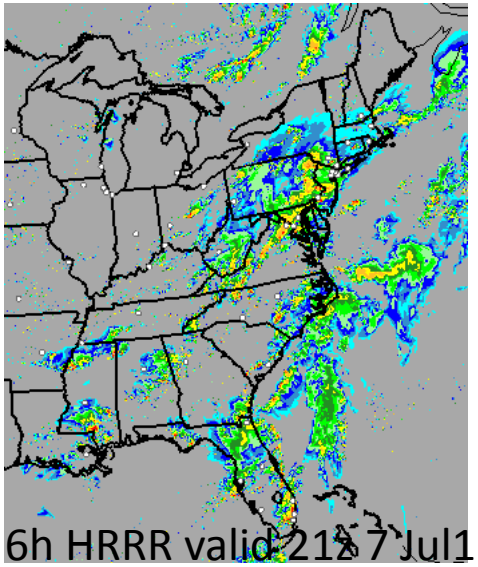
2011 improvements in weather guidance for aviation from hourly updated NOAA models: *HRRR, Rapid Refresh*

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



6h HRRR valid 21Z 7 Jul11

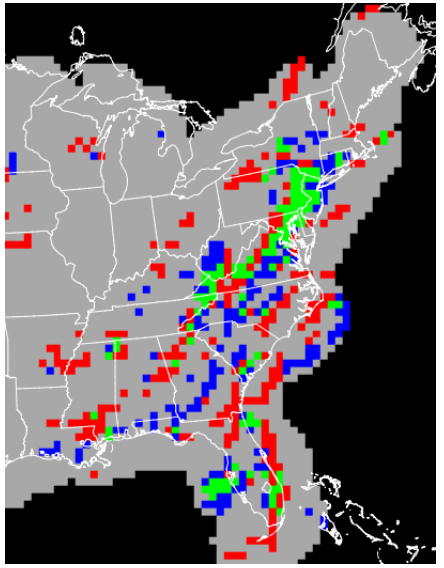
NOAA Earth System Research Lab, Boulder, CO

Stan Benjamin

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

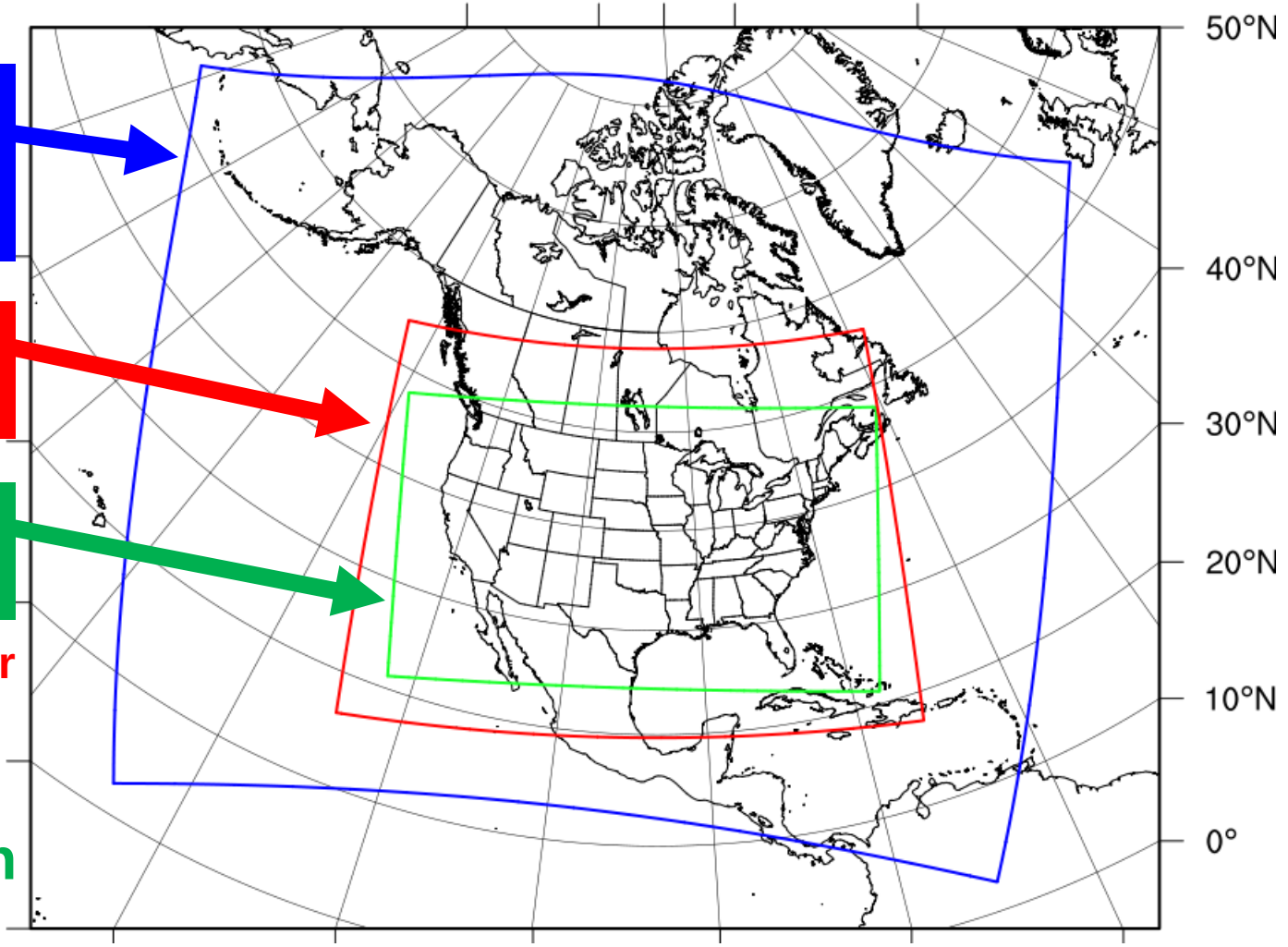


Hourly Updated NOAA NWP Models

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

Model	Run at:	Domain	Grid Points	Grid Spacing	Vertical Levels	Vertical Coordinate	Lowest Level	Pressure Top
RUC	GSD, NCEP	CONUS	451 x 337	13 km	50	Sigma/ Isentropic	5 m	~50 mb
RR	GSD, NCEP-exp	North America	758 x 567	13 km	50	Sigma	8 m	10 mb
HRRR	GSD	CONUS	1799 x 1059	3 km	50	Sigma	8 m	85 mb

Model	Version	Time-Step	Forecast Length	Initialized	Boundary Conditions	Run Time	# of CPUs
RUC	N/A	18 s	18 hrs	Hourly (cycled)	NAM	~25 min	36
RR	WRF-ARW v3.2+	60 s	18 hrs	Hourly (cycled)	GFS	~25 min	160
HRRR	WRF-ARW v3.2+	15-20 s	15 hrs	Hourly (no-cycle)	RUC	~50 min	1000

NOAA/ESRL/GSD/AMB Models

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Changes for HRRR in 2011

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HRRR	WRF-ARW v3.2+	18-23 s	15 hrs	Hourly (no-cycle)	RR	~50 min	1064

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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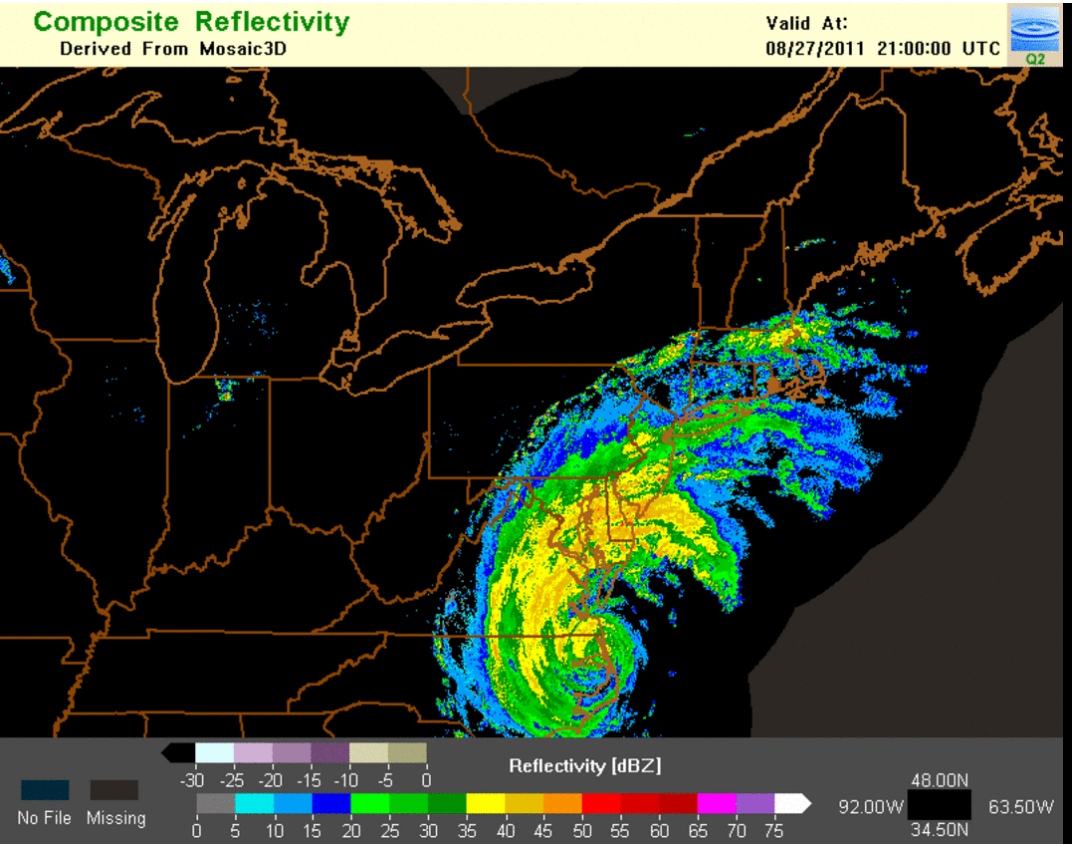
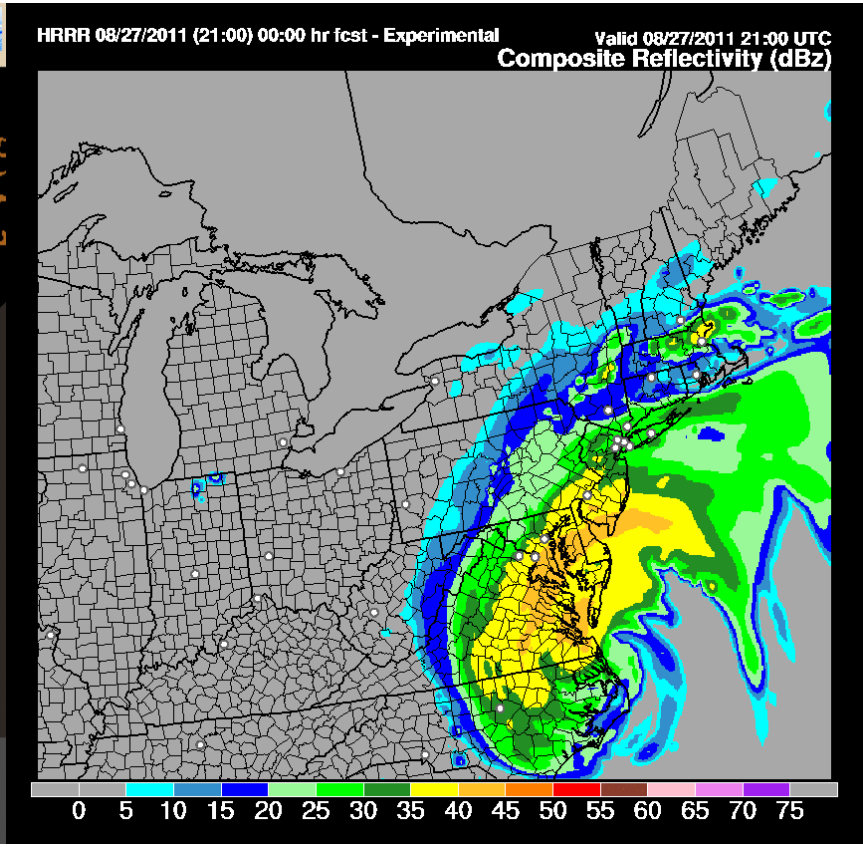
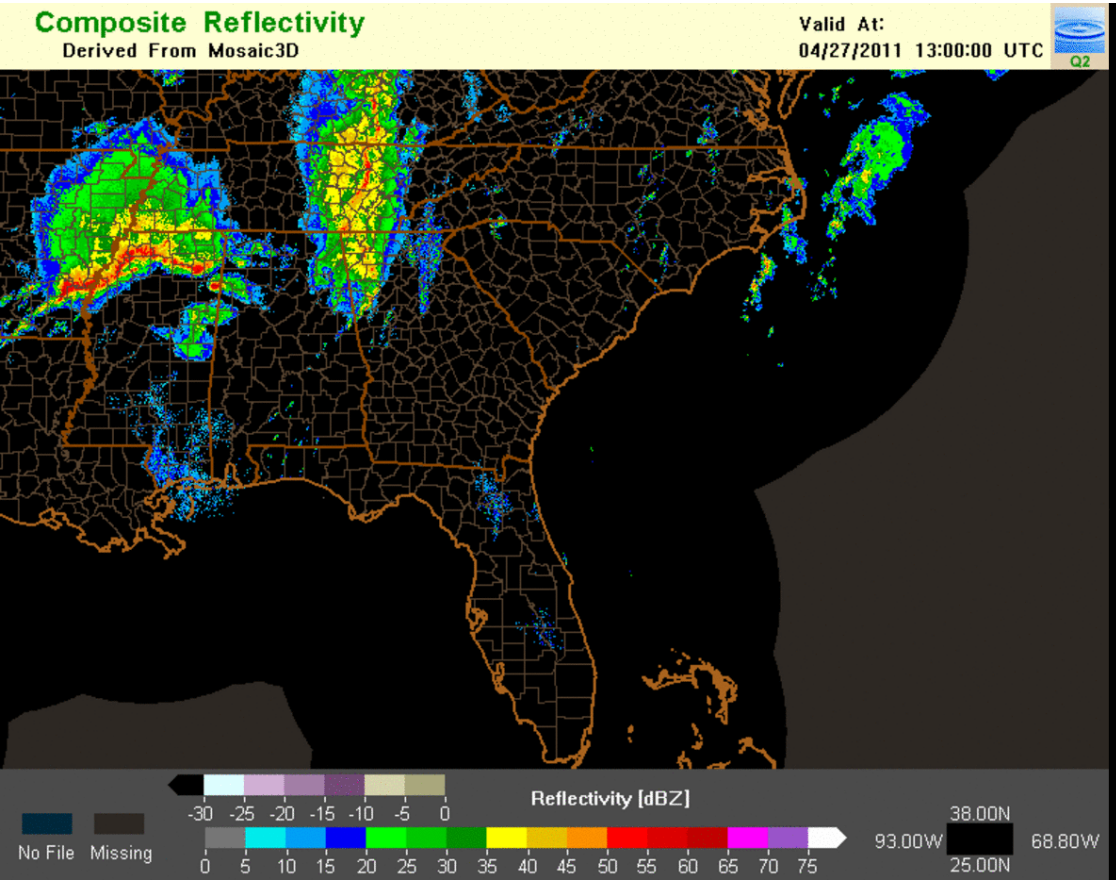
HRRR 15h forecast – 27 August 2011 - Initialized 2100 UTC

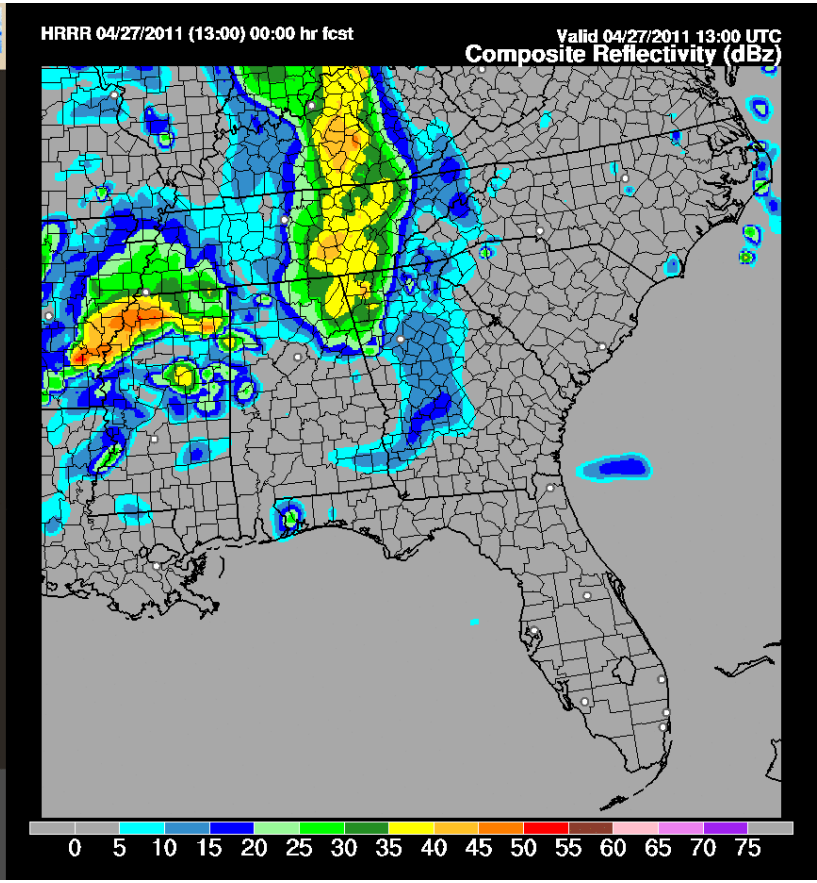




Hurricane (Tropical Storm) Irene

HRRR 15h forecast – 27 April 2011
Initialized 1300 UTC



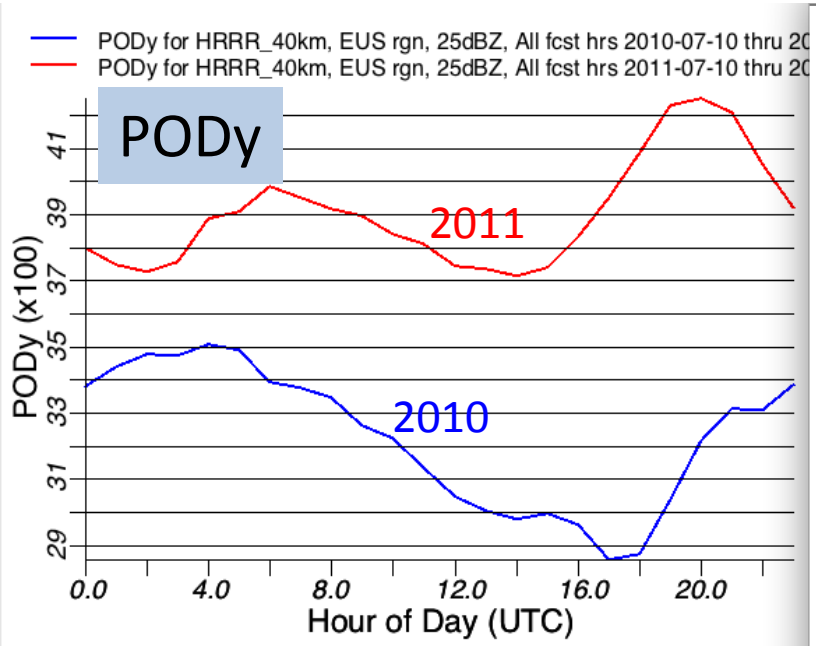


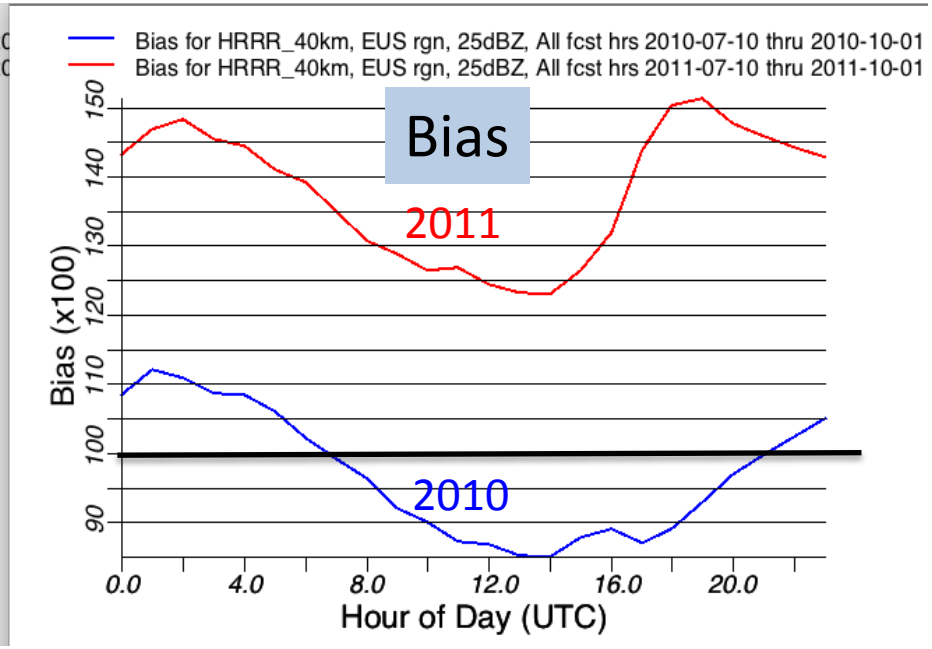
Severe weather outbreak – tornadoes in Alabama including Tuscaloosa

HRRR skill in **2011** vs. **2010**

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

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

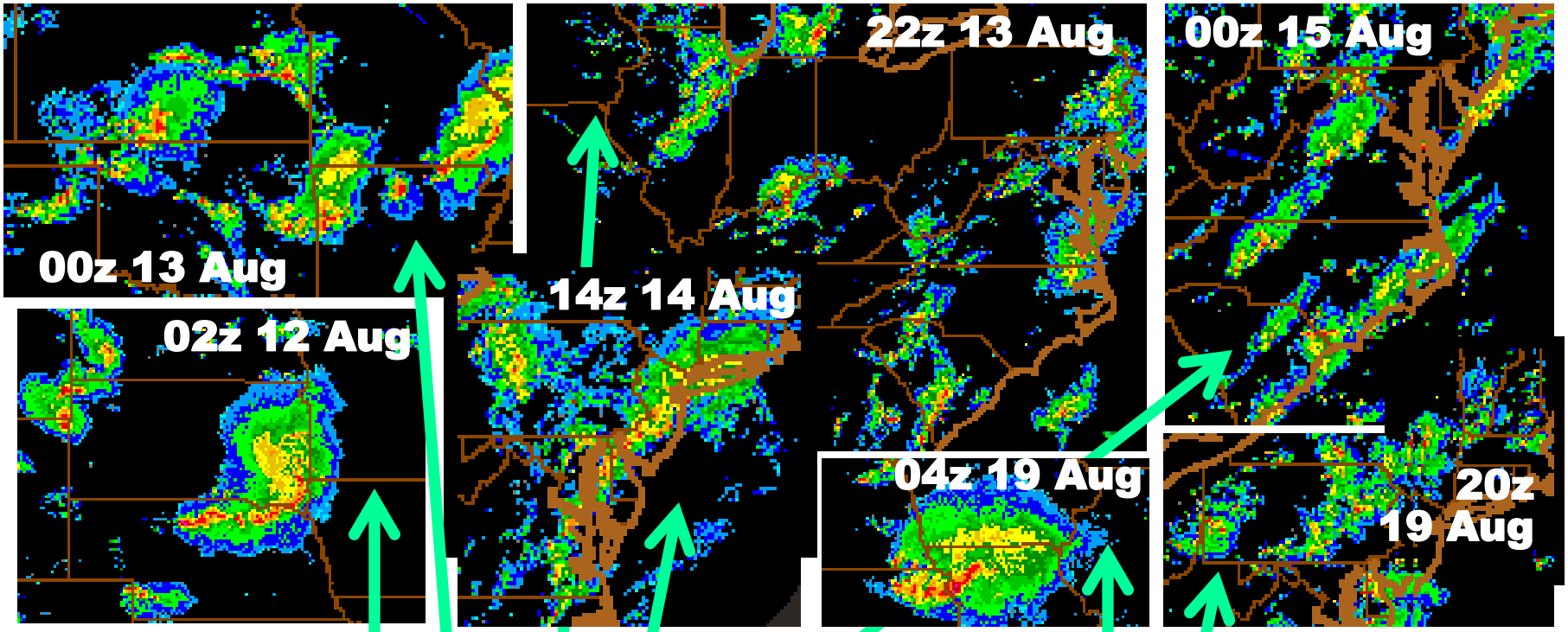




HRRR-2011 had a much higher PODy, especially for 15z-21z.

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

RETROSPECTIVE

NO radar assimilation

RUC -- HRRR Every 2 hours

RR -- HRRR Every 1 hour

REAL-TIME

YES radar assimilation

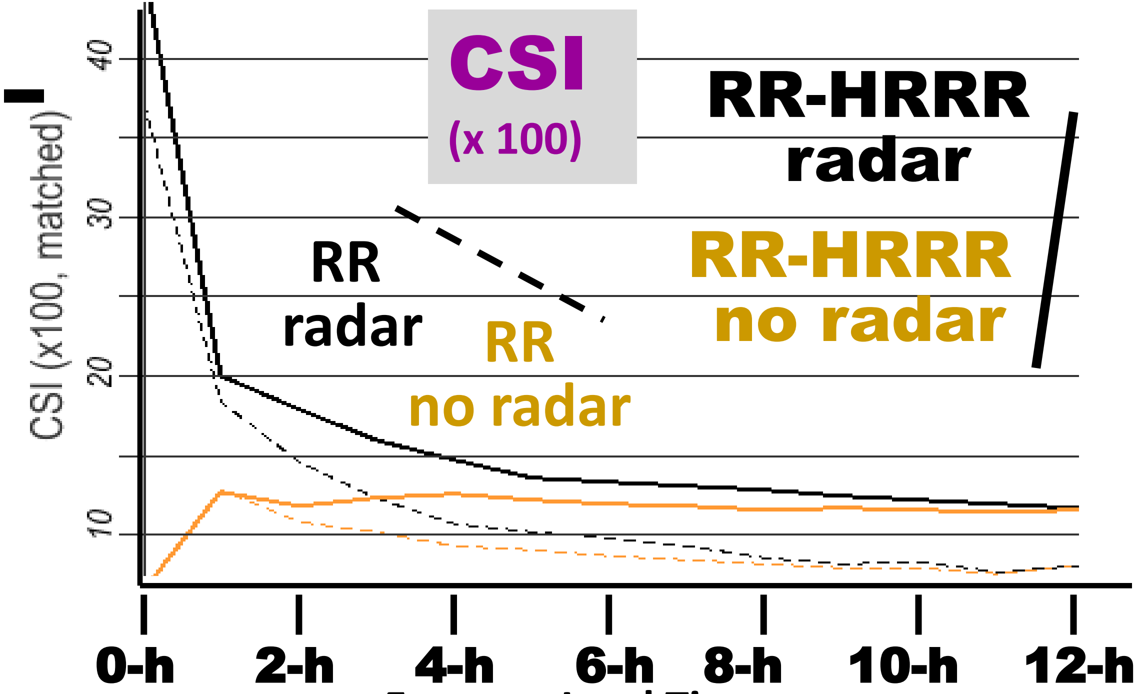
Aug 2011 11 12 13 14 15 16 17 18 19 20 21

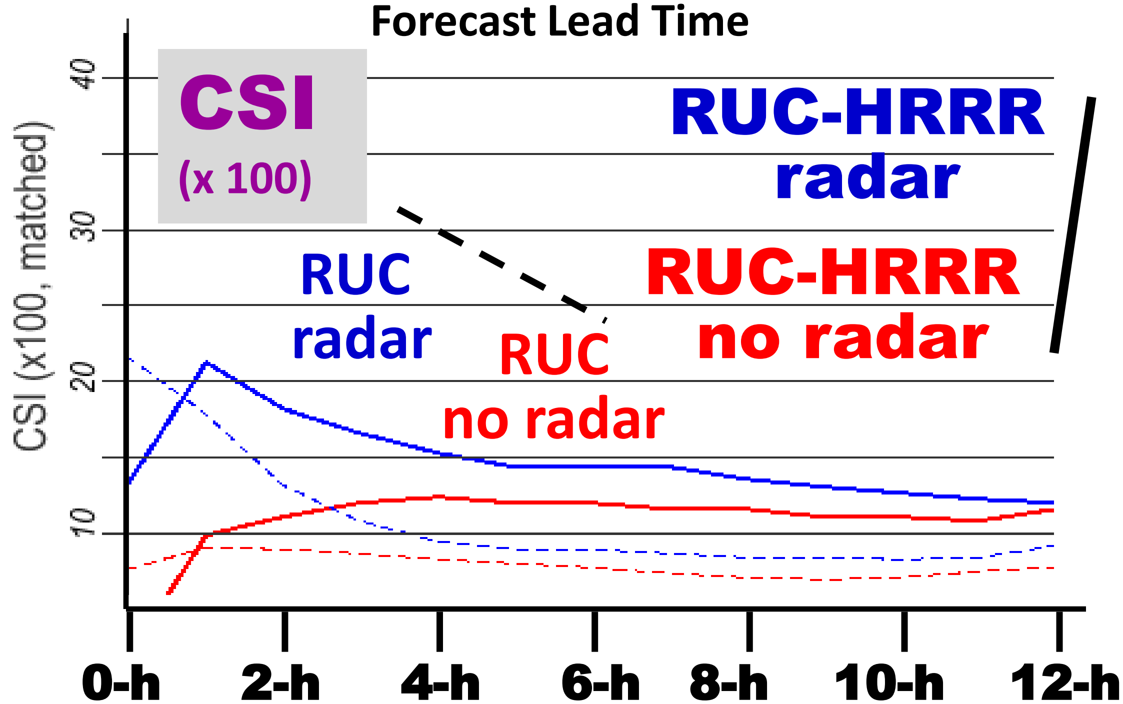
"parent" vs. "child" Reflectivity Verification

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

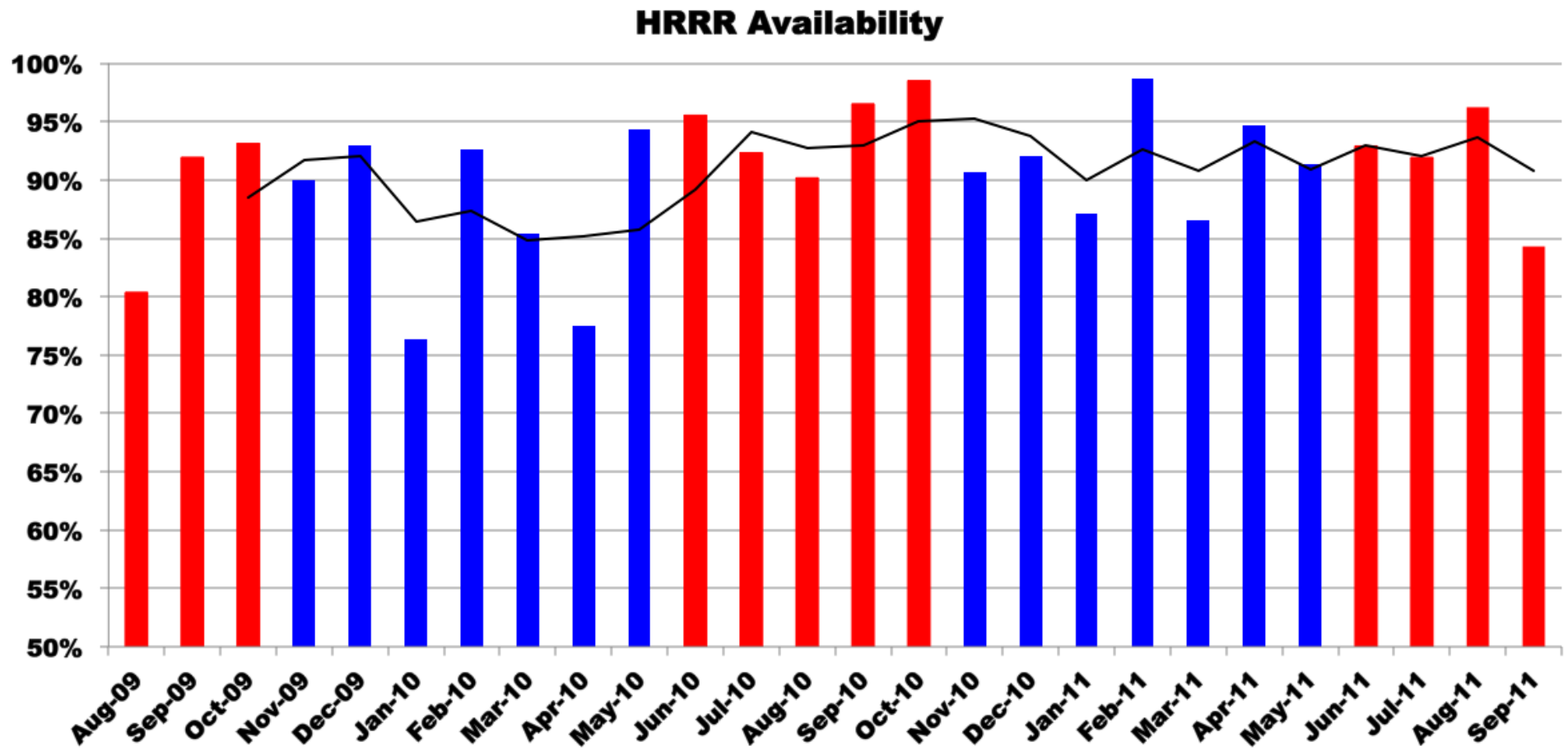




Transition from RUC to Rapid Refresh at NCEP

- 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

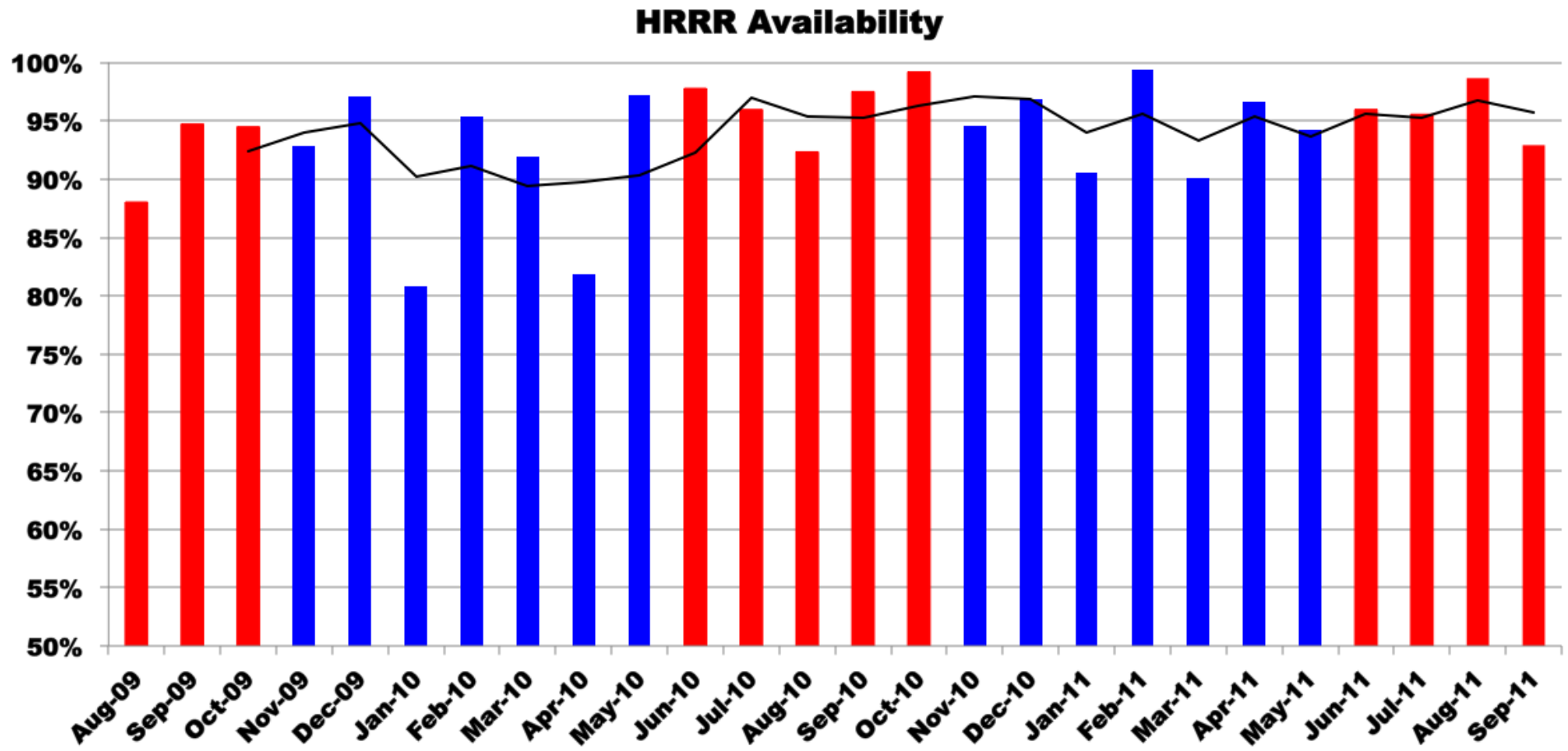
HRRR Hourly Reliability (≥ 12 hr forecast)
All Missed/Incomplete Runs



CoSPA Operational Evaluation Periods

3 month running average

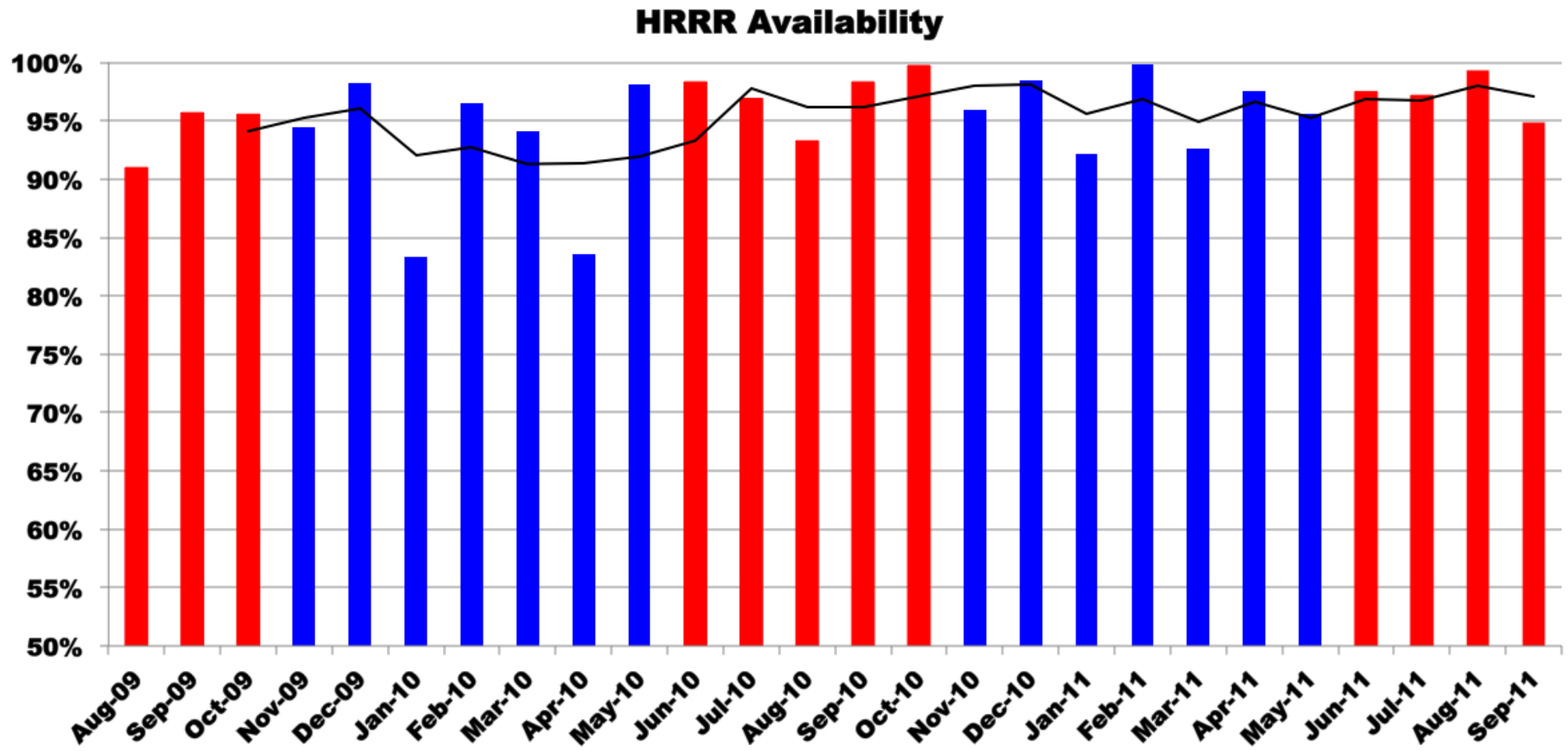
HRRR Hourly Reliability (≥ 12 hr forecast)
More Than One Consecutive Missed/Incomplete Run



CoSPA Operational Evaluation Periods

3 month running average

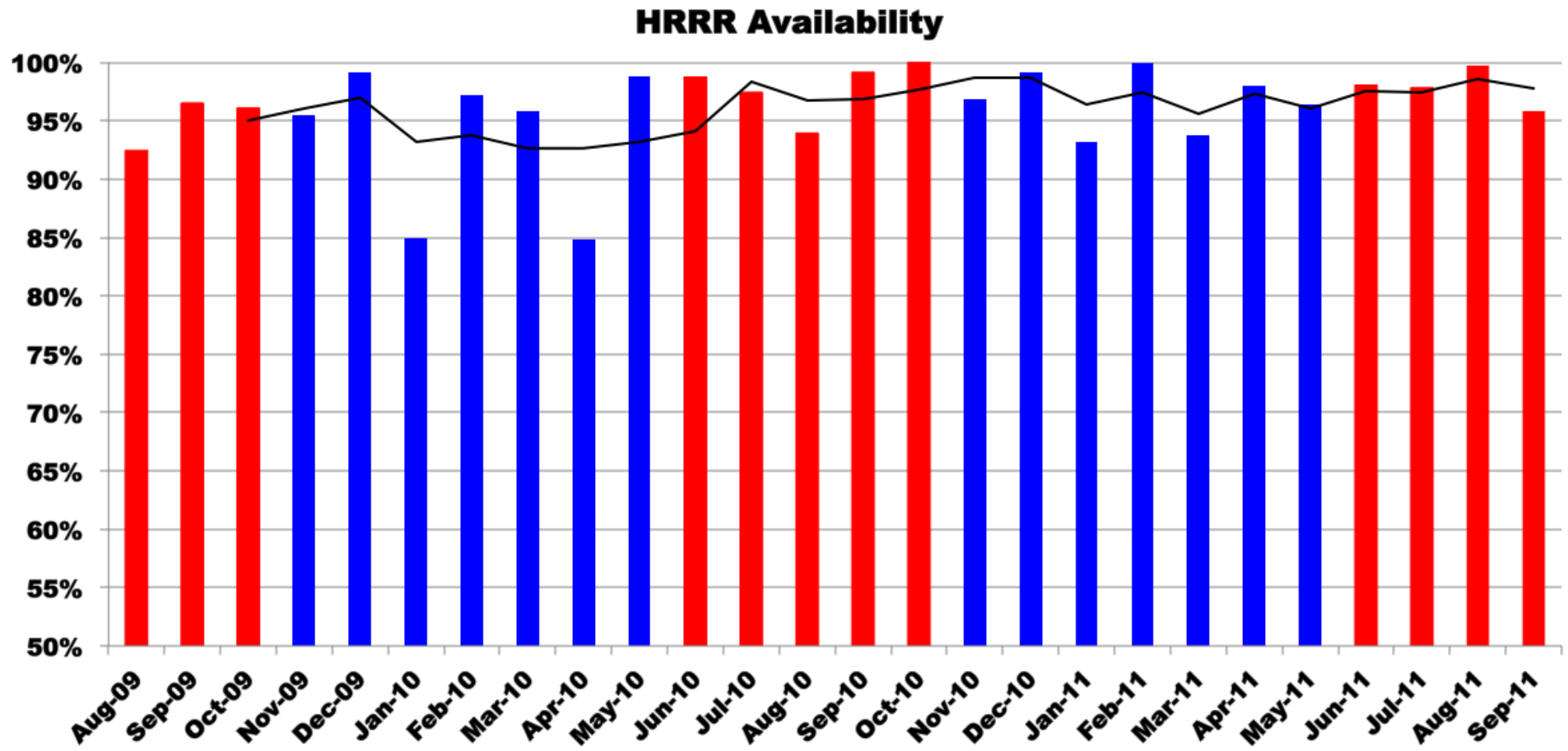
HRRR Hourly Reliability (≥ 12 hr forecast)
More Than Two Consecutive Missed/Incomplete Runs



CoSPA Operational Evaluation Periods

3 month running average

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



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

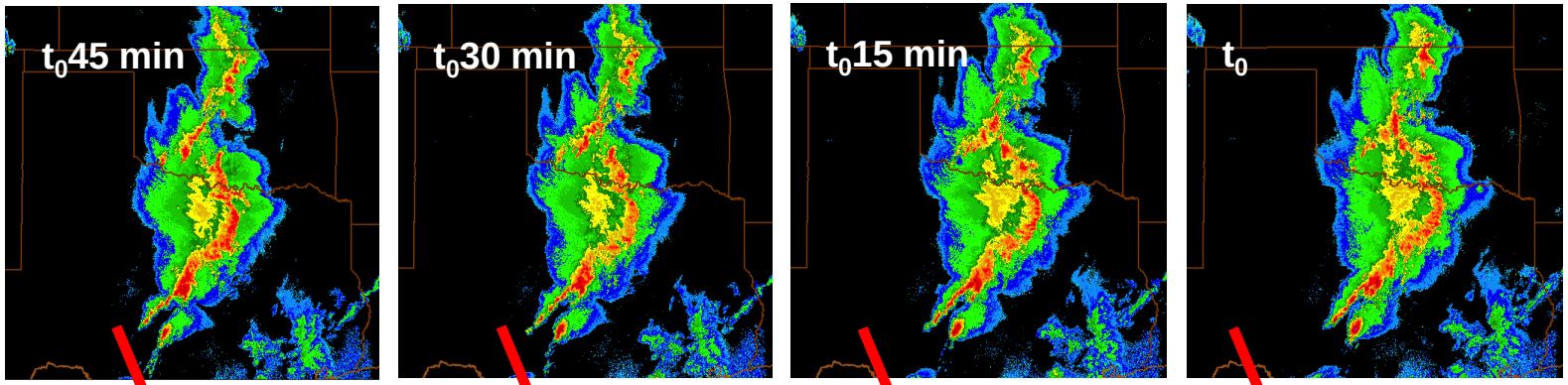
• Conversion of all output to GRIB2 format	Apr 2011
• Transition from RUC to RR parent model	Apr 2011
• DOE-funded HRRR FTP site for energy industry	May 2011

• 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

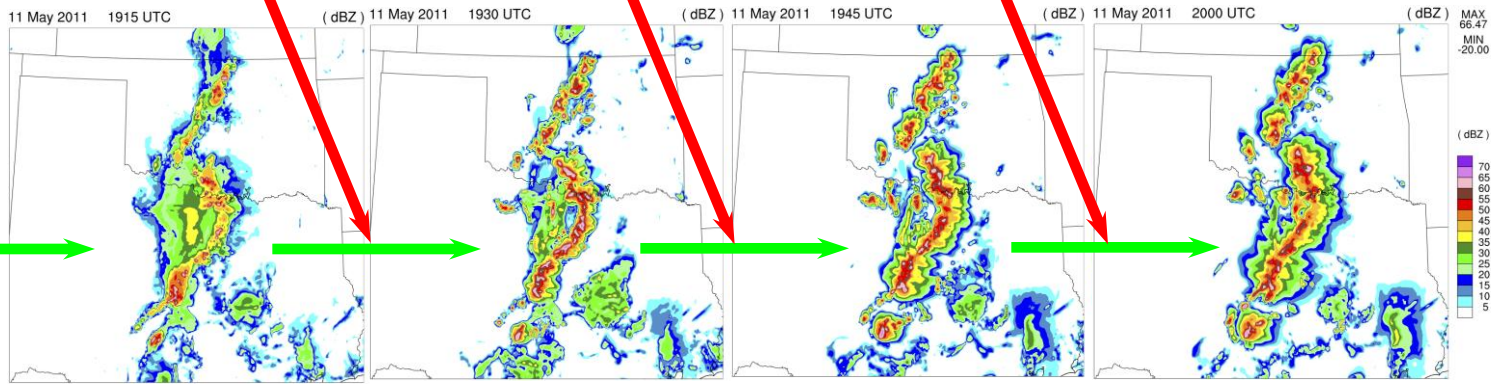
HRRR (3-km) grid produces convective storms explicitly

Reflectivity-based temp. tendencies are applied during sub-hourly cycling (forward model integration only, no digital filtering)



NSSL 3D mosaic

reflectivity-based temperature tendency

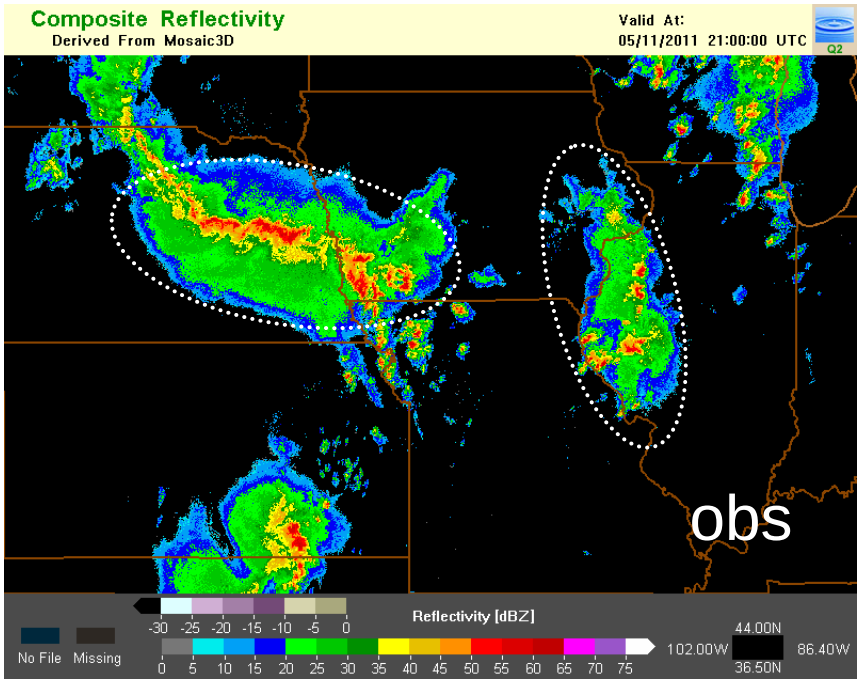


t_0–60 min **t_0–45 min** **t_0–30 min** **t_0–15 min** **t_0**

HRRR composite reflectivity

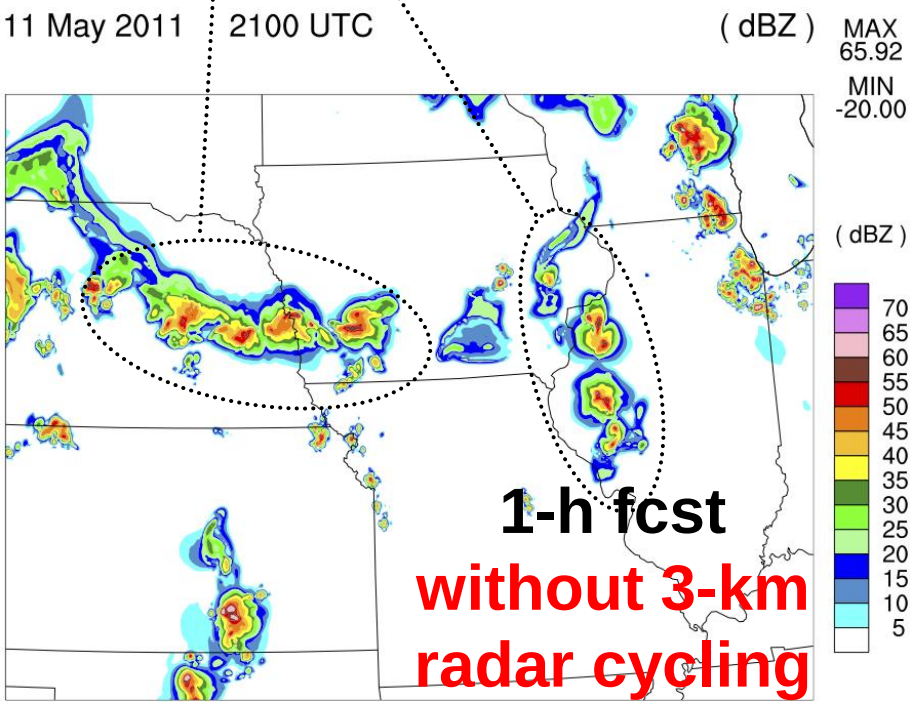
interpolation from RR, hydrometeor specification

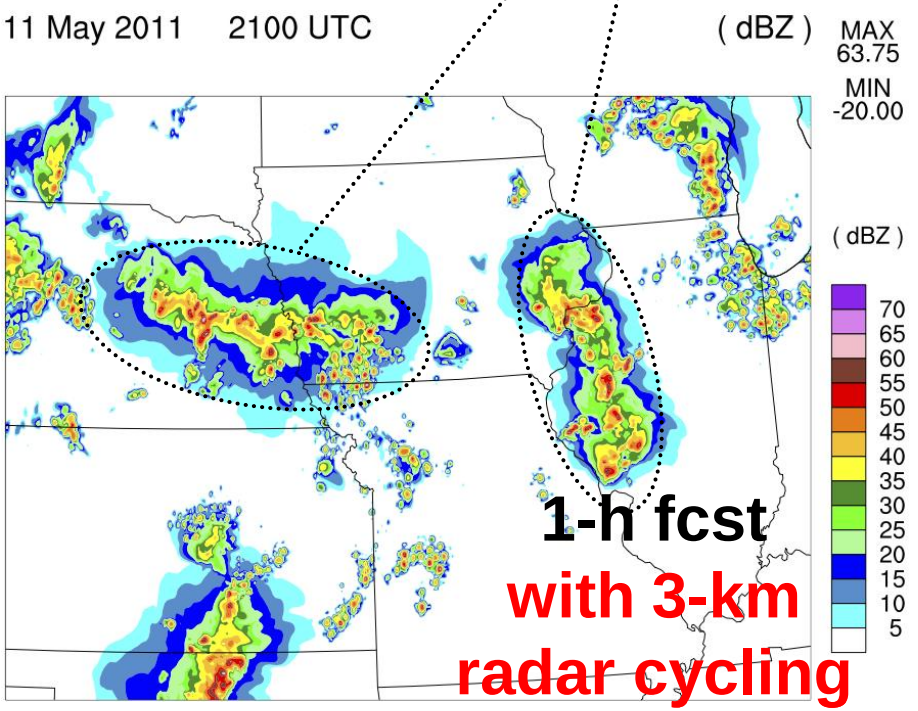
Composite Reflectivity 2100 UTC 11 May 2011



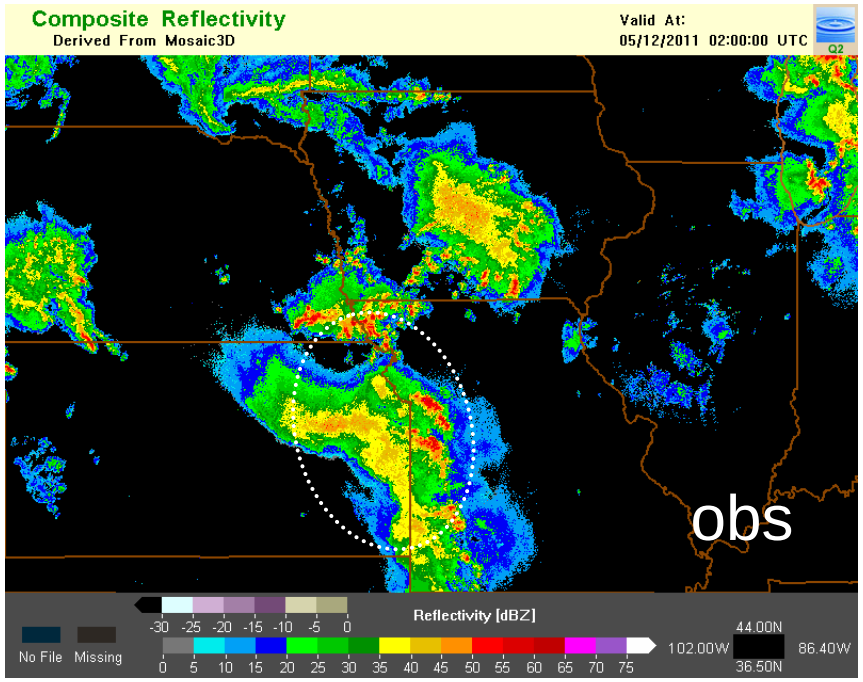
convection develops quickly (RR cycling, DDFI)

more accurate representation of system maturity

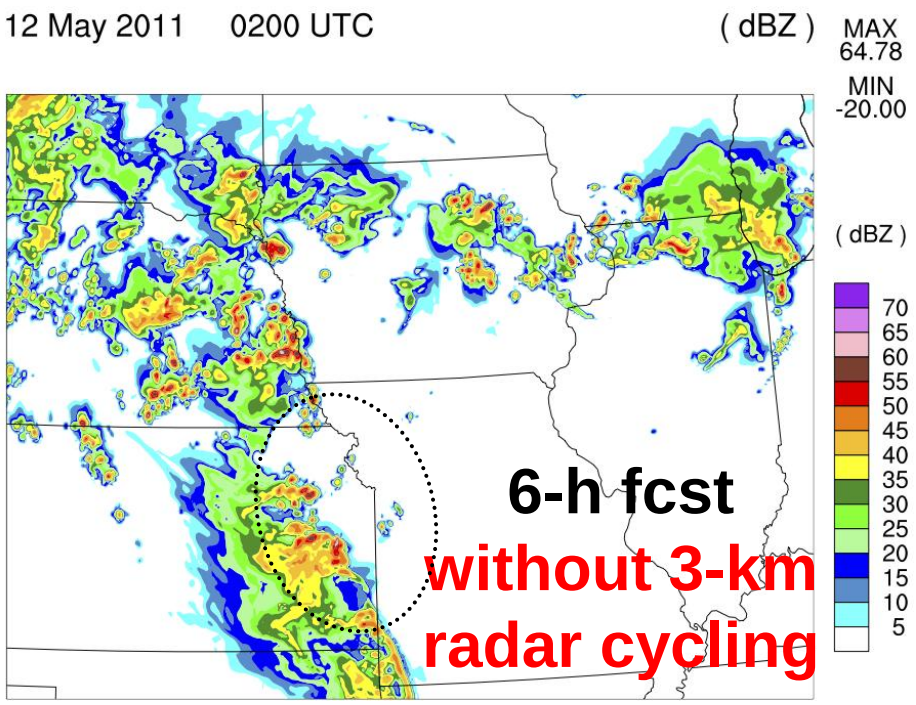


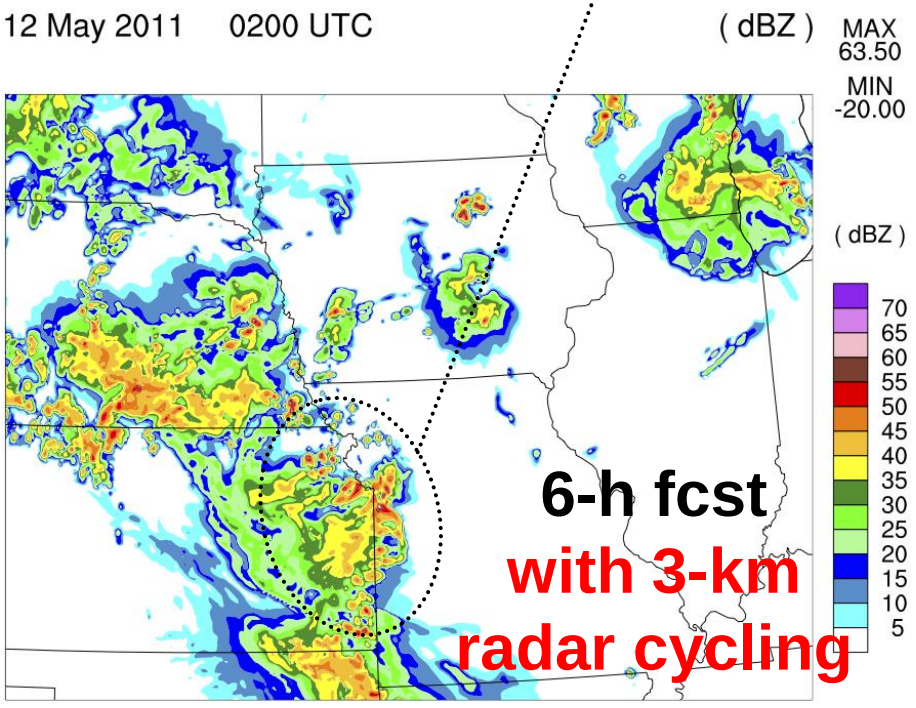


Composite Reflectivity 0200 UTC 11 May 2011



more accurate forecast of convective system propagation



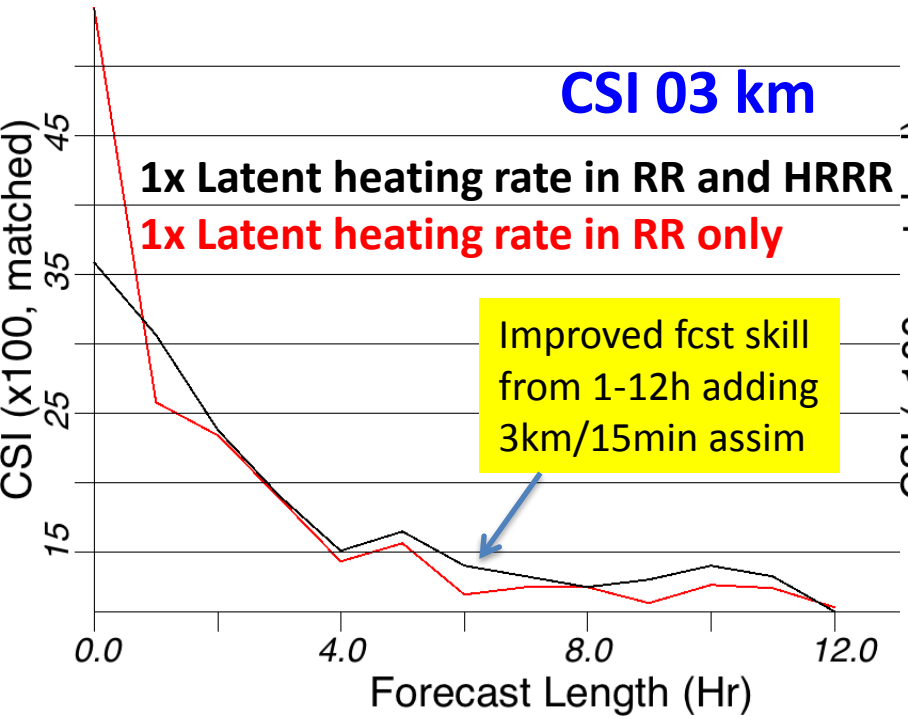


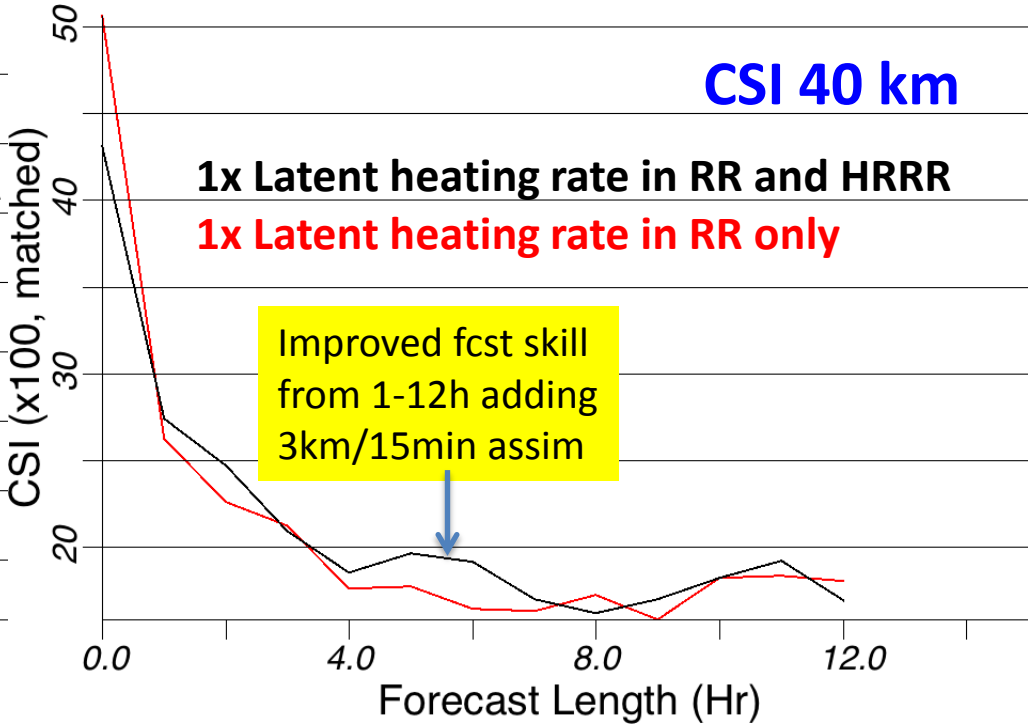
Initial testing – *additional* 3km radar assimilation in 15-min cycle

(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





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

RRv2/HRRR Model Development and Evaluation

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

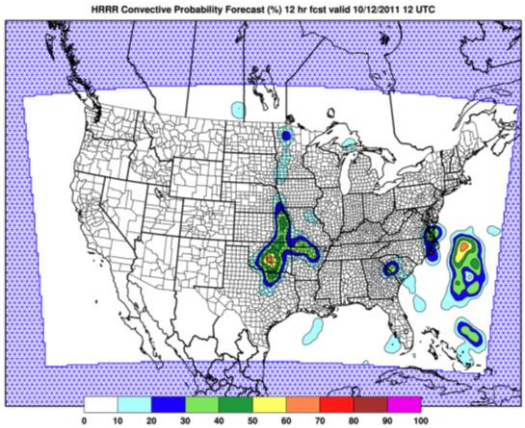
"Simplistic" 13-km latent heating
No 3-km data assimilation

Implement

"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** **current testing,**
  - volcanic ash, visibility, fires **real-time ~2017?**