NCEP Production Suite Review
3 -5 December 2013

Hourly updated models:
Rapid Refresh / HRRR review

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SCIENCE, SERVICE & STEWARDSHIP

Rapid Refresh "version 2"

Scheduled implementation 28 Jan 2014

- Upgrades: **EnKF-3DVAR hybrid DA, MYNN PBL, 9-layer LSM, better cloud/precip anx**
- RAPv2 significant improvement over RAPv1
  Better winds, mid-level moisture, near-surface fields, convective environments

High-Resolution Rapid Refresh

Scheduled implementation Q3 2014

- **3-km, radar assimilation, hourly to 15h**
- Two real-time experimental versions, (Jet, Zeus) each with > 90% run reliability
- 1-h pre-forecast 15-min cycled radar DA at 3-km, followed by 3-km GSI 3DVAR
  Improved storm forecasts from RAPv2 environment fields and 3-km radar DA

Rapid Refresh and HRRR
NOAA hourly updated models

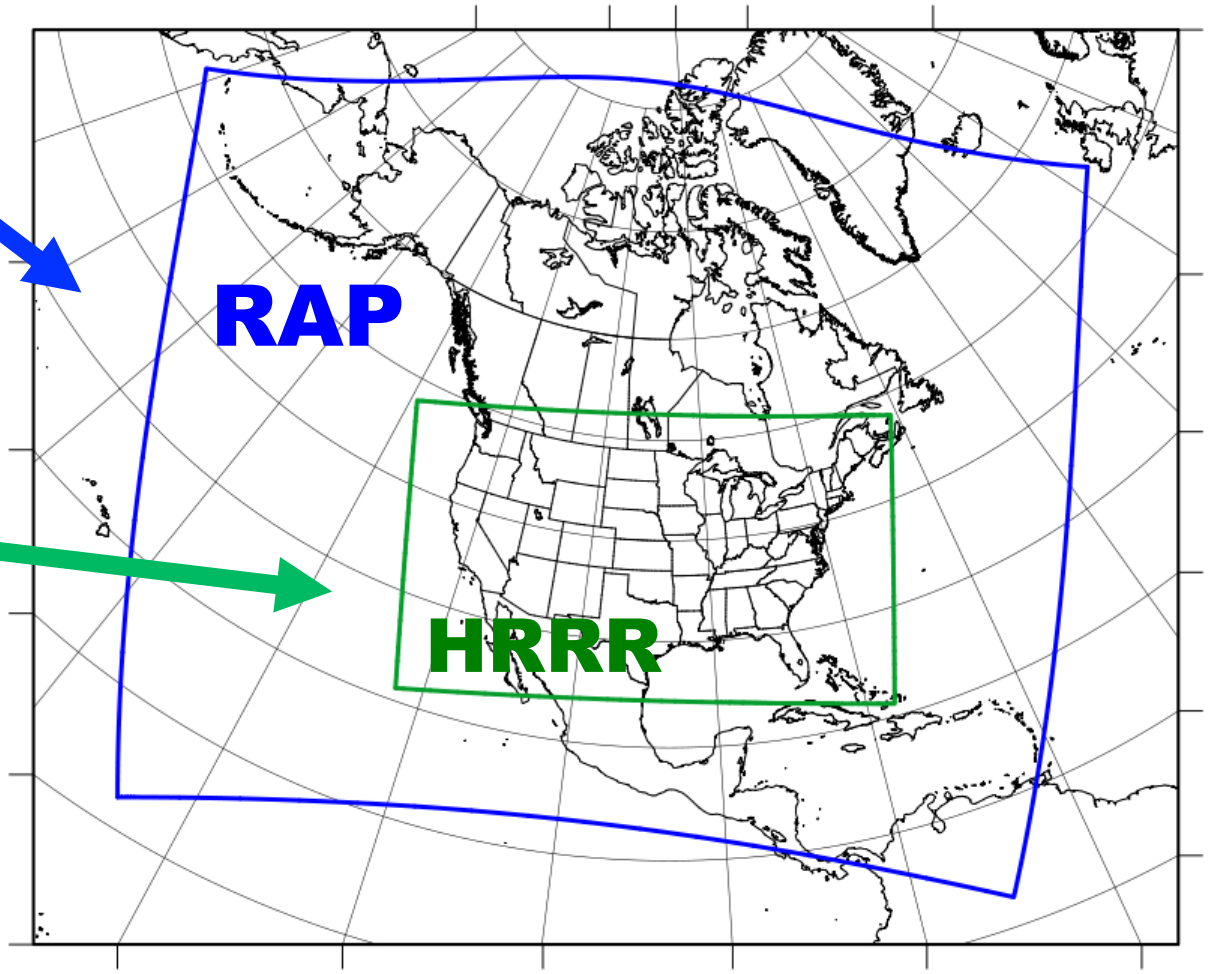
13km Rapid Refresh (RAP) (mesoscale)

Version 2 – scheduled NCEP implementation Q2 (currently 28 Jan)

3km HRRR (storm-scale)

High-Resolution Rapid Refresh

Scheduled NCEP Implementation Q3 2014



RAPv2 Prediction System Overview

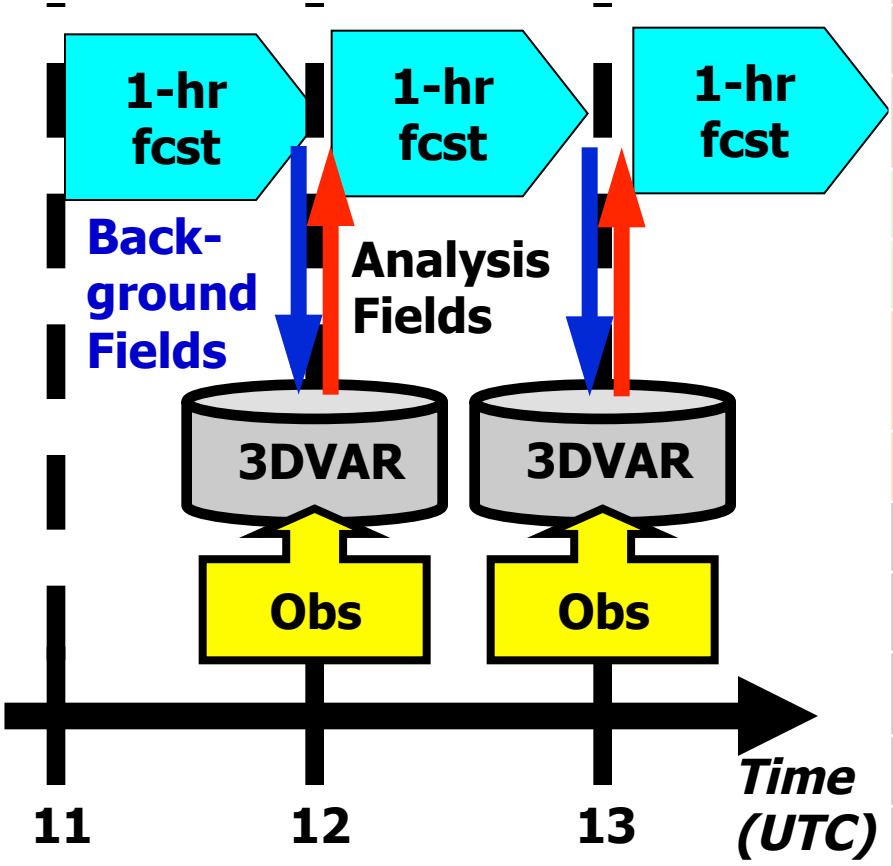
- **Hourly updated mesoscale analyses / forecasts**
  - WRF-ARW model (Grell-3 cumulus param, Thompson microphysics, RUC-Smirnova land-surface, MYNN PBL scheme)
  - GSI hybrid analysis using 80-member global ensemble
  - 13-km, 50 levels, 24 cycles/day – each run out to 18 hours
  - 6-hour catch-up "partial" cycle run twice per day from GFS
  - Output grids: 13, 20, and 40 km CONUS, 32 km full domain, 11 km Alaska, 16 km Puerto Rico
- **Use and downstream dependencies**
  - Used by SPC, AWC, WPC, NWS FOs, FAA, energy industry, and others for short-range forecasts and hourly analyses
  - Downscaled RAP serves as first guess for RTMA
  - RAP serves as initial condition for SREF members
  - RAP will be used to initialize Hi-Res Rapid Refresh (HRRR), scheduled for implementation Q3 2014 and HRW runs

Rapid Refresh
Hourly Update Cycle

Partial cycle atmospheric fields – introduce GFS information 2x/day

Cycle hydrometeors

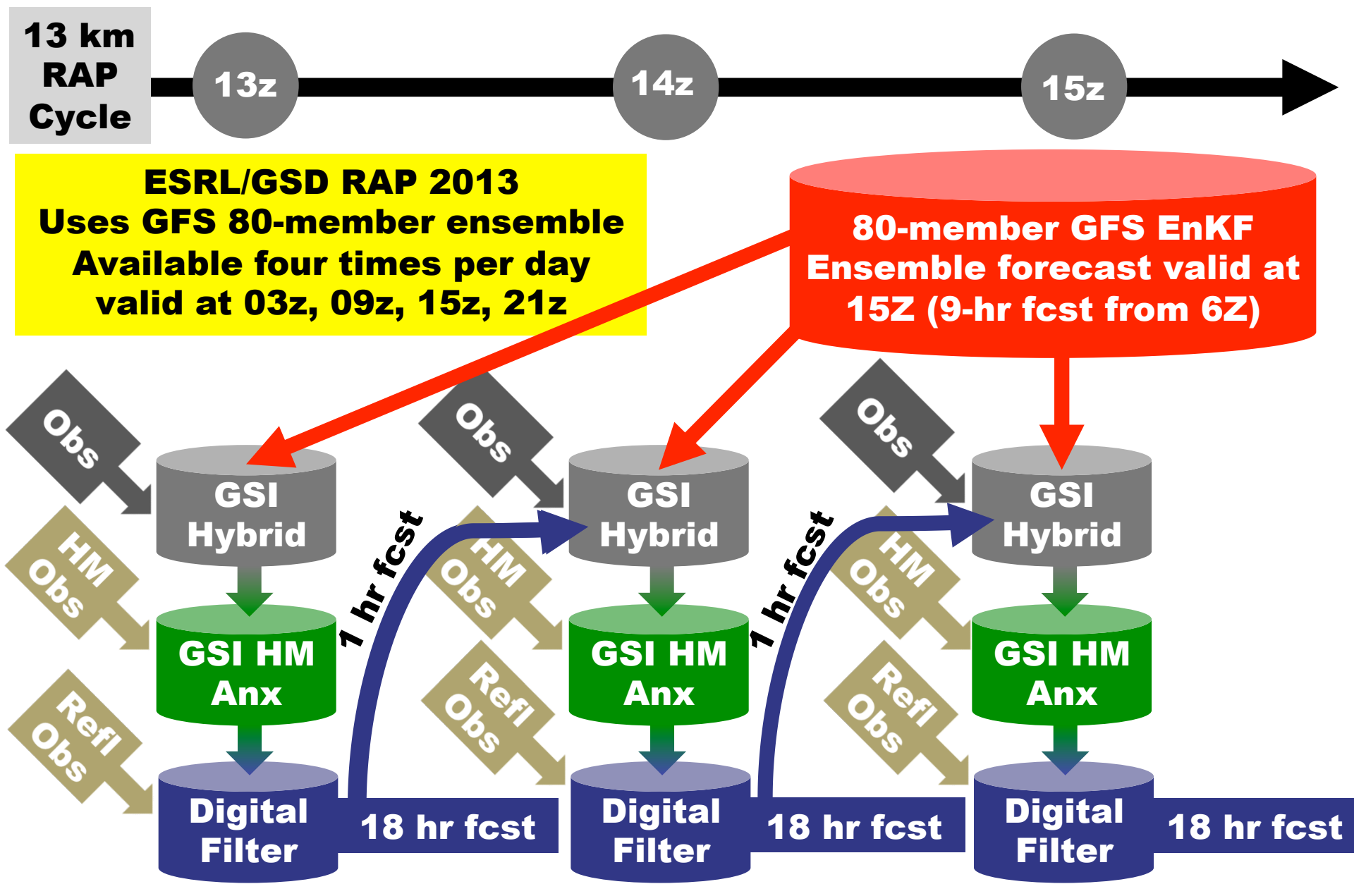
Fully cycle all land-sfc fields (soil temp, moisture, snow)



Observations Used

Hourly Observations	RAP 2013 N. Amer
Rawinsonde (T,V,RH)	120
Profiler – NOAA Network (V)	21
Profiler – 915 MHz (V, Tv)	25
Radar – VAD (V)	125
Radar reflectivity - CONUS	1km
Lightning (proxy reflectivity)	**NLDN, GLD360**
Aircraft (V,T)	2-15K
Aircraft - WVSS (RH)	0-800
Surface/METAR (T,Td,V,ps,cloud, vis, wx)	2200- 2500
Buoys/ships (V, ps)	200-400
GOES AMVs (V)	2000- 4000
AMSU/HIRS/MHS radiances	Used
GOES cloud-top press/temp	13km
GPS – Precipitable water	260
WindSat scatterometer	2-10K

RAPv2 Hybrid Data Assimilation



RAP version 2 upgrades

Data Assimilation	Model
GFS EnKF-3DVAR hybrid data assimilation PBL-based pseudo-innovations Surface-obs-based soil moisture/temp adjustment Low cloud building / other cloud enhancements Temp-dependent radar hydrometeor building Lightning data assimilation GSI trunk update	**Physics changes** MYJ → MYNN PBL scheme 9-layer RUC LSM (from 6-layer) MODIS land-use (fractional) Modified roughness length Revised Thompson cloud m-phys. **Higher-order numerics introduced** Positive definite scalar advection 5th-order vertical advection Update to WRFv3.4.1

RAPv2 enhancements from RAPv1

Data Assimilation	Assimilation Type	PBL Pseudo Innovations	Soil Adjustment	Low-Cloud Building	Snow Cover Building	Lightning Obs (radar refl proxy)	Tower/Nacelle/ Sodar Obs
RAPv1	GSI 3D-VAR	No	No	No	No	No	No
RAPv2	GSI EnKF-3DVAR Hybrid	Yes	Yes	Yes	Yes + rev trimming	Yes	Yes

Model	Version	Horiz/Vert Advection	Scalar Advection	Upper-Level Damping	SW Radiation Update	Land Use	LSM	PBL	Microphysics	Radiation LW/SW
RAPv1	WRF-ARW V3.2+	$5^{th}/3^{rd}$	Monotonic	w-Rayleigh 0.02	30 min	USGS	RUC 6-lev	MYJ	Thompson V3.1	RRTM/ Goddard
RAPv2	WRF-ARW v3.4.1+	$5^{th}/5^{th}$	Positive-Definite	w-Rayleigh 0.2	10 min	MODIS Fractional	RUC 9-lev	MYNN	Thompson v3.4.1	RRTM/ Goddard

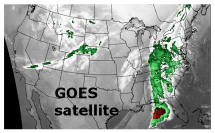
Cloud and Precipitating Hydrometeor Analysis Improvements in RAPv2

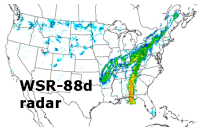
Surface temperature-dependent radar-hydrometeor building
Consistent rain (droplet) number concentration and mixing ratio retrievals from radar refl obs
Rain and snow mixing ratio retrievals reversible with Thompson reflectivity diagnostic

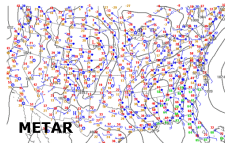
Conservation of virtual potential temperature during cloud building/clearing
Water vapor reduced to subsaturation when cloud clearing
Elevation correction to match model and observed precipitable water
Limitation of precipitable water innovation to 10% of background

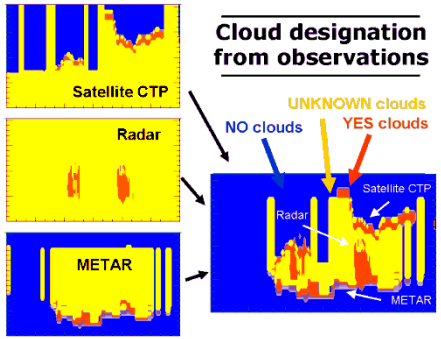
Rapid Refresh Specific Analysis Features

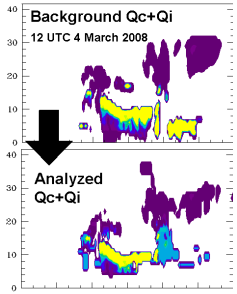
Cloud and hydrometeor analysis



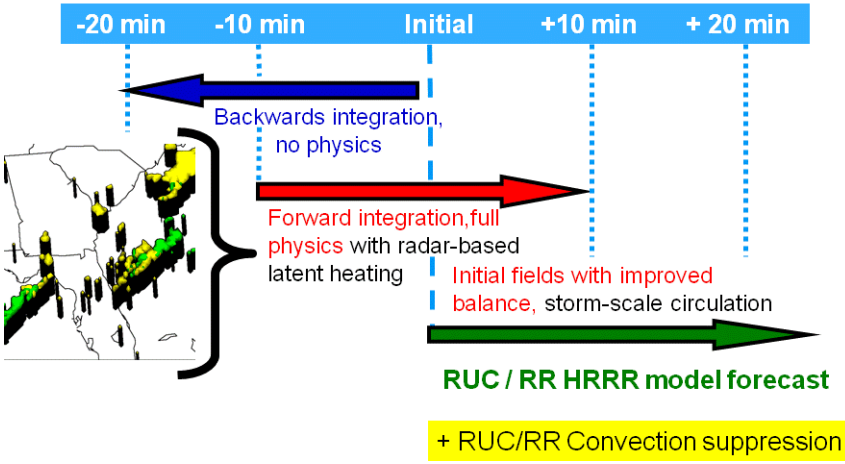








Digital filter-based reflectivity assimilation (DDFI)



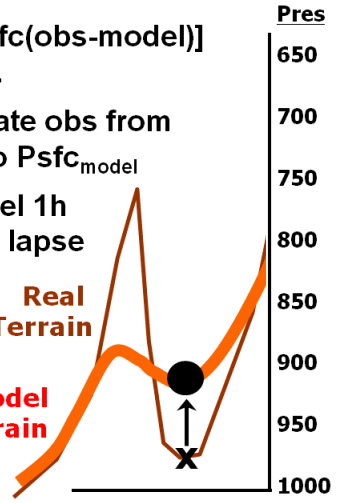
Special treatments for surface observations

Elevation correction

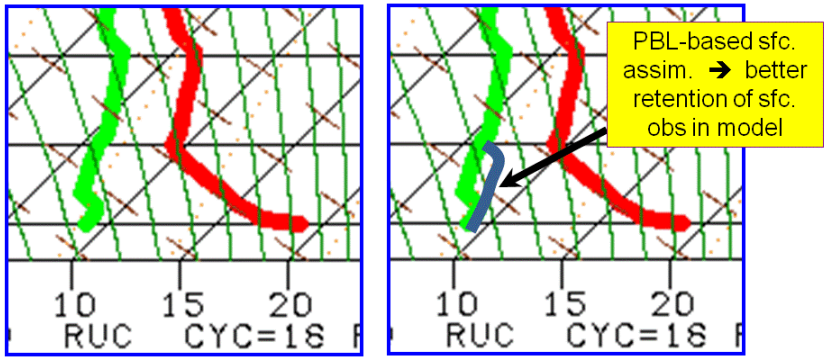
If abs[Psfc(obs-model)] < 70 hPa.

Extrapolate obs from $Psfc_{obs}$ to $Psfc_{model}$

Use model 1h low-level lapse rate.



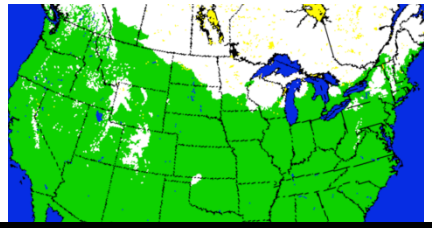
PBL-based pseudo-observations



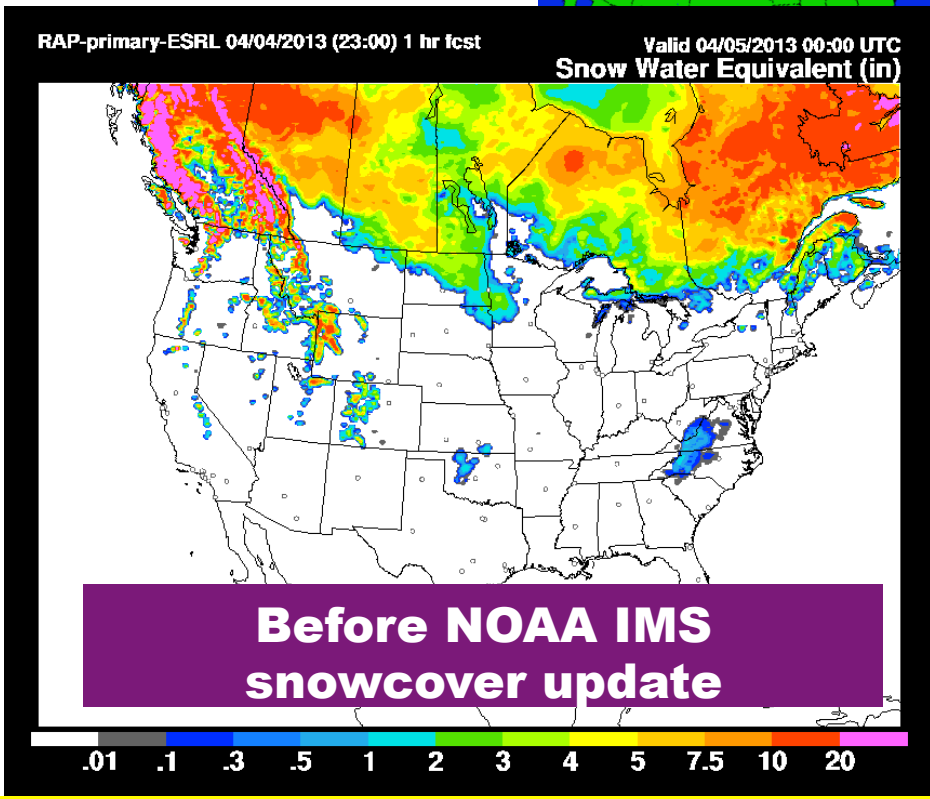
RAPv2 Snow Updating

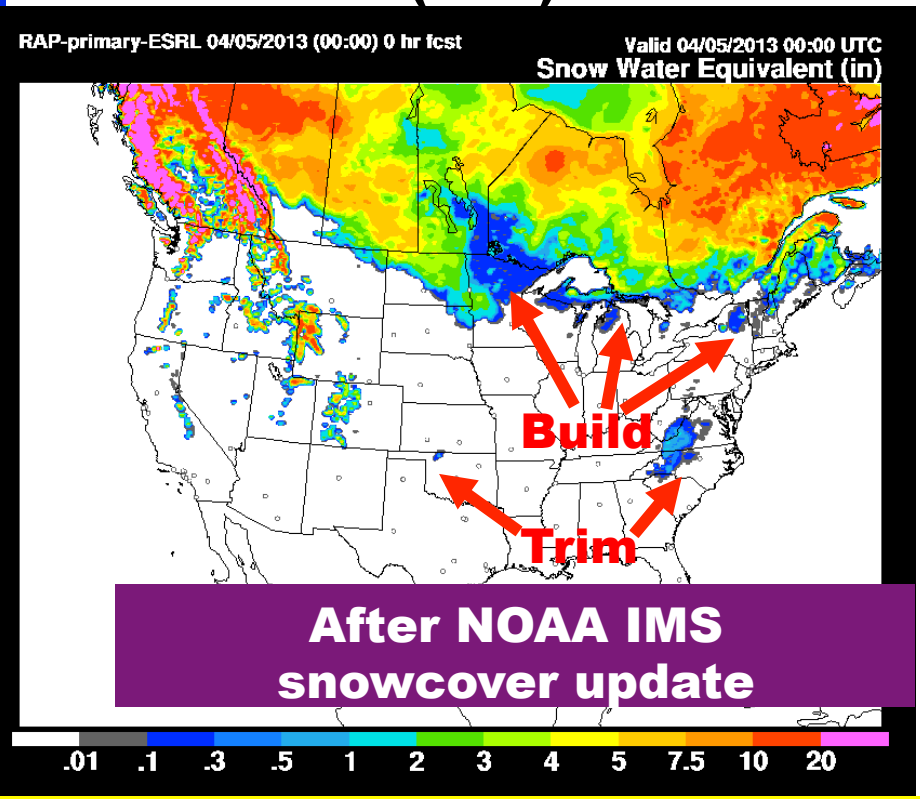
Surface Snow Water Equivalent
Valid 00z 05 April 2013

GSI Snow Cover Analysis (Run 00z Daily)



Using Interactive Multisensor Snow/Ice Mapping System (IMS)





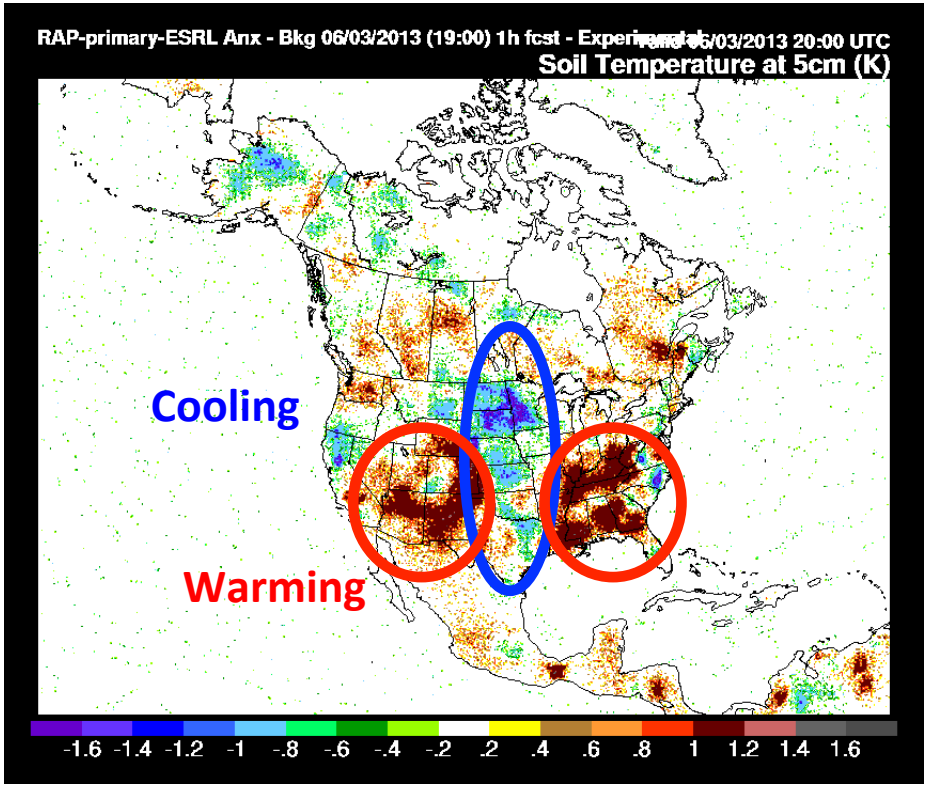
Improved snowcover

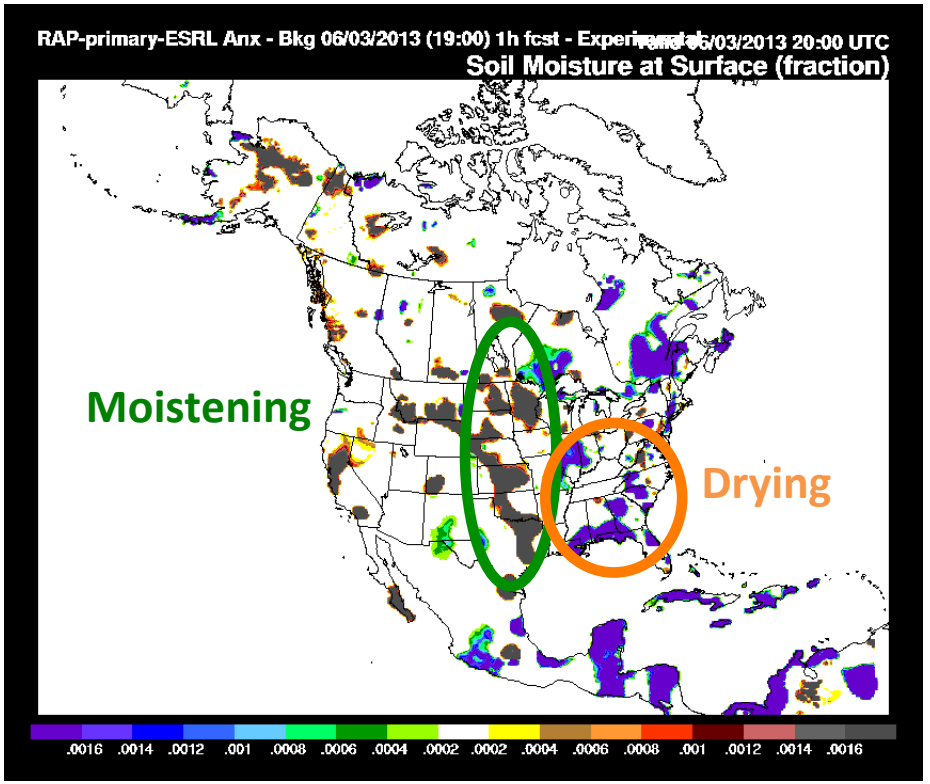
RAPv2 Soil Adjustment

Soil Temperature

Valid 20 UTC 03 June 2013

Soil Moisture





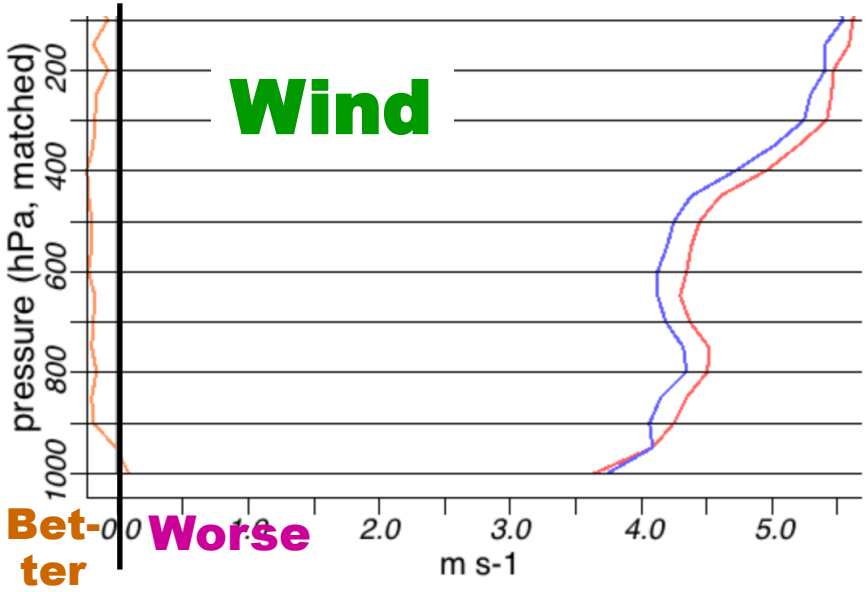
Based upon surface temperature and dewpoint analysis increments – new option within GSI. Critical also for HRRR

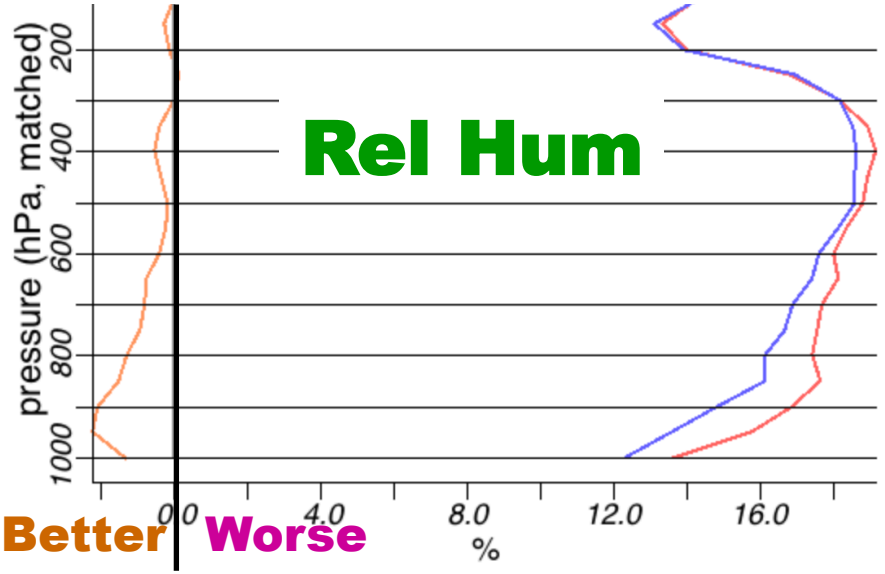
Improved soil, near-surface temperature, moisture

RAPv2 development and evaluation

- Real-time development and evaluation
  - Development and testing - 2012 through Winter 2013
  - Code freeze - April 2013
  - Real-time parallel evaluation vs. OPER RAPv1
- Retrospective evaluation
  - 30 day wintertime period (25 Jan – 25 Feb 2013)
  - 30 day summertime period (15 May – 15 June 2013)
  - Comparison against real-time OPER RAPv1
- Compare: upper-air, surface, precipitation, ceiling/vis

Upper-air: RAPv2 vs. oper RAPv1





RAPv2 **RAPv1**

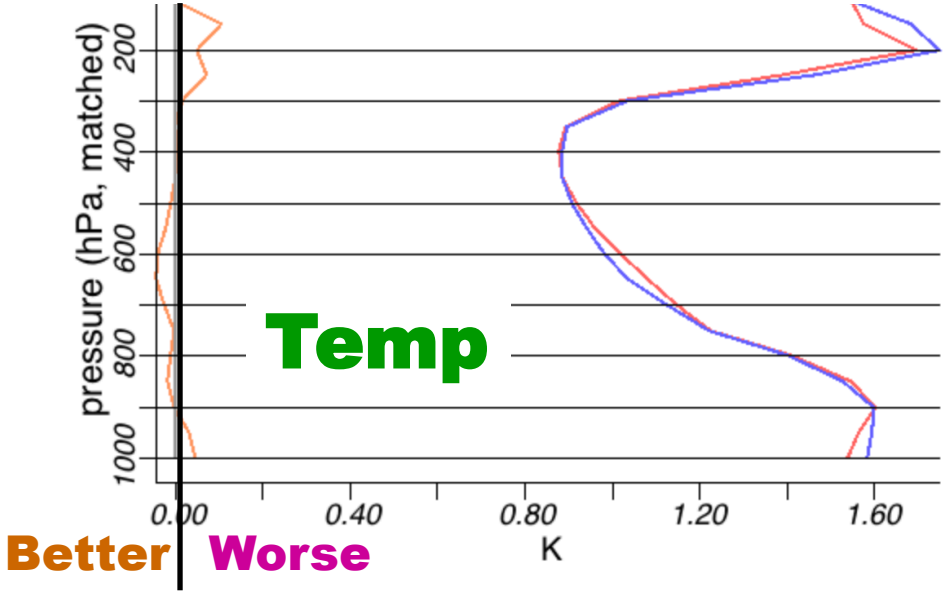
upper-air verification

+ 6 h forecast

RMS Error

25 Jan – 25 Feb 2013

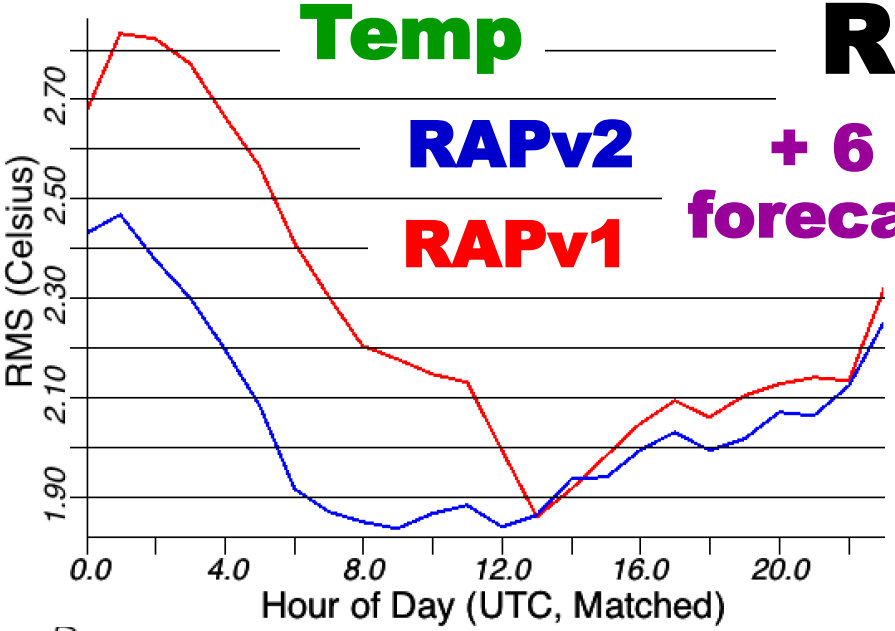
(Winter Retro)



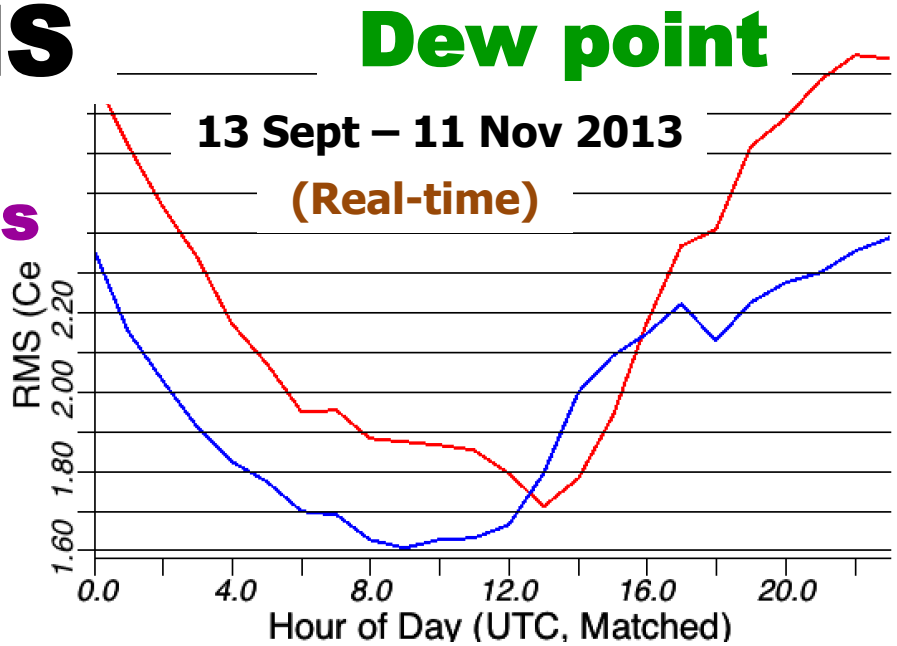
2m T and Td: RAPv2 vs. oper RAPv1

RMS

Temp

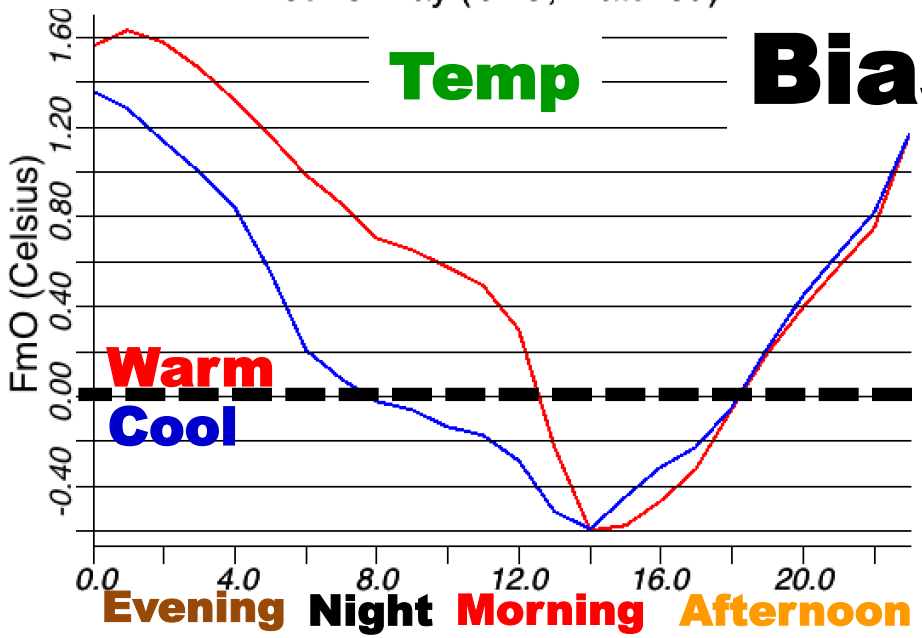


Dew point

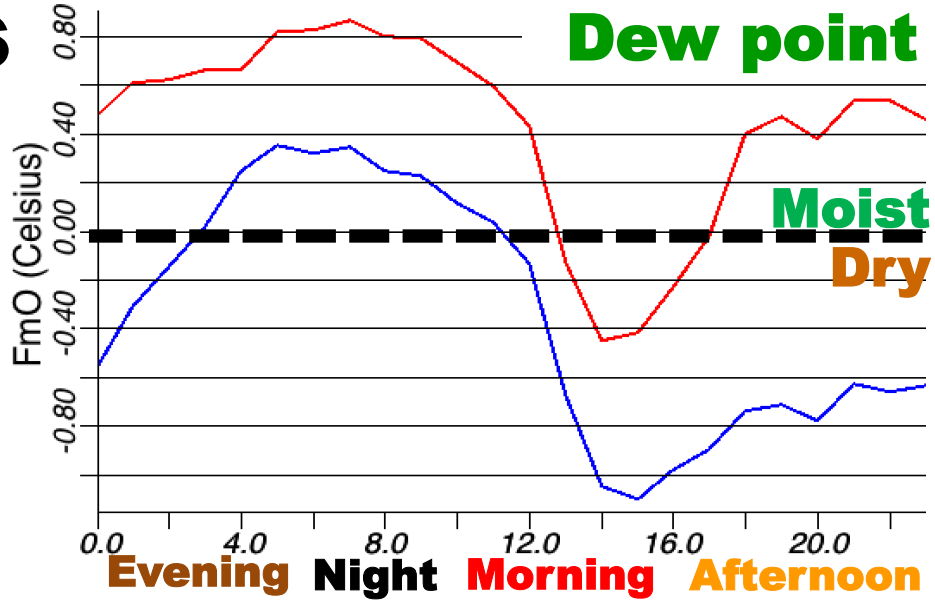


Bias

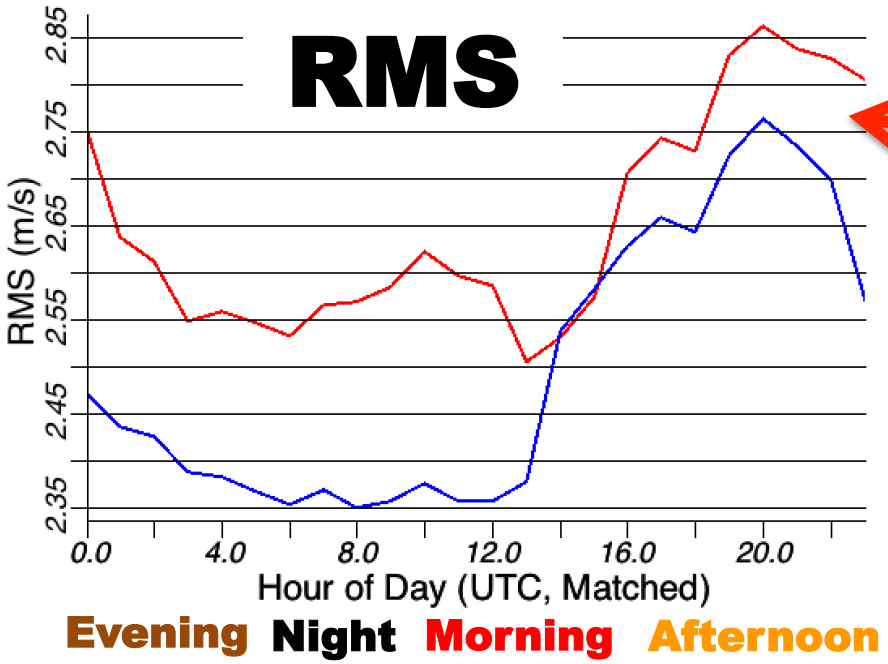
Temp



Dew point

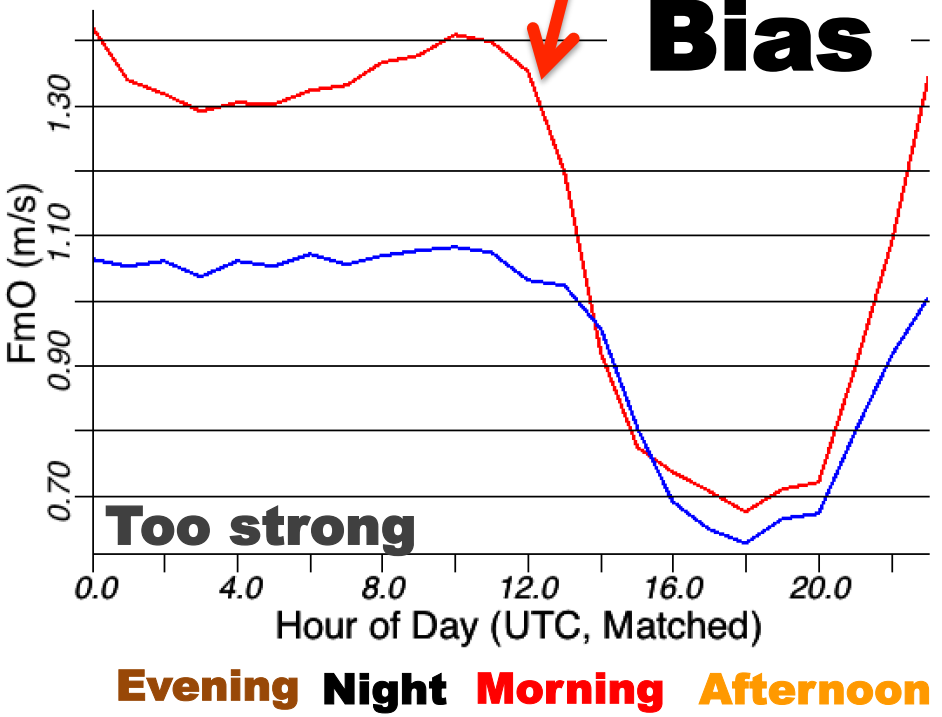


10m winds: RAPv2 vs. oper RAPv1



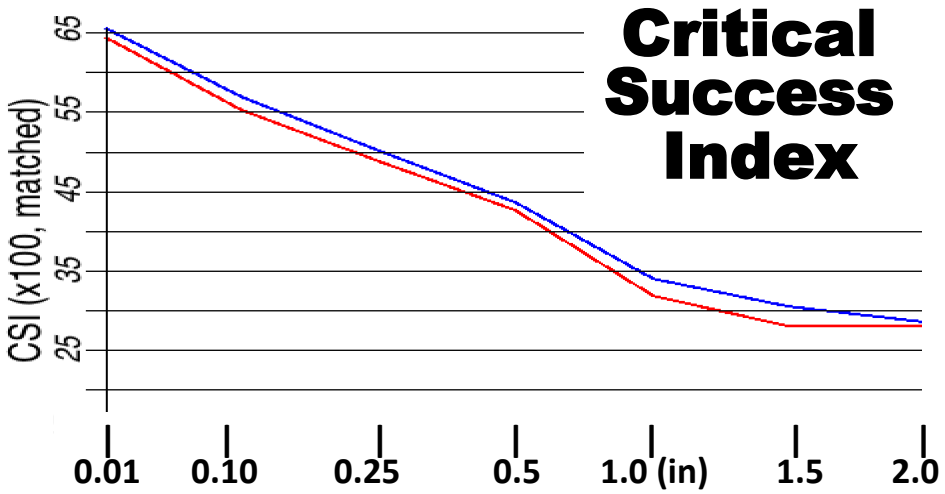
RAPv2 has lower **RMS** vector 10m wind errors than RAPv1 at all times of day.

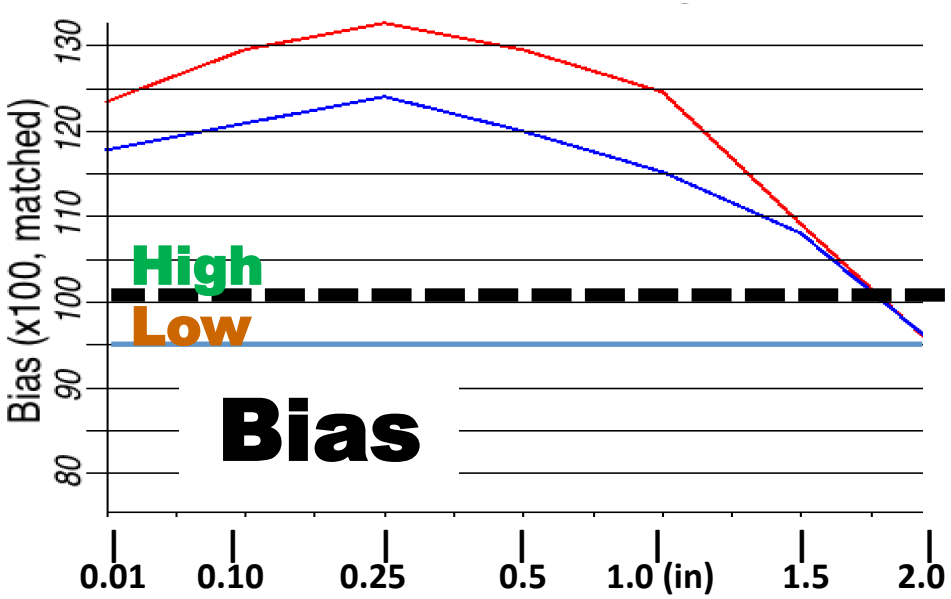
RAPv2 has lower (better) positive 10m wind speed **bias (F-O)** than RAPv1 at all times of day



6h 10m wind forecasts
Eastern/Central US
12 Sept – 11 Nov 2013
RAPv1 vs. RAPv2

12 h precip: RAPv2 vs. oper RAPv1





RAPv2
vs.
RAPv1
24-h precip. verification

2 x 12h fcst
13 Oct – 11 Nov 2013

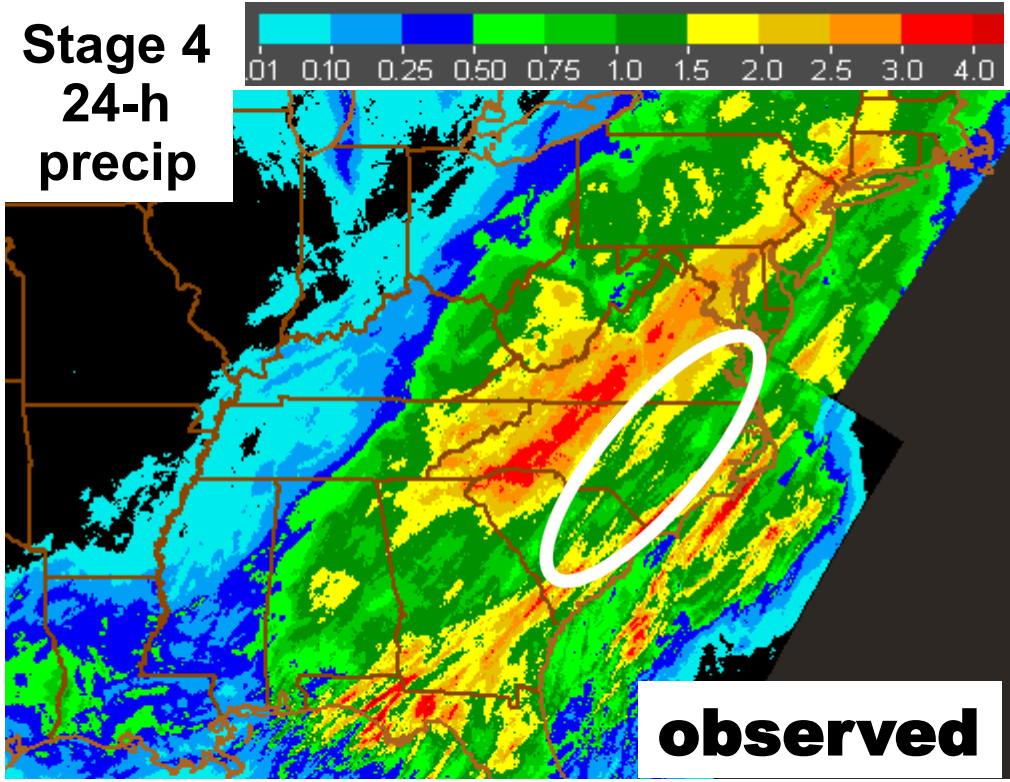
Interpolated to 40-km grid

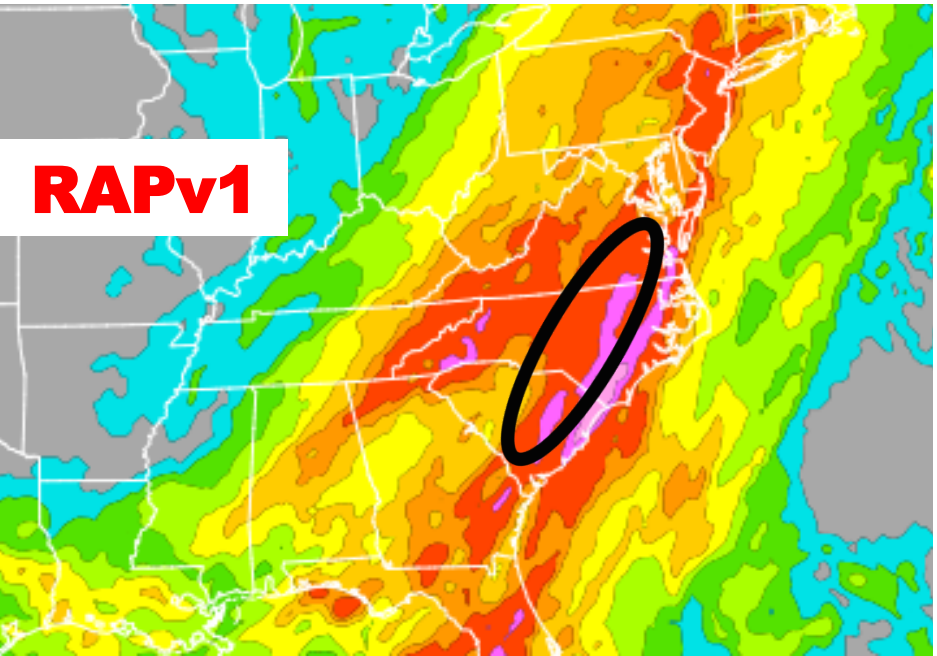
Precipitation Forecasts

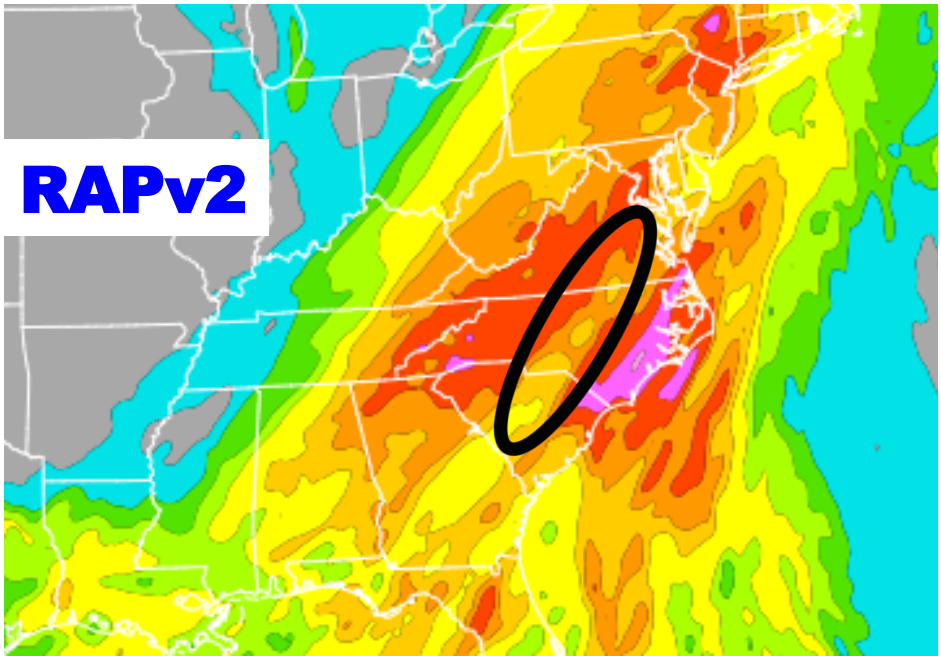
RAPv2
vs.
RAPv1

2 x 12h fcst
ending 12z
27 Nov 2013

Stage 4
24-h
precip







Precipitation Forecasts

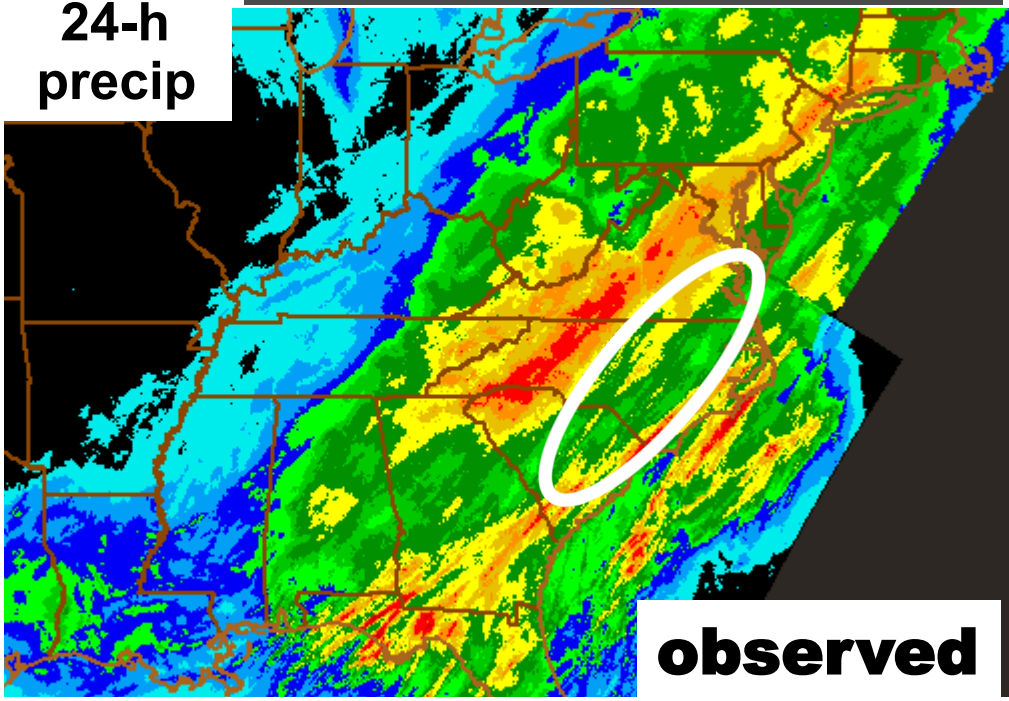
RAPv2
vs.
RAPv1

2 x 12h fcst
ending 12z
27 Nov 2013

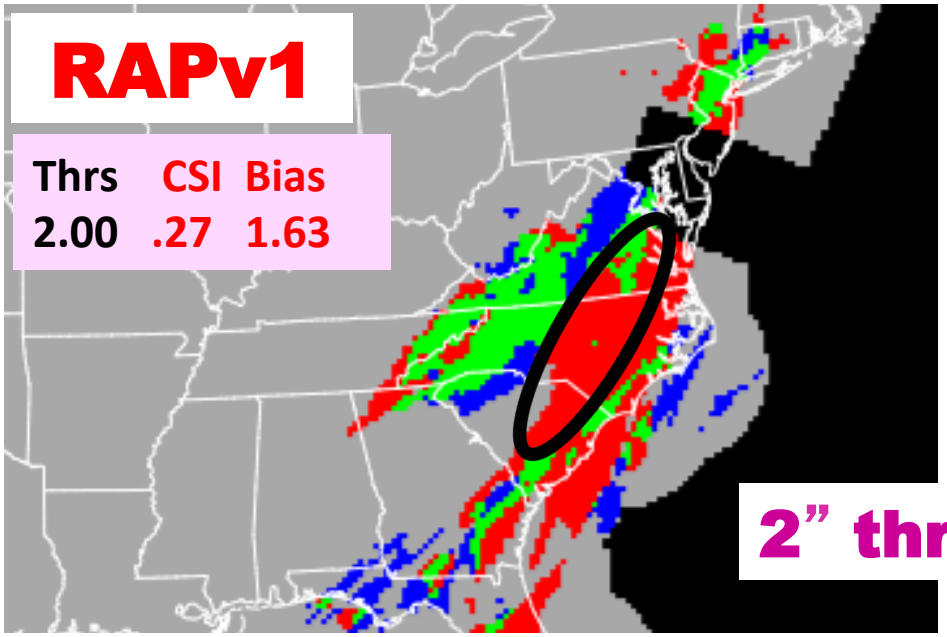
Miss FA Hit

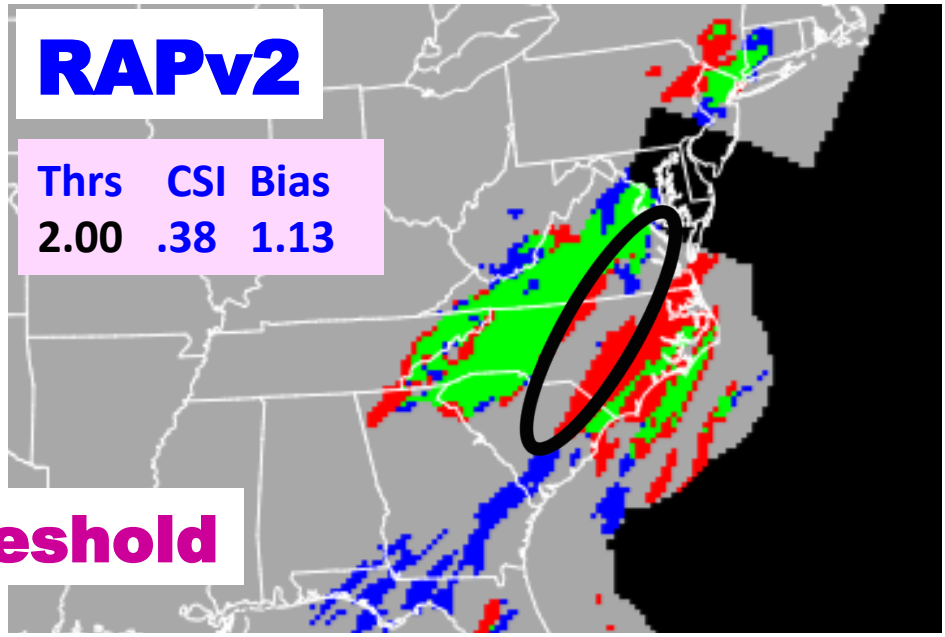
Stage 4
24-h
precip

.01 0.10 0.25 0.50 0.75 1.0 1.5 2.0 2.5 3.0 4.0



observed



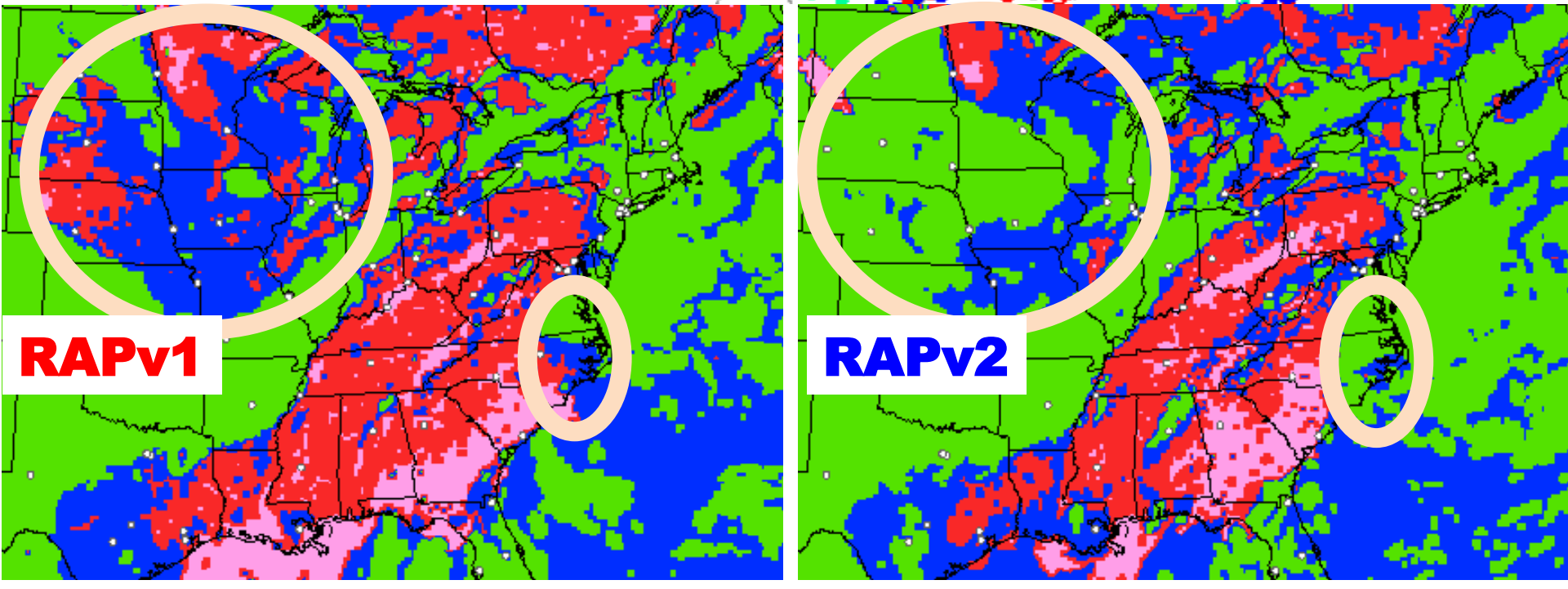


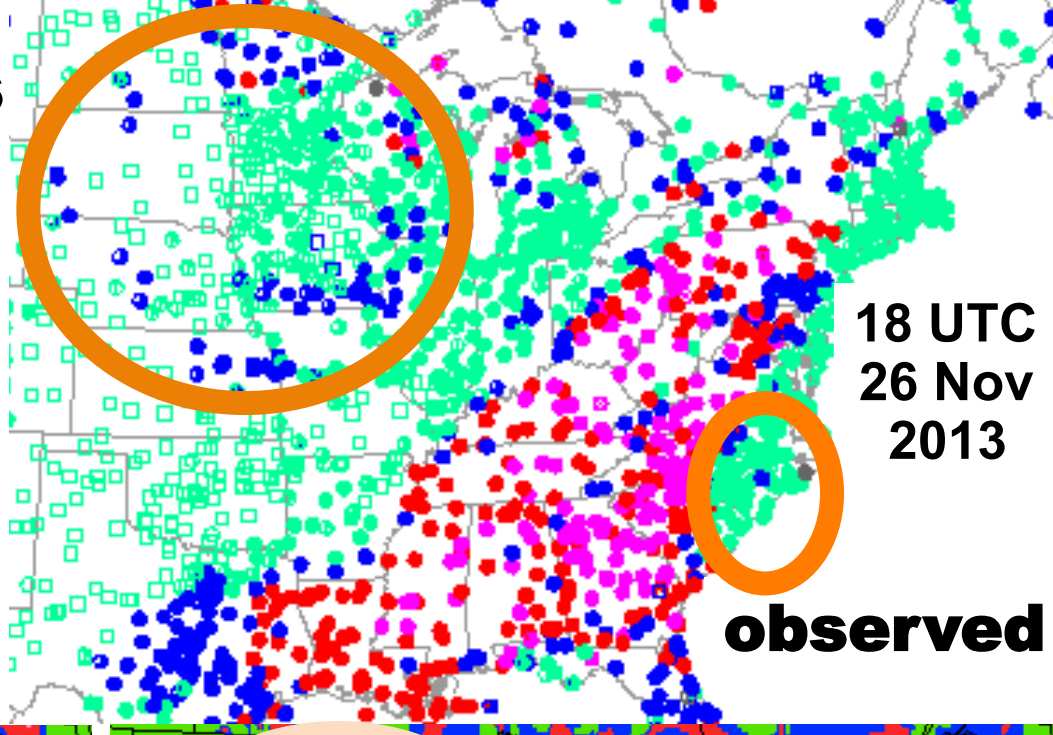
2” threshold

Aviation Flight Rules (ceiling and visibility)

RAPv2
vs.
RAPv1

06 UTC
+ 12h fcst





Summary: RAPv2 vs. RAPv1

Winds -- Consistent RAPv2 improvement, for both upper-air and surface, for all seasons

Moisture -- Improved RAPv2 RH forecasts aloft. Reduced RMS 2m dewpoint error, more so at night

Temperature -- Similar RAPv2 skill for upper-air. **Improved skill for surface in warm season**

Precipitation and clouds – Improvement for precipitation, slight improvement for ceiling

Rapid Refresh and HRRR
NOAA hourly updated models

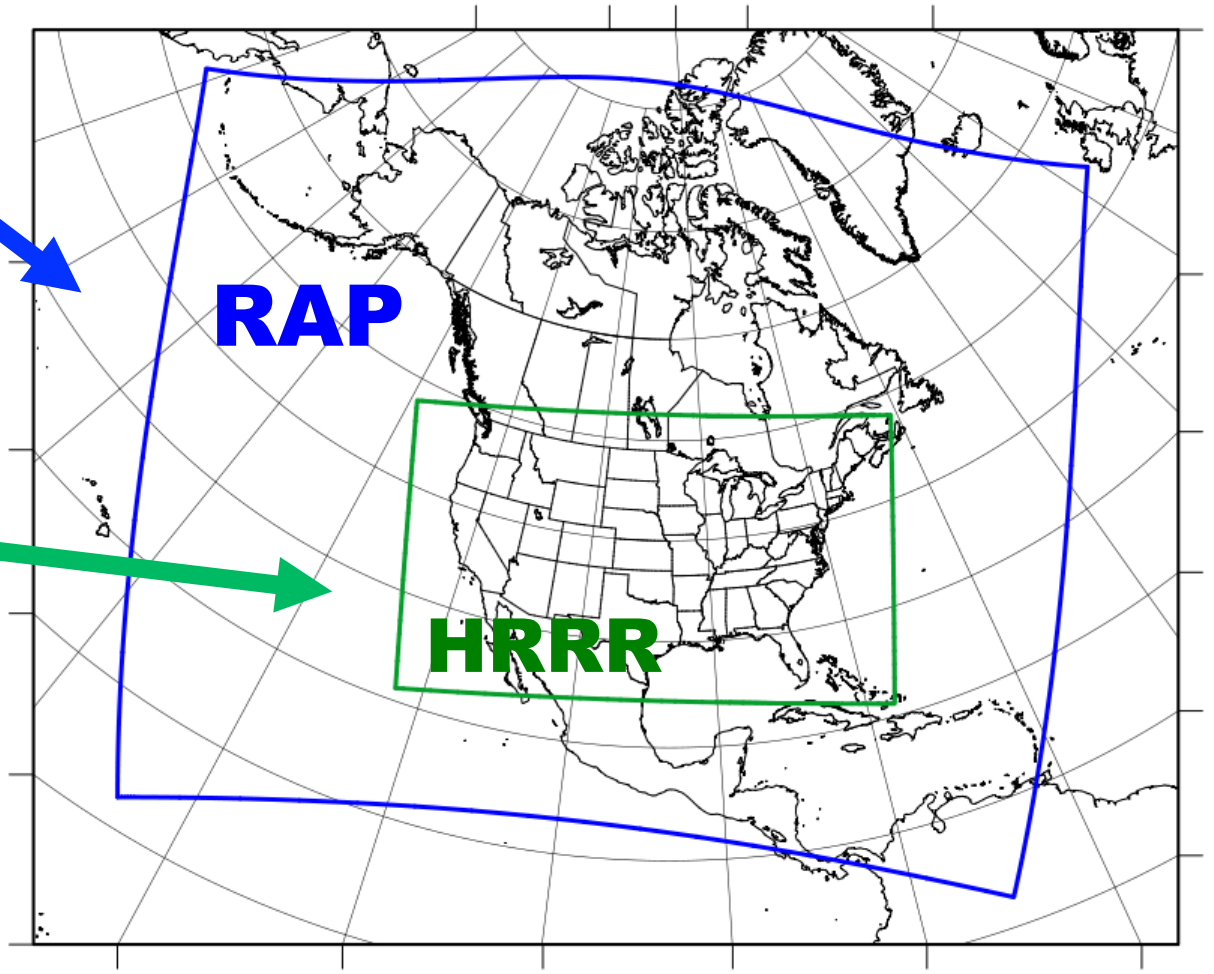
13km Rapid Refresh (RAP) (mesoscale)

Version 2 – scheduled NCEP implementation Q2 (currently 28 Jan)

3km HRRR (storm-scale)

High-Resolution Rapid Refresh

Scheduled NCEP Implementation Q3 2014



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, Iberdrola, 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
National Weather Service (NWS): 2-D and 3-D grids
    Operational weather forecasting
Weather Prediction Center (WPC): 2-D grids
    Quantitative precipitation forecasting
United States Air Force (USAF): 2-D grids
    Operational weather forecasting
Air Resources Laboratory (ARL): Tiled 3-D HRRR grids
    Dispersion forecasts, Local wind forecasts in complex terrain

Aviation

Severe Weather

Renewable Energy

Forecasting

Verification of RAPv2 vs HRRR

Recent Fall Season (12 Sept 2013 – 18 Nov 2013) HRRR vs RAPv2												
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	HRRR	HRRR			HRRR	HRRR	HRRR	RAP	RAP	Equal	Equal	Equal
6-hr	HRRR	HRRR	HRRR	Equal	HRRR	HRRR	HRRR	HRRR	HRRR	HRRR	Equal	Equal
12-hr	HRRR	HRRR	HRRR	HRRR	HRRR	HRRR	HRRR	HRRR	HRRR	HRRR	HRRR	HRRR

Warm Season (01 May 2013 – 25 June 2013) HRRR vs RAPv2												
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	HRRR	HRRR			HRRR	HRRR	RAP	RAP	RAP	Equal	Equal	RAP
6-hr	HRRR	HRRR	Equal	HRRR	HRRR	HRRR	Equal	Equal	RAP	Equal	Equal	RAP
12-hr	Equal	Equal	HRRR	HRRR	HRRR	HRRR	HRRR	HRRR	RAP	HRRR	HRRR	RAP

RAP and HRRR 2012 Configuration

Model	Run at:	Domain	Grid Points	Grid Spacing	Vertical Levels	Pressure Top	Boundary Conditions	Initialized
RAP	GSD, NCO	North America	758 x 567	13 km	50	10 mb	GFS	Hourly (cycled)
HRRR	GSD	CONUS	1799 x 1059	3 km	50	20 mb	RAP	Hourly - RAP (no-cycle)

Model	Version	Assimilation	Radar DA	Radiation LW/SW	Microphysics	Cumulus Param	PBL	LSM
RAP	WRF-ARW v3.3.1+	GSI 3D-VAR	13-km DFI	RRTM/ Goddard	Thompson v3.3.1	G3 + Shallow	MYJ	RUC 6-lev
HRRR	WRF-ARW v3.3.1+	None: RAP I.C.	None	RRTM/ Dudhia	Thompson v3.3.1	None	MYJ	RUC 6-lev

Model	Horiz/Vert Advection	Scalar Advection	Upper-Level Damping	6th Order Diffusion	SW Radiation Update	Land Use	MP Tend Limit	Time-Step
RAP	$5^{th}/5^{th}$	Positive-Definite	w-Rayleigh 0.2	Yes 0.12	10 min	MODIS Fractional	0.01 K/s	60 s
HRRR	$5^{th}/5^{th}$	Positive-Definite	w-Rayleigh 0.2	No	5 min	MODIS Fractional	0.07 K/s	20-23 s

RAP and HRRR 2013 Configuration

Model	Run at:	Domain	Grid Points	Grid Spacing	Vertical Levels	Pressure Top	Boundary Conditions	Initialized
RAP	GSD, NCO	North America	758 x 567	13 km	50	10 mb	GFS	Hourly (cycled)
HRRR	GSD	CONUS	1799 x 1059	3 km	50	20 mb	RAP	Hourly - RAP (no-cycle)

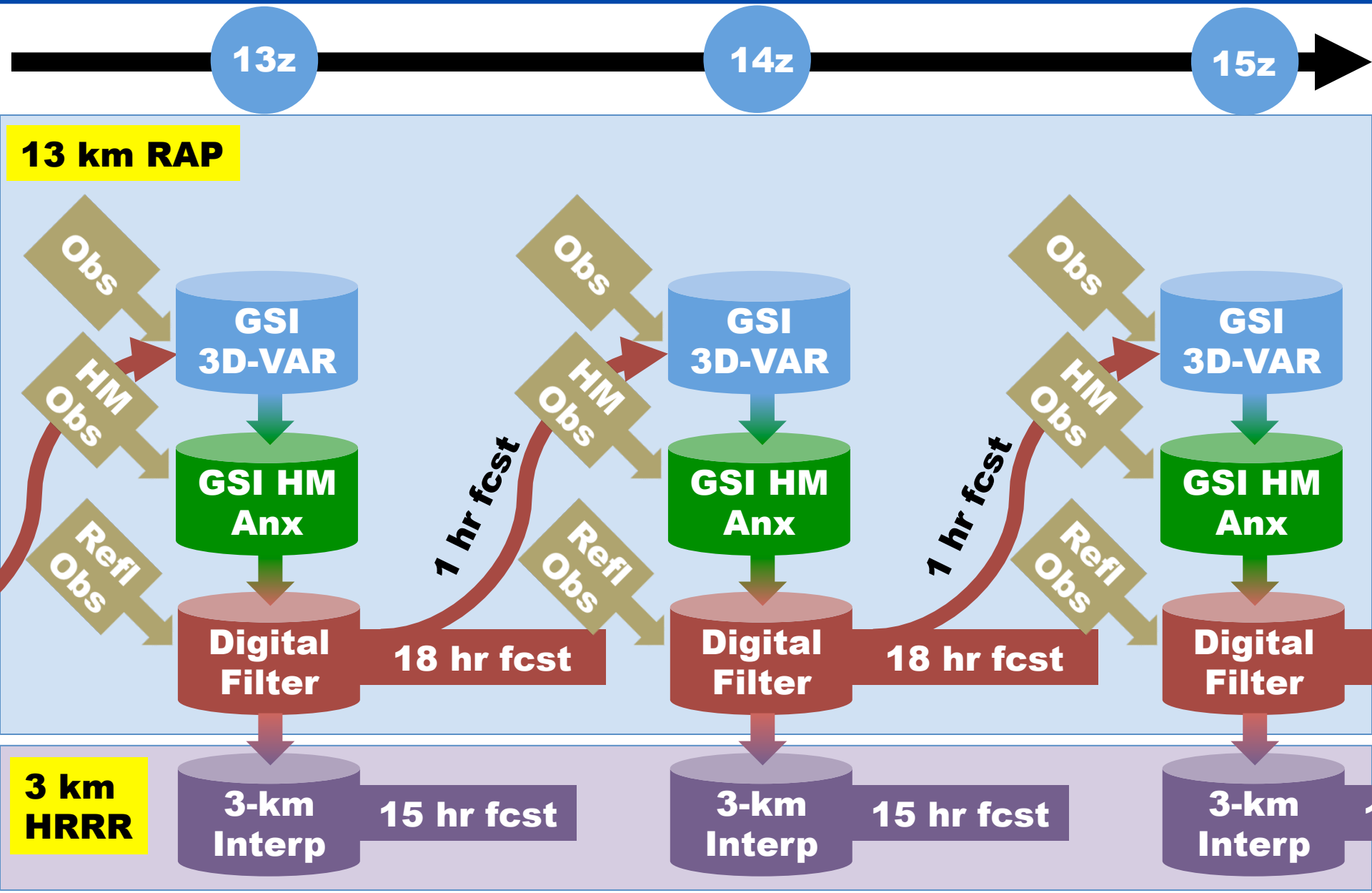
Model	Version	Assimilation	Radar DA	Radiation LW/SW	Microphysics	Cumulus Param	PBL	LSM
RAP	WRF-ARW v3.4.1+	GSI Hybrid 3D-VAR/Ensemble	13-km DFI	RRTM/ Goddard	Thompson v3.4.1	G3 + Shallow	MYNN	RUC 9-lev
HRRR	WRF-ARW v3.4.1+	GSI 3D-VAR	3-km 15-min LH	RRTM/ Goddard	Thompson v3.4.1	None	MYNN	RUC 9-lev

Model	Horiz/Vert Advection	Scalar Advection	Upper-Level Damping	6th Order Diffusion	SW Radiation Update	Land Use	MP Tend Limit	Time-Step
RAP	$5^{th}/5^{th}$	Positive-Definite	w-Rayleigh 0.2	Yes 0.12	10 min	MODIS Fractional	0.01 K/s	60 s
HRRR	$5^{th}/5^{th}$	Positive-Definite	w-Rayleigh 0.2	No	5 min	MODIS Fractional	0.07 K/s	20-23 s

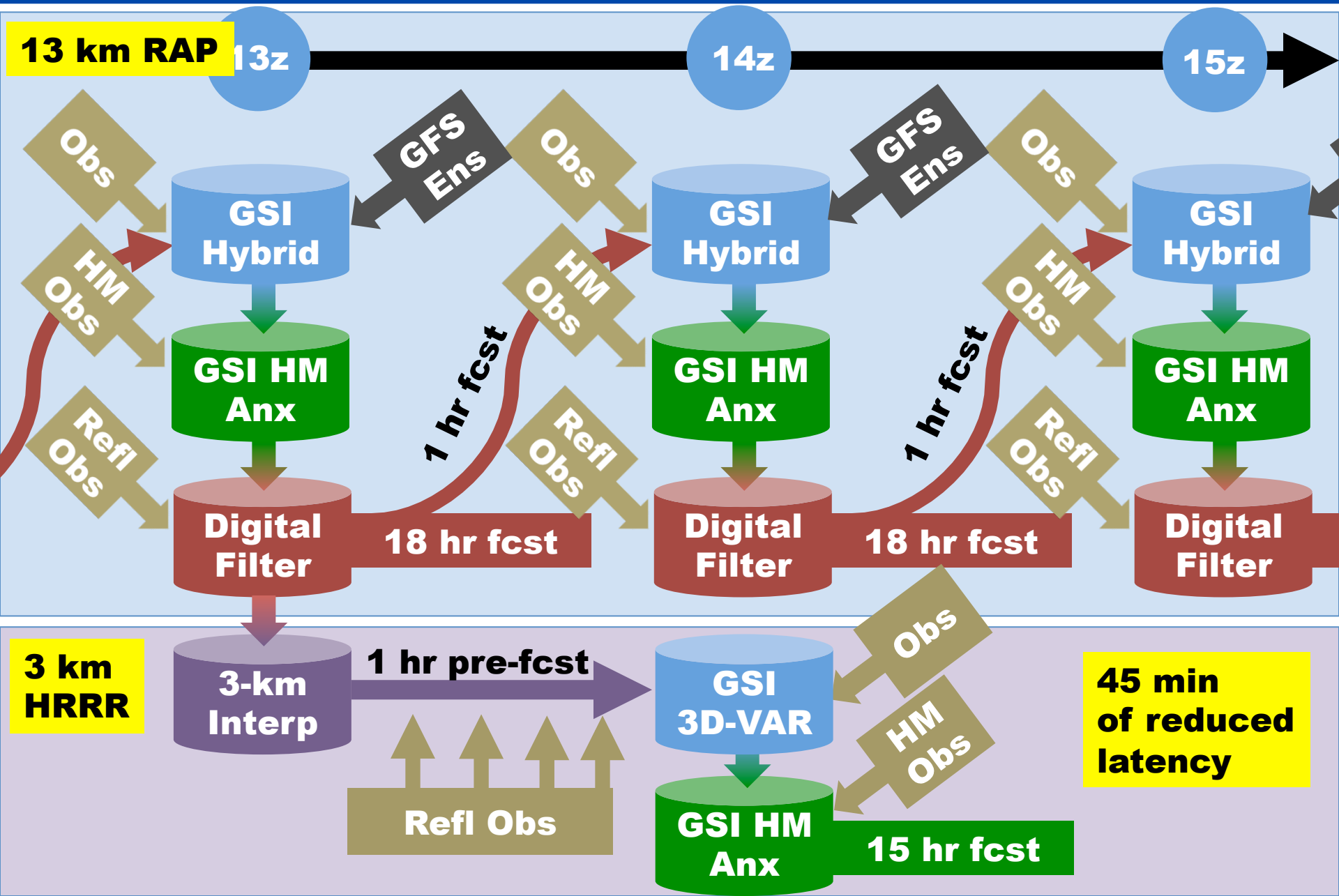
ESRL RAP/HRRR Changes in Apr 2013

	Model	Data Assimilation
RAP-ESRL (13 km)	WRFv3.4.1+ incl. physics changes (incl. snow-radiation fix) **Physics changes:** MYNN PBL scheme –Olson version 9-layer RUC LSM (from 6-layer) Modified roughness length Thompson microphysics update Updated reflectivity diagnostic	Merge with GSI trunk GFS ensemble background error cov Stronger/symmetric soil adjustment, adapted for 9-layer LSM Radar hydrometeor building/clearing Snow cover building (added) /modified trimming (no low-level temp limit)
HRRR (3 km)	WRFv3.4.1+ incl. physics changes (incl. snow-radiation fix) **Physics changes:** MYNN PBL scheme -Olson version 9-layer RUC LSM (from 6-layer) Modified roughness length Thompson microphysics update Updated reflectivity diagnostic	3-km/15 min radar reflectivity assim 3-km GSI full-data assim for last pass, including 3-km hydrometeor assim **Changes with high/medium importance for *overall* forecast skill**

2012 HRRR Initialization from RAP



2013 HRRR Initialization from RAPv2



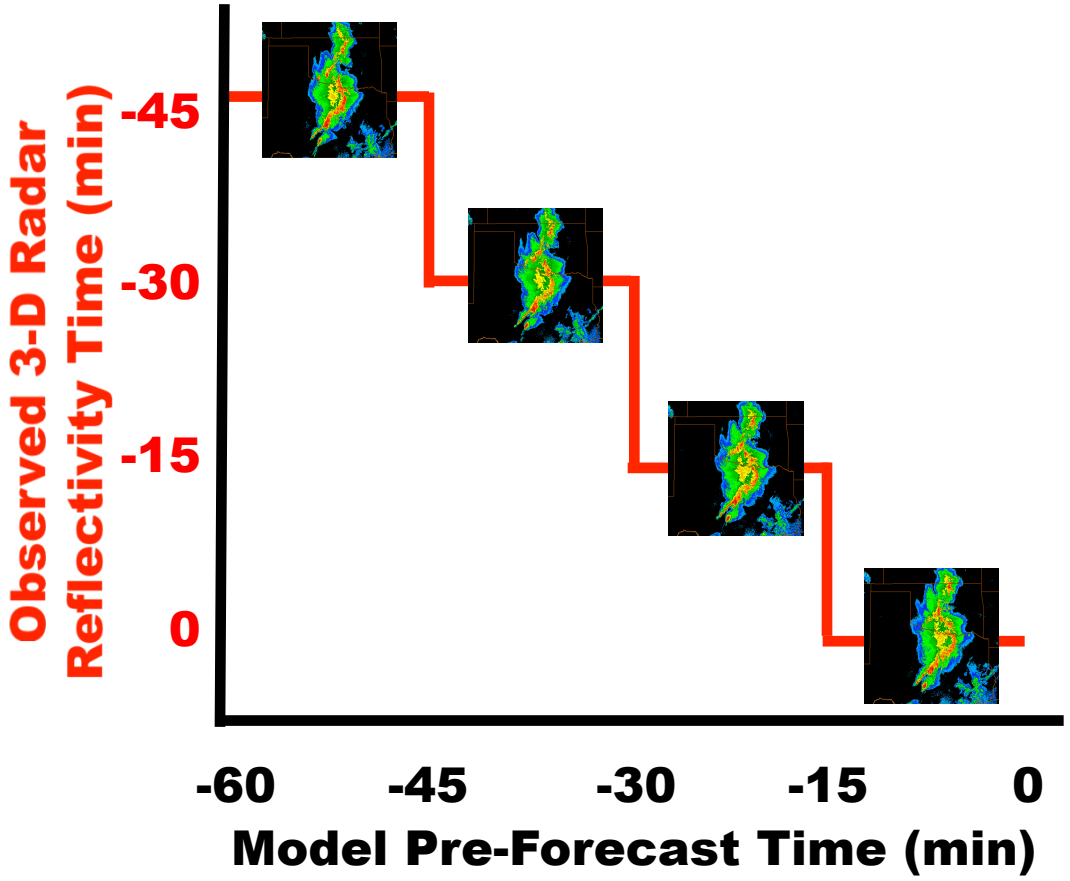
HRRR 2013 Pre-Forecast Hour

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 ≥ 35 dBZ over depth ≥ 200 mb (avoids bright banding)**
- **Zero heating rate where obs reflectivity ≤ 0 dBZ**
- **Model microphysics heating rate preserved elsewhere**

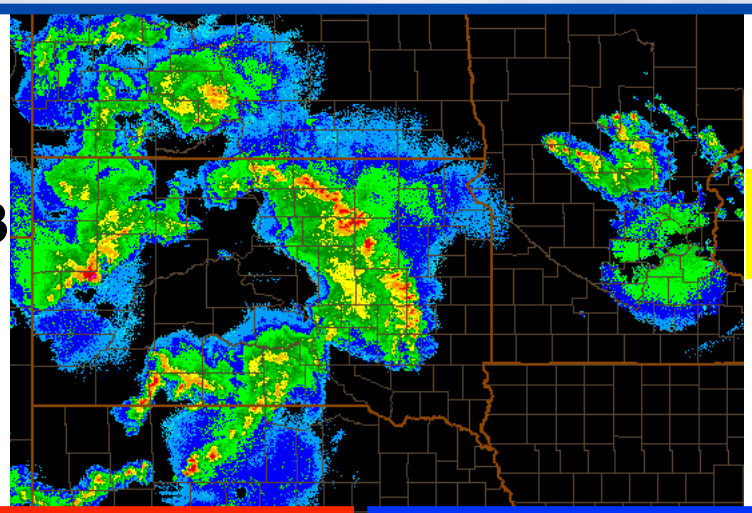
$$LH(i,j,k) = \left(\frac{1000}{p}\right)^{R_d/c_p} \frac{(L_v + L_f)(f[Z_e])}{t * c_p}$$

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 (300s i.e. 5 min)

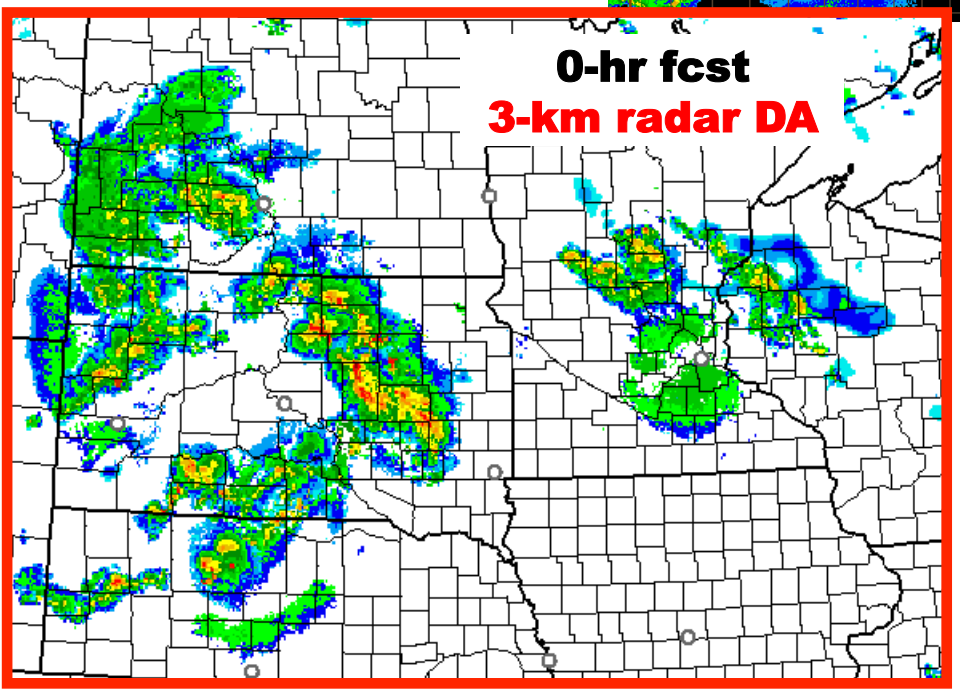


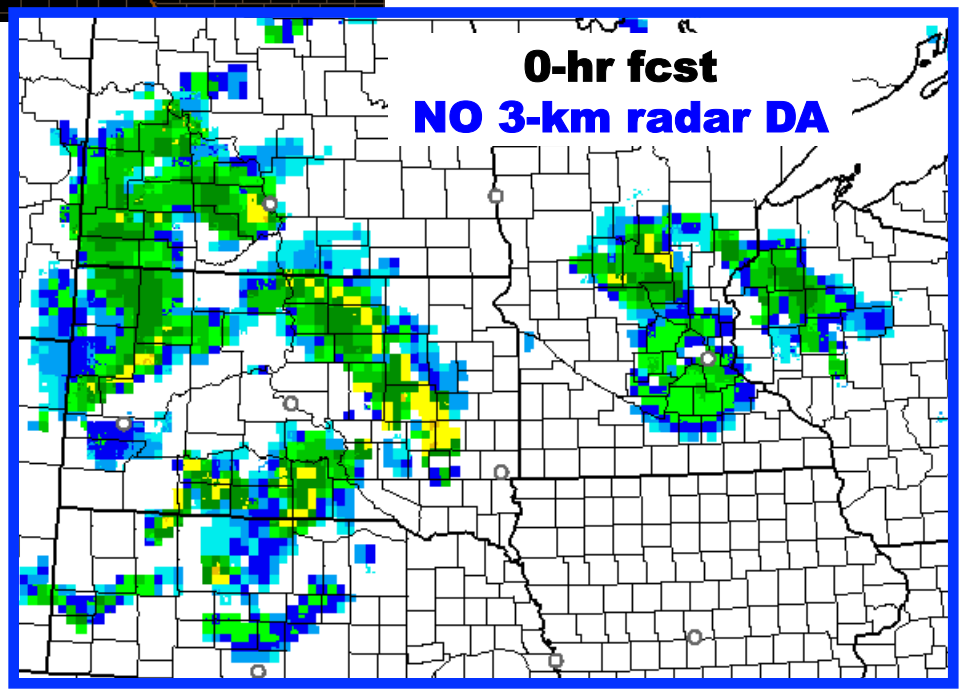
Improved 0-2 hr Convective Fcsts

Radar Obs
05:00z 18 May 2013



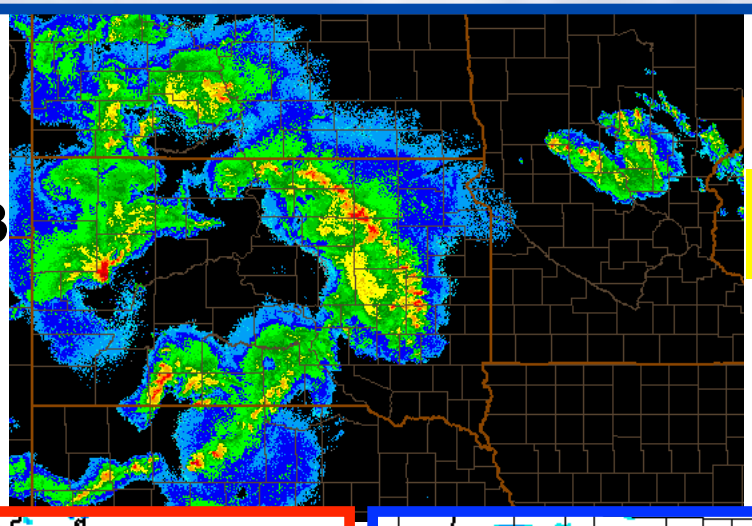
05z + 0 min



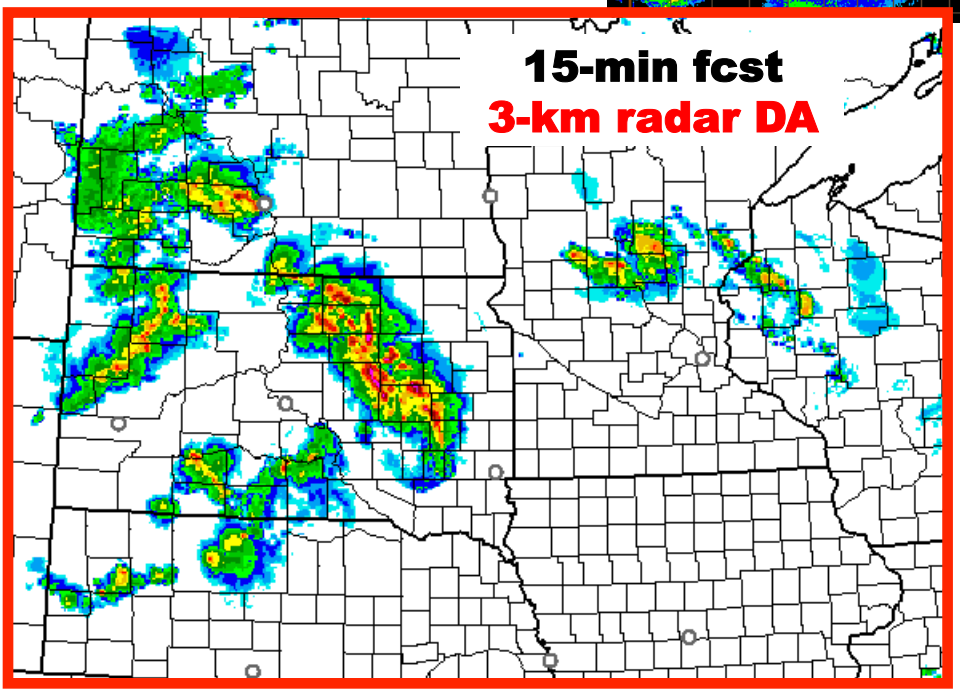


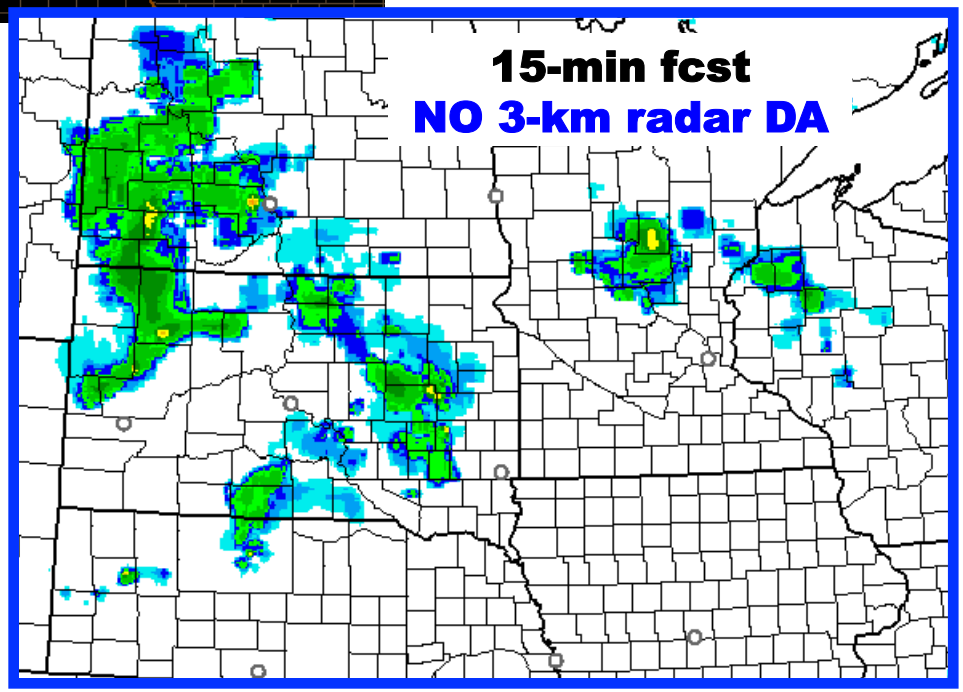
Improved 0-2 hr Convective Fcsts

Radar Obs
05:15z 18 May 2013



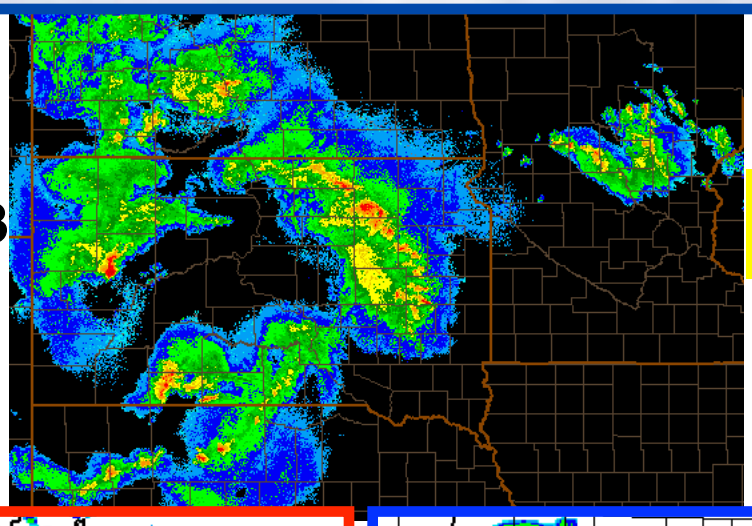
05z + 15 min



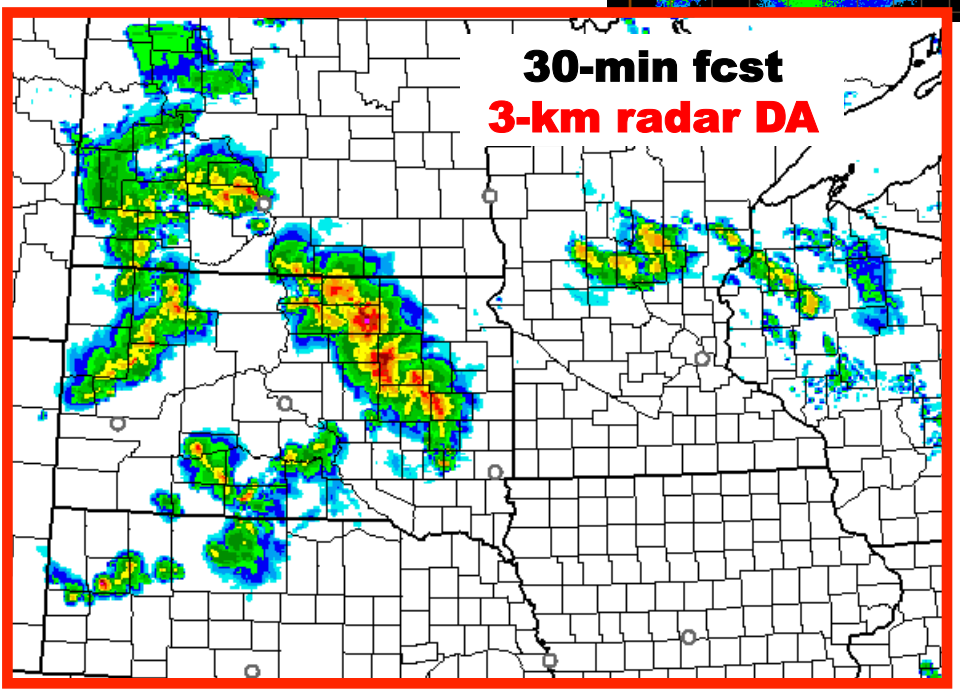


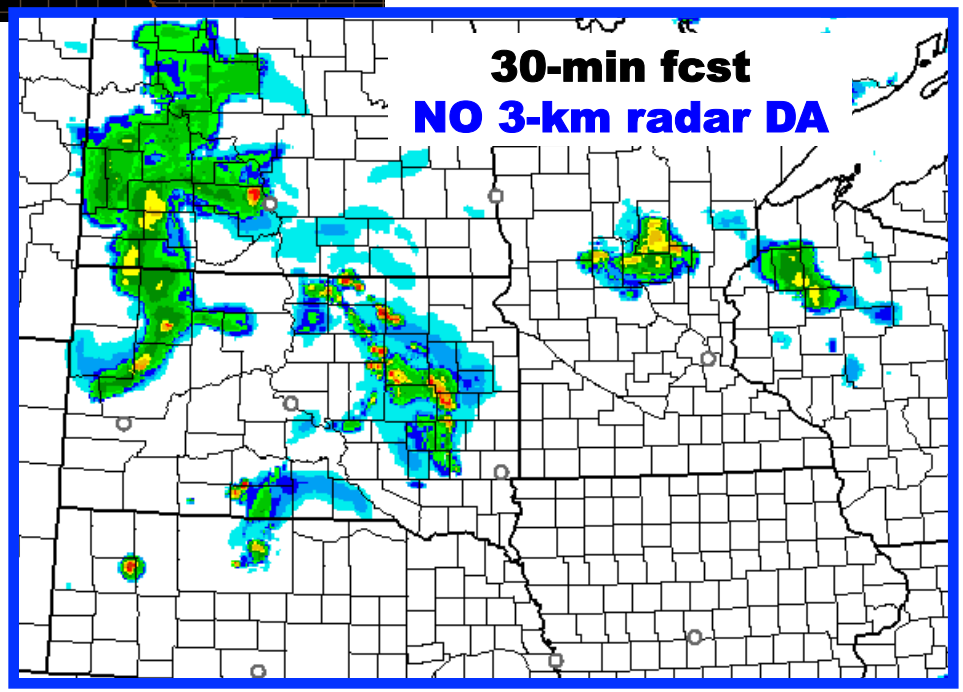
Improved 0-2 hr Convective Fcsts

Radar Obs
05:30z 18 May 2013



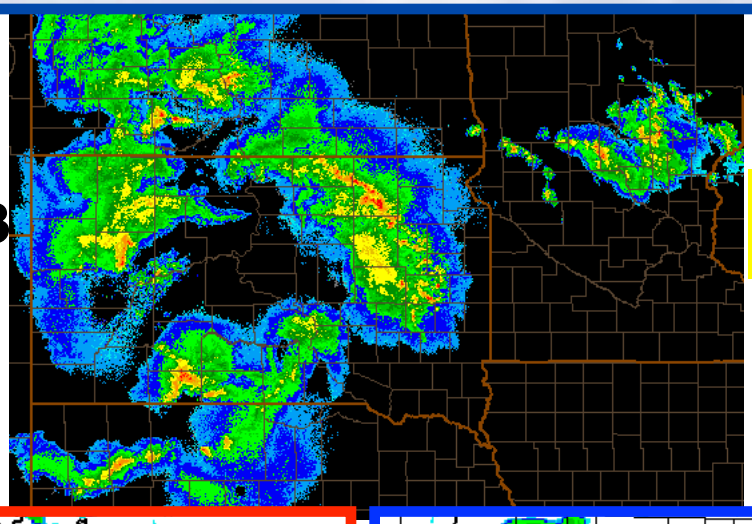
05z + 30 min



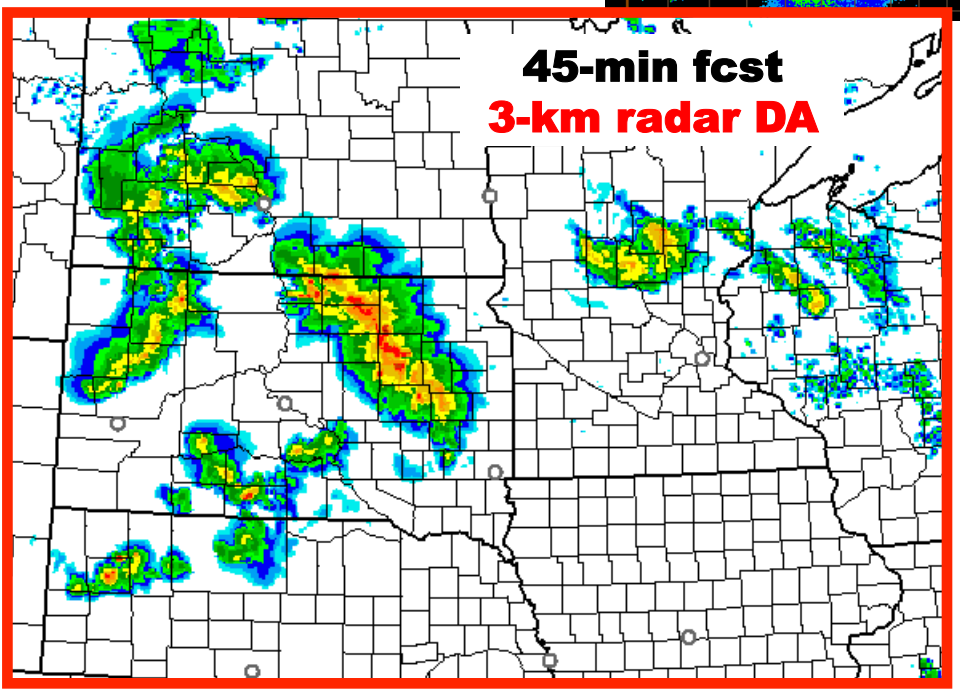


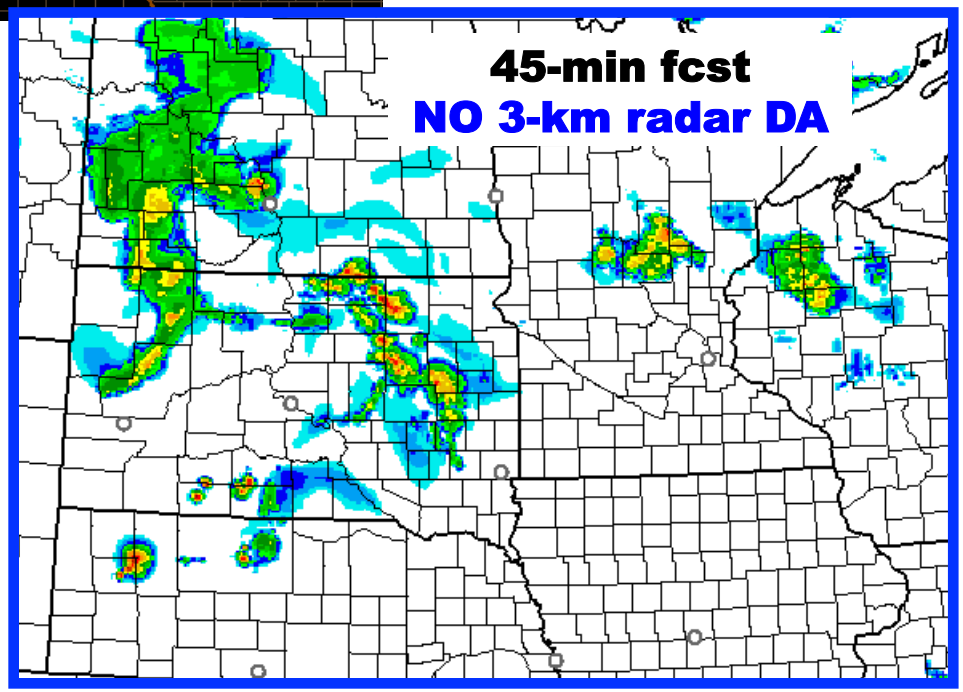
Improved 0-2 hr Convective Fcsts

Radar Obs
05:45z 18 May 2013



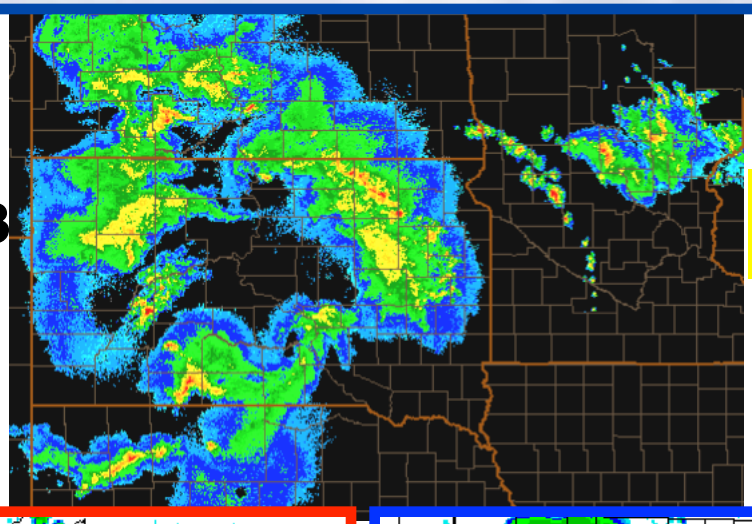
05z + 45 min



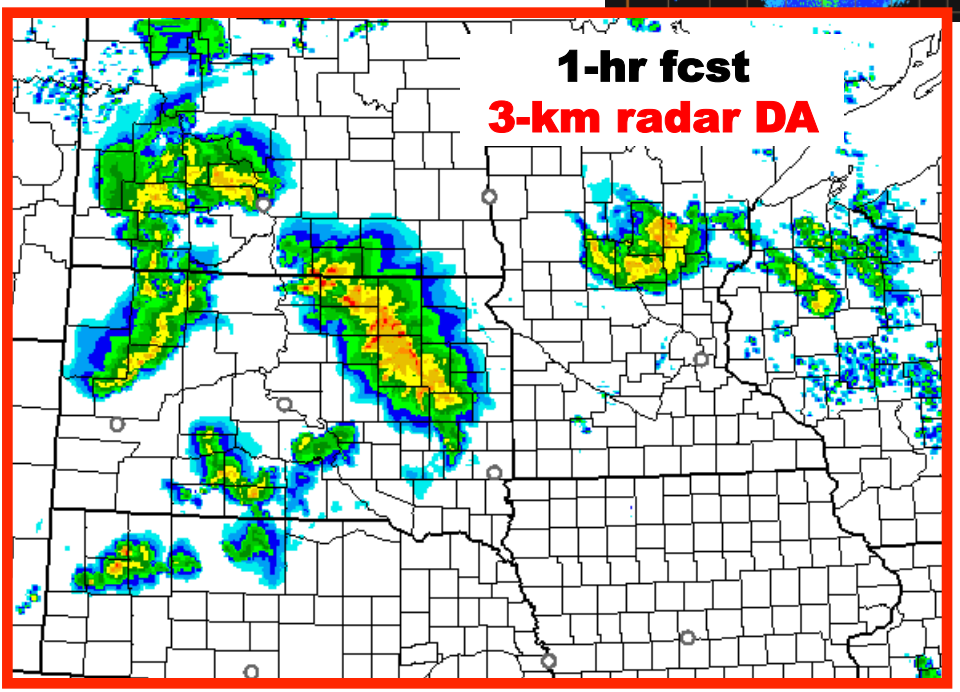


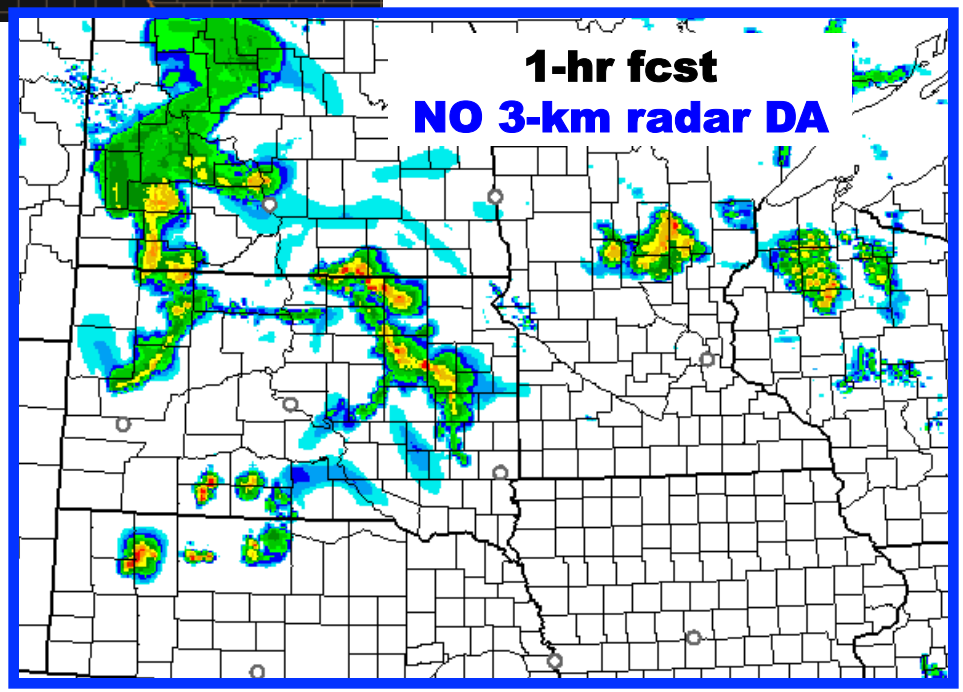
Improved 0-2 hr Convective Fcsts

Radar Obs
06:00z 18 May 2013



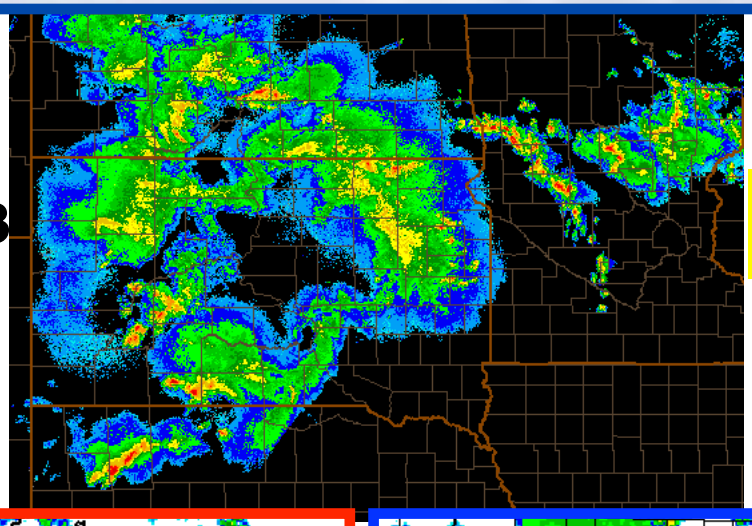
05z + 1 hour



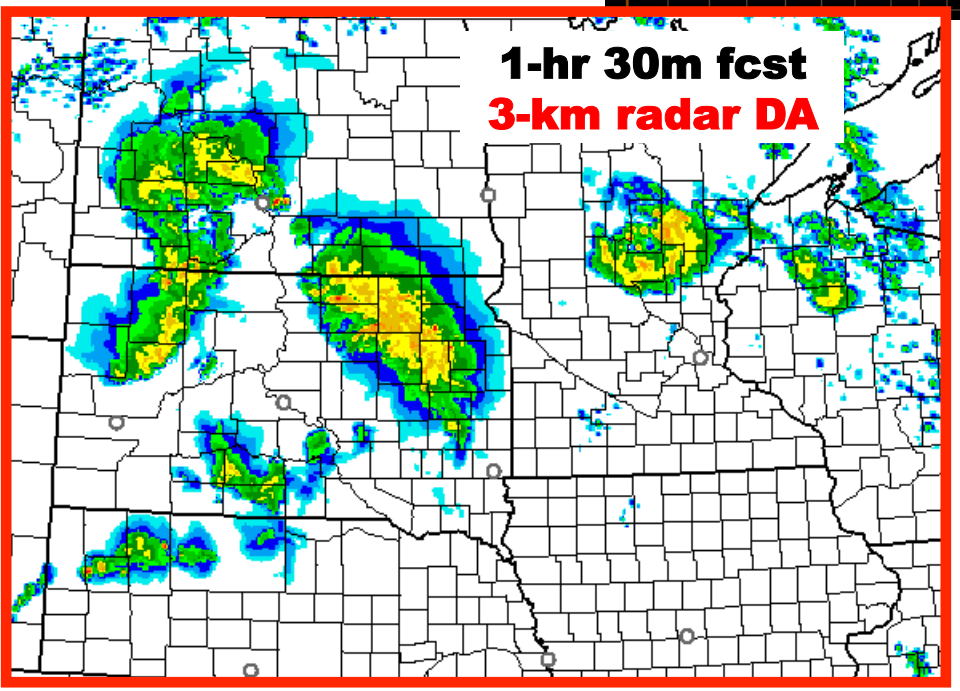


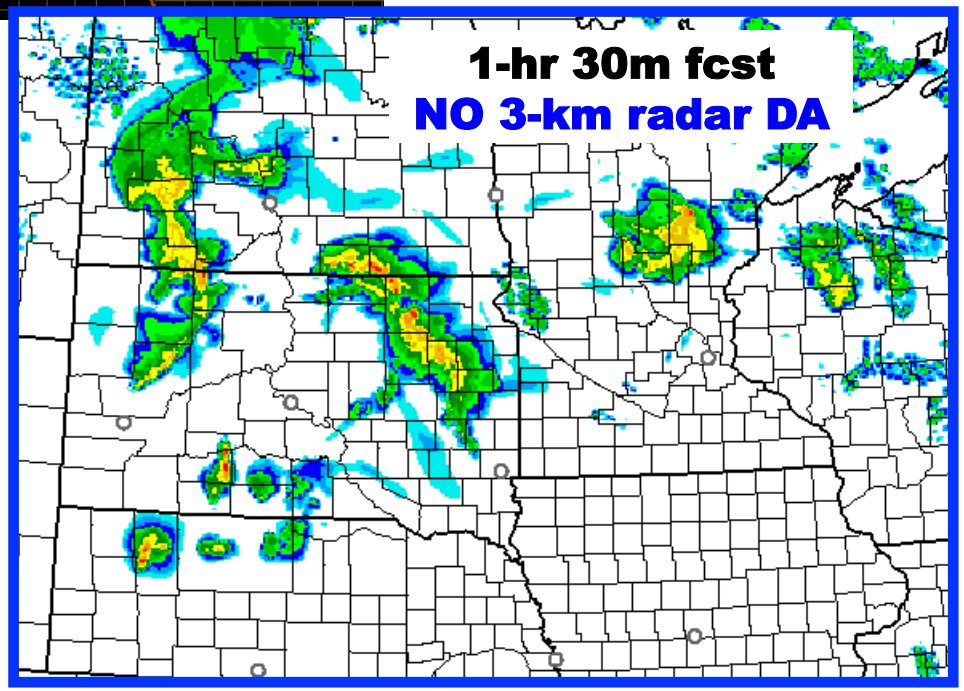
Improved 0-2 hr Convective Fcsts

Radar Obs
06:30z 18 May 2013



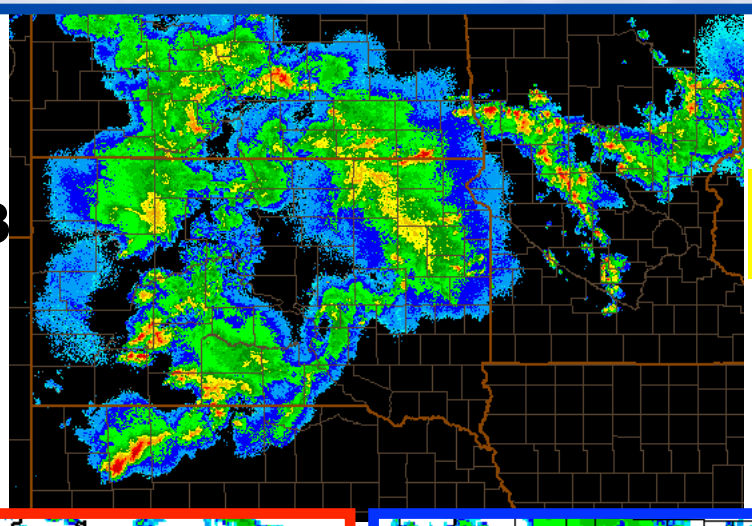
05z + 1:30 mi



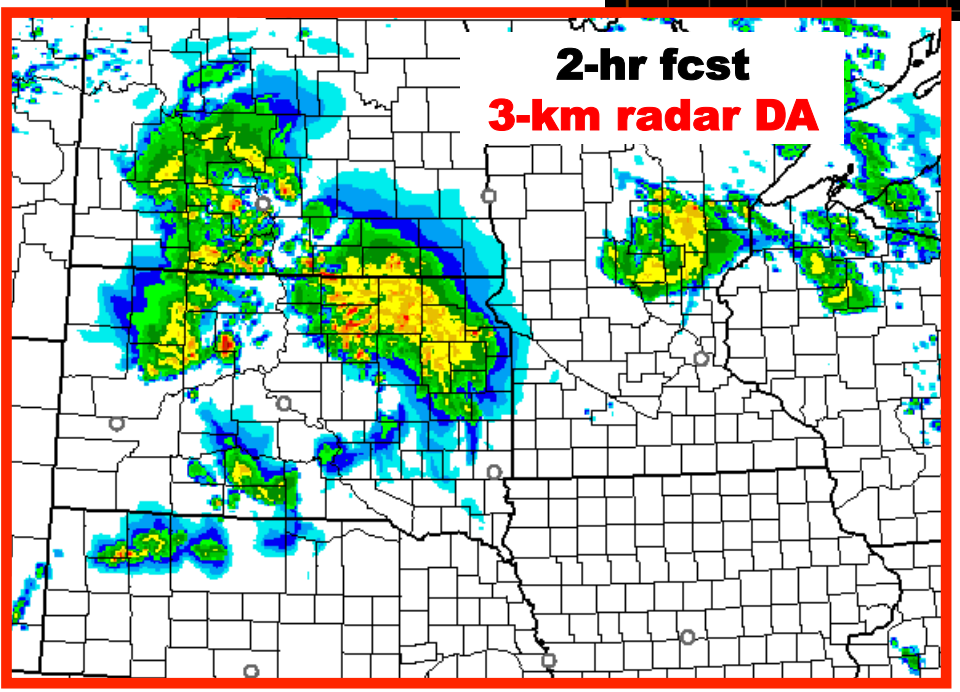


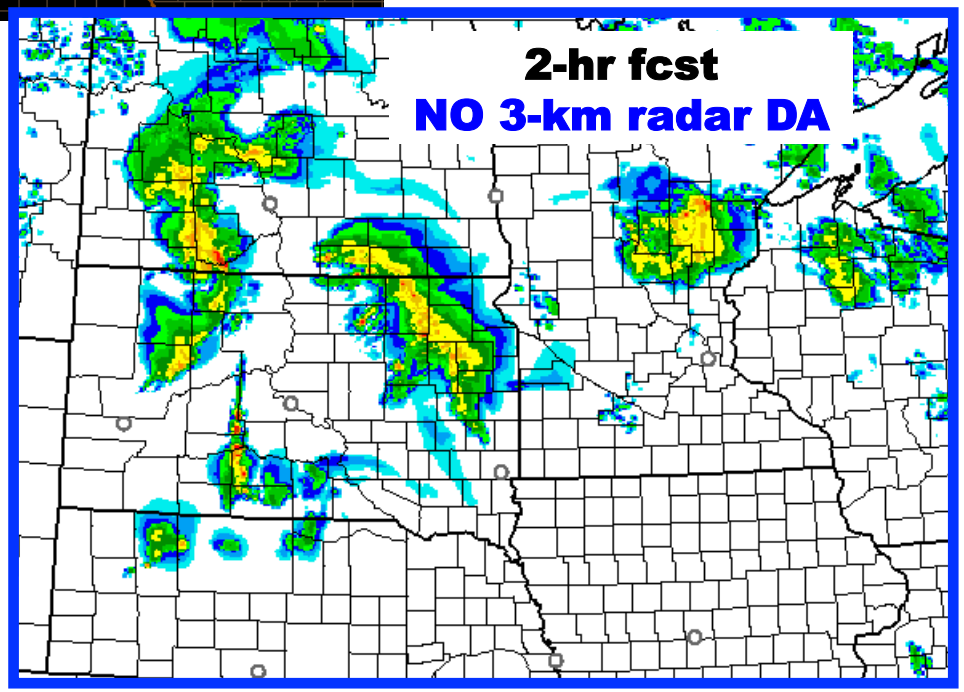
Improved 0-2 hr Convective Fcsts

Radar Obs
07:00z 18 May 2013



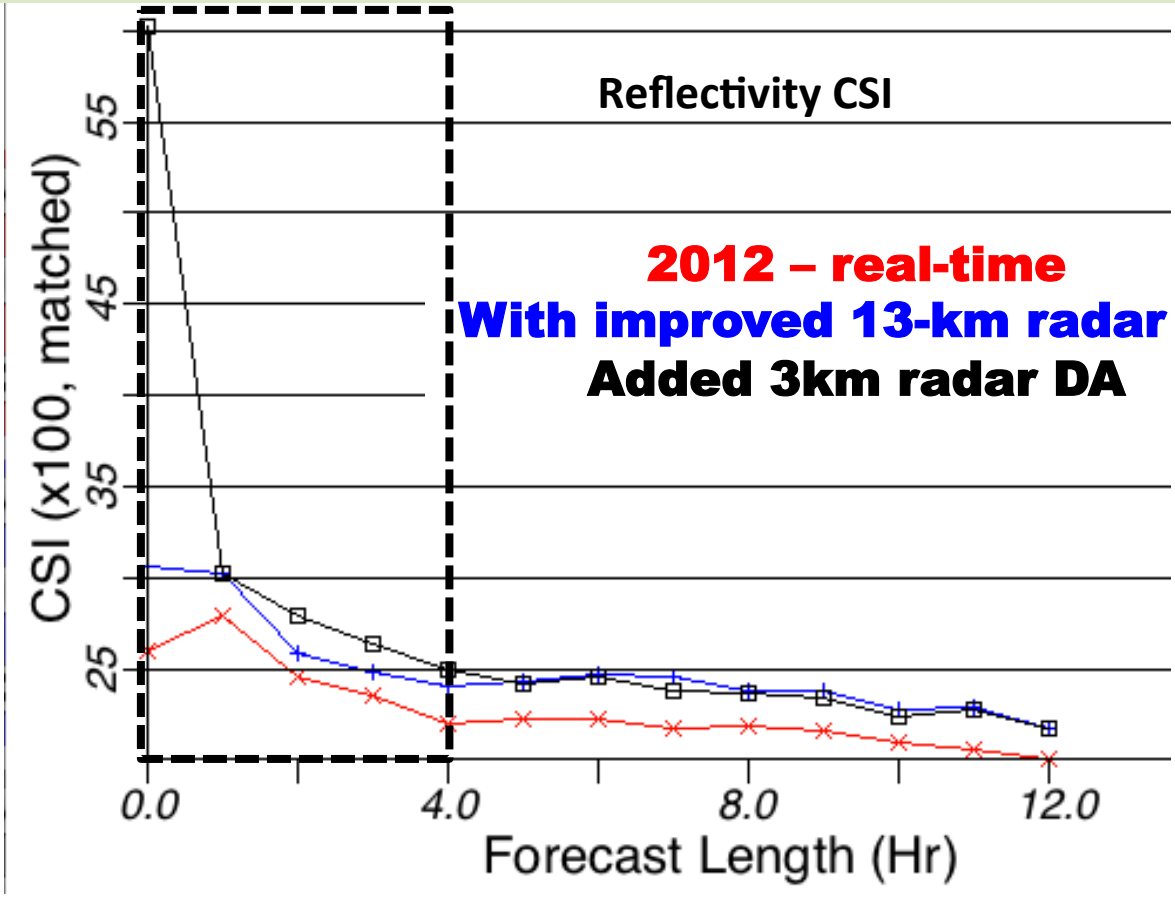
05z + 2hr min





HRRR Reflectivity Verification

7-day retrospective period May-June 2012
Forecasts every 2 hours
> 25 dBZ Composite Reflectivity
Eastern half of US upscale to 20 km

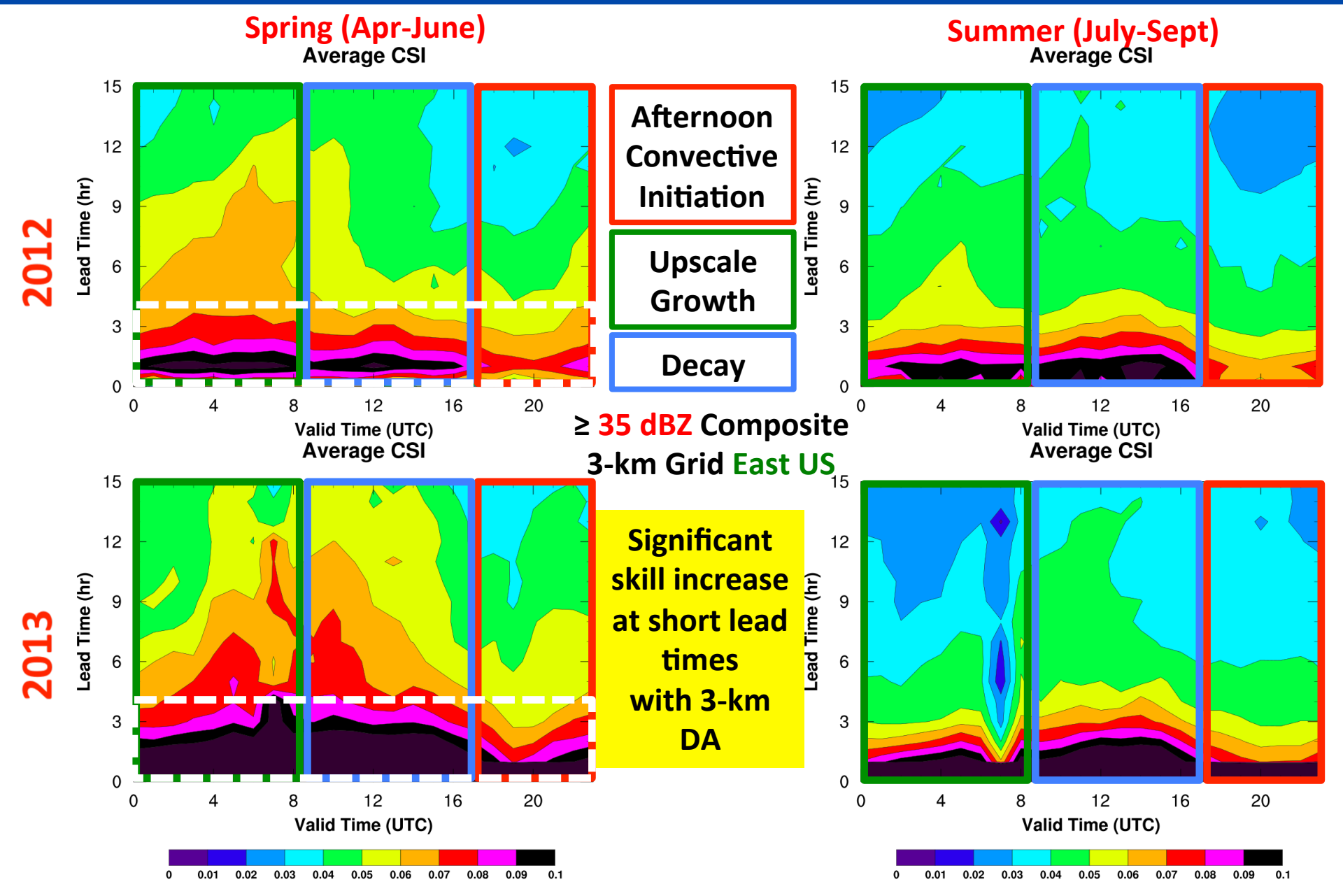


2012 – real-time
With improved 13-km radar DA
Added 3km radar DA

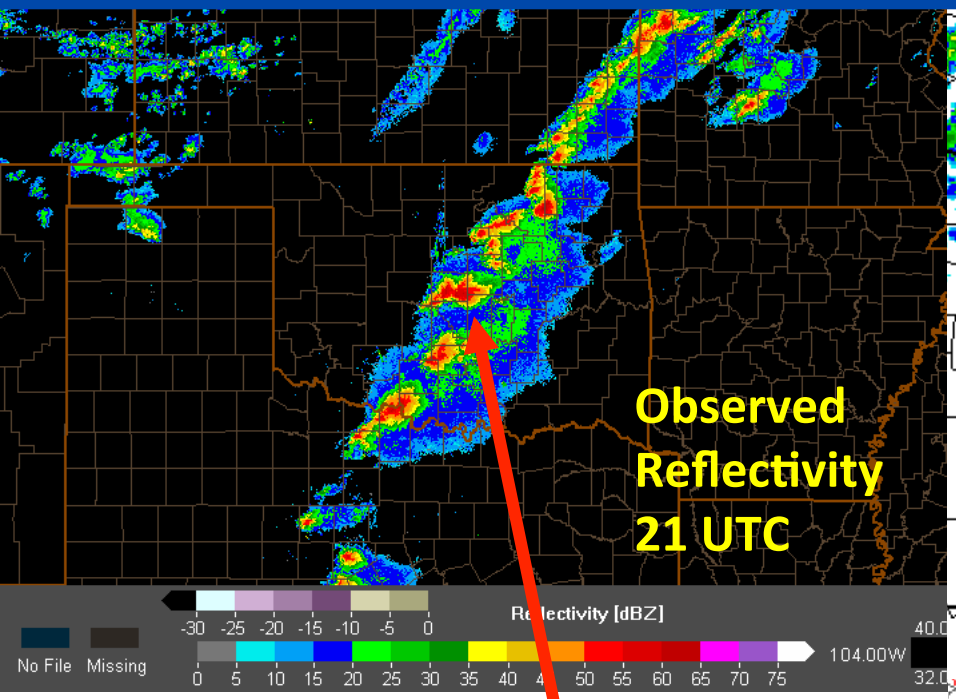
Improved 0-2 hr Convective Forecasts

Improvement Evident to ~4 hrs

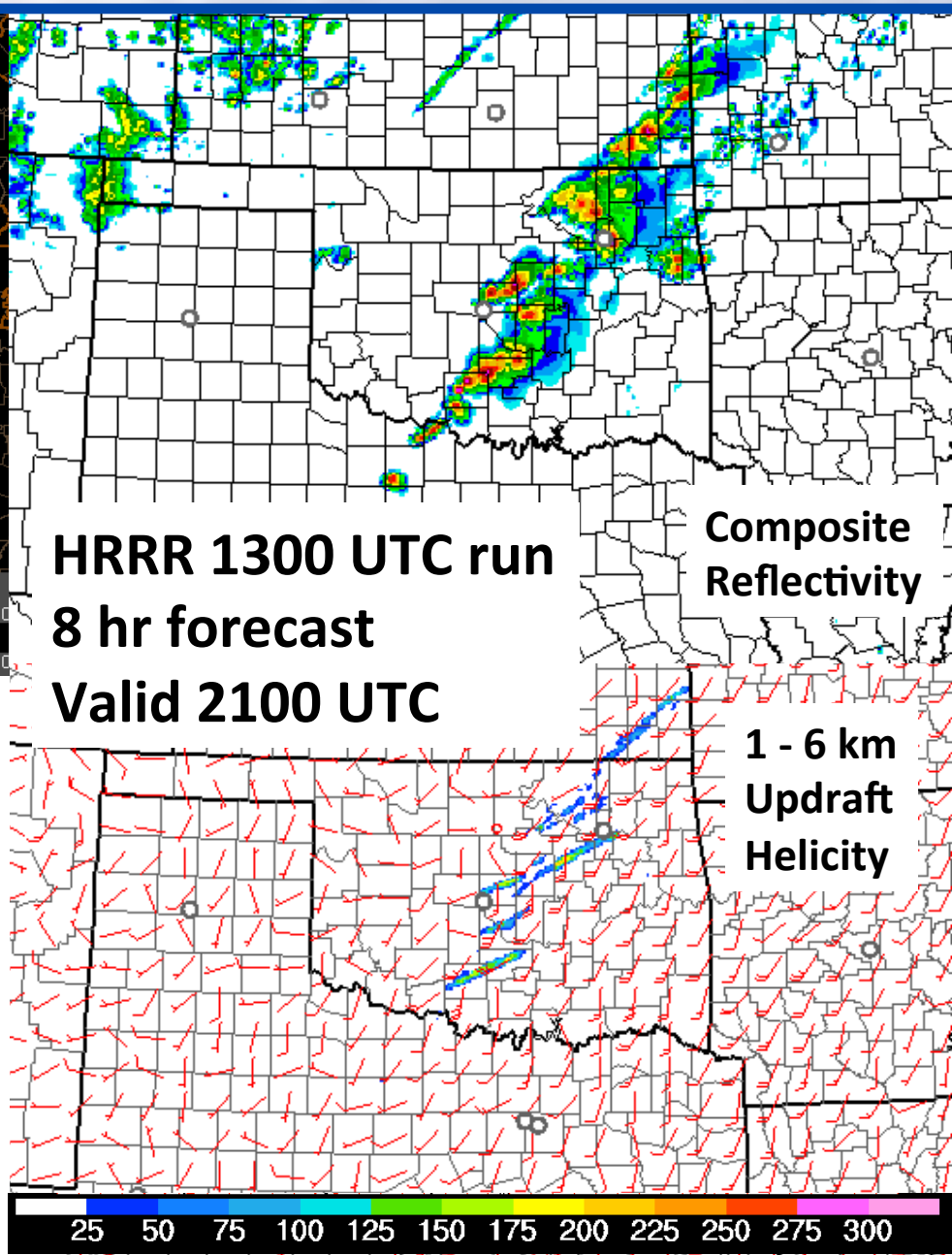
Lead Time vs Valid Time

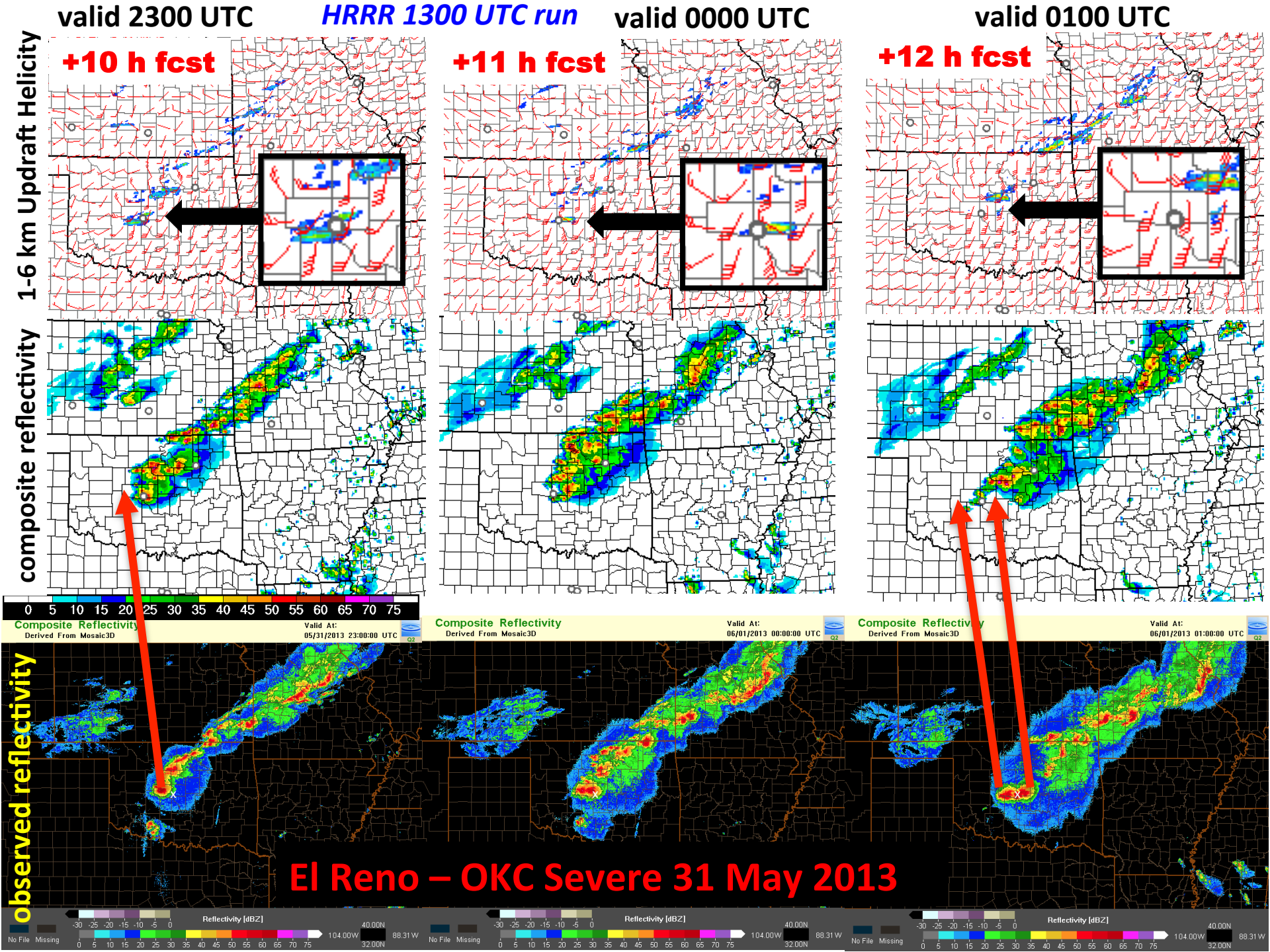


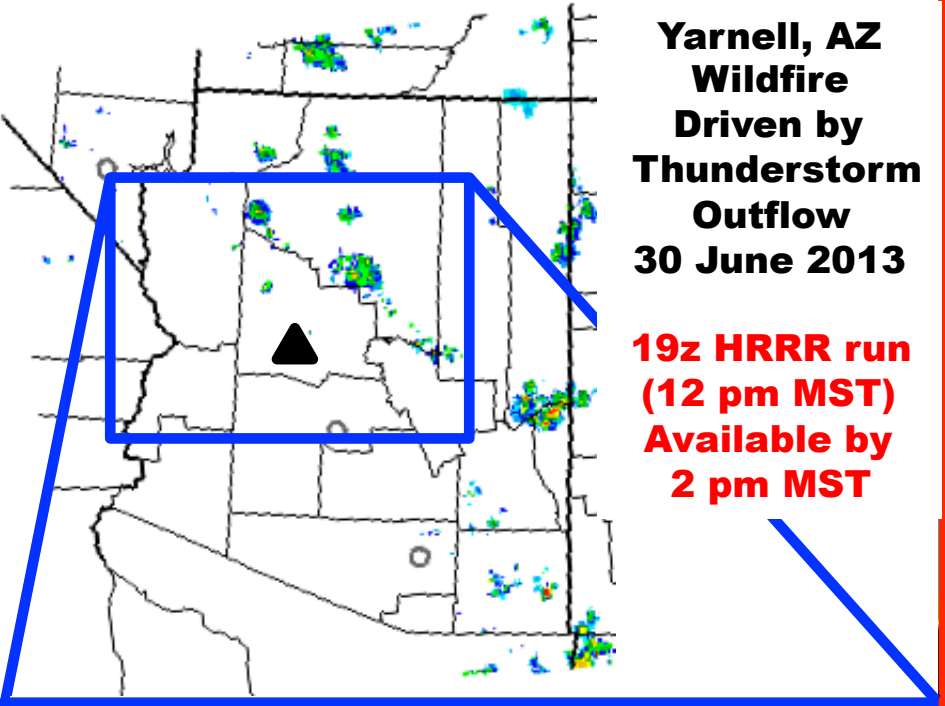
HRRR Case Studies



Moore, OK
20 May 2013
20 – 21 UTC
Tornadic Supercell



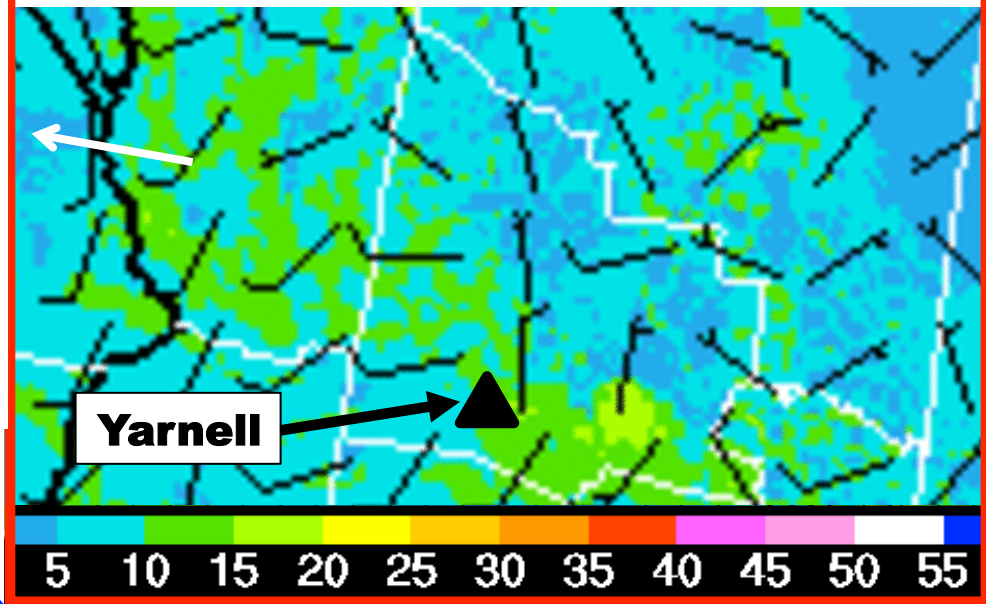

valid 2300 UTC
HRRR 1300 UTC run
valid 0000 UTC
valid 0100 UTC
+10 h fcst
+11 h fcst
+12 h fcst
1-6 km Updraft Helicity
composite reflectivity
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
Composite Reflectivity
Derived From Mosaic3D
Valid At:
05/31/2013 23:00:00 UTC
Composite Reflectivity
Derived From Mosaic3D
Valid At:
06/01/2013 00:00:00 UTC
Composite Reflectivity
Derived From Mosaic3D
Valid At:
06/01/2013 01:00:00 UTC
observed reflectivity
El Reno – OKC Severe 31 May 2013
Reflectivity [dBZ]
No File
Missing
104.00W
88.31W
40.00N
32.00N



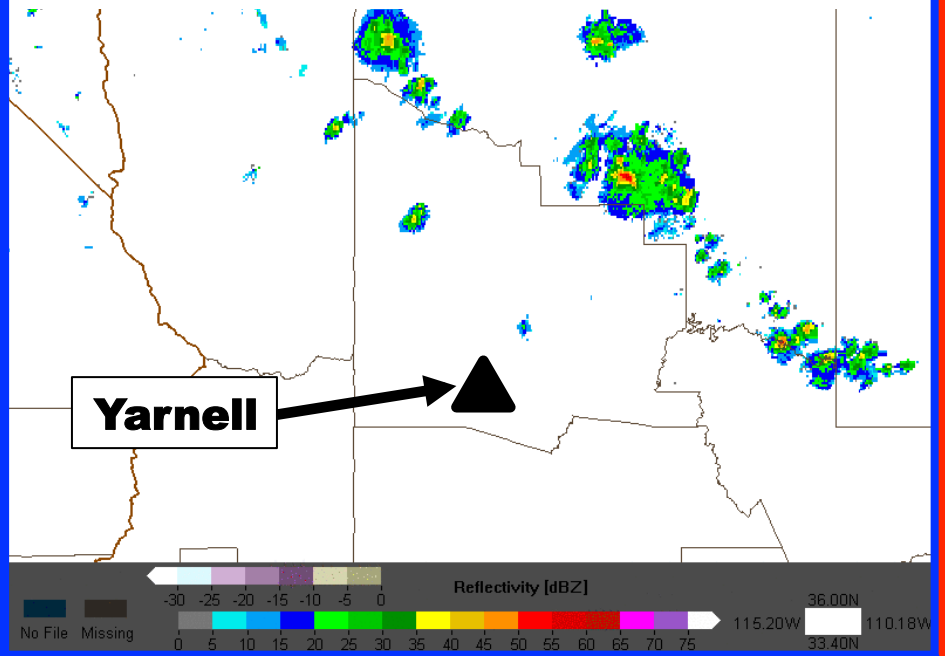
Yarnell, AZ Wildfire Driven by Thunderstorm Outflow 30 June 2013

19z HRRR run (12 pm MST) Available by 2 pm MST

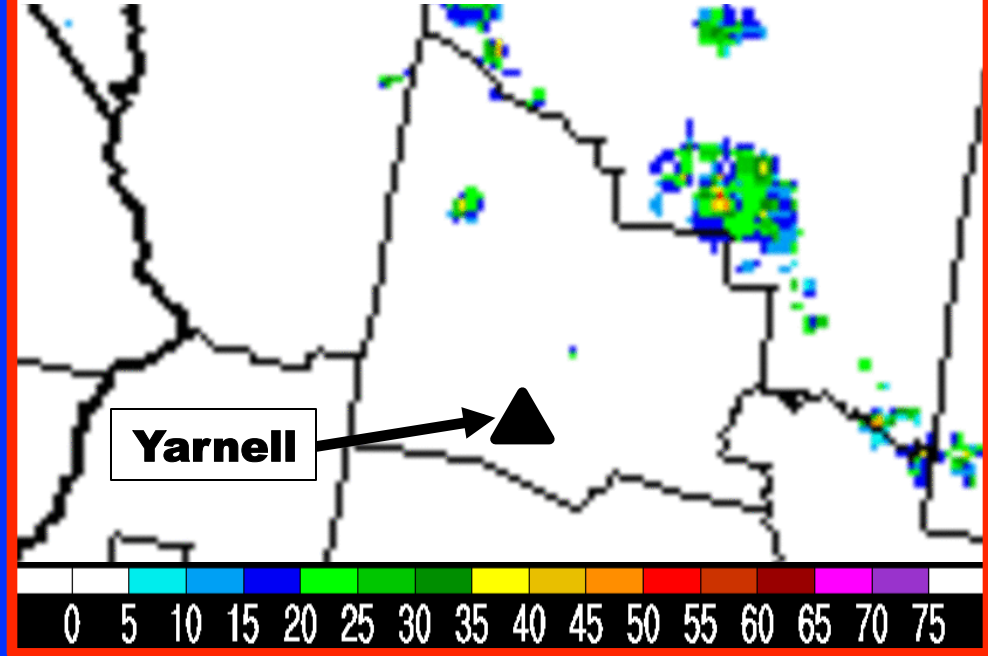
HRRR Fcst 80m Wind (kts)



Observed Radar (dBZ)



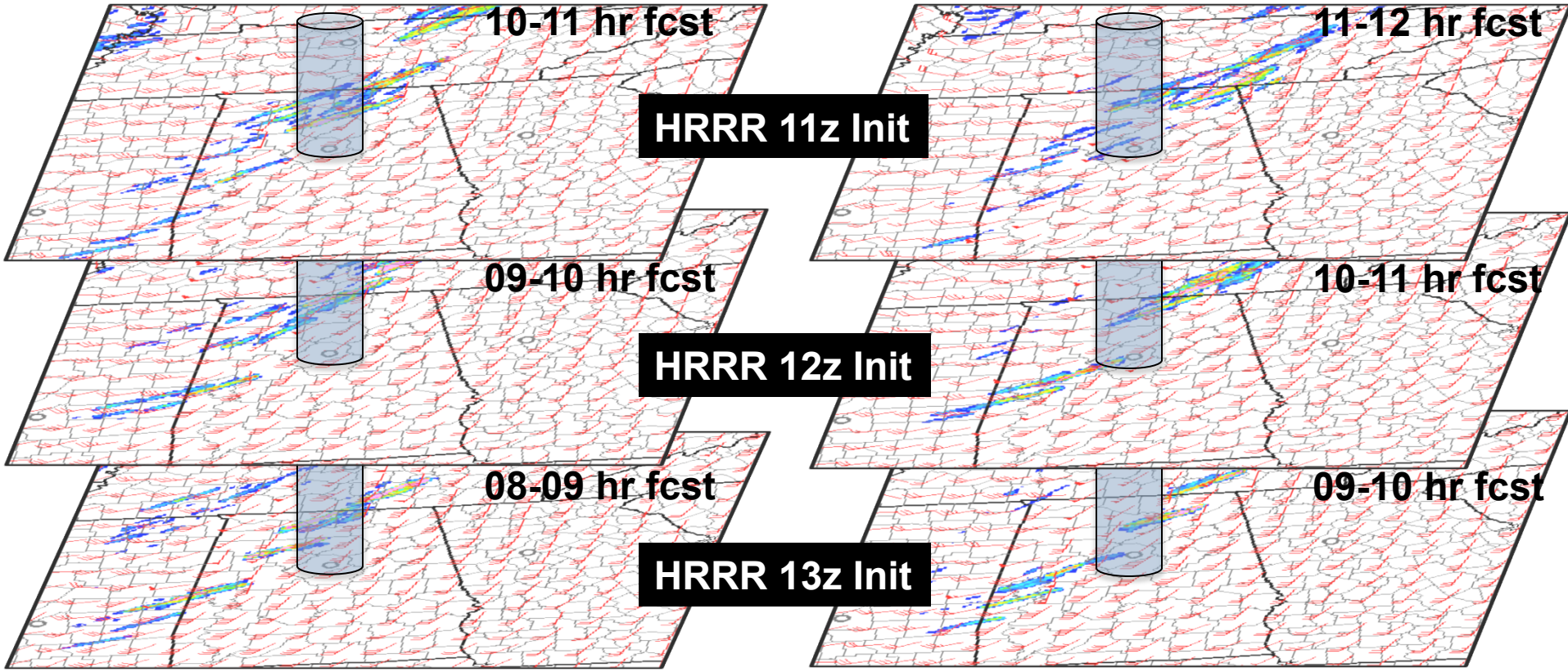
HRRR Fcst Radar (dBZ)



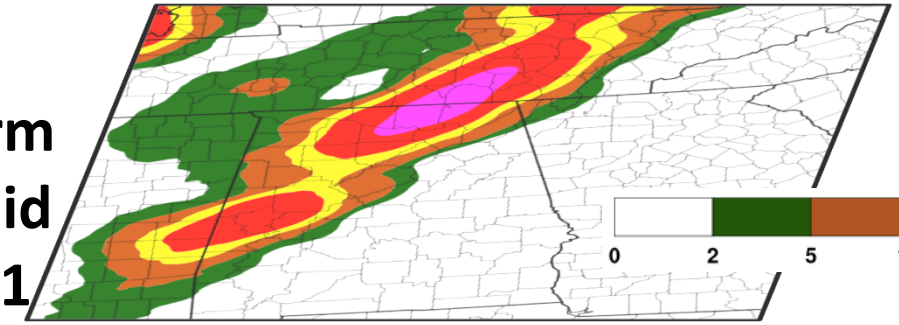
Time-lagged Ensemble

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



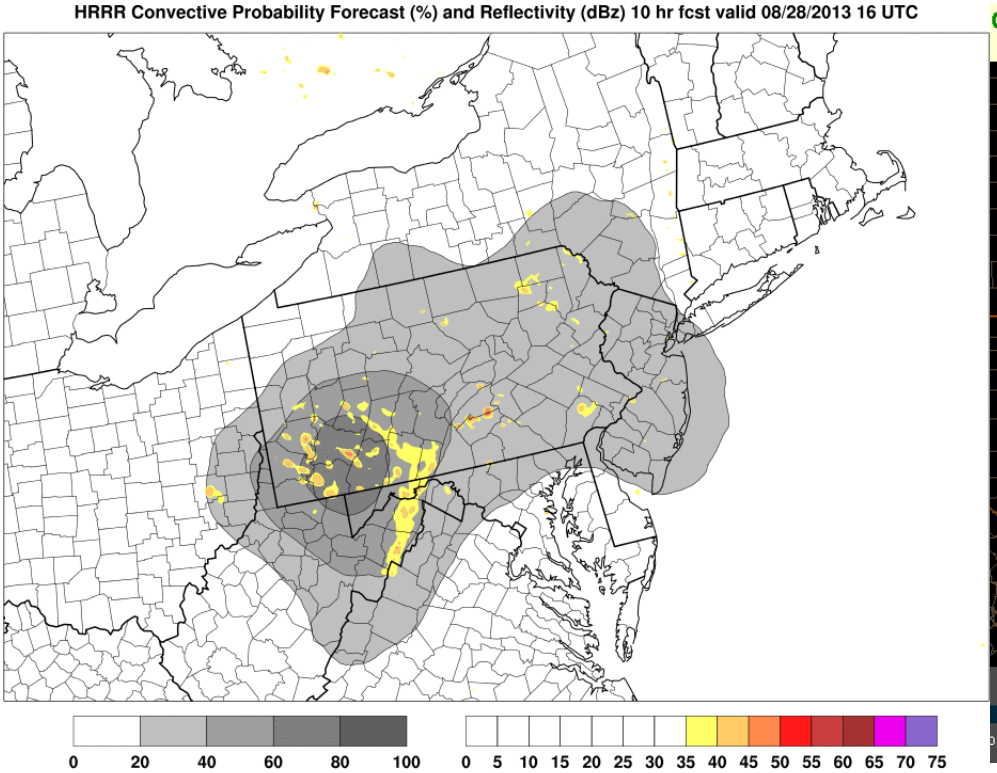
Spatial radius 45 km
Time radius 1 hr
UH threshold 25 m^2/s^2

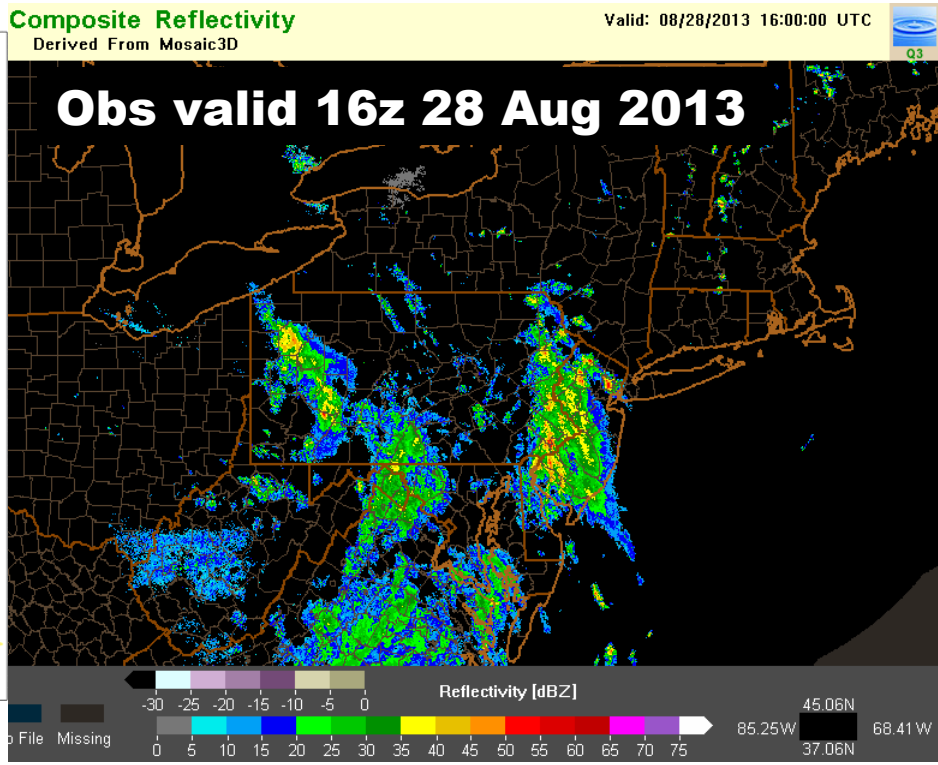
HRRR Conv Prob Fcst (HCPF)

Probabilities slowly evolve providing identifiable run-to-run trends

Convective structure (permeability etc…) still accessible

Distributed in GRIB2 to AWC starting in August 2013



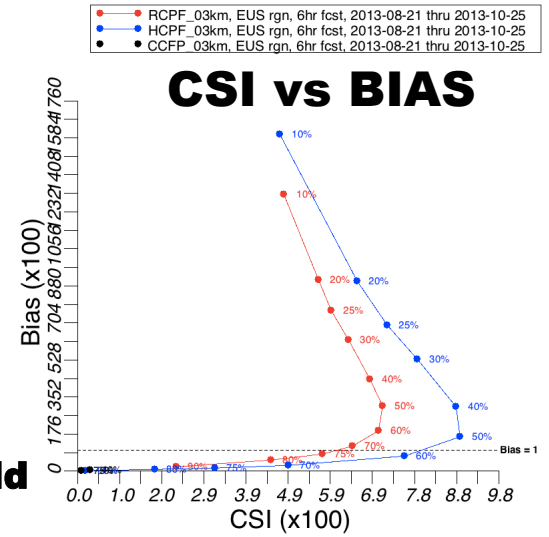


HCPF Verification

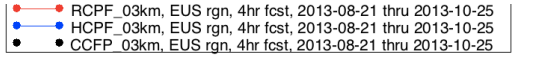
HCPF (blue) being developed to replace legacy RUC conv prob fcst (RCPF in red)

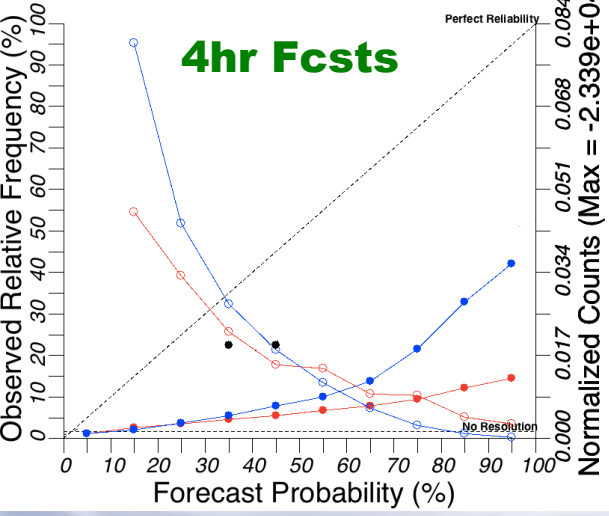
HCPF more statistically reliable in eastern US but over forecasts (no calibration yet)

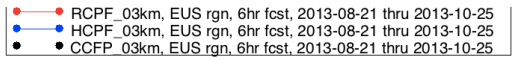
HCPF max CSI @ 50% with BIAS ~1.7

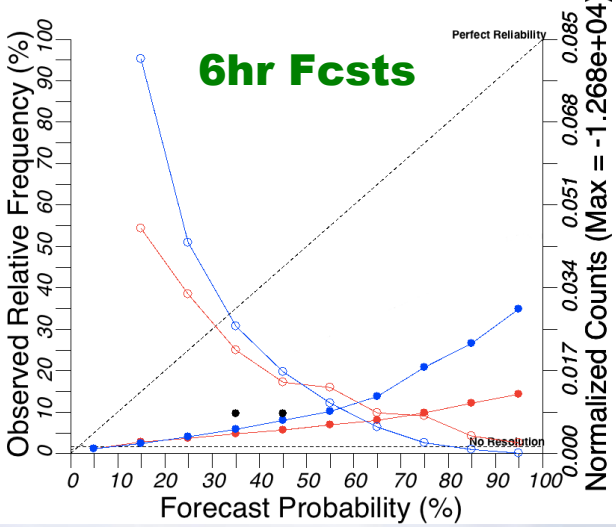


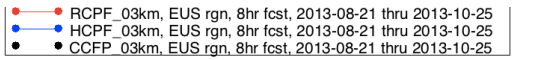
Reliability Diagrams using 35 dBZ NSSL threshold on 3-km grid Aug-Oct 2013 Eastern US

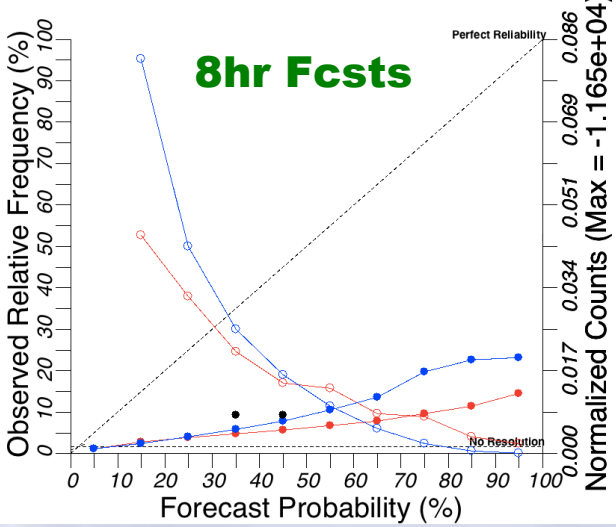










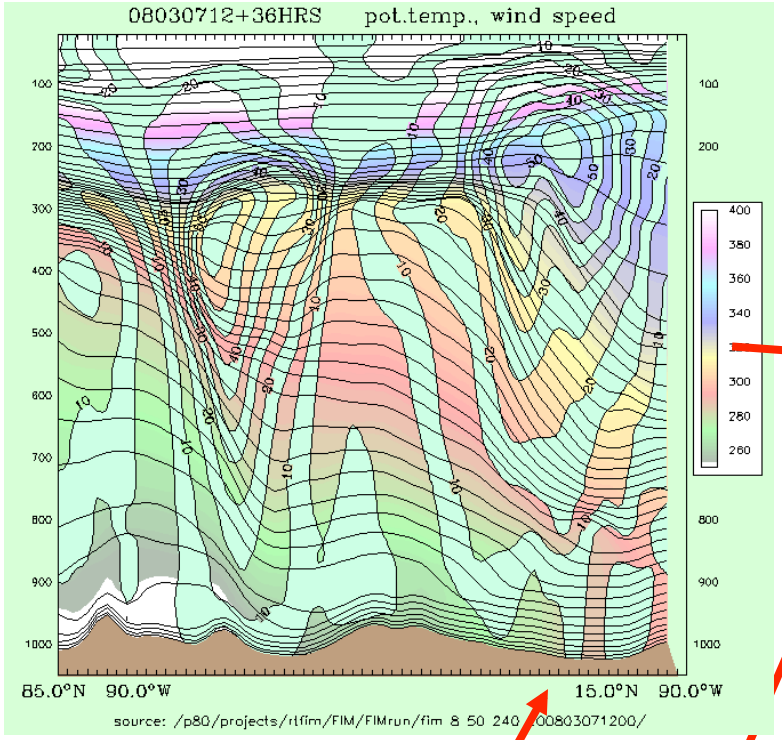


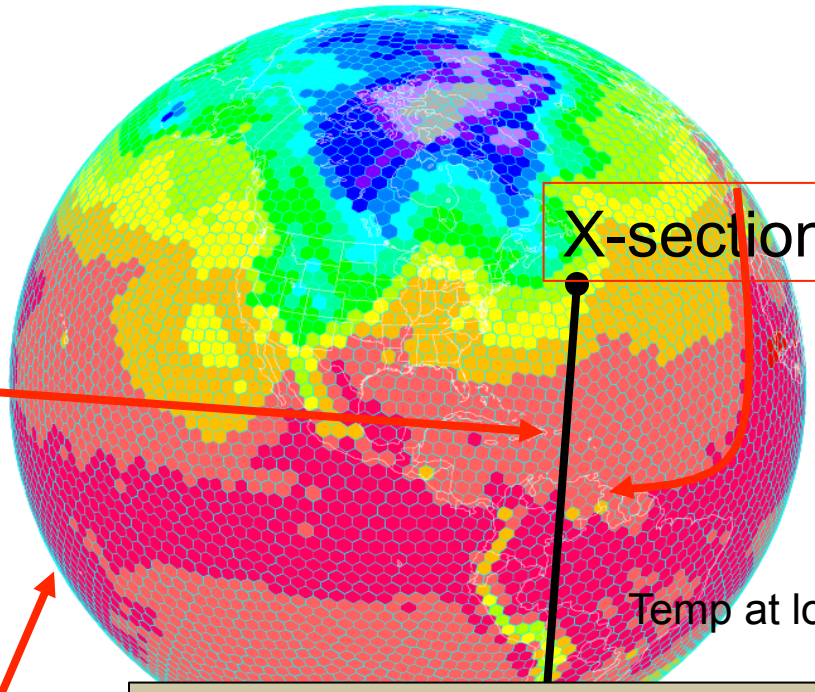
Candidate RAPv3/HRRRv2 Changes

	Model	Data Assimilation
RAP-ESRL (13 km)	WRFv3.5.1+ incl. physics changes **Physics changes:** Grell-Freitas convective scheme MYNN PBL scheme - Olson version Thompson microphysics w/aerosols RRTMG radiation scheme Direct and diffuse GHI components	Merge with GSI trunk Radial velocity assimilation Mesonet assimilation Aircraft temperature bias correction Full-column cloud assimilation Radiance bias correction GOES cloud-top cooling assimilation RARS data assimilation Forward model to cloud fraction from SW radiation variants
HRRR (3 km)	WRFv3.5.1+ incl. physics changes **Physics changes:** MYNN PBL scheme - Olson version Thompson microphysics w/aerosols RRTMG radiation scheme Direct and diffuse GHI components Shallow cumulus parameterization **Numerics changes:** 6th order diffusion in flat terrain	3-km hybrid assimilation Radial velocity assimilation Mesonet assimilation **Changes with high/medium importance for *overall* forecast skill**

RAP/HRRR Implementation Map

ESRL – experimental version	NWS-NCEP - operational
• RAPv1 – used in 2011 – Initialized 2011 HRRR – effective but too many storms	• Implemented 1 May 2012
• RAPv2 – used in 2012-2013 – Initialized 2012-2013 HRRR – Better use of surface obs / radar, storm bias eliminated, Hybrid DA	• RAPv2 - Scheduled to be implemented in Jan 2014, running in NCEP/NCO testing now
• HRRR – 2012 – Major improvement over 2011 HRRR, storm coverage/accuracy	
• **HRRR – 2013** – **3km/15min radar assimilation** – **Initialized from RAPv2-2013** – **Available 45 min earlier, much more accurate 0-15h storm forecasts, more reliable 2-computer**	• HRRRv1 – Scheduled to be implemented in Apr 2014, HRRR tested on WCOSS with 45-min runtime on 60 nodes, 3-km DA setup underway





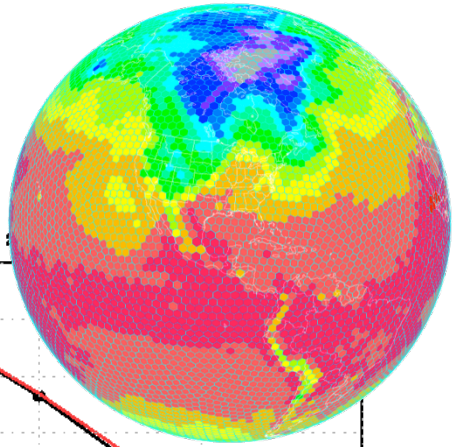
Flow-following-finite-volume Icosahedral Model FIM

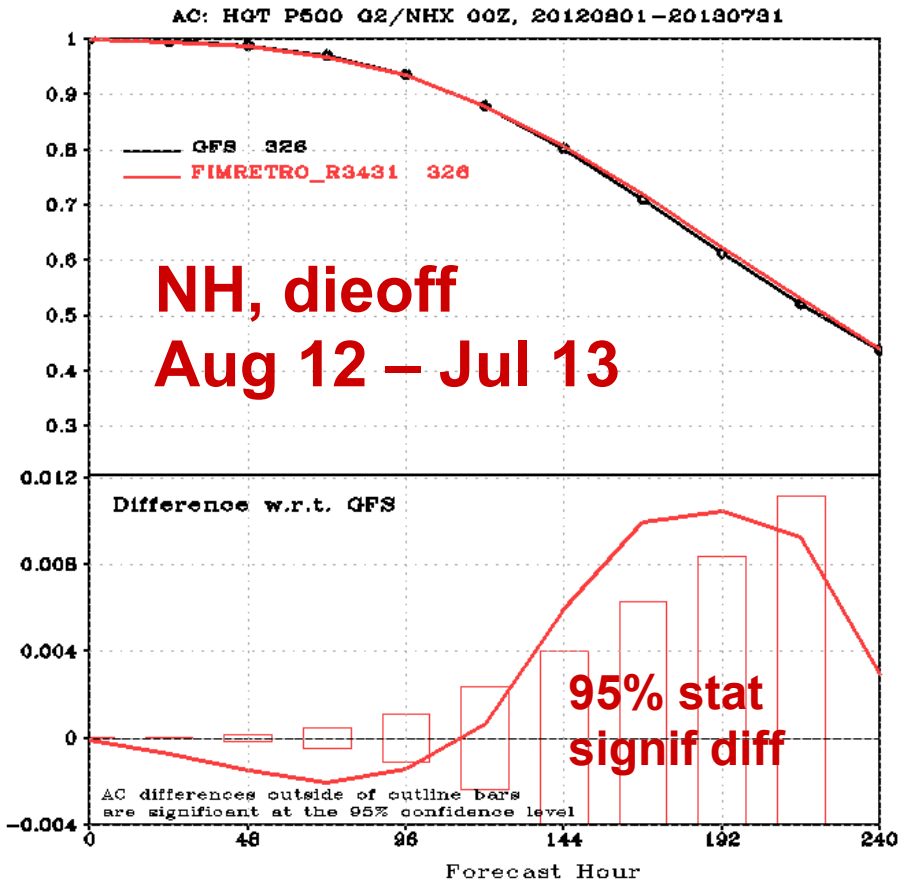
http://fim.noaa.gov

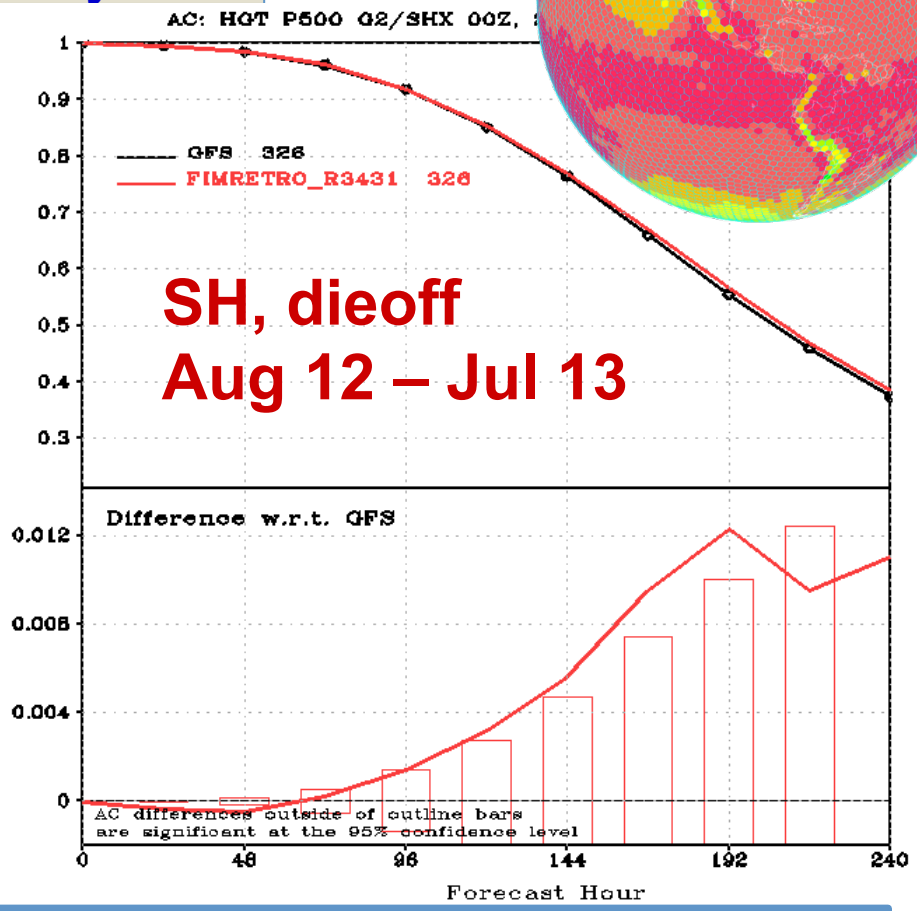
Sandy Supplemental funded *High-Impact Wx Pred Proj (HIWPP)* - will include

- ESRL/NCEP eval of exper multi-model ensemble - GFS and FIM (10 mem each)
- Pre-NMME testing (FIM/ iHYCOM)
- GSI/hybrid DA dev w/ FIM

500-hPa Height Anomaly Correlation
FIM-30km global vs. GFS operational
- FIM with GFS IC, GFS phys, dyn core only diff



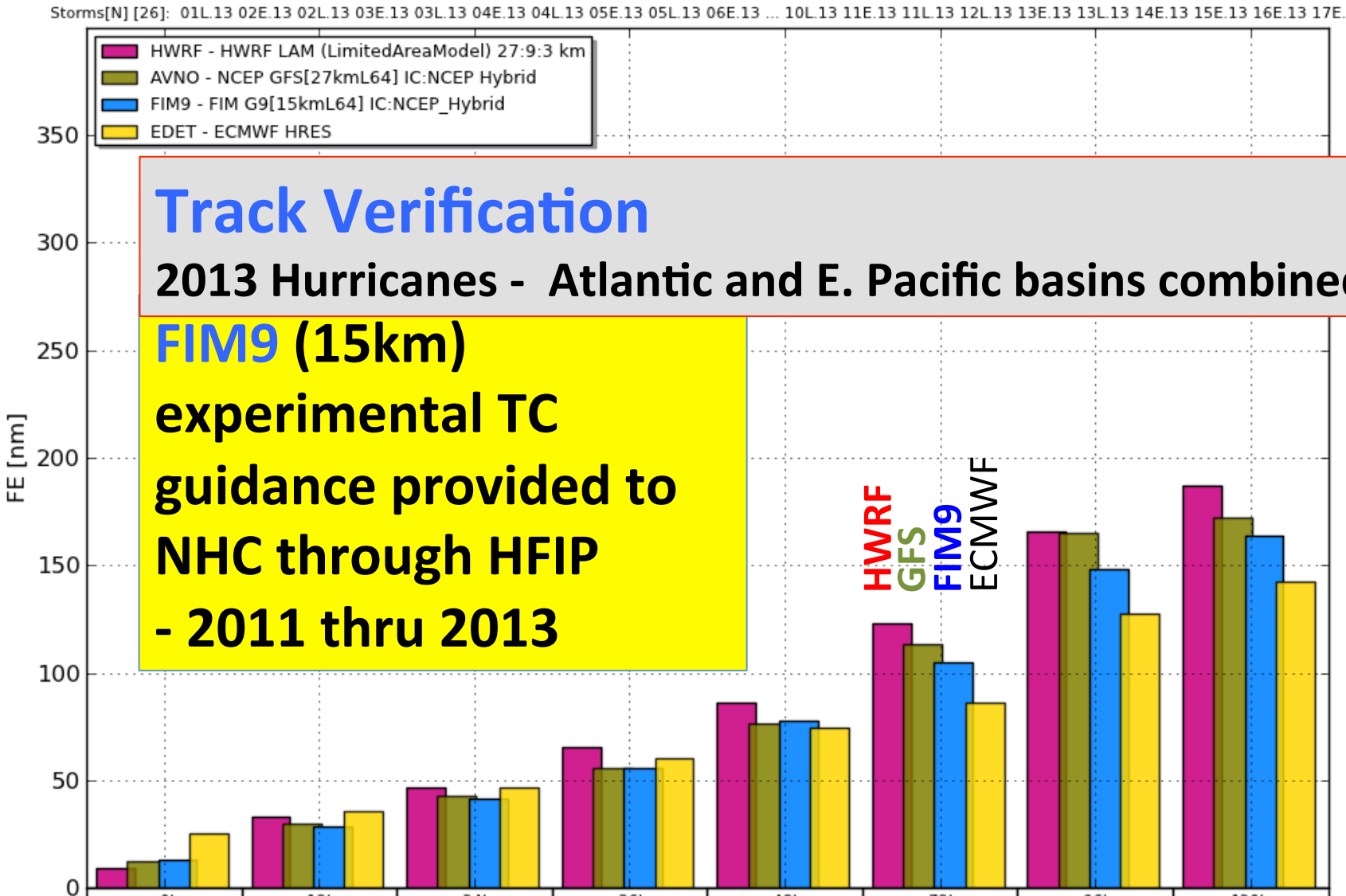




Results from 12-month test- August 2012 through July 2013

FIM better skill than GFS for 5+ day duration in N. Hemisphere, 4+ day duration for S. Hemisphere, statistically significant in both SH and NH

EPAC/LANT 2013 HWRF v GFS v FIM9 v ECMWF



Track Verification

2013 Hurricanes - Atlantic and E. Pacific basins combined

FIM9 (15km) experimental TC guidance provided to NHC through HFIP - 2011 thru 2013

	0h	12h	24h	36h	48h	72h	96h	120h
hwrf	9[196]	33[159]	47[137]	65[117]	86[96]	123[59]	166[42]	187[28]
avno	12[196]	30[159]	43[137]	56[117]	76[96]	113[59]	165[42]	172[28]
fim9	13[196]	28[159]	42[137]	56[117]	78[96]	105[59]	148[42]	164[28]
edet	25[196]	36[159]	47[137]	60[117]	74[96]	86[59]	127[42]	143[28]

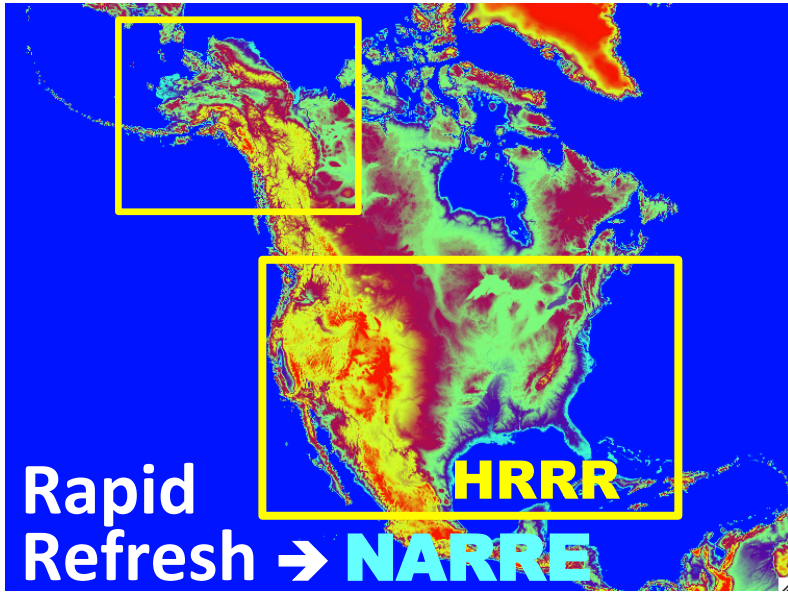
Evolution of hourly updated NOAA modeling

May 2012 – Rapid Refresh oper at NCEP

Jan-Feb 2014 –Rapid Refresh v2 – oper at NCEP

- PBL/soil/radar assimilation enhancements
  - ➔ **Improved surface forecasts, convective environment fields**
- Hybrid ensemble-variational GSI assimilation
- Model – improved cloud / PBL / LSM, numerics improvements, updated WRF

~Apr 2014 – HRRR (3km) - planned oper at NCEP with 3km/15min radar refl. assimilation



North American Rapid Refresh Ensemble

- **NMM, ARW cores**
- **Hourly updating with GSI-hybrid EnKF**
- **Initially 6 members, 3 each core, physics diversity (stochastic only or with RAP/ NAM/NCAR suites)**
- **Hourly forecasts to 24-h**
- **NMMB (+ARW?) members to 84-h 4x/day**

Future oper @ NCEP

2015 – RAPv3/HRRRv2

2017 – Ensemble Rapid Refresh/NAM – NARRE (w/ hybrid 4d-ens/var DA)

2019? – Ensemble HRRR – HRRRE – (ultimately with hourly ~3km ensemble DA)