.3 km grid</td>
<td>28</td>
<td>GFS</td>
<td>Symmetric perturb. to Member 27</td>
</tr>
<tr>
<td>14</td>
<td>GFS</td>
<td>GD cumulus in 3.3 km grid</td>
<td>29</td>
<td>GFS</td>
<td>Correlated sounding perturbation</td>
</tr>
<tr>
<td>15</td>
<td>GFS</td>
<td>KF cumulus in 3.3 km grid</td>
<td>30</td>
<td>GFS</td>
<td>Symmetric perturb. to Member 29</td>
</tr>
</tbody>
</table>
E-RTFDDA Operation for Dugway Proving Ground

D1: map \( \Delta X = 30 \text{ km} \)
D2: terrain \( \Delta X = 10 \text{ km} \)
D3: land use \( \Delta X = 3.33 \text{ km} \)

250 km
X
250 km
E-RTFDDA Spaghetti Meteograms
“Effective actions”

Good with WRF & MM5

Work with models of different physics suites

WRF vs. MM5 separations
NAM vs. GFS separations

Model forecast accuracy and bias appear to affect “obs-nudging” analyses fitted to observations.
Effective actions

WRF vs. MM5 separations
NAM vs. GFS separations

Model forecast accuracy and bias appear to affect “obs-nudging” analyses fitted to observations.

Good with WRF & MM5
Work with models of different physics suites

10m SPD, 06Z cycles daily for Mar 15, 16, 17 & 18, 2008 at DPG SAMS08
2008 Feb-Mar Mean: 2-m Temperatures

Feb/March 2008 mean for DS08 (40.2 / -113.17)

Feb/March 2008 mean for DS07 (40.23 / -112.73)

Feb/March 2008 mean for DS12 (40.3 / -112.45)

Feb/March 2008 mean for DS01 (40.18 / -112.92)

Forecast Time (06z cycle)
2008 Feb-Mar Mean: 10-m Winds

SAMS08

SAMS07

SAMS12

SAMS01
Feb-Mar Mean of DPG E-RTFDDA Dom 2 Outputs

Surface mean wind vector and wind speed STD (m/s), valid at 18Z

MM5 36h FCST

WRF 36h FCST

MM5 Analysis

WRF Analysis
Surface temperature and temperature STD (m/s), valid at 18Z
Previously studied using MM5 by PSU
Standard NCAR/NWS ADP radiosondes12 hourly and surface observations (3 hourly).

→ Set WRF with the same domain configuration ($\Delta x = 36$ km), ICs, BCs, Obs, physics suite and nudging parameters as used in MM5.
→ Used to systematically test the community WRF obs-nudging codes and algorithms
Fit to surface observations

Fct (y) vs. obs (x)

2-m T →

10-m U →

MM5/FDDA

WRF/FDDA

T [°F] vs. SYNOP [°F]

Bias = 0.6, RMS = 2.6

Bias = 0.7, RMS = 2.9

U [m/s] vs. SYNOP [m/s]

Bias = -0.0, RMS = 2.3

Bias = 0.0, RMS = 2.4
Remarks from the controlled case study

- Valuable exercise to review/validate WRF obs-nudging scheme
- Help enhance the robustness of the WRF obs-nudging scheme for the broad community applications
- A showcase indicating the advantage of community involvement

**Specific gains:**

1. A utility program to pipe NCAR MSS ADP data to obs-nudging
2. Using sfc observations without sfc pressure
3. A flexibility for using height-based obs directly
4. A need to enhance the ability for enhance
5. Adjust for more intuitive namelist and diagnostic printouts
6. Dealing with more configurable domain options in WRF
Advantages of Obs-nudging

- Assimilate T, U, V and RH of all platforms
- Direct data-model interaction: simple, effective and flexible
- Based on the same foundational formulation as other DA schemes
- Continuous (model-nature) state synchronization

Obs-nudging Ensemble

- Real-time mesoscale data assimilation and prediction
- Systematic comparisons of MM5 versus WRF
- Impact of physics schemes and other model components
- R&D of 4D-EnkF using nudging and EnKF hybrid

Updates in WRF3.0

- Different obs for nested domains
- Domain-dependent influence radii and time windows
- “Double-scan” - multi-scale
- Code cleaning, bug fixes and
- Others

New Updates Coming Soon

- Accommodate the extra flexibility of WRF domains setting over MM5
- Height-based observation and incomplete surface data
- Utility program to ingest NCAR/NWS ADP data
- Adjusting space and time weights
Road Map for Obs-nudging Development

Advanced Obs-nudging formulation

- Build “proper” mesoscale ensembles - heterogeneous
- Evaluate EnKF using the “proper” ensemble
- Incorporate Kalman Gain to obs-nudging weights

Ensemble RTFDDA (NCAR/RAL)
(Obs-nudging ensembles)

Improvement areas:
- Spatial weights
- Temporal weights
- Diverse data sources

Hybrids:
- 3DVAR
- VDRAS
- Grid-nudging FDDA

Basic Obs-nudging formulation