HIGH-RESOLUTION RAPID REFRESH (HRRR) Initial Implementation V1.0.4

Briefing to NCEP Director

September 22, 2014

Presented by: Geoff Manikin EMC

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Jim Taft, Jim Abeles IBM

Charter Overview

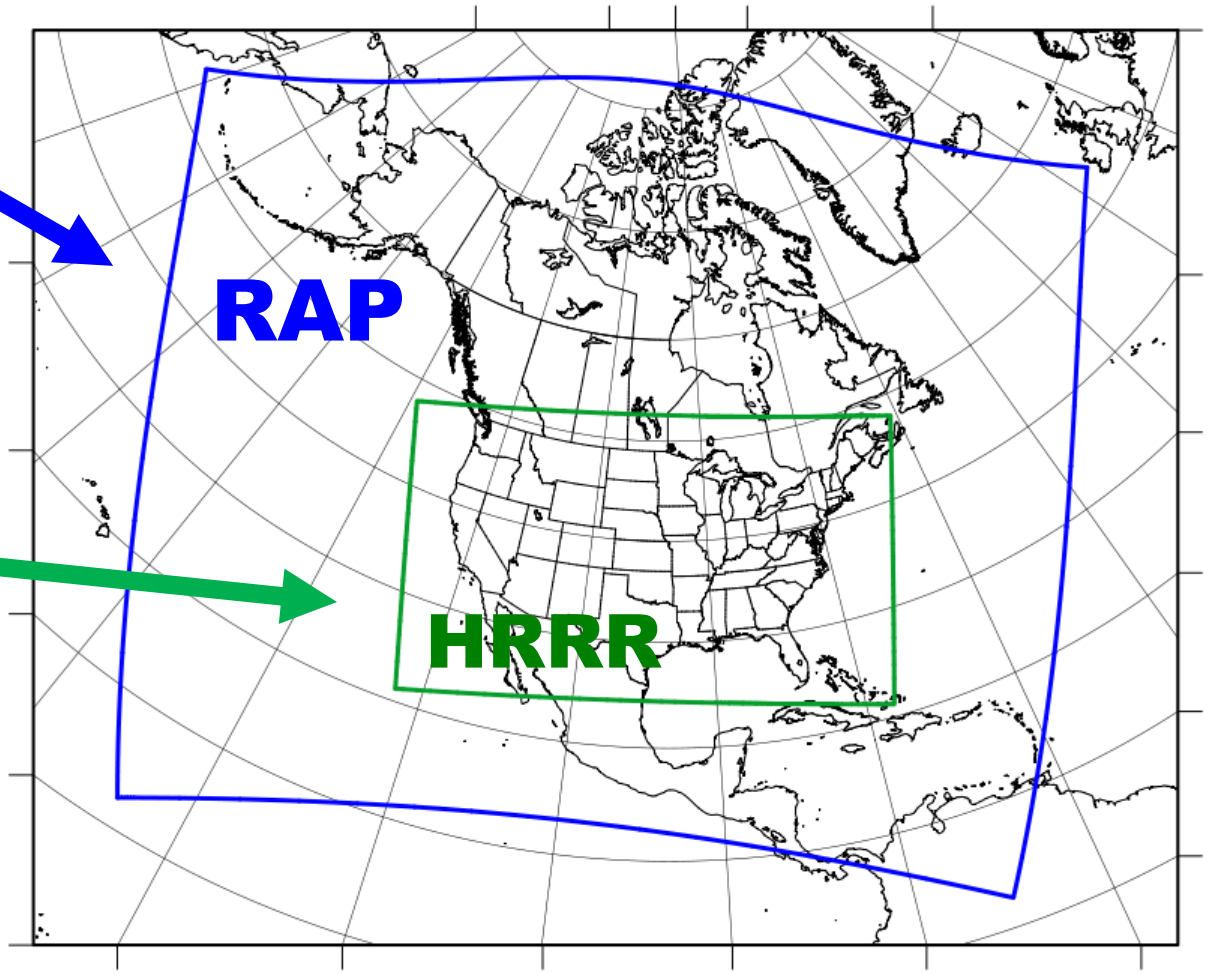
- **This project is an NWS and NCEP Annual Operating Plan (AOP) milestone for Q4 FY2014**
- **Implementation scheduled for 30 September 2014**
- **Hi-Res Rapid Refresh description**
  - **Used by SPC, AWC, WPC, FAA, NWS offices and others for detailed short-range forecasts, especially convective evolution**
  - **24 cycles/day – each run out to 15 hours**
  - **Each run is independent**

Rapid Refresh and HRRR
NOAA hourly updated models

13km Rapid Refresh (RAP)
(mesoscale)

V2 in ops: 2/25/14

3km HRRR
(storm-scale)

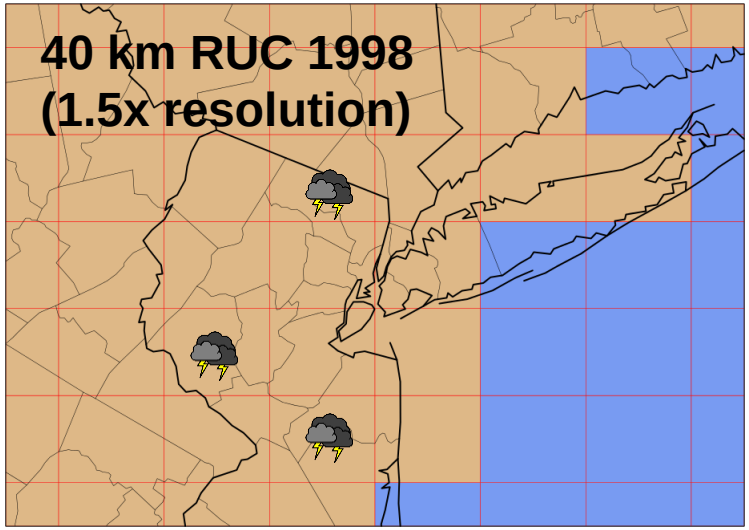


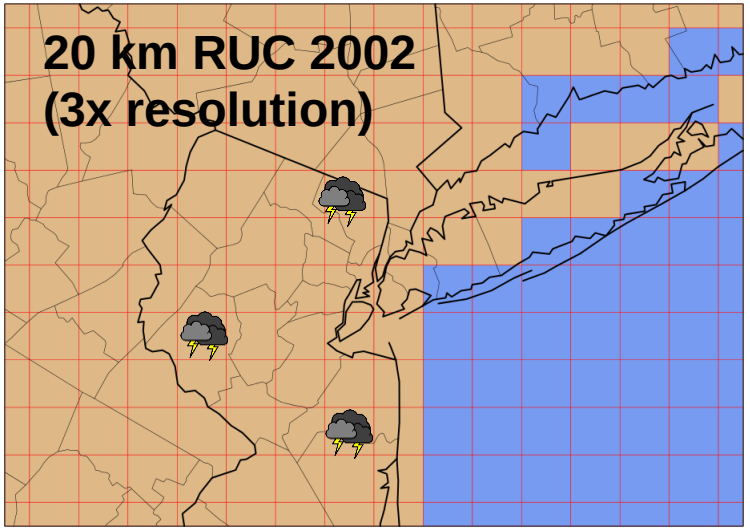
High-Resolution Rapid Refresh
Scheduled NCEP Implementation Sept 2014

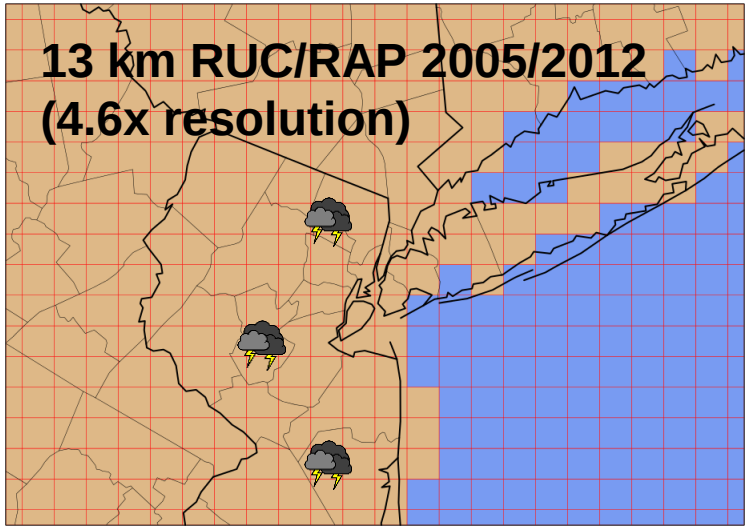
We have the RAP – why do need the HRRR?

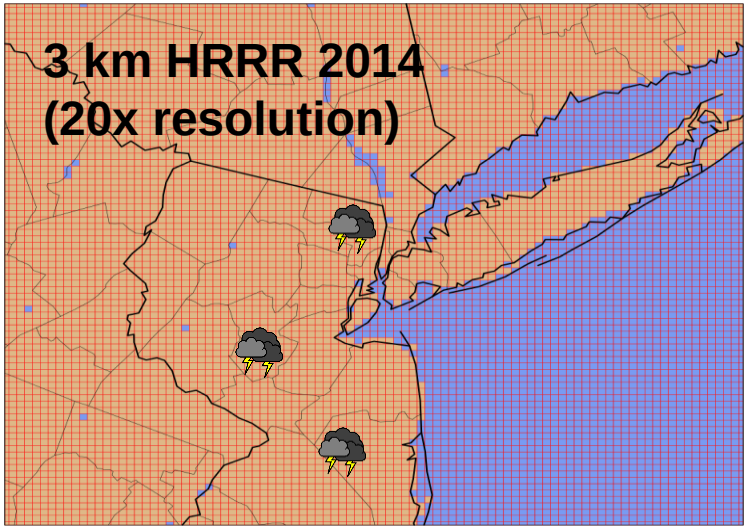
- Increased resolution of basic fields like temperatures/winds/visibility, etc to resolve mesoscale features
- Explicitly allows convection, allowing for storm-scale structure; shows skill at predicting storms with strong rotation, bow echoes, etc.
- Provides hourly updates at high resolution
- Will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

High Impact Prediction Needs: Higher Resolution Models

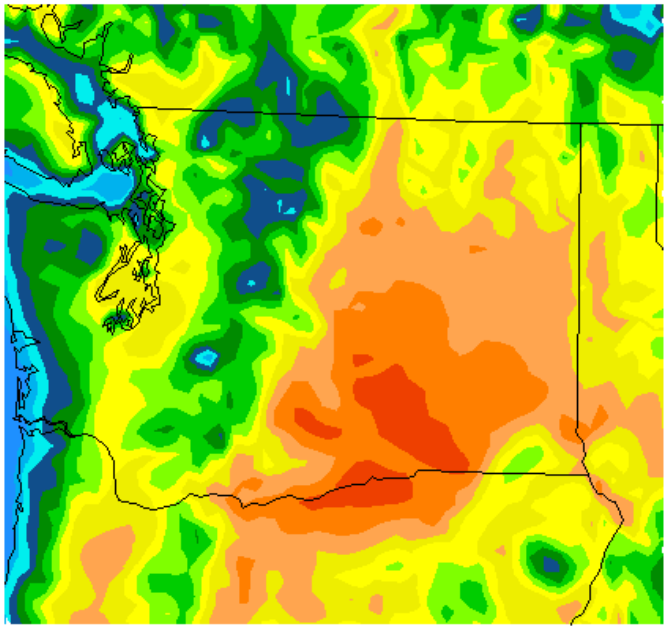


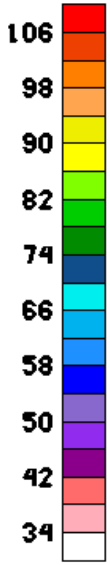




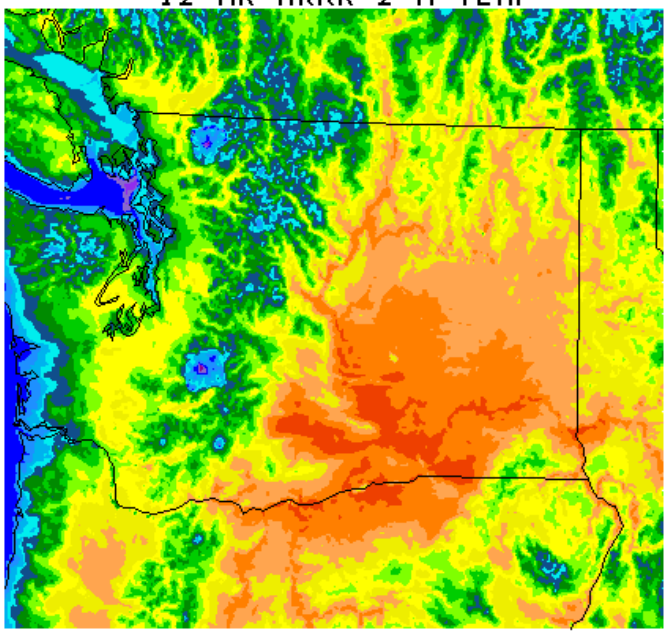


12-HR RAP 2-M TEMP

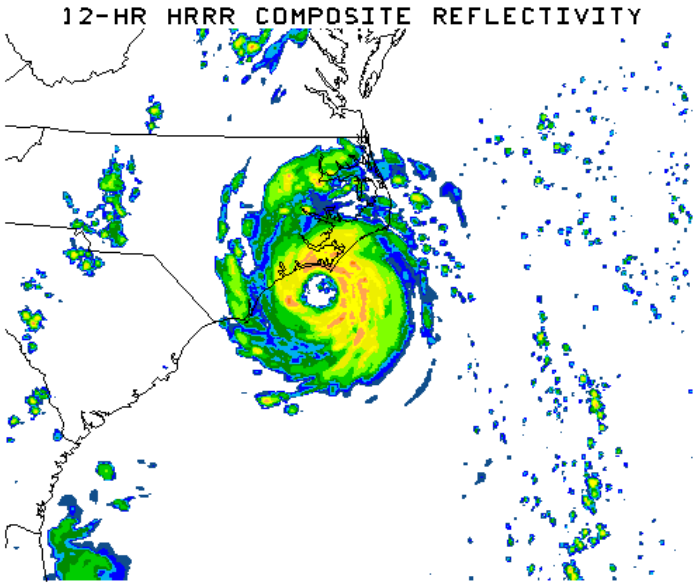


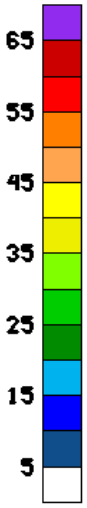


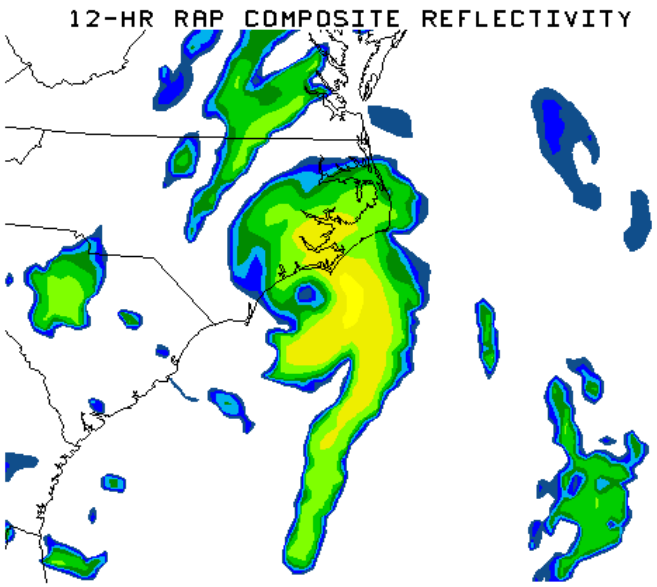
12-HR HRRR 2-M TEMP

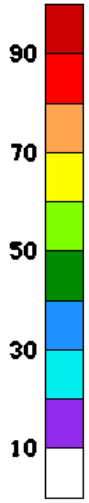


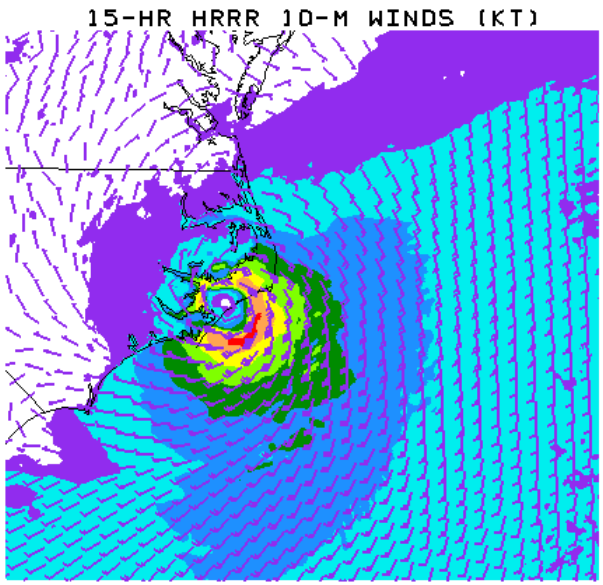
Hurricane Arthur



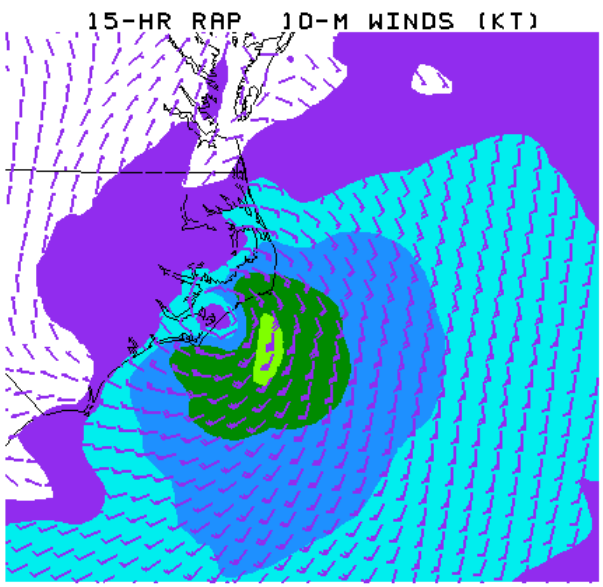








FCST MADE 15Z 07/03

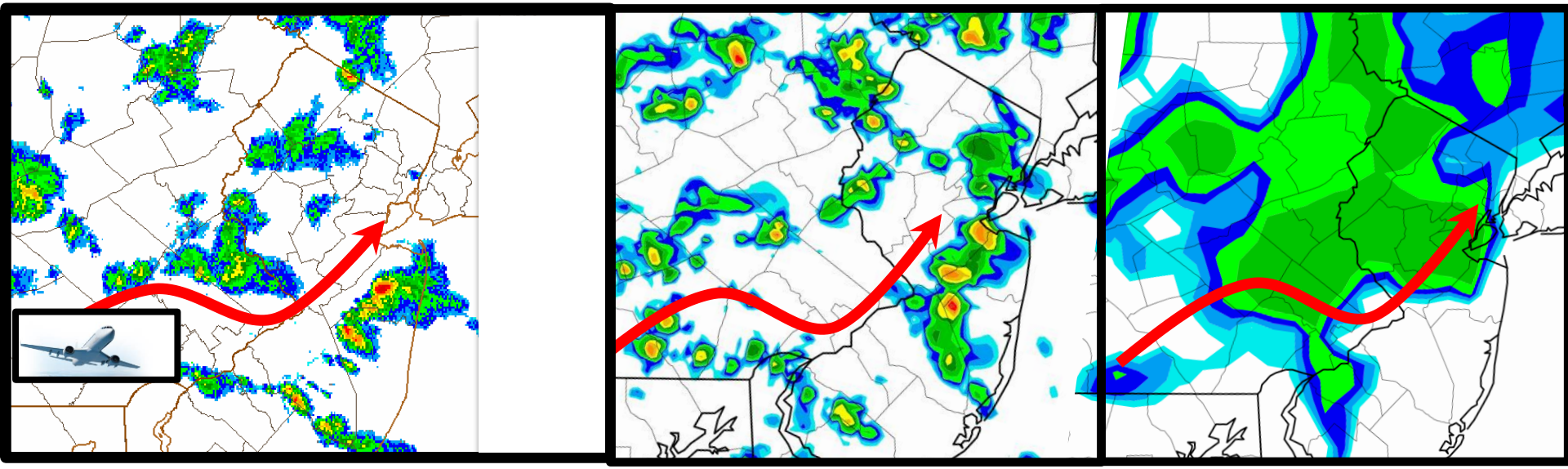


High Impact Prediction Needs: Higher Resolution Models

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

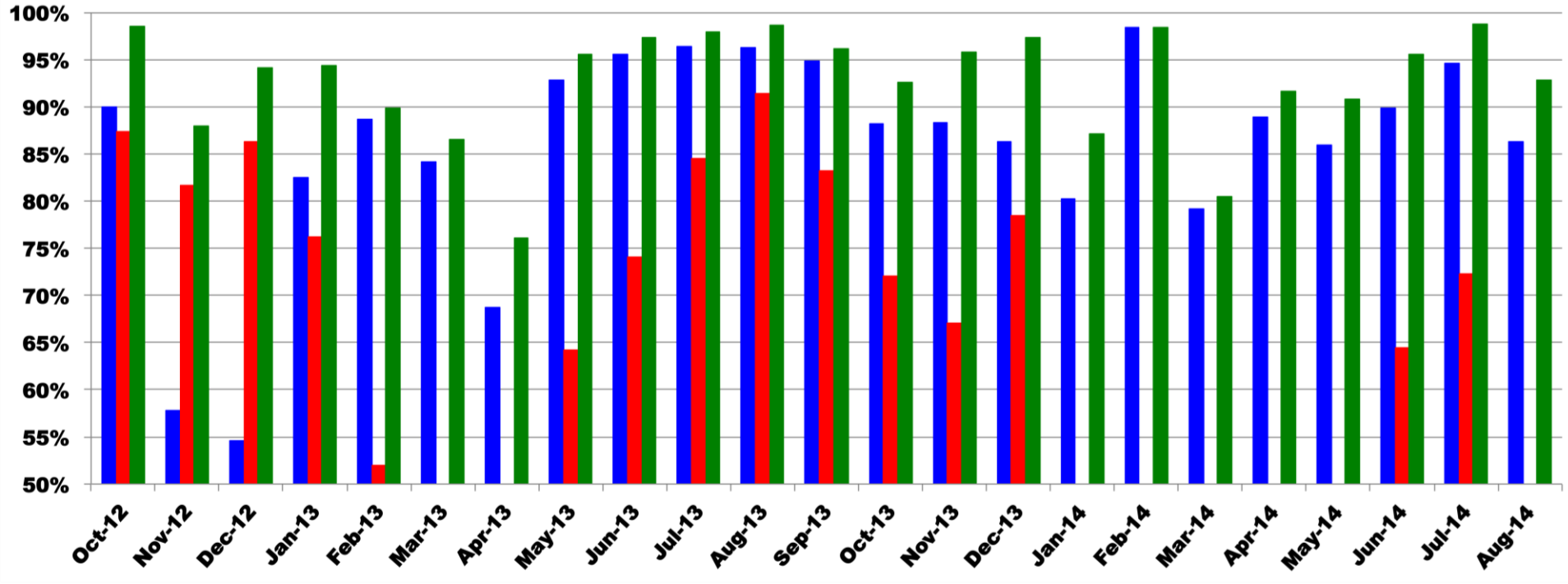
No Estimate of Permeability

Why run the HRRR at NCEP?

- GSD version has a significant time lag – often completes over 2 hours after the synoptic start time; NCEP HRRR F00 files 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 and/or zeus outages
- GSD can put more time into model development instead of maintaining HRRR data feed and web site graphics
- Generate 1st guess files for RTMA/URMA
- Become part of the forthcoming HRRRE
- Generate bufr and gempak data
- Get data into AWIPS

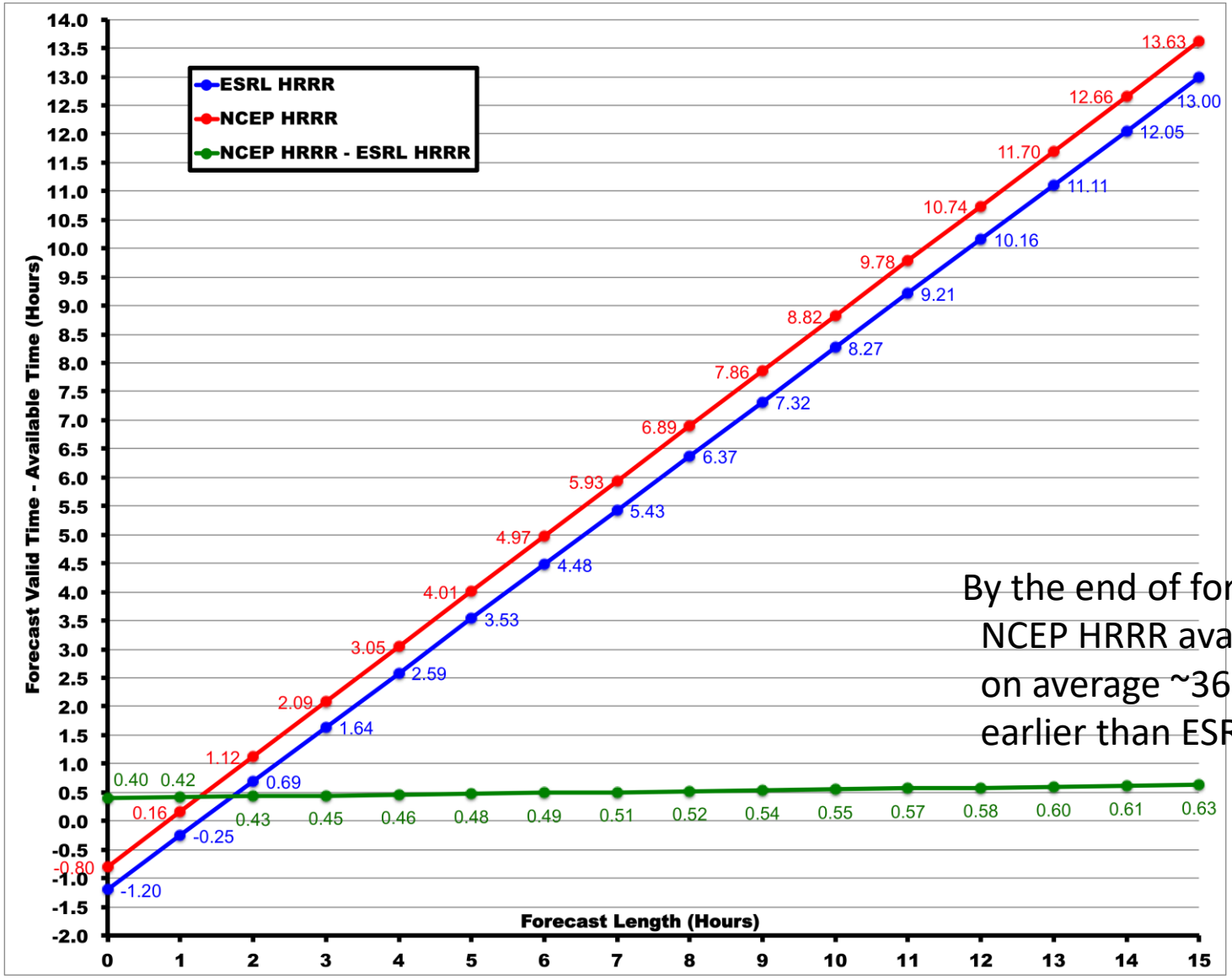
HRRR Availability

HRRR 12 hr fcst availability
Includes all missed/incomplete runs



Jet (HRRR primary) Zeus (HRRR backup) Union

HRRR Forecast Latency

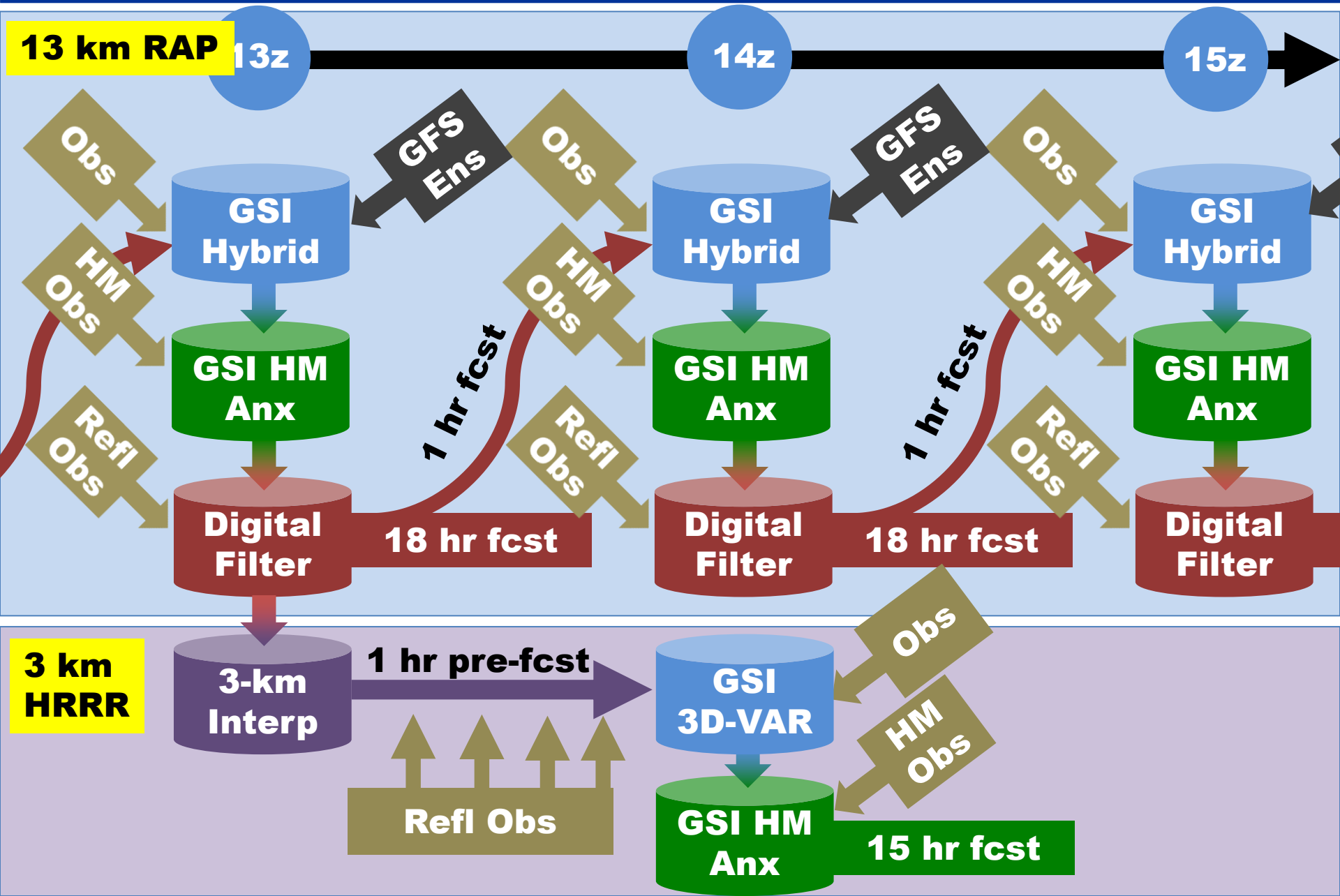


By the end of forecast, NCEP HRRR available on average ~36 min earlier than ESRL HRRR

HRRR Basic Overview

- Runs every hour (24/day) – no cycling
- 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



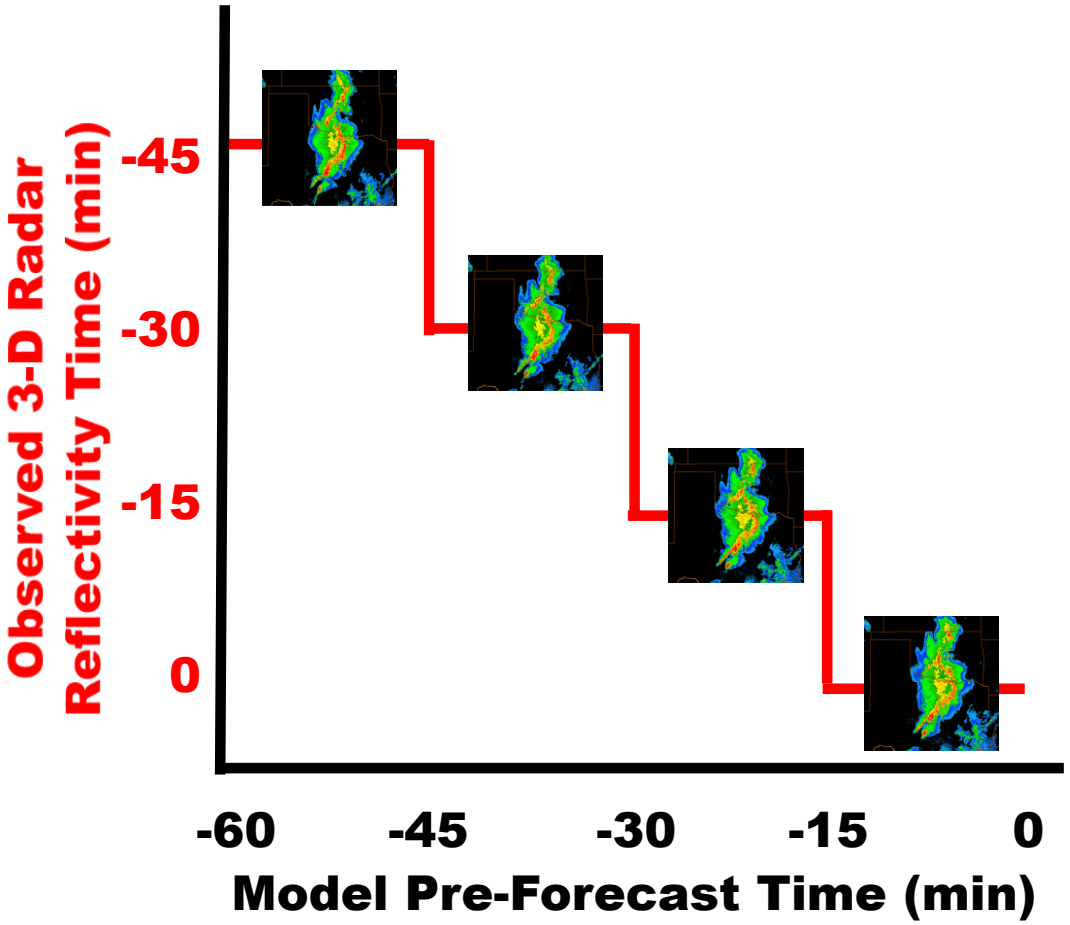
HRRR Pre-Forecast Hour

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**

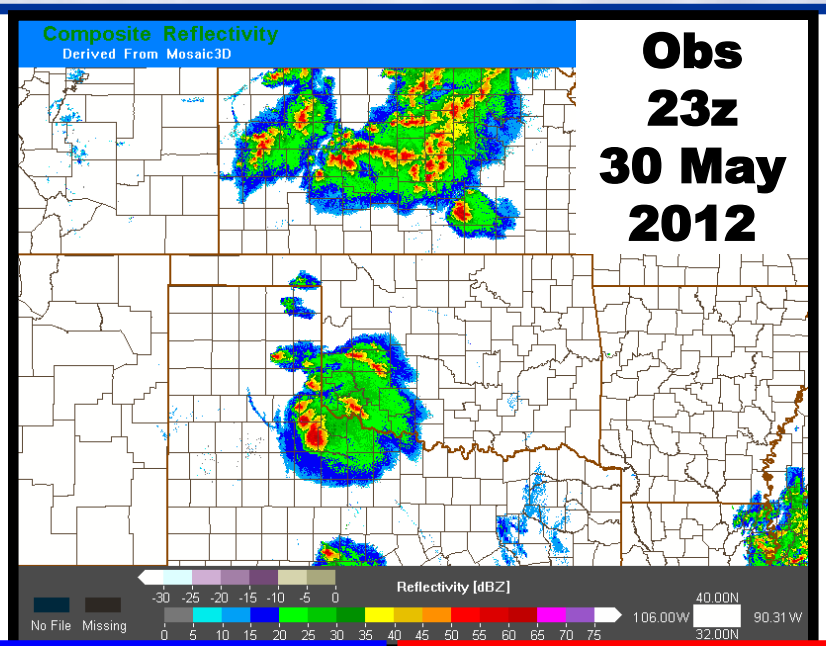
$$LH(i,j,k) = \left(\frac{1000}{p}\right)^{R_d/c_p} \frac{(L_v + L_f)(f[Z_e])}{t * c_p}$$

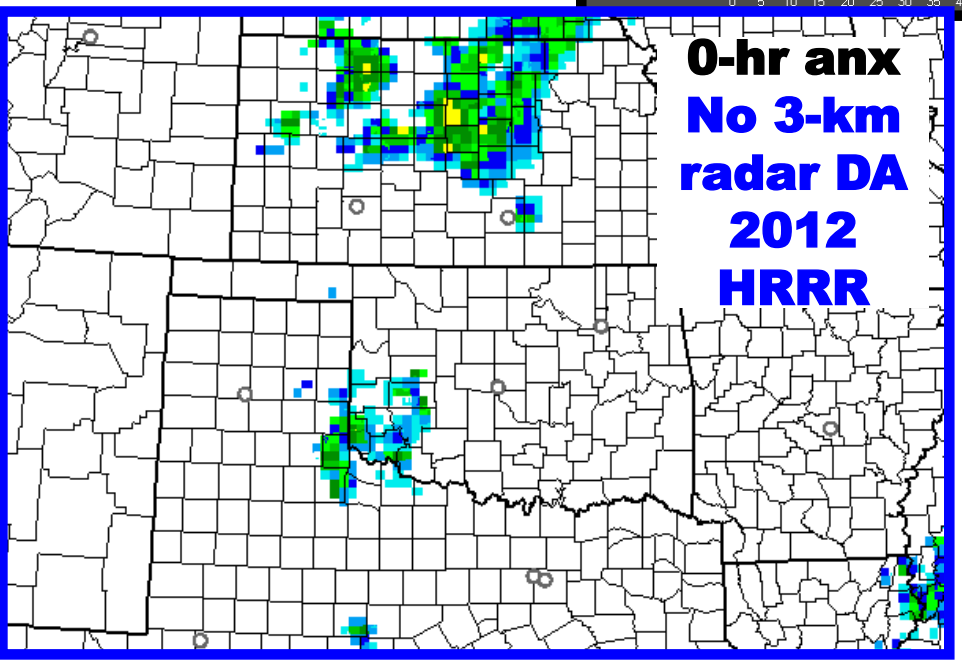
LH = Latent Heating Rate (K/s)
p = Pressure
L_v = Latent heat of vaporization
L_f = Latent heat of fusion
R_d = Dry gas constant
c_p = Specific heat of dry air at constant p
$f[Z_e]$ = Reflectivity factor converted to rain/snow condensate
t = Time period of condensate formation (1200s i.e. 20 min)

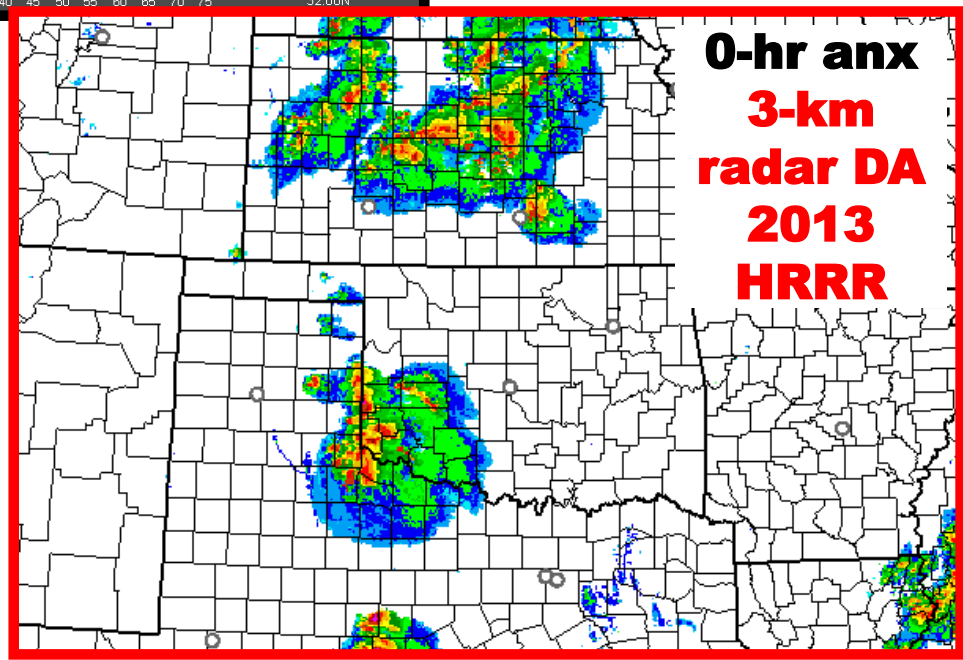


Why use almost 20 minutes to run a 1-hr spin-up?

HRRR 2013 3-km GSI HM Analysis







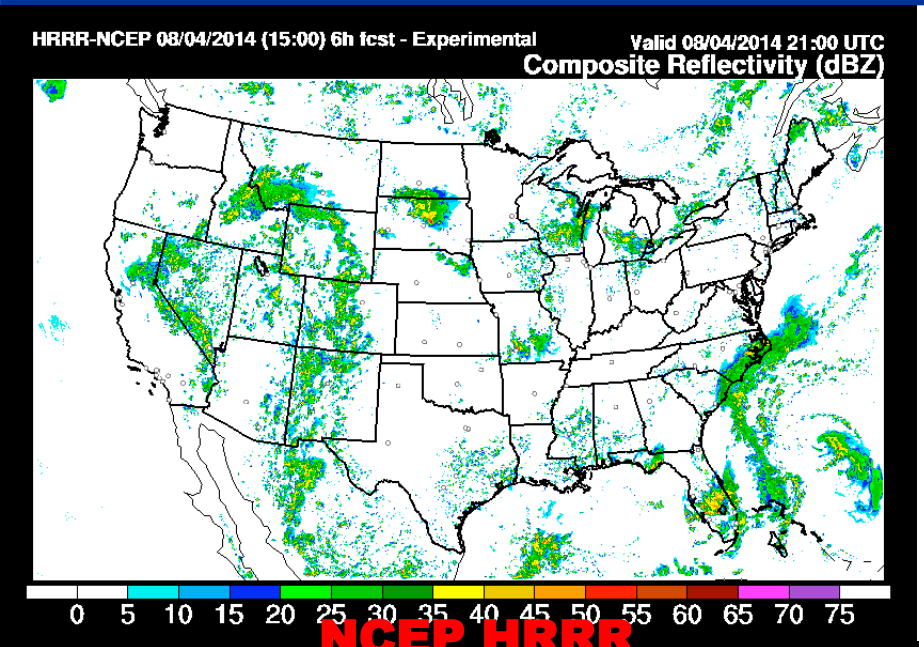
POLICY for “LATE” RUNS

- 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

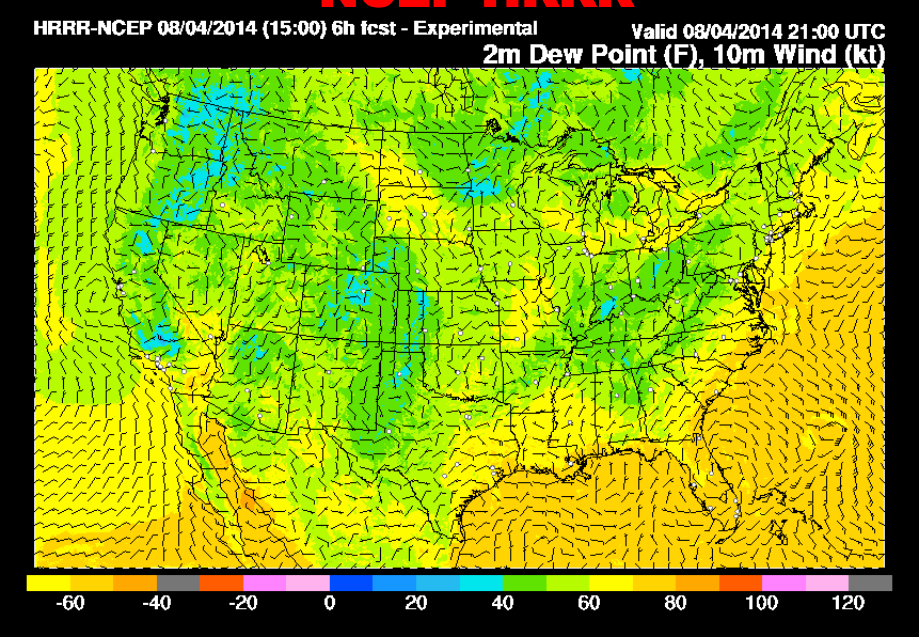
DEVELOPMENT TESTING

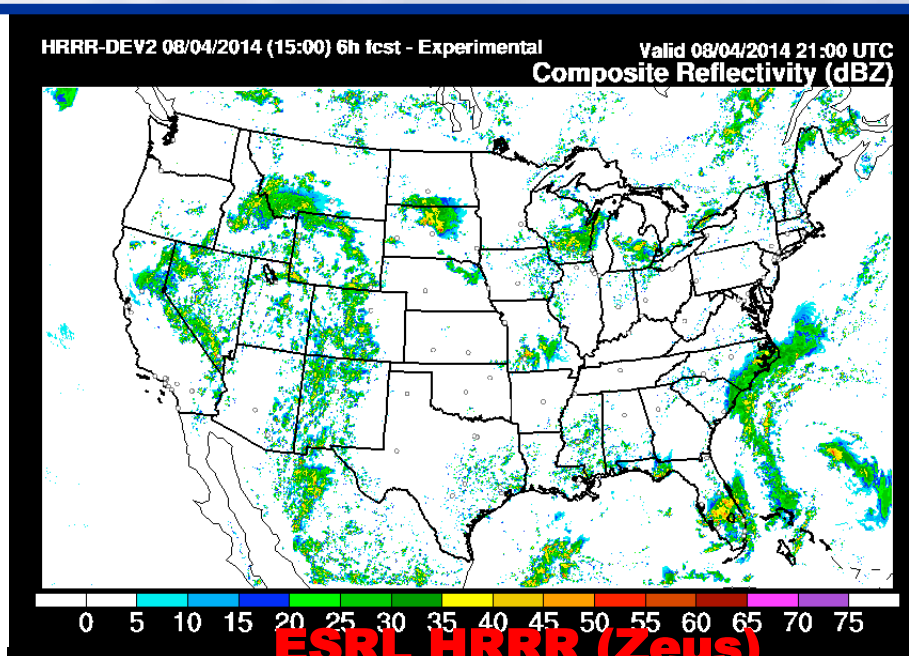
- **CONUS HRRR run at GSD for 4+ years**
- **Built at EMC Jan-May 2014 – significant work required to get entire cycle to fit on WCOSS**
- **Using 2013 version except for bug fix to address cold bias over snow pack**
- **Issue with discontinuity involving terrain at boundaries resolved in early July**
- **Only other crashes were caused by configuration settings suggested by IBM – were able to speed up forecast by 3 minutes, but occasional crashes occurred, so these settings were omitted**
- **NCO parallel running stably since early July – only changes since have been to post-processing or script clean-ups or functionality enhancements, except for correction to analysis of 2-m dew points in early August**

Validation with ESRL HRRR (Zeus)

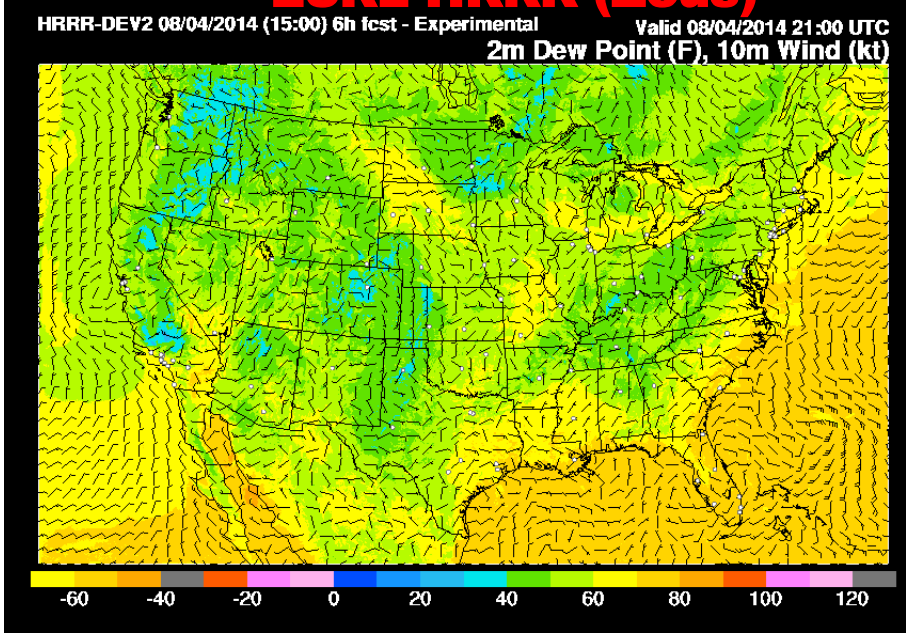


NCEP HRRR





ESRL HRRR (Zeus)



NCO/EMC Synergy

- There was no way to run an hourly cycle requiring 70+ nodes in development queues
- NCO agreed to build a HRRR parallel on-the-fly so that “EMC testing” could be performed in the operational environment
- Many thanks to NCO SPA Jen Yang who dealt with frequent code/script updates and helped build a more robust configuration
- This is a great and necessary method to test parallels with large resource requirements, and EMC / GSD thank NCO for working with us to make it happen

PRODUCTS

For each forecast hour (16), generate

- 3 km file with data on pressure levels
- 3 km file with data on native levels
- 3 km file with mostly 2-D (surface) data
- 2.5 km NDFD file for AWIPS and 2.5 km “smartinit” file for RTMA/URMA
- gempak file generated from “surface” data file

Also generate bufr sounding file with all 16 forecast hours

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
- Cat 15/30/45/60 past hour into a single file
- gempak file

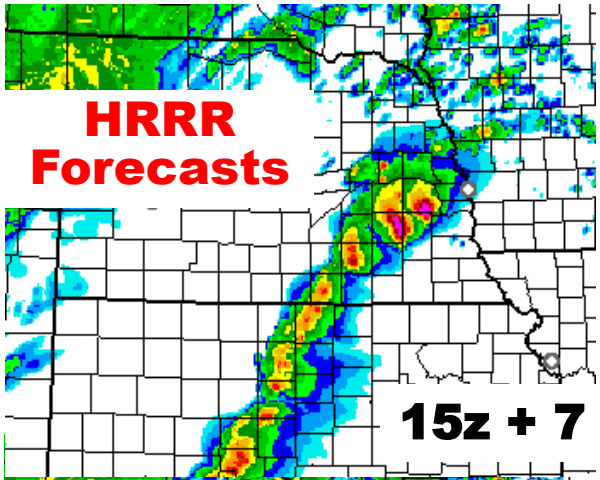
1.05 GB per cycle / 25.2 GB per day
gempak adds 1.14 GB/cycle / 27.4 GB per day

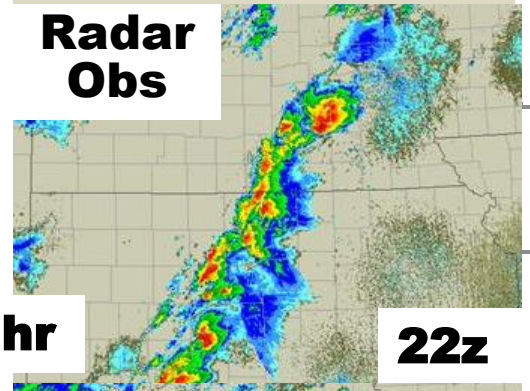
SOME RECENT CASES

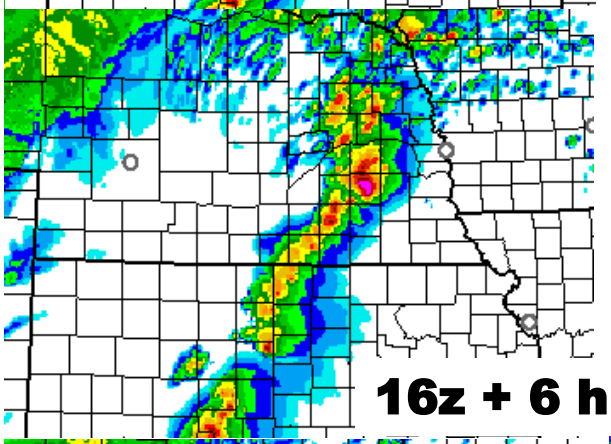
11 May 2014

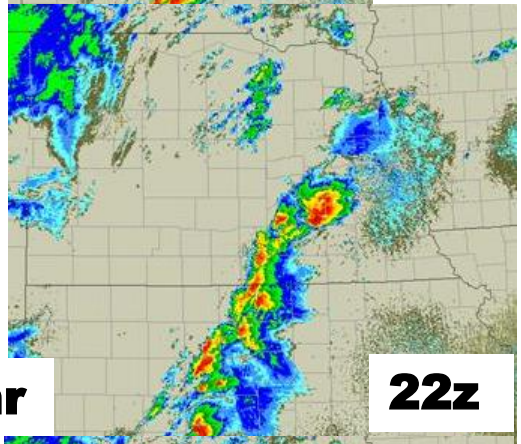
HRRR Forecasts

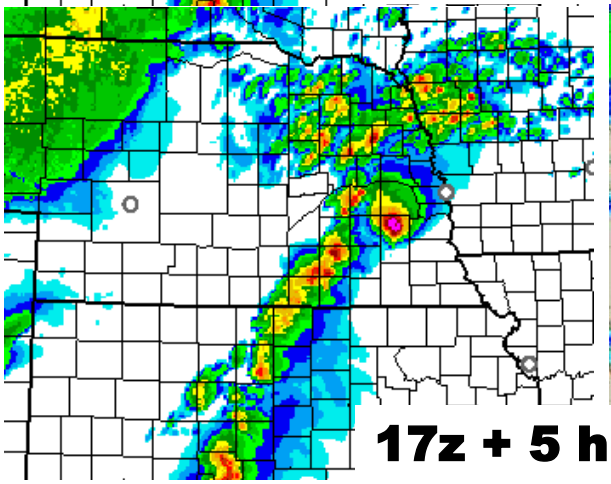
Radar Obs

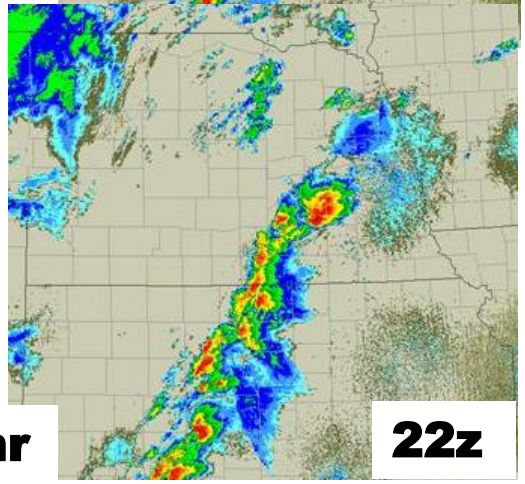




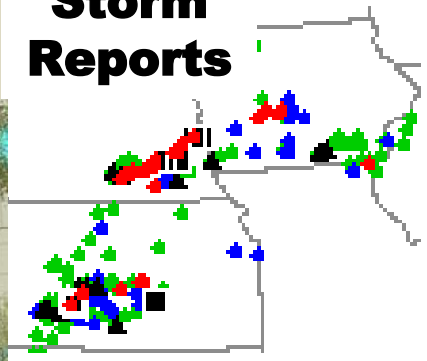








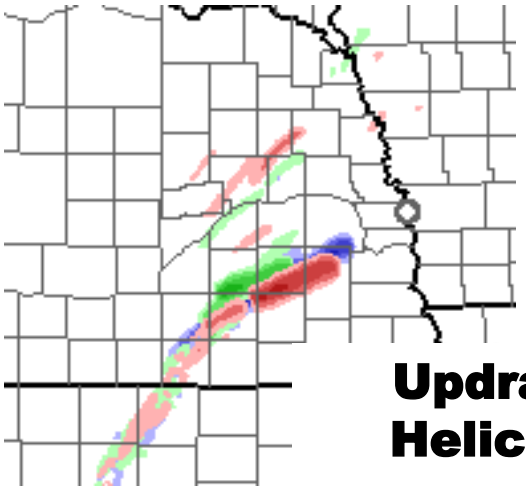
Storm Reports



Hourly Runs

Frequent Measure of Run-To-Run Consistency

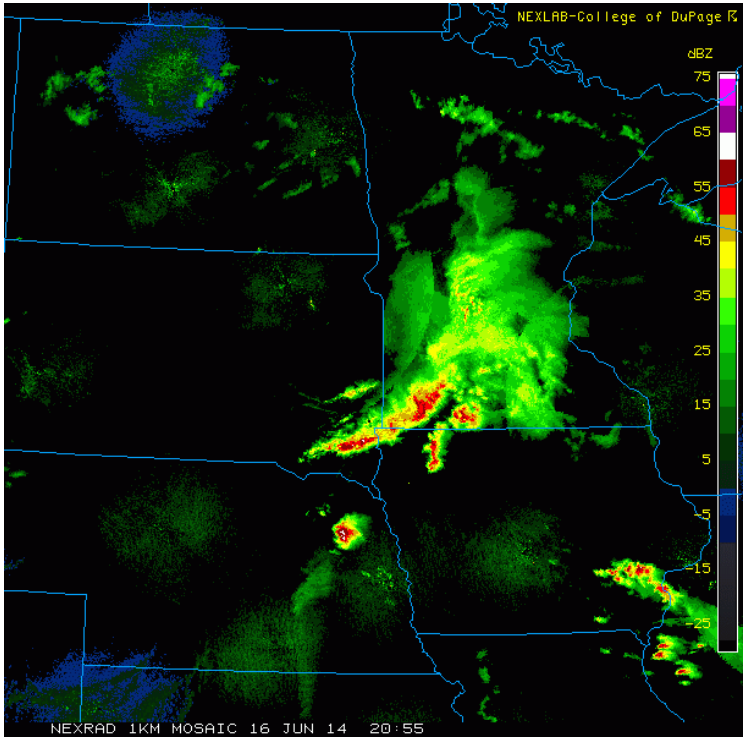
Can Provide Forecaster Confidence



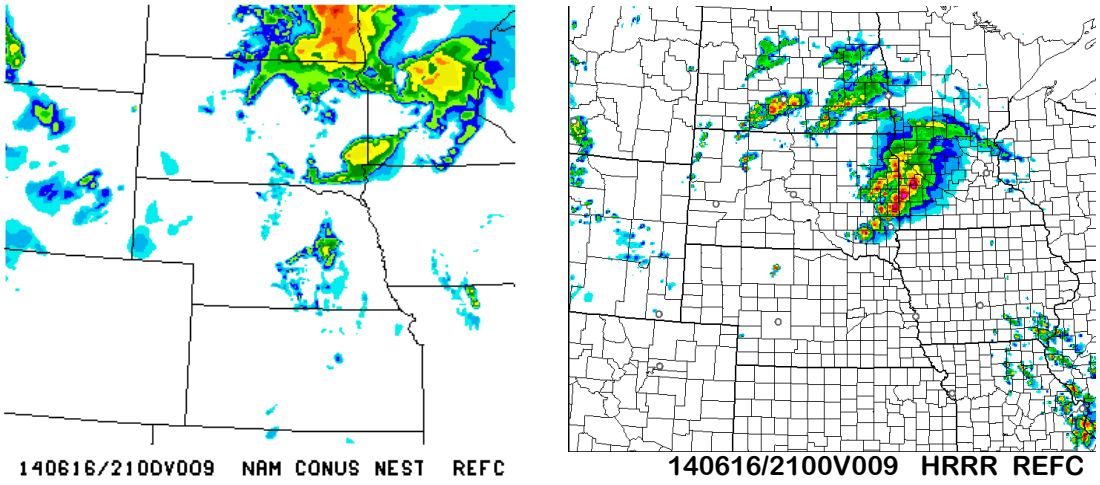
Updraft Helicity

Three Run Time-Lagged Ensemble

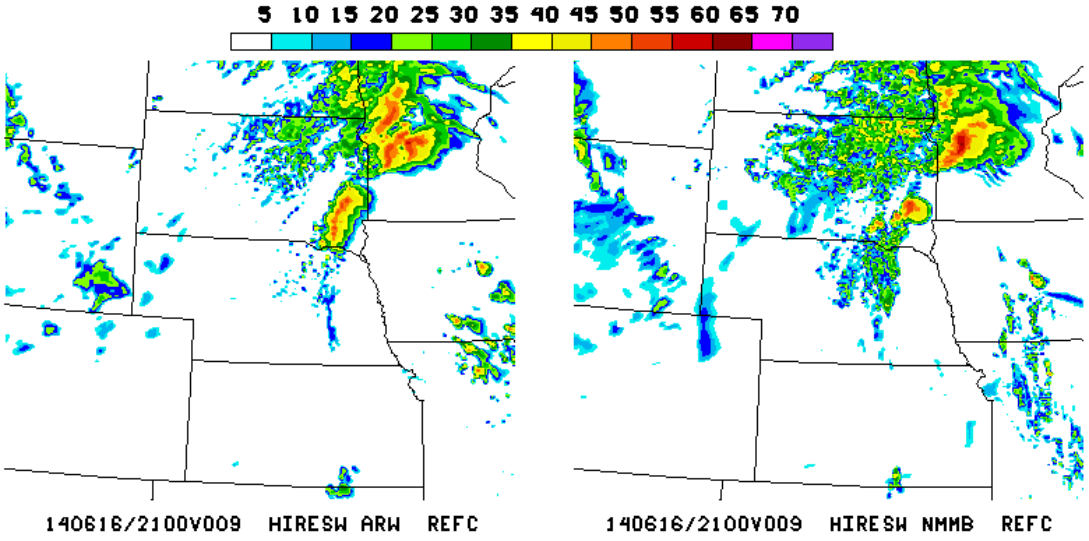
June 16 “Twin Tornado” Supercell in northeast Nebraska



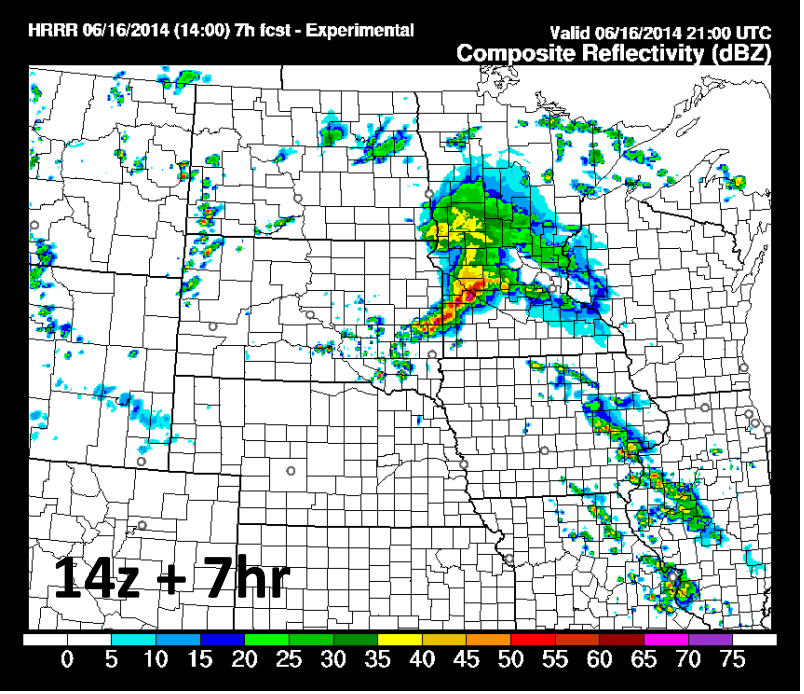
12z Hi-Res Guidance Shows Uncertainty

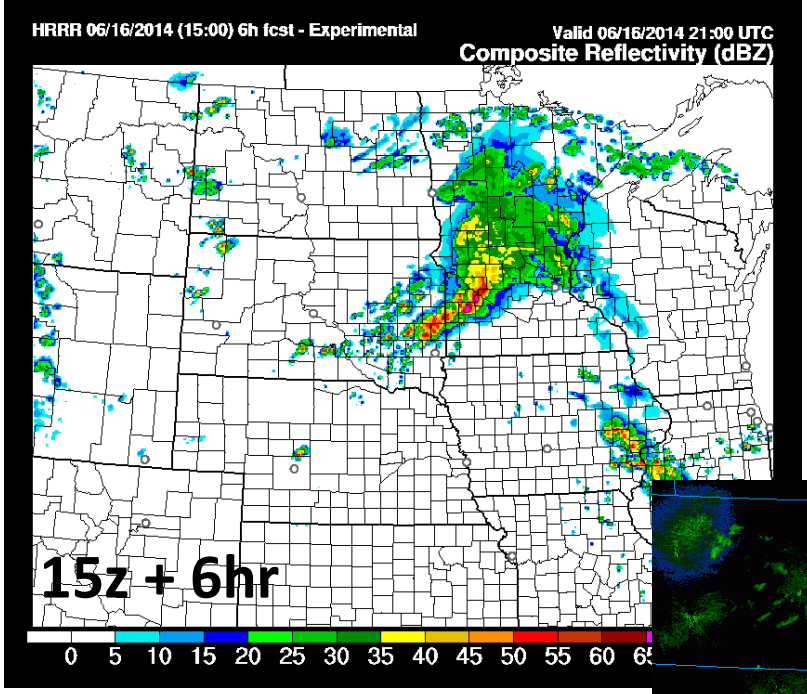


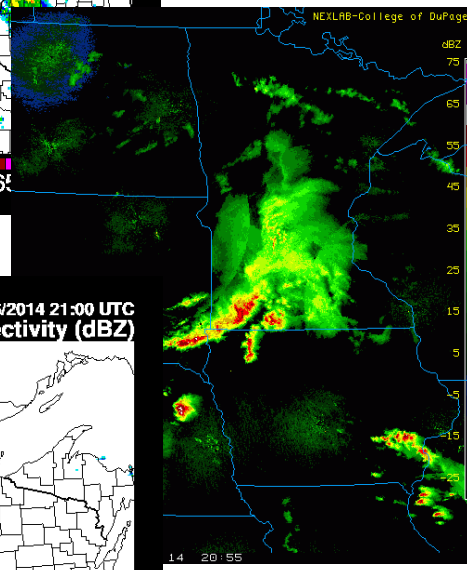
Where is the threat across this region?

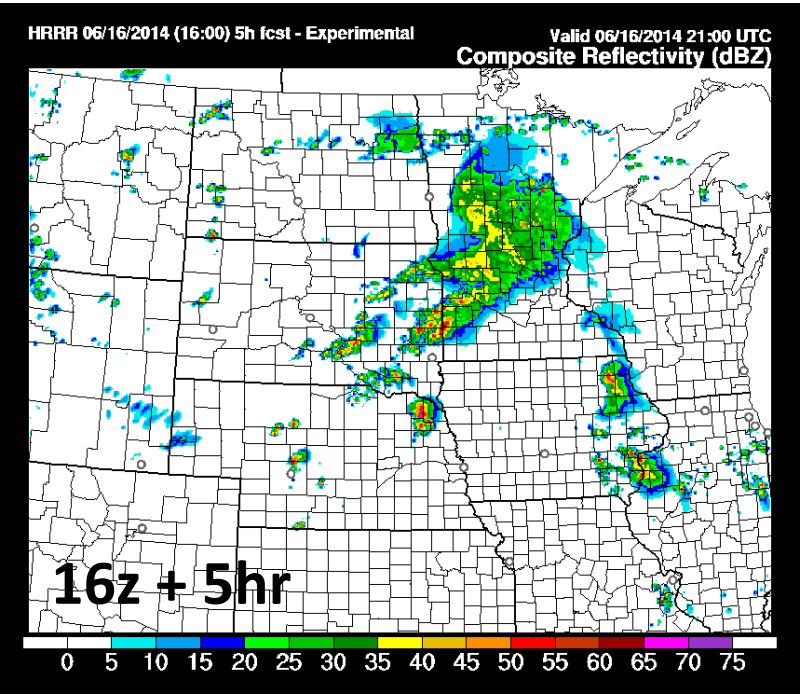


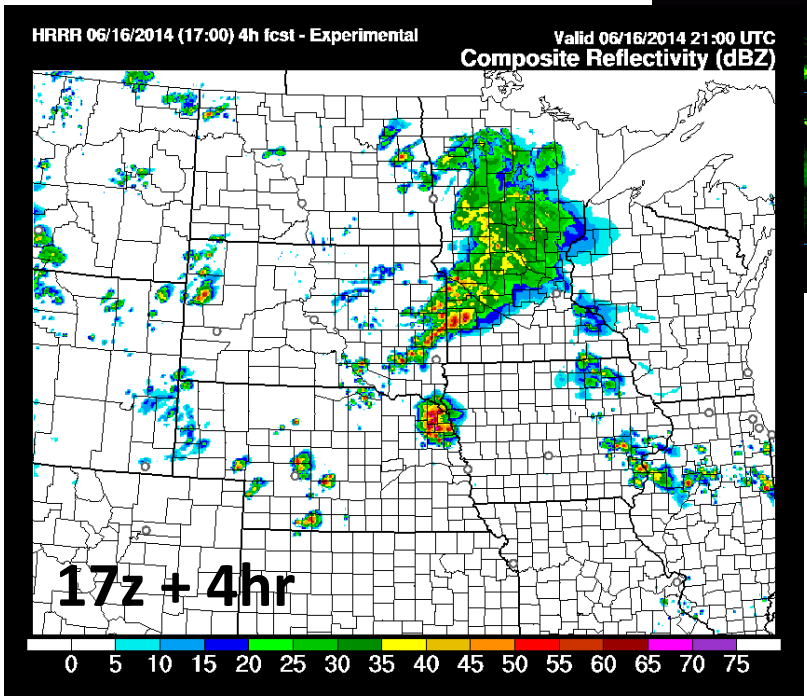
Will severe storms be ongoing by 21z?











Clear trend in hourly cycle for enhanced risk in northeast NE

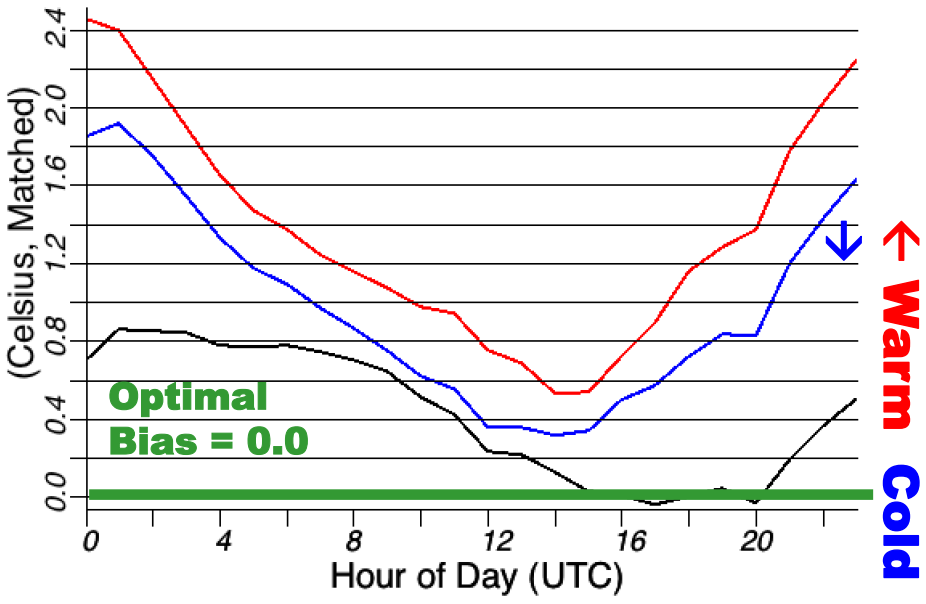
Preview of NCEP RAPv3/HRRRv2

Improved 2-m 12 hr temperature forecasts with reduction of daytime warm bias

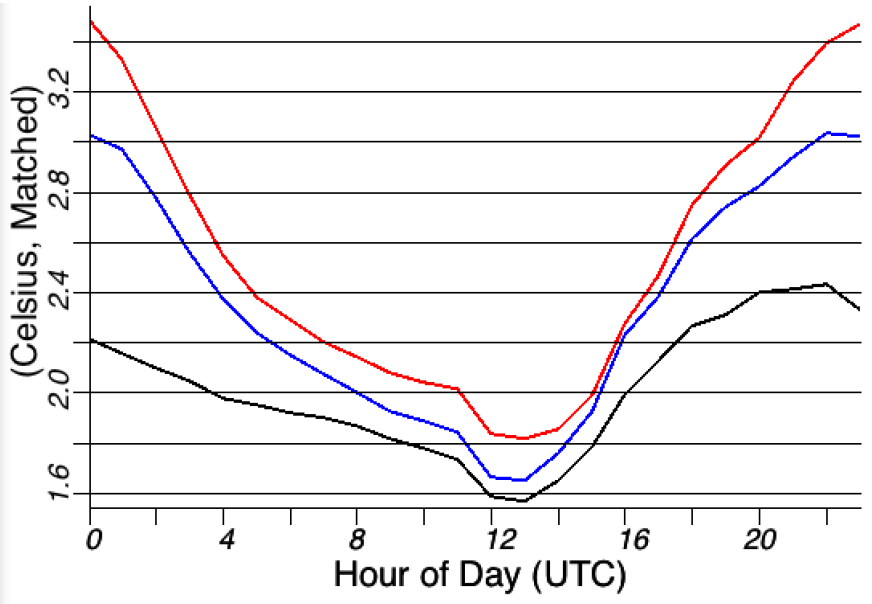
Eastern US
15 August – 18 September 2014

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

BIAS (Forecast – Obs)



RMSE



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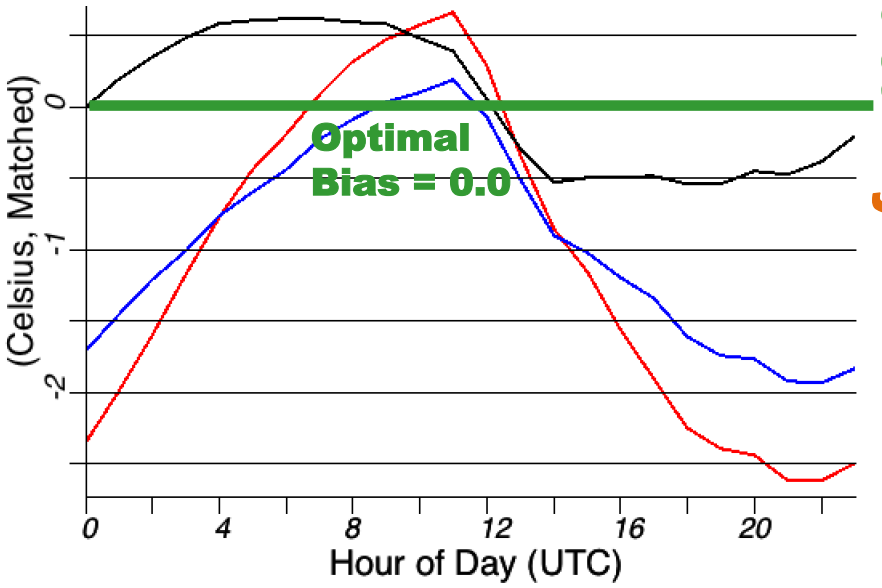
-- **Developmental ESRL RAPv3 with recent DA and model changes (candidates for final RAPv3)**

BIAS (Forecast – Obs)



↑ Moist Dry ↓

RMSE