RAPID REFRESH (RAP) Upgrade V3.0.0
HIGH-RESOLUTION RAPID REFRESH (HRRR) Upgrade V2.0.0

EMC Change Configuration Board
January 29, 2016

Presented by: Geoff Manikin
Collaborators: Corey Guastini, Curtis Alexander, Stan Benjamin, Steve Weygandt, Ming Hu, Tanya Smirnova, John Brown, Joe Olson, James Kenyon, David Dowell, Haidao Lin, Eric James
Overview of Changes

• Updated versions of WRF-ARW model, GSI, and post
• Introduce ensemble/hybrid data assimilation in HRRR and greater weighting in RAP
• Enlarge RAP domain to match NAM
• Forecast length extension for both RAP and HRRR
• Update snow processes directly in the HRRR instead of relying on the interpolation of the RAP guess
• Add cycling of land-sfc fields in the HRRR
• Switch RAP to generate grib2 output directly from post
• Switch to using grib2 MRMS files and create backup capability
• Increase applications of assimilation of radar reflectivity data to a broader spectrum of weather conditions
• Add assimilation of mesonet and radial wind data
• Switch format of RAP history files from binary to parallel netcdf
• Switch format of HRRR history files from netcdf to parallel netcdf
• Add restart capability

– This project is an NWS and NCEP Annual Operating Plan (AOP) milestone for Q3 FY2016
Proposed RAP domain Expansion

Will facilitate development of upcoming NAM/RAP ensemble and aid in initialization of SREF ARW members
Forecast Extensions

• RAP will be increased from 18 to 21 hours
• HRRR will be increased from 15 to 18 hours
• HRRR extension to F18 and upcoming NAMRR implementation set the stage for HREF implementation in 2017
**RAP/HRRR DEPENDENCIES**

**UPSTREAM:** GFS, prepbufr, EnKF, MRMS

**DOWNSTREAM-RAP:** SREF, RTMA/URMA, HRRR, HYSPLIT, Verification

**DOWNSTREAM-HRRR:** RTMA/URMA, Verification

**Upstream dependencies require following enhancements:**
1. Obsproc_rap_v2.1.0 released 1/29/16
2. Switching to hi-res EnKF input files with this upgrade

**Downstream dependencies require following enhancements:**
1. All HRRR changes accounted for in HRRRv2
2. RTMA/URMA upgrade (including common terrain/land mask files) being done simultaneously
3. HYSPLIT changes being coordinated with B Stunder
4. Verification updates coordinated with P Shafran
• HRRRv1 runs with ~85 nodes
• HRRRv2 runs with ~110 nodes
• RAPv2 runs with ~25 nodes
• RAPv3 runs with ~50 nodes
RAP PRODUCT CHANGES

RAP currently generates:

- 13, 20, and 40 km hourly output on pressure levels (grid covering CONUS+)
- 13, 20 km hourly output on native levels (CONUS+)
- 11 km hourly Alaska output
- 13 km hourly full domain output for both native and pressure levels
- 32 km hourly full domain output
- 16 km hourly Puerto Rico output
- smartinit output for CONUS, AK, PR, Juneau zoom
- bufr sounding files

CHANGES

- RAP will output grib2 directly
- extra forecast hours
- add Hawaii grid (243) and smartinit grid
- expanded CONUS smartinit grid
- native grid files will increase in size based on domain change
- all output files will have additional parameters
HRRR PRODUCT CHANGES

HRRR currently generates:
- 3 km output on native and pressure levels and smaller file with sfc parameters
- 2.5 km NDFD/smartinit output
- 15 minute sub-hourly data (small subset of parameters)
- bufr sounding files

CHANGES
- all output files will have additional parameters
- extra forecast hours
- start sending sub-hourly output to AWIPS
CHARTER OVERVIEW

– Expected Benefits to End Users Associated with Upgrade

• Significant improvement in 2-m temperature and dew point biases, particularly the warm, dry late afternoon bias
• Mitigation of these biases significantly feeding back to boundary layer structure and instability, reflectivity, ceiling, and precip forecasts
• Overall improved synoptics
• Improvements to 10-m winds
RUPv3/HRRRv2 Warm/Dry Bias Mitigation

### Component Mitigating Items

<table>
<thead>
<tr>
<th>Component</th>
<th>Mitigating Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSI Data Assimilation</td>
<td>Canopy water cycling</td>
</tr>
<tr>
<td></td>
<td>Temp pseudo-innovations thru model boundary layer</td>
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<td></td>
<td>More consistent use of surface temp/dewpoint data</td>
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<tr>
<td>GFO Convective Parameterization</td>
<td>Shallow cumulus radiation attenuation</td>
</tr>
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<td>Improved retention of stratification atop mixed layer</td>
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<tr>
<td>Thompson Microphysics</td>
<td>Aerosol awareness for resolved cloud production</td>
</tr>
<tr>
<td></td>
<td>Attenuation of shortwave radiation</td>
</tr>
<tr>
<td>MYNN Boundary Layer</td>
<td>Mixing length parameter changed</td>
</tr>
<tr>
<td></td>
<td>Thermal roughness in surface layer changed</td>
</tr>
<tr>
<td></td>
<td>Coupling boundary layer clouds to RRTMG radiation</td>
</tr>
<tr>
<td>RUC Land Surface Model</td>
<td>Reduced wilting point for more transpiration</td>
</tr>
<tr>
<td></td>
<td>Keep soil moisture in croplands above wilting point</td>
</tr>
</tbody>
</table>

**WCOSS Science Quarterly** • **RUPv3/HRRRv2** • **18 November 2015**
Huge reductions in skin temps
With significant positive impact on 2-m temps
Mitigation of warm, dry bias leads to huge improvement for instability
**Case Studies: HRRRv2 Improved Convective Forecasts**

Better storm environment from physics improvements

**Oper HRRRv1**

**Oper HRRRv1**

**22z + 5hfcst**

**Improved convection** (reduced over-prediction, better location)

**Better storm**

**Environment**

from physics improvements

**Oper HRRRv1**

**Oper HRRRv1**

**Truth 03z**

**13 July 2015**

**Exper HRRRv2**

**Exper HRRRv2**

**00z**

**5 June 2015**

**Observations 00z 22 June 2015**

**Exper HRRRv2**

**18z + 6hfcst**

**Oper HRRRv1**

**Oper HRRRv1**

**00z 22 June 2015**

**Exper HRRRv2**

**18z + 6hfcst**

**Oper HRRRv1**
Case Studies HRRRv2: Winter Precipitation

WPC Snowfall Analysis

Early Snowfall Accumulation Period
15-hr forecasts valid from 20z 22 Jan – 11z 23 Jan 2016

Late Snowfall Accumulation Period
15-hr forecasts valid from 12z 23 Jan – 03z 24 Jan 2016

Reduction of precip SE of DCA-PHL axis
DEVELOPMENT TESTING

- RAPv3/HRRRv2 developed/tested at GSD for 2+ years
- Code frozen February 2015
- Built at EMC in spring/summer 2015

VERIFICATION

- GSD will provide real-time and retrospective statistics, generated from their RAP/HRRR systems run with same version of code
- EMC Stats unreliable due to
  - too many broken cycles
  - inability to run the HRRR every hour due to contention for resources
  - error introduced into microphysics by IBM that is not in the ESRL backup
- Testing being performed to confirm that the systems match
Reproducibility from GSD to EMC

RAPv3 (GSD)  RAPv3 (EMC)

9-hr 500 mb Temps

12-hr 2-m Temps
RAPv3 Winter Retro Verification: Surface

CONUS 01 - 31 Jan 2015

Exper RAPv3       Oper RAPv2     RAPv3 - RAPv2 Difference

RAP Surface 12-hr Forecast RMSE

RAP Surface 12-hr Forecast Bias

Reduced bias

Reduced fast bias
RAPv3 Summer Retro Verification: Surface


Exper RAPv3       Oper RAPv2       RAPv3 - RAPv2 Difference

RAP Surface 12-hr Forecast RMSE

- 2m Temp
- 2m Dewpt
- 10m Wind

RAP Surface 12-hr Forecast Bias

- 2m Temp
- 2m Dewpt
- 10m Wind

Reduced warm bias
Reduced dry bias
Reduced fast bias
RAPv3 Winter Retro Verification: UpperAir

US 15 01 – 31 Jan 2015

Exper RAPv3  Oper RAPv2  RAPv3 - RAPv2 Difference

RAP Upper-Air 6-hr Forecast RMSE

RAP Upper-Air 12-hr Forecast RMSE

Reduced warm bias

Reduced fast bias
RAPv3 Summer Retro Verification: UpperAir


Exper RAPv3       Oper RAPv2     RAPv3 - RAPv2 Difference

RAP Upper-Air 12-hr Forecast RMSE

RAP Upper-Air 12-hr Forecast BIAS (00 UTC Only)

Reduced warm bias

Reduced slow bias
RAPv3 Winter Retro Verification: Precip

Eastern US 01 – 31 Jan 2015

Exper RAPv3       Oper RAPv2

RAP Eastern US Precipitation 6-hr Forecast

<table>
<thead>
<tr>
<th>CSI 13-km</th>
<th>CSI 20-km</th>
<th>BIAS 13-km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moist</td>
<td>Moist</td>
<td>Moist</td>
</tr>
</tbody>
</table>

CSI (x100, matched)

BIAS (x100, matched)

0.01 0.10 0.25 0.5 1.0 1.5 2.0 3.0 (in)
Reduced moist bias at low precip thresholds

Reduced dry bias at high precip thresholds
<table>
<thead>
<tr>
<th>Date Range</th>
<th>Experiment 1</th>
<th>Experiment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern US 1 – 31 Jan 2015</td>
<td>Exper HRRRv2</td>
<td>Oper HRRRv1</td>
</tr>
<tr>
<td>HRRR Eastern US Precipitation 6-hr Forecast</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CSI 3-km</td>
<td></td>
<td></td>
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<tr>
<td>CSI 40-km</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BIAS 3-km</td>
<td></td>
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</tbody>
</table>

 CSI (x100, matched) vs Forecast Length (Hr)

<table>
<thead>
<tr>
<th>Date Range</th>
<th>Experiment 1</th>
<th>Experiment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern US 15 Jul – 15 Aug 2015</td>
<td>Exper HRRRv2</td>
<td>Oper HRRRv1</td>
</tr>
<tr>
<td>HRRR Eastern US Precipitation 6-hr Forecast</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CSI 3-km</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CSI 40-km</td>
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</tbody>
</table>
HRRRv1 to v2 Reflectivity Forecast Skill

May-June 2015

- 40 dBZ
  - 35 dBZ
  - 30 dBZ
  - 25 dBZ

Low Bias   CREF High Bias

HRRRv1 (oper) HRRRv2 (exper)

High Afternoon Bias Persists Lower Thresholds Improved in HRRRv2
GSI minimization warning
Warning in minimization

• Final gnorm gross check failure:
  – in both the operational and parallel RAPs
  – changed the threshold on the convergence warning from the default of 3.5e-4 to 6.0e-3 to remove the convergence warnings
  – executed RAP regression test to see the impact of doubling the inner loop count (50 to 100)
    • A doubling of the runtime (8 to 15 min)
    • RAP retros with 50 inner loop and 100 inner loop produce almost identical forecast results (see next couple of slides)

Case study:
Final gnorm from GSI with 100 inner loops: 1.683612468420213871E-06
Final gnorm from GSI with 50 inner loops: 2.989984336024733972E-04

• Gnorm check (reset):
  – Only in the operational RAP
  – This problem is resolved in the parallel RAP
    • inclusion of more radiance data (RARS)
    • cycled radiance bias correction
Vertical RMSE profile for 0 and 1 hour forecast.

- **Red**: GSI with 50 inner loops
- **Blue**: GSI with 100 inner loops

### 0-hr Winds
- Pressure (hPa), matched
- 0-hr Winds
- Pressure (hPa), matched
- 0-hr Winds

### 0-hr RH
- Pressure (hPa), matched
- 0-hr RH
- Pressure (hPa), matched
- 0-hr RH

### 0-hr Temp
- Pressure (hPa), matched
- 0-hr Temp
- Pressure (hPa), matched
- 0-hr Temp

### 1-hr Winds
- Pressure (hPa), matched
- 1-hr Winds
- Pressure (hPa), matched
- 1-hr Winds

### 1-hr RH
- Pressure (hPa), matched
- 1-hr RH
- Pressure (hPa), matched
- 1-hr RH

### 1-hr Temp
- Pressure (hPa), matched
- 1-hr Temp
- Pressure (hPa), matched
- 1-hr Temp

Boxes show 95% confidence.
Vertical profile for 3 and 6 hour forecast

3-hr Winds

6-hr Winds

3-hr RH

6-hr RH

3-hr Temp

6-hr Temp

Red: GSI with 50 inner loops  blue: GSI with 100 inner loops
Surface RMSE for 0 and 1 hour forecast

Red: GSI with 50 inner loops  blue: GSI with 100 inner loops
Surface RMS and bias time series for 1 forecast

**1-hr Winds**
- Red: GSI with 50 inner loops
- Blue: GSI with 100 inner loops

**1-hr Dewpoint**
- Red: GSI with 50 inner loops
- Blue: GSI with 100 inner loops

**1-hr Temp**
- Red: GSI with 50 inner loops
- Blue: GSI with 100 inner loops
Plan Schedule

- Concluded schedule
  - Project kick off meeting – Mar 2, 2015
- Remaining schedule
  - EMC CCB meeting – Jan 29, 2016
  - Code Handoff – Feb 5, 2016
  - Submit TIN – Feb 12, 2016
  - NCO 30-day parallel in April
  - Implementation May 12, 2016
Project Information and Highlights

**Lead:** Geoff DiMego and Geoff Manikin, EMC and Steven Earle NCO

**Scope:** Significant upgrade that introduces:
- upgrades to model core and initialization;
- upgrade to assimilation of radar reflectivity data
- expansion of RAP domain to match NAM domain
- extension of forecast length for both models
- updated versions of RAP and HRRR to be implemented simultaneously

**Expected Benefits:**
1. Overall improved skill.
2. Mitigate severe warm, dry daytime bias.
3. Keep RAP and HRRR codes consistent.
4. Set the stage for future RAP/NAM ensemble.

**Issues/Risks**

**Issues:** cannot run every HRRR cycle in parallel

**Risks:** difficult to accurately verify model, now that some cycling is being added

**Mitigation:** must rely on supplemental ESRL statistics

### Scheduling

<table>
<thead>
<tr>
<th>Milestone (NCEP)</th>
<th>Date</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial coordination with SPA team</td>
<td>02/20/2015 → 3/3/2015</td>
<td>Complete</td>
</tr>
<tr>
<td>EMC testing complete / EMC CCB</td>
<td>03/15/2015 → 5/8 → 08/24 → 11/13 → 1/15/2016</td>
<td></td>
</tr>
<tr>
<td>Final Code Delivered to NCO</td>
<td>03/29/2015 → 5/26 → 9/1 → 11/20 → 1/22/2016</td>
<td></td>
</tr>
<tr>
<td>SPA begins prep work for 30 day test ** Requires 2 SPAs for this work</td>
<td>03/30/2015 → 5/27 → 9/2 → 11/23 → 1/25/2016</td>
<td></td>
</tr>
<tr>
<td>IT testing ends</td>
<td>5/15/2015 → 7/15 → 10/10 → 2/15/2016 → 4/21/2016</td>
<td></td>
</tr>
<tr>
<td>Management Briefing</td>
<td>06/19/2015 → 8/7 → 11/13 → 2/26/2016 → 5/7</td>
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</tbody>
</table>

### Finances

**Associated Costs:**
- HRRR and RAP task usage will both increase by 2x
- some additional AWIPS products will likely be added in conjunction with extension of forecast length