WRF-RTFDDA Optimization and Wind Farm Data Assimilation

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Acknowledgements:
Luca Delle Monache, Tom Warner, Becky Ruttenberg, John Exby and Brice Lambi

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH
Outline

1) Motivation

2) Impact of WRF Model Physics

3) Assimilation of Wind Farm Meteorological Data

4) On-going R&D
Motivation

• Errors in limited-area NWP model forecasts
  ▪ Imperfect model physics and numerics (finite difference)
  ▪ initial conditions
  ▪ lateral boundary conditions
  ▪ surface boundary conditions

• Goal: to optimize model performance by focusing on model physics and initial conditions
  ▪ Sensitivity of various WRF physics and the best combination of physics options,
  ▪ Improve DA by using wind farm meteorological data.
Impact of WRF Physics: Cases

Dec 13-14 2008 Ramp-Up Case

Focused on ramp-up in XXXX Wind Farm (~300 MW).

Jun 26-27 2009 Ramp-Up Case

Stage IV 1-h precip accum (mm): 2009062621
WRF Model Physics in Two Weather Cases

• Focused on wind speed forecast in XXXX wind farm
• Winter ramp-up: fronts/cyclone
   Dec 13-14, 2008 case
   Physics sensitivity:
    • PBL/surface layer schemes
    • Land surface model
• Summer ramp-up: convective storm
   Jun 26-27, 2009 case
   Physics sensitivity:
    • Cumulus parameterization schemes (CPSs)
    • Cloud microphysics
Impact of WRF Model Physics: Setup

- First guess + 3-hourly BC: GFS003

- Data ingest:
  - MADIS, ACARS, WMO
  - Mesonet, wind profilers

d01: 127 X 113 X 36

d02: 252 X 231 X 36

d03: 540 X 570 X 36
## WRF Physics Sensitivity Experiments for Winter Case

<table>
<thead>
<tr>
<th>surface layer scheme</th>
<th>land surface model</th>
<th>PBL model</th>
<th>μphysics scheme</th>
<th>cumulus param (d01 &amp; d02)</th>
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<tr>
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<td>YSU</td>
<td>Lin</td>
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<td>MYJ TKE</td>
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Winter cases focused on land surface and PBL physics.
## WRF Physics Sensitivity Experiments for Summer Case

<table>
<thead>
<tr>
<th>surface layer scheme</th>
<th>land surface model</th>
<th>PBL scheme</th>
<th>μphysics</th>
<th>cumulus param (d01/d02)</th>
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<td>WSM6</td>
</tr>
</tbody>
</table>

Summer cases focused on moist physics.
Impact of WRF Model Physics:
Winter Case

Cedar Creek
Comparison of Error Statistics
Dec. 13 - 14, 2008 Case

XX farm averaged wind speed BE (m/s)

BE = \frac{\sum_{i=1}^{N} (F_i - O_i)}{N}

XX farm averaged wind speed MAE (m/s)

MAE = \frac{\sum_{i=1}^{N} |F_i - O_i|}{N}
Impact of WRF Model Physics: Summer Case
Impact of WRF Model Physics: Summer Case

Cedar Creek

Jun 26 2009

Jun 27 2009
Comparison of Error Statistics
Jun 26 - 27, 2009 Case

XX farm averaged wind speed BE (m/s)

XX farm averaged wind speed MAE (m/s)
Summary: Impact of WRF Model Physics

- For the winter case (frontal passage):
  - Large-scale forcing dominant.
  - Improvements in DA important.
  - Lowest error scores: RUC and MYJ.

- For the summer case (convective storm):
  - Sensitivity to microphysics and outer grid CPS.
  - Double moment microphysics (Morrison and WDM6) the best.

- Feasibility of sophisticated physics options in realtime forecast?
Assimilation of Wind Farm Met. Data

Wind farm Data Processing

- Average Met Tower wind directions and assign them for turbines
- Averages turbine wind speed to closest WRF grid points

Wind farm data reformat

WRF RTFDDA
Assimilation of Wind Farm Met. Data

- Access to ~2000 turbine and over 30 Met Tower observations in real time in CO, NM, TX, and MN.

- 8 wind farm turbine data (with access to Met Towers) are already being assimilated:

- More wind farms will eventually be added.
Assimilation of Wind Farm Met. Data

- Met Towers N/A? Solution: wind direction from
  - previous forecast (easy to implement) or
  - directly from model during forecast (harder to implement)
- Test case: Dec. 13-14 2008 – XXX Wind Farm
- 3 grid setup: $\Delta x = 30, 10, 3.3. \text{ km (smaller d03)}$
- XXXX turbine/Met Tower data only
- Exp 1: DA test of turbine data with various sources of wind direction.
- Exp 2: Nudging coefficient test.
EXP 2: NUDGING COEFFICIENT TEST

- changed nudging coefficient for wind (10 times the default)

- Worked with run using current model wind direction.

- default:
  - obs_rinxy = 200, 90, 36
  - obs_rinfmx = 2., 6., 18.,

- extra nudging
  - obs_rinxy = 300, 200, 100
  - obs_rinfmx = 4., 12., 36.,
Assimilation of Wind Farm Data Experiments

DA: $u, v$

$|u|$ always a bit smaller
NUDGING COEFFICIENT TEST

- **default nudging**
  - small false ramp

- **10X nudging**
  - forecast starts here

- **obs**

- **turbine-avg wind speed (m/s)**

- **forecast starts here**
Data Assimilation Tests: Findings

• The best wind speed forecasts (best to worst):
  ▪ Met Tower wind direction,
  ▪ Current model wind direction,
  ▪ Previous forecast wind direction.

• Better solution: using current model wind direction when Met Tower unavailable.

• Extra nudging can improve wind speed forecast, but parameters have limits.
Ongoing Work

• For physics impact studies, 2 more summer cases and 1 more winter case.

• Currently modifying WRF to selectively increase nudging weights for turbine data.

• Make WRF accept wind speed only turbine data.

• Improve algorithms to cope with inconsistencies between model terrain and observation station elevation.