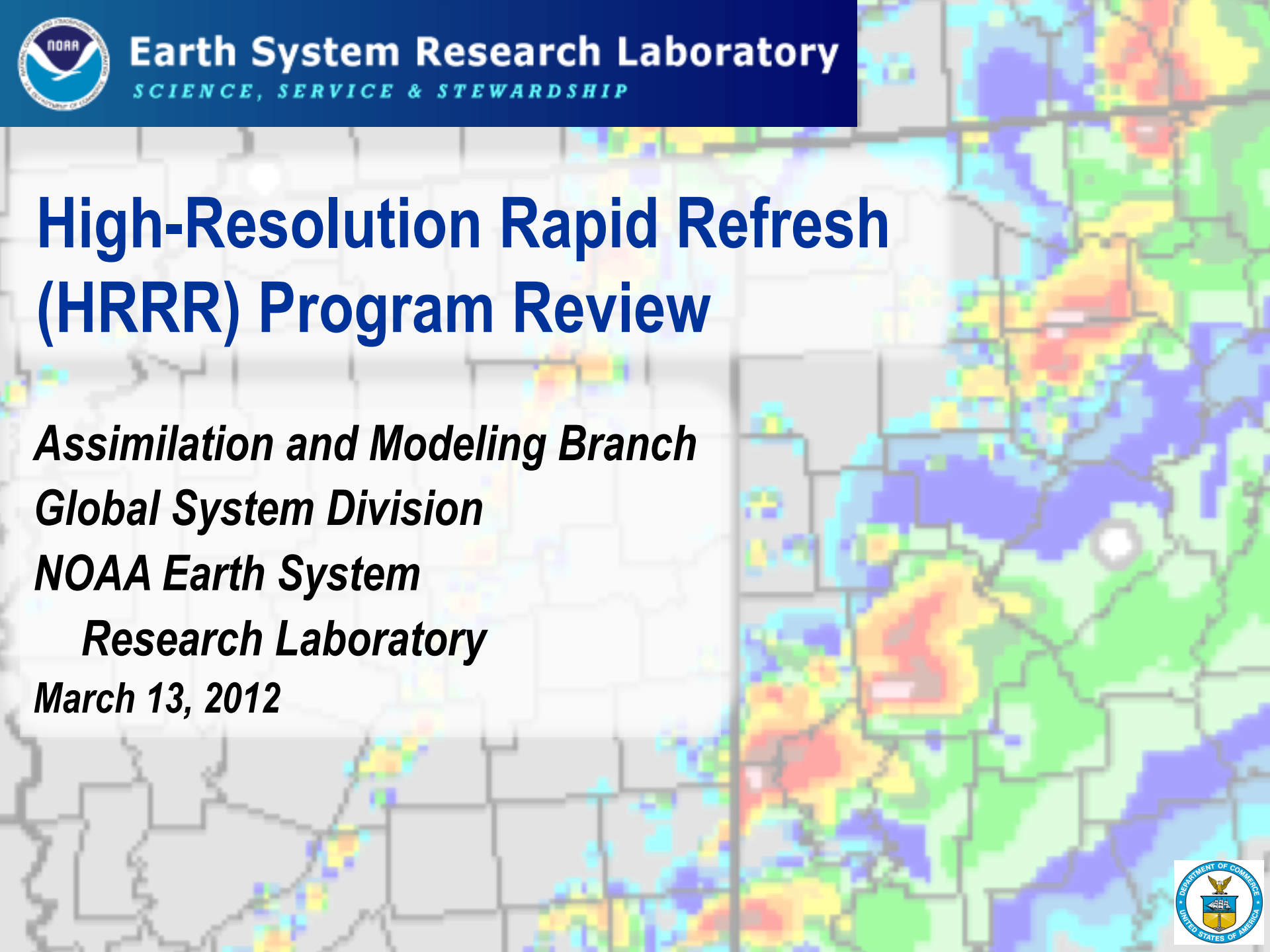

Earth System Research Laboratory

SCIENCE, SERVICE & STEWARDSHIP

High-Resolution Rapid Refresh (HRRR) Program Review

Assimilation and Modeling Branch

Global System Division

NOAA Earth System Research Laboratory

March 13, 2012

HRRR Program Review Outline

1:30	Opening Remarks	Stan Benjamin
1:30 – 1:40	Program Overview	Curtis Alexander
1:40 – 1:50	Initial Conditions: Rapid Refresh	Steve Weygandt
1:50 – 2:00	Model Development	David Dowell
2:00 – 2:10	Case Studies and Applications	Eric James
2:10 – 2:20	Forecast Verification	Patrick Hofmann
2:20	Summary and Future Plans	Curtis Alexander
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HRRR Program Key Partners

NOAA/ESRL/GSD/AMB

Stan Benjamin
Steve Weygandt
Curtis Alexander
David Dowell
Patrick Hofmann
Eric James
Brian Jamison
Susan Sahm
Kevin Brundage
Steven Peckham
John M. Brown
Tanya Smirnova
Ming Hu
Haidao Lin
Joe Olson
Tracy Lorraine Smith
Bill Moninger
Georg Grell
Xue Wei
Bernie Johnson

NOAA/ESRL/GSD (or HPC)

Bob Lipschutz
Craig Tierney
Chris Harrop
Leslie Hart
Forrest Hobbs
John Schneider

NOAA/ESRL

James Wilczak
Melinda Marquis
Sandy MacDonald

NOAA/NCEP

GSI developers
Geoff DiMego
Geoff Manikin
Dennis Keyser
John Derber
Steve Weiss

NCAR

WRF developers
DTC developers
James Pinto
Matthias Steiner
Ken Stone

FAA

Jenny Colavito
Warren Fellner
Steve Abelman
Jaime Figueroa

MIT/LL

Marilyn Wolfson
Haig Iskenderian
Bill Dupree

DOE

Stan Calvert

Hourly Updated NWP Models

13km Rapid Refresh (RAP) (mesoscale)

Replaces RUC at NCEP -planned 03/20/12

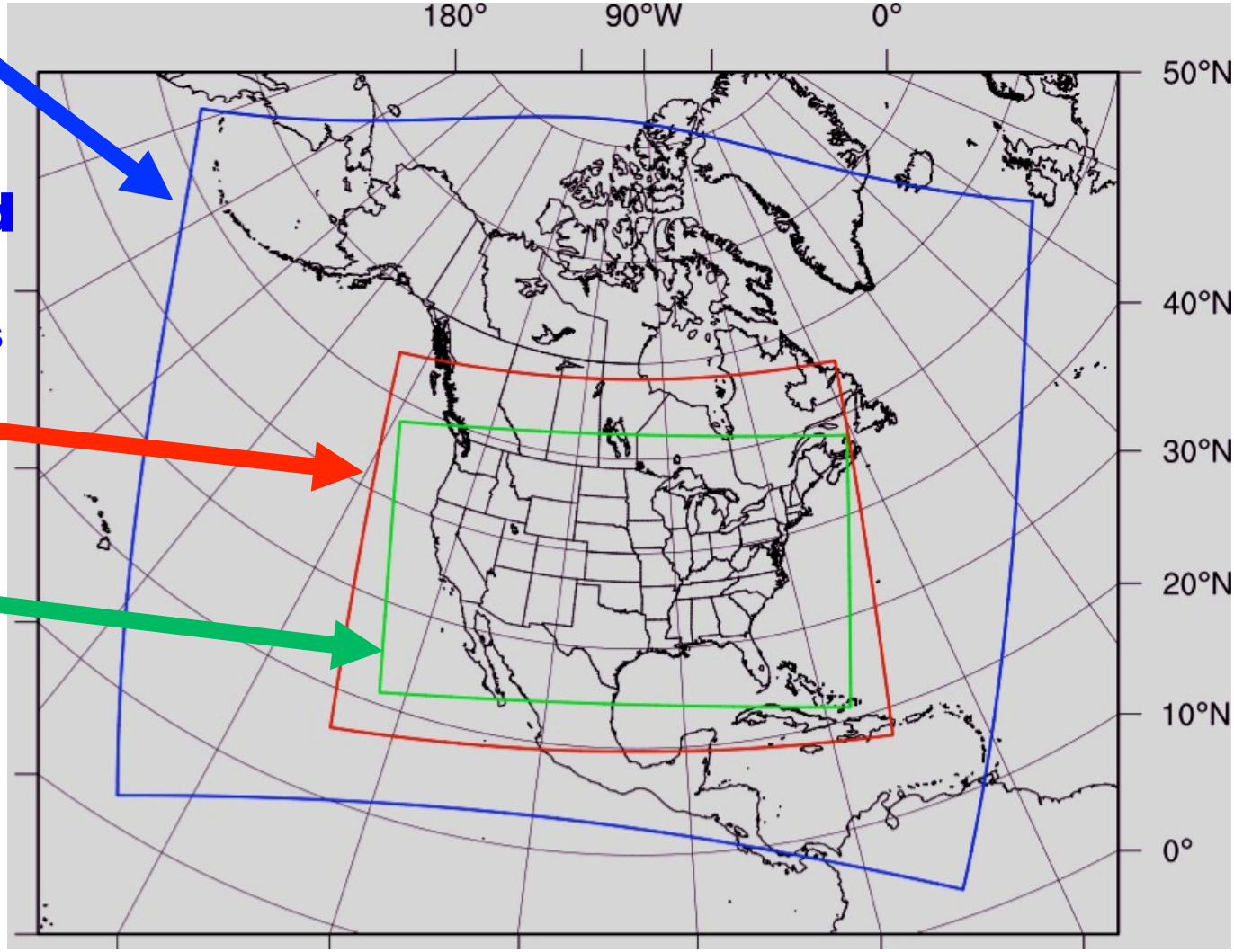
WRF, GSI, RUC features

13km RUC (mesoscale)

3km HRRR (storm-scale)

High-Resolution Rapid Refresh

Experimental 3km nest inside RAP, hourly 15-h fcst



HRRR Users and Applications

Aviation Weather Center (AWC): 2-D grids
Federal Aviation Administration (FAA) Command Center
National Center for Atmospheric Research (NCAR): 2-D, 3-D, 15-min grids
    Operational evaluation in CoSPA
Storm Prediction Center (SPC): 2-D grids
    Operational severe weather forecasting and evaluation
National Severe Storms Laboratory (NSSL): 2-D, 3-D and 15-min grids
    Mesoscale analysis, Short-term precipitation forecasts
National Centers for Environmental Prediction (NCEP): 15-min grids
    Real Time Mesoscale Analysis (RTMA)
Department of Energy/NOAA Wind Forecast Improvement Project (WFIP)
    ~12 energy private sector companies via WFIP (WindLogics, 3Tier, AWS Truepower, Precision Wind, Weather Channel, etc.)
    Real-time forecasts of turbine-level wind and solar irradiance
Colorado State University (CSU/CIRA): 2-D grids
    Verification of solar irradiance forecasts at SURFRAD sites
Air Resources Laboratory (ARL): Tiled 3-D HRRR grids
    Dispersion forecasts, Local wind forecasts in complex terrain
National Weather Service (NWS): 2-D and 3-D grids
    Operational weather forecasting
United States Air Force (USAF): 2-D grids
    Operational weather forecasting

Aviation

Severe Weather

Renewable Energy

Forecasting

Evolution of the HRRR

Historical programmatic decisions

1998	Addition of digital filter initialization (DFI) to RUC model for 1hr cycling
2005	Switch to moist version of DFI in RUC model at NCEP
2007	Availability of national NSSL 3-D radar:

- Recognition of radar assimilation "opportunity" within moist DFI
- Initial RUC testing of radar-DFI technique, success
- Recognition of <5km-scale (storm-scale) modeling with RUC radar-DFI analysis using WRF model, initial testing, success
- Set up initial NE Corridor domain for HRRR
- Goal: Avoid lateral boundary condition issue for local models

2009-10	Implement radar processing from RUC inside GSI Implement DFI and DFI-radar technique in WRF
2007-09	Increase domain of HRRR based on FAA, NOAA, DOE funding
2011 April	Switch parent model for HRRR from RUC to Rapid Refresh

Future and Goals of the HRRR

Current or upcoming decisions in near future

- Details on implementation of HRRR on new HPCS (zeus)
- Interaction with FAA, NWS and HPCS on "hardened" HRRR for HPCS (zeus/jet)

Ties to larger goals

NOAA Research:

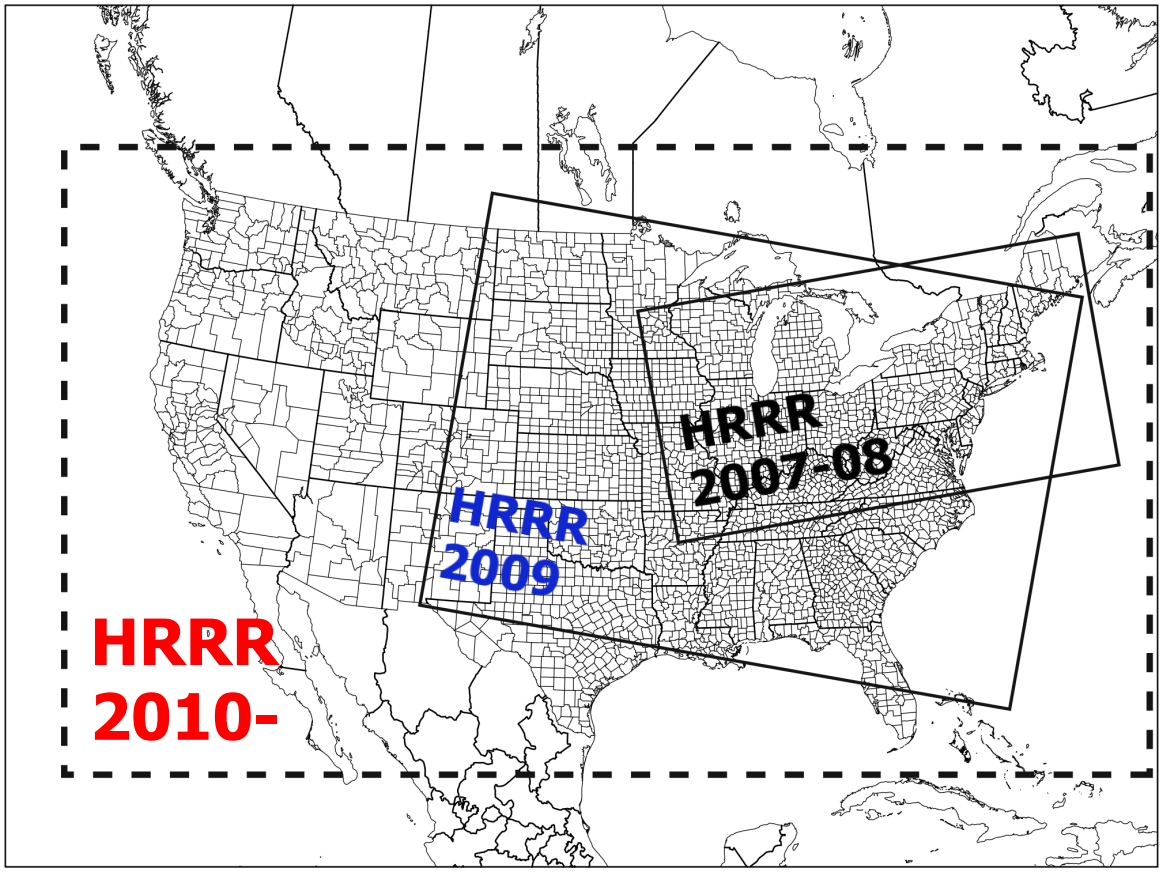
What improvements to *observing systems, analysis approaches, and models* will allow better analysis/prediction of atmosphere, ocean, and hydro land processes?

ESRL role:

- **Develop new or improved models and assimilation techniques**
- **Improve prediction and understanding of phenomena**
- **Support operational forecasting and research**
- **Apply those "sharpened tools" to --**
- **Aviation, severe weather, hydrology, energy, other**

Evolution of the HRRR Domain

Hourly frequency maintained



May – Oct 2010 HRRR run reliability

94.5% HRRR completion rate (including scheduled downtime)

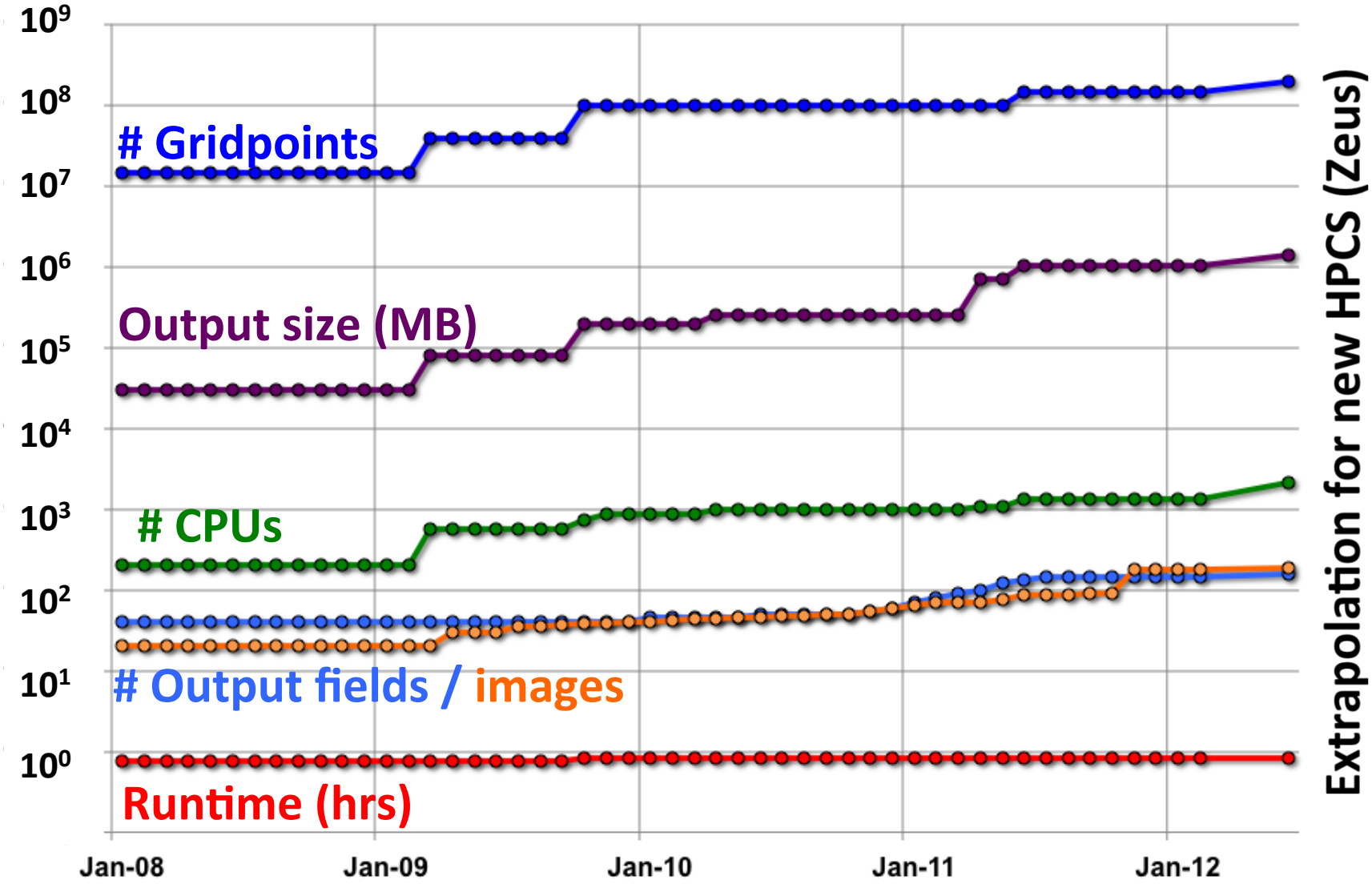
140 TB
2088 CPUs

September 2007
Initial HRRR domain:
northeastern United States
"aviation corridor"
745 x 383 grid points
200 processors

March 2009
Domain expansion:
Eastern 2/3 of the US
1000 x 700 grid points
568 processors

October 2009
Domain expansion:
CONUS
1800 x 1060 grid points
15 hour forecasts
1000 processors

HRRR Growth


10^9
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10^1
10^0
Gridpoints
Output size (MB)
CPUs
Output fields / images
Runtime (hrs)
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Extrapolation for new HPCS (Zeus)

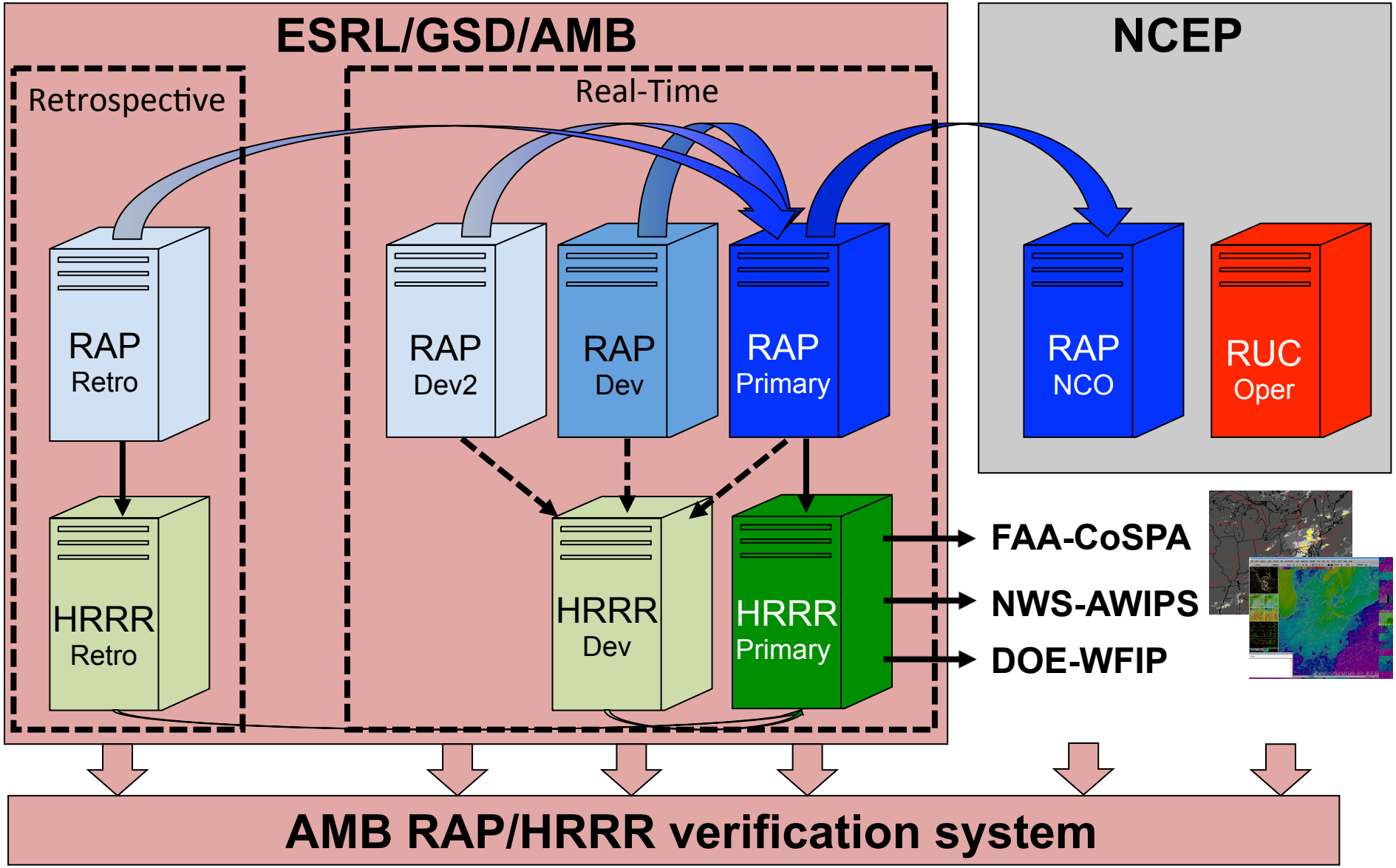
HRRR Milestones

• Inception over northeastern US	Sept 2007
• Integration into CoSPA: Aviation Users	Spring 2008
• Domain expansion to eastern US	Mar 2009
• HCPF time-lagged ensemble inception	May 2009
• HRRR WRF-ARW updated to v3.1.1	Oct 2009
• Domain expansion to CONUS	Oct 2009
• HRRR WRF-ARW updated to v3.2	Apr 2010
• Forecast period extended to 15 hrs	Apr 2010
• Real-time multi-scale reflect. verification	June 2010
• Parallel (shadow) retrospective system	Sept 2010
• Attained ~95% reliability	Jun 2010

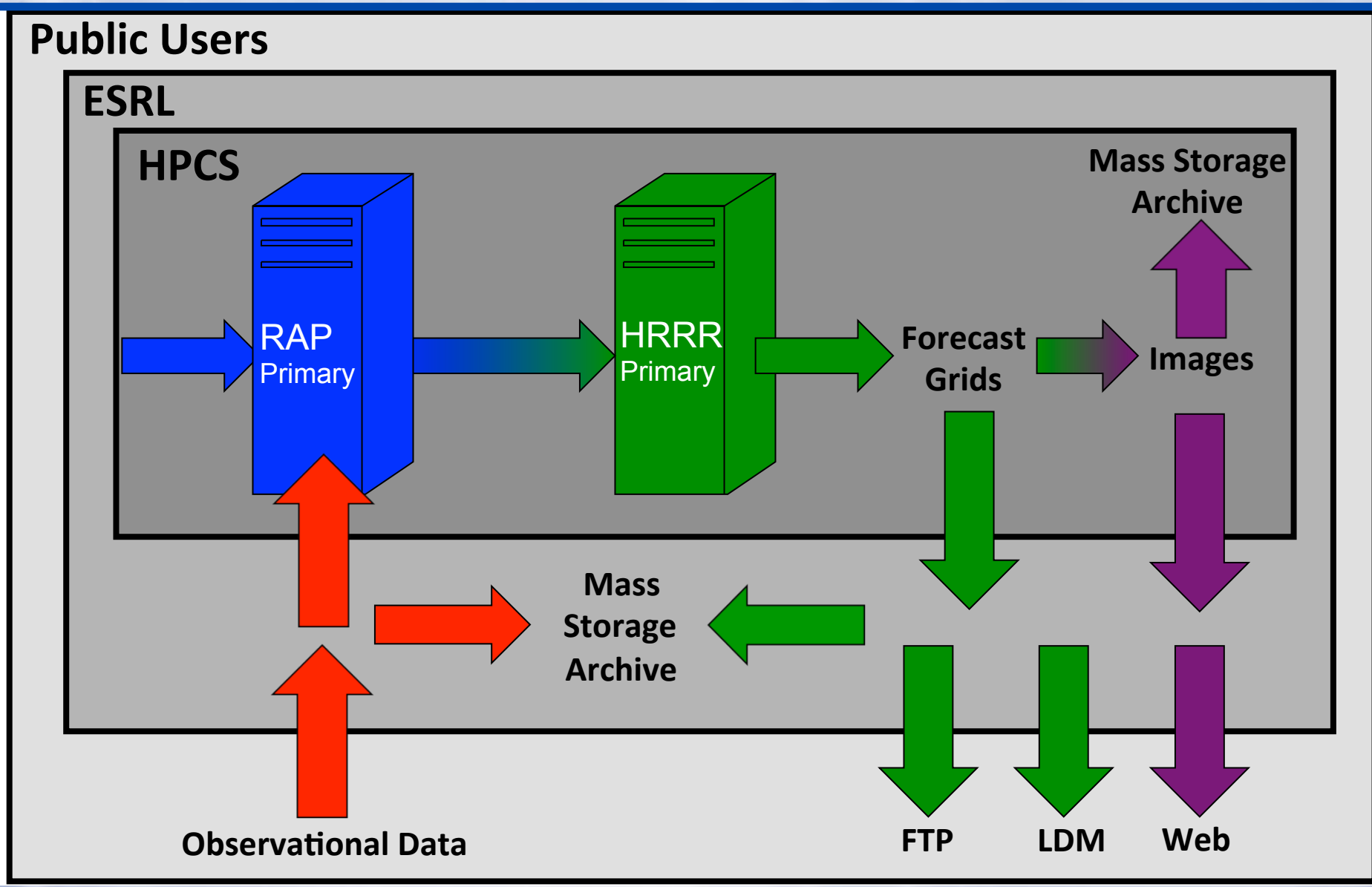
HRRR (and RAP) Milestones

• Reduced latency to ~2 hrs	Dec 2010
• Conversion of all output to GRIB2 format	Apr 2011
• Transition from RUC to RAP parent model	Apr 2011
• DOE-funded HRRR FTP site for energy industry	May 2011
• Update to WRF-ARW v3.3.1	Feb 2012
• Rapid Refresh operational at NCEP	Mar 2012
• 3-km data assimilation and cycling	2012
• Ensemble Rapid Refresh (NARRE) at NCEP	2014
• HRRR operational at NCEP	2015?
• Ensemble HRRR (HRRRE) at NCEP	2016?

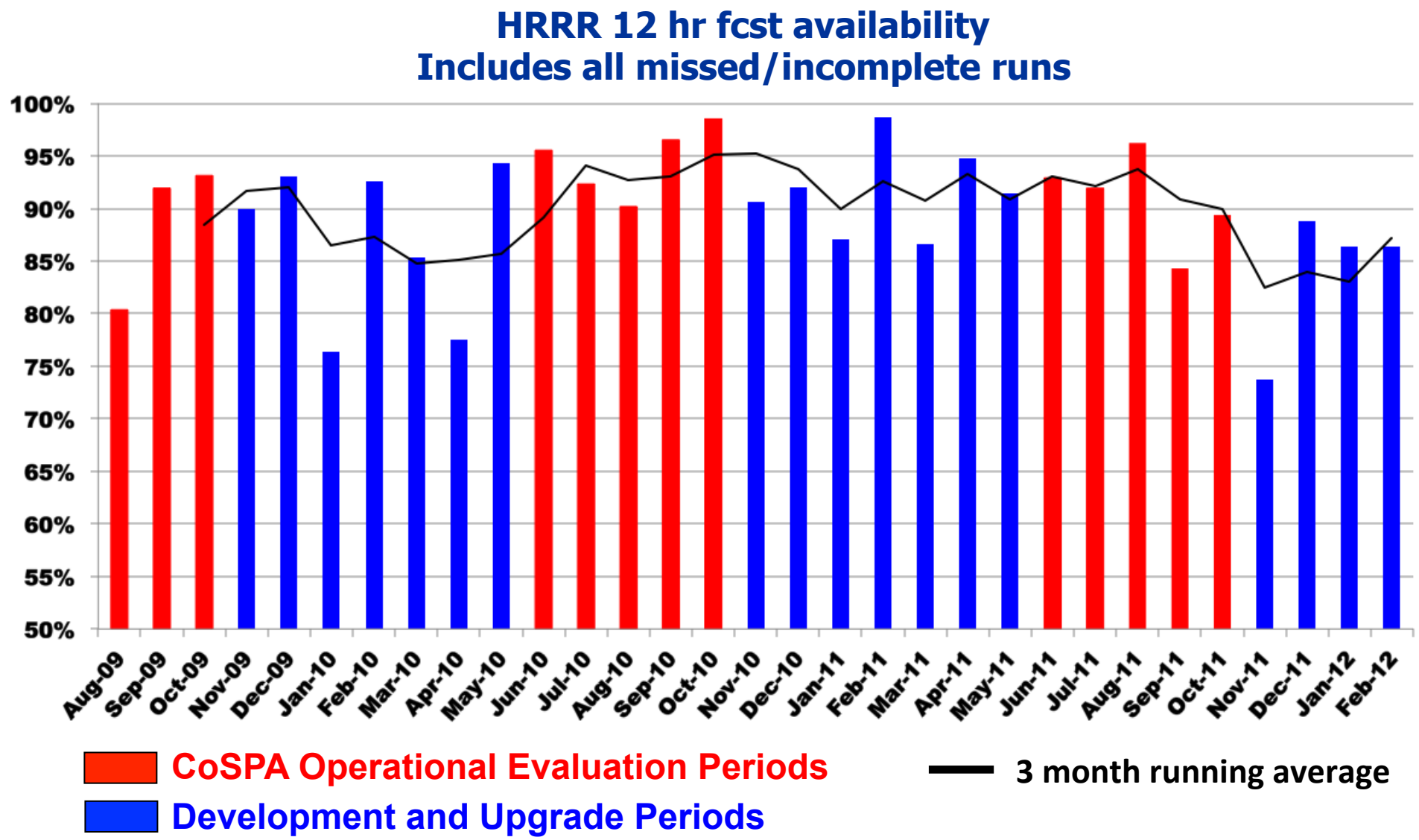
Model Configurations



HRRR Dataflow



HRRR Reliability



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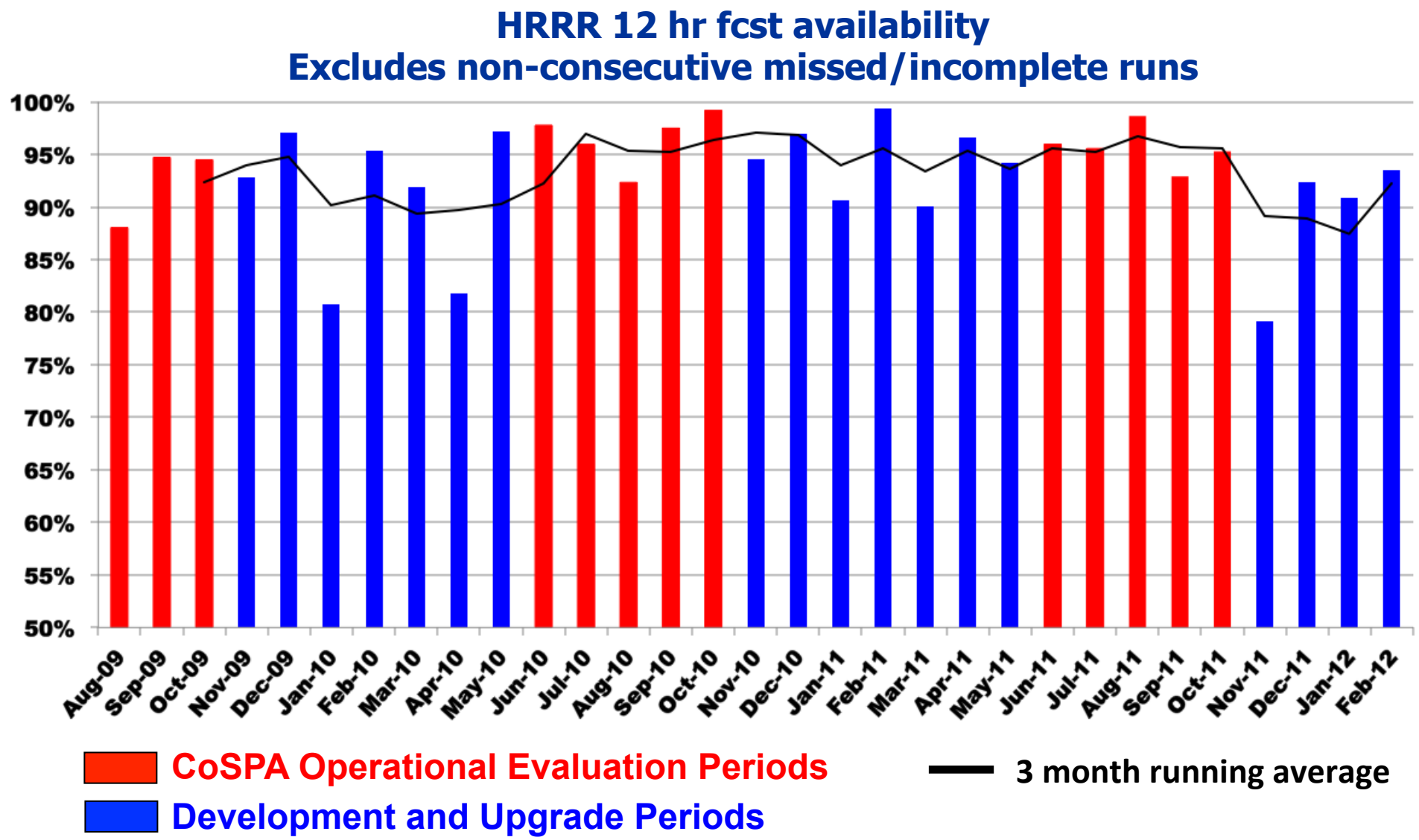
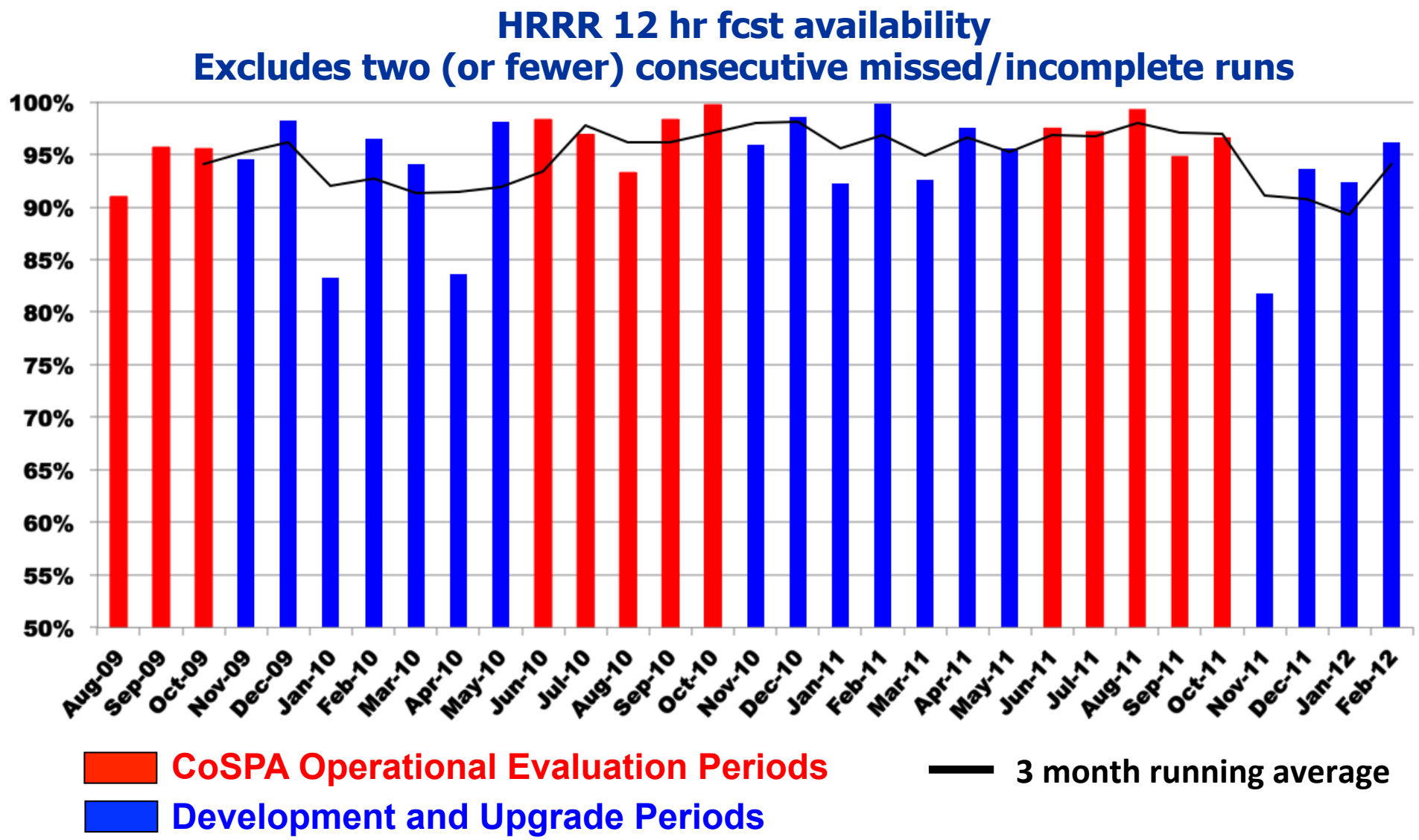
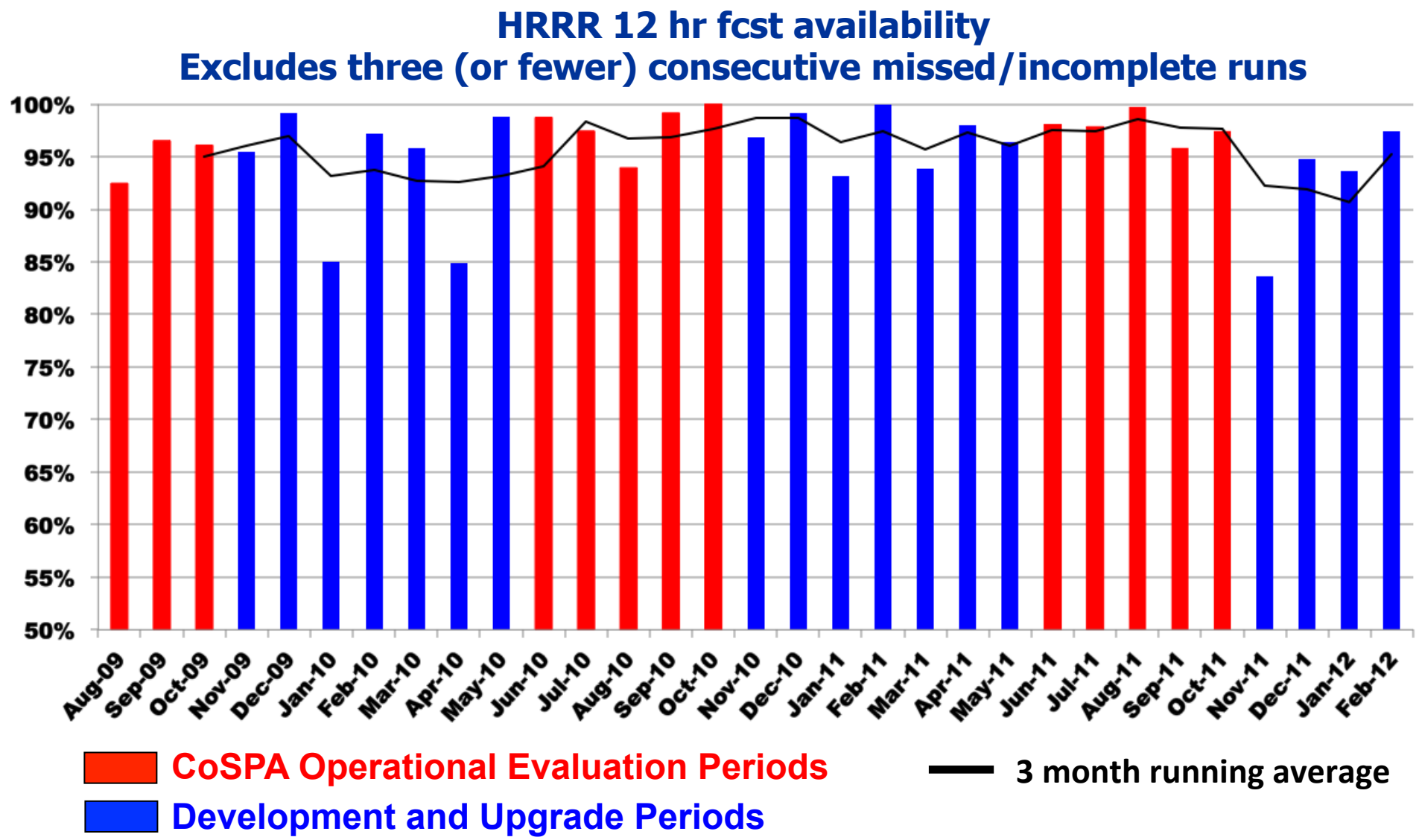


HRRR Reliability



HRRR Reliability



HRRR Transition to NCEP

- **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% via coordination of downtimes for Boulder vs. Fairmont computers
- **2015 – NCEP running HRRR**
  - NOAA/NCEP computing budget – will allow no increase before 2015
- Conclusion***: Interim HRRR computing for 2012-14 on 2 sites to provide "research regular" HRRR from NOAA for NWS, FAA, DOE/energy users***

HRRR Forecasts for Aviation

CoSPA: Collaborative effort: ESRL/GSD, NCAR/RAL, MIT/LL

Provide 0-8 hr thunderstorm intensity and echo top guidance to aviation community

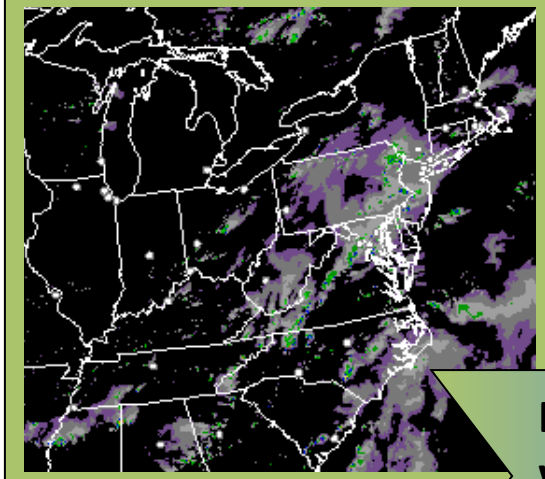
HRRR 15 UTC 08 July 2011
6 hr forecast valid 21 UTC

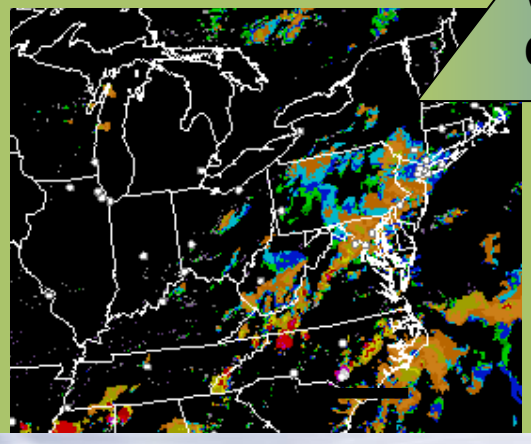
CoSPA 17 UTC 08 July 2011
4 hr forecast valid 21 UTC

Observation
Valid 21 UTC 08 July 2011

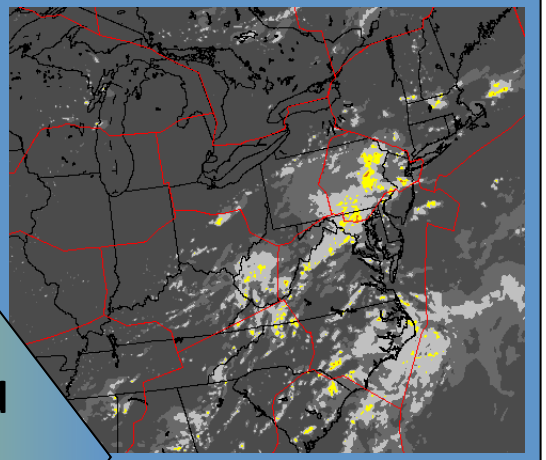
VIL

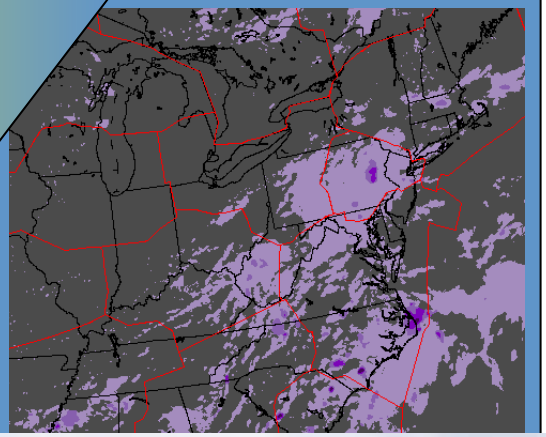
Echo Top

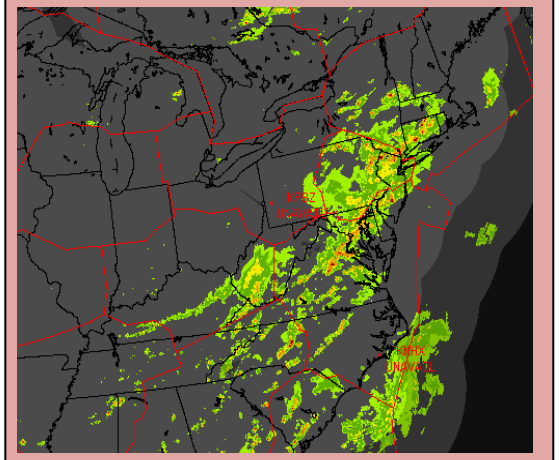


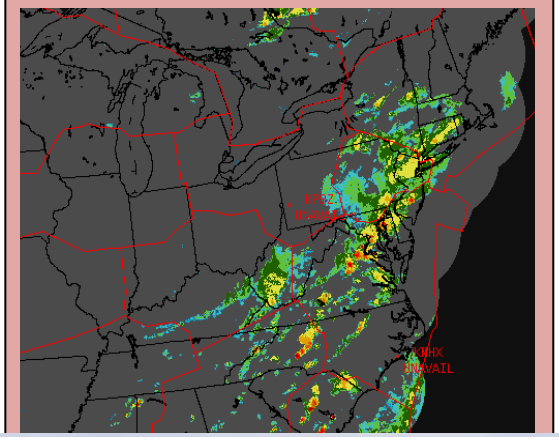


Blend with CIWS

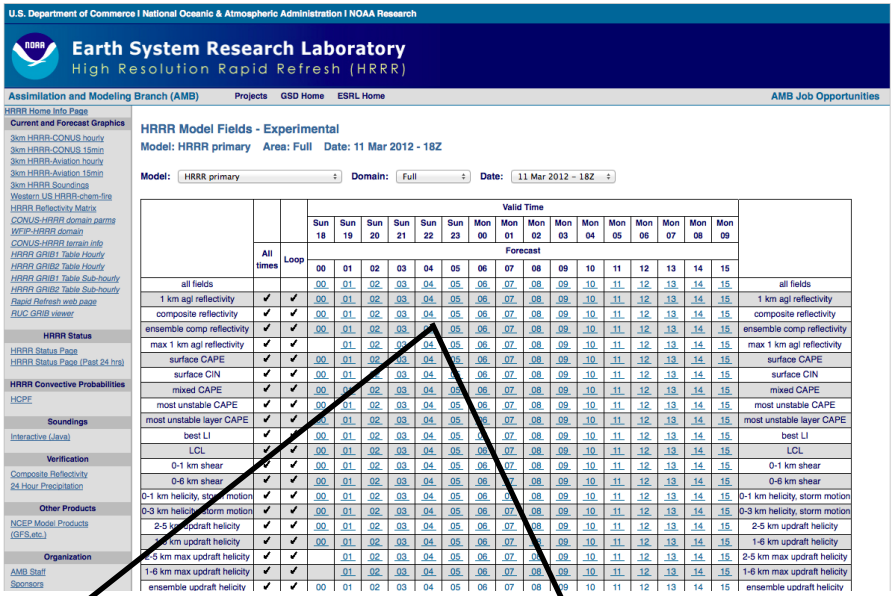








HRRR Websites



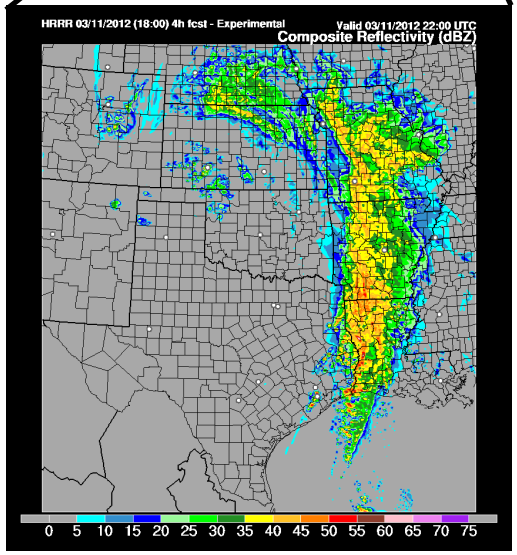
HRRR Web Pages:

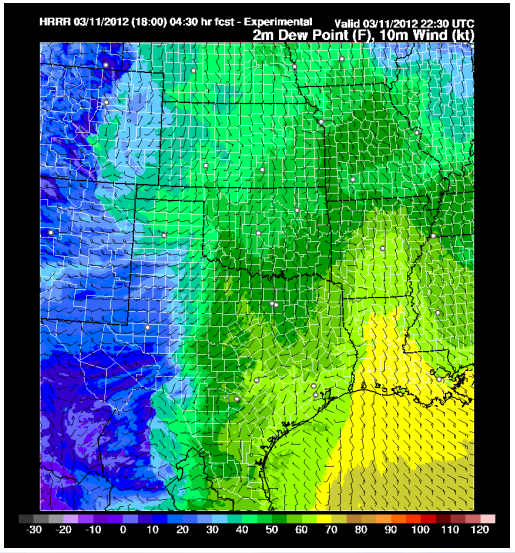
Hourly Plan-View Forecast Fields

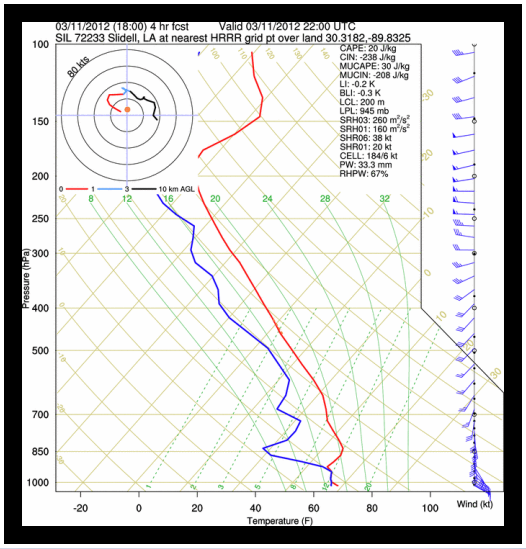
Sub-Hourly Plan-View Forecast Fields

Sounding Forecasts

http://rapidrefresh.noaa.gov/hrrrconus/
http://rapidrefresh.noaa.gov/hrrrconus15min/
http://rapidrefresh.noaa.gov/soundings/







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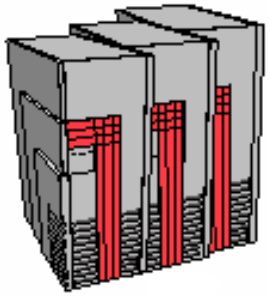
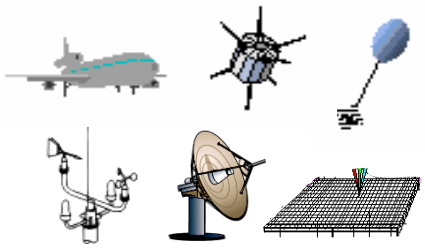
RAP: Data assimilation engine for HRRR

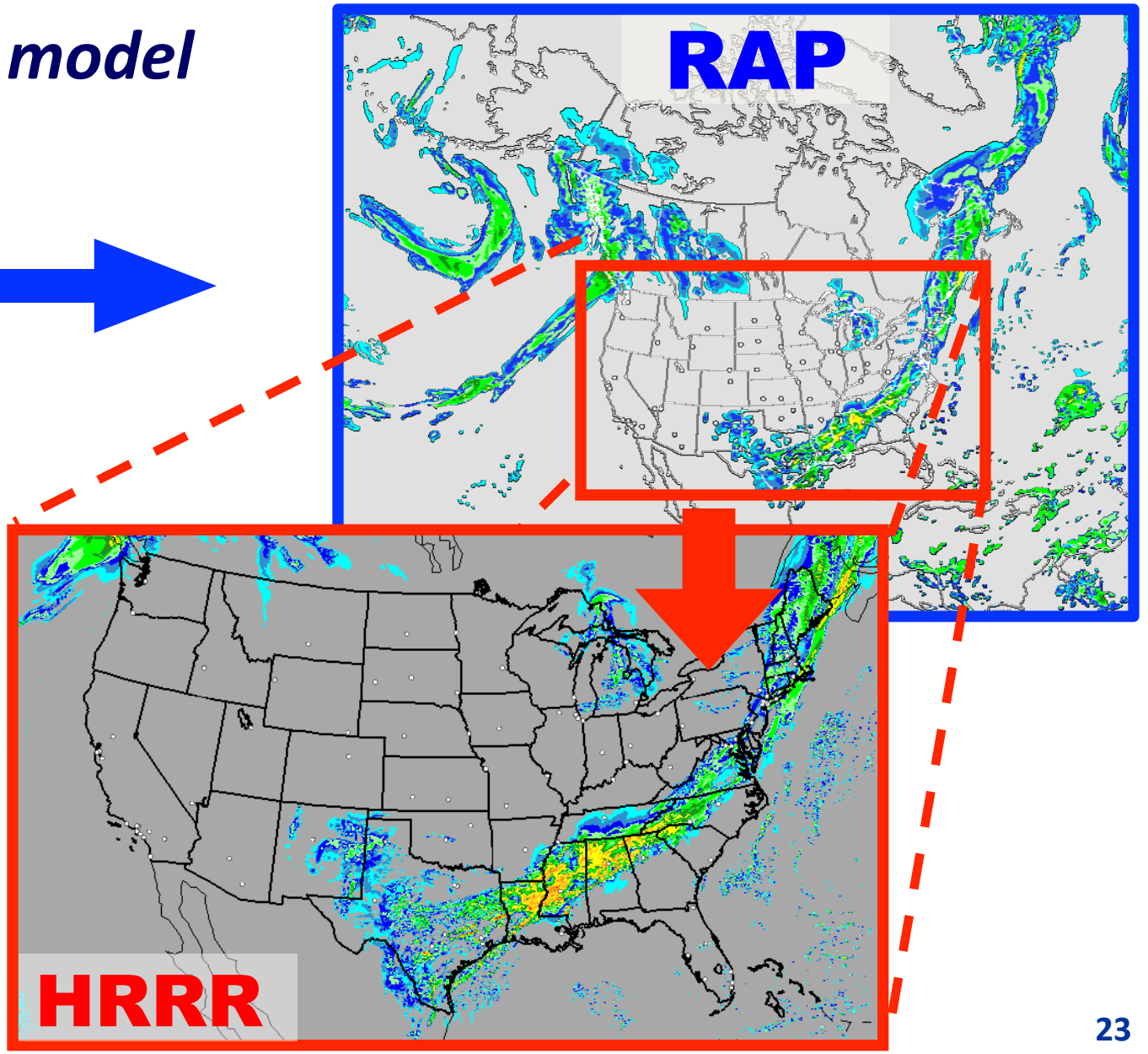
Hourly cycling model



Data Assimilation cycle



Observations



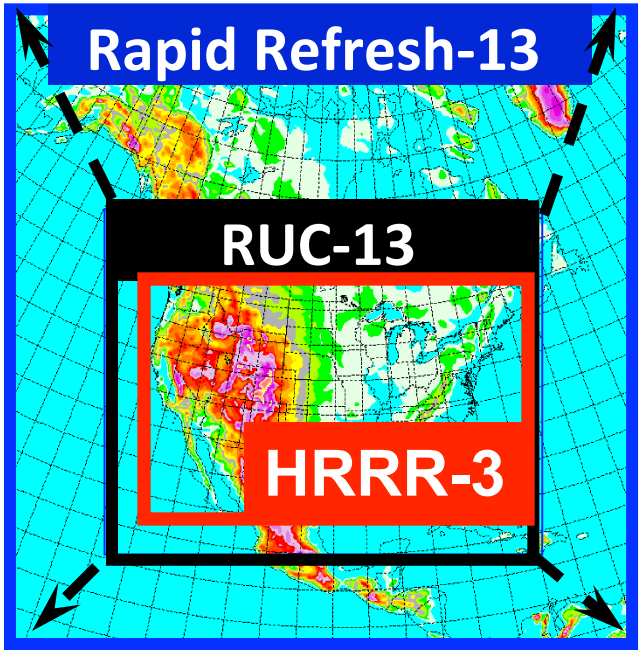
Rapid Refresh and HRRR
NOAA hourly updated models

NCEP **RUC → Rapid Refresh (March 20, 2012)**

— Advanced community codes (ARW and GSI)

— Retain key features from RUC analysis / model system (hourly cycle, radar DFI assimilation, cloud analysis)

— RAP guidance for aviation, severe weather, energy applications



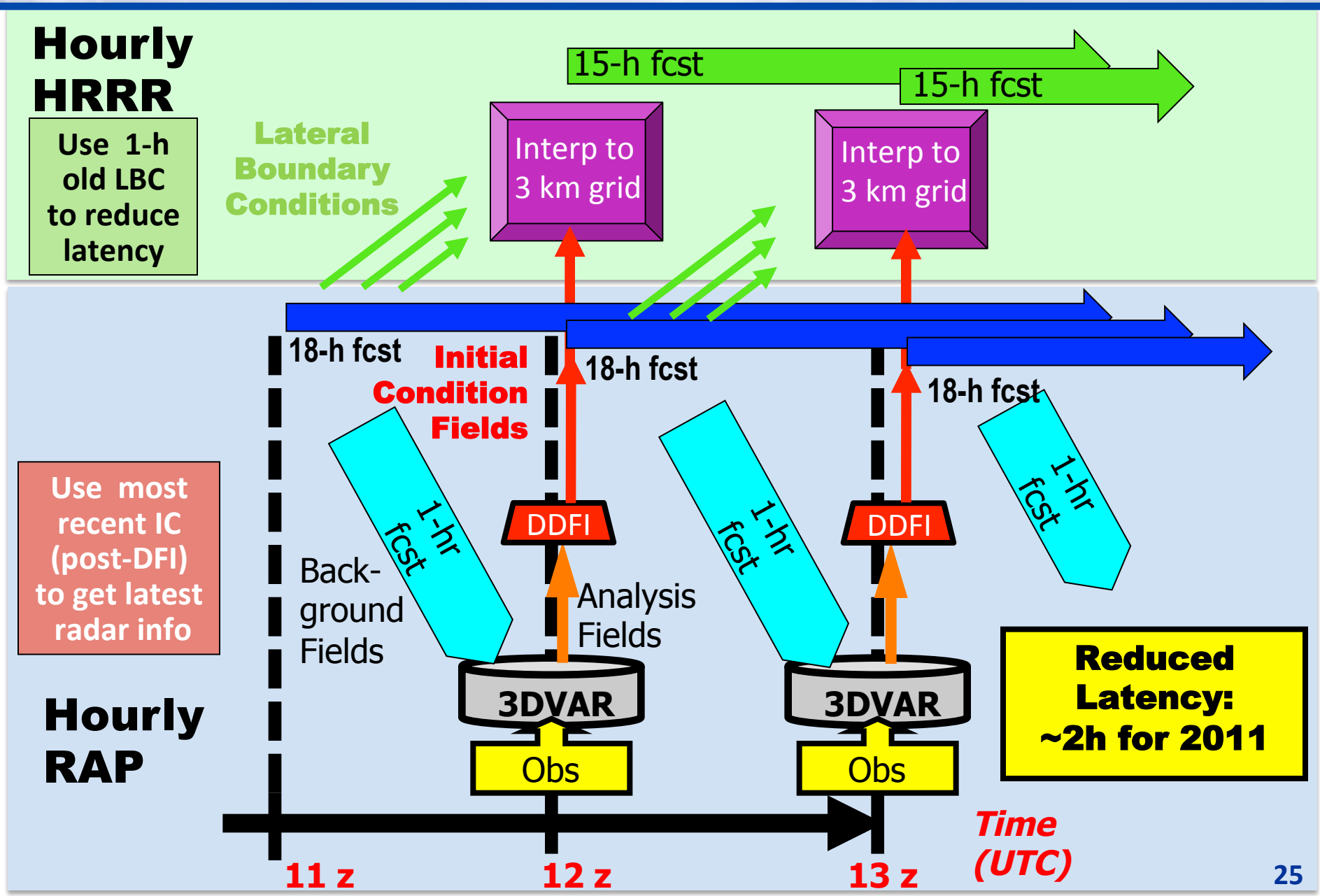
GSD **Rapid Refresh v2**

— Many improvements, target NCEP implement early 2013?

GSD **HRRR**

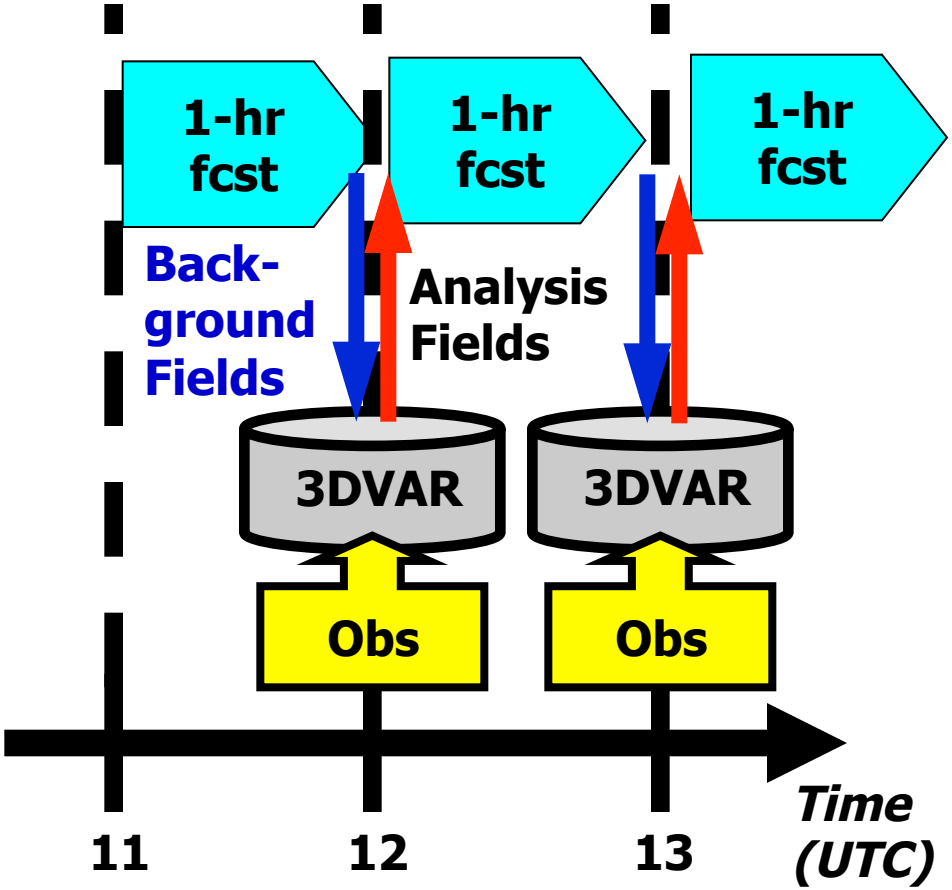
– Runs as nest within RAP v2

Hourly HRRR Initialization from RAP



Rapid Refresh Update cycle

Cycle hydrometeors
Cycle soil temp., moisture, snow



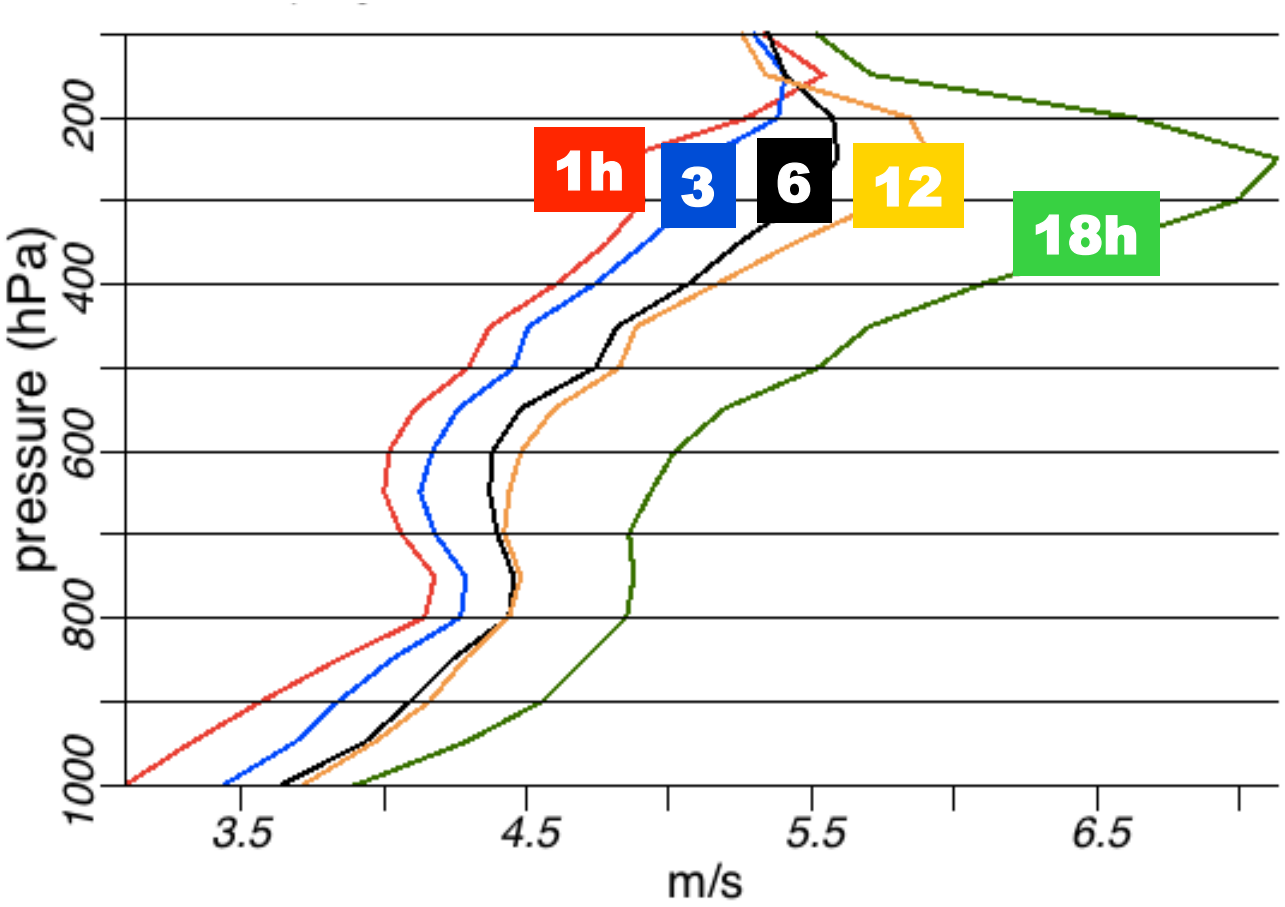
RAP hourly counts (ESRL only)
Observations / hour

Rawinsonde (12h)	120
NOAA profilers	21
VAD winds	~125
PBL – profiler/RASS	~25
Aircraft (wind, temp)	2K-15K (avg 7K)
Aircraft-WVSS (RH)	0-800 (avg 520)
Surface/METAR	~2500
Buoy/ship	200-400
GOES cloud winds	4000-8000
GOES cloud-top pres	10 km res
GPS precip water	~260
Mesonet (temp, dpt)	~8000 (fall 12)
Mesonet (wind)	~4000 (fall 12)
METAR-cloud-vis-wx	~2000
AMSU-A/B/HIRS/etc. radiances	
GOES radiances	fall 12
Radar reflectivity	1km
Lightning (proxy refl)	NLDN, GLD360
Radar radial wind	level 2.5
Nacelle/tower/sodar	20/100/10

RAP error reduction to 1-h forecast

Rapid Refresh
Wind forecast accuracy vs. forecast length

1 Jan -
7 Mar 2012
- Verification against raobs



The Rapid Refresh is able to use recent obs to improve forecast skill down to 1-h projection

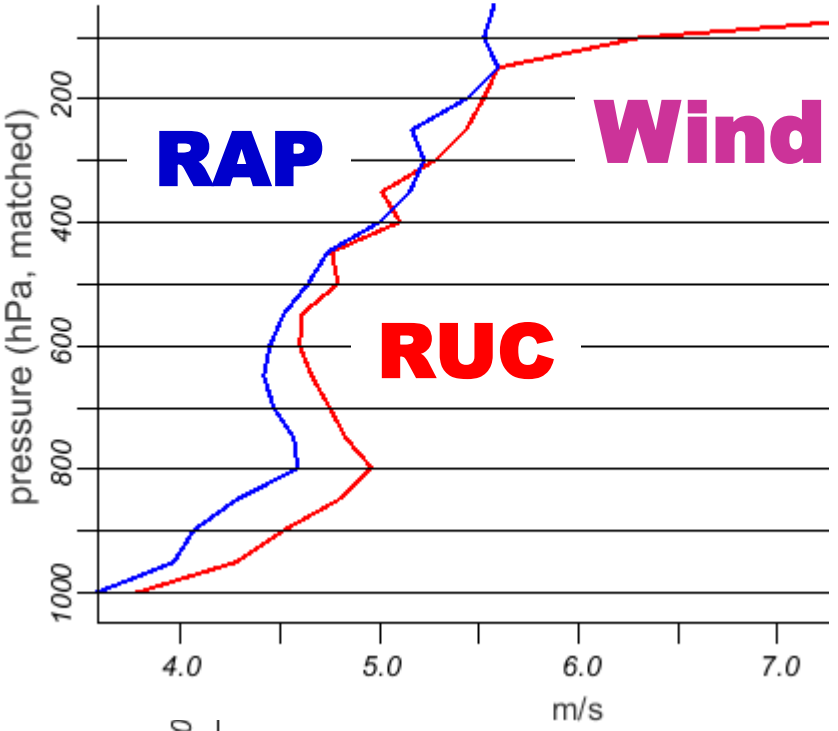
RUC vs. RAP

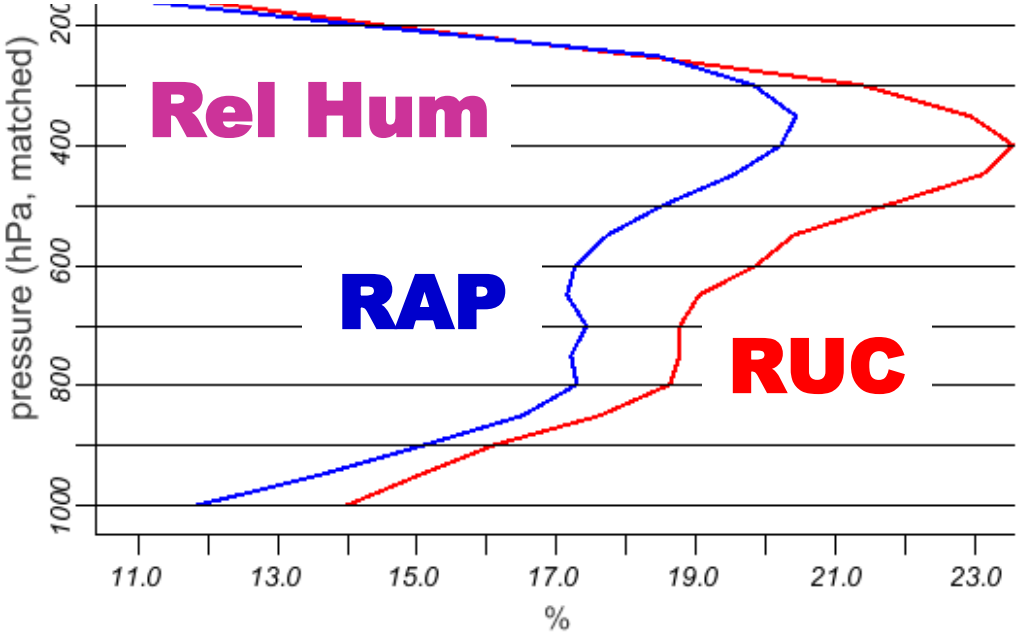
upper-air verification

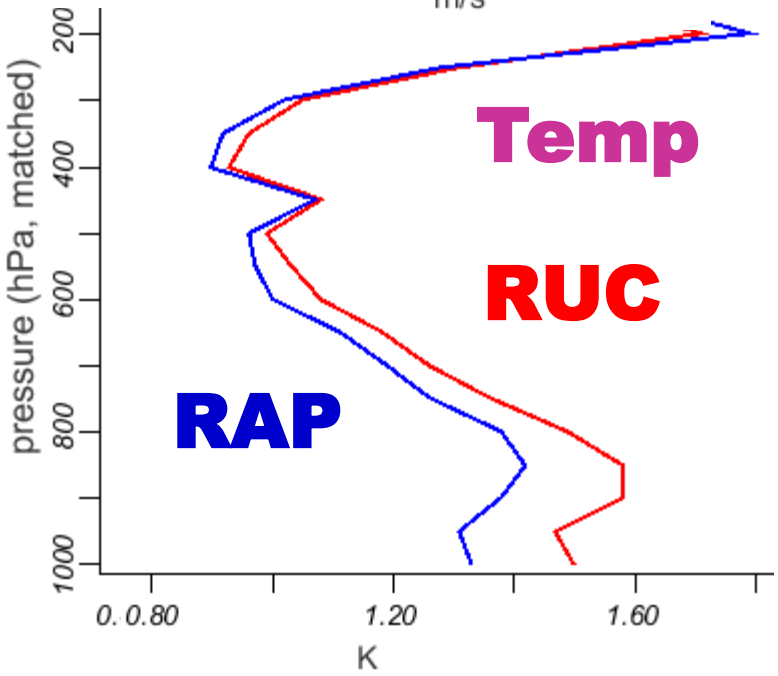
+ 3h forecast

RMS Error

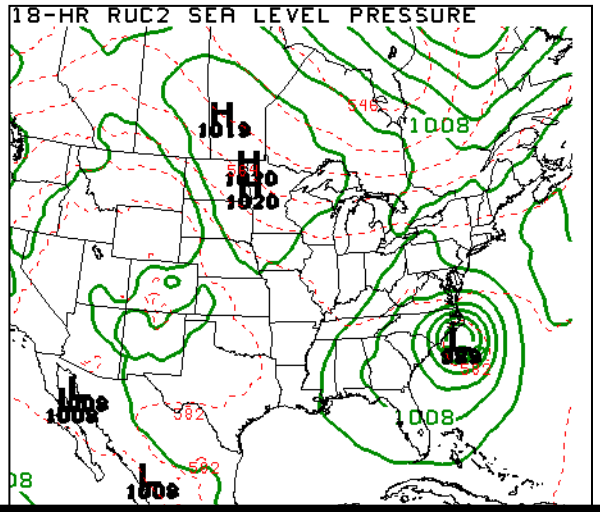
15 Feb 2012 – 8 March 2012

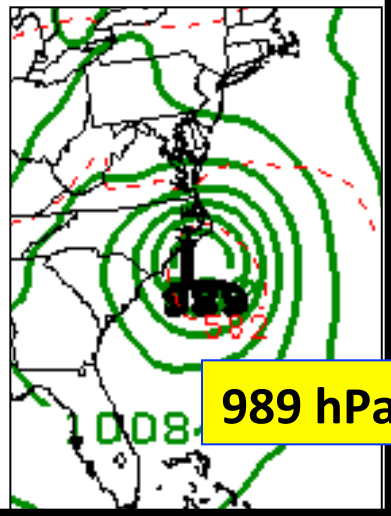




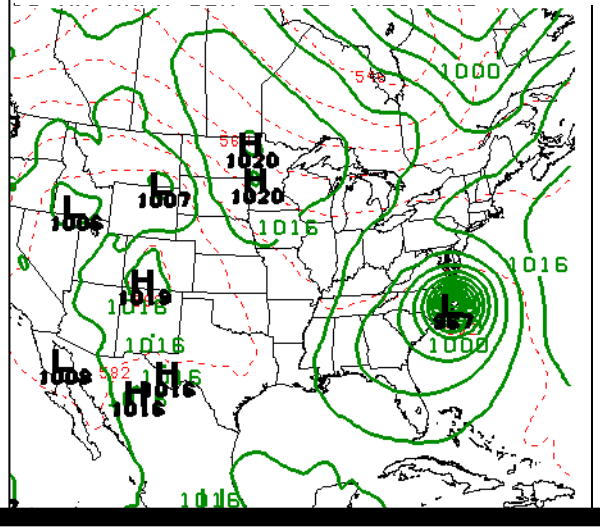


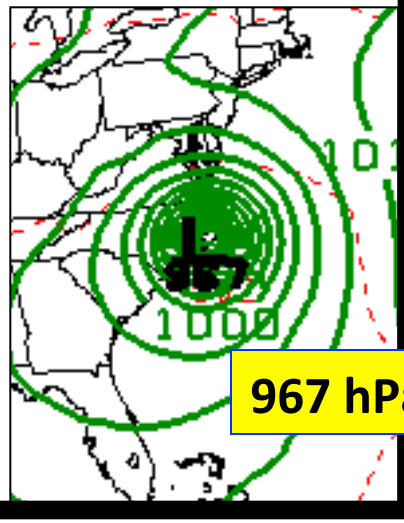
RUC 18h fcst



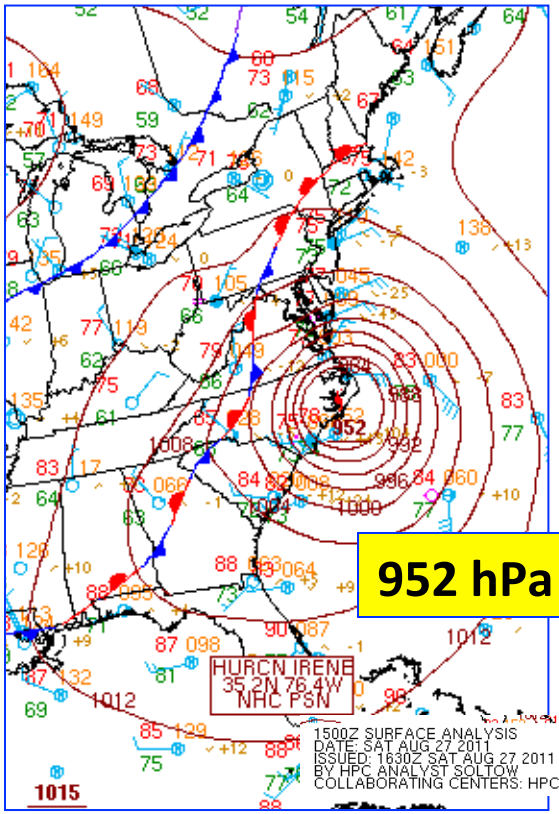


RAP 18h fcst





Hurricane Irene



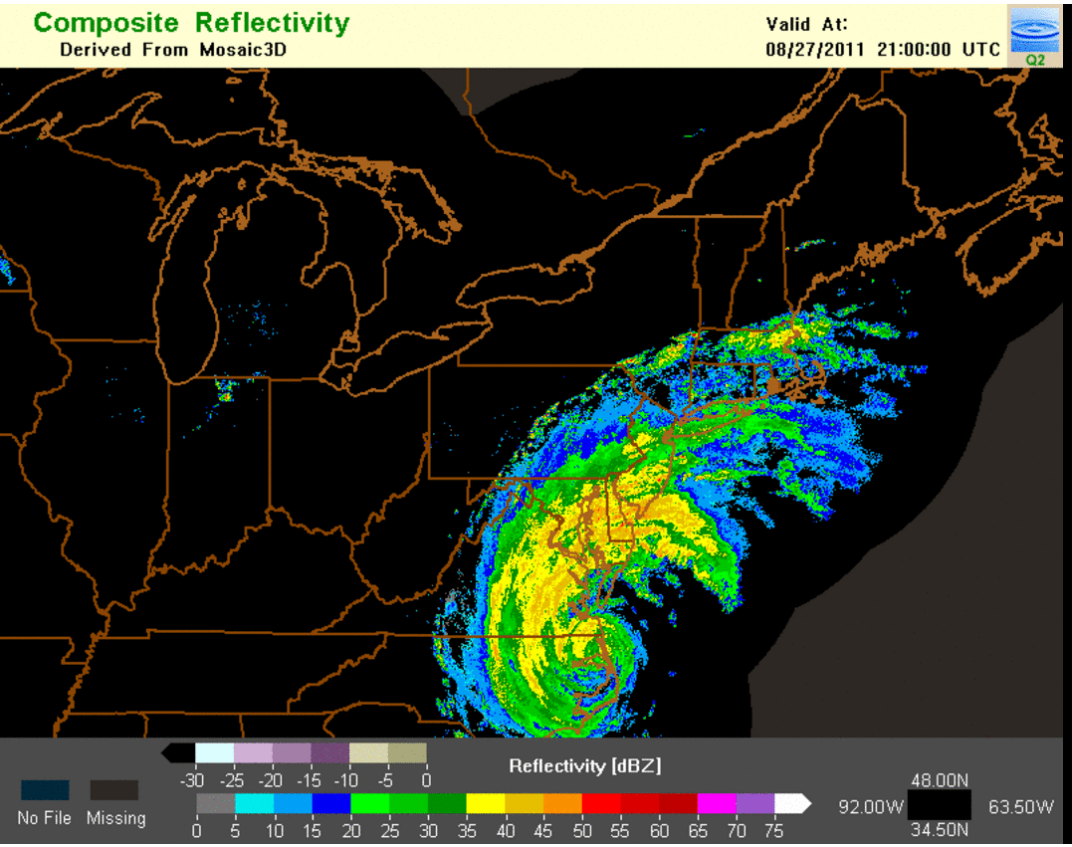
Observations

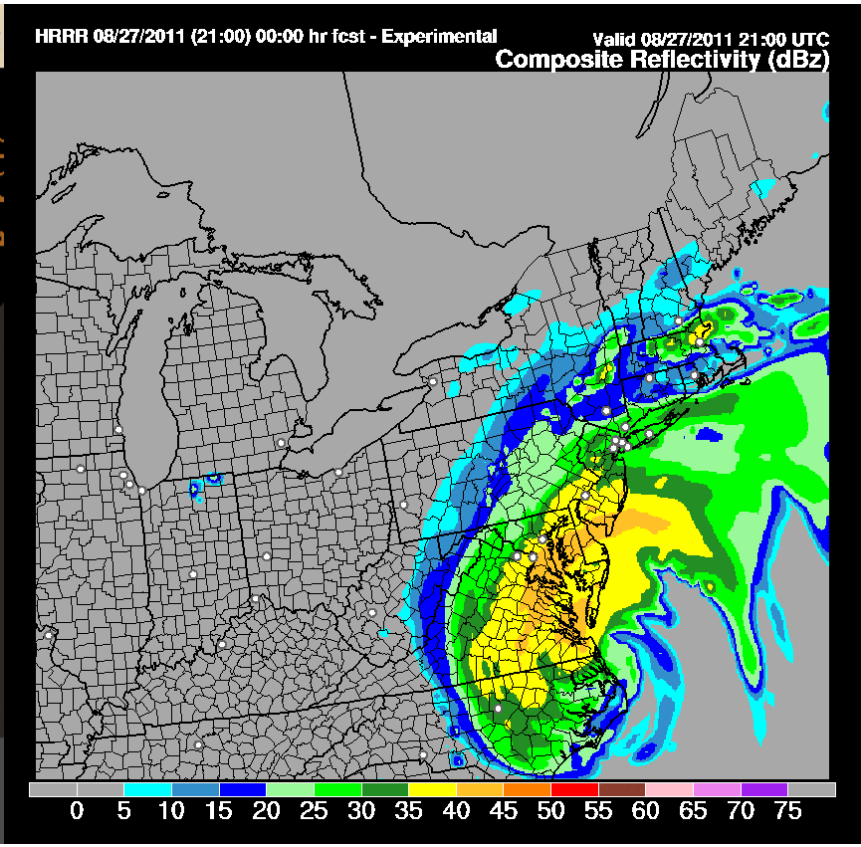
15z Sat 27 Aug 2011

RAP much improved for tropical systems (partial cycling with GFS), much better RTMA background for TC cases

TC improvement: RAP → HRRR

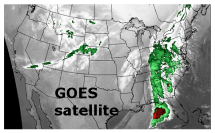
Comparison of HRRR forecast reflectivity (with 15-min output frequency) and observed reflectivity for Hurricane Irene

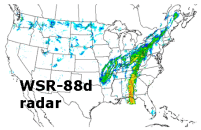


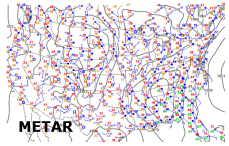


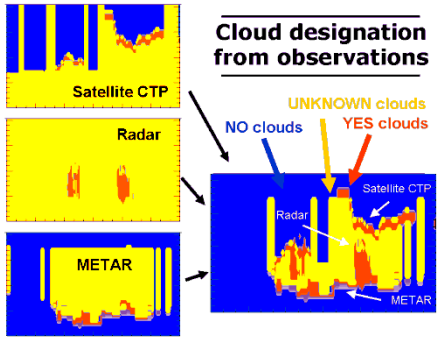
Rapid Refresh – specific analysis features

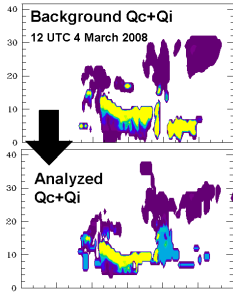
Cloud and hydrometeor analysis











Special treatments for surface observations

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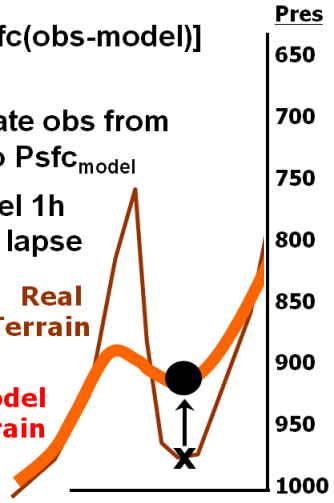
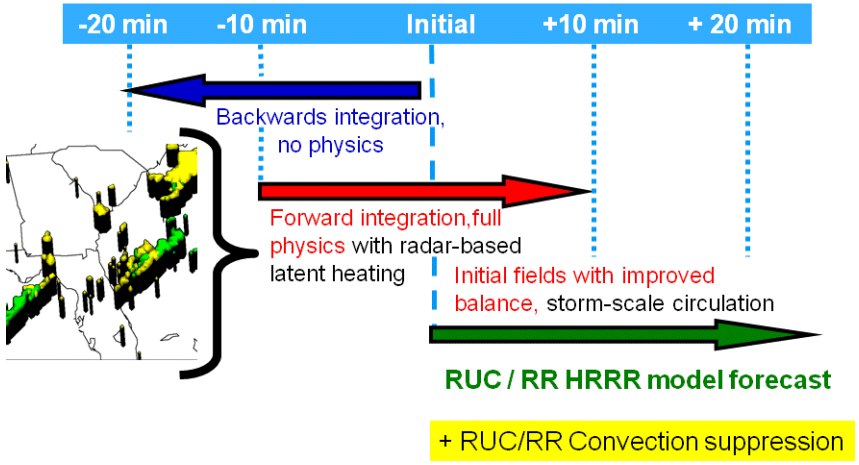
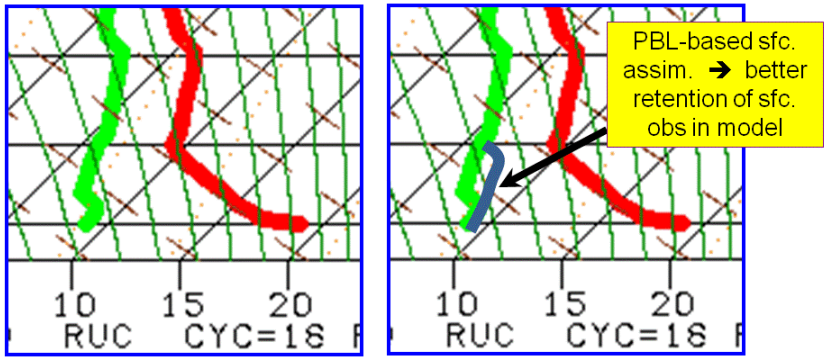


Digital filter-based reflectivity assimilation

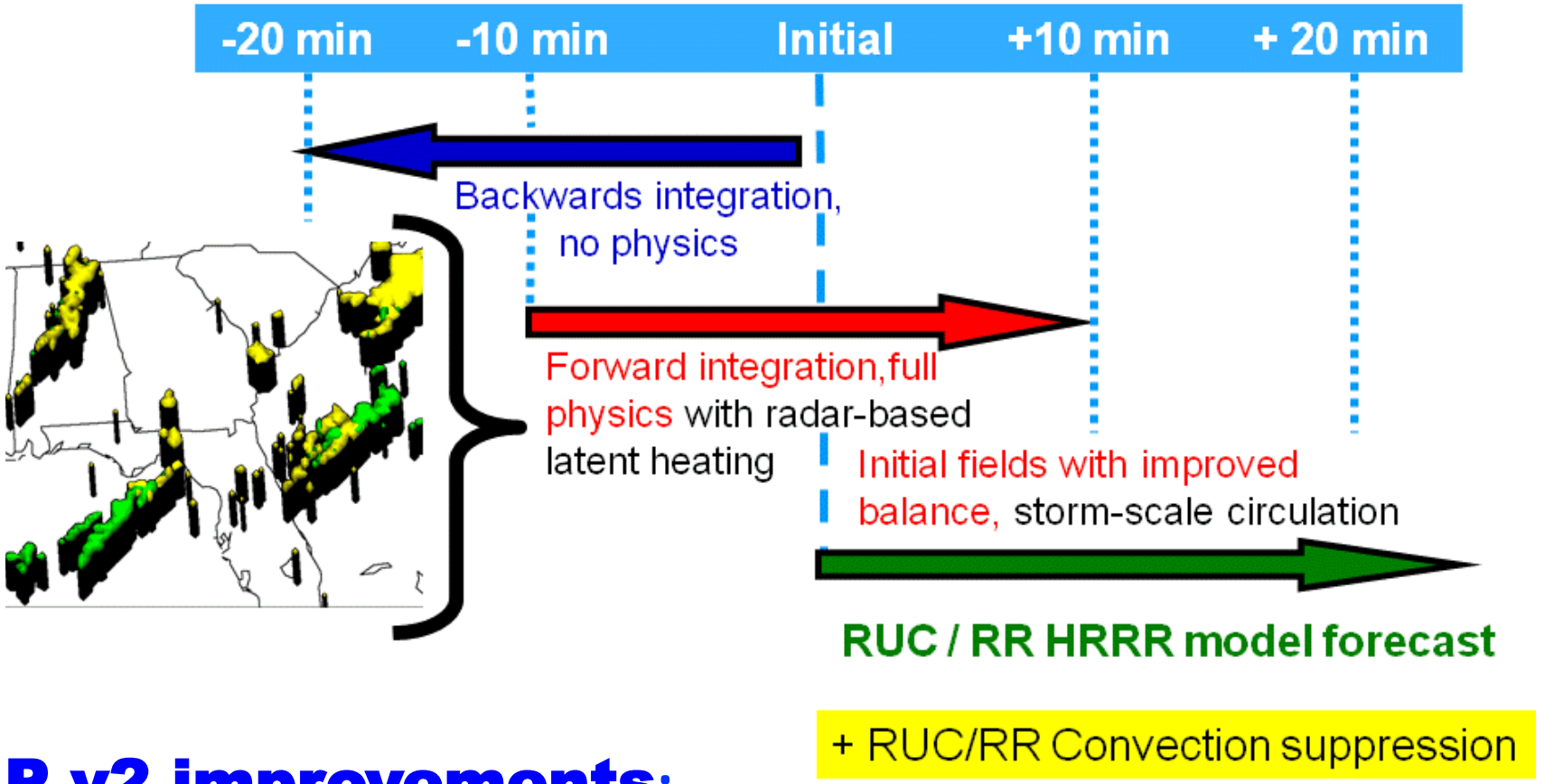


PBL-based pseudo-observations



Rapid Refresh – specific analysis features

DFI-radar reflectivity assimilation



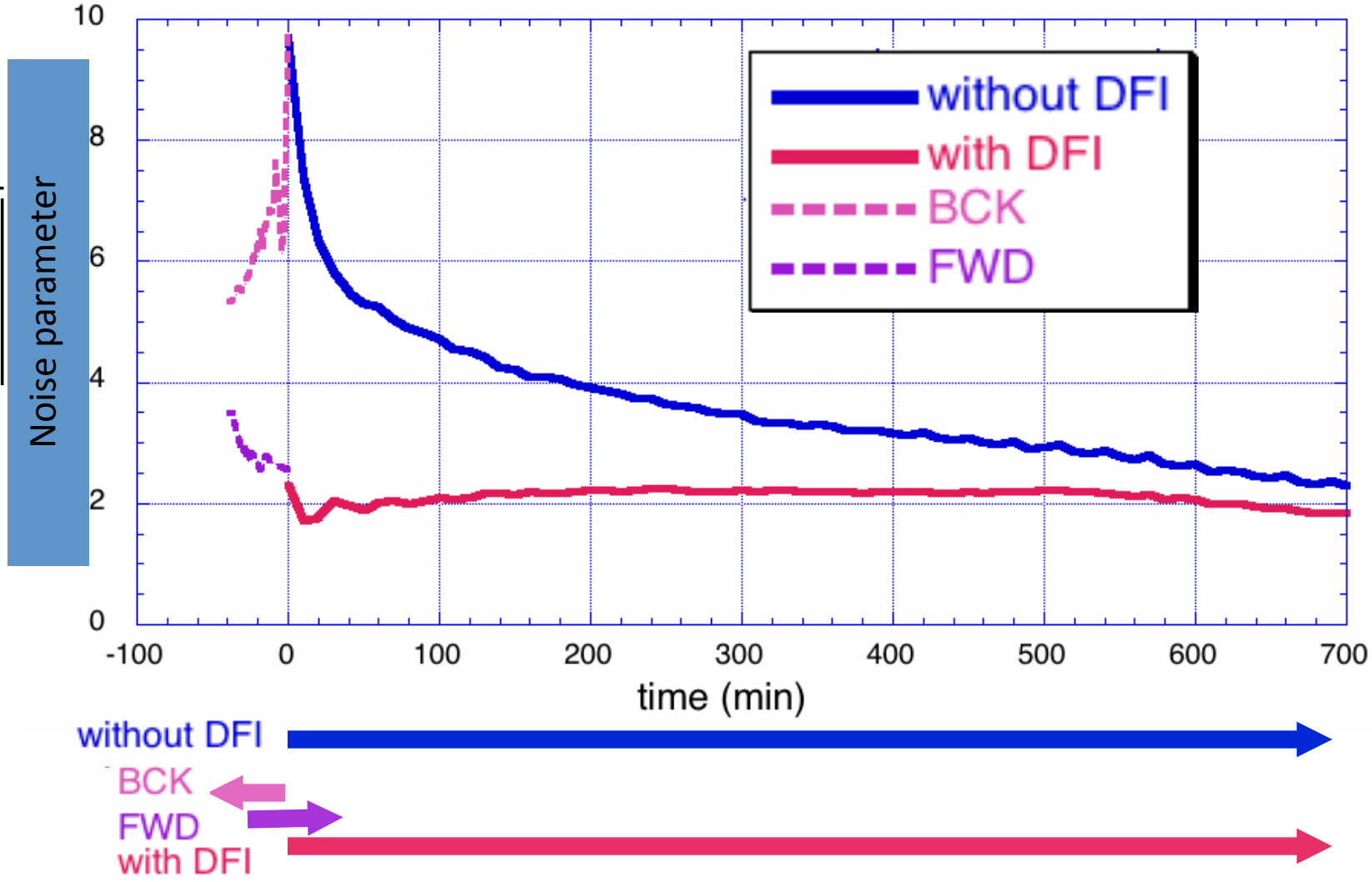
RAP v2 improvements:

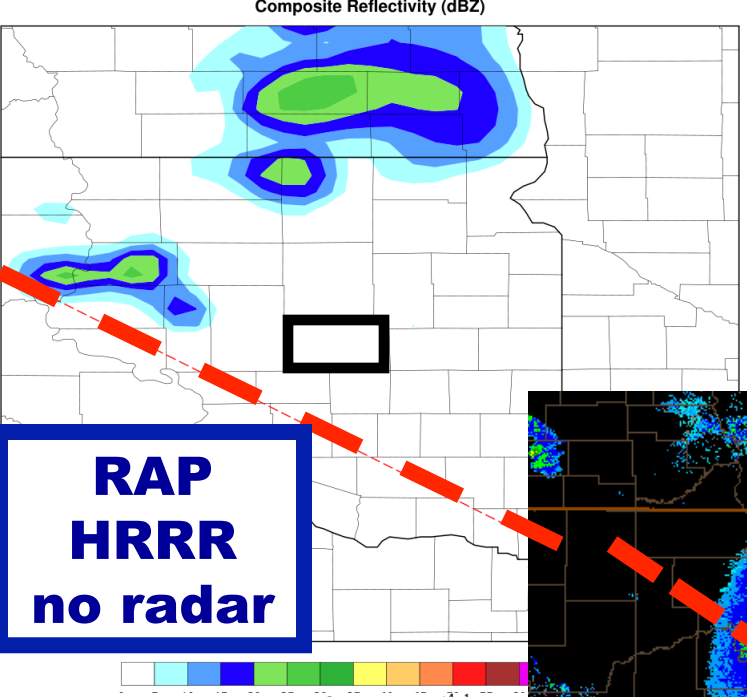
(1) Temperature-dependent hydrometeor specification from 3D radar reflectivity (less 1h precip bias)

Diabatic Digital Filter Initialization

Reduce noise in RUC and Rapid Refresh

$$\left|\frac{\partial p_{sfc}}{\partial t}\right|$$



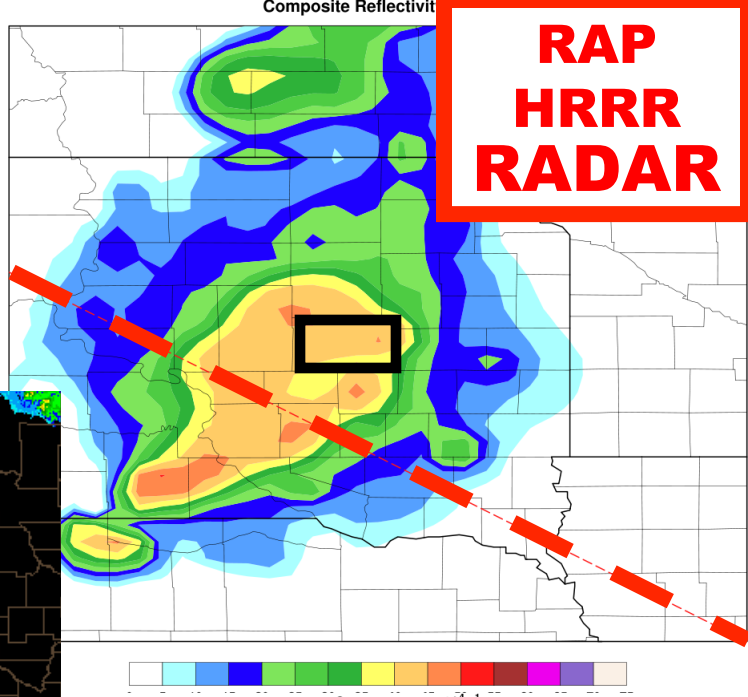


Reflectivity

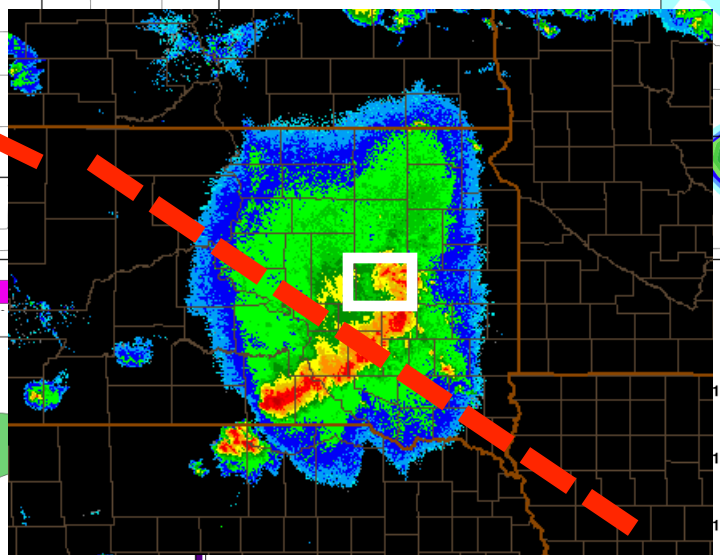
00z init

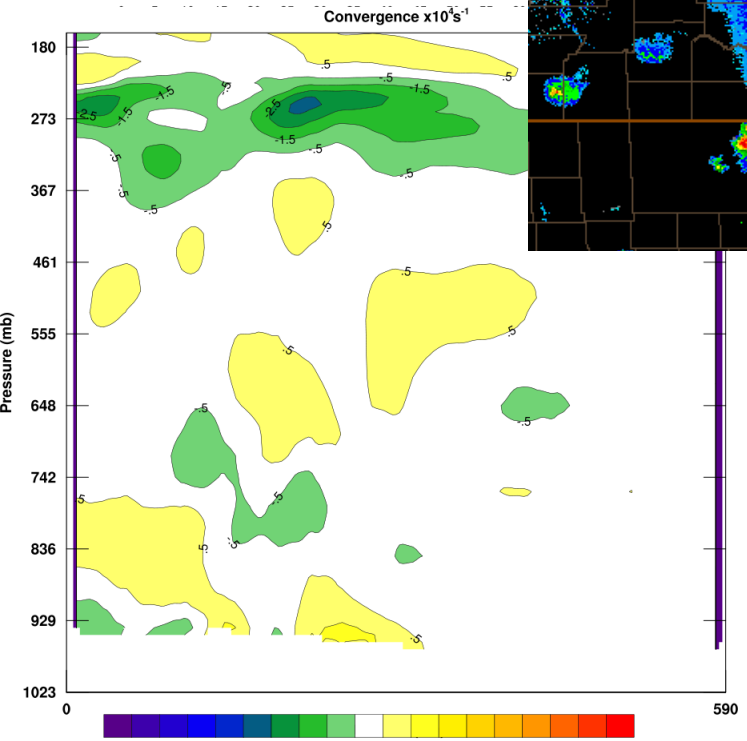
00z 12 Aug 2011

RAP HRRR RADAR

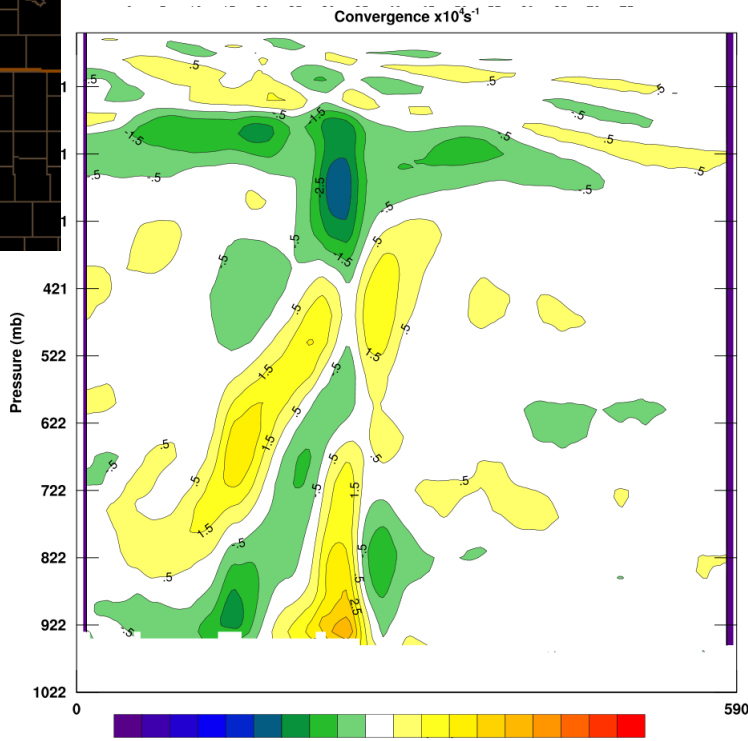


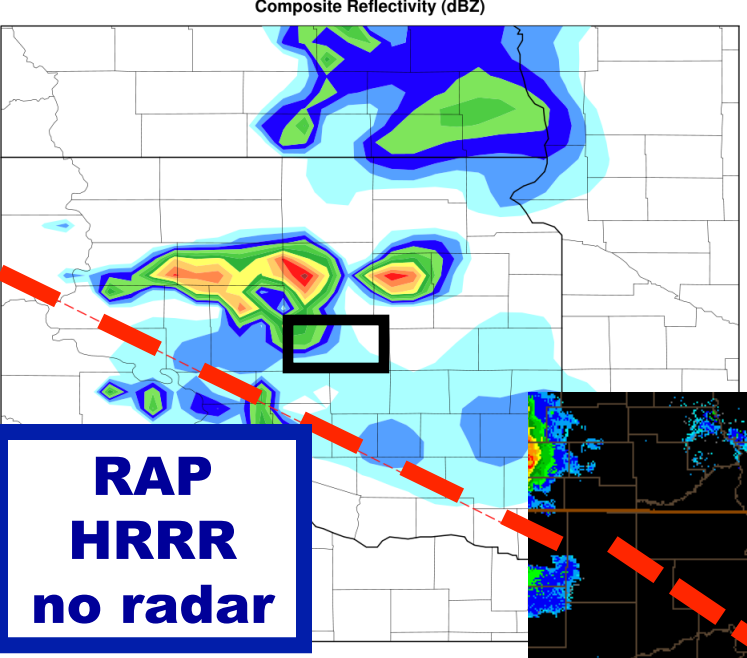
RAP HRRR no radar





Convergence Cross-Section





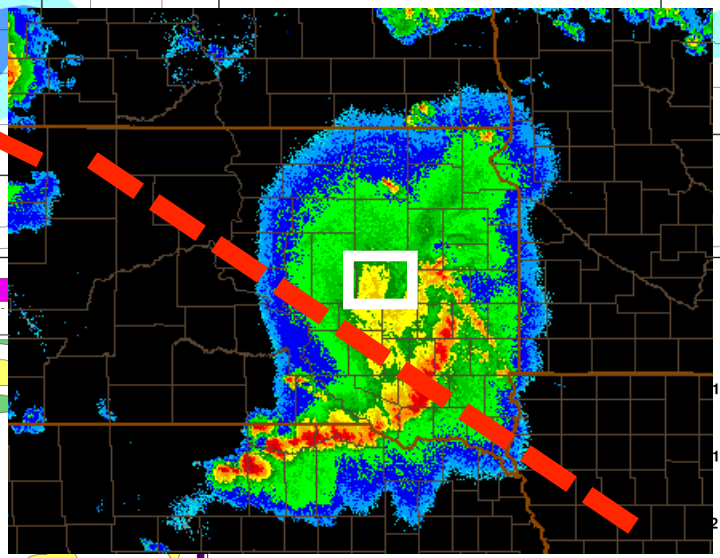
Reflectivity

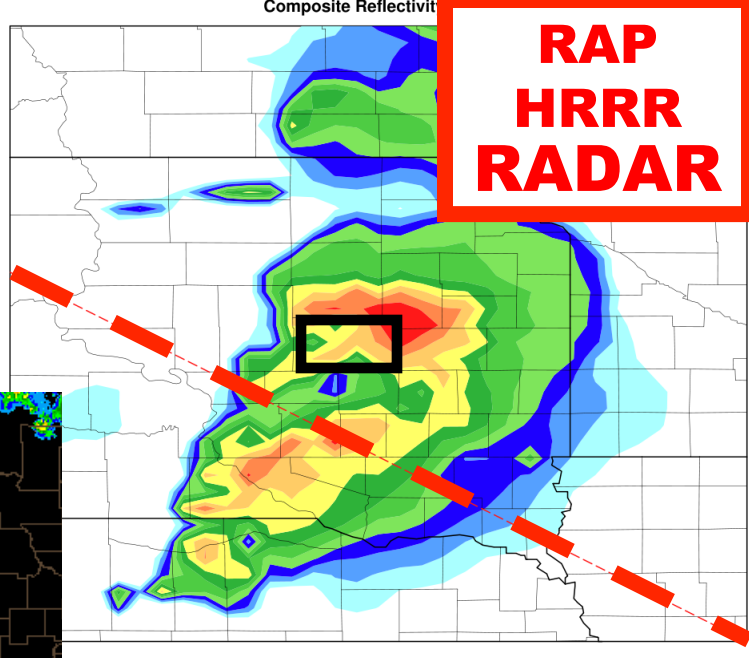
+1h fcst

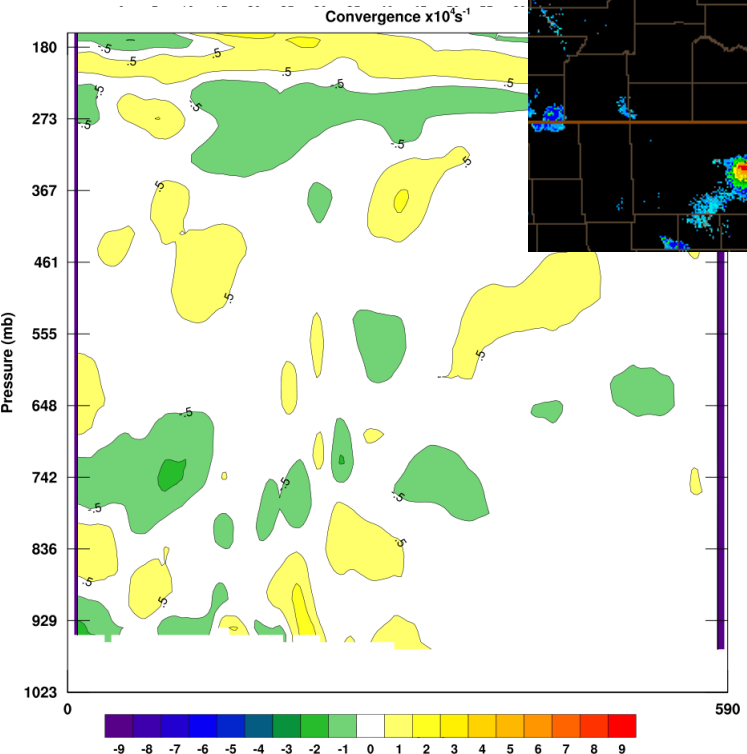
01z 12 Aug 2011

RAP HRRR RADAR

RAP HRRR no radar







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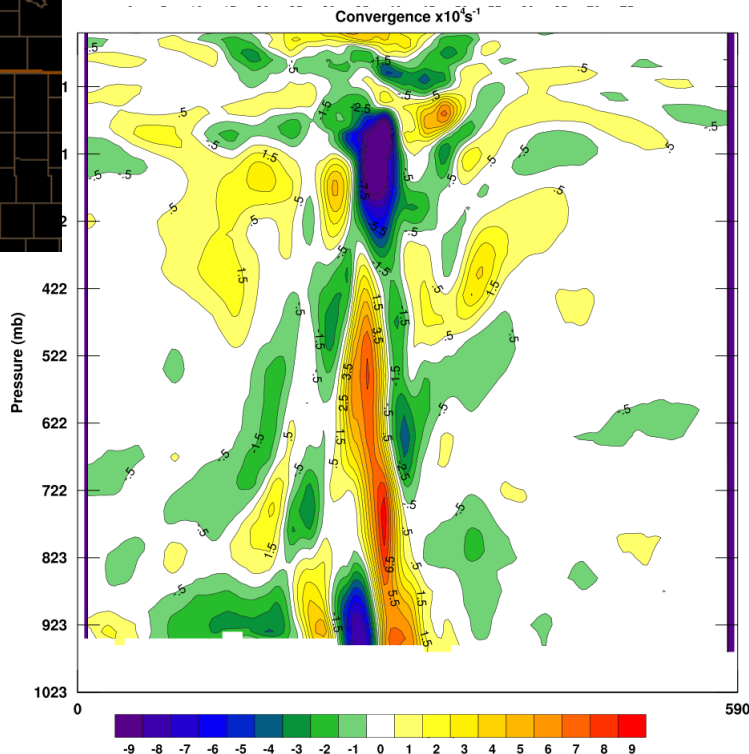
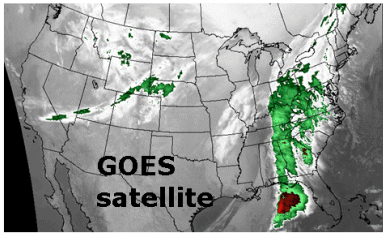
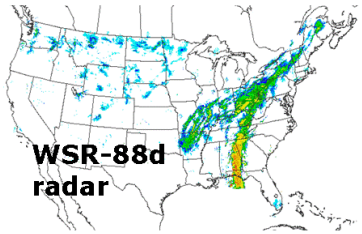
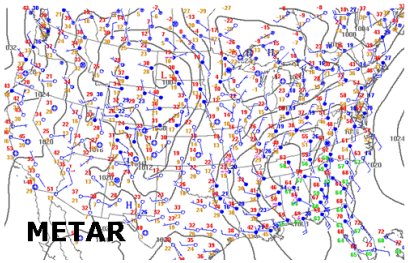


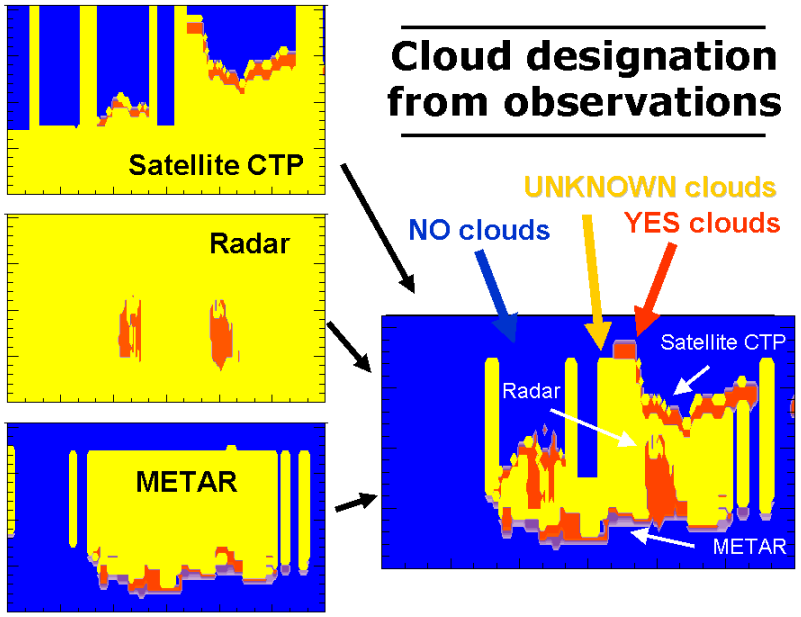
Rapid Refresh – specific analysis features

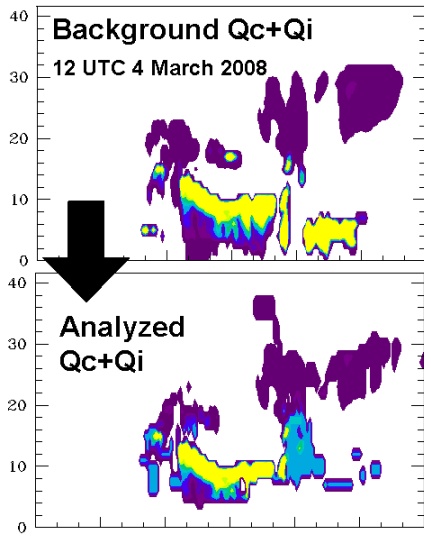
Cloud and hydrometeor analysis









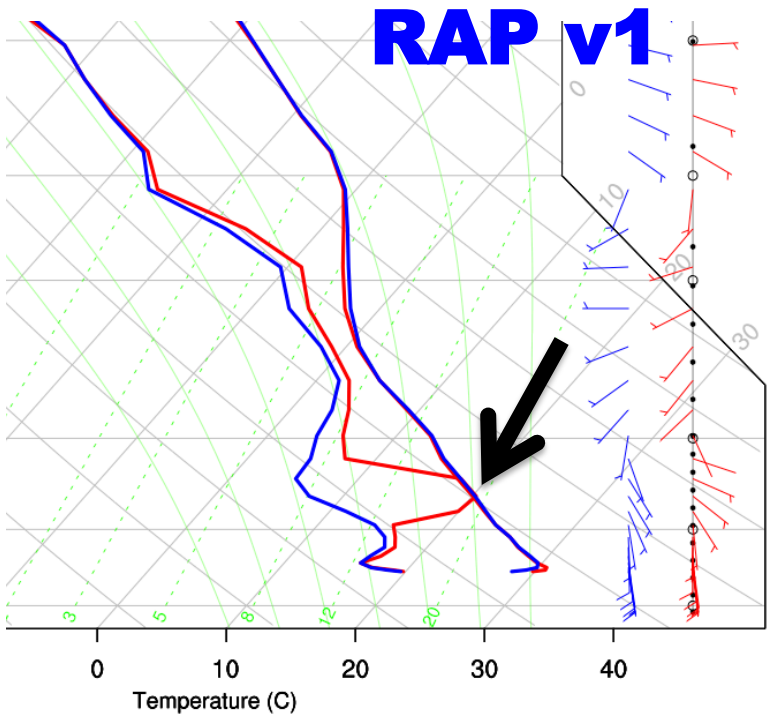


RAP v2 improvements:

(1) Conserve virtual potential temperature for cloud building

(2) Building of low-level clouds from GOES data

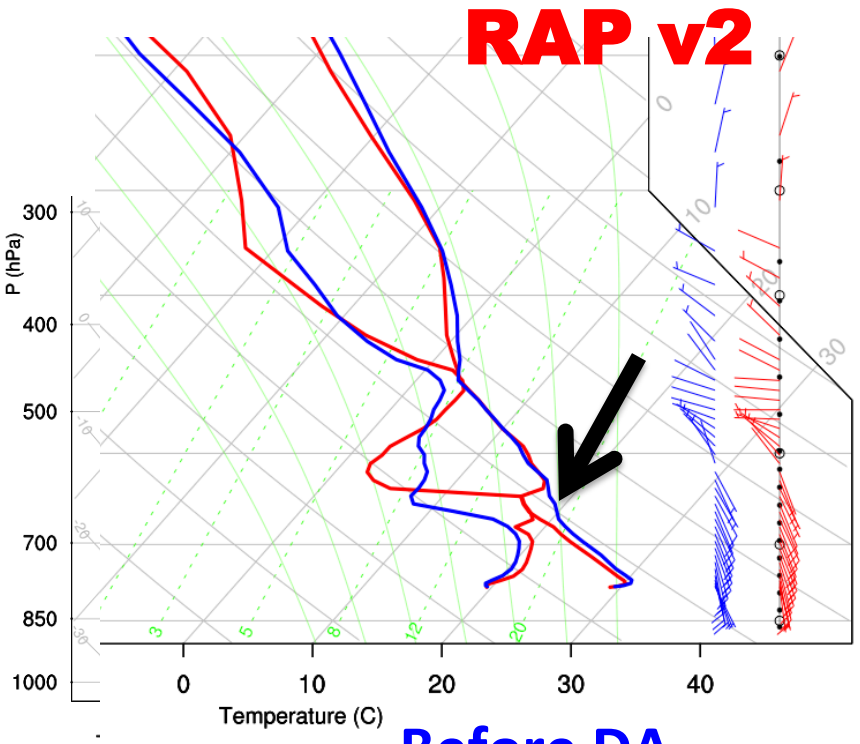
Improved cloud analysis: assume virtual potential temperature is conserved



Before DA

After DA

NOT conserving θ_v



Before DA

After DA

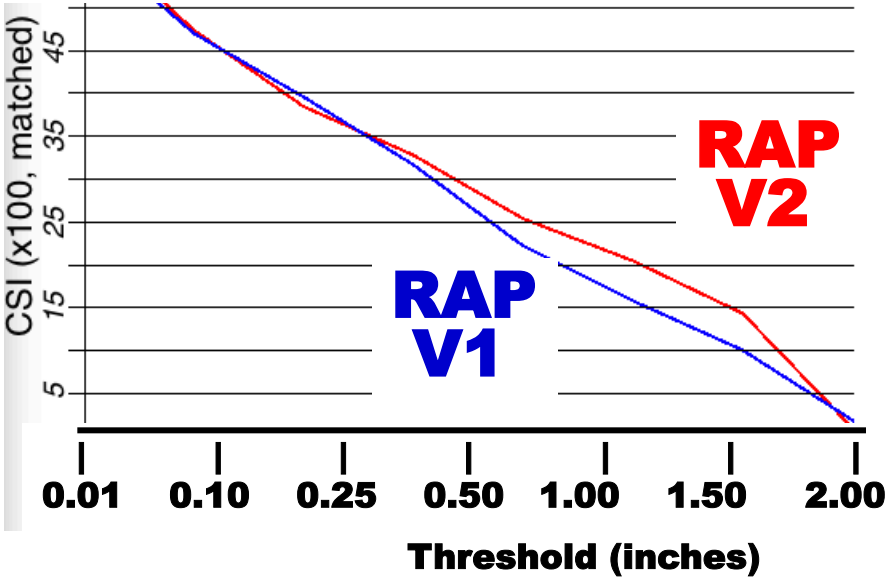
conserving θ_v

RAP Precipitation Verification

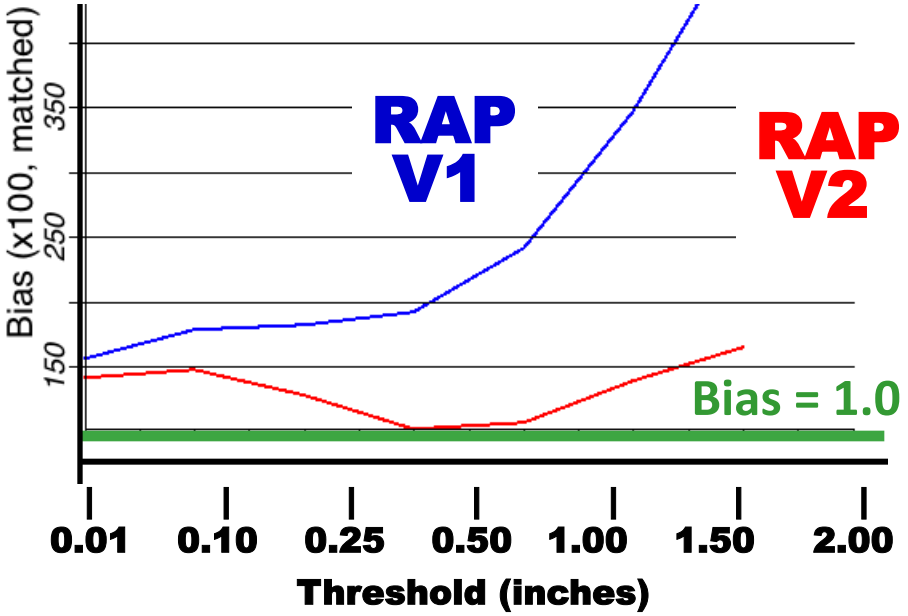
Eastern US, 8x3hr Forecasts vs. 24h CPC

11-21 August 2011

CSI 13 km



Bias 13km

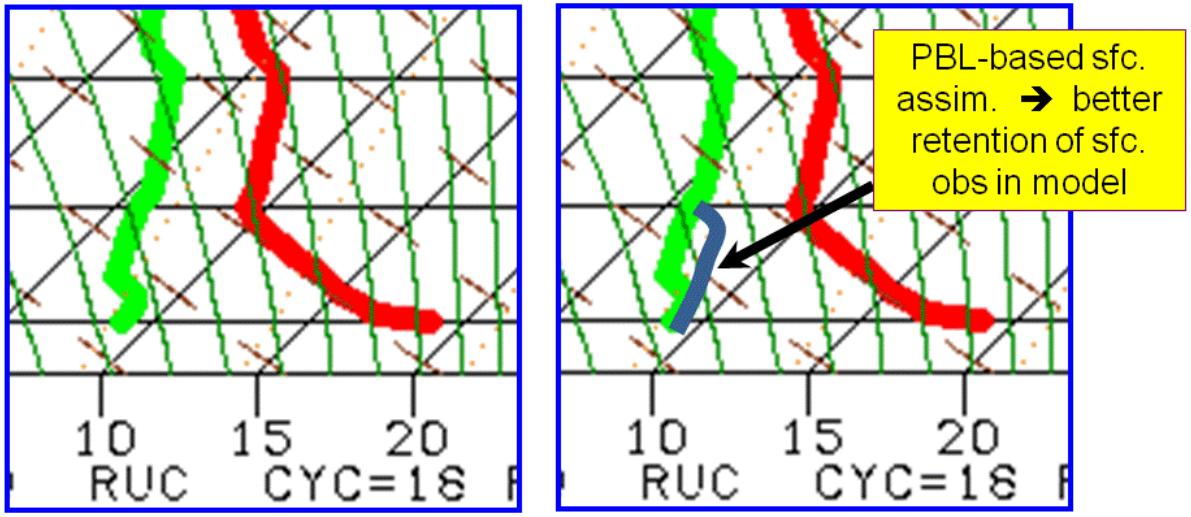


RAP version 2 has better CSI, much improved bias

Rapid Refresh – specific analysis features

Special treatment for surface observations

PBL-based pseudo-observations



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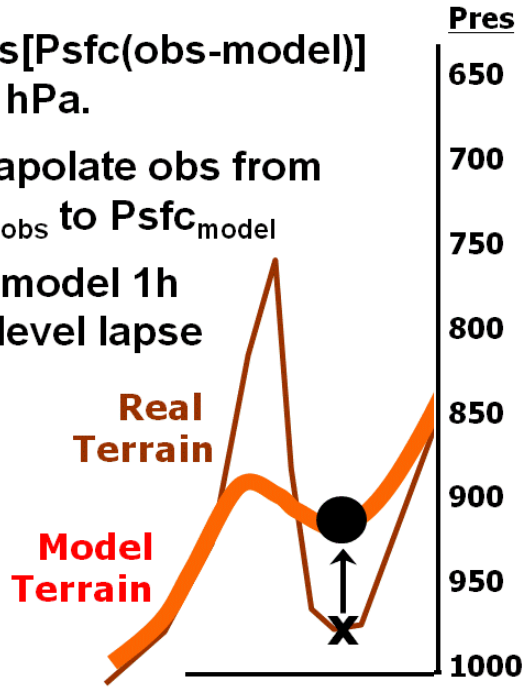
Use model 1h low-level lapse rate.



RAP v2 improvements:

(1) Assimilation of surface moisture pseudo-obs in PBL

(2) Soil adjustment based on near-surface temperature / moisture increments

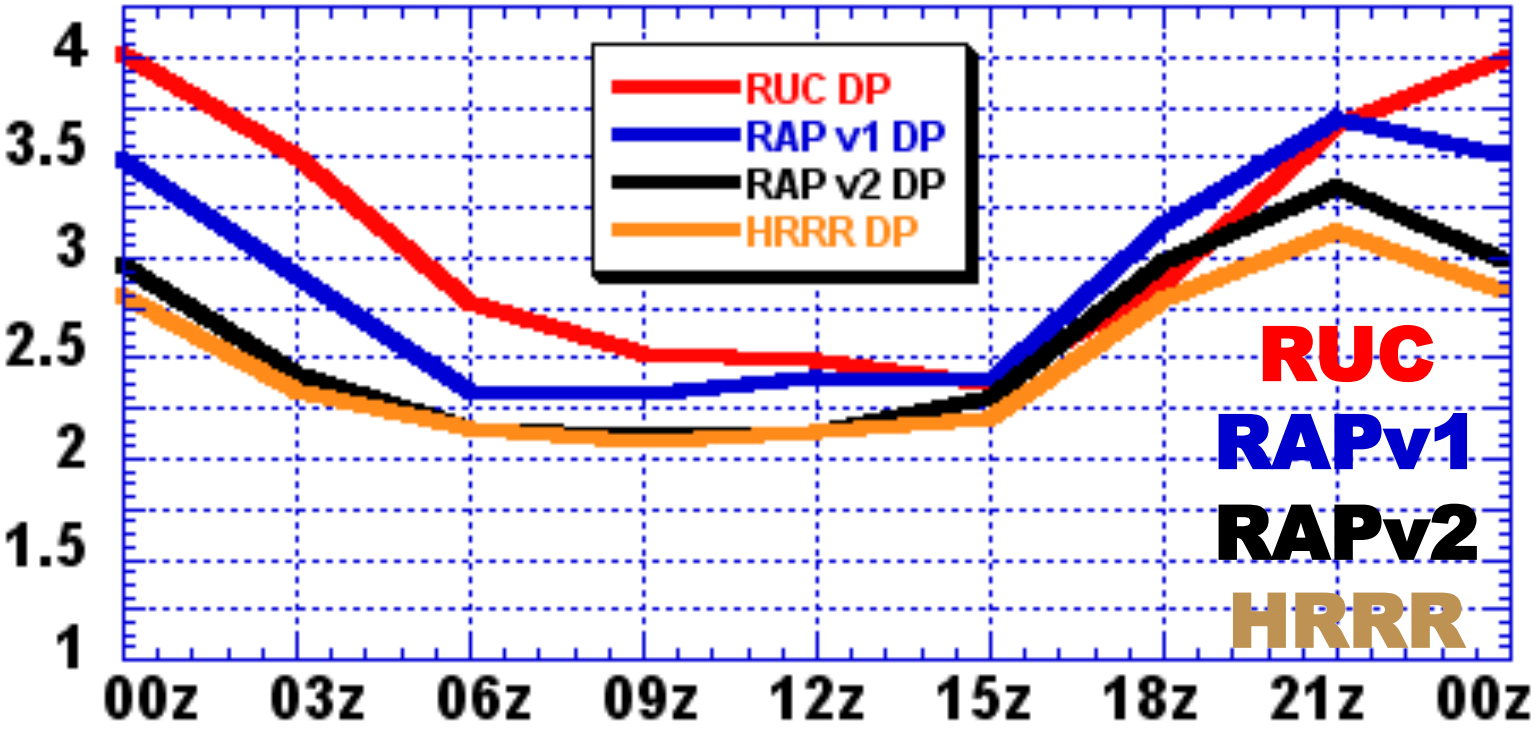
(3) Elevation correction, innovation limits for PW obs

RUC vs. RAPv1 vs. RAPv2 vs. HRRR surface dew point verification

6-h fcst dewpoint RMS diurnal variation

4-week comparison
9 Feb – 7 Mar 2012

RMS errors:
RUC > RAPv1 > RAPv2 > HRRR



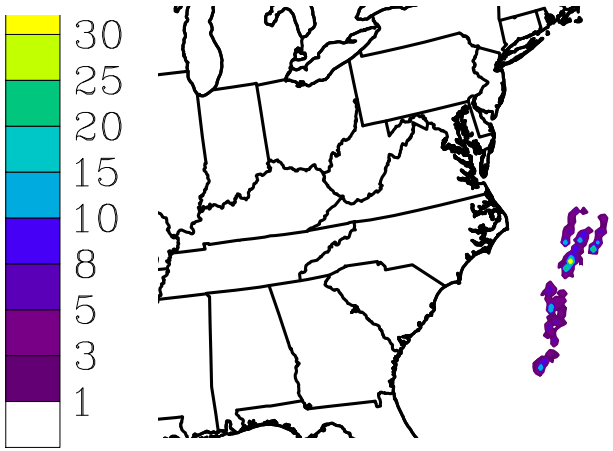
Rapid Refresh – new observations

RAP v2 new observation sources

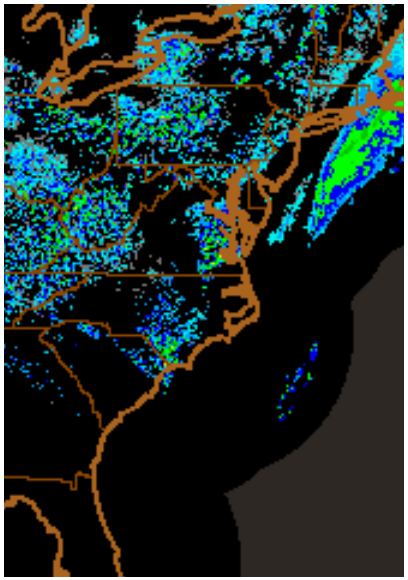
(1) Extended range lightning data (proxy for reflectivity)

(2) Wind energy (tower, nacelle, sodar) observations

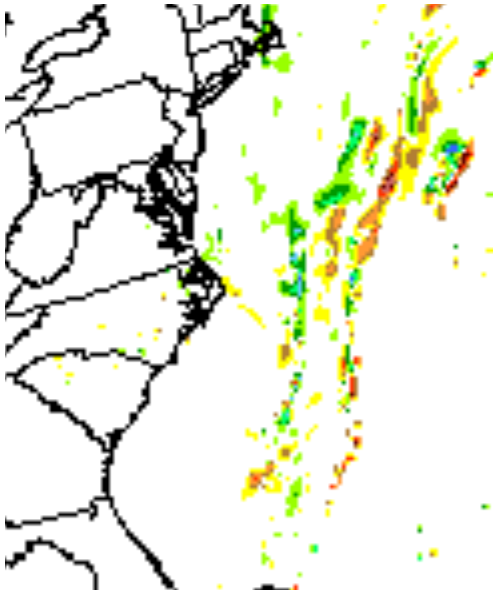
(3) Radar radial velocity



LTG flash density



Obs reflectivity



1h fcst refl. diff between RAP w/ and w/o lightning

Merge RAP GSI code with GSI code from recent NCEP/community trunk versions

Rapid Refresh assimilation – summary

Accurate mesoscale fields from Rapid Refresh: key aspect of HRRR success

- Use of state-of-the-art community codes (GSI, WRF)
- Hourly assimilation of conventional observations
- Use of many novel observation types and special assimilation techniques for them

HRRR improvement strongly dependent on improvements in RAP data assimilation

- Initial RAP (NCEP implement planned for March 20, 2012) is significant improvement over current NCEP RUC
- RAP v2 provides further significant improvement over RAP v1 (especially for moisture, precipitation)

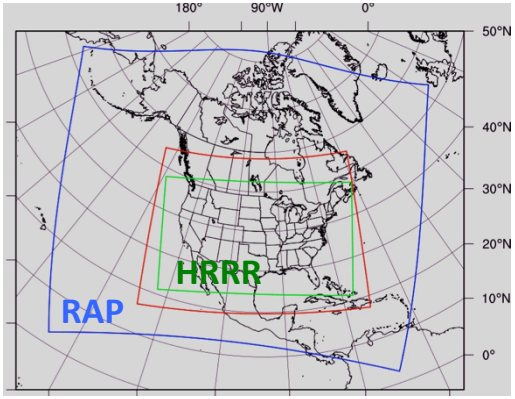
RAPv2 improving HRRR now, NCEP implement early 2013?

HRRR Program Review Outline

1:30	Opening Remarks	Stan Benjamin
1:30 – 1:40	Program Overview	Curtis Alexander
1:40 – 1:50	Initial Conditions: Rapid Refresh	Steve Weygandt
1:50 – 2:00	Model Development	David Dowell
2:00 – 2:10	Case Studies and Applications	Eric James
2:10 – 2:20	Forecast Verification	Patrick Hofmann
2:20	Summary and Future Plans	Curtis Alexander
2:20 – 2:30	Questions	

HRRR and RAP-ESRL Model Details

Model	Domain	Grid Points	Grid Spacing	Vertical Levels	Boundary Conditions	Initialized
RAP-ESRL	North America	758 x 567	13 km	50	GFS	Hourly (cycled)
HRRR	CONUS	1799 x 1059	3 km	50	RAP-ESRL	Hourly (no-cycle)



Model	Version	Assimilation	Radar DFI	Radiation	Microphysics	Cum Param	PBL	LSM
RAP-ESRL	WRF-ARW v3.3.1+	GSI-3DVar	Yes	RRTM/ Goddard	Thompson v3.3.1	G3 + Shallow	MYJ	RUC v3.3.1
HRRR	WRF-ARW v3.3.1+	None: RAP I.C.	No	RRTM/ Goddard	Thompson v3.3.1	None	MYJ	RUC v3.3.1

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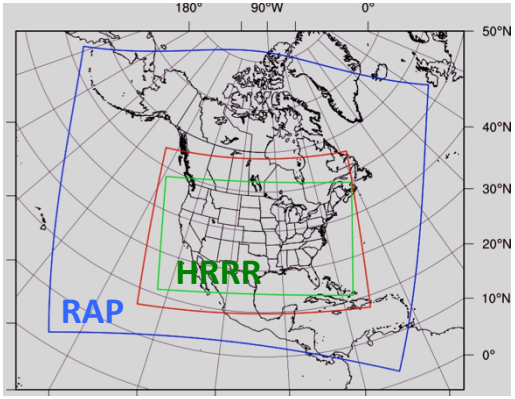

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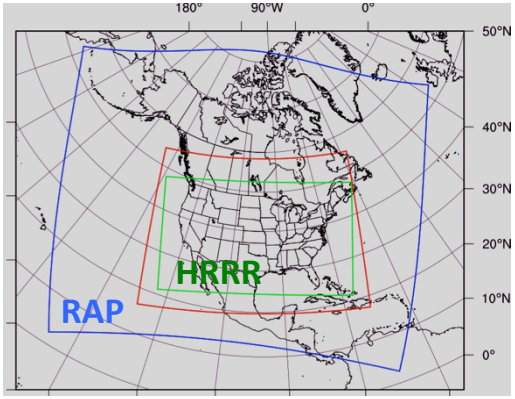

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HRRR	WRF-ARW v3.3.1+	None: RAP I.C.	No	RRTM/ Goddard	Thompson v3.3.1	None	MYJ	RUC v3.3.1

HRRR Forecast Behavior

2011

(1) **High bias** in convection over **eastern US**

(2) **False alarms**

(3) **Lead** in convective initiation (early AM runs)

(4) **Difficulty** maintaining **mesoscale convective systems**

(5) **Reflectivity biases** in snow and convective storms

RAP/HRRR Model Development and Evaluation

2012 Targets

(1) **Lower peak bias** in convection over **eastern US**

(2) **Fewer false alarms**

(3) **Improved timing** of convective initiation

(4) **More success** maintaining **mesoscale convective systems**

(5) **More realistic reflectivity**

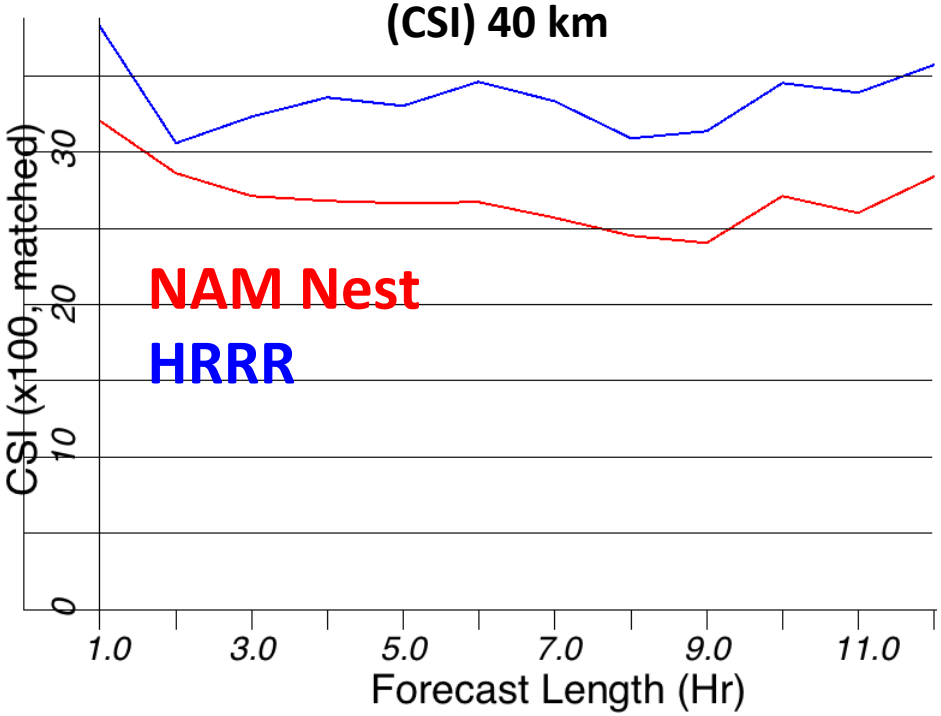
RAP and HRRR Changes 2011-2012

	Model	Data Assimilation
RAP-ESRL (13 km)	WRFv3.3.1+ Physics changes (convection, microphysics, land-surface, PBL) Numerics changes (w-damp upper bound conditions, 5th-order vertical advection) MODIS land use, fractional 30→10 min shortwave radiation New reflectivity diagnostic	Soil adjustment Temp-dep radar-hydrometeor building PW assim mods Cloud assim mods Tower/nacelle/sodar observations GLD360 lightning GSI merge with trunk Radial wind assim
HRRR (3 km)	WRFv3.3.1+ Physics changes (microphysics, land-surface, PBL) Numerics changes (w-damp upper bound conditions, 5th-order vertical advection) MODIS land use, fractional 30→05 min shortwave radiation New reflectivity diagnostic	3 km/15 min reflect assim 3 km radial wind assim 3 km cloud cycling 3 km land-surface cycling

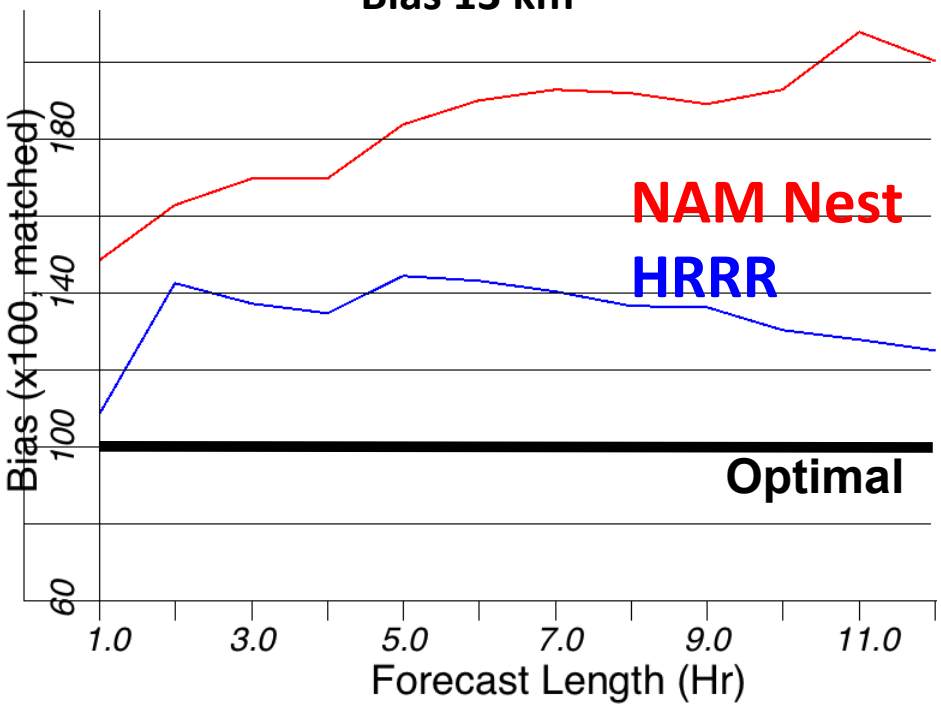
Reflectivity Forecast Verification

Reflectivity ≥ 25 dBZ **Eastern US** **3 - 9 March 2012**

Critical Success Index (CSI) 40 km



Bias 13 km

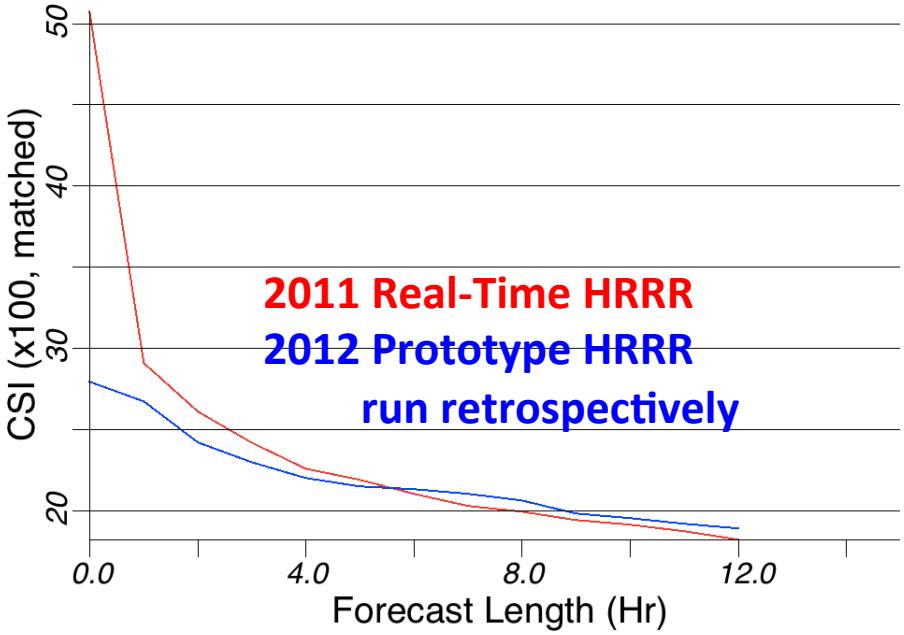


NAM Nest: **4-km grid spacing, CONUS, every 6 hours**

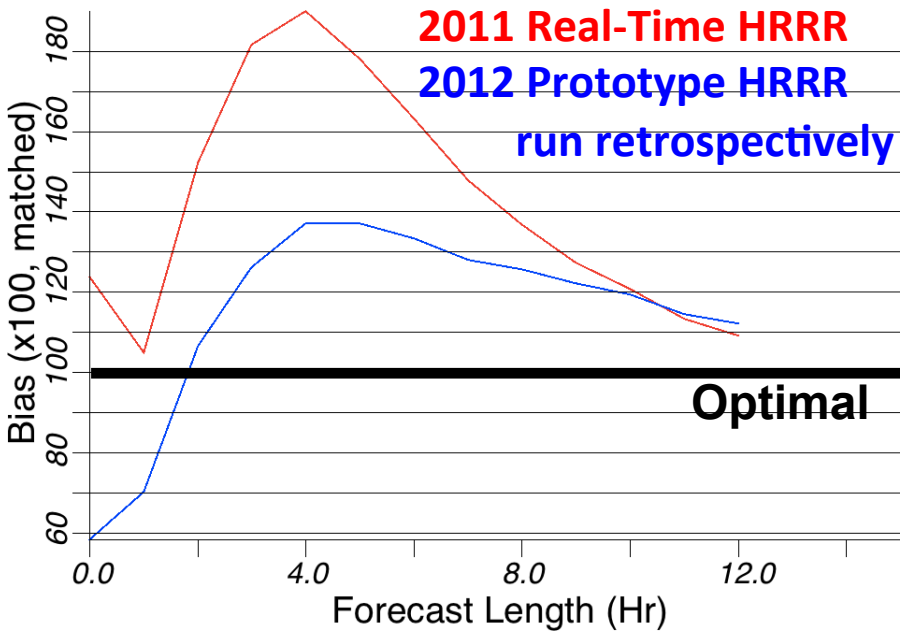
Reflectivity Forecast Verification

Reflectivity ≥ 20 dBZ **Eastern US** **32 Cases from August 2011**

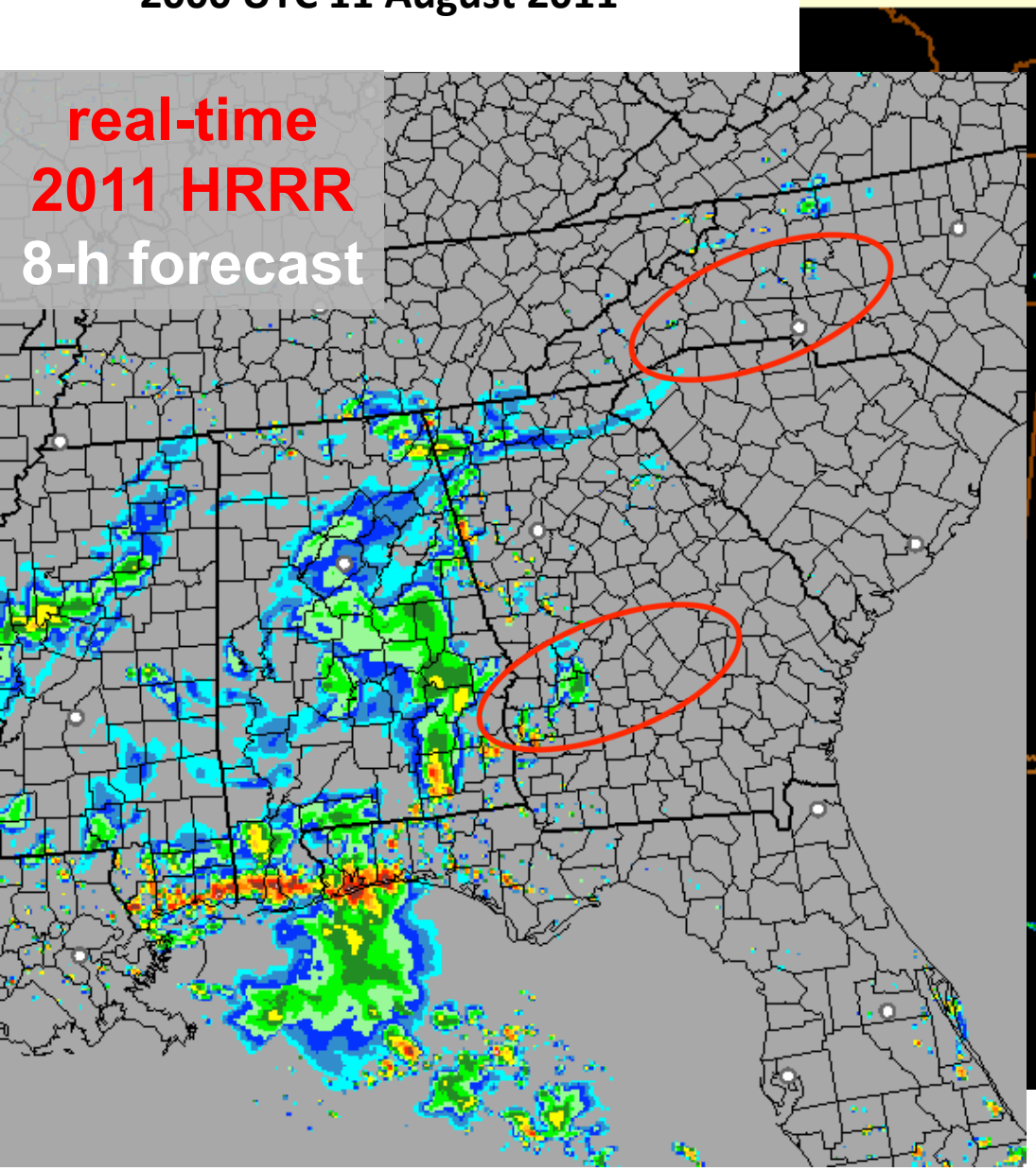
Critical Success Index (CSI) 40 km

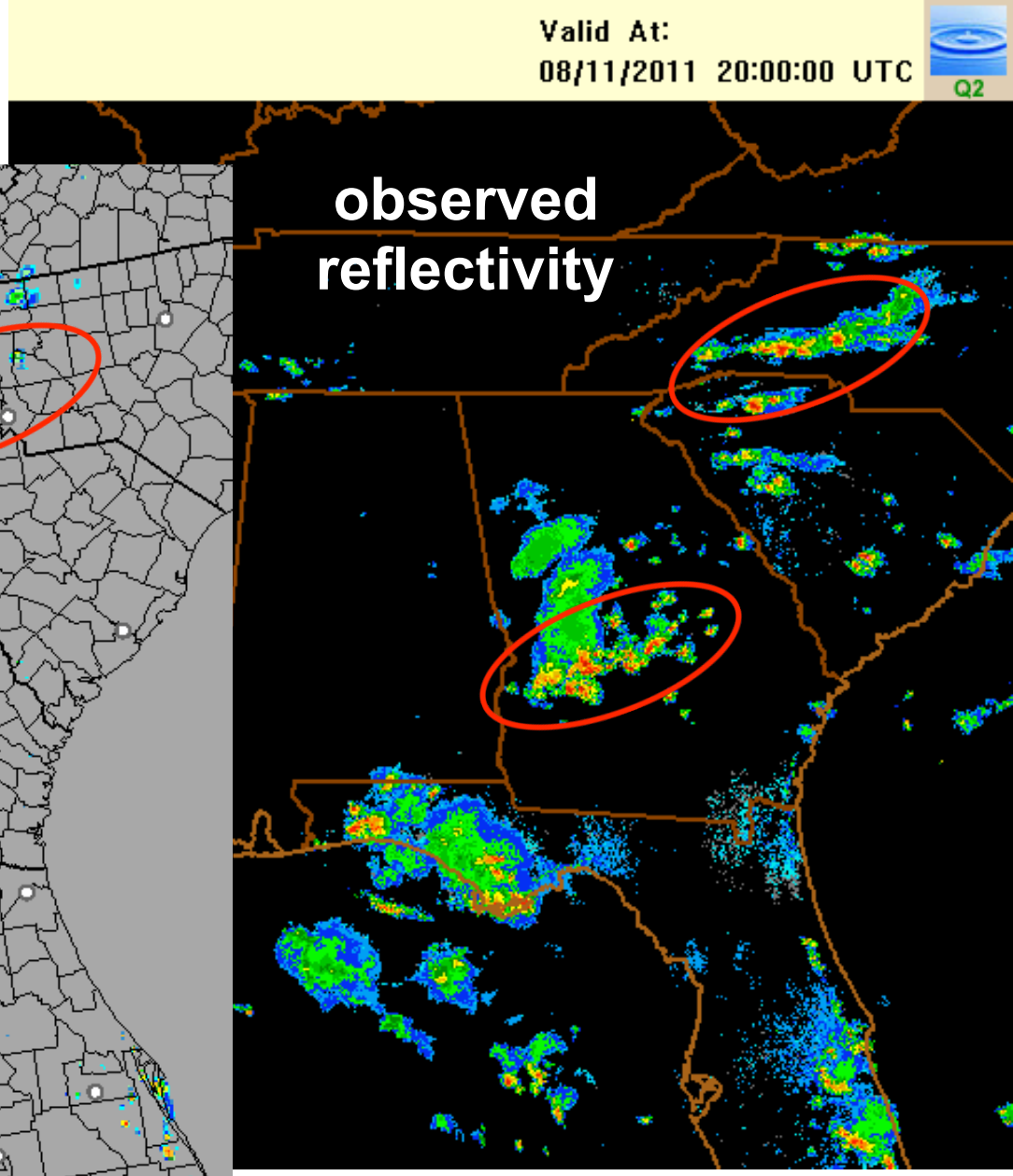


Bias 3 km



2000 UTC 11 August 2011





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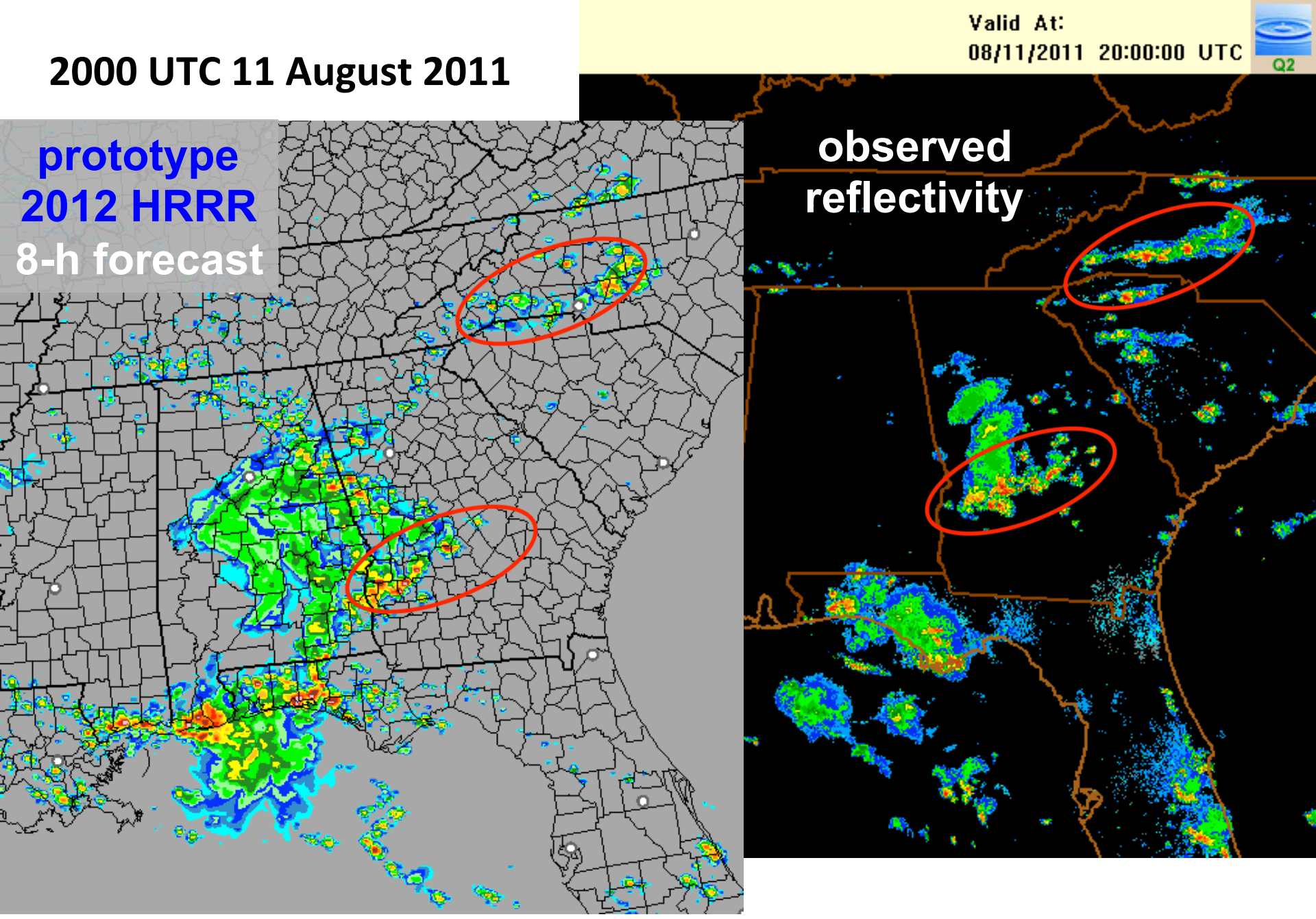
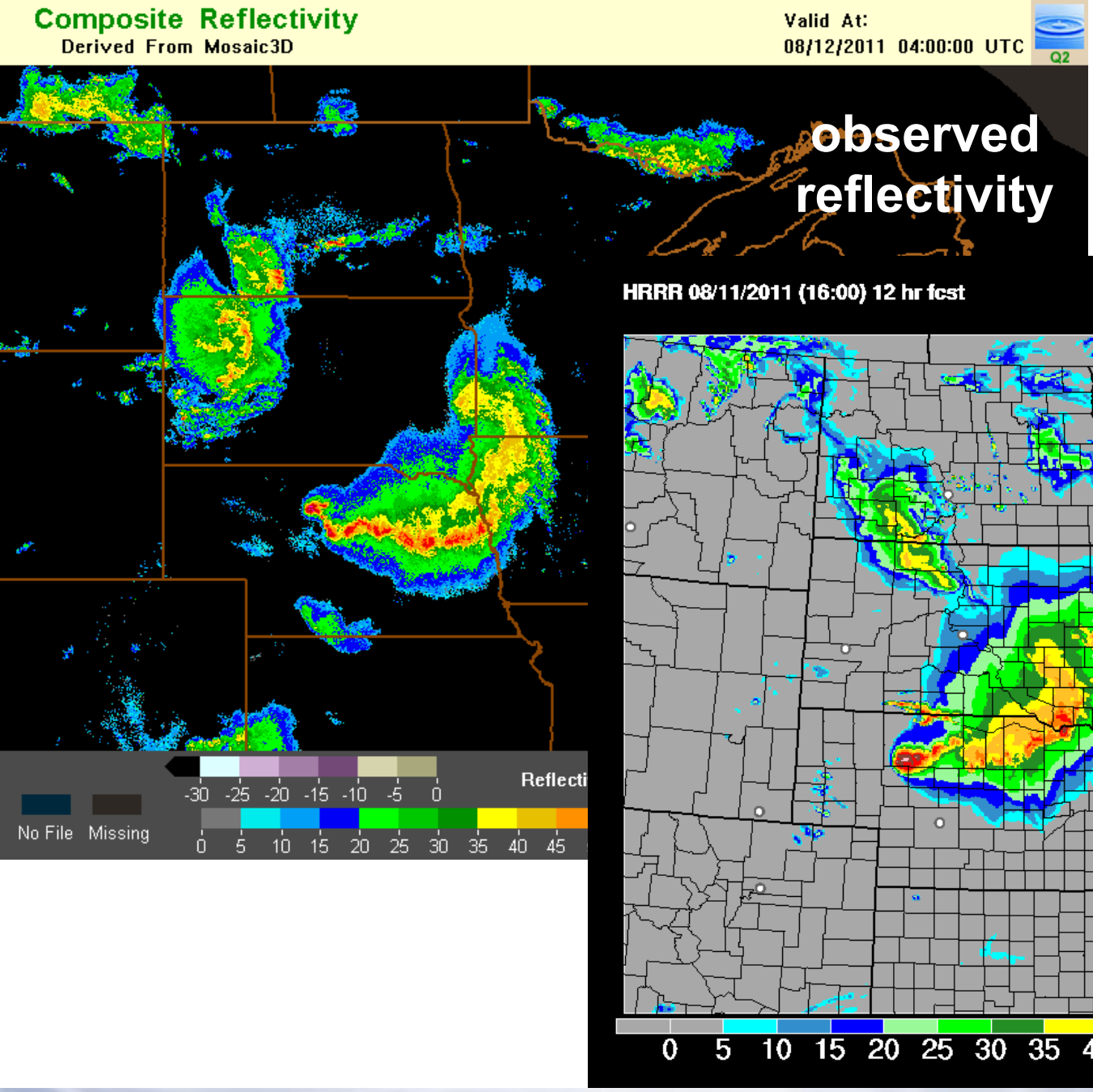
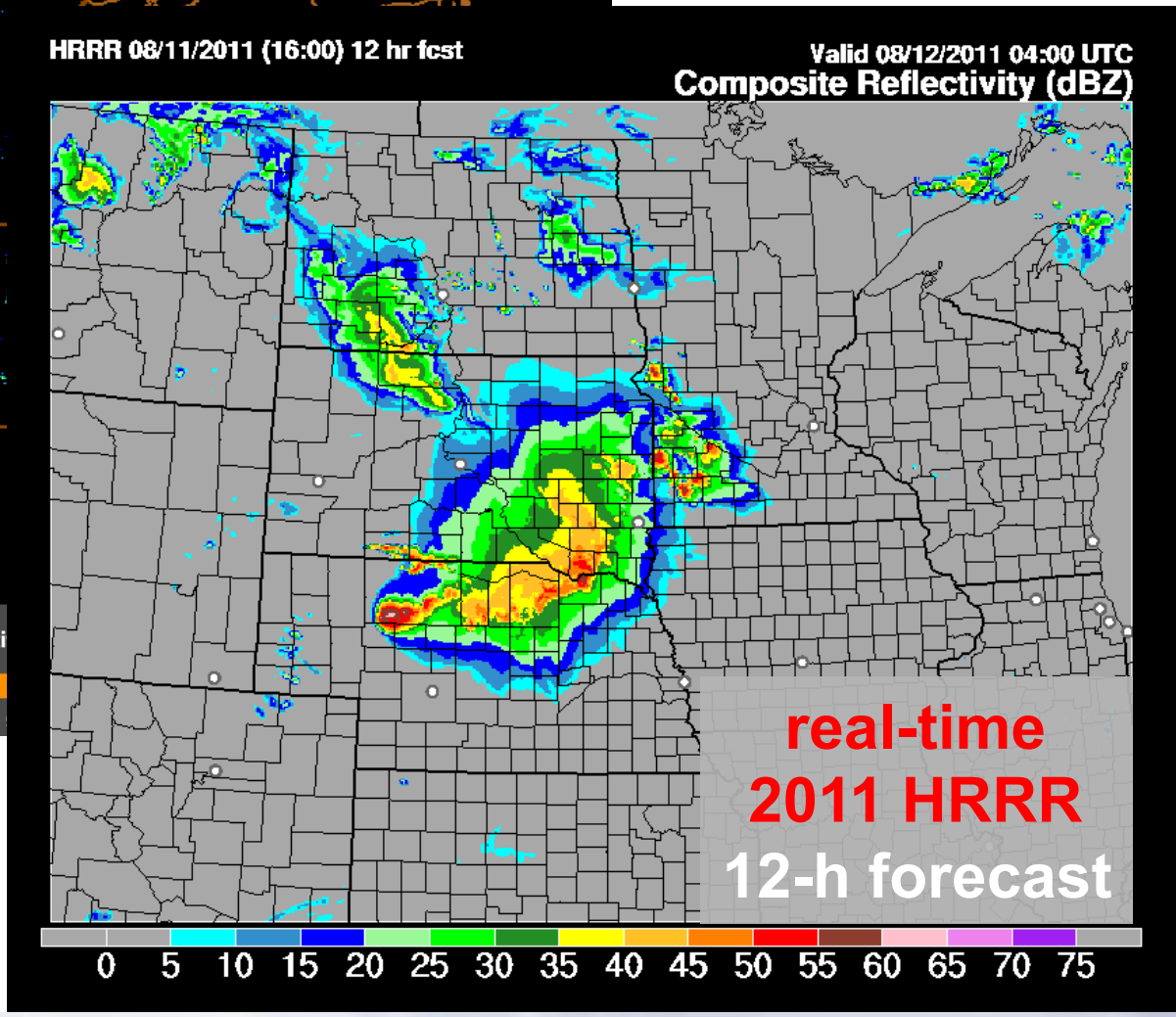
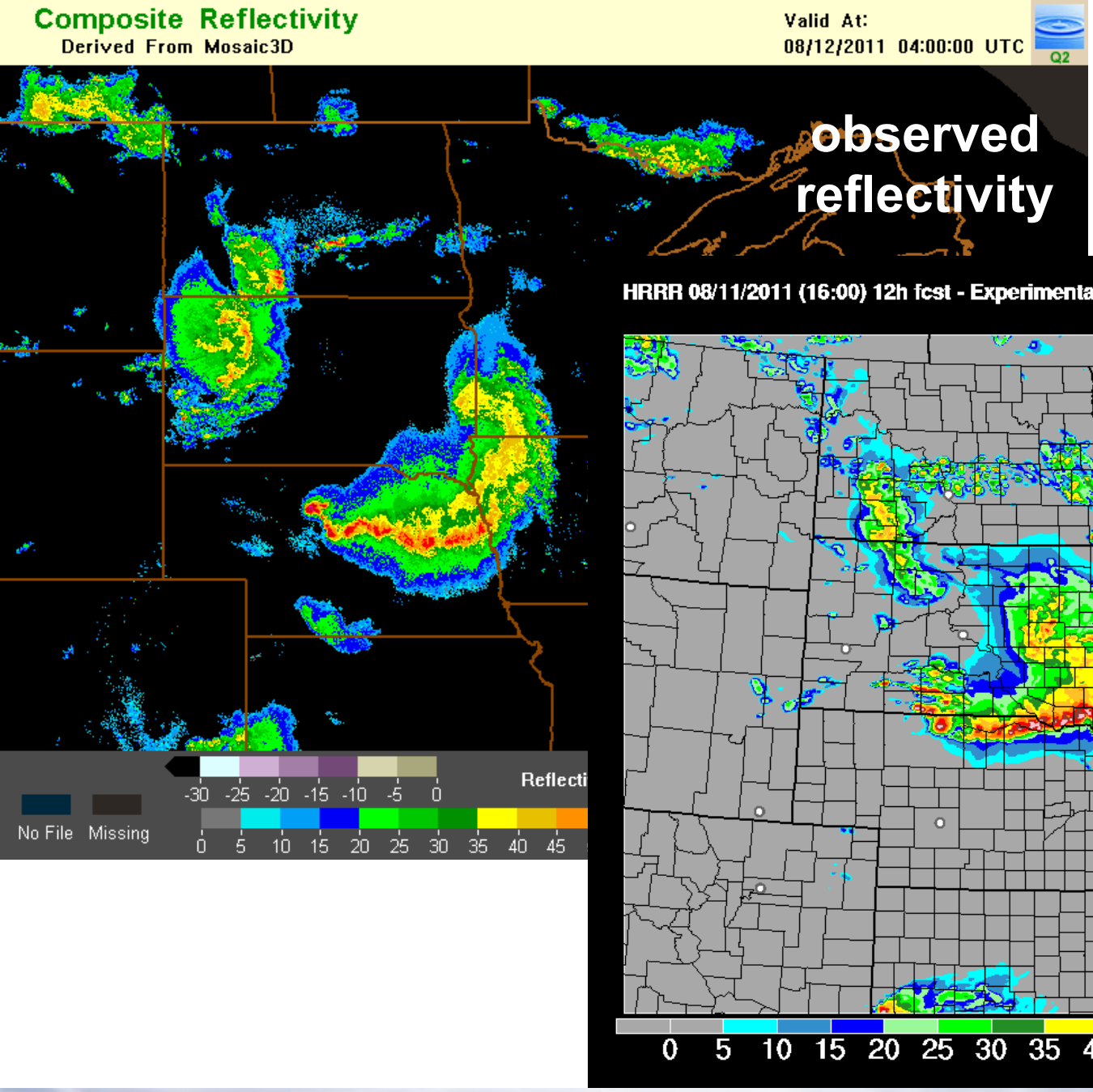



Composite Reflectivity
Derived From Mosaic3D
Valid At:
08/12/2011 04:00:00 UTC
Q2
observed reflectivity
Reflecti
-30 -25 -20 -15 -10 -5 0
No File
Missing
0 5 10 15 20 25 30 35 40 45


HRRR 08/11/2011 (16:00) 12 hr fcst
Valid 08/12/2011 04:00 UTC
Composite Reflectivity (dBZ)
real-time
2011 HRRR
12-h forecast
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75


Composite Reflectivity
Derived From Mosaic3D
Valid At:
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Q2
observed reflectivity
Reflecti
-30 -25 -20 -15 -10 -5 0
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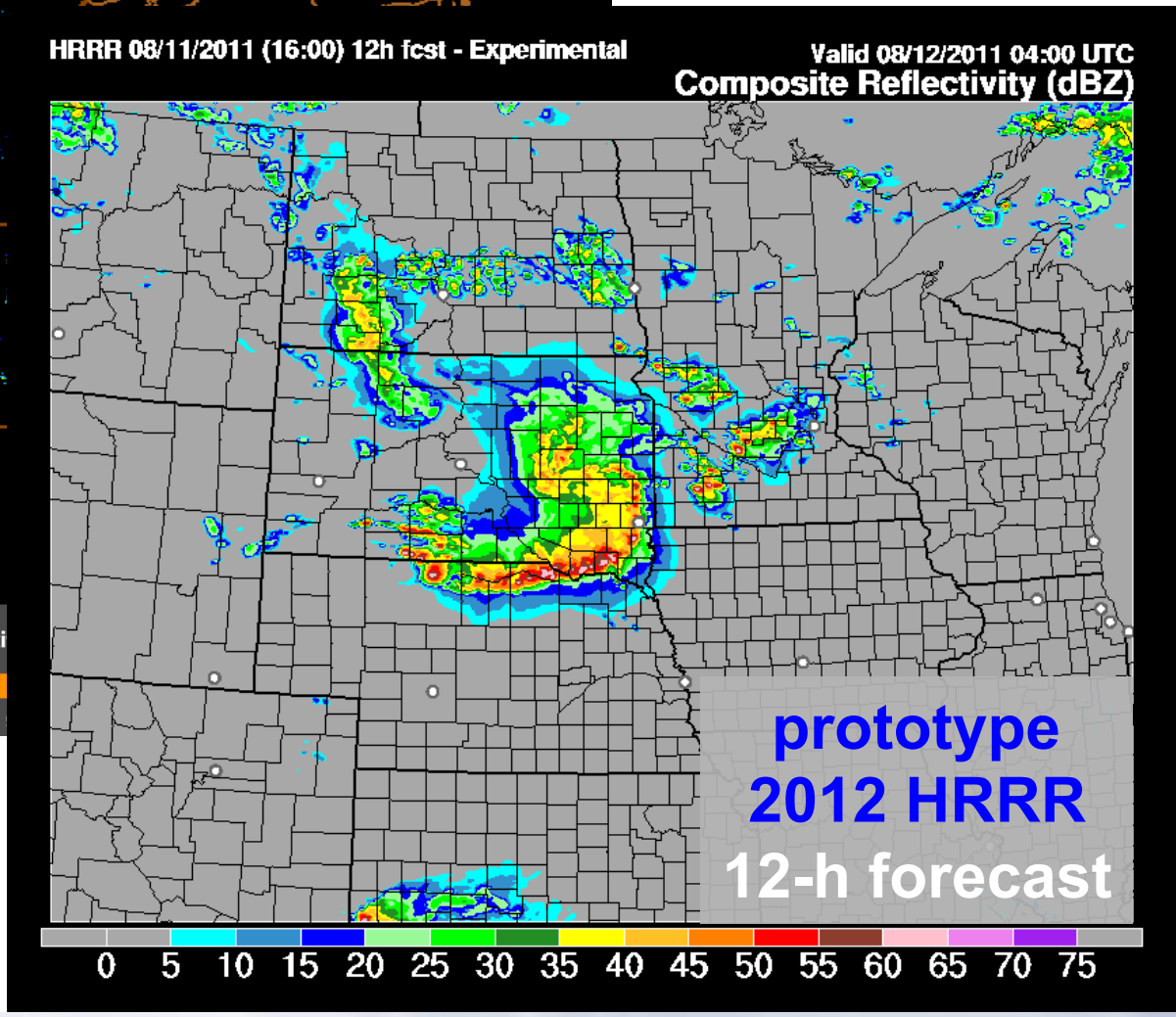
HRRR 08/11/2011 (16:00) 12h fcst - Experimental
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Composite Reflectivity (dBZ)
prototype
2012 HRRR
12-h forecast
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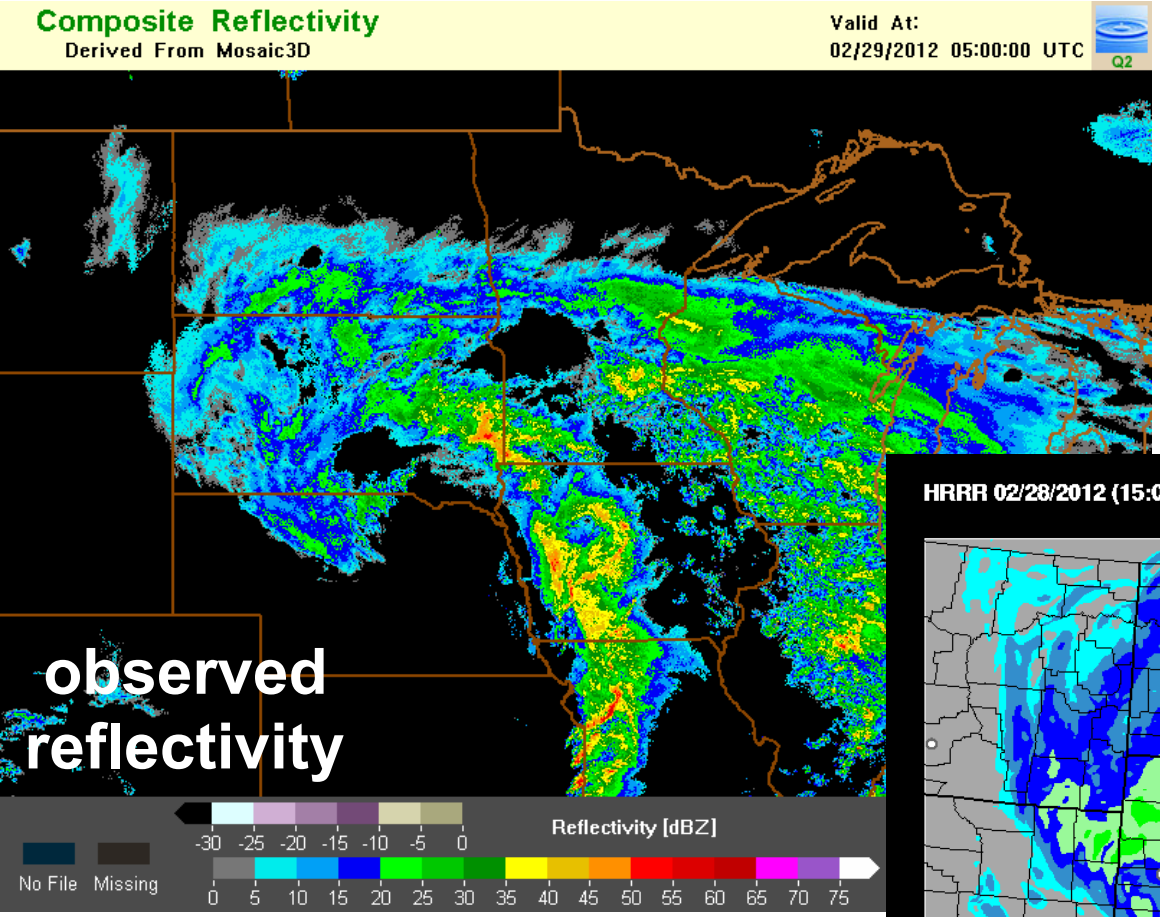
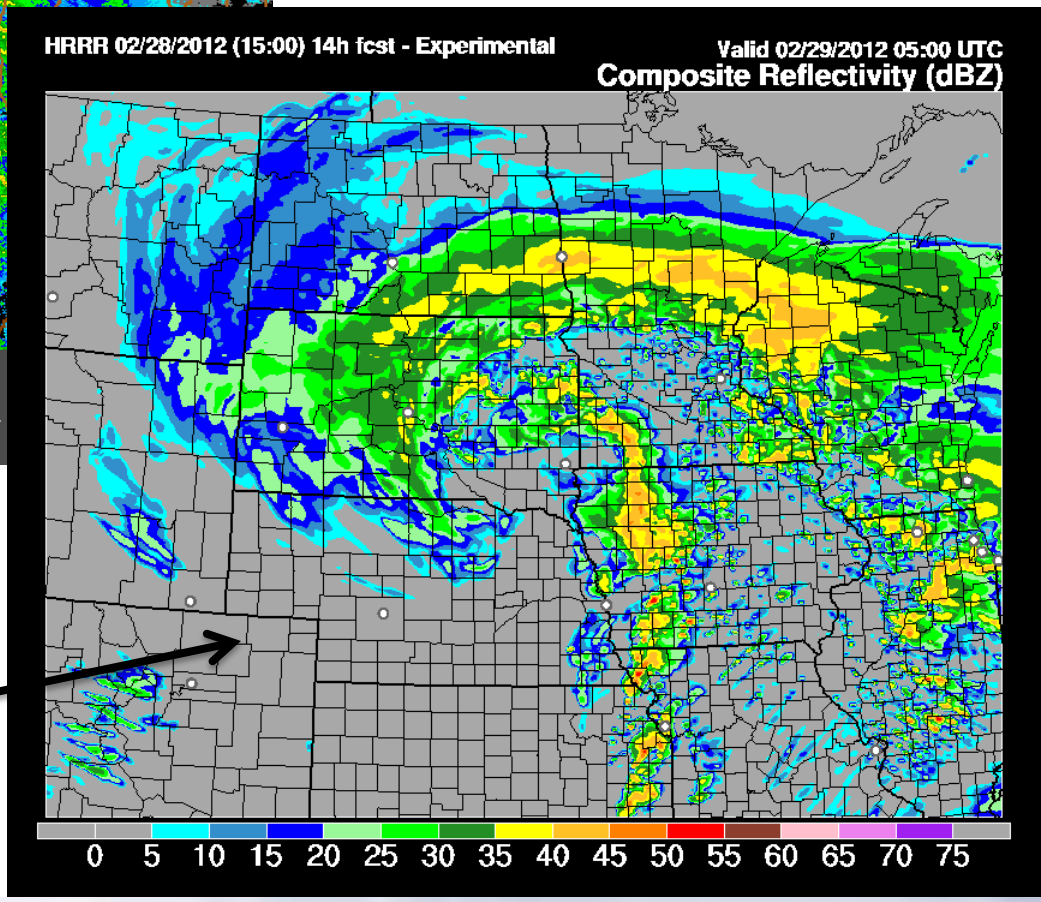


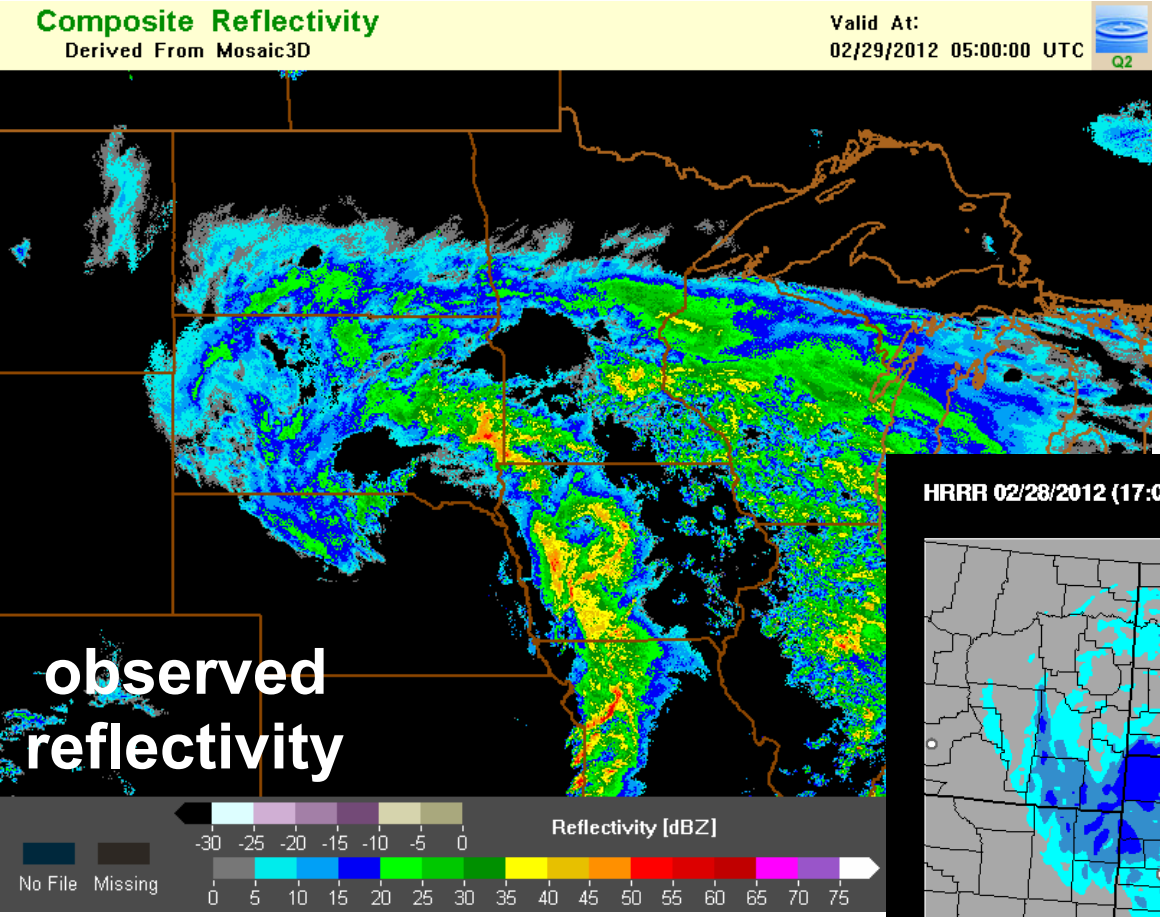


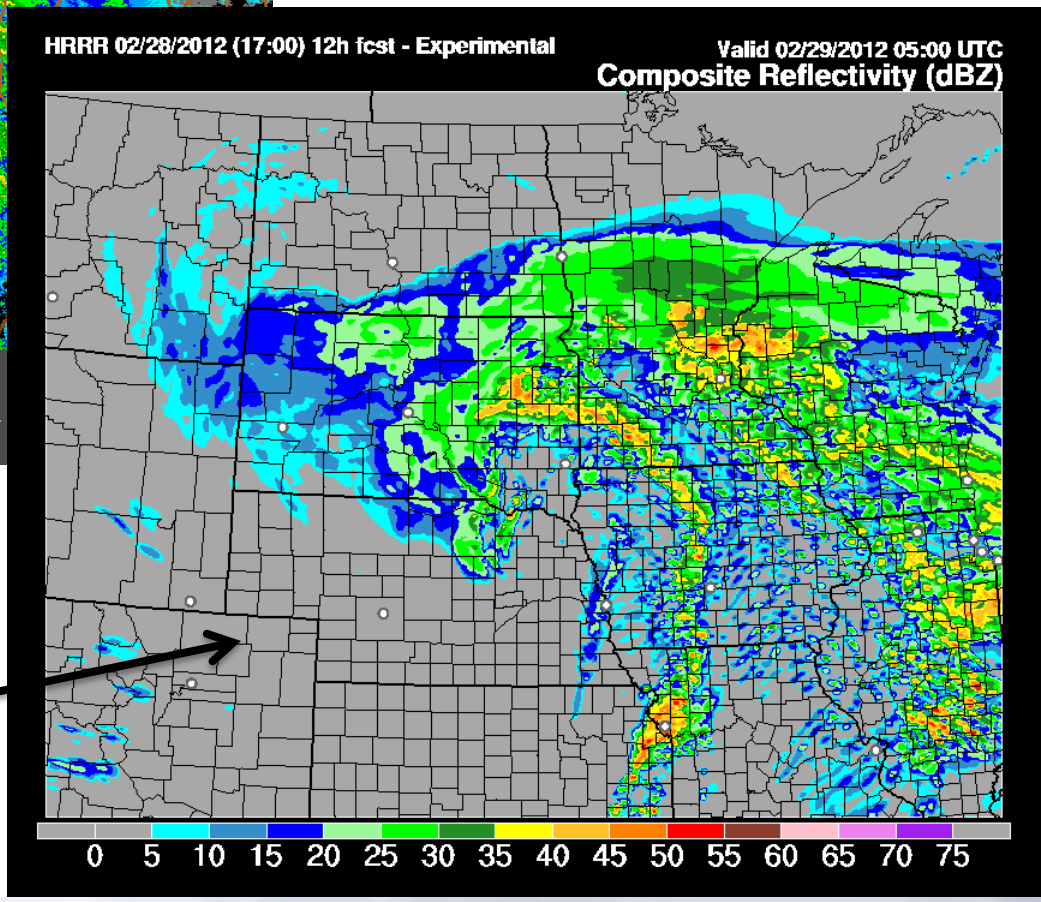
HRRR 14-h forecast

initialized 1500 UTC 28 Feb 2012

WRF 3.2

old reflectivity diagnostic





HRRR 12-h forecast

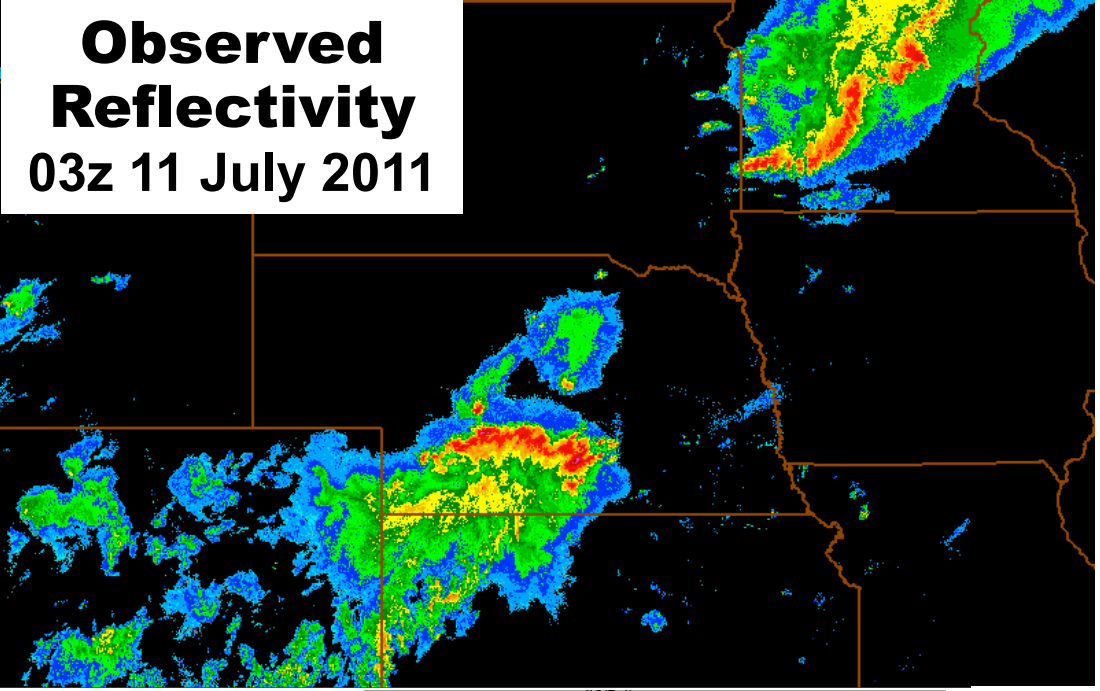
initialized 1700 UTC 28 Feb 2012

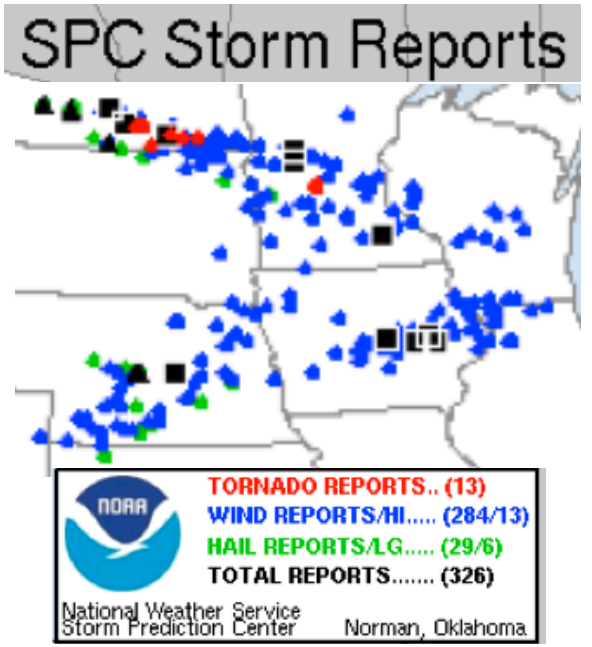
WRF 3.3.1

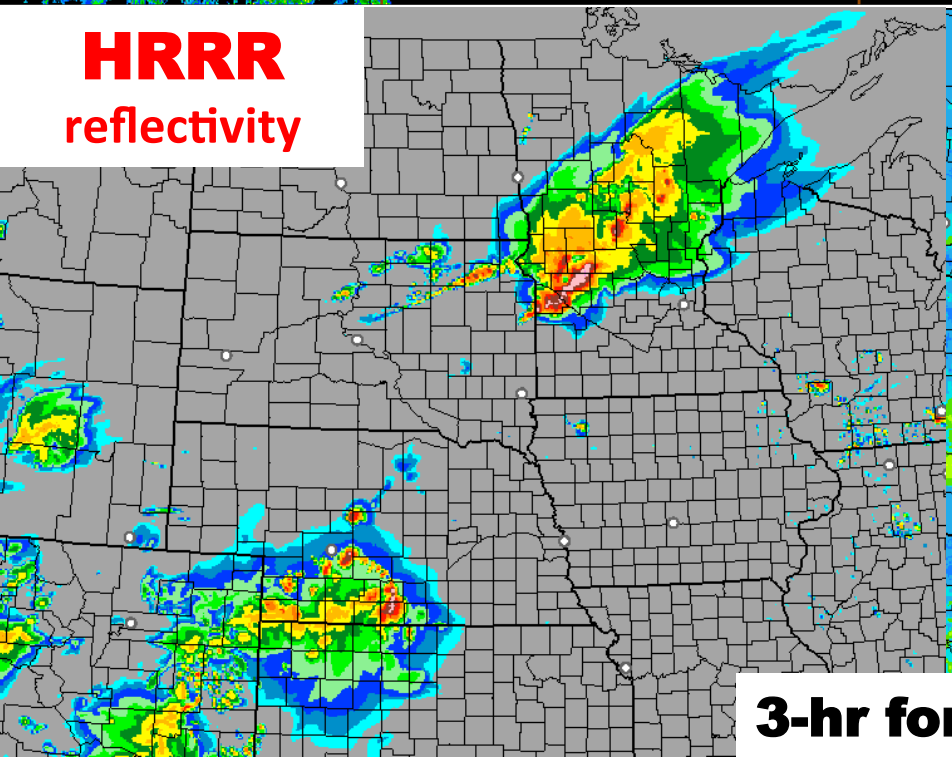
new reflectivity diagnostic

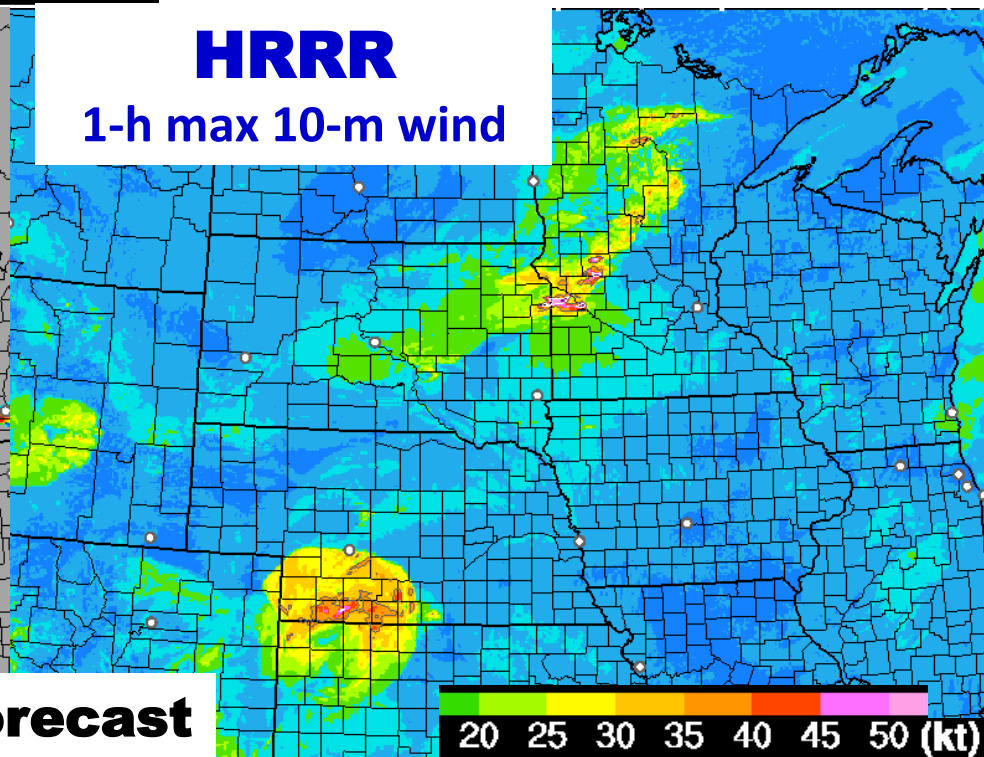
HRRR Program Review Outline

1:30	Opening Remarks	Stan Benjamin
1:30 – 1:40	Program Overview	Curtis Alexander
1:40 – 1:50	Initial Conditions: Rapid Refresh	Steve Weygandt
1:50 – 2:00	Model Development	David Dowell
2:00 – 2:10	Case Studies and Applications	Eric James
2:10 – 2:20	Forecast Verification	Patrick Hofmann
2:20	Summary and Future Plans	Curtis Alexander
2:20 – 2:30	Questions	

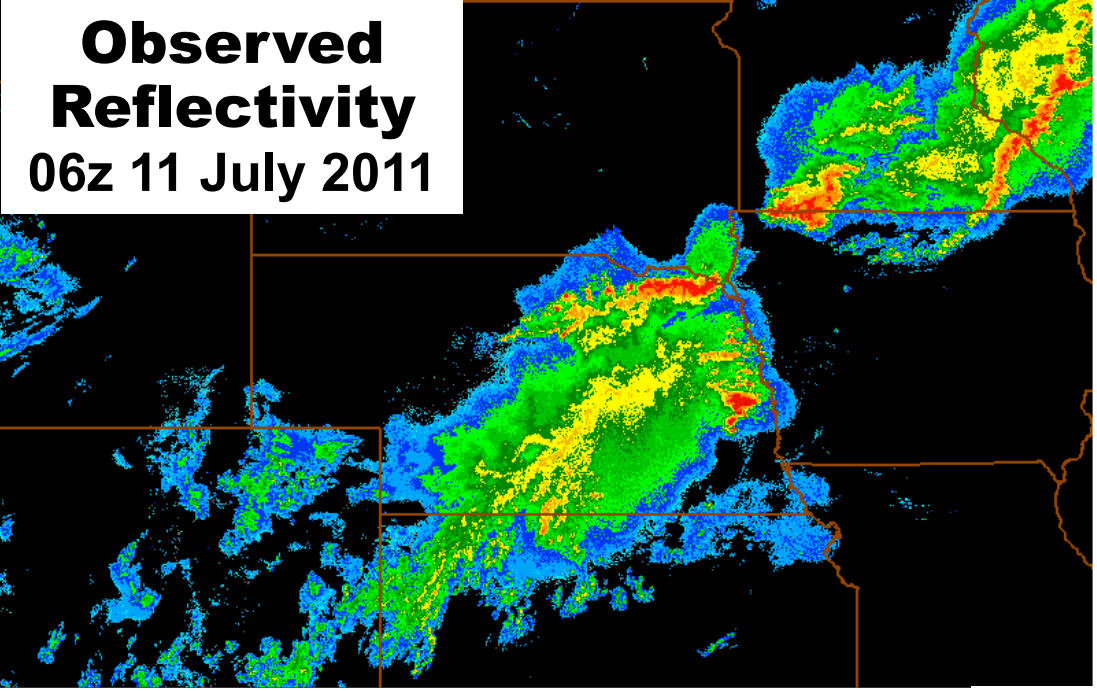


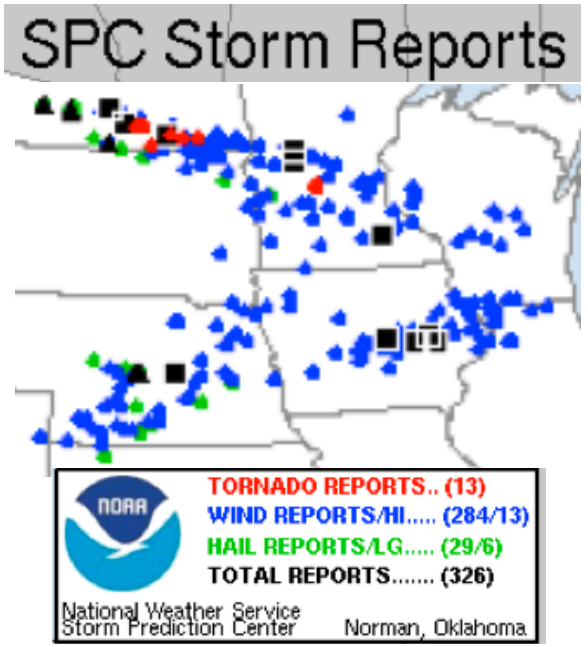


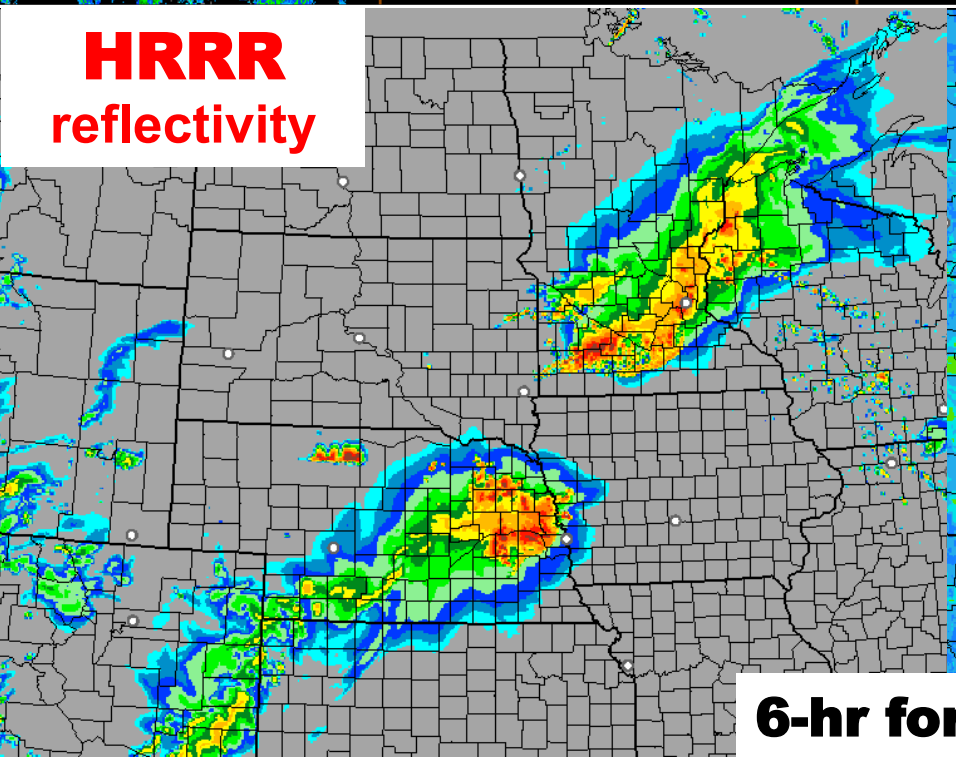


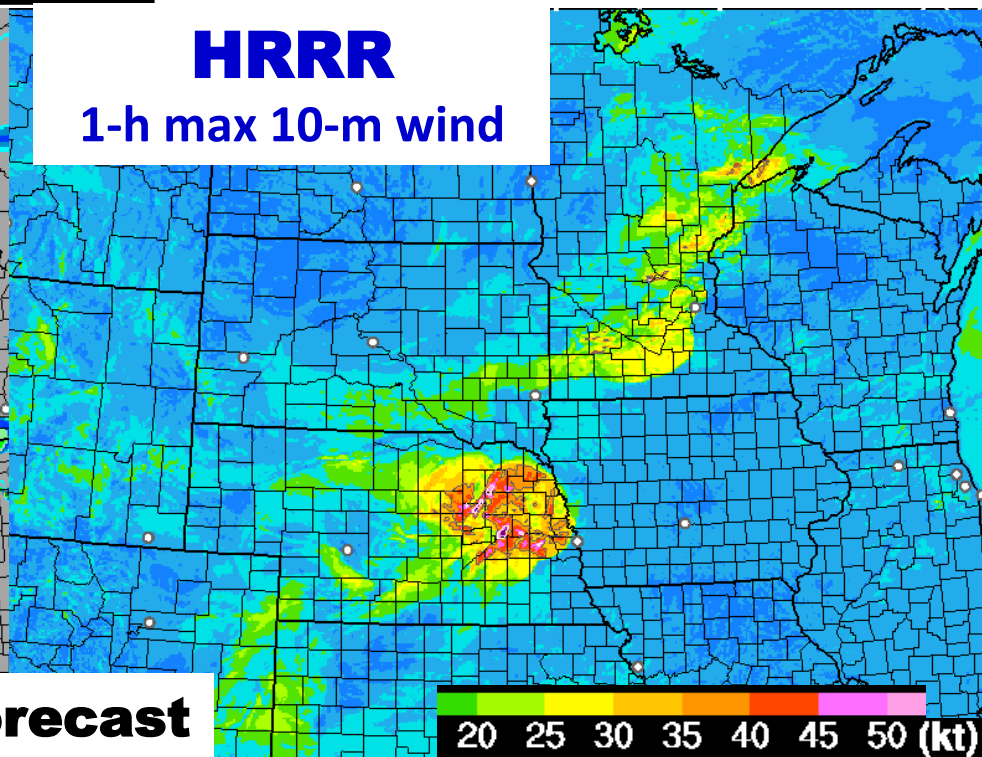


3-hr forecast



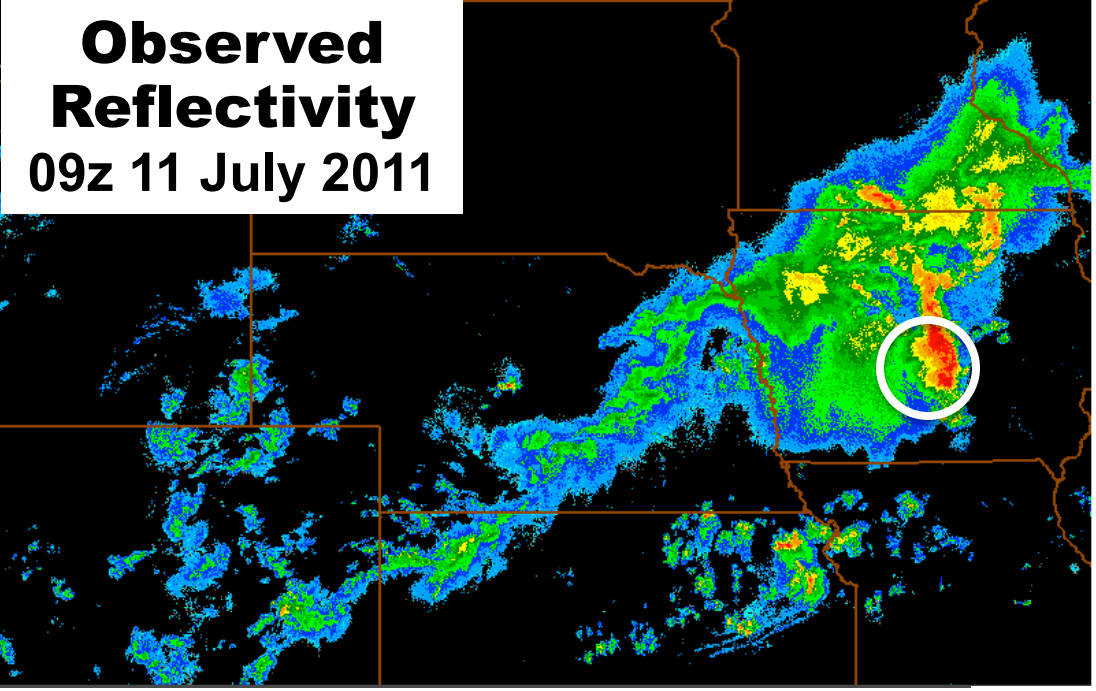




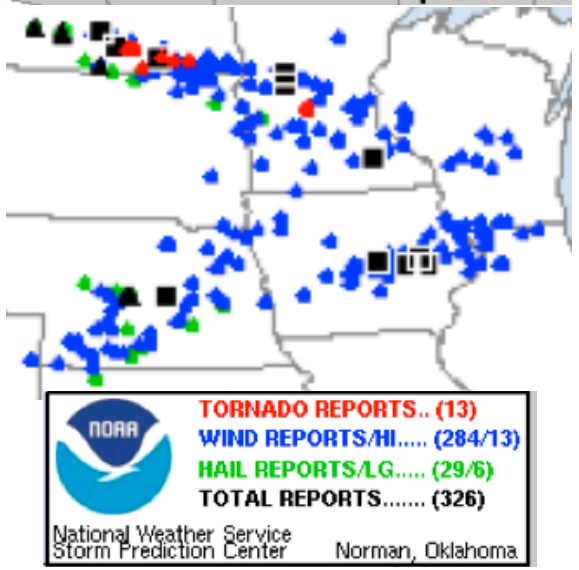


6-hr forecast

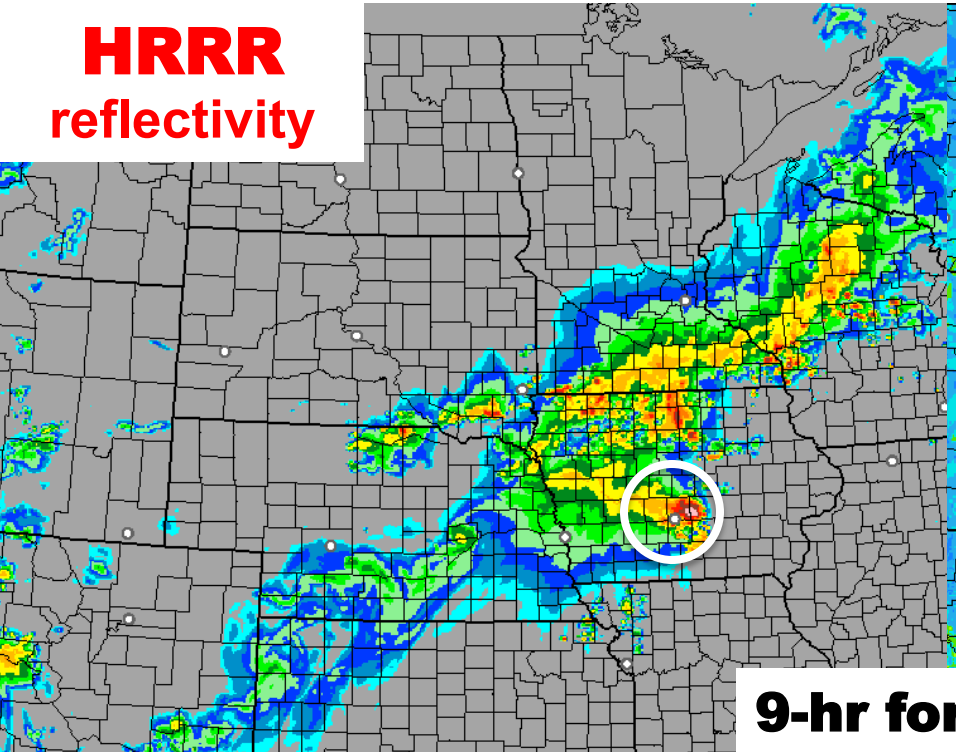
Observed Reflectivity
09z 11 July 2011



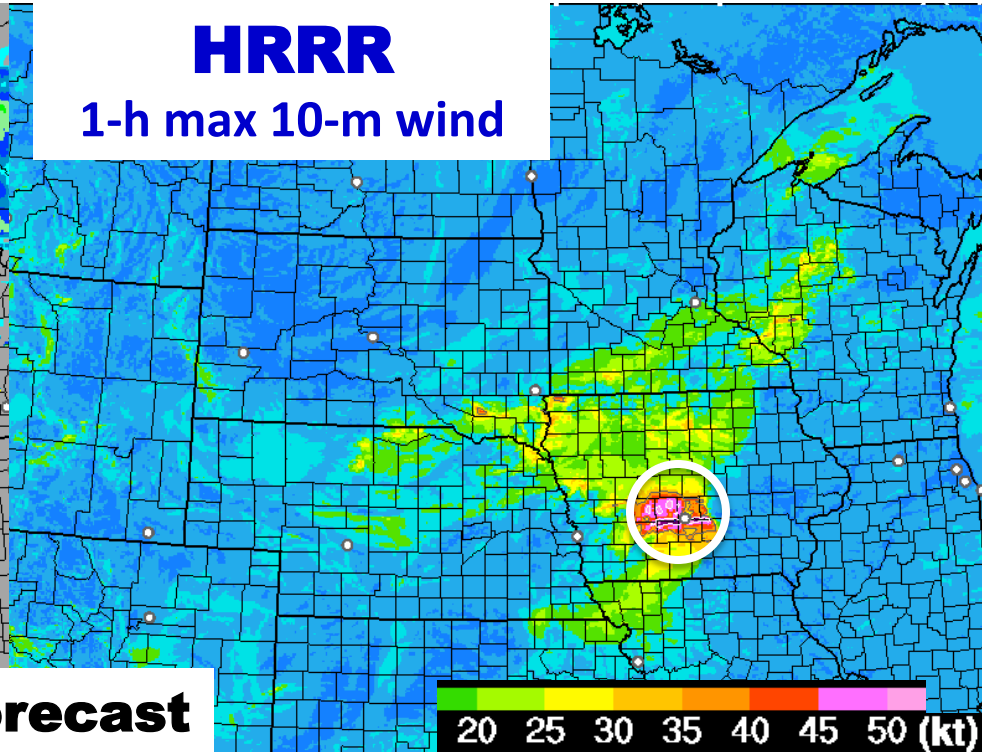
SPC Storm Reports



HRRR
reflectivity

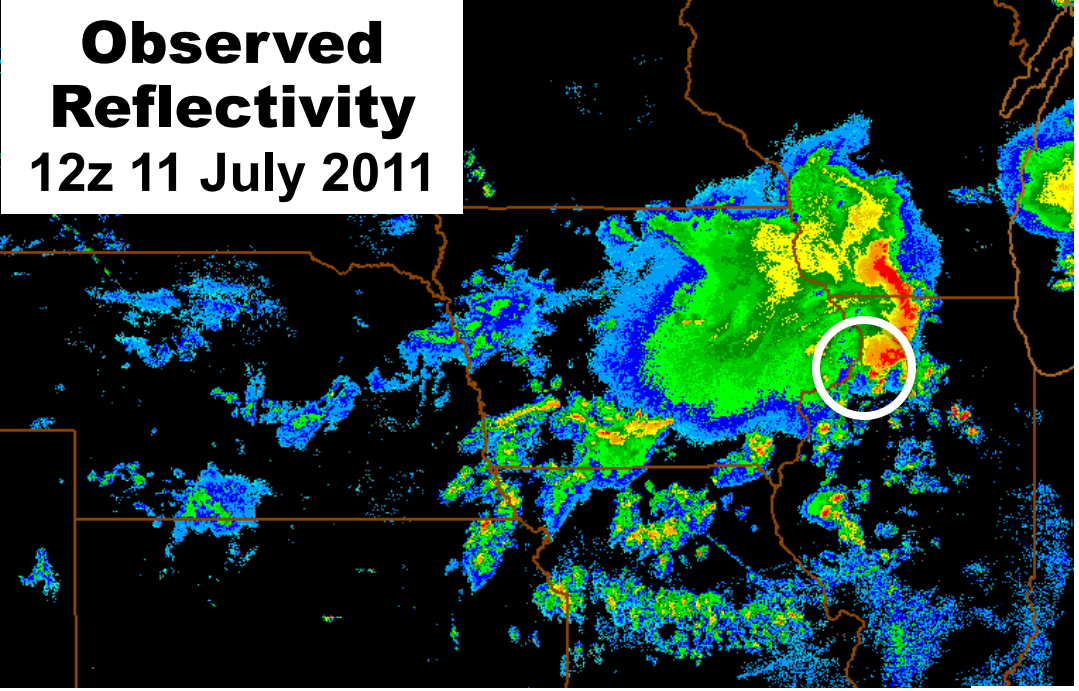


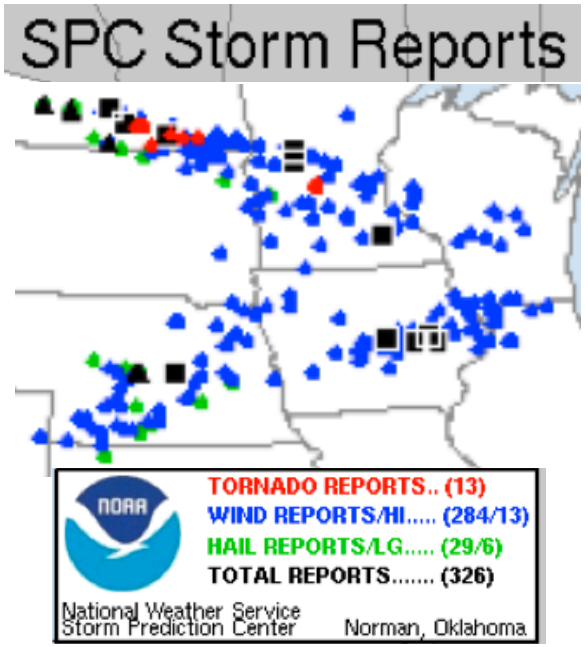
HRRR
1-h max 10-m wind



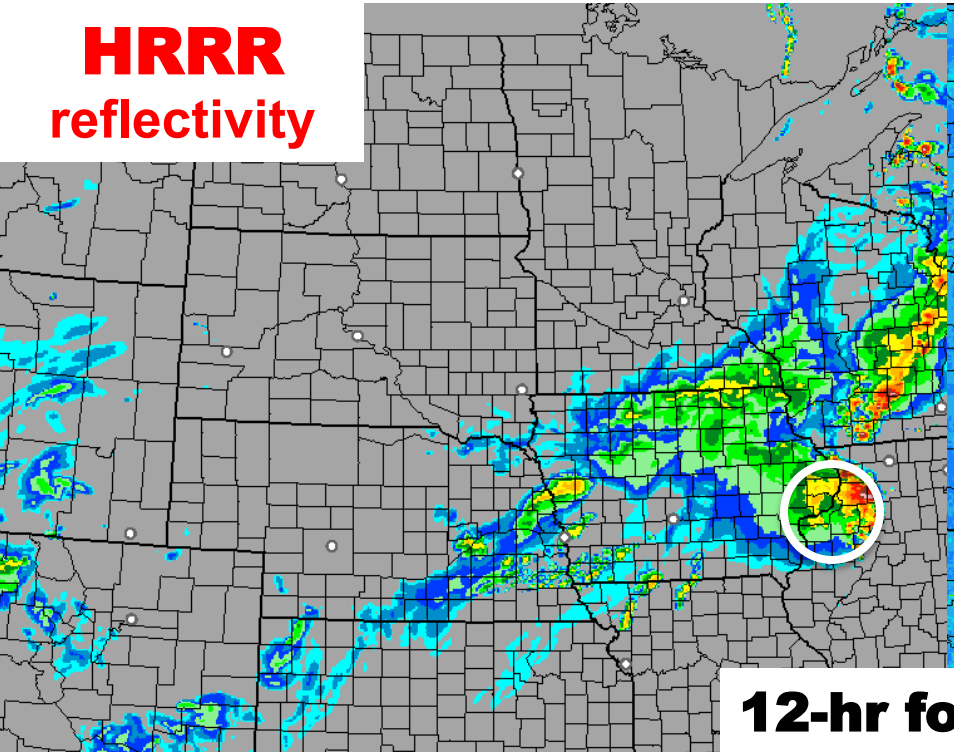
9-hr forecast

Observed Reflectivity
12z 11 July 2011

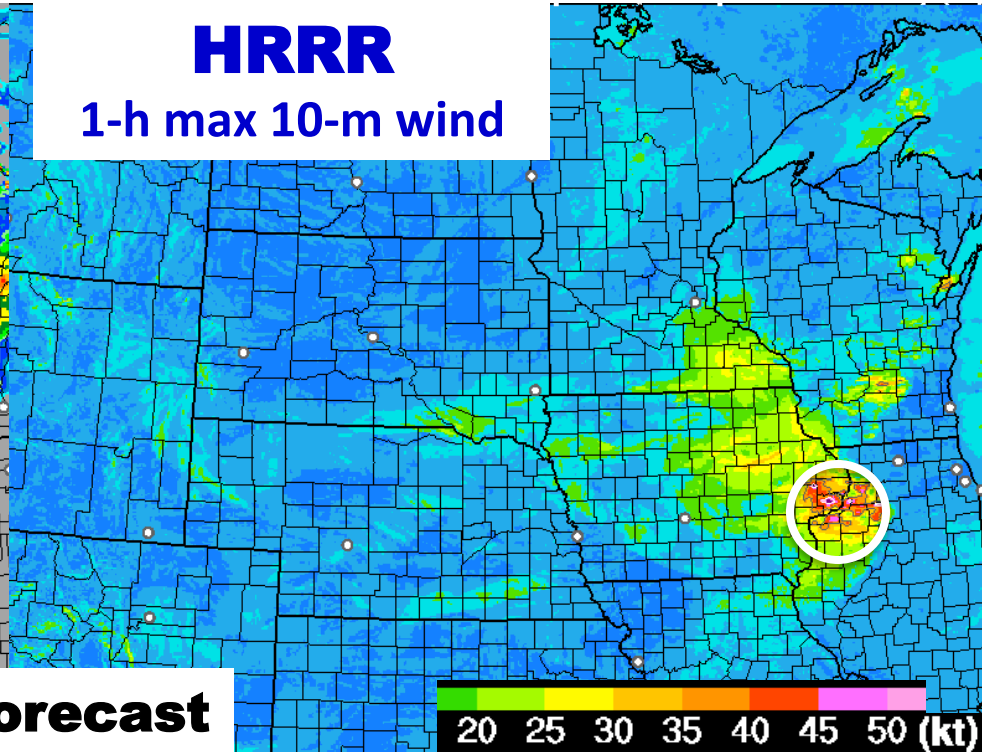




HRRR
reflectivity

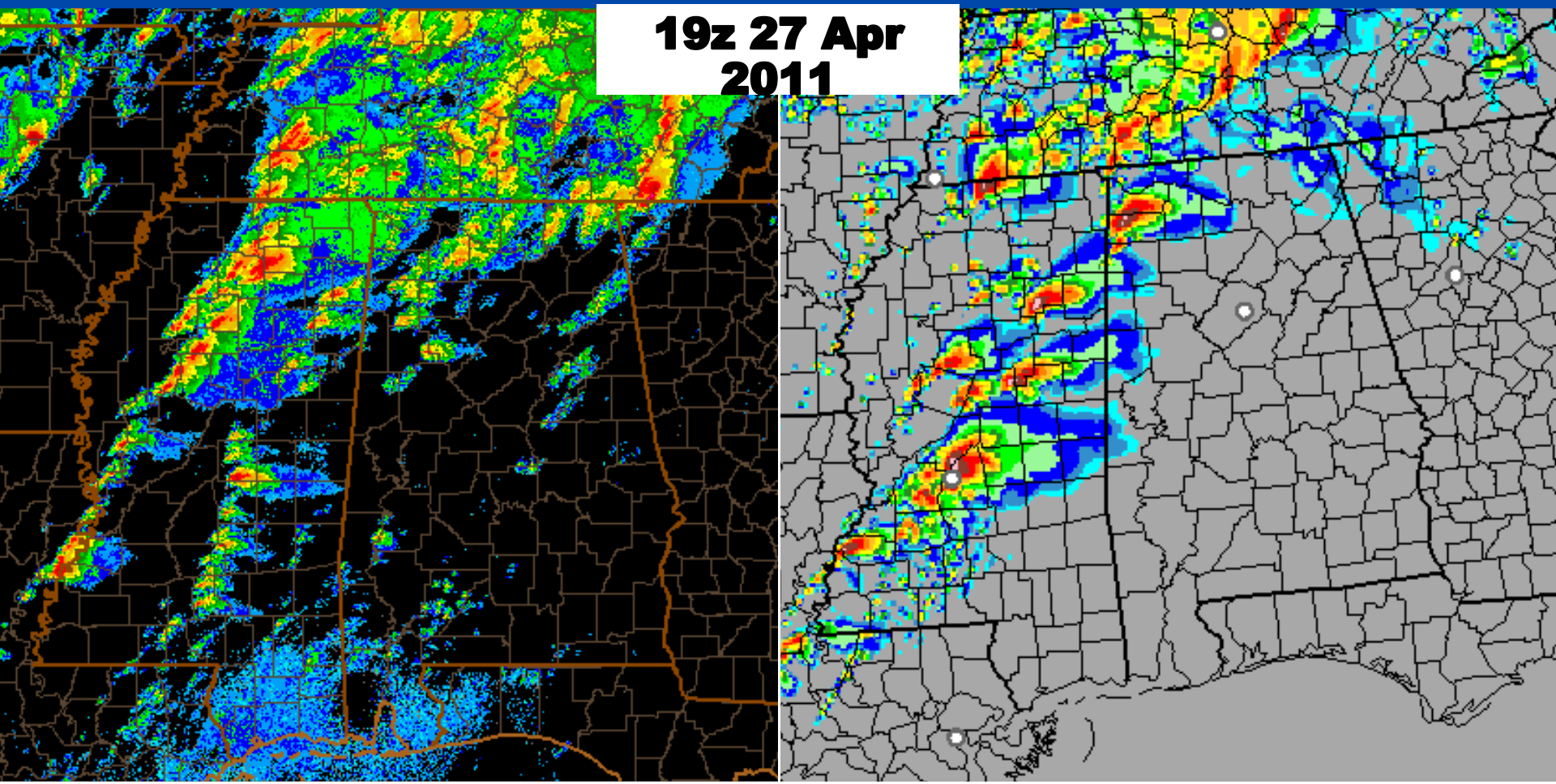


HRRR
1-h max 10-m wind



12-hr forecast

HRRR Case Studies

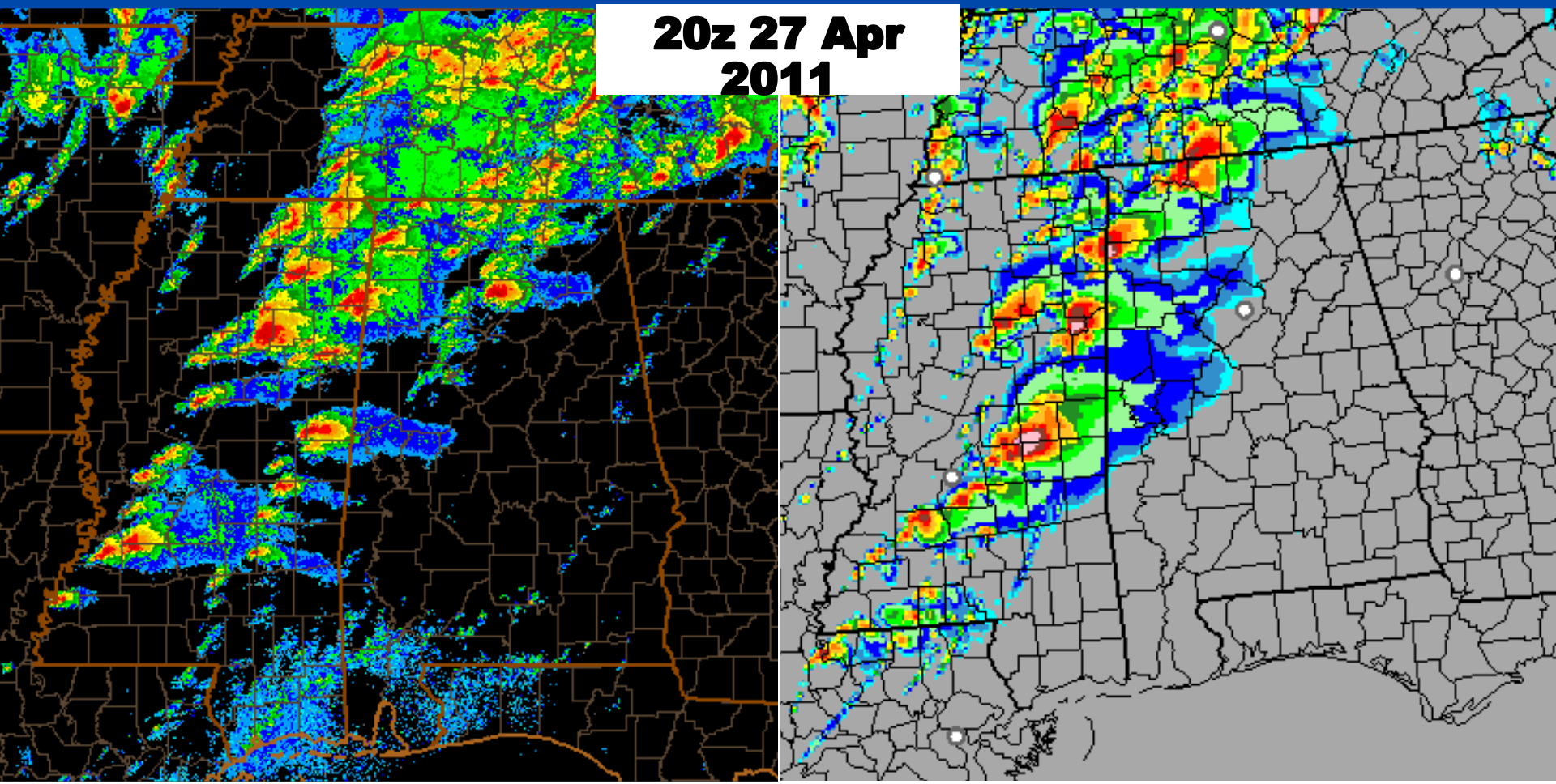


NSSL mosaic

HRRR

13z + 6 hr fcst

HRRR Case Studies

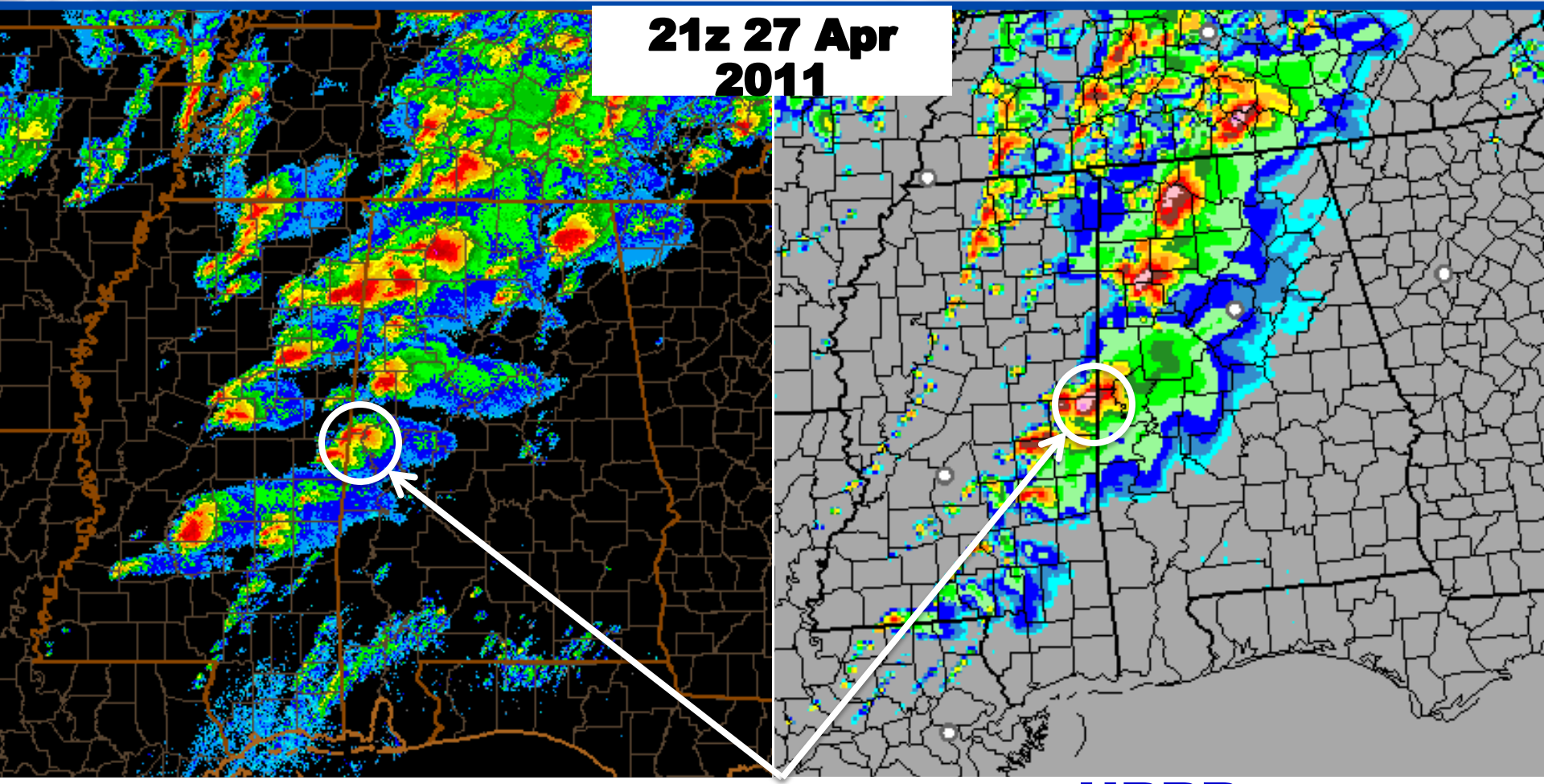


NSSL mosaic

HRRR

13z + 7 hr fcst

HRRR Case Studies



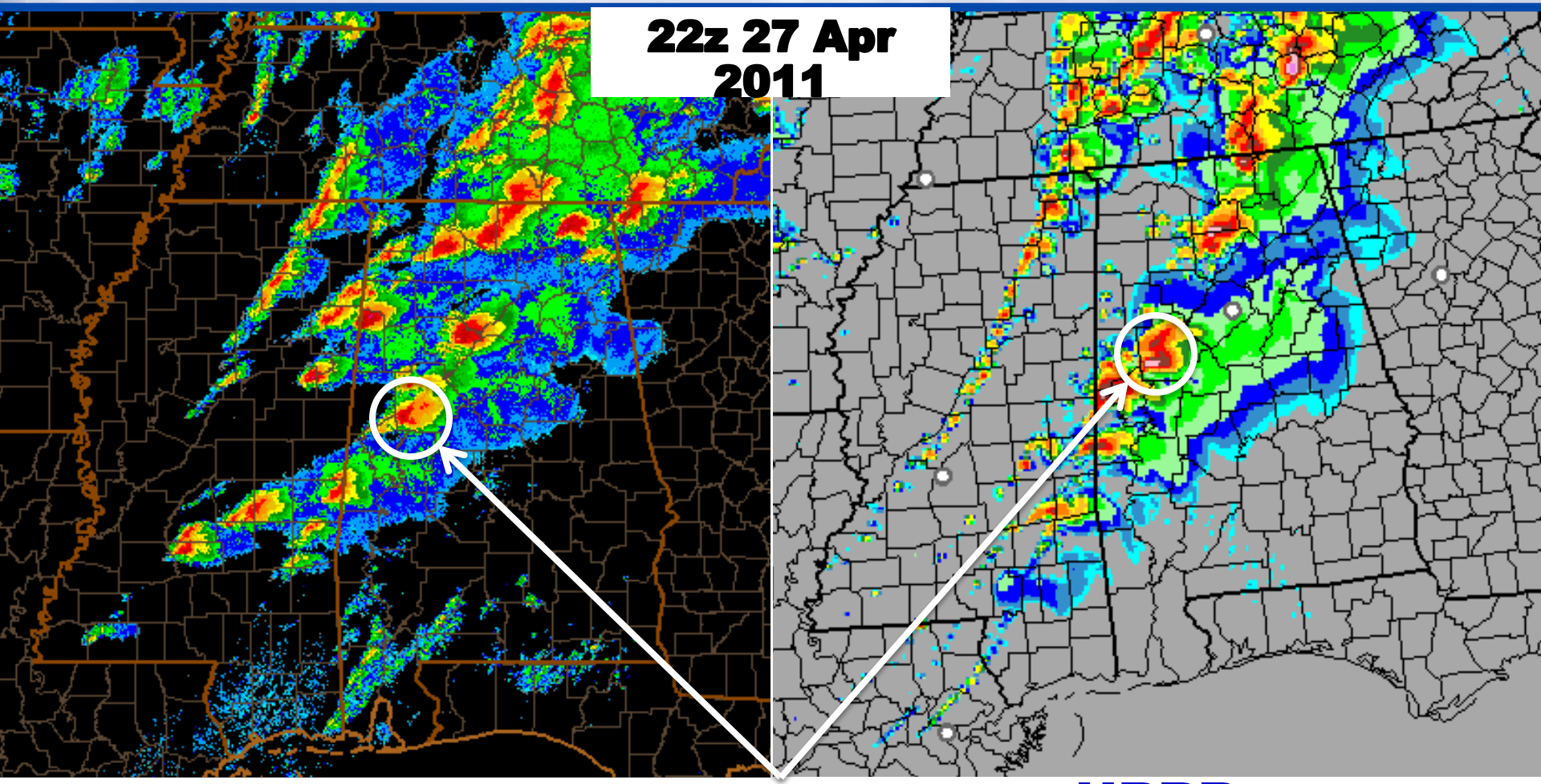
NSSL mosaic

Tuscaloosa-Birmingham tornadic supercell

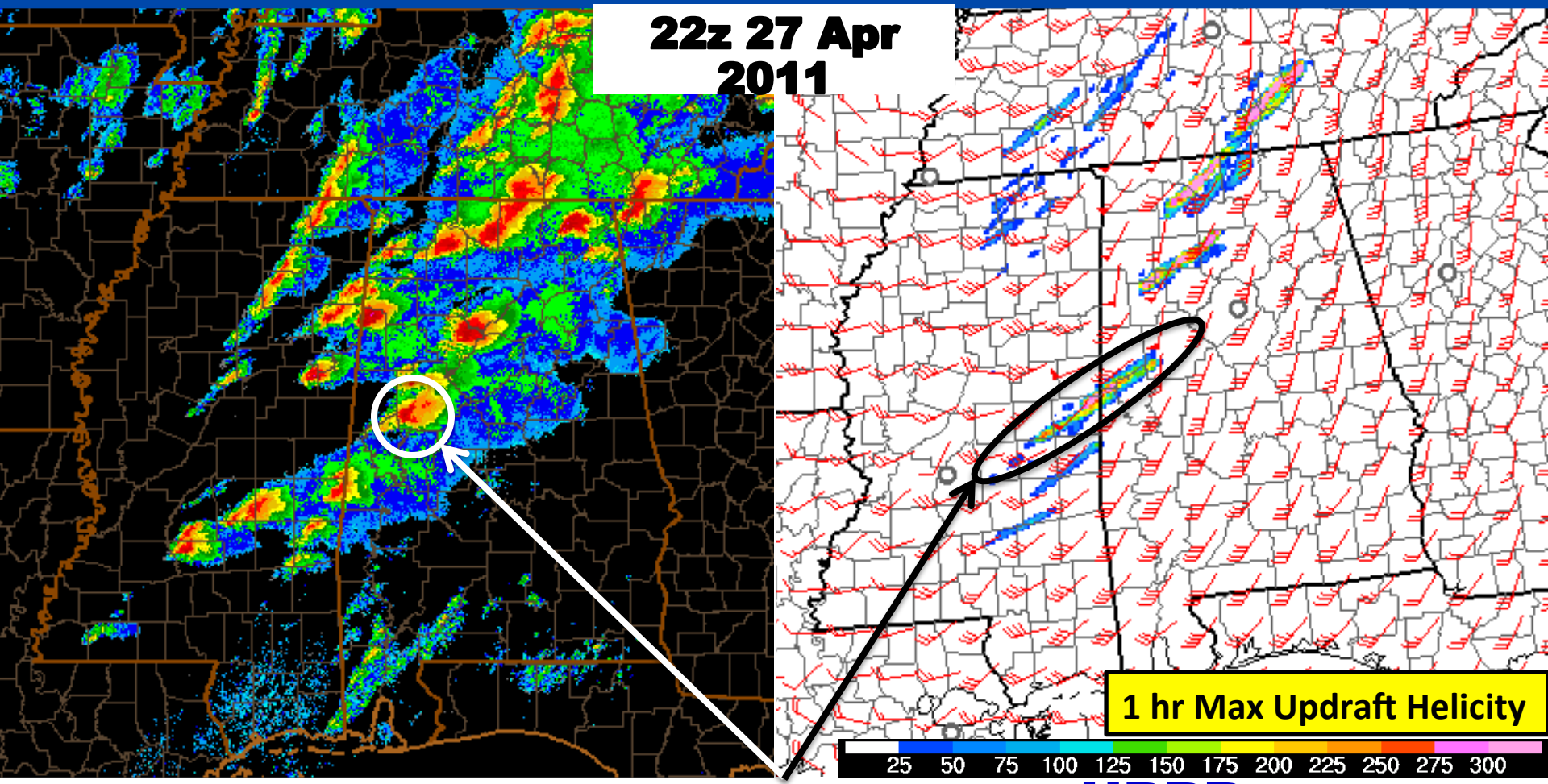
HRRR

13z + 8 hr fcst

HRRR Case Studies



HRRR Case Studies



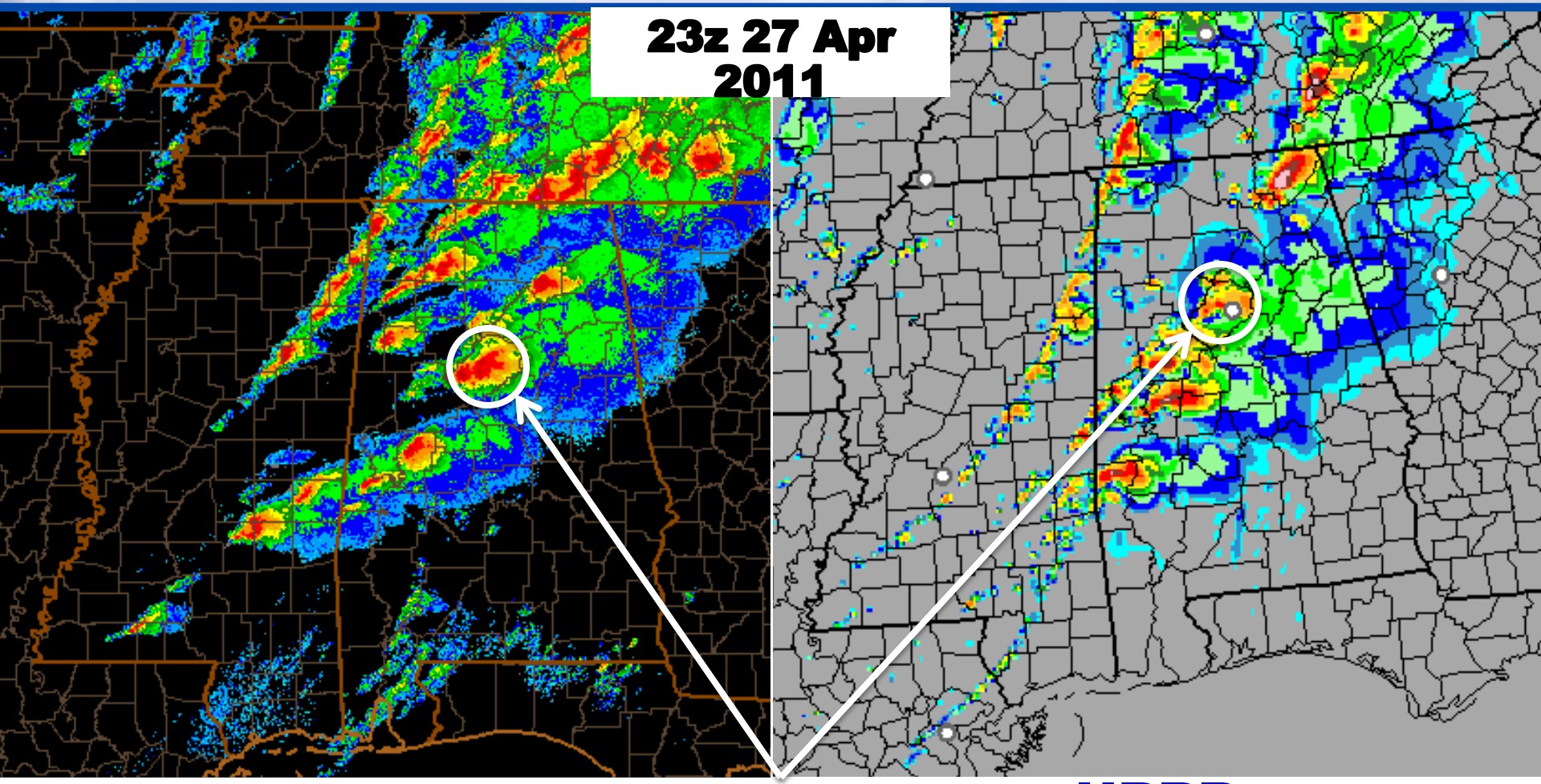
NSSL mosaic

Tuscaloosa-Birmingham tornadic supercell

HRRR

13z + 9 hr fcst

HRRR Case Studies



NSSL mosaic

Tuscaloosa-Birmingham tornadic supercell

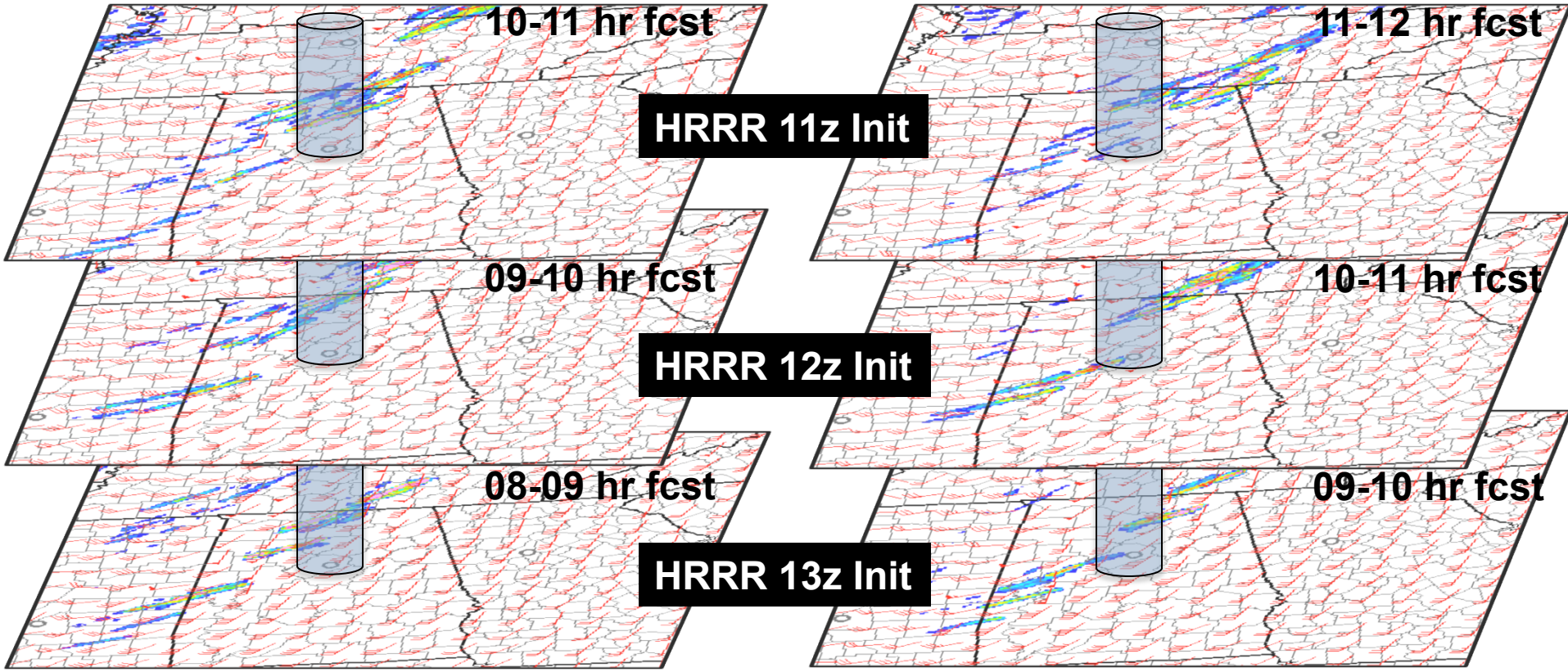
HRRR

13z + 10 hr fcst

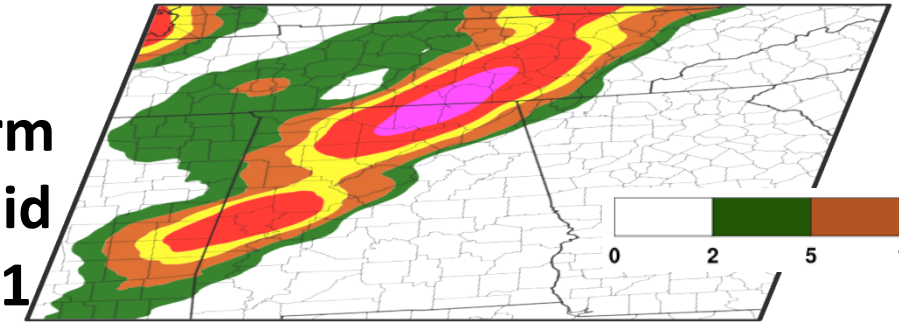
Time-lagged Ensemble

Forecasts valid 21-22z 27 April 2011

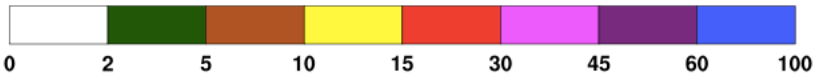
Forecasts valid 22-23z 27 April 2011



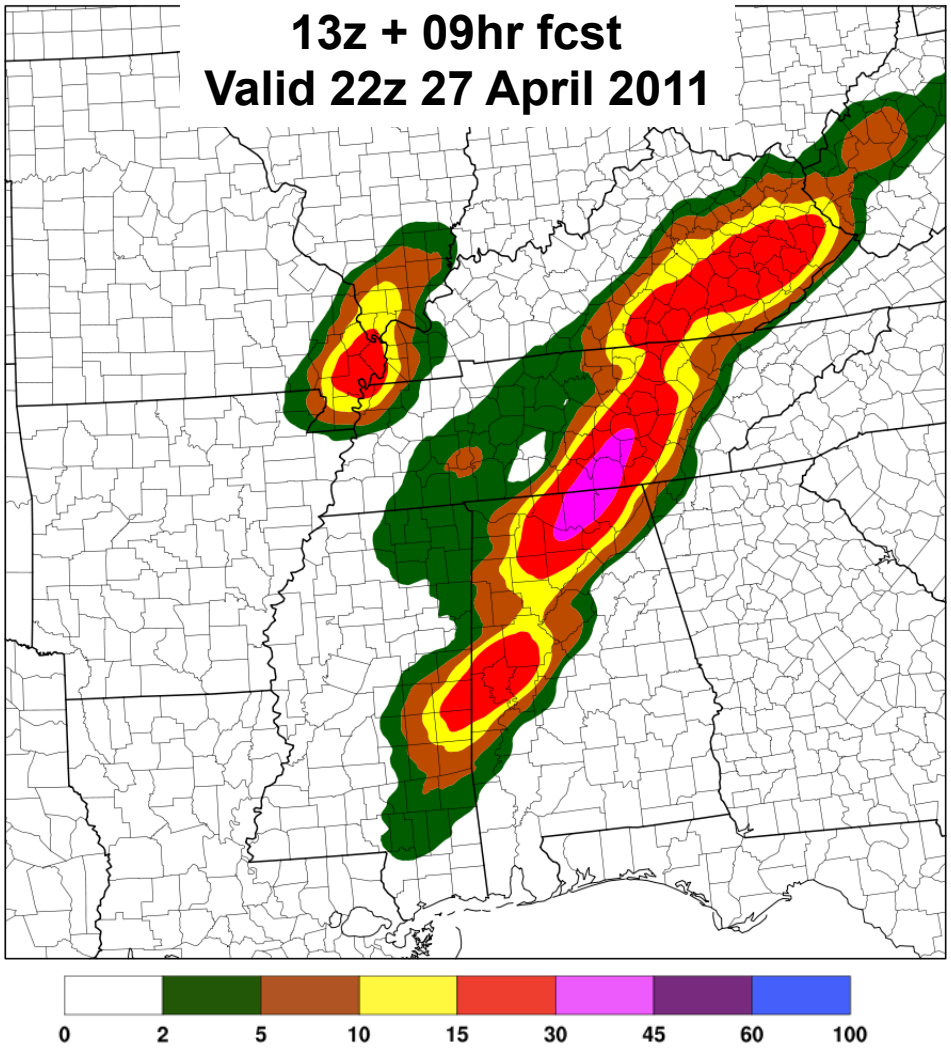
All six forecasts combined to form probabilities valid 22z 27 April 2011



Spatial radius 45 km
Time radius 1 hr
UH threshold 25 m^2/s^2

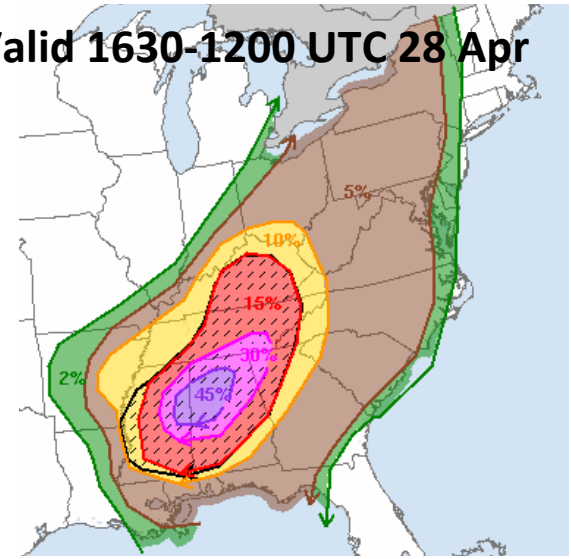


Example: 27 April 2011

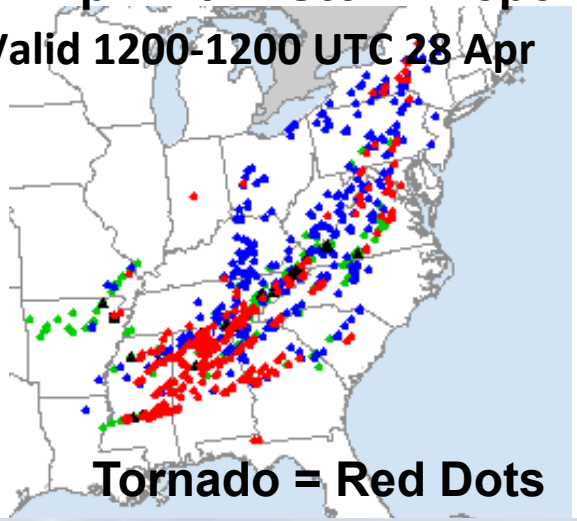


Tornadic Storm Probability (%)

1630z SPC Tornado Probability

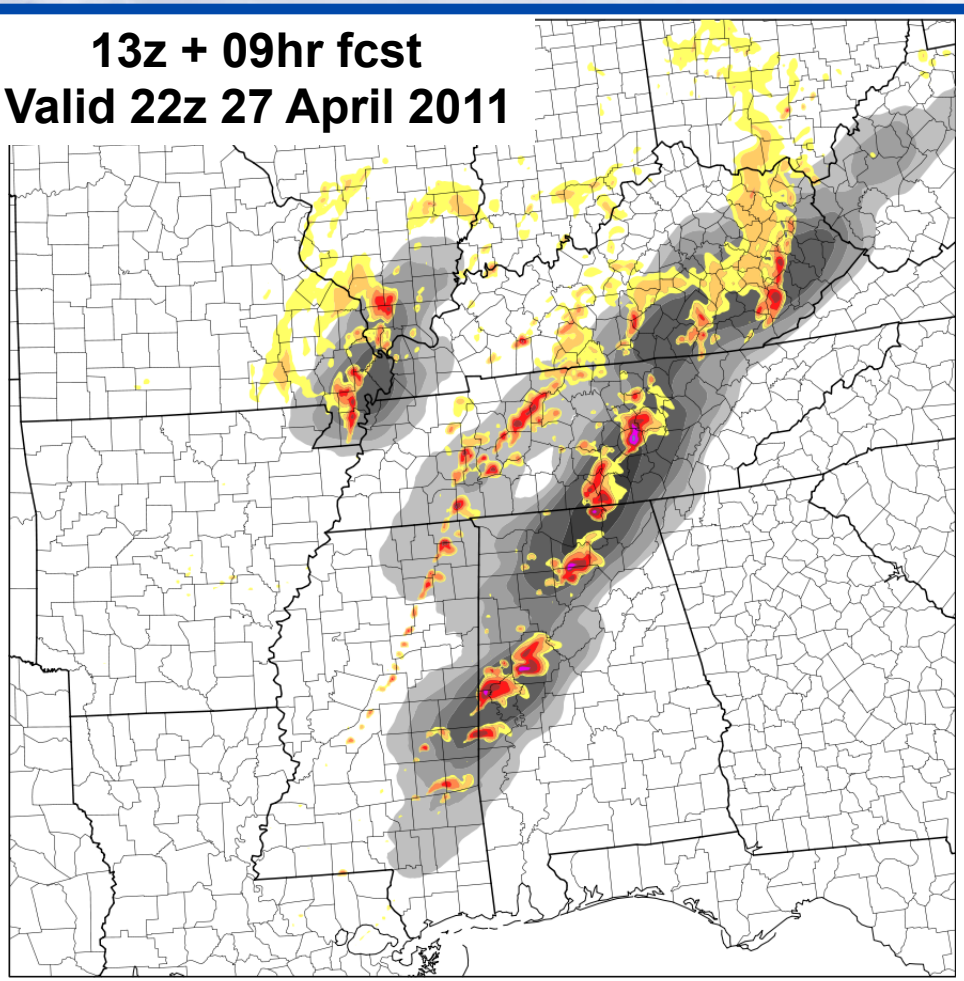


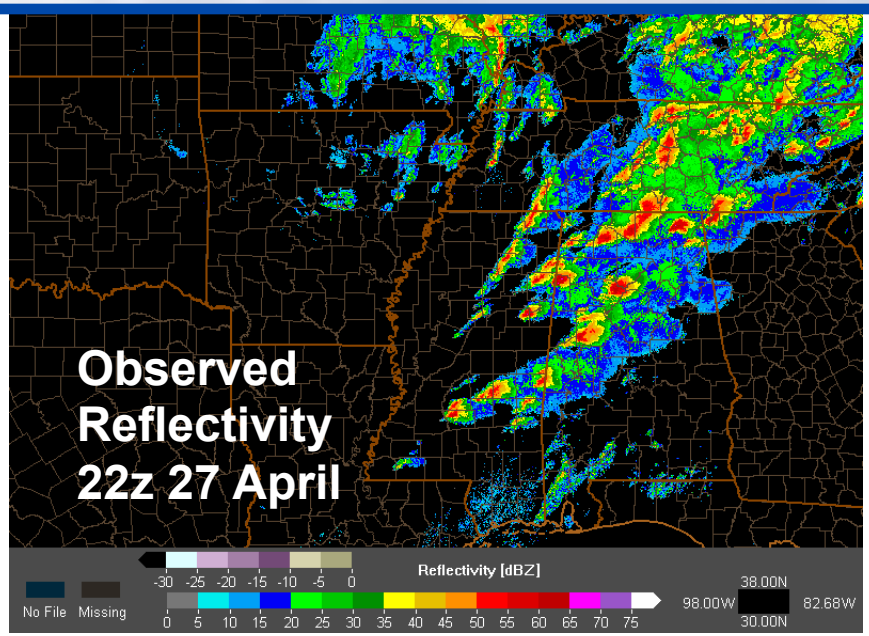
27 April 2011 Storm Reports



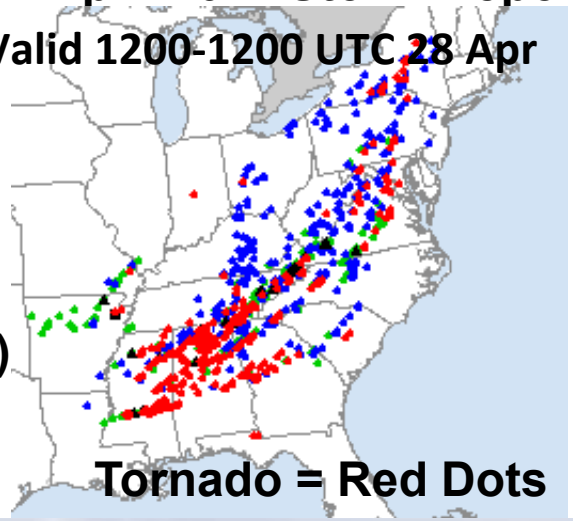
Example: 27 April 2011

13z + 09hr fcst
Valid 22z 27 April 2011





27 April 2011 Storm Reports
Valid 1200-1200 UTC 28 Apr



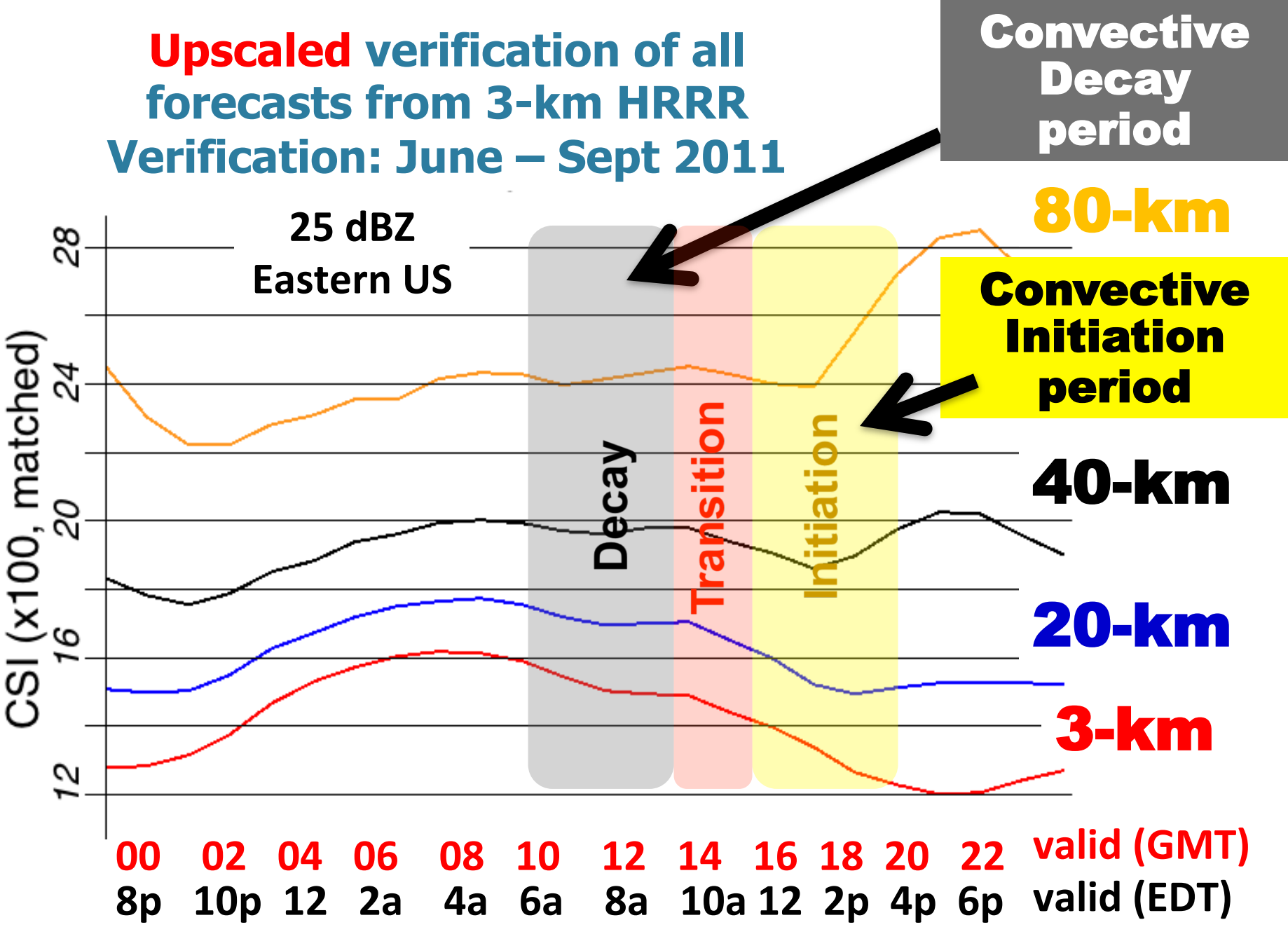
Tornadic Storm Probability (%)

Reflectivity (dBZ)

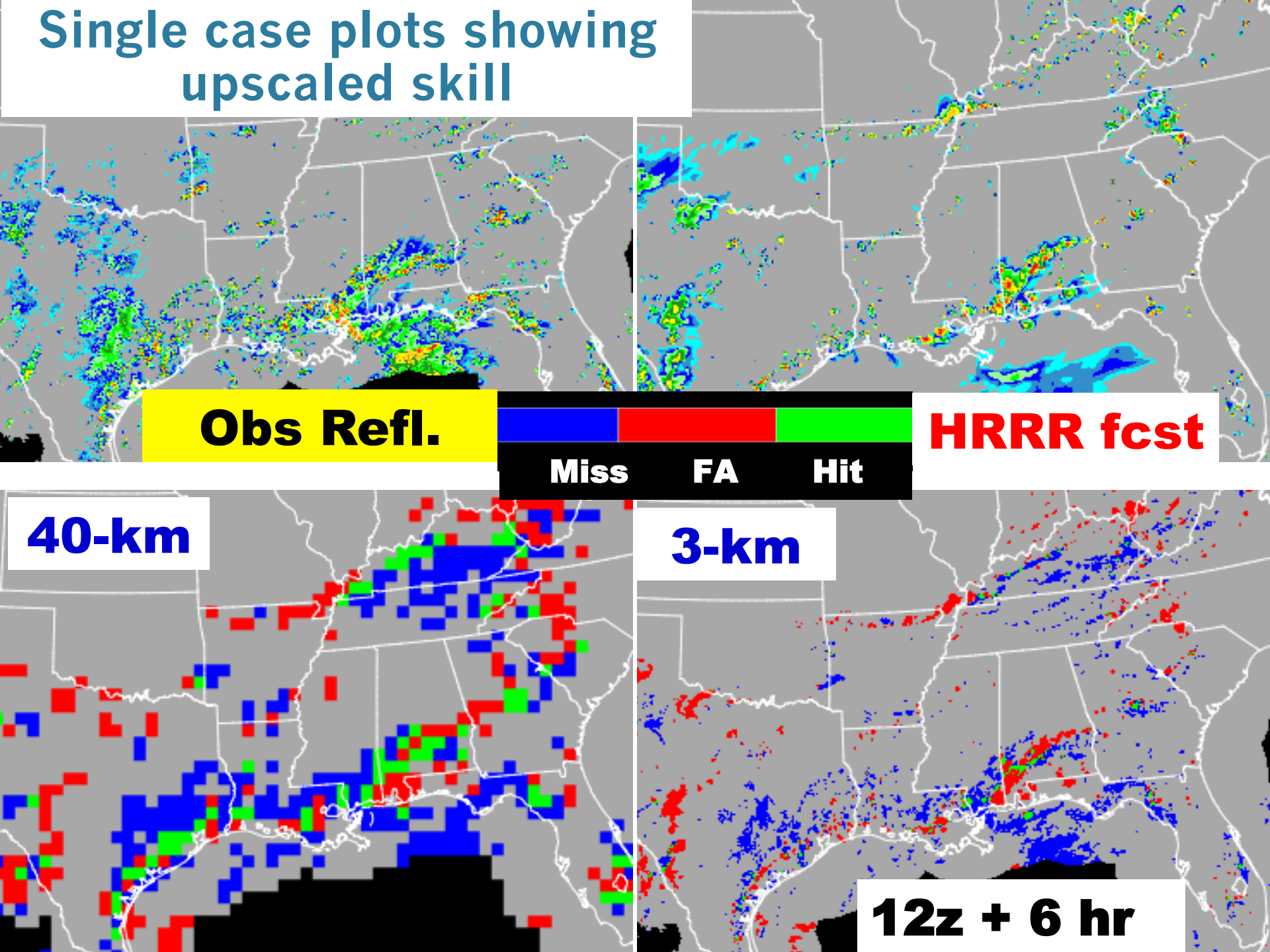
HRRR Program Review Outline

1:30	Opening Remarks	Stan Benjamin
1:30 – 1:40	Program Overview	Curtis Alexander
1:40 – 1:50	Initial Conditions: Rapid Refresh	Steve Weygandt
1:50 – 2:00	Model Development	David Dowell
2:00 – 2:10	Case Studies and Applications	Eric James
2:10 – 2:20	Forecast Verification	Patrick Hofmann
2:20	Summary and Future Plans	Curtis Alexander
2:20 – 2:30	Questions	

Upscaled verification of all forecasts from 3-km HRRR
Verification: June – Sept 2011



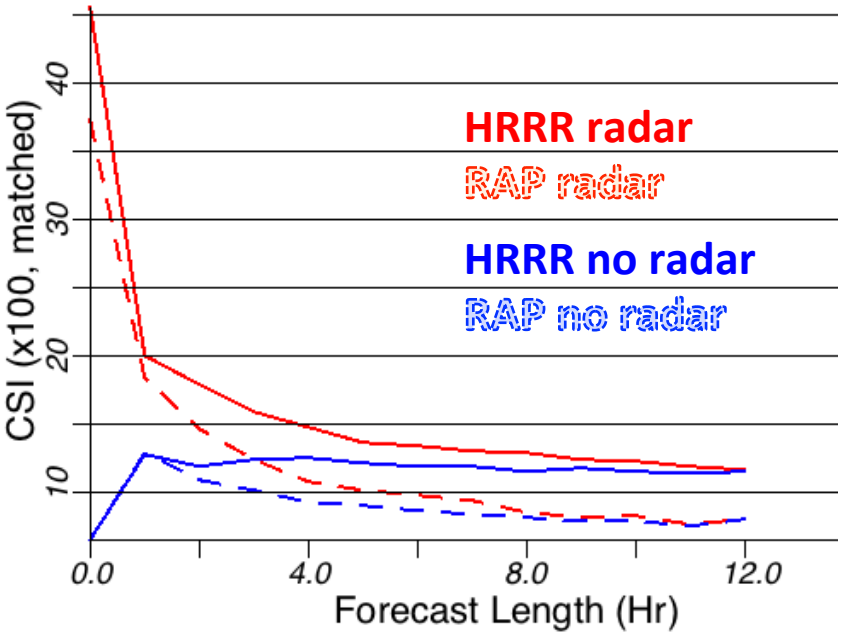
Single case plots showing upscaled skill



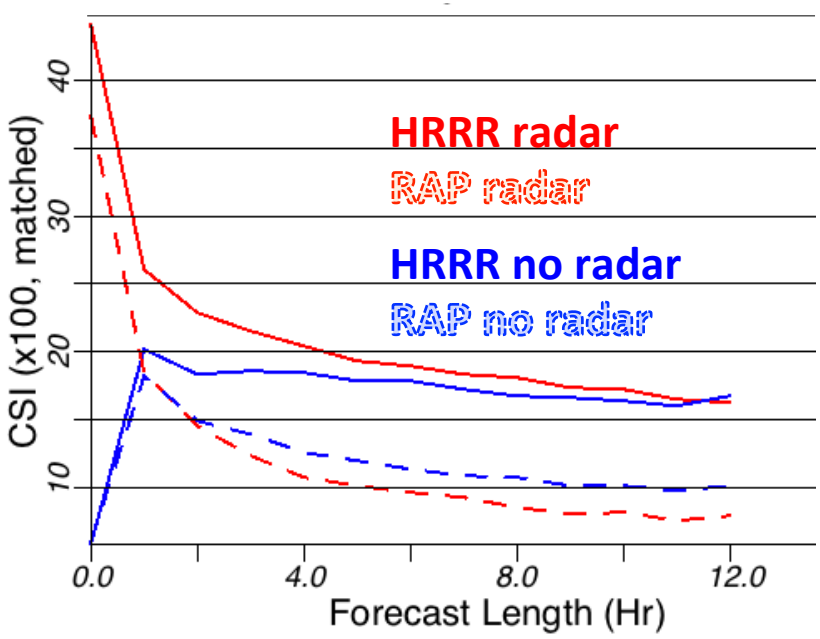
RAP/HRRR Reflectivity Verification

Eastern US, Reflectivity > 25 dBZ
11-21 August 2011

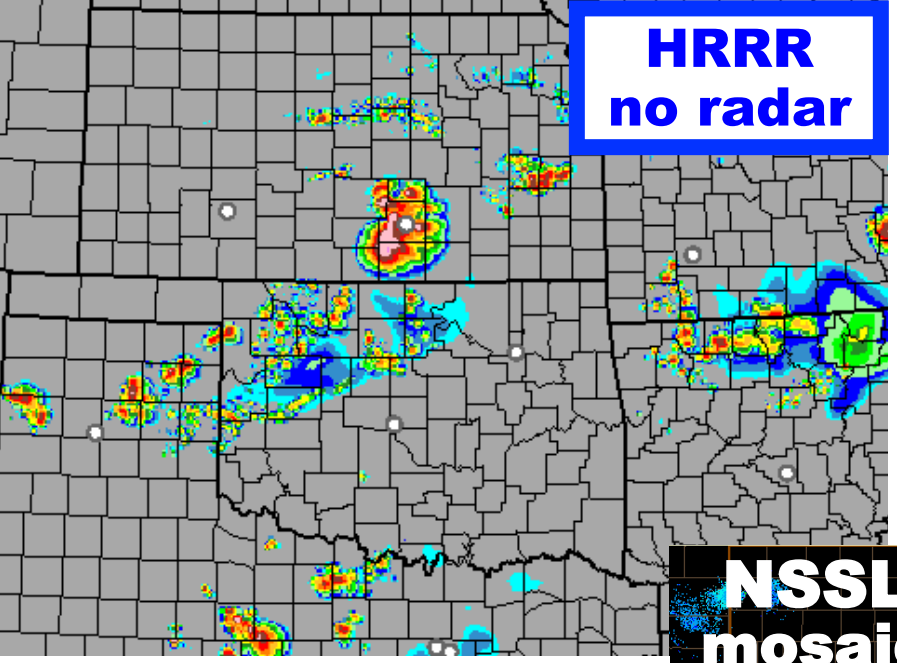
CSI 13 km

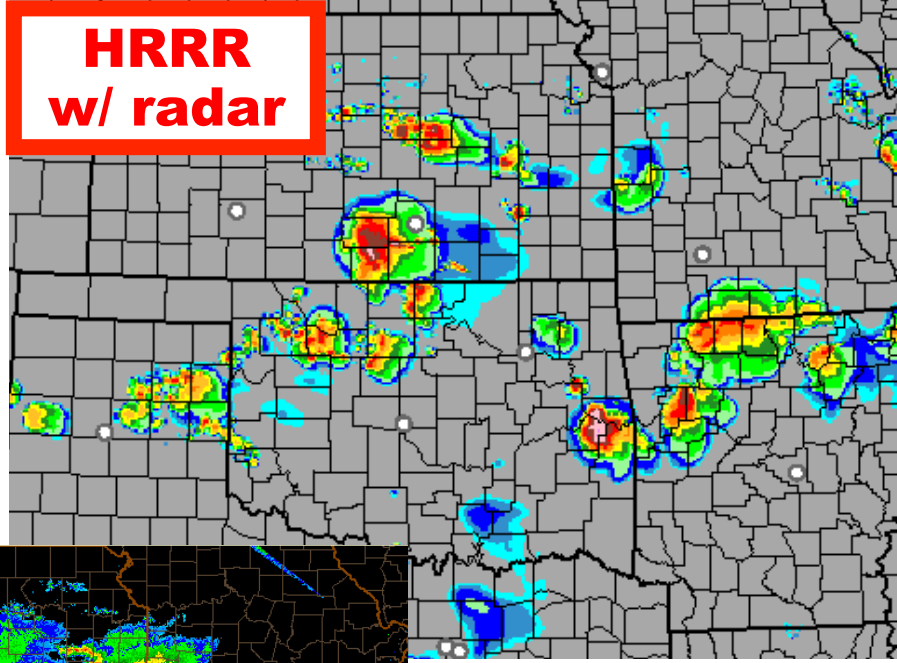


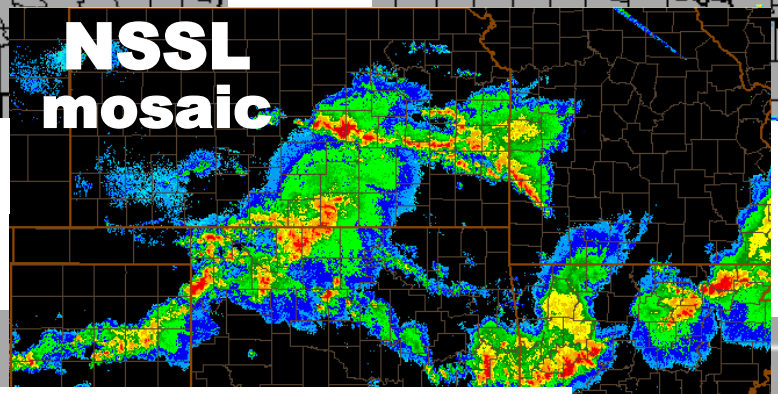
CSI 40 km



- **3km HRRR forecasts improve upon RAP 13km forecasts, especially at coarser scales → much better upscaled skill**
- **Radar DDFI adds skill at both 13km and 3km**







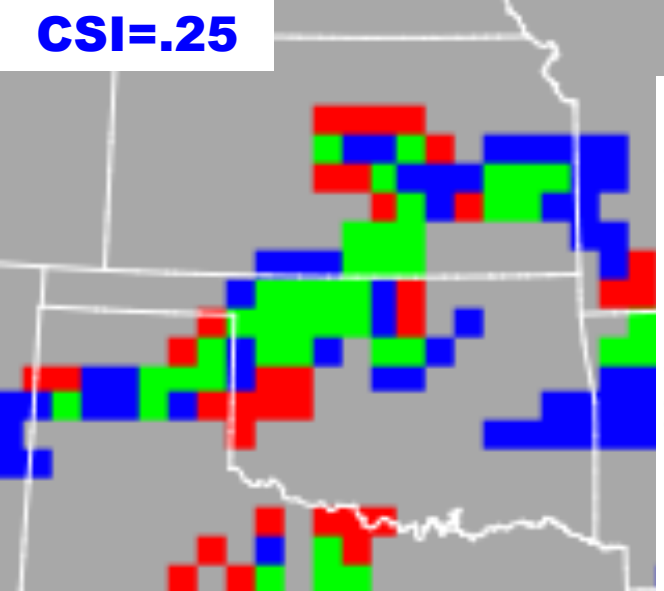
00z + 1 hr fcsts

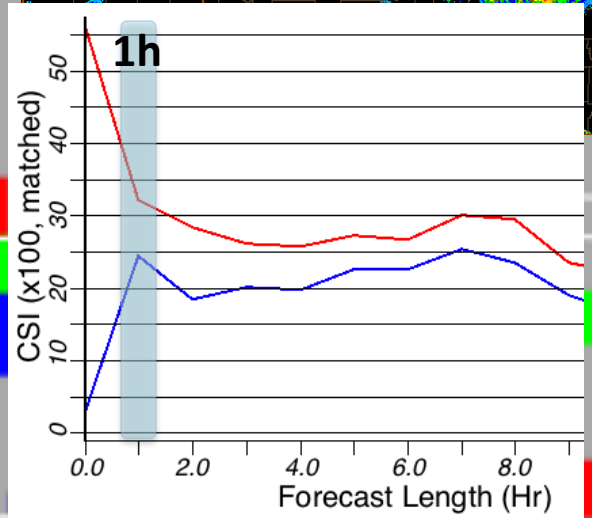
Miss FA Hit

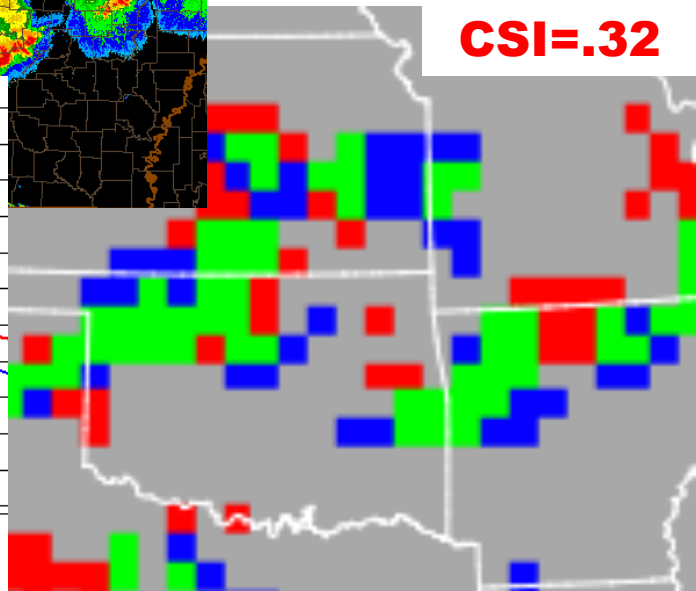
01z 13 Aug 2011

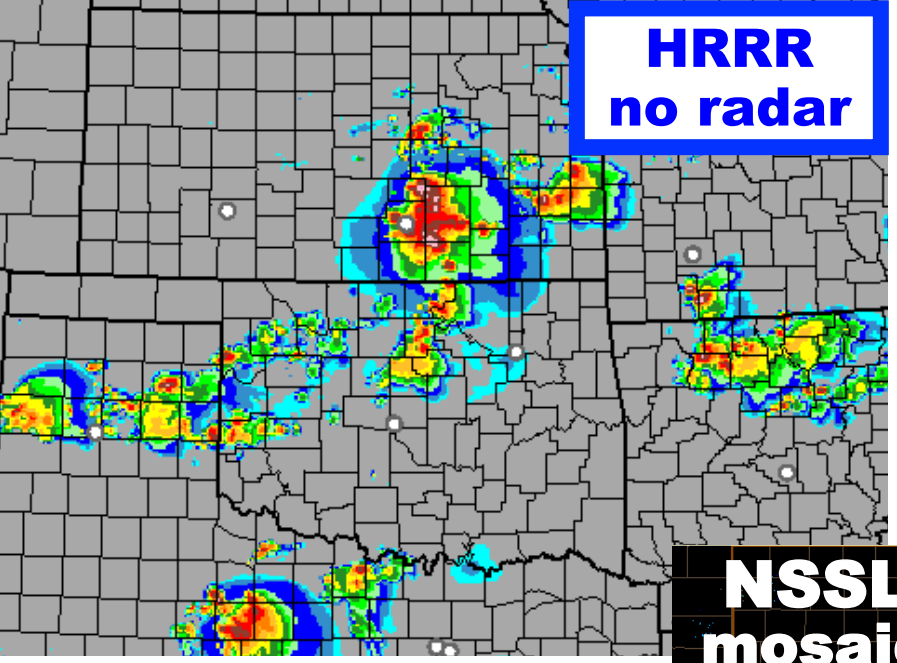
CSI=.25

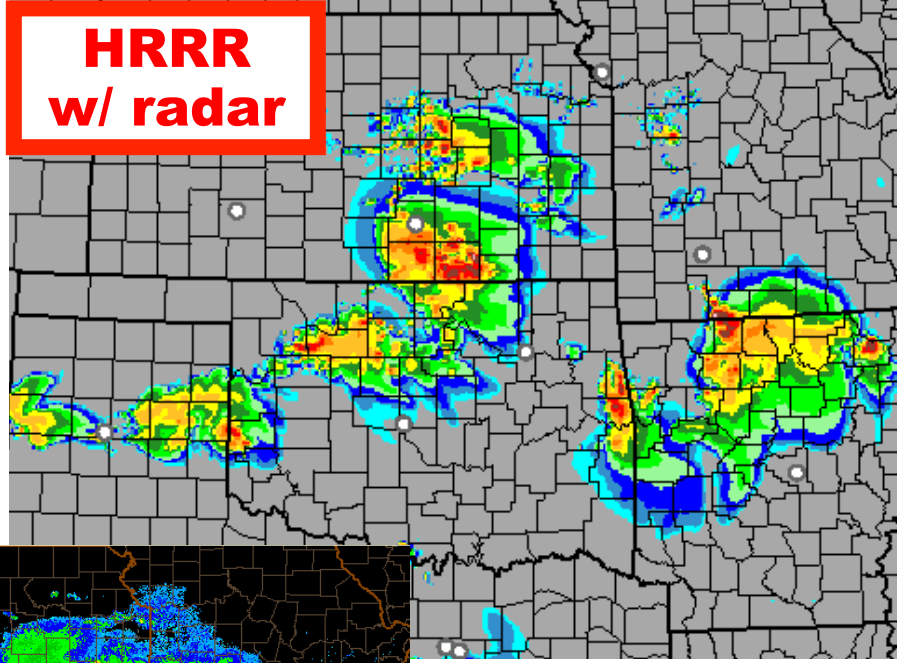
CSI=.32

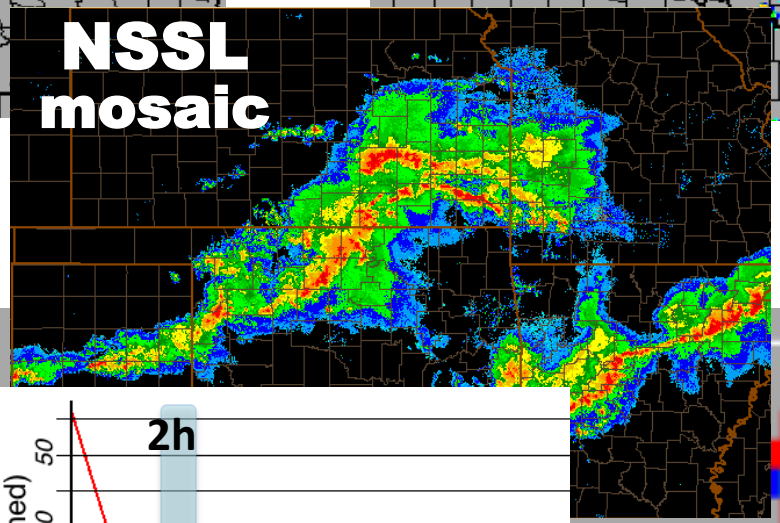












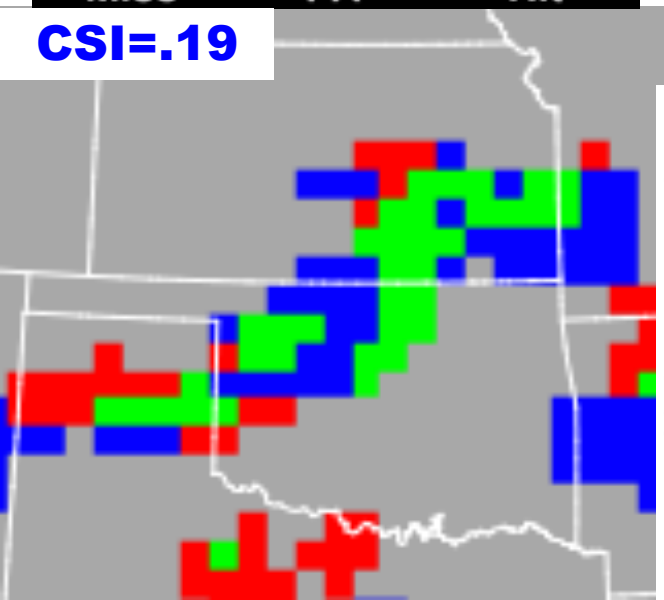
00z + 2 hr fcsts

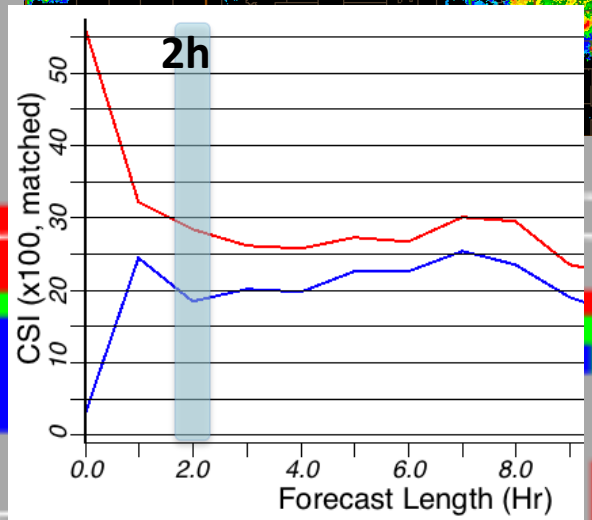
Miss FA Hit

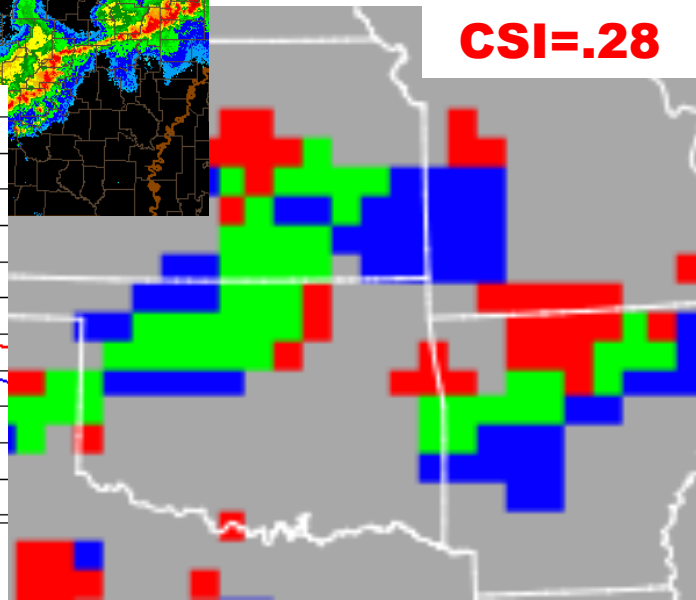
02z 13 Aug 2011

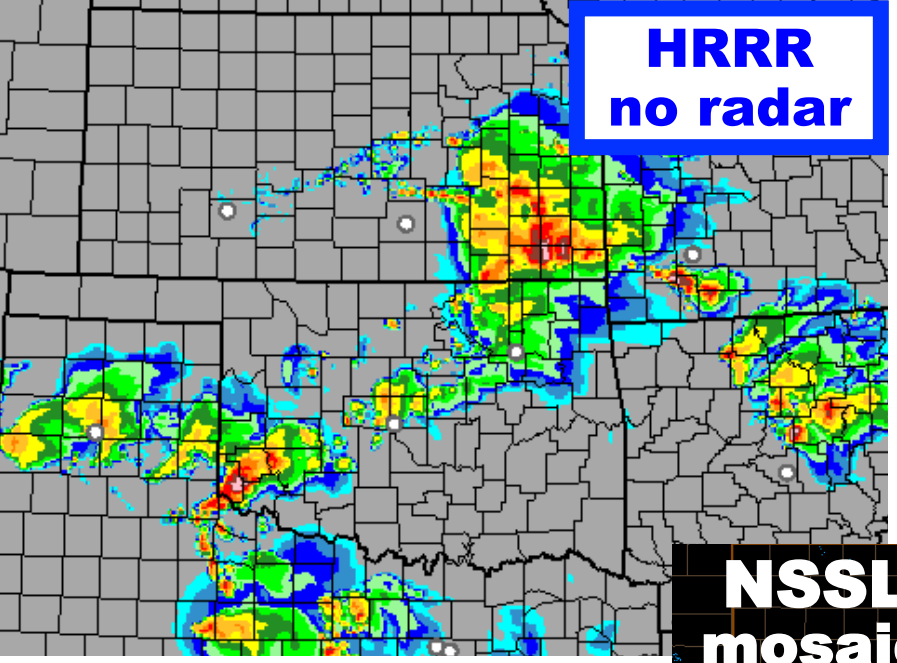
CSI=.19

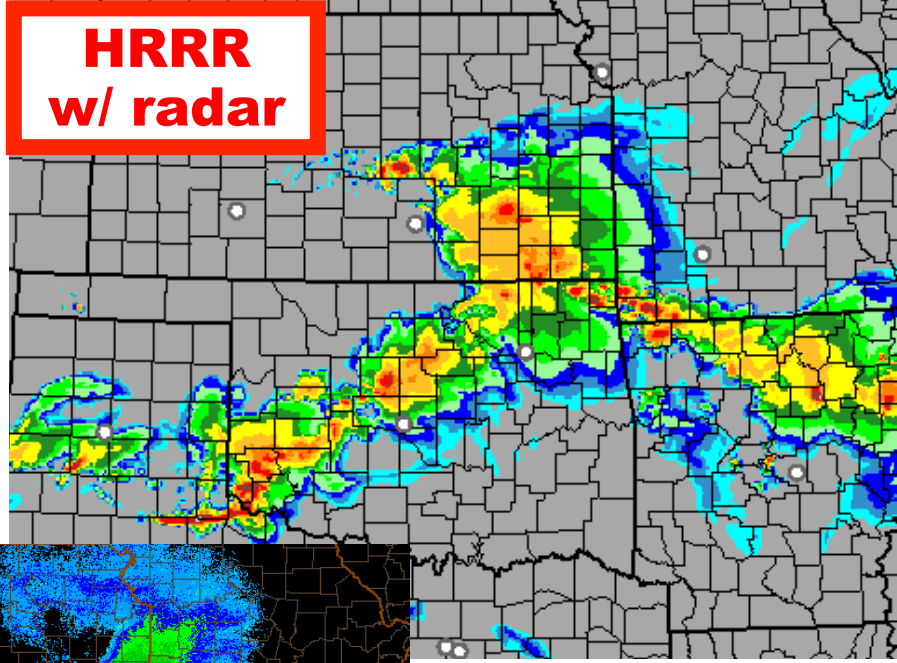
CSI=.28

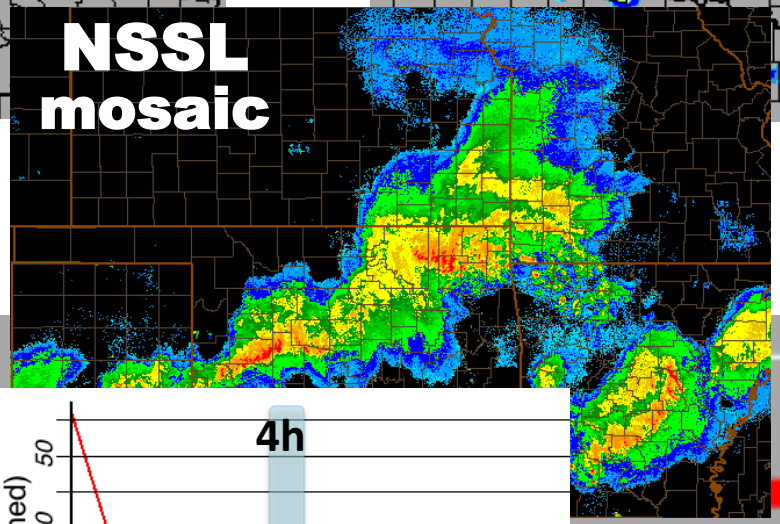












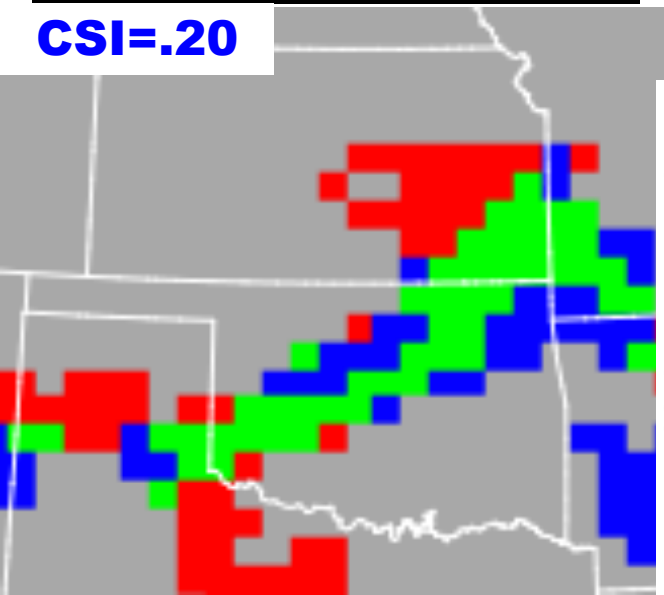
00z + 4 hr fcsts

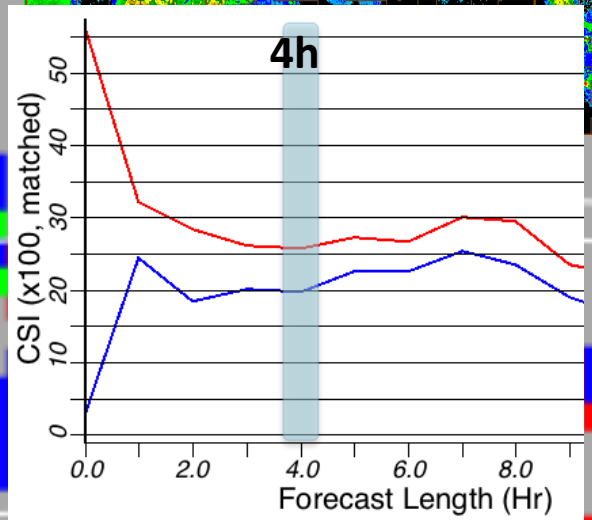
Miss FA Hit

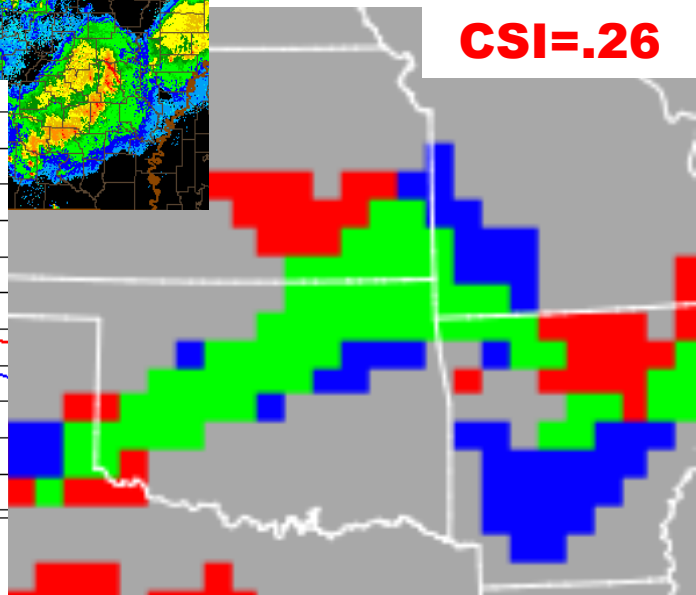
04z 13 Aug 2011

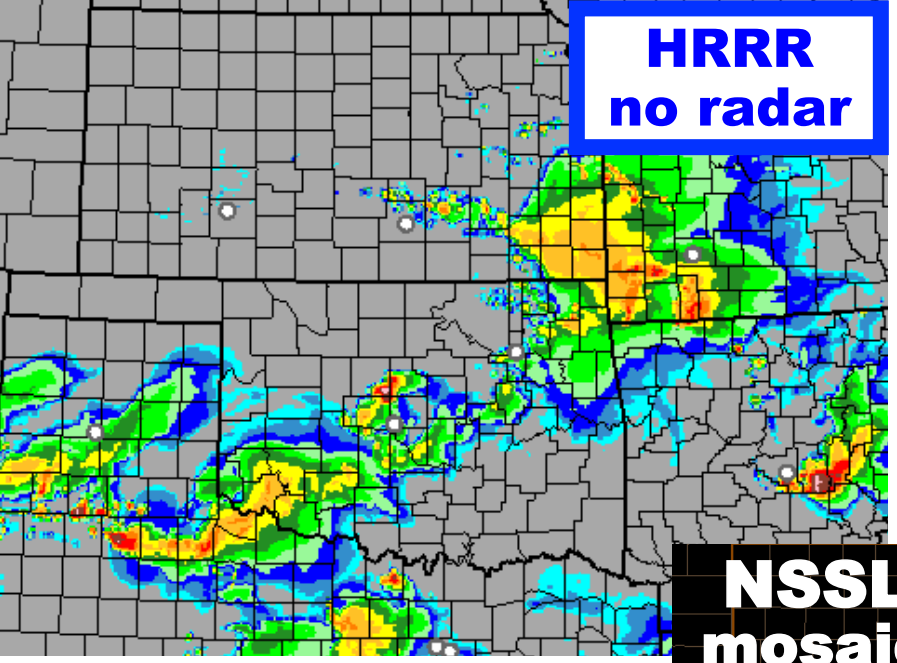
CSI=.20

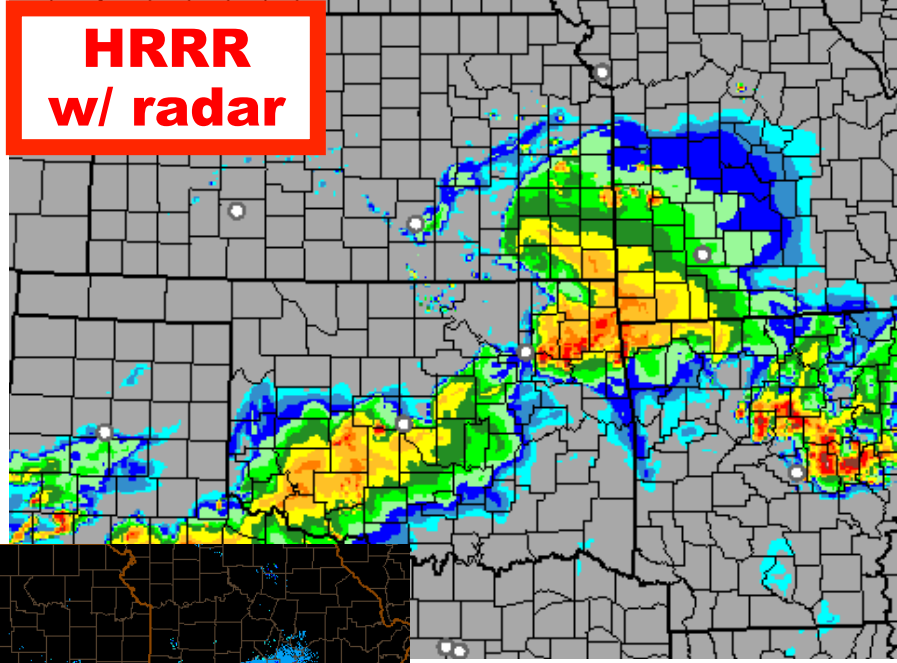
CSI=.26

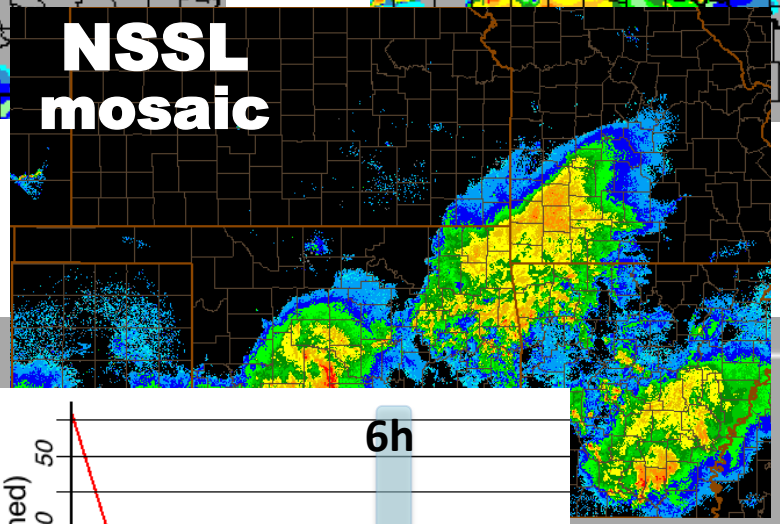












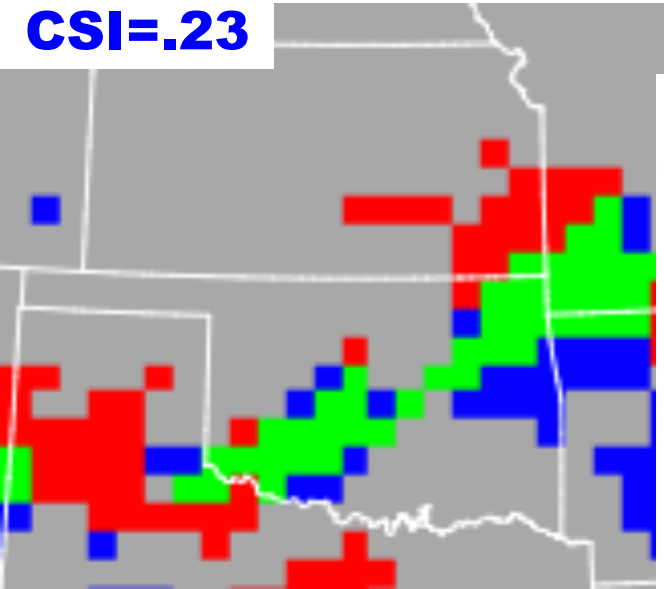
00z + 6 hr fcsts

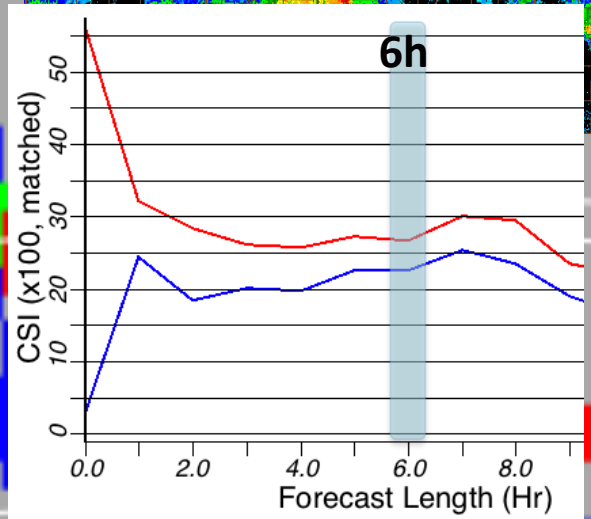
Miss FA Hit

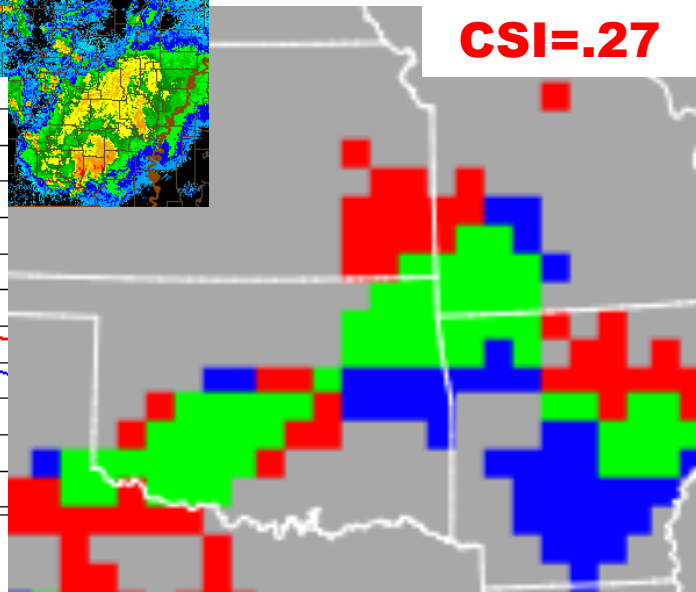
06z 13 Aug 2011

CSI=.23

CSI=.27





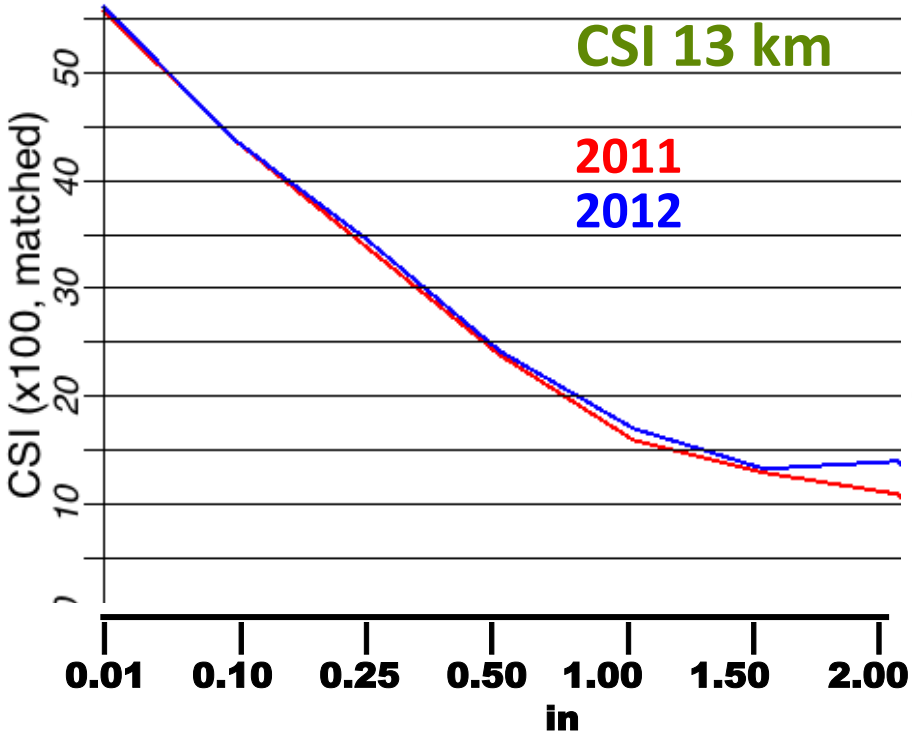


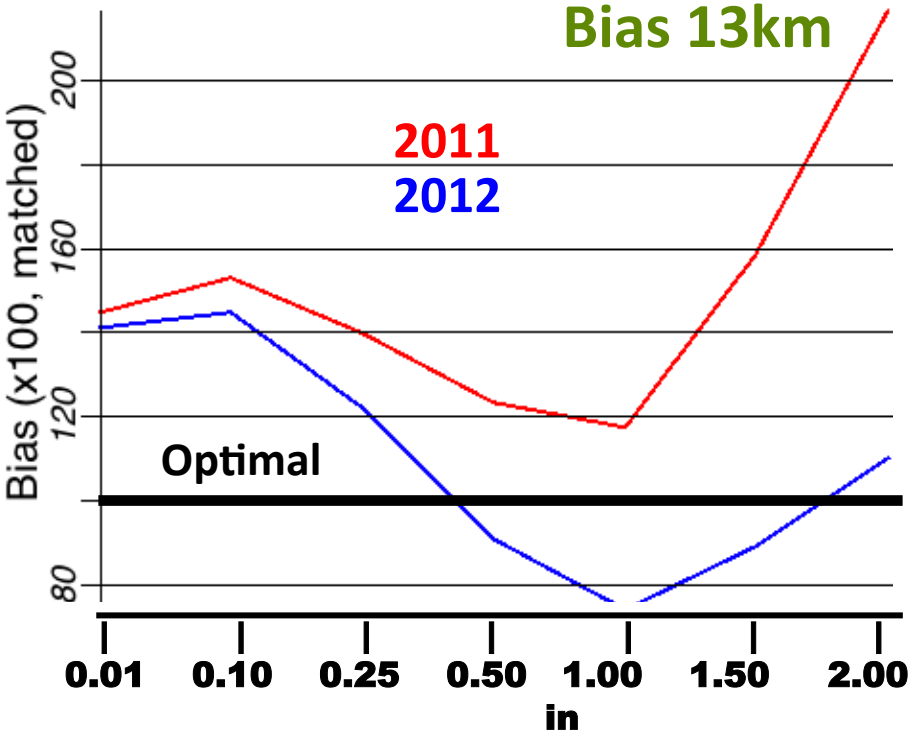
2011 vs. 2012 RAP

Precipitation Verification

Eastern US, 2x12hr Forecasts vs. 24h CPC

11-21 August 2011





Forecast skill maintained, and even improved at the highest thresholds

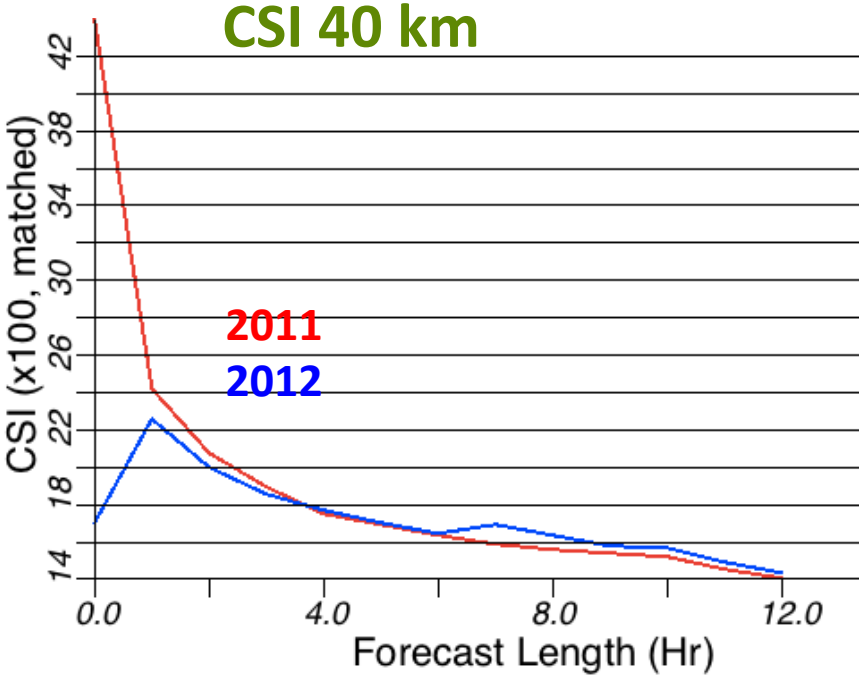
2012 configuration has a MUCH reduced bias!

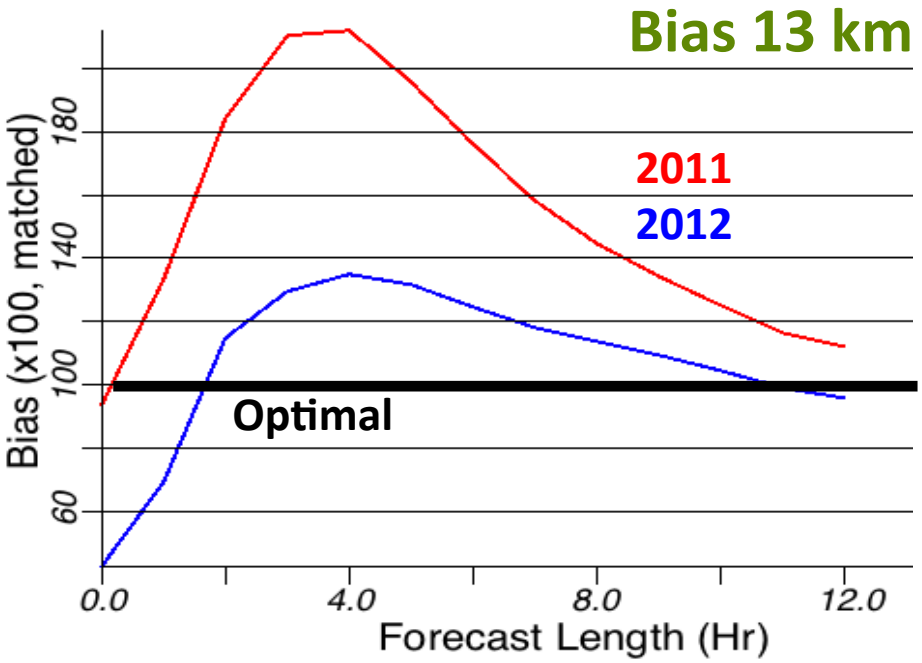
2011 vs. 2012 HRRR

Reflectivity Verification

Eastern US, Reflectivity > 25 dBZ

11-21 August 2011





Forecast skill similar, but 2012 configuration has a MUCH reduced bias!

Verification of HRRR vs RAP-ESRL

Cold Season (29 Jan 2012 – 10 Mar 2012) HRRR vs RAP												
Lead Time	Clouds		Precip (13 km)		Reflectivity (40 km)		Upper-Air			Surface		
	Ceiling < 500 ft	Vis < 0.5 mile	> 0.1 inch	> 1.0 inch	25 dBZ	35 dBZ	Temp	RH	Wind	Temp	Dewpt	Wind
3-hr	Equal	HRRR	N/A	N/A	Equal	HRRR	HRRR	HRRR	Equal	HRRR	Equal	HRRR
6-hr	HRRR	Equal			HRRR	HRRR	HRRR	HRRR	Equal	HRRR	HRRR	HRRR
12-hr	HRRR	HRRR			HRRR	HRRR	HRRR	RAP	RAP	HRRR	HRRR	HRRR

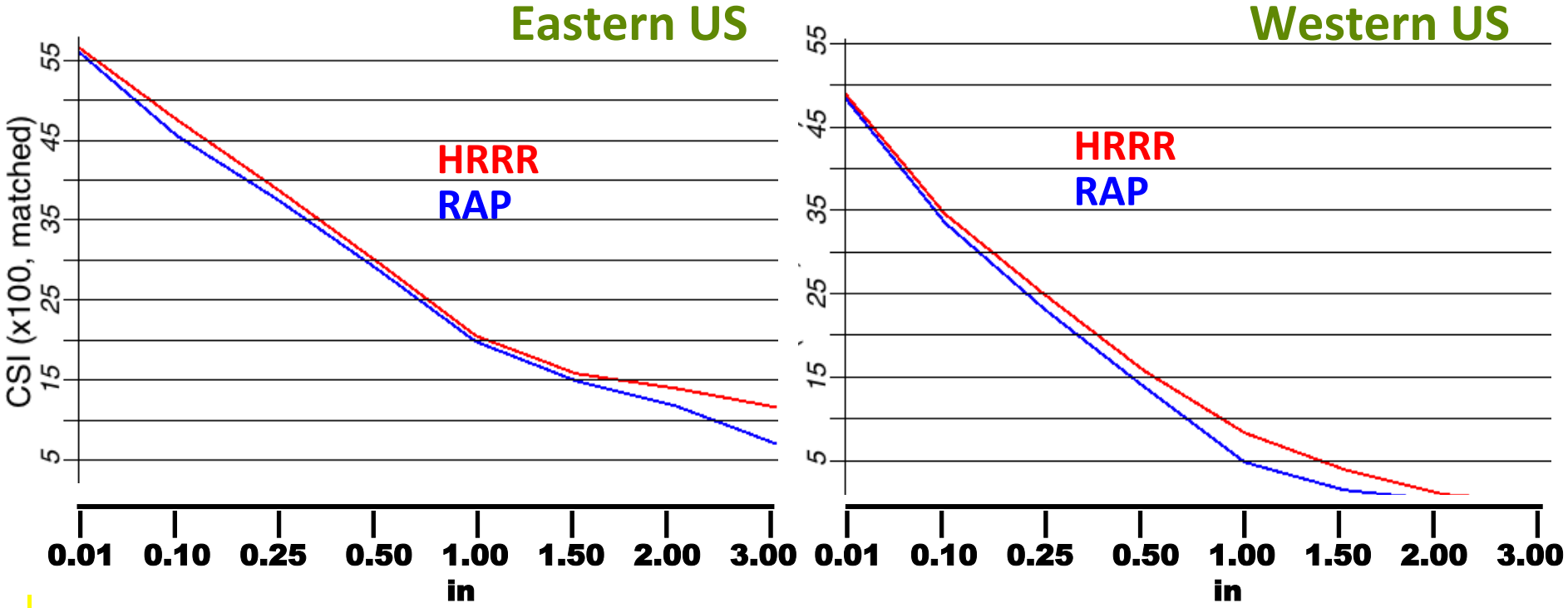
Warm Season (15 April 2011 – 25 October 2011) HRRR vs RAP												
Lead Time	Clouds		Precip (13 km)		Reflectivity (40 km)		Upper-Air			Surface		
	Ceiling < 500 ft	Vis < 0.5 mile	> 0.1 inch	> 1.0 inch	25 dBZ	35 dBZ	Temp	RH	Wind	Temp	Dewpt	Wind
1-hr	HRRR	RAP	HRRR	Equal	HRRR	HRRR	HRRR	HRRR	HRRR	RAP	RAP	HRRR
3-hr	HRRR	HRRR			HRRR	HRRR	HRRR	HRRR	RAP	Equal	RAP	Equal
6-hr	HRRR	HRRR			HRRR	HRRR	HRRR	HRRR	RAP	HRRR	Equal	Equal

HRRR vs. RAP-ESRL

Precipitation Verification

13km scale, 2x12hr Forecasts vs. 24h CPC

June - Sept 2011

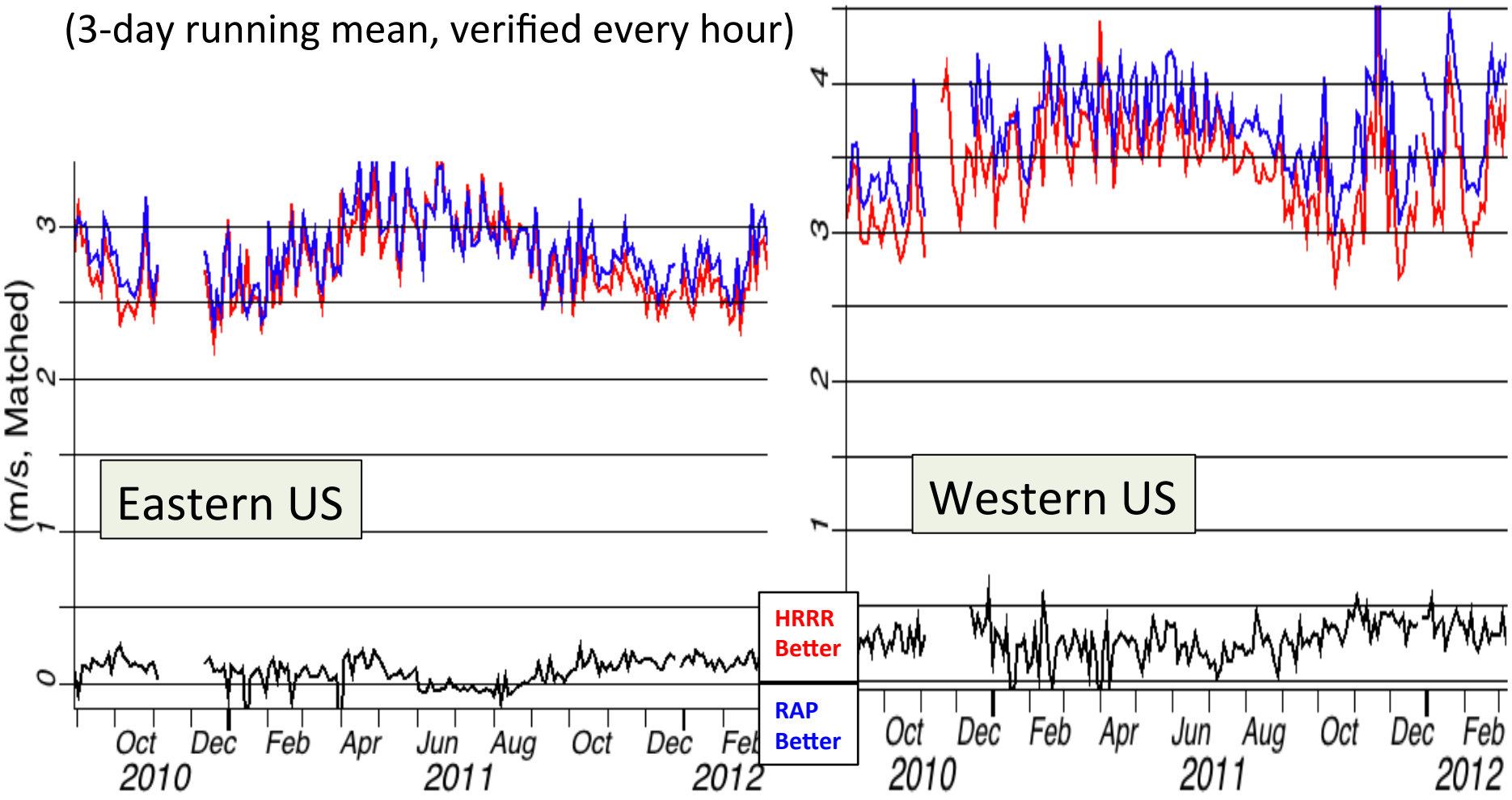


Forecast skill better in HRRR, especially at higher thresholds and in the Western US

HRRR vs. RAP-ESRL – 12h forecasts

10m wind rms difference from METARs

(3-day running mean, verified every hour)



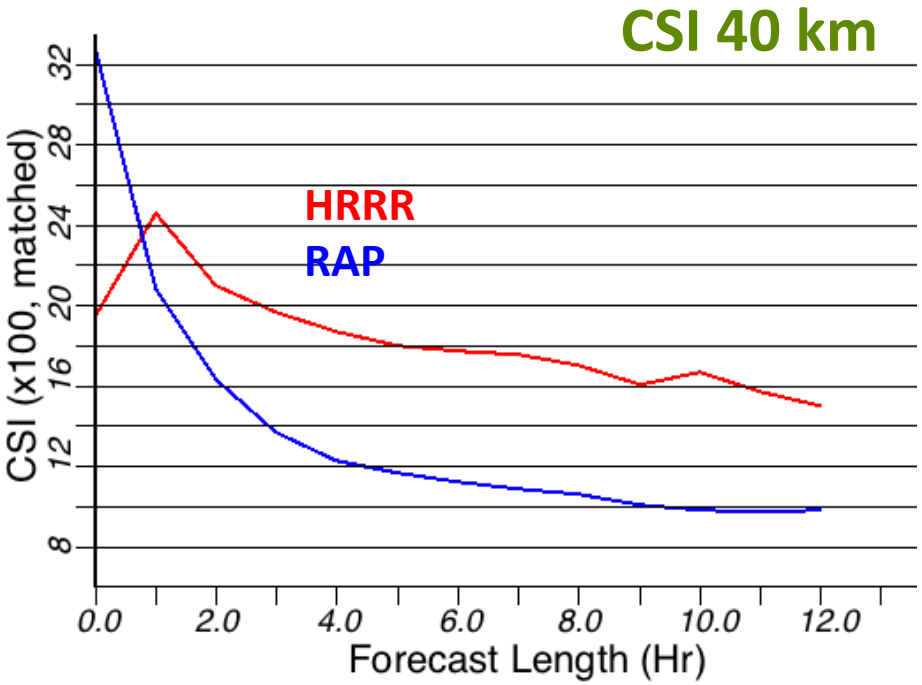
HRRR more accurate than RAP, more so in western US, especially since Oct 2011

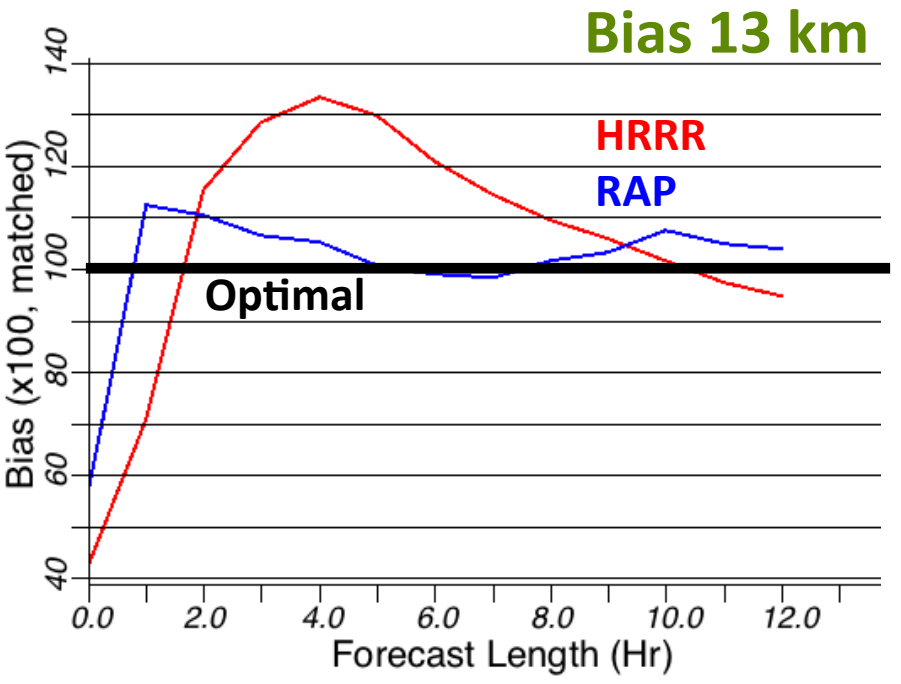
2012 HRRR vs. 2012 RAP-ESRL

Reflectivity Verification

Eastern US, Reflectivity > 25 dBZ

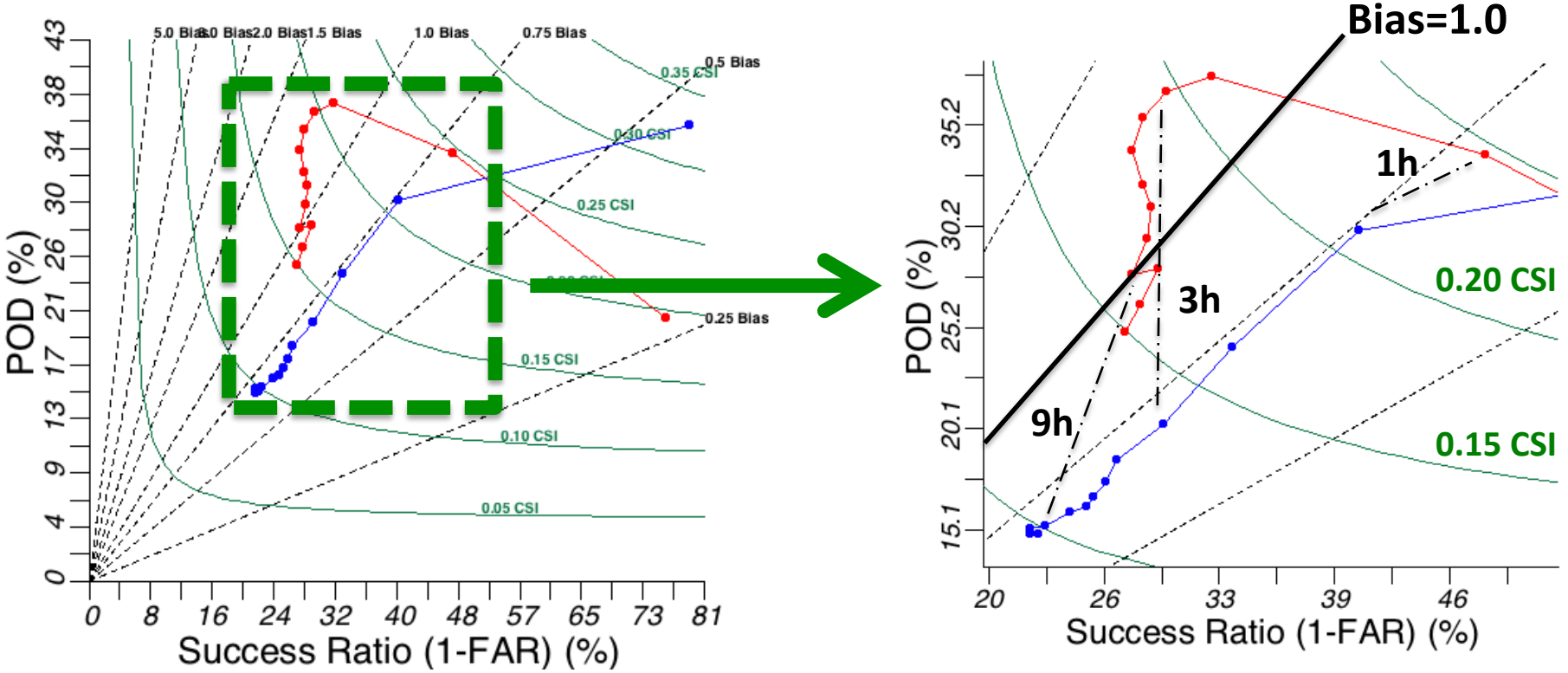
Aug 2011





3km HRRR forecasts show much greater skill than 13km RAP forecasts, while maintaining very similar biases

2012 HRRR vs. 2012 RAP-ESRL
Performance Diagrams



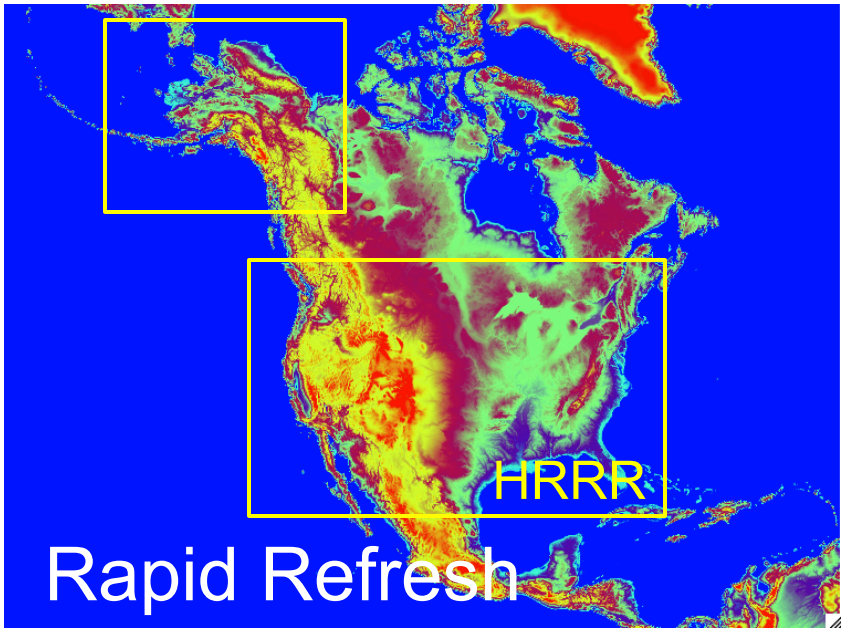
HRRR has more optimal Bias and higher CSI

HRRR Program Review Outline

1:30	Opening Remarks	Stan Benjamin
1:30 – 1:40	Program Overview	Curtis Alexander
1:40 – 1:50	Initial Conditions: Rapid Refresh	Steve Weygandt
1:50 – 2:00	Model Development	David Dowell
2:00 – 2:10	Case Studies and Applications	Eric James
2:10 – 2:20	Forecast Verification	Patrick Hofmann
2:20	Summary and Future Plans	Curtis Alexander
2:20 – 2:30	Questions	

Future Plans for Hourly Updated Models

- Mar 2012 – Rapid Refresh operational at NCEP
- Early 2013 – Rapid Refresh v2 –
  - cloud/surface/soil assimilation➔much lower moist bias (better convective fcsts), GOES, sodar/tower/nacelle winds, updated GSI
  - model – MODIS land use, cloud/PBL/ numerical improvements, updated WRF
- 2013 – application of hybrid/EnKF assimilation to RAP in real-time testing
- 2012-14 – HRRR @ESRL improves, add Fairmont/zeus HRRR to reach 99%
- 2015 – High-Resolution Rapid Refresh operational at NCEP for CONUS



- 2015 – Ensemble Rapid Refresh – **NARRE** w/ hybrid assim
- 2016 – Add operational Alaska HRRR
- 2017 – CONUS Ensemble HRRR – **HRRRE**

N.American Rapid Refresh Ensemble

- **NEMS-based NMM, ARW cores**
- **Hourly updating with GSI-hybrid EnKF**
- **Initially 6 members, 3 each core, physics diversity (RAP, NAM, NCAR suites)**
- **Forecasts to 24-h**
- **NMM to 84-h 4x per day**

Other improvements in init testing

- RAP with inline chem, chem DA
- 15-min radar data assimilation
- Storm-scale radar data assimilation

HRRR Program Review Outline

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List of Acronyms

AMB	Assimilation and Modeling Branch
AMSU	Advanced Microwave Sounding Unit
ARL	Air Resources Laboratory
ARW	Advanced Research WRF (Model)
AWIPS	Advanced Weather Interactive Processing System
CIWS	Corridor Integrated Weather System
CONUS	Contiguous United States
CoSPA	Consolidated Storm Prediction for Aviation (FAA experimental thunderstorm forecast program)
CPC	Climate Prediction Center
CIRA	Cooperative Institute for Research in the Atmosphere
CSI	Critical Success Index
CSU	Colorado State University
DA	Data Assimilation
DDFI	Diabatic Digital Filter Initialization
DFI	Digital Filter Initialization
DOE	Department of Energy
DTC	Developmental Testbed Center
EnKF	Ensemble Kalman Filter
ESRL	Earth System Research Laboratory
FAA	Federal Aviation Administration
FAR	False Alarm Ratio
FTP	File Transfer Protocol
G3	Grell Three Dimensional (Convective Parameterization Scheme)
GOES	Geostationary Operational Environmental Satellite
GPS	Global Positioning System
GSD	Global Systems Division
GSI	Gridpoint Statistical Interpolation
HPCC	High Performance Computer Consortium
HPCS	High Performance Computer System
HRRR	High-Resolution Rapid Refresh (Model)

List of Acronyms (continued)

HRRRE	High-Resolution Rapid Refresh Ensemble
LDM	Local Data Manager
METAR	Aviation routine weather report
MIT/LL	Massachusetts Institute of Technology/Lincoln Laboratory
MODIS	MODerate resolution Imaging Spectroradiometer
MYJ	Mellor-Yamada-Janjic (Boundary Layer Scheme)
NCAR	National Center for Atmospheric Research
NARRE	North American Rapid Refresh Ensemble
NCEP	National Centers for Environmental Prediction
NEMS	NOAA Environmental Modeling System
NAM	North American Mesoscale (Model)
NMM	Non-hydrostatic Mesoscale Model
NMMB	Non-hydrostatic Mesoscale Model B-Grid
NOAA	National Oceanic and Atmospheric Administration
NSSL	National Severe Storms Laboratory
NWS	National Weather Service
PBL	Planetary Boundary Layer
POD	Probability of Detection
RAP	Rapid Refresh (Model)
RASS	Radio Acoustic Sounding System
RMS	Root Mean Square
RRTM	Rapid Radiative Transfer Model
RTMA	Real Time Mesoscale Analysis (Hourly updated surface analysis from NCEP)
RUC	Rapid Update Cycle (Model)
SPC	Storm Prediction Center
UH	Updraft Helicity
USAF	United States Air Force
VAD	Velocity Azimuth Display
WFIP	Wind Forecast Improvement Project (DOE NOAA program)
WRF	Weather Research and Forecast (Model)

List of Acronyms (continued)

WSR-88D	Weather Surveillance Radar – 1988, Doppler
WVSS	Water Vapor Sensing System
3D-VAR	Three Dimensional Variational Data Assimilation