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

EMC Change Configuration Board
August 6, 2014

Presented by: Geoff Manikin EMC

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

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Jianbing Yang, Becky Cosgrove, Justin Cooke, Carissa Klemmer, Boi Vuong, Chris Magee NCO

Jim Taft, John Michalakes, Jim Abeles IBM

Charter Overview

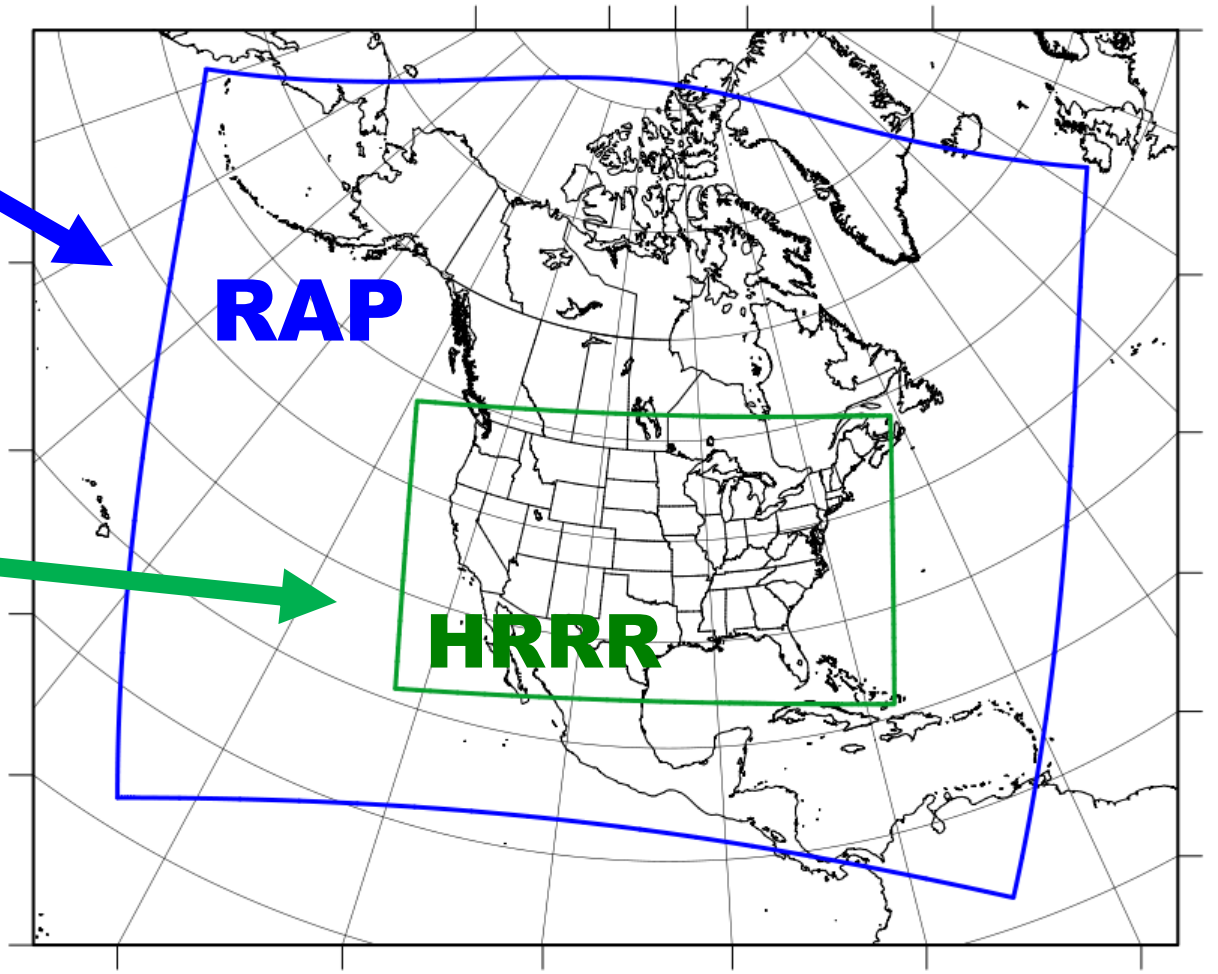
- **This project is an NWS and NCEP Annual Operating Plan (AOP) milestone for Q4 FY2014**
- **Implementation scheduled for 23 September 2014**
- **Hi-Res Rapid Refresh description**
  - **Used by SPC, AWC, WPC, FAA, NWS offices and others for details short-range forecasts, especially convective evolution**
  - **24 cycles/day – each run out to 15 hours**
  - **No cycling**

Rapid Refresh and HRRR
NOAA hourly updated models

13km Rapid Refresh (RAP)
(mesoscale)

V2 in ops: 2/25/14

3km HRRR
(storm-scale)

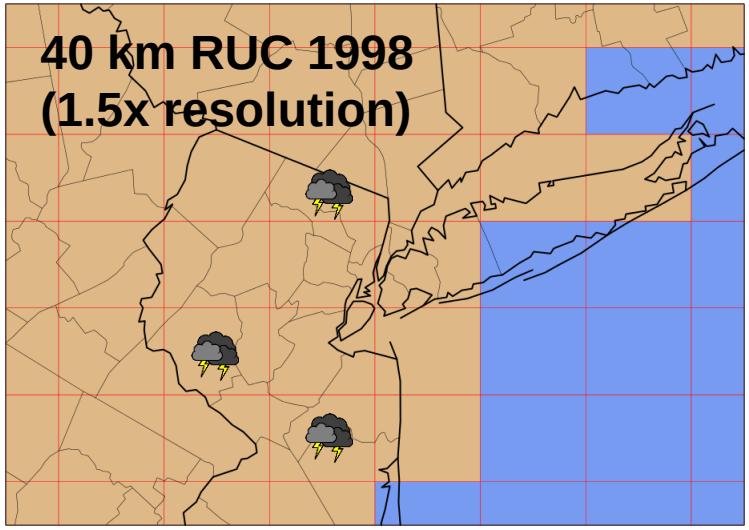


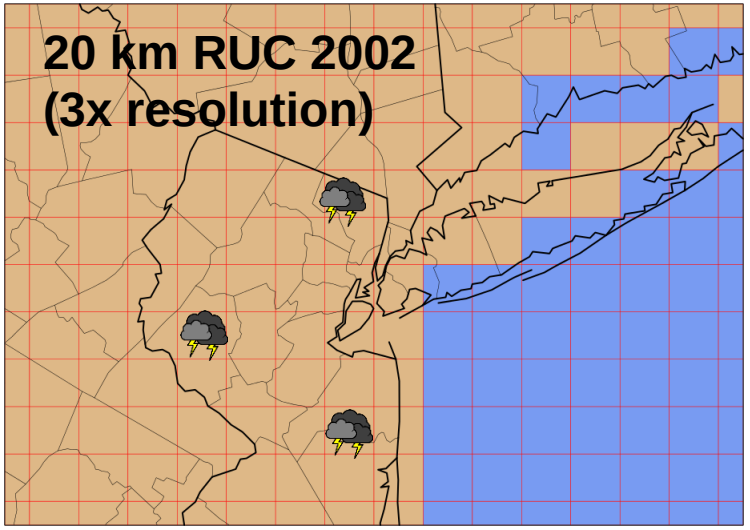
High-Resolution Rapid Refresh
Scheduled NCEP Implementation Sept 2014

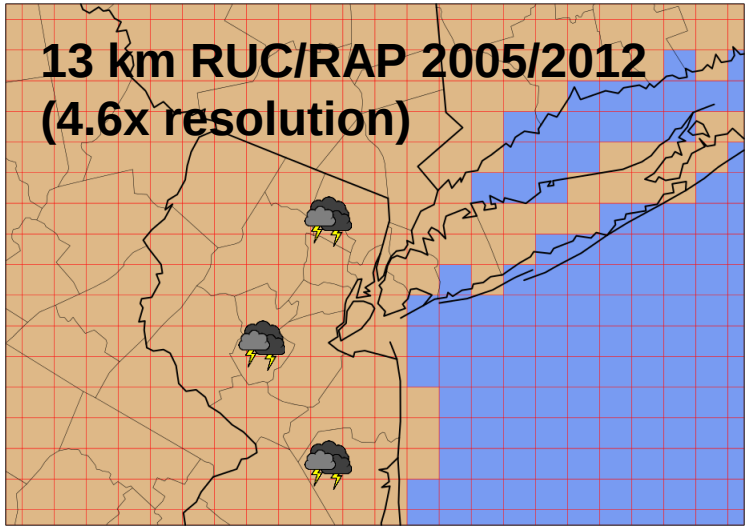
We have the RAP – why do need the HRRR?

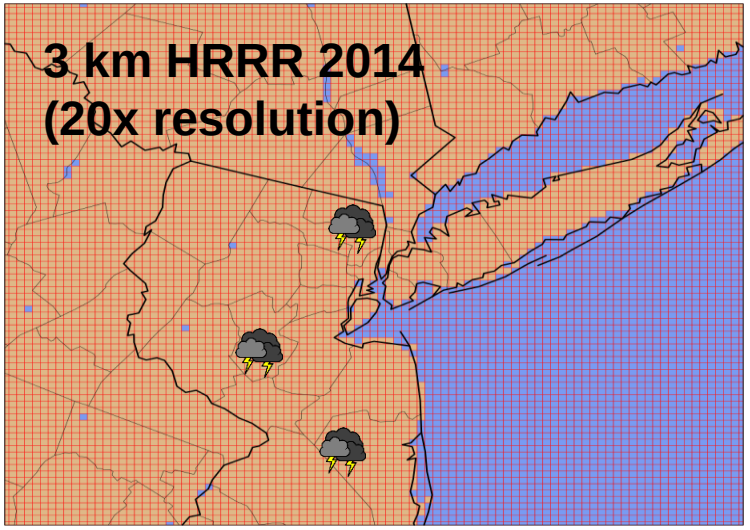
- Increased resolution of basic fields like temperatures/winds/visibility, etc to resolve mesoscale features
- Explicitly resolves convection, allowing for storm-scale structure; shows skill at predicting storms with strong rotation, bow echoes, etc.
- Provides hourly updates at high resolution
- Will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

High Impact Prediction Needs: Higher Resolution Models







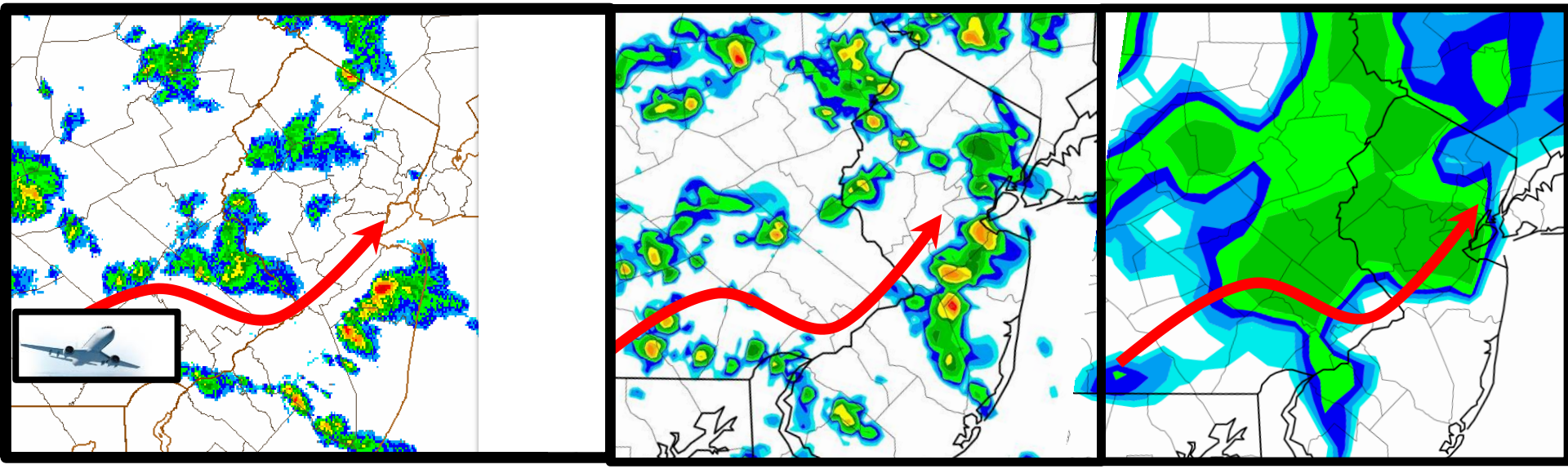


High Impact Prediction Needs: Higher Resolution Models

07 June 2012 5 PM EDT
Reality

3-km HRRR
Explicit
Convection 6 hr forecast

13-km RAP
Parameterized
Convection 6 hr forecast



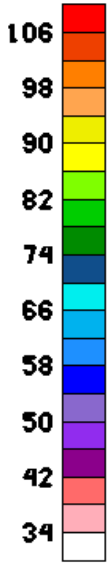
Aircraft must Navigate Around Thunderstorms

Accurate Storm Structure

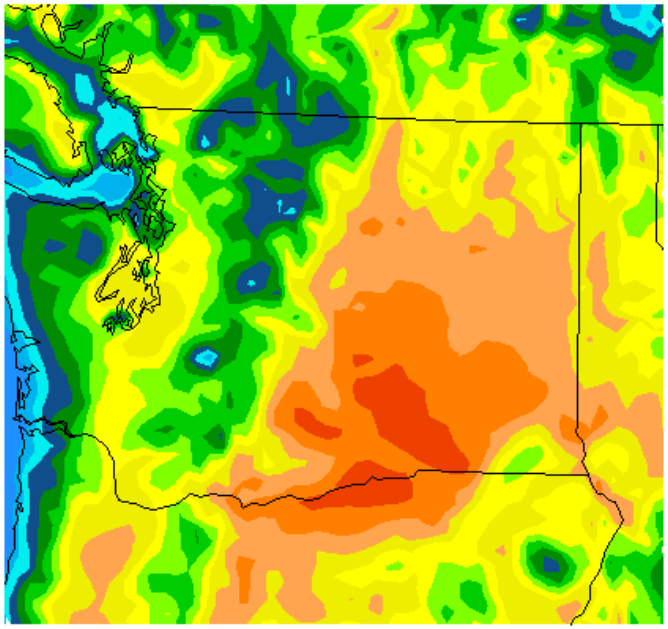
Accurate Estimate of Permeability

No Storm Structure

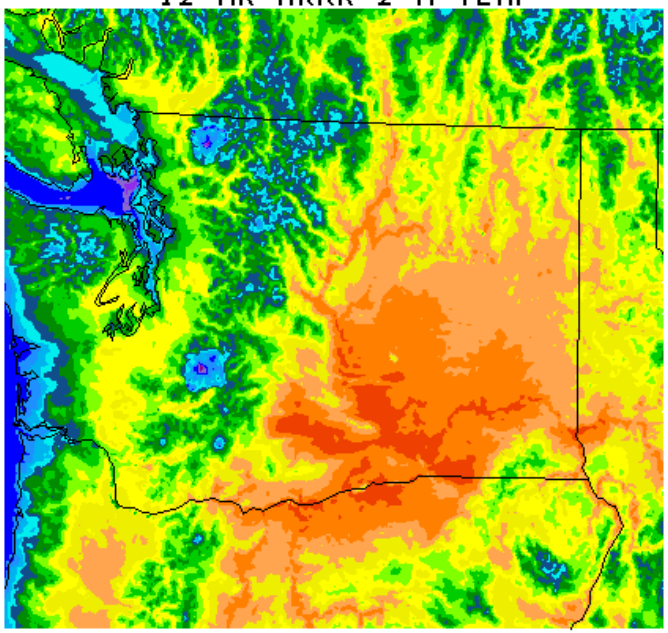
No Estimate of Permeability

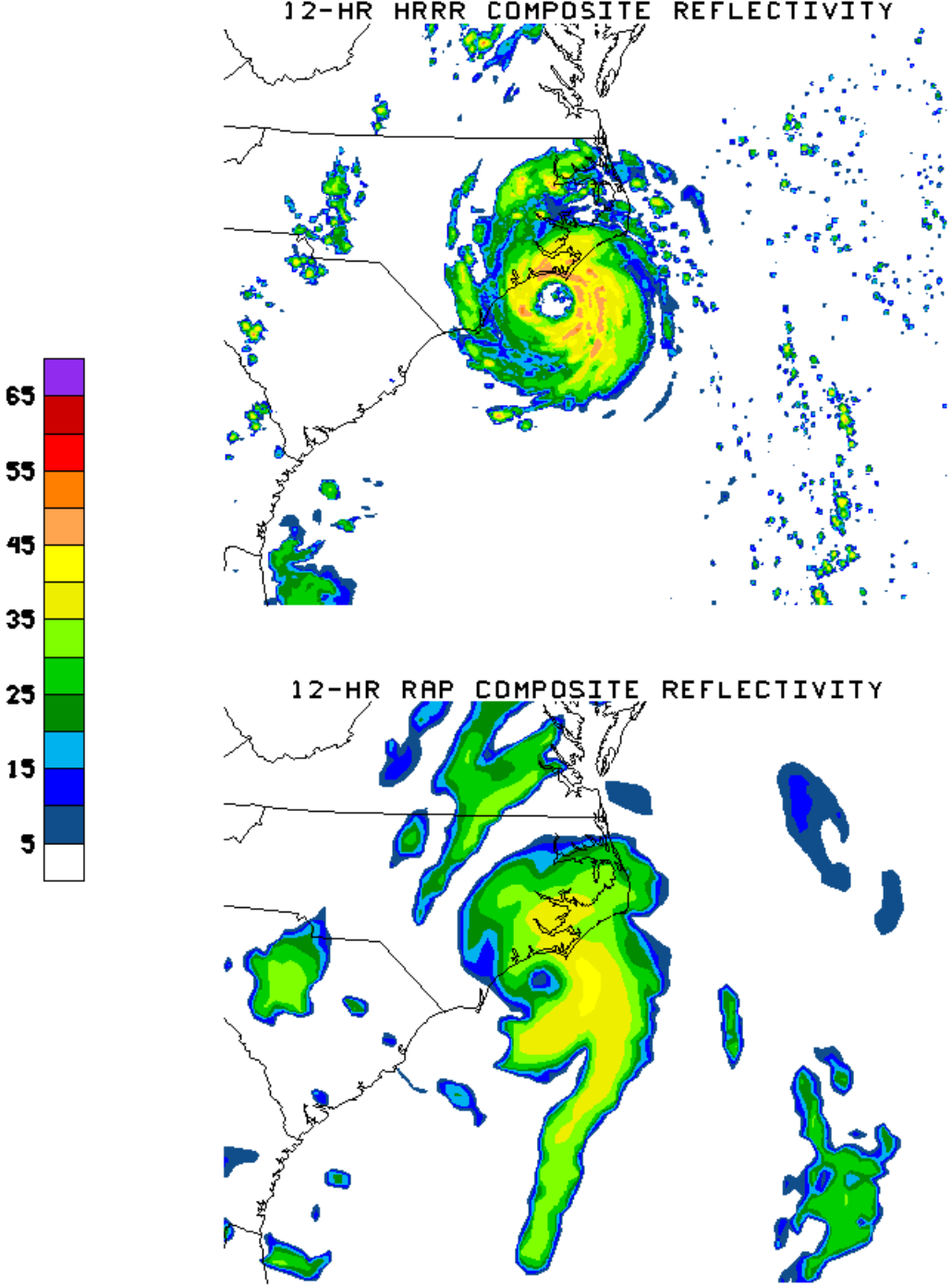


12-HR RAP 2-M TEMP

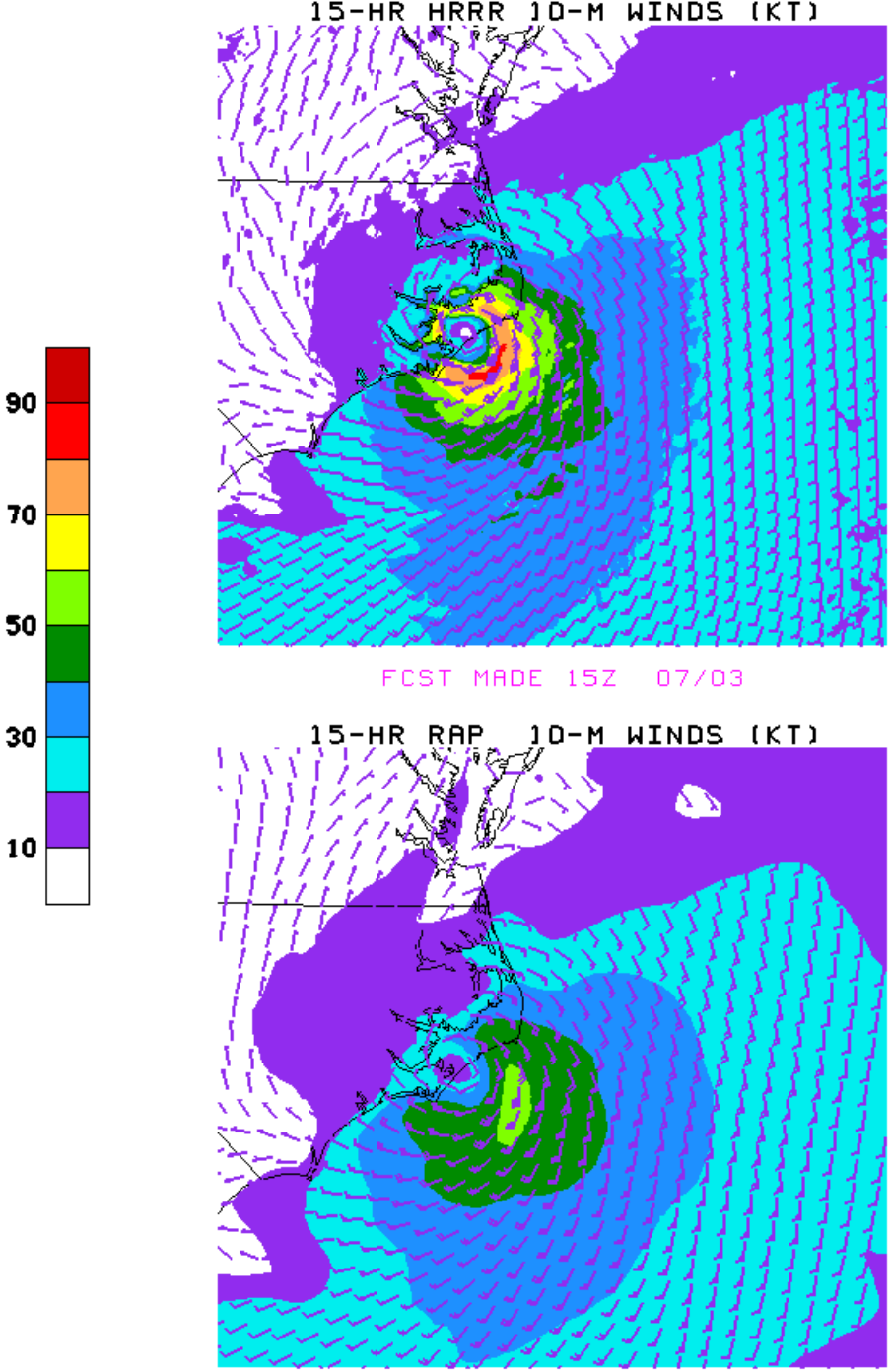


12-HR HRRR 2-M TEMP





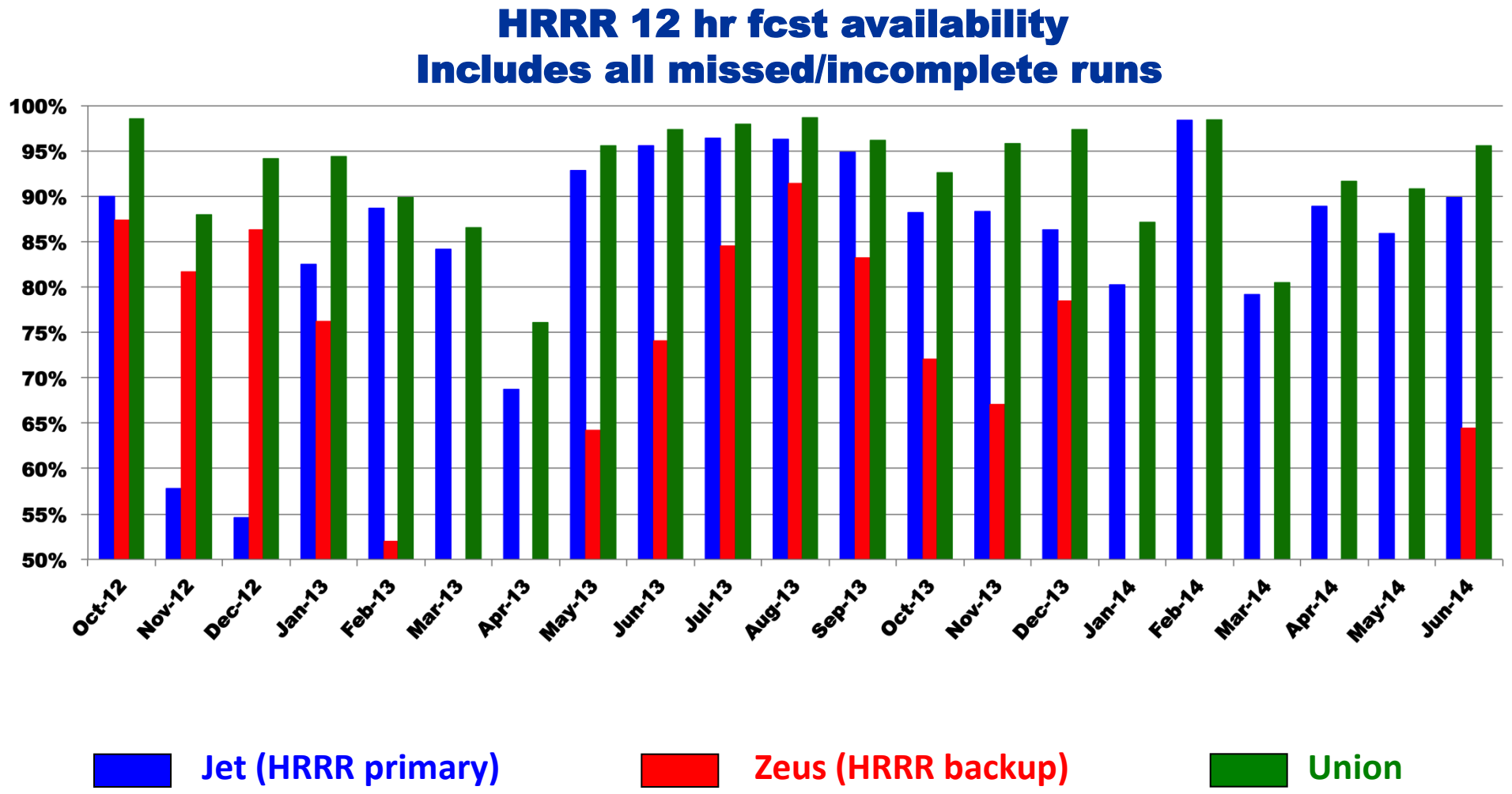
Hurricane Arthur


15-HR HRRR 10-M WINDS (KT)
90
70
50
30
10
FCST MADE 15Z 07/03
15-HR RAP 10-M WINDS (KT)

Why run the HRRR at NCEP?

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

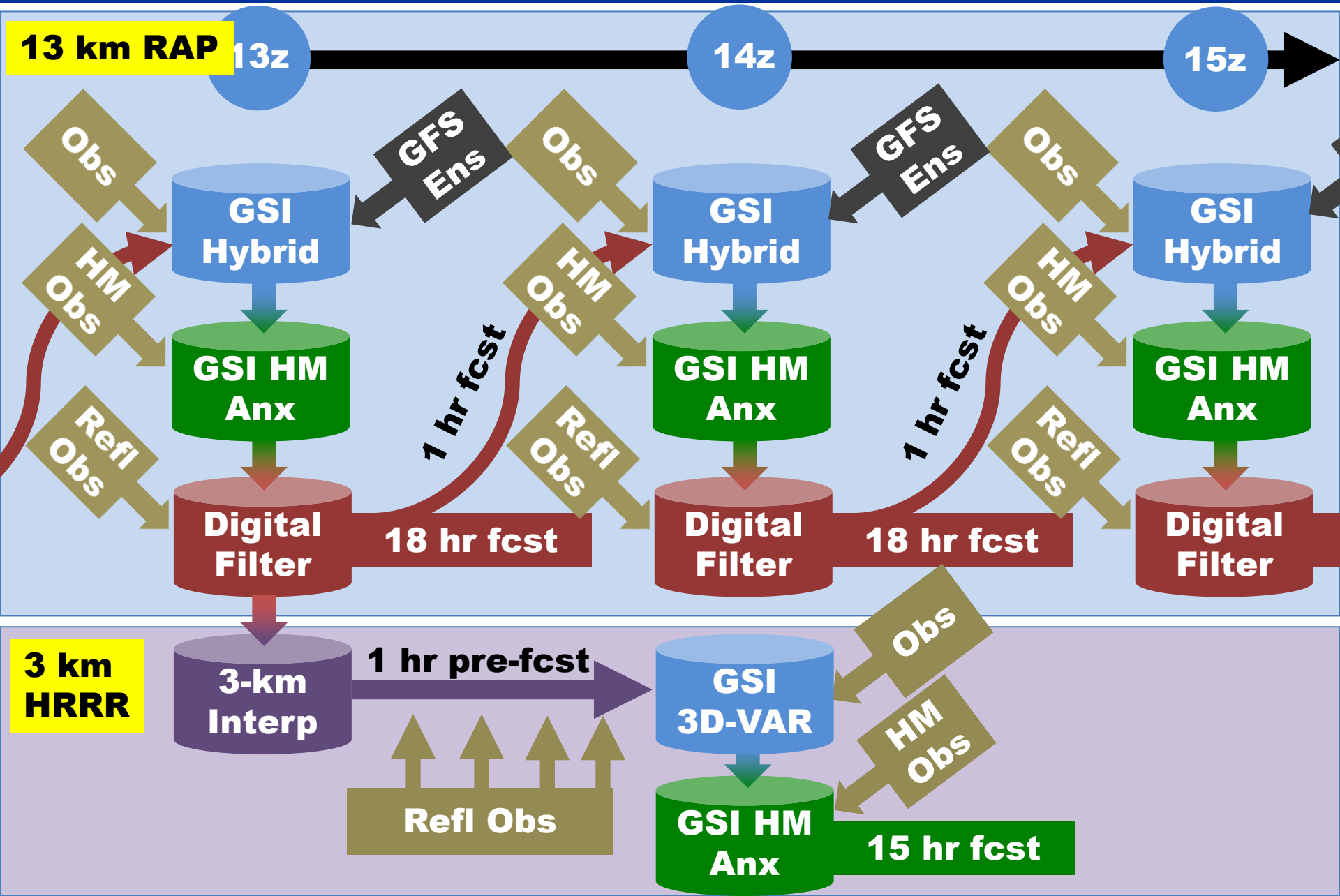
HRRR Availability



HRRR Basic Overview

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

HRRR Initialization from RAPv2



Structure – Part 1: Before the Forecast

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

4 min + 3 min + 5 min + 6 min = 18 min

RESOURCES – allocated ~80 nodes

- Interpolation of RAP guess: 6 nodes
- Process radar data: 4 min: 4 nodes

← Simultaneous ←

- Make boundary conditions: 6 nodes
- Process cloud data: 1 node
- Generate temp. tendencies: 1 node

← Simultaneous ←

- 1-hr spinup forecast: 75 nodes
- GSI (analysis): 30 nodes

- 3 minute overlap between the spinup forecast and the boundary processing

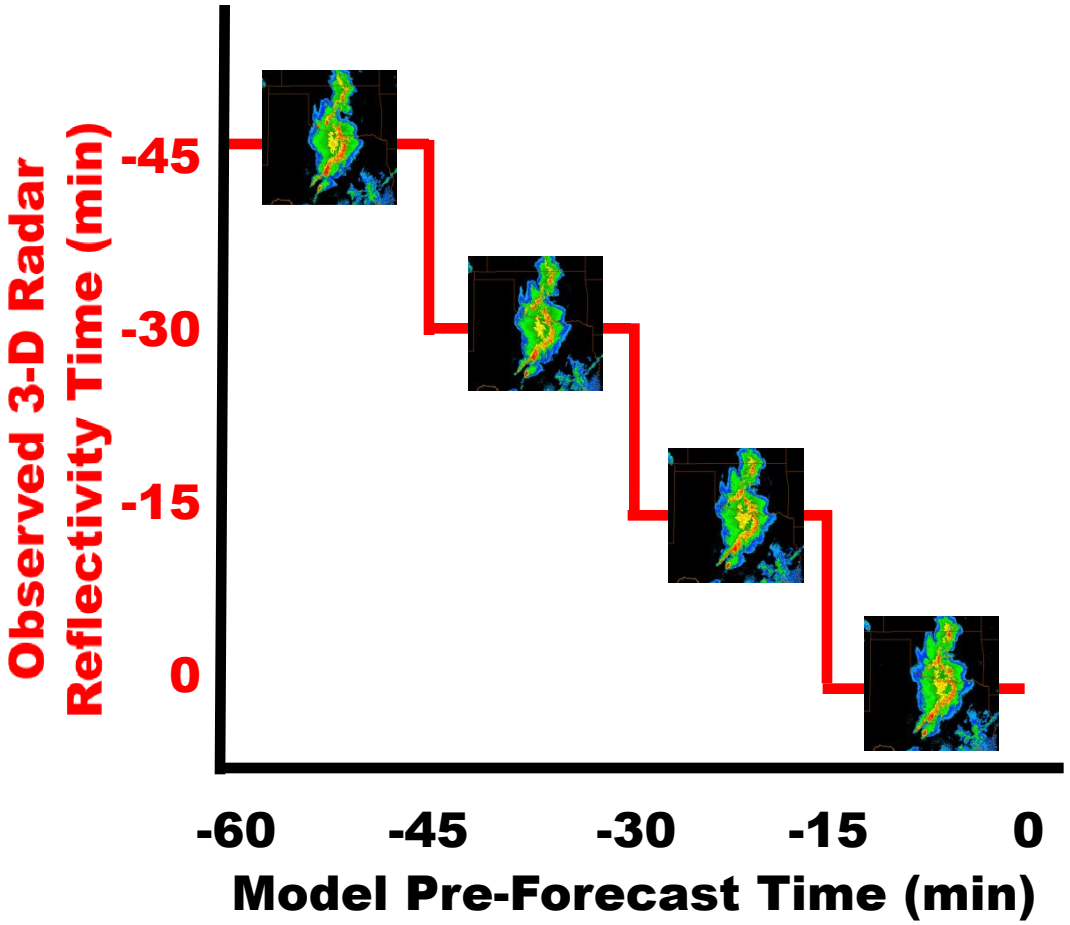
HRRR Pre-Forecast Hour

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 ≥ 28 dBZ over depth ≥ 200 mb (avoids bright banding)**
- **Zero heating rate where obs reflectivity ≤ 0 dBZ**
- **Model microphysics heating rate preserved elsewhere**

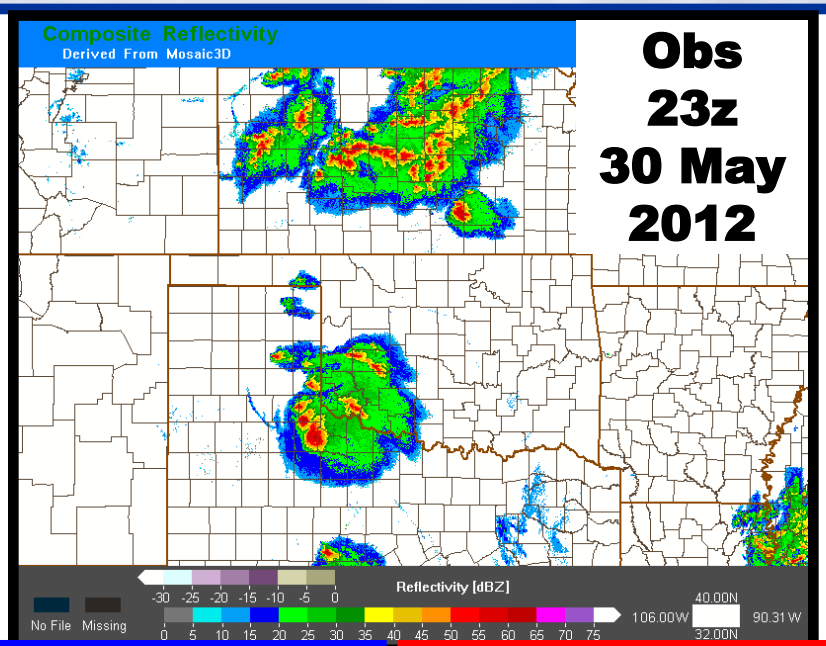
$$LH(i,j,k) = \left(\frac{1000}{p}\right)^{R_d/c_p} \frac{(L_v + L_f)(f[Z_e])}{t * c_p}$$

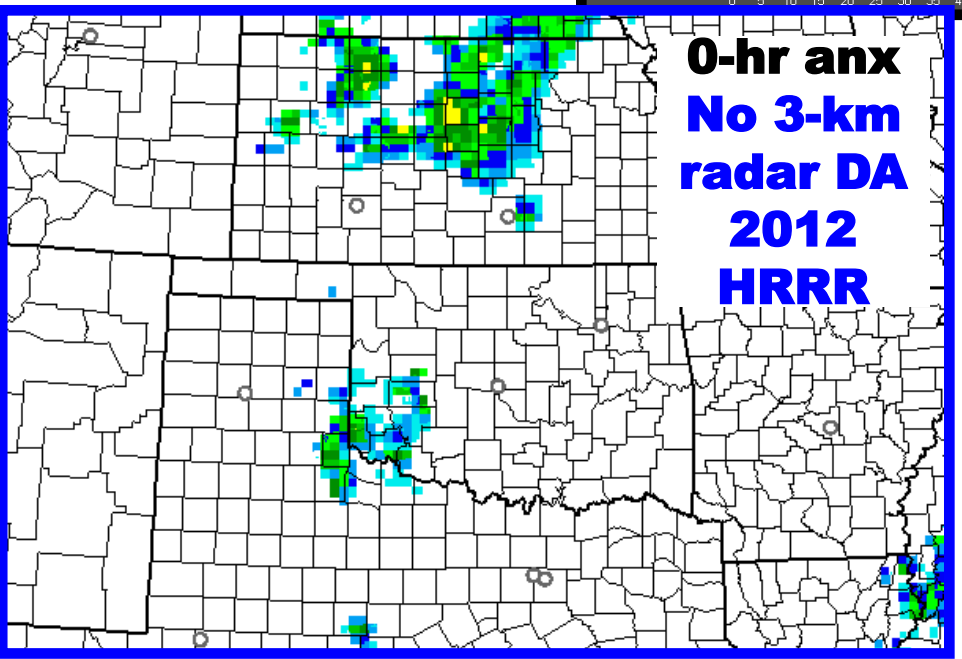
LH = Latent Heating Rate (K/s)
p = Pressure
L_v = Latent heat of vaporization
L_f = Latent heat of fusion
R_d = Dry gas constant
c_p = Specific heat of dry air at constant p
$f[Z_e]$ = Reflectivity factor converted to rain/snow condensate
t = Time period of condensate formation (600s i.e. 10 min)

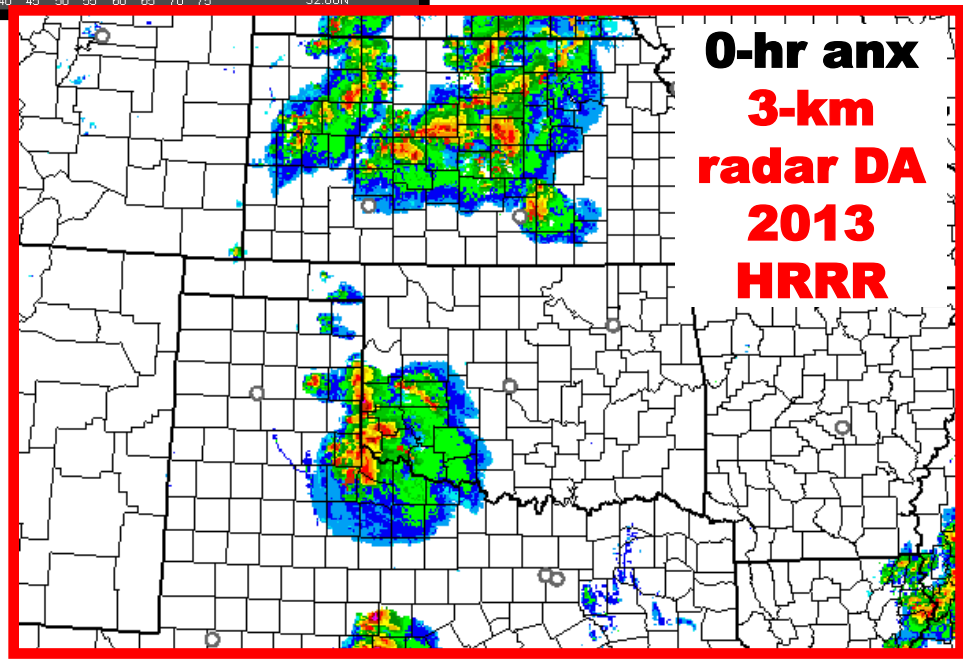


Why use almost 20 minutes to run a 1-hr spin-up?

HRRR 2013 3-km GSI HM Analysis

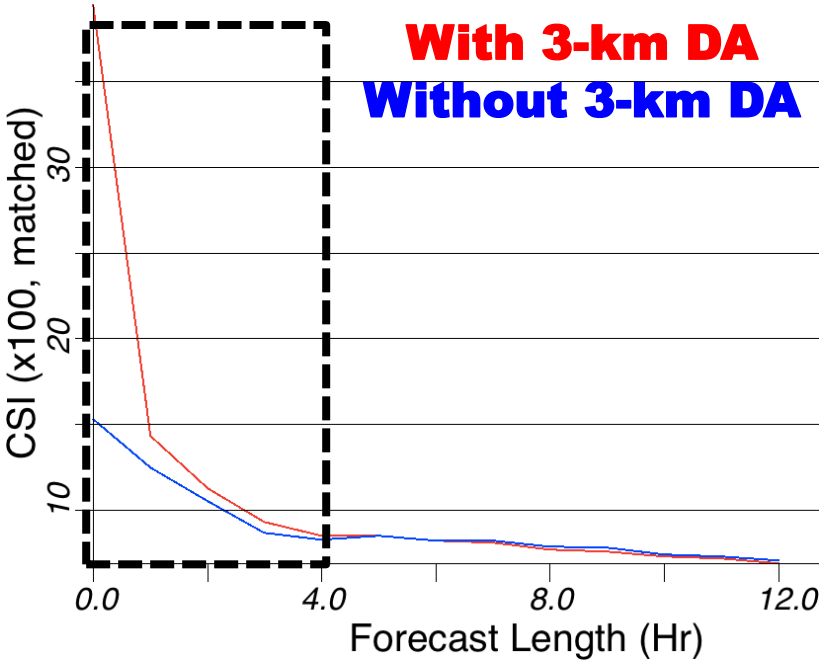


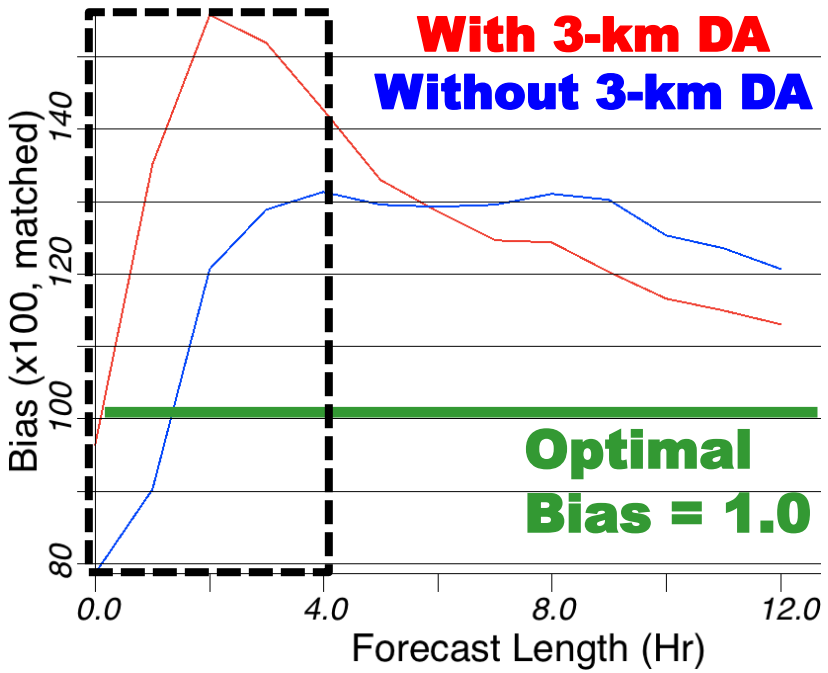




HRRR 2013 3-km GSI Data Assim

Statistical Retrospective Comparison
30 May - 04 June 2012 (55 matched runs)
3-km grid ≥ 35 dBZ
Eastern US





Improved 0-4 hr convection

Structure – Part 2: Forecast and Products

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

RESOURCES – allocated ~80 nodes

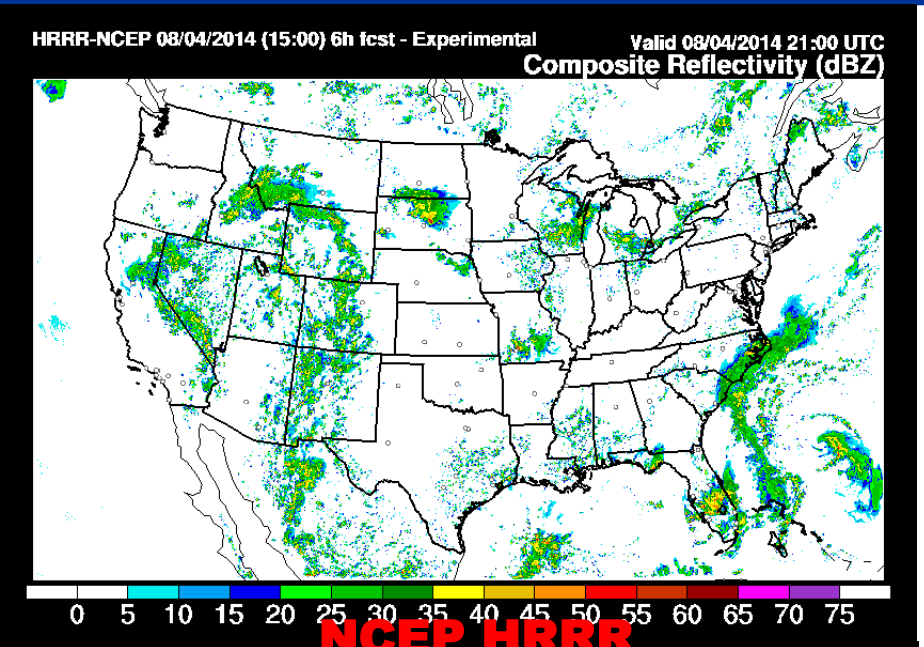
- 15-hr model forecast: 70 nodes
- Simultaneous hourly post-processing: 2 nodes each
- Simultaneous hourly wrfbufr: 1 node each
- Simultaneous sub-hourly post-processing: 2 nodes each
- Sounding post (bufr): 1 node (shared)
- Gempak: 1 node (shared)

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

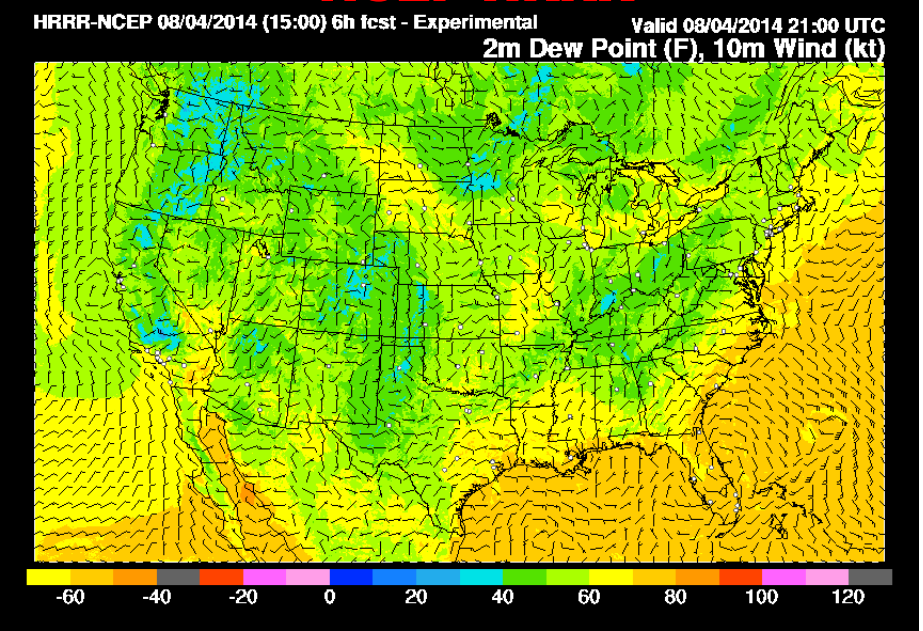
POLICY for “LATE” RUNS

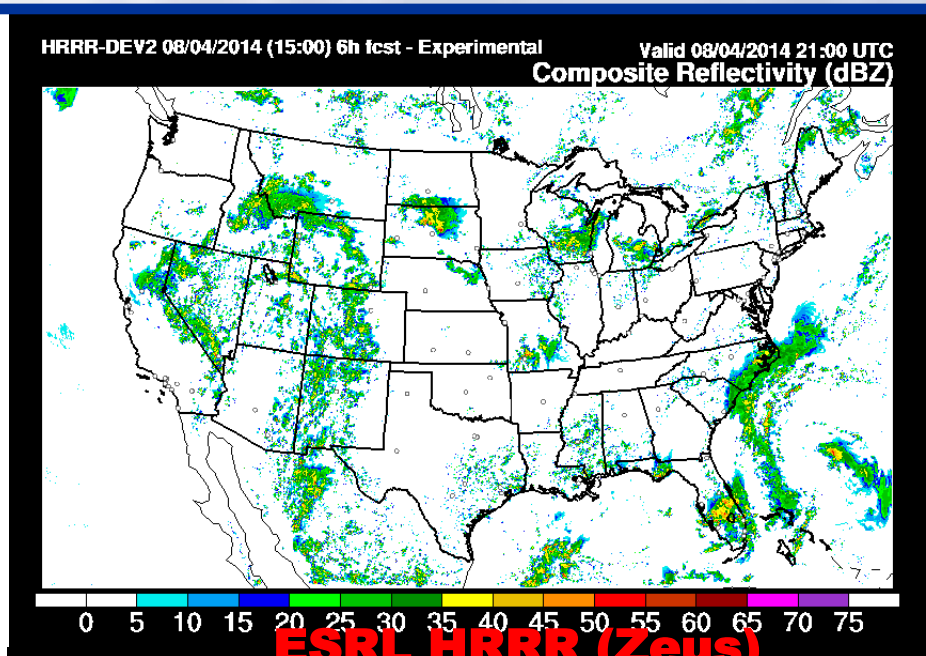
- NCEP HRRR completes in ~63 minutes (forecast job is finished by ~57 minutes)
- By the 66 minute mark, the next hour’s 1-hr spin-up forecast needs all of the nodes
- When the current hour’s spin-up forecast is ready to begin, if the previous hour’s free forecast has not yet reached F14, the current hour’s cycle will be canceled
- This scenario has been rare during testing, occurring only when there are significant system glitches

Validation with ESRL HRRR (Zeus)

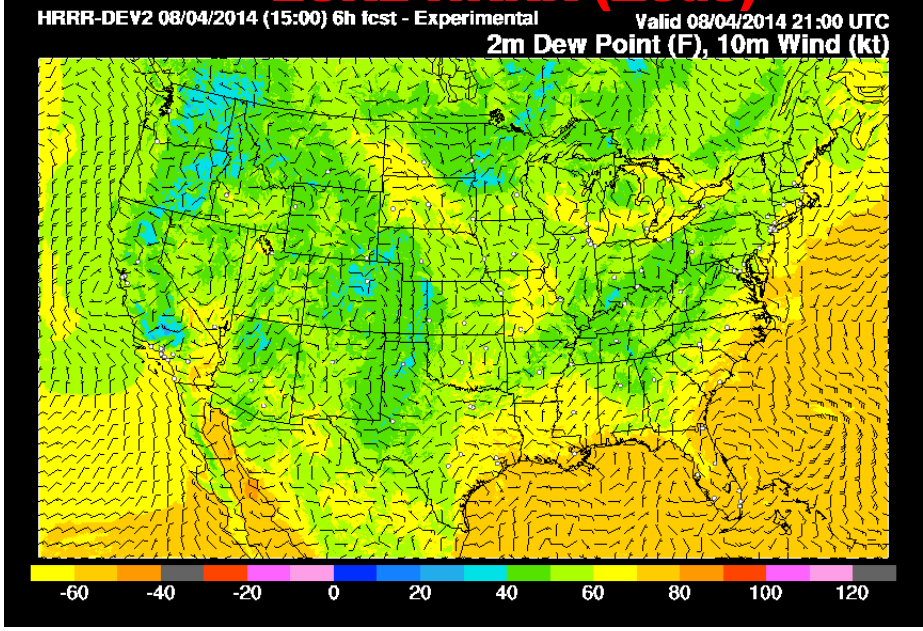


NCEP HRRR





ESRL HRRR (Zeus)



DEPENDENCIES

UPSTREAM: RAP, RAP obs processing, RAP "early" 00/12z obs processing

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

Implementation requires following enhancements:

1. Implementation of corrected g2tmpl library

TIN: Issued 1 August 2014

DEVELOPMENT TESTING

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

PROPOSED EVALUATION TEAM

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

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

PRODUCTS

For each forecast hour (16), generate

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

16.4 GB per cycle / 400 GB per day

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

For every 15 minutes, generate

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

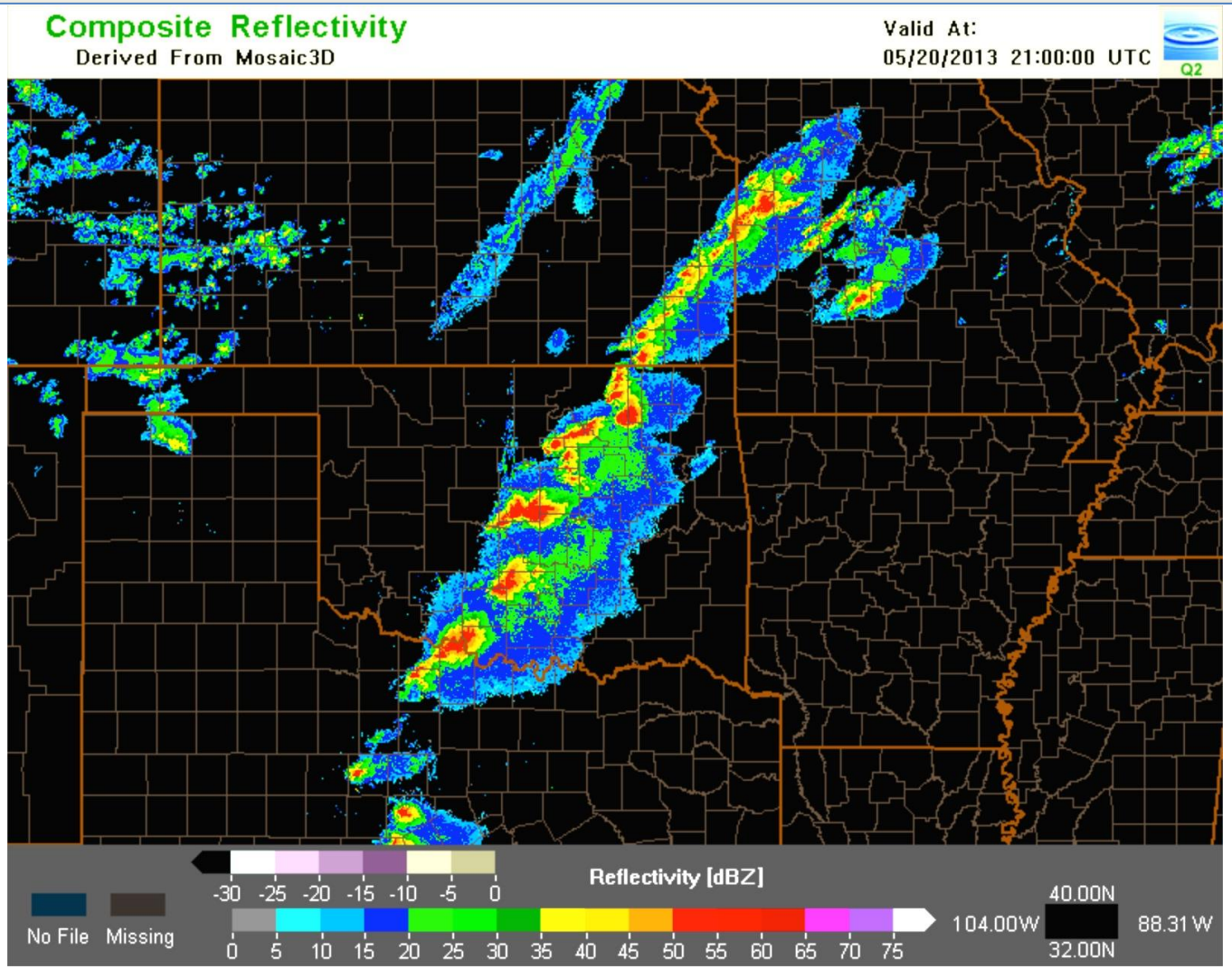
1.05 GB per cycle / 25.2 GB per day

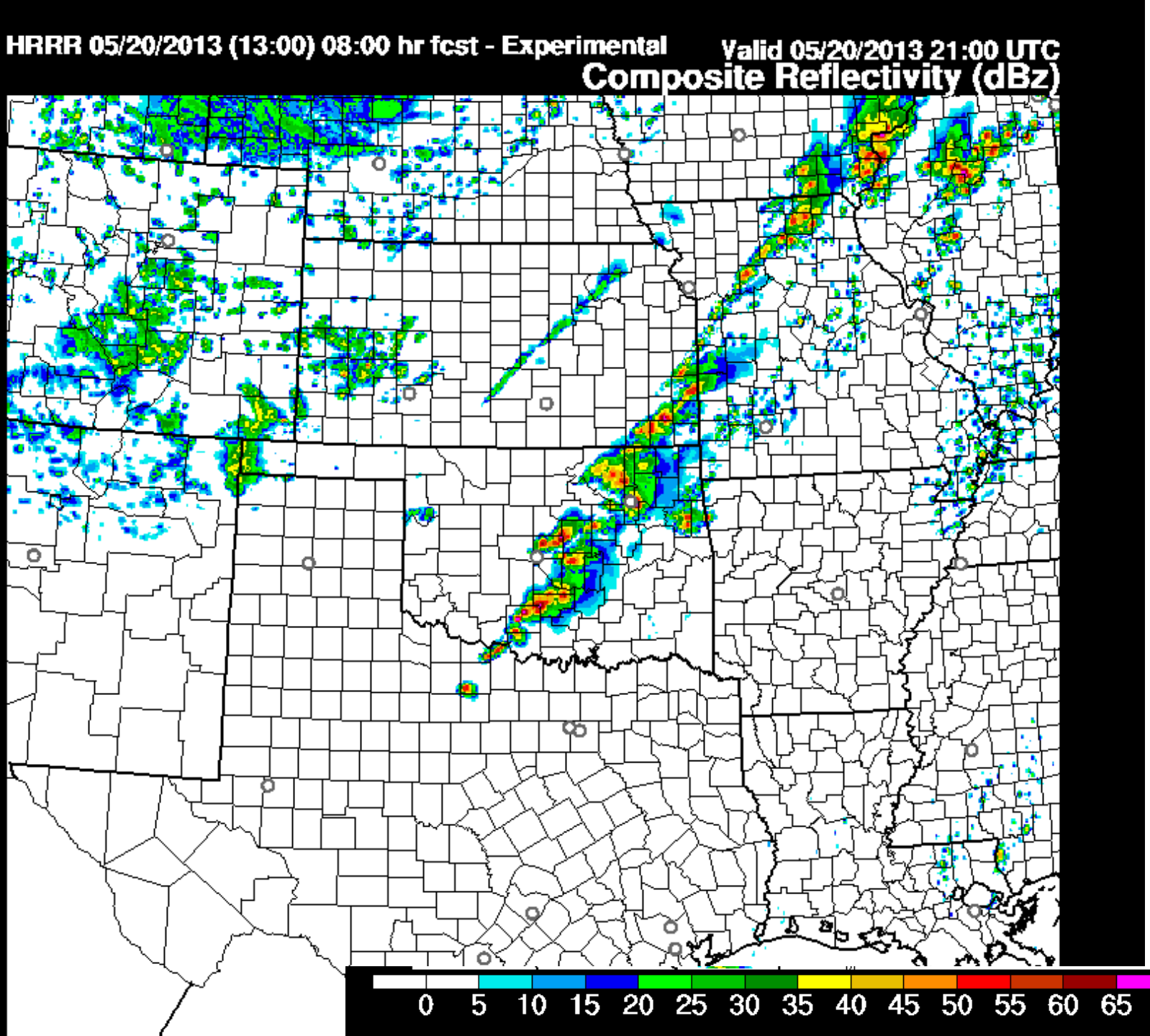
gempak adds 1.14 GB/cycle / 27.4 GB per day

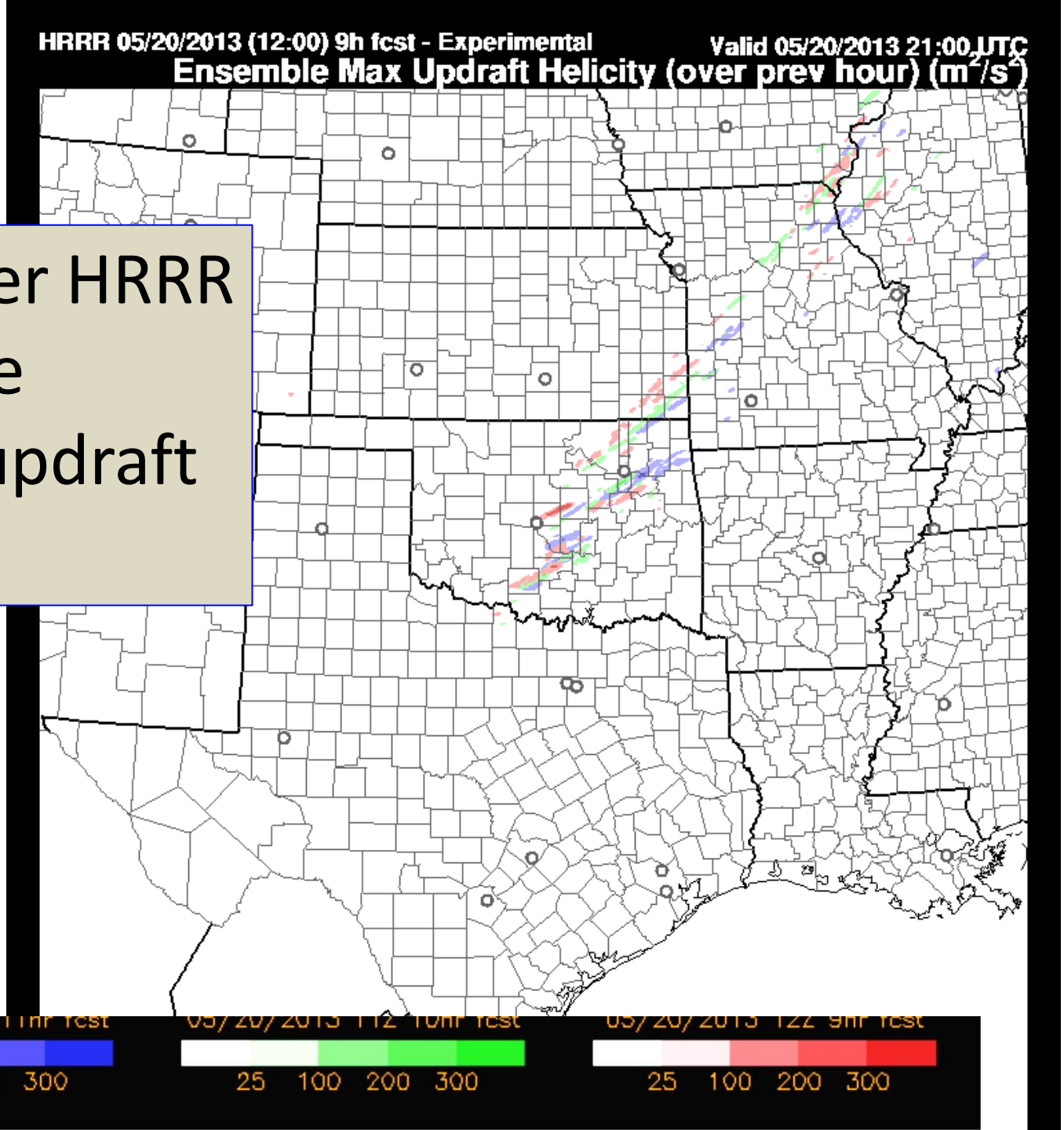
Initial Analysis of Product Volume

Disk Usage	**Current Production**	**Expected New Production**	**Actual New Production**
IBM Disk	-	1.6 TB/day	-
IBM Tape	-	TDB	-
NCEP FTP Server	-	425 GB/day	-
NWS FTP Server	-	Same?	-

Observed radar reflectivity – 2100 UTC 20 May 2013




HRRR 05/20/2013 (13:00) 08:00 hr fcst - Experimental
Valid 05/20/2013 21:00 UTC
Composite Reflectivity (dBz)
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75



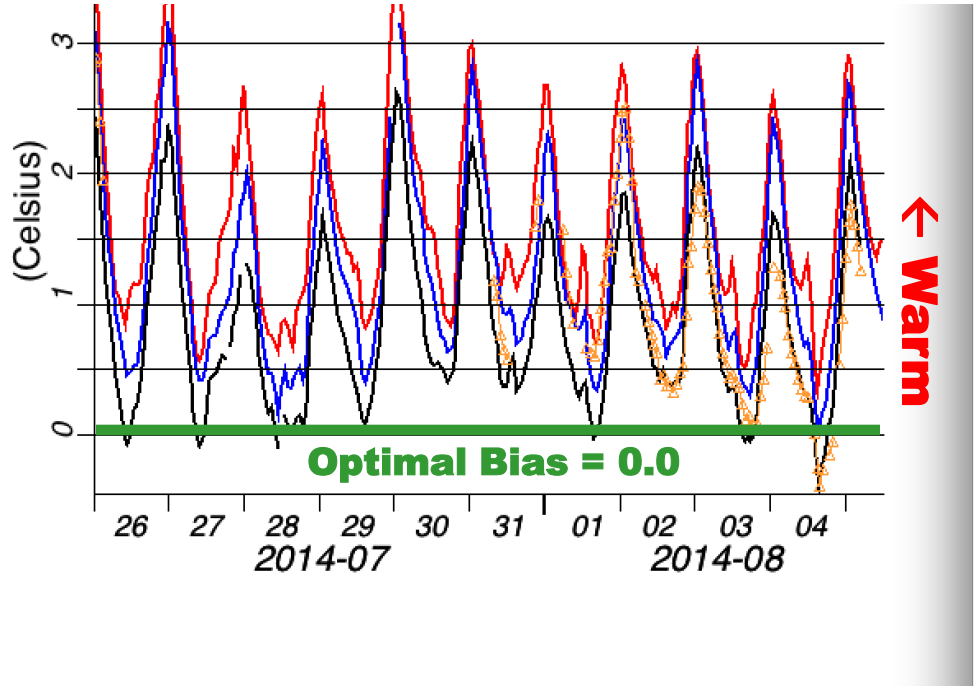
3-member HRRR ensemble
Max 1h updraft helicity

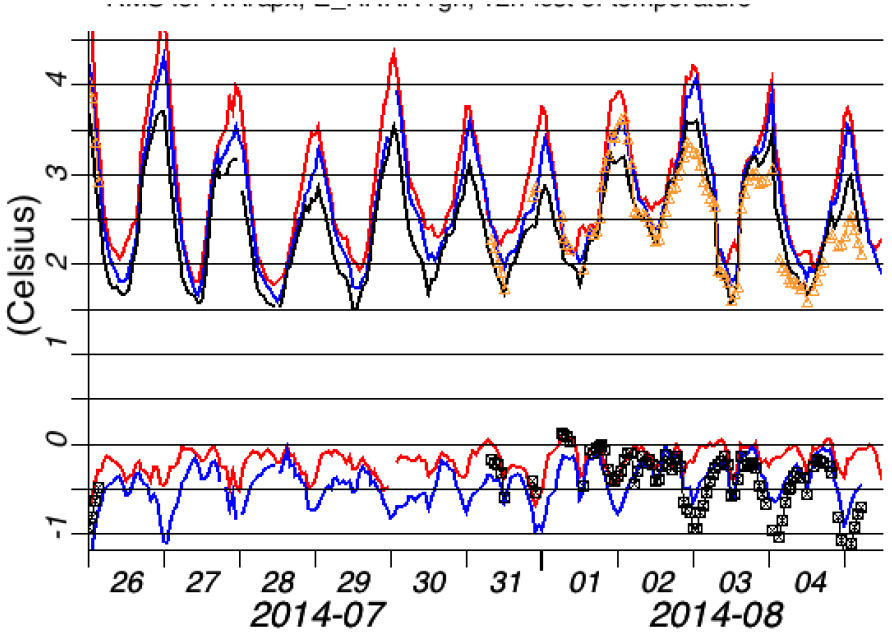
Preview of NCEP RAPv3/HRRRv2

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

BIAS (Forecast – Obs) **RMSE**

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





Preview of NCEP RAPv3/HRRRv2

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

BIAS (Forecast – Obs) **RMSE**

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-- Primary ESRL RAP with initial RAPv3 code
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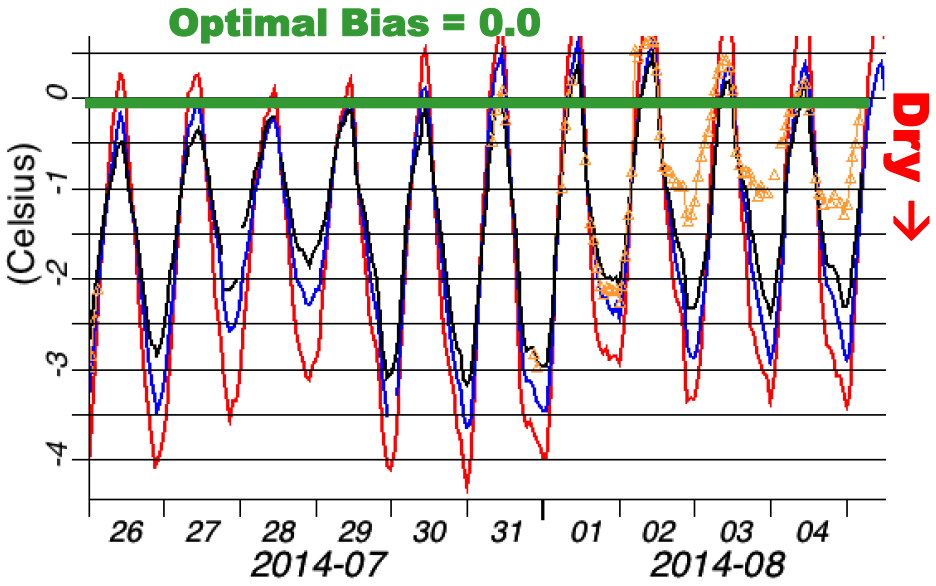

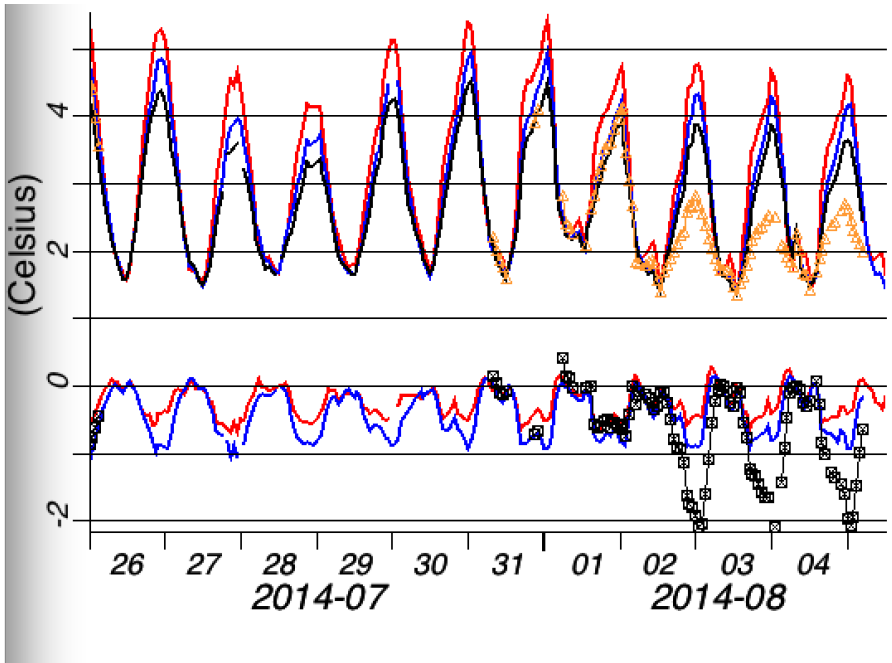

Hi-Resolution Rapid Refresh v1.0.0

Project Status as of 8/6/14

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Project Information and Highlights

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

Scope:

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

Expected Benefits:

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

Y

Scheduling

Milestone (NCEP)	Date	Status
EMC testing complete	6/30/2014	COMPLETED
Final code submitted to NCO	7/7/2014	COMPLETED
Technical Information Notice Issued	8/1/2014	COMPLETED
EMC CCB Approval	8/6/2014	
Parallel testing begun in NCO	7/16/2014	COMPLETED
IT testing begins	8/11/2014	
IT testing ends	8/18/2014	
Real-time evaluation begins	8/11/2014	
Real-time evaluation ends	9/10/2014	
Management Briefing	9/18/2014	
Implementation	9/23/2014	

Y

Issues/Risks

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

G

Finances

Associated Costs:

Funding Sources:

R Management Attention Required	Y Potential Management Attention Needed	G On Target