HI-RES RAPID REFRESH (HRRR)
Initial Implementation V1.0.1

EMC Change Configuration Board
August 6, 2014

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Collaborators: Curtis Alexander, Stan Benjamin, Steve Weygandt, David Dowell, Eric James, Ming Hu, Tanya Smirnova, John Brown, Joe Olson, and the rest of the ESRL/GSD crew

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Jianbing Yang, Becky Cosgrove, Justin Cooke, Carissa Klemmer, Boi Vuong, Chris Magee  NCO
Jim Taft, John Michalakes, Jim Abeles  IBM
Charter Overview

– This project is an NWS and NCEP Annual Operating Plan (AOP) milestone for Q4 FY2014

– Implementation scheduled for 23 September 2014

– Hi-Res Rapid Refresh description
  • Used by SPC, AWC, WPC, FAA, NWS offices and others for details short-range forecasts, especially convective evolution
  • 24 cycles/day – each run out to 15 hours
  • No cycling
Rapid Refresh and HRRR
NOAA hourly updated models

13km Rapid Refresh (RAP) (mesoscale)
V2 in ops: 2/25/14

3km HRRR (storm-scale)

High-Resolution Rapid Refresh
Scheduled NCEP Implementation Sept 2014
We have the RAP – why do need the HRRR?

- Increased resolution of basic fields like temperatures/winds/visibility, etc. to resolve mesoscale features
- Explicitly resolves convection, allowing for storm-scale structure; shows skill at predicting storms with strong rotation, bow echoes, etc.
- Provides hourly updates at high resolution
- Will provide high-resolution 1st guesses to RTMA/URMA
High Impact Prediction Needs: Higher Resolution Models

- 40 km RUC 1998 (1.5x resolution)
- 20 km RUC 2002 (3x resolution)
- 13 km RUC/RAP 2005/2012 (4.6x resolution)
- 3 km HRRR 2014 (20x resolution)
High Impact Prediction Needs: Higher Resolution Models

07 June 2012 5 PM EDT
Reality

3-km HRRR
Explicit Convection 6 hr forecast

13-km RAP
Parameterized Convection 6 hr forecast

Aircraft must Navigate Around Thunderstorms

Accuracy Storm Structure
Accurate Estimate of Permeability

No Storm Structure
No Estimate of Permeability
Hurricane Arthur
Why run the HRRR at NCEP?

- GSD version has a significant time lag – often completes over 2 hours after the synoptic start time; NCEP version F00 available 44 minutes past the start time, with final products available 83 minutes after start time
- GSD must often truncate or even cancel cycles
- GSD runs subject to jet outages
- GSD can put more time into model development instead of maintaining HRRR data feed and web site with graphics
- Generate bufr and gempak data
- Get data into AWIPS
HRRR Availability

HRRR 12 hr fcst availability
Includes all missed/incomplete runs

Jet (HRRR primary)  Zeus (HRRR backup)  Union
HRRR Basic Overview

- Runs every hour (24/day)
- Uses previous hour’s post-digital filter RAP analysis interpolated from 13 km to 3 km to initiate pre-forecast period
- Uses previous hour’s RAP forecast for boundary conditions (01/13z HRRR uses 2-hr old RAP due to 00/12z RAP having later start time)
- Runs a 1-hr spin-up forecast, using temperature tendencies obtained from processing radar data every 15 minutes to help properly initialize ongoing precipitation
- Runs a 3 km GSI after spin-up forecast to assimilate new data and a separate GSI to assimilate hydrometeor obs
- Model forecast is integrated out to 15 hours
- Full post-processing is done for every forecast hour; subset of fields is post-processed every 15 minutes
- Bufr output and gempak data generated for each forecast hour; gempak files also generated for the smaller sub-hourly data sets
Structure – Part 1: Before the Forecast

- Interpolation of RAP guess: 2 min
- Process radar data: 4 min
- Make boundary conditions: 10 min (not needed until free forecast)
- Process cloud data: < 1 min
- Generate temp. tendencies: 2.5-3 min
- 1-hr spinup forecast: 5-6 min
- GSI (analysis): 5-6 min

4 min + 3 min + 5 min + 6 min = 18 min
RESOURCES – allocated ~80 nodes

• Interpolation of RAP guess:  6 nodes
• Process radar data: 4 min:  4 nodes
• Make boundary conditions: 6 nodes
• Process cloud data:  1 node
• Generate temp. tendencies:  1 node
• 1-hr spinup forecast: 75 nodes
• GSI (analysis): 30 nodes

- 3 minute overlap between the spinup forecast and the boundary processing
Temperature Tendency (i.e. Latent Heating) = f(Observed Reflectivity)
LH specified from reflectivity observations applied in four 15-min periods
NO digital filtering at 3-km
Reflectivity observations used to specify latent heating in previous 15-min period as follows:
• Positive heating rate where obs reflectivity ≥ 28 dBZ over depth ≥ 200 mb (avoids bright banding)
• Zero heating rate where obs reflectivity ≤ 0 dBZ
• Model microphysics heating rate preserved elsewhere

\[ LH(i, j, k) = \frac{1000 \cdot R_d / c_p}{p} \frac{(L_v + L_f)(f[Z_e])}{t \cdot c_p} \]

LH = Latent Heating Rate (K/s)
p = Pressure
L_v = Latent heat of vaporization
L_f = Latent heat of fusion
R_d = Dry gas constant
c_p = Specific heat of dry air at constant p
f[Z_e] = Reflectivity factor converted to rain/snow condensate
t = Time period of condensate formation (600s i.e. 10 min)
Why use almost 20 minutes to run a 1-hr spin-up?
HRRR 2013 3-km GSI HM Analysis

Composite Reflectivity
Derived From Mosaic3D

Obs 23z
30 May 2012

0-hr anx
No 3-km radar DA 2012 HRRR

0-hr anx
3-km radar DA 2013 HRRR
Statistical Retrospective Comparison
30 May - 04 June 2012 (55 matched runs)
3-km grid ≥ 35 dBZ
Eastern US

Improve 0-4 hr convection
Structure – Part 2: Forecast and Products

- 15-hr model forecast: ~39-40 min
- Simultaneous hourly post-processing + smartinit: ~7 min each
- Simultaneous hourly wrfbufr: 1-2 min each
- Simultaneous subhourly post-processing: 2 min each
- Sounding post (bufr): 2 min
- Gempak: runs alongside post manager
RESOURCES – allocated ~80 nodes

- 15-hr model forecast: 70 nodes
- Simultaneous hourly post-processing: 2 nodes each
- Simultaneous hourly wrfbufr: 1 node each
- Simultaneous sub-hourly post-processing: 2 nodes each
- Sounding post (bufr): 1 node (shared)
- Gempak: 1 node (shared)

- Maximum overlap is 3 hourly post jobs, 2 subhourly post jobs, the gempak job, and 1 wrfbufr job for a system total of 82 nodes
- Efforts to further speed up forecast job were unsuccessful
POLICY for “LATE” RUNS

• NCEP HRRR completes in ~63 minutes (forecast job is finished by ~57 minutes)

• By the 66 minute mark, the next hour’s 1-hr spin-up forecast needs all of the nodes

• When the current hour’s spin-up forecast is ready to begin, if the previous hour’s free forecast has not yet reached F14, the current hour’s cycle will be canceled

• This scenario has been rare during testing, occurring only when there are significant system glitches
Validation with ESRL HRRR (Zeus)
DEPENDENCIES

**UPSTREAM:** RAP, RAP obs processing, RAP “early” 00/12z obs processing

**DOWNSTREAM:** RTMA (eventually), HRRRE-TL (eventually)

Implementation requires following enhancements:

1. Implementation of corrected g2tmpl library
DEVELOPMENT TESTING

- CONUS HRRR run at GSD for 4+ years
- Built at EMC Jan-May 2014
- Using 2013 version except for bug fix to address cold bias over snow pack
- Issue with discontinuity involving terrain at boundaries resolved in early July
- Only other crashes were caused by configuration settings suggested by IBM – were able to speed up forecast by 3 minutes, but occasional crashes occurred
- NCO parallel running stably since early July – only changes since have been to post-processing
- 30-day evaluation to begin 8/11
### PROPOSED EVALUATION TEAM

<table>
<thead>
<tr>
<th>Organization</th>
<th>Recommended</th>
<th>Optional (nice to have)</th>
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</thead>
<tbody>
<tr>
<td>NCEP Centers</td>
<td>EMC, NCO</td>
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<tr>
<td>NCEP Service Centers</td>
<td>WPC, SPC, AWC</td>
<td>OPC, NHC</td>
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<tr>
<td>NWS Region / WFO</td>
<td>ER, CR, SR, WR</td>
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<tr>
<td>Other NWS or NOAA components</td>
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<td></td>
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<tr>
<td>External Customers / Collaborators</td>
<td>FAA</td>
<td></td>
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</table>

GSD has set up web site to provide graphics from NCEP parallel run
PRODUCTS

For each forecast hour (16), generate
- 3 km file with data on pressure levels  350 MB (each file)
- 3 km file with data on native levels      545 MB
- 3 km file with mostly 2-D (surface) data  82 MB
- 2.5 km NDFD file for AWIPS    96 MB
- bufr sounding file   22 MB          gempak file  210 MB

16.4 GB per cycle / 400 GB per day
  gempak files add 3.3 MB per cycle/ 80 GB per day

For every 15 minutes, generate
- 3 km file with very limited 2-D (surface) data    22 MB
- Time labels are in minutes
- Cat 15/30/45/60 past hour into a single file     75 MB
- gempak file   71.2 MB

1.05 GB per cycle / 25.2 GB per day
  gempak adds 1.14 GB/cycle / 27.4 GB per day
<table>
<thead>
<tr>
<th>Disk Usage</th>
<th>Current Production</th>
<th>Expected New Production</th>
<th>Actual New Production</th>
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</thead>
<tbody>
<tr>
<td>IBM Disk</td>
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<td>1.6 TB/day</td>
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<td>IBM Tape</td>
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<td>TDB</td>
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<tr>
<td>NCEP FTP Server</td>
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<td>425 GB/day</td>
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<tr>
<td>NWS FTP Server</td>
<td>-</td>
<td>Same?</td>
<td>-</td>
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</table>
Observed radar reflectivity – 2100 UTC 20 May 2013
3-member HRRR ensemble
Max 1h updraft helicity
Preview of NCEP RAPv3/HRRRv2

Improved 2-m 12 hr **temperature forecasts** with reduction of warm bias
Eastern US Time Series

**BIAS (Forecast – Obs)**

- Developmental ESRL RAPs with DA and model changes (candidates for final RAPv3)
- Primary ESRL RAP with initial RAPv3 code
- Operational NCEP RAPv2

**RMSE**

Optimal Bias = 0.0

← Warm
Preview of NCEP RAPv3/HRRRv2

Improved 2-m 12 hr **dewpoint forecasts** with reduction of dry bias
Eastern US Time Series

BIAS (Forecast – Obs)

Optimal Bias = 0.0

---/-- Developmental ESRL RAPs with DA and model changes (candidates for final RAPv3)
-- Primary ESRL RAP with initial RAPv3 code
-- Operational NCEP RAPv2

RMSE

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Hi-Resolution Rapid Refresh v1.0.0  
Project Status as of 8/6/14

Project Information and Highlights

Lead: Geoff DiMego, Geoff Manikin EMC and Chris Magee, NCO

Scope:
1. Initial version of 3 km Hi-Res Rapid Refresh
2. Similar to RAP but allows explicit convection
3. Initialized from previous hour’s RAP analysis interpolated to 3 km. Radar data assimilated every 15 minutes to allow a one-hour “spinup” forecast, followed by a final 3 km GSI.
4. Output generated every 15 minutes of forecast

Expected Benefits:
1. Hourly hi-resolution forecasts of convective evolution and structure along with various parameters relevant to severe storm, aviation, and winter weather forecasting

Issues/Risks

Issues: no margin for error with 30-day evaluation period
Risks: any clock reset or CWD will push this to Q1FY15
Mitigation: lots of praying

Scheduling

<table>
<thead>
<tr>
<th>Milestone (NCEP)</th>
<th>Date</th>
<th>Status</th>
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<tr>
<td>EMC testing complete</td>
<td>6/30/2014</td>
<td>COMPLETED</td>
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<tr>
<td>Final code submitted to NCO</td>
<td>7/7/2014</td>
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<tr>
<td>Technical Information Notice Issued</td>
<td>8/1/2014</td>
<td>COMPLETED</td>
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<tr>
<td>EMC CCB Approval</td>
<td>8/6/2014</td>
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<tr>
<td>Parallel testing begun in NCO</td>
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<td>IT testing begins</td>
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<td>IT testing ends</td>
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<tr>
<td>Real-time evaluation begins</td>
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<td>Management Briefing</td>
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<td>Implementation</td>
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Finances

Associated Costs:

Funding Sources:

Management Attention Required  Potential Management Attention Needed  On Target