2011 improvements in weather guidance for aviation from hourly updated NOAA models: *HRRR, Rapid Refresh*

Key info
- 3km HRRR – switch from RUC to Rapid Refresh parent – April 2011
- 13km Rapid Refresh replacing 13km RUC
  - final testing at NCEP, planned implementation – Dec11–Jan12
- HRRR – key component for CoSPA
  - 2012 – 3km radar assimilation, radial wind, soil adjustment

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Steve Weygandt, Curtis Alexander, Ming Hu,
Tanya Smirnova, David Dowell, rest of ESRL team,
NCAR, NCEP, CoSPA partners (MIT/LL,NCAR)

*Friends and Partners in Aviation Weather*
12 October 2011 - Las Vegas - NBAA
Hourly Updated NOAA NWP Models

Rapid Refresh (RR) replaces RUC at NCEP in Dec11-Jan12
WRF, GSI with RUC features

13km Rapid Refresh (mesoscale)

13km RUC (mesoscale)

3km HRRR (storm-scale)

RUC – current oper model, new 18h fcst every hour

High-Resolution Rapid Refresh
Experimental 3km nest now inside RR, new 15-h fcst every hour
## NOAA/ESRL/GSD/AMB Models

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<tr>
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<th>Grid Spacing</th>
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**Changes for HRRR in 2011**

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Key changes to 3km HRRR since last FPAW in October 2010

- **Change of parent model from RUC to Rapid Refresh** – April 2011
  - Community frameworks - WRF-ARW model, GSI data assimilation
  - Additional observations – Satellite radiances, aircraft water vapor (UPS, SWA), boundary-layer profilers
  - Much improved initialization for tropical cyclones
- **Less diffusion in HRRR model** – April 2011
  - Increases # of smaller storms, avoided mountain wave problems
- **Improved scripts, trick added to increase speed of WRF model**
  - 30 min faster availability
- **Added assimilation of surface pseudo-observations in boundary layer** – 7 July 2011
  - Less moist bias, helped reduced excessive convective storm coverage in May-June 2011
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Severe weather outbreak – tornadoes in Alabama including Tuscaloosa
HRRR skill in 2011 vs. 2010

E. US – 25 dBZ, averaged to 40km, 10 July - 30 Sept

Averaged over all forecast durations (1h-12h) valid at each time of day

HRRR-2011 had a much higher PODy, especially for 15z-21z.

But HRRR-2011 also had too high a bias (from too moist soil). Granted, HRRR-2010 was too low (dry) from 08z-21z.
HRRR Experiments – does radar help?

RUC -- HRRR
RR -- HRRR

RUC -- HRRR
RR -- HRRR

Every 2 hours
Every 1 hour

REAL-TIME
RETROSPECTIVE

NO radar assimilation
YES radar assimilation

Aug 2011
11 12 13 14 15 16 17 18 19 20 21
“parent” — — — — vs. “child” — — — —

Reflectivity Verification

25 dBZ 13-km
Eastern US

Matched Comparison
12,13,14,19 Aug. 2011
All init times

→3-km fcsts improve upon parent 13-km forecasts
→ radar assim adds skill at both 13-km and 3-km
Transition from RUC to Rapid Refresh at NCEP

• Implementation now expected Dec 2011 – Jan 2011
• 3-mo delay due to prior NAM implementation delays
  – Large NCEP model implementations must be sequential
• Significant changes in RR since FPAW in Oct 2010, especially in Nov-December 2010
  – Key problems in WRF model and data assimilation solved
• Rapid Refresh (initial version) frozen in March 2011
  – ESRL version through Oct 2011 (for CoSPA)
• Changes now in development for **RR version 2**.
  – RRv2 – to be implemented at ESRL during Nov11 to Mar12
    • Will improve HRRR forecasts in 2012
  – RRv2 at NCEP later in 2012 pending NCEP computer availability
CoSPA Operational Evaluation Periods

HRRR Hourly Reliability (≥ 12 hr forecast)
All Missed/Incomplete Runs

HRRR Availability

CoSPA Operational Evaluation Periods

3 month running average
CoSPA Operational Evaluation Periods

HRRR Hourly Reliability ($\geq$ 12 hr forecast)
More Than One Consecutive Missed/Incomplete Run

HRRR Availability

CoSPA Operational Evaluation Periods

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HRRR Hourly Reliability (≥ 12 hr forecast)
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HRRR Availability

CoSPA Operational Evaluation Periods

3 month running average
HRRR Hourly Reliability (≥ 12 hr forecast)
More Than Three Consecutive Missed/Incomplete Runs

HRRR Availability

CoSPA Operational Evaluation Periods

3 month running average
HRRR computer reliability from NOAA

• **Current – 1 computer running HRRR**
  – NOAA/ESRL – Boulder
  – Current reliability: 97% for last 12h months (allowing up to 3h gaps)

• **2012-14 – 2 computers running HRRR – interim solution**
  – Boulder – computer 1
  – Fairmont, WV – computer 2
  – Expected reliability to increase further to 98.5-99%
  – In discussion: Fill in missing HRRR products with hourly 13km Rapid Refresh and 6-hourly 4km NAM-nest
    • lower quality: can’t have storm-resolving resolution and hourly updating with radar assimilation outside of the HRRR

• **2015 – NCEP running HRRR**
  – NOAA/NCEP computing budget – will allow no increase before 2015
  – Cost of HRRR – 15-22% (!) of current NCEP computing for all operational models (GFS, NAM, RUC, ensembles)

• Computing acquisition for NOAA Research (e.g., HRRR processors funded by FAA and NOAA) has been very efficient
  – Also, very costly to go from ~99% to 99.9%

• **Conclusion:** Interim HRRR computing for 2012-14
HRRR (and RR) Future Milestones

- Conversion of all output to GRIB2 format  
  Apr 2011
- Transition from RUC to RR parent model  
  Apr 2011
- DOE-funded HRRR FTP site for energy industry  
  May 2011
- Update to WRF-ARW v3.3.1  
  Nov 2011
- Reflectivity data assimilation at 3 km scale  
  2012
- Adjustment to soil moisture from surface obs  
  Nov 2011
- Extension of surface obs through boundary layer  
  Jul11, Nov11
- Assimilate radial velocity at 3 km scale  
  2012
- Incorporate SatCast products at 3 km scale  
  2012
- Apply cloud analysis (with METAR and satellite)  
  at 3km resolution  
  2012
Reflectivity Assimilation on 3-km (HRRR) Grid

HRRR (3-km) grid produces convective storms explicitly. Reflectivity-based temp. tendencies are applied during sub-hourly cycling (forward model integration only, no digital filtering).

Reflectivity-based temperature tendency

interpolation from RR, hydrometeor specification
convection develops quickly (RR cycling, DDFI)

11 May 2011 2100 UTC

more accurate representation of system maturity

1-h fcst without 3-km radar cycling

1-h fcst with 3-km radar cycling
Composite Reflectivity
0200 UTC
11 May 2011

more accurate forecast of convective system propagation

12 May 2011 0200 UTC

6-h fcst
without 3-km radar cycling

12 May 2011 0200 UTC

6-h fcst
with 3-km radar cycling
Initial testing – *additional* 3km radar assimilation in 15-min cycle (Radar-DFI in 13-km RR (parent model) **AND 3-km HRRR 15-min cycling**)

Eastern US, Reflectivity > 25 dBZ

**HRRR Reflectivity Verification** – select cases in May-July 2011

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**CSI 03 km**

1x Latent heating rate in RR and HRRR
1x Latent heating rate in RR only

**CSI 40 km**

1x Latent heating rate in RR and HRRR
1x Latent heating rate in RR only

Improved fcst skill from 1-12h adding 3km/15min assim
HRRR Forecast Behavior

**2011**

1. Higher bias in convection over eastern US
2. Difficulty propagating/maintaining MCSs
3. Lead in convective initiation (early AM runs)
4. False alarm cases

**2012 Targets**

1. Lower peak bias in convection over eastern US
2. Less difficulty propagating/maintaining MCSs
3. Improve timing convective initiation (early AM runs)
4. Fewer false alarm cases

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“Simplistic” 13-km latent heating
No 3-km data assimilation

RRv2/HRRR Model Development and Evaluation

“Smarter” 13-km latent heating
3-km radar data assimilation
HRRR (and RR) Recent/Future Milestones

- DOE-funded HRRR FTP site for energy industry
  May 2011
- HCPF - HRRR Convective Probabilistic Forecast
  - 2011 version – May 2011
- Reflectivity data assimilation at 3 km scale
  2012
- Assimilate radial velocity at 3 km scale
  2012
- HRRR demo @ESRL, @WV improves accuracy/reliability
  2012-14
- Rapid Refresh operational at NCEP
  Dec11-Jan12
- Ensemble Rapid Refresh (NARRE) at NCEP
  ~2014
- HRRR operational at NCEP
  2015?
- Ensemble HRRR (HRRRE) at NCEP
  2016?
- Chemistry added to RR and HRRR for
  volcanic ash, visibility, fires
  current testing, real-time ~2017?