20th Conference on Integrated Observing and Assimilation Systems for the Atmospheres, Oceans, and Land-surface
13 January 2016

Radar Data Assimilation impacts in the Rapid Refresh (RAP) and High-Resolution Rapid (HRRR)

NOAA/ESRL/GSD/EMB

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RAP and HRRR Radar DA Evolution

2007	CONUS 3-D Radar Mosaic Developed by NSSL
2009	Radar reflectivity assimilation in 13-km operational RUC
2012	Radar reflectivity assimilation in 13-km operational RAP
2013	Radar reflectivity assimilation in 3-km experimental HRRR
2014	Radar reflectivity assimilation in 3-km operational HRRR
2016	Radar radial velocity assimilation in 13-km RAPv3
2016	Radar radial velocity assimilation testing in 3-km GSD HRRR
2016	Preliminary tests of storm-scale assimilation in 3-km GSD HRRR

Rapid Refresh and HRRR
NOAA hourly updated models

Current NCEP operational:

RAPv2 -- Feb 2014

HRRRv3 – Sept. 2014

Planned NCEP upgrade:

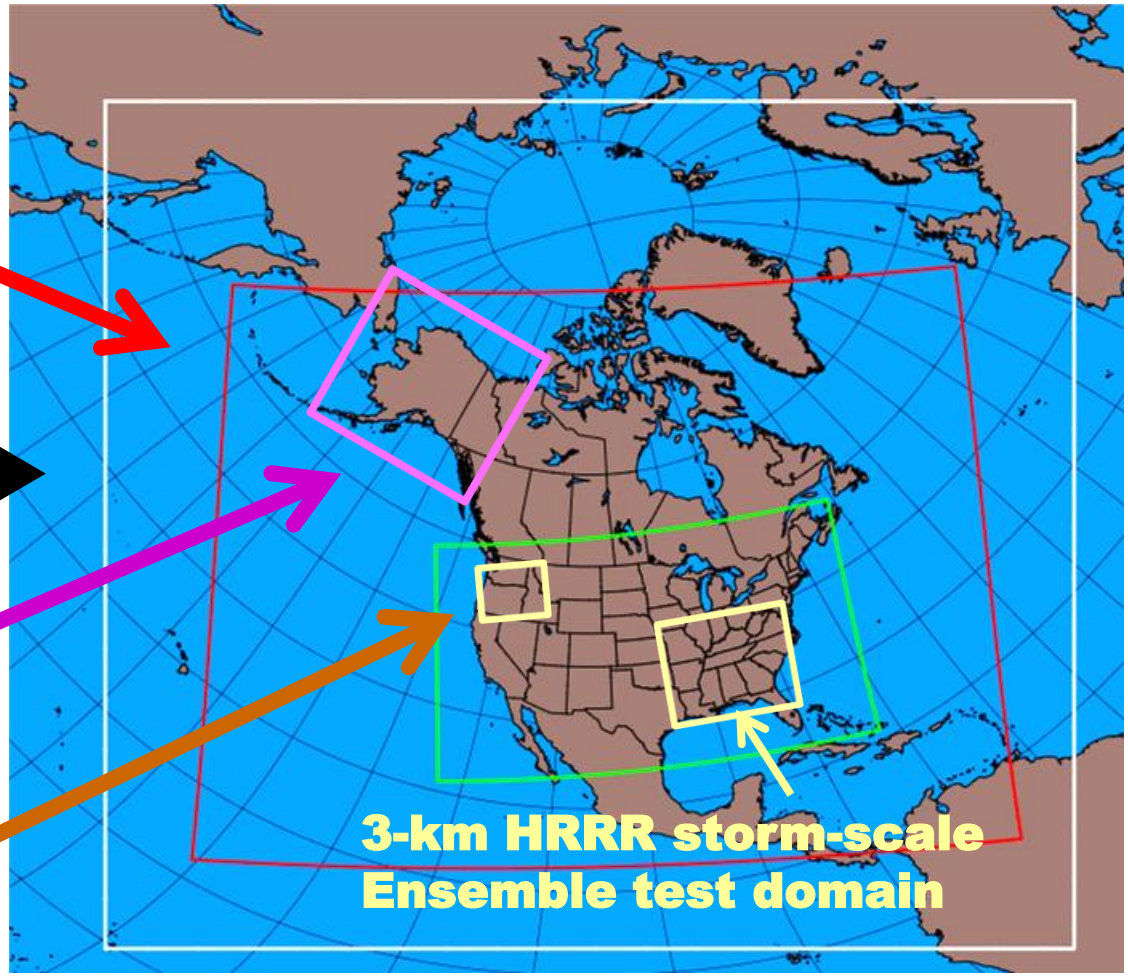
RAPv3 -- May 2016

HRRRv2 – May 2016

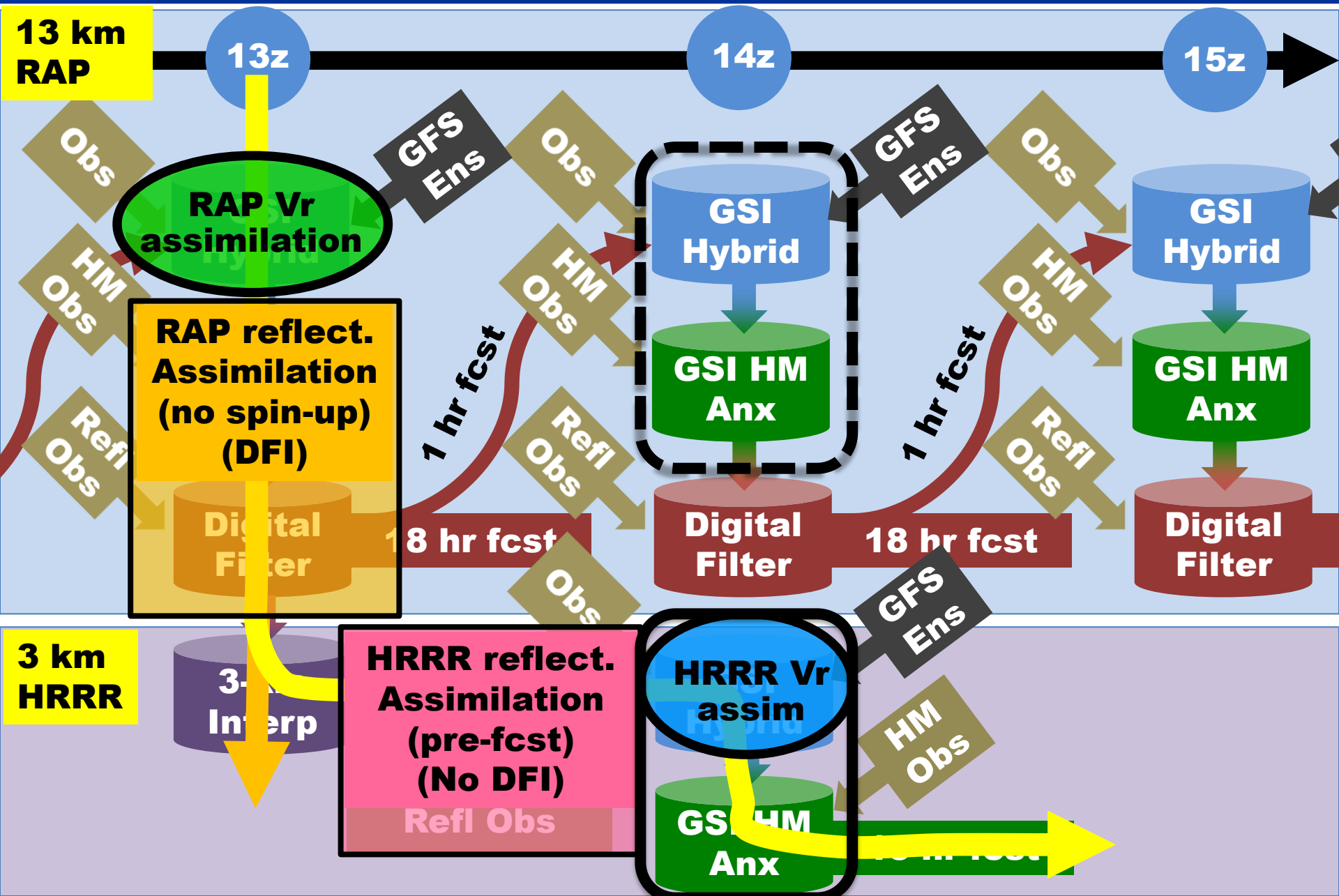
GSD test domains

HRRR-AK 3-km (planned)

750 m HRRR nest used for WFIP2 tests



RAPv3 and HRRRv2 Initialization

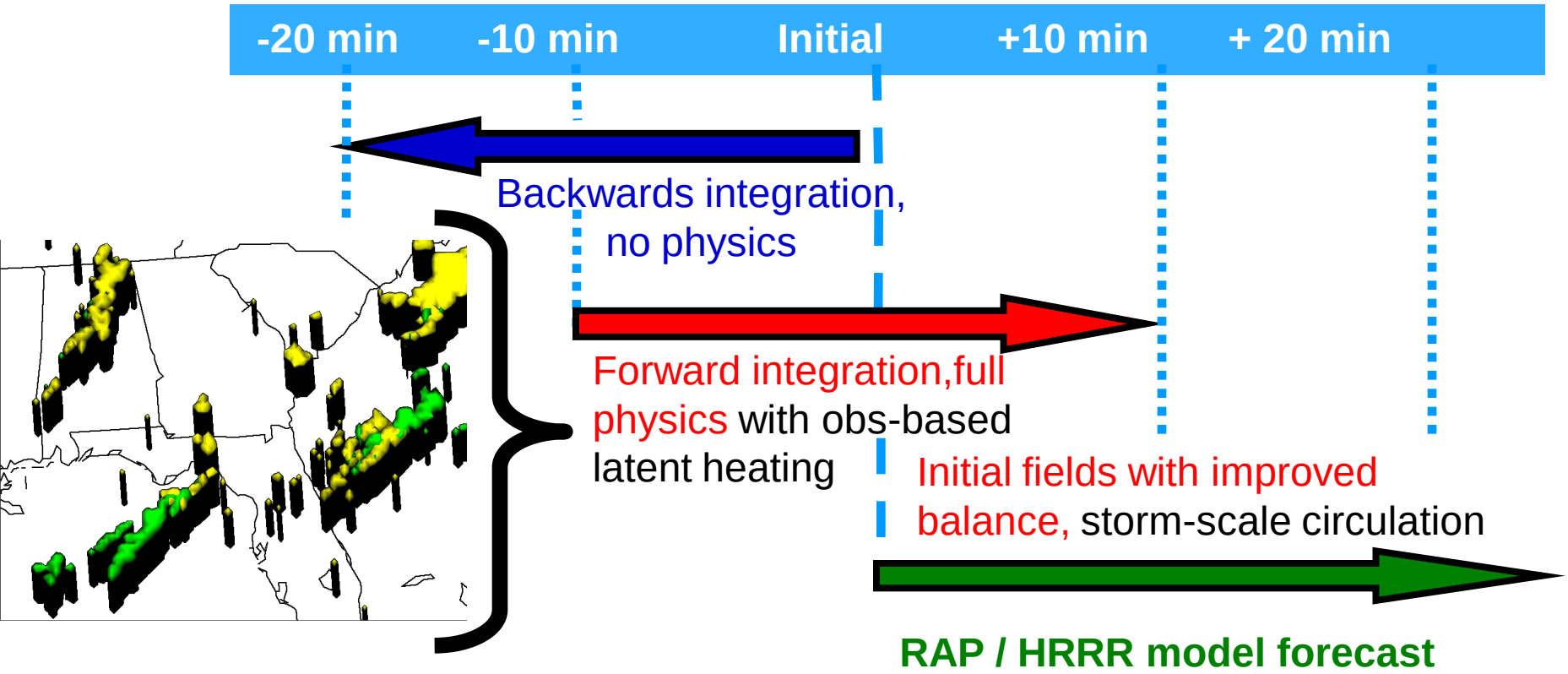


RAP digital filter assimilation

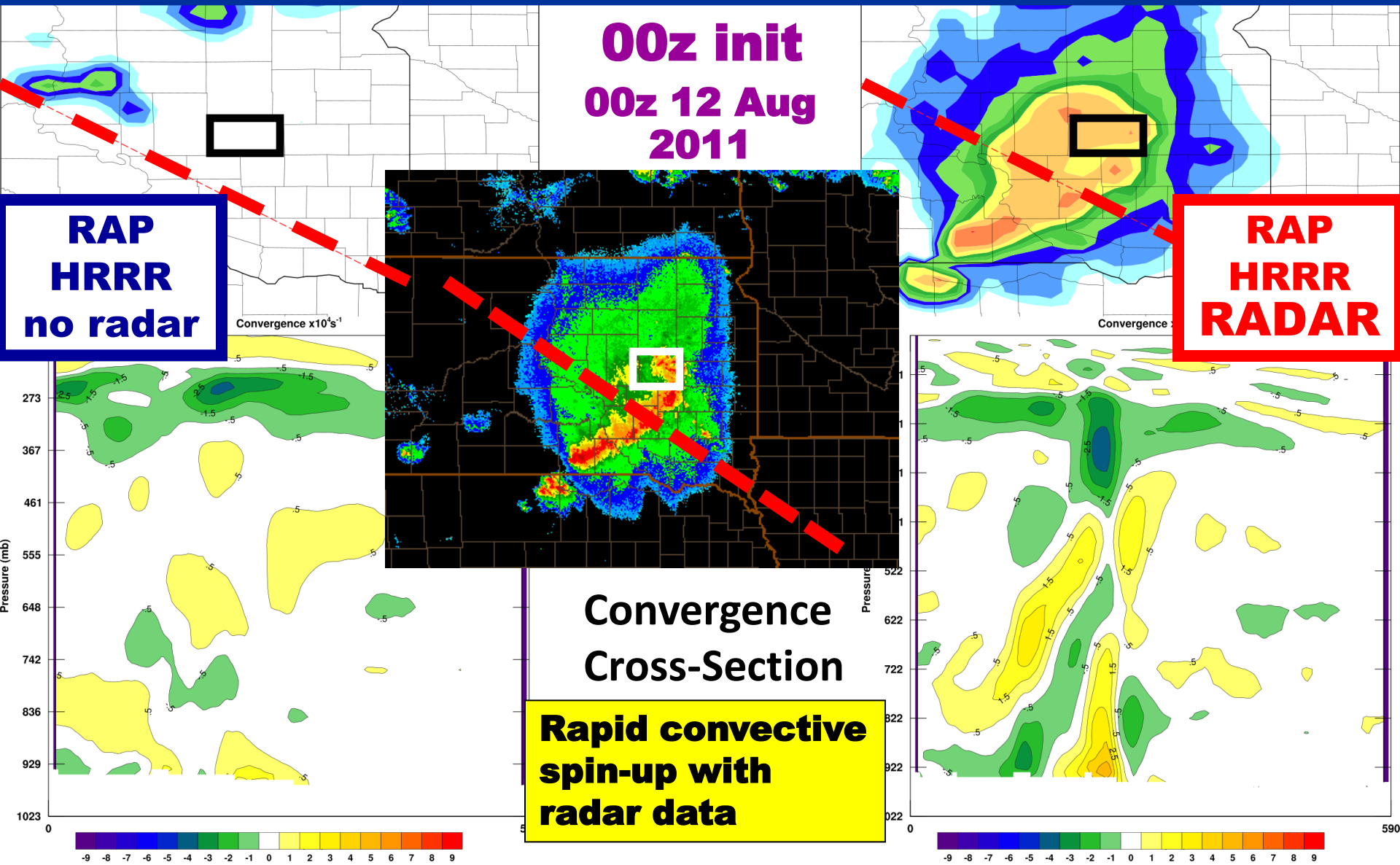
Digital filter-based assimilation initializes ongoing / developing convection / precipitation regions

Use for following obs types:

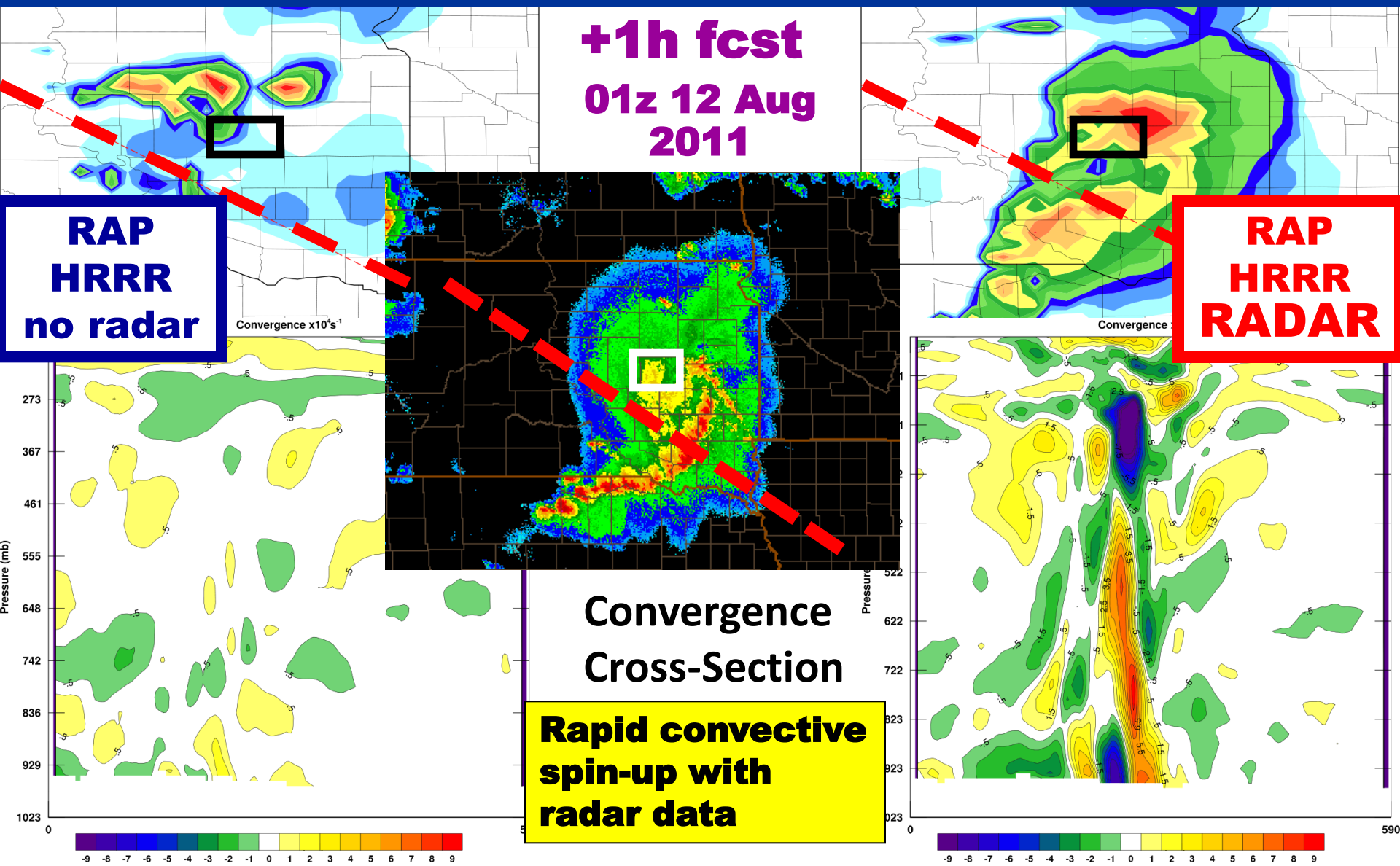
- ➔ **Radar reflectivity**
- ➔ **Lightning**
- ➔ **Satellite cloud-top cooling rate**



Radar Reflectivity Assimilation



Radar Reflectivity Assimilation



Radar Reflectivity Data Assimilation

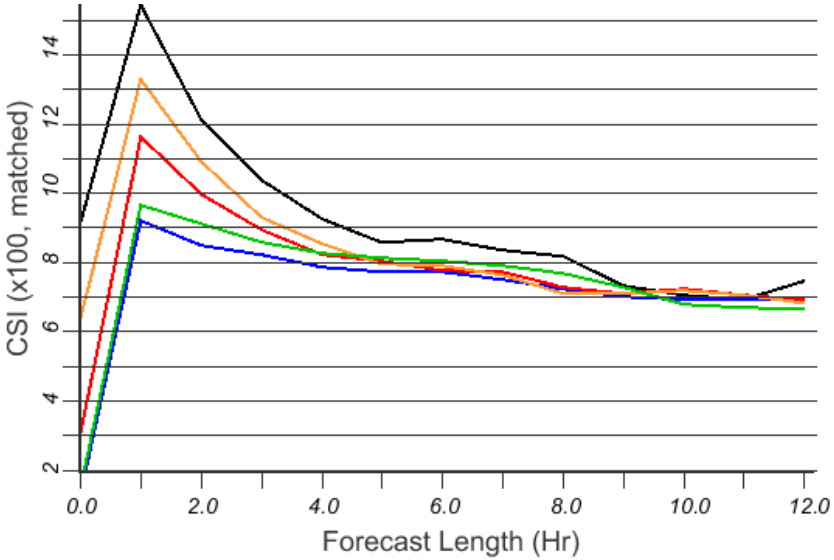
Changing Strength (how much) of Latent Heating

HRRR – RUC third
HRRR – RAP third
HRRR – RAP full
HRRR – RUC full
HRRR – RAP double

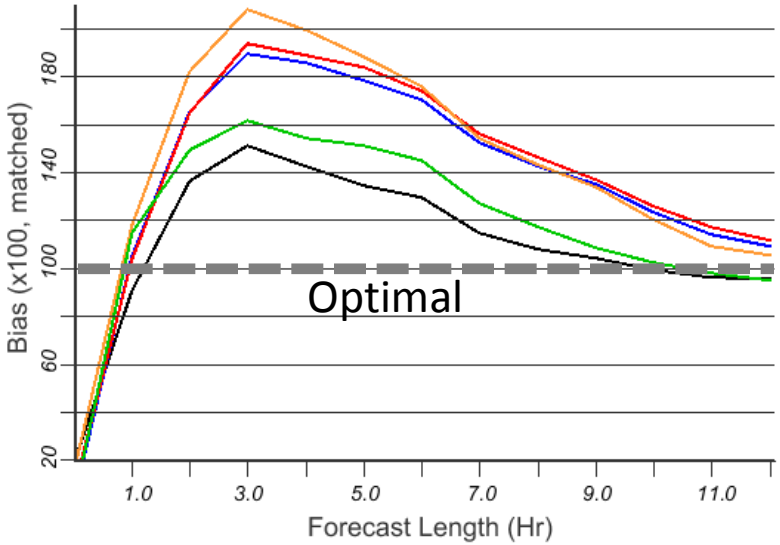
20-km 30dBZ CSI

20-km 30dBZ BIAS

← Less Skill More Skill →

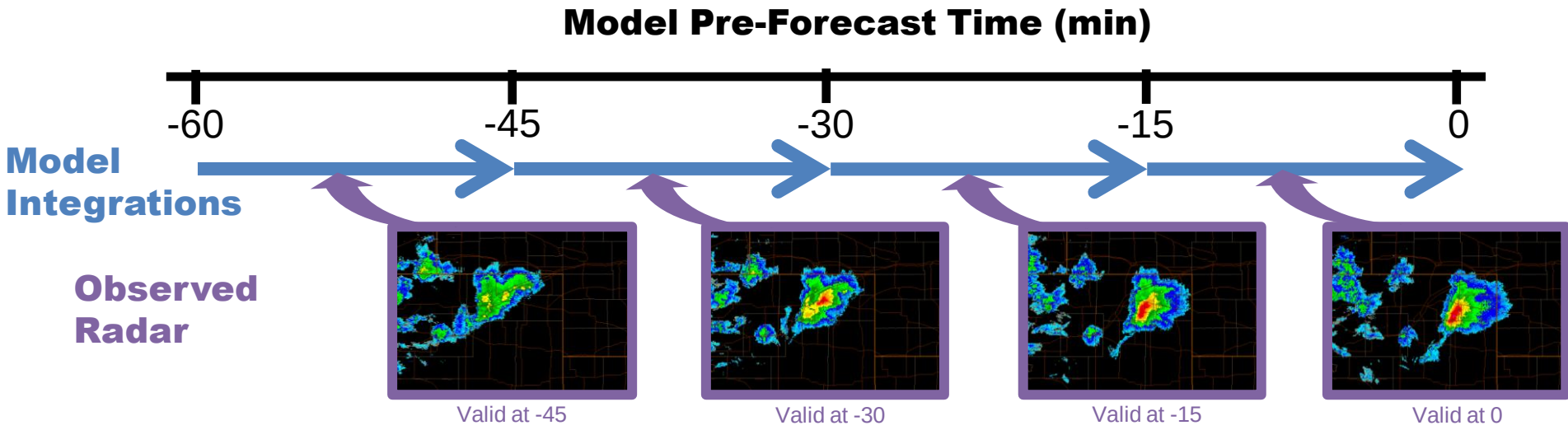


Increasing skill with more forcing



But also higher bias…

Rapid Refresh and HRRR Radar Reflectivity Assimilation



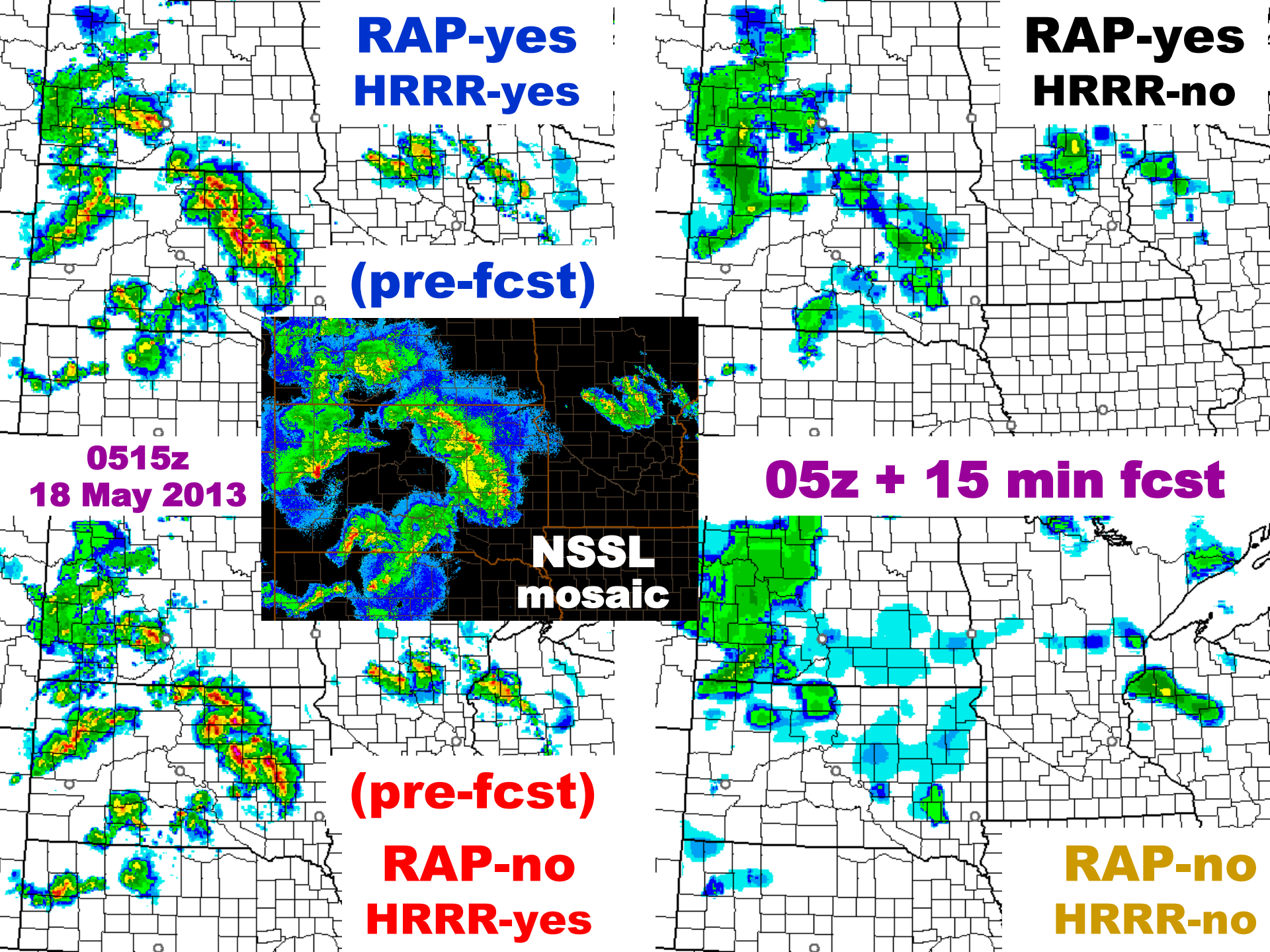
During the 1-hour pre-forecast, reflectivity observations are used to specify latent heating rates (microphysics temperature tendency) in each previous 15-min period:

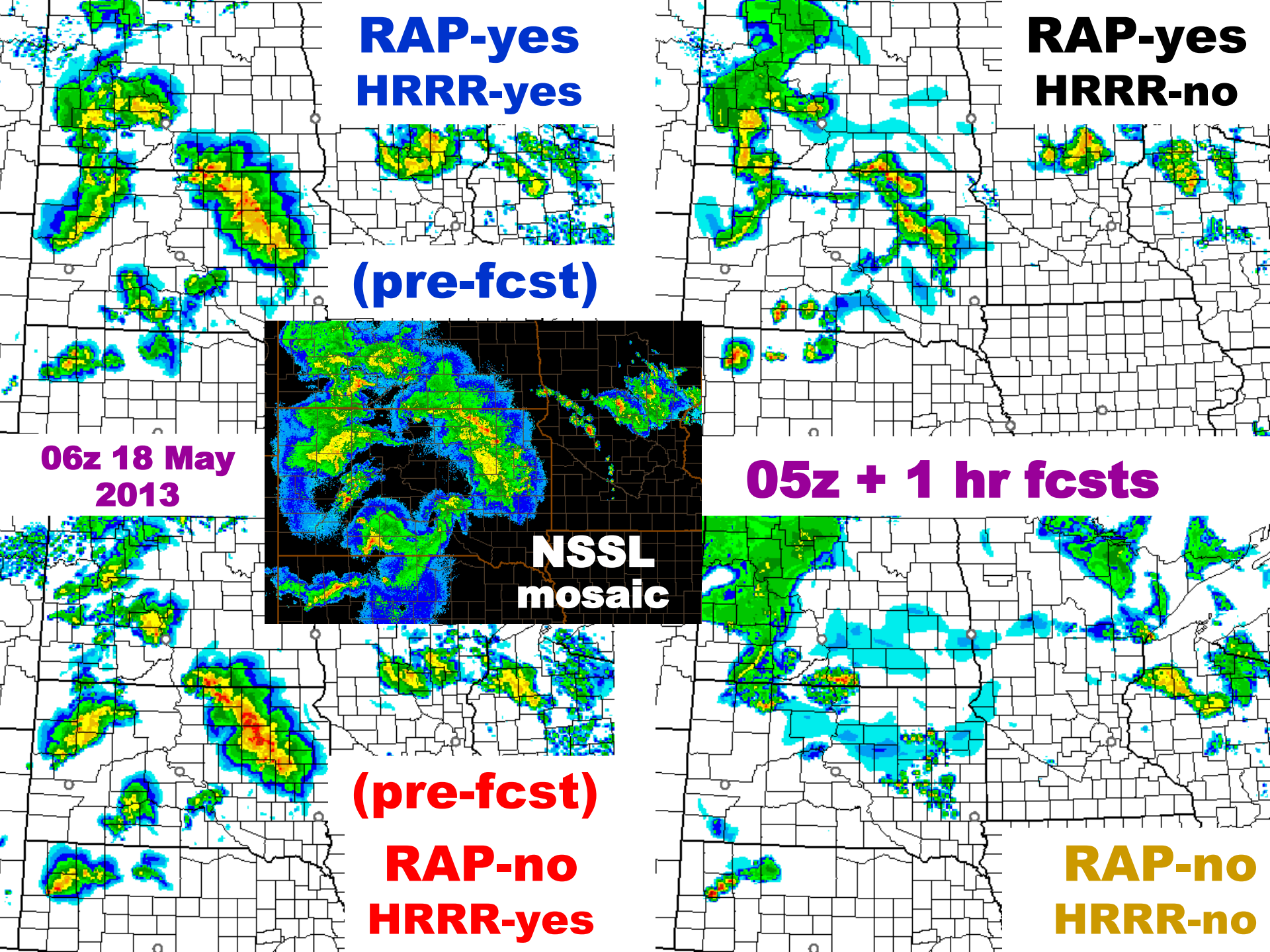
- Observed Reflectivity ≤ 0 dBZ : Zero heating rate to suppress spurious model precipitation.
- 0 dBZ < Observed Reflectivity < 28 dBZ : Model microphysics heating rate preserved.
- Observed Reflectivity ≥ 28 dBZ : Positive heating rate to promote convective development.
- No radar coverage: Model microphysics heating rate preserved.

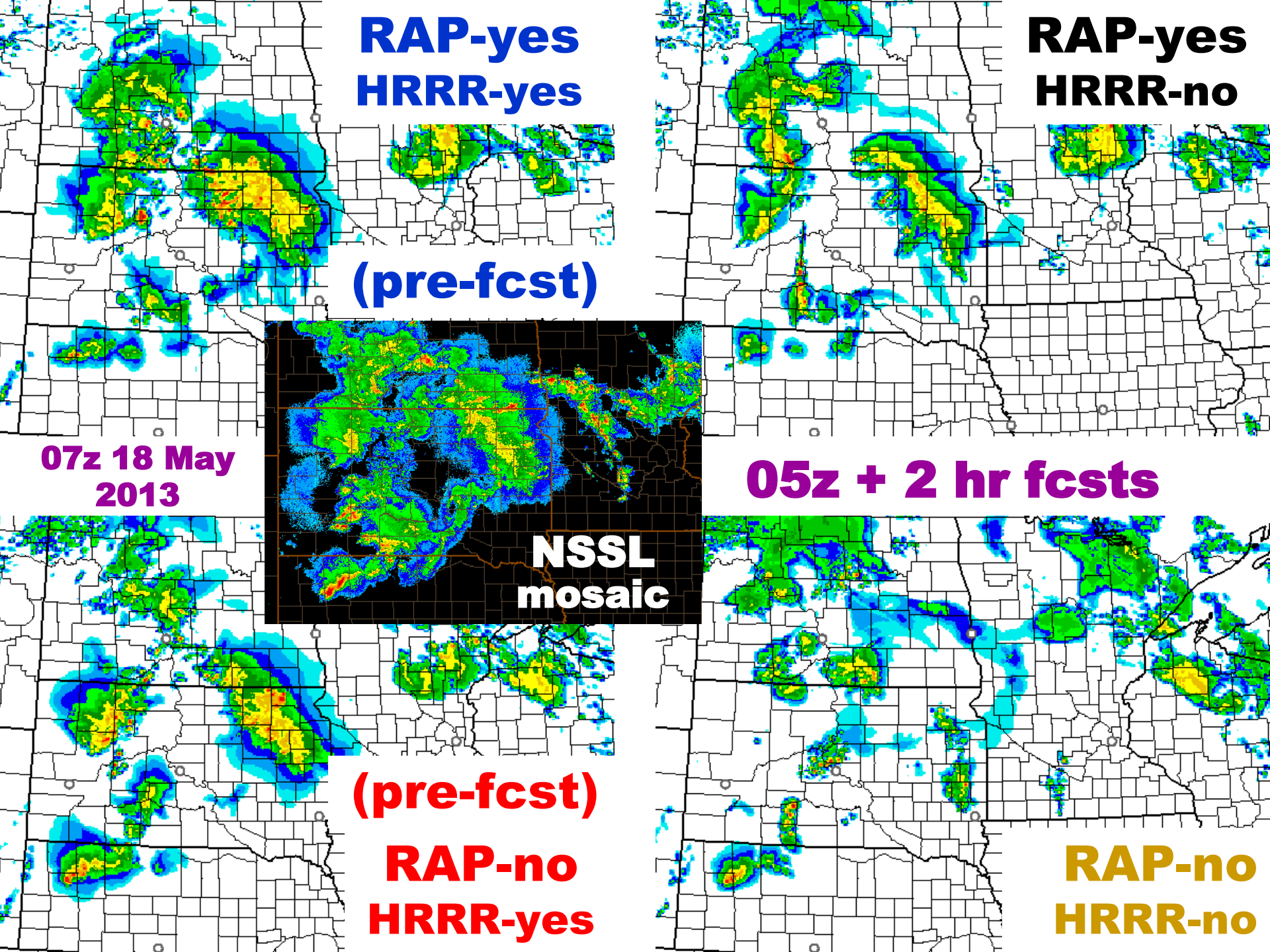
RAP/HRRR Hydrometeor Analysis

Variables Updated	Add to model?	Remove from model?	Which observations are used?
cloud water, cloud ice, temperature, water vapor	Yes, below 1.2 km AGL	Yes	Satellite cloud top, Ceilometers
Rain water, snow water	Yes, If 2m T < 5 C: add to full column, Else: add at observed maximum reflectivity level and where obs 15-28 dBZ	Yes	Radar reflectivity

- Obs indicate clouds, at low-levels, the model hydrometeors are updated.
- Model does not have the observed mid- to upper-level clouds, the HM analysis is not going to add them.
- Cloud ice and cloud water number concentration updates have recently been included in the analysis.


RAP-yes
HRRR-yes
(pre-fcst)
RAP-yes
HRRR-no
0515z
18 May 2013
NSSL
mosaic
05z + 15 min fcst
(pre-fcst)
RAP-no
HRRR-yes
RAP-no
HRRR-no


RAP-yes
HRRR-yes
(pre-fcst)
RAP-yes
HRRR-no
06z 18 May
2013
NSSL
mosaic
05z + 1 hr fcsts
(pre-fcst)
RAP-no
HRRR-yes
RAP-no
HRRR-no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HRRR-yes
(pre-fcst)
RAP-yes
HRRR-no
07z 18 May
2013
NSSL
mosaic
05z + 2 hr fcsts
(pre-fcst)
RAP-no
HRRR-yes
RAP-no
HRRR-no

Retro HRRR Skill vs. forecast length

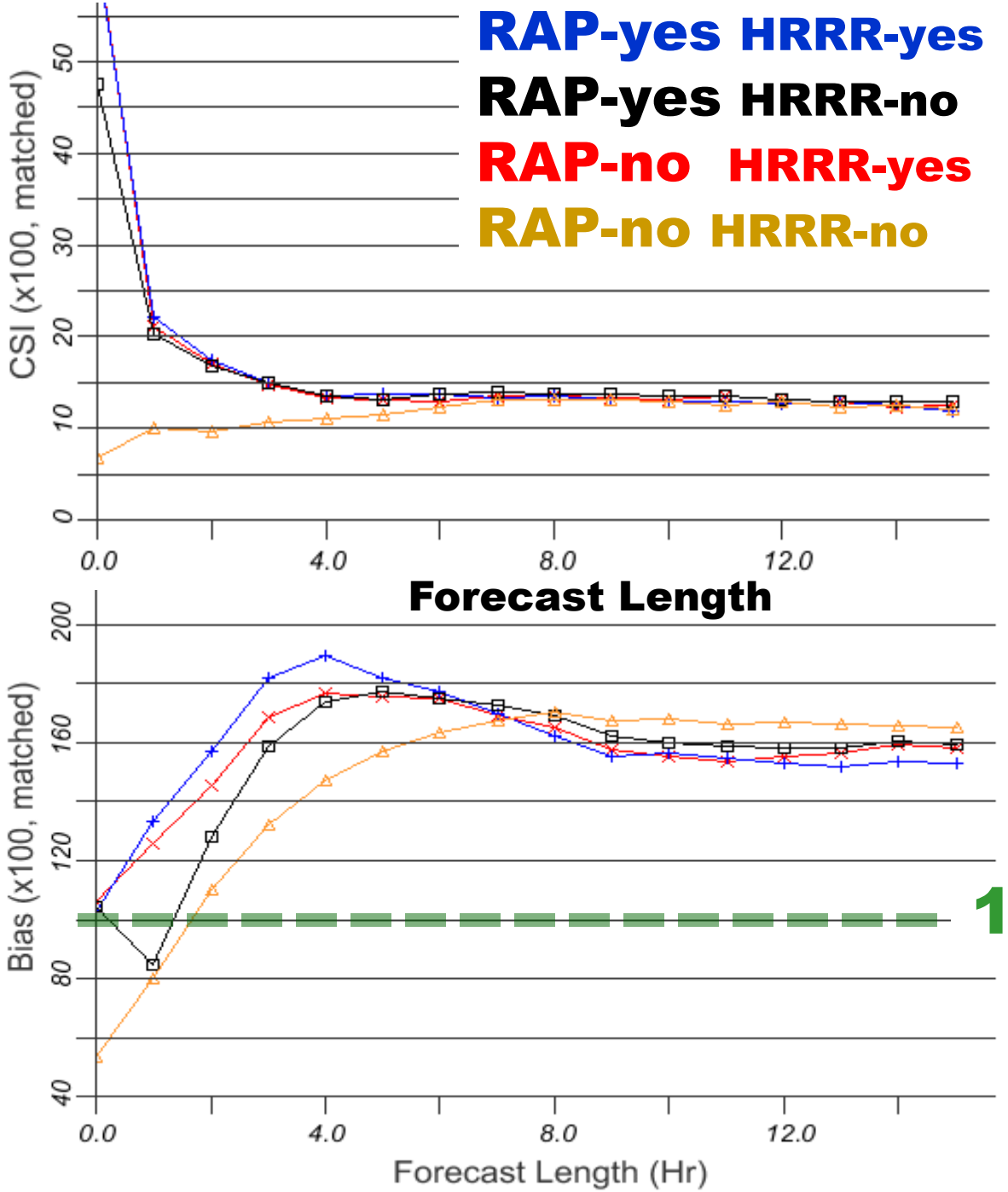
CSI

Overall Scores

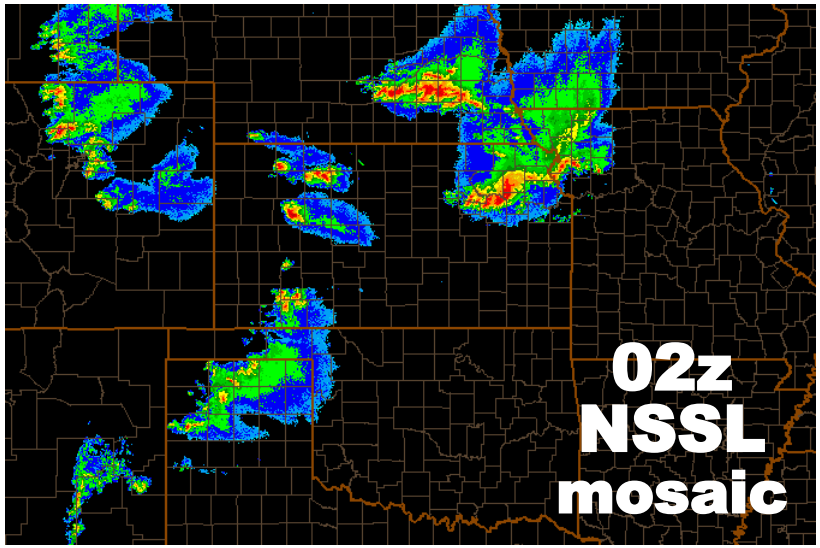
~30 HRRR runs

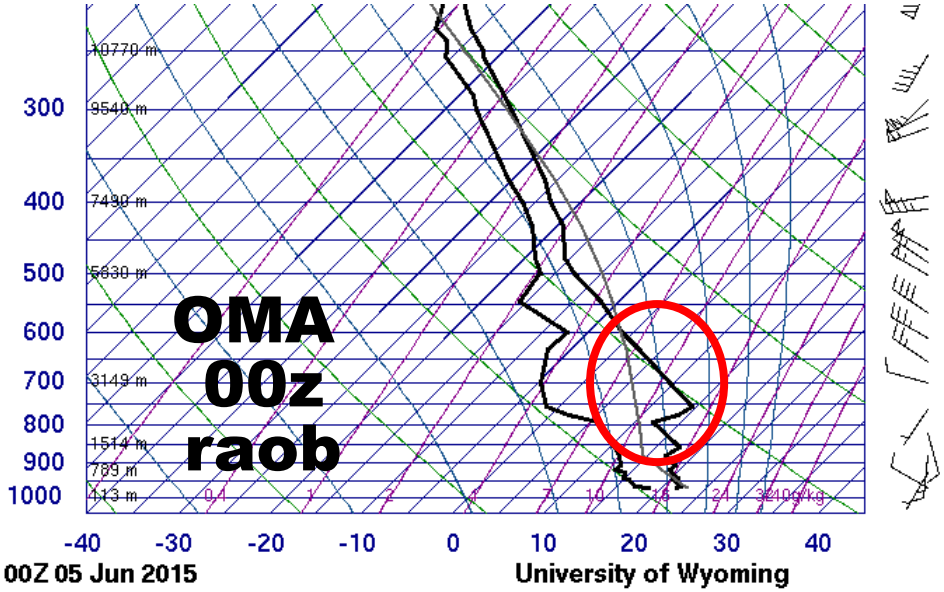
Bias (3-km)

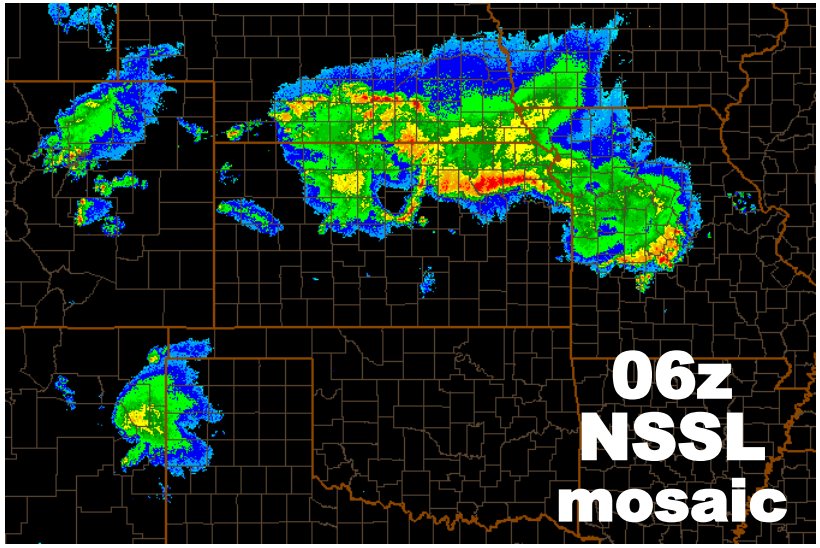
16-20 May 2013
Eastern US
30 dbz

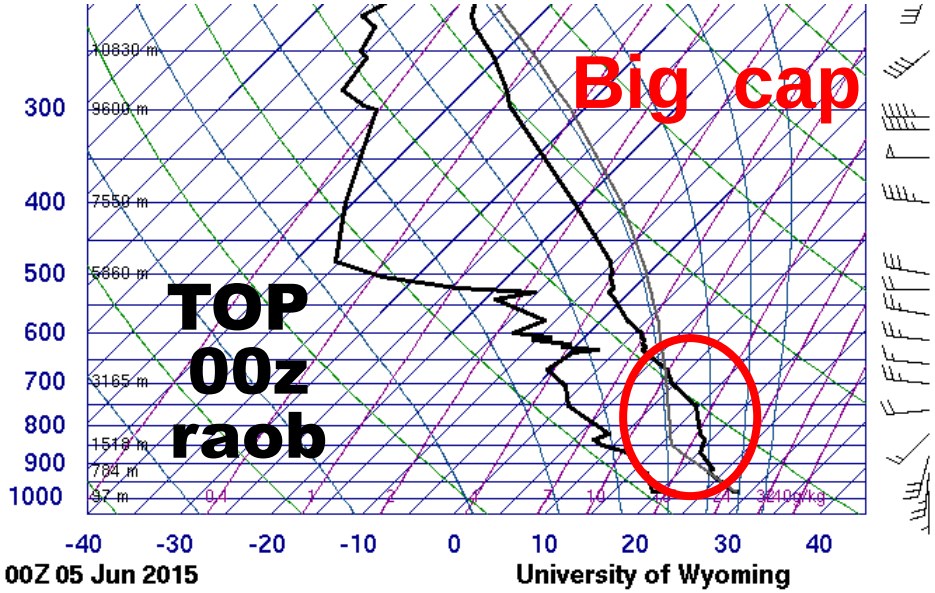


HRRR radial velocity assim test case









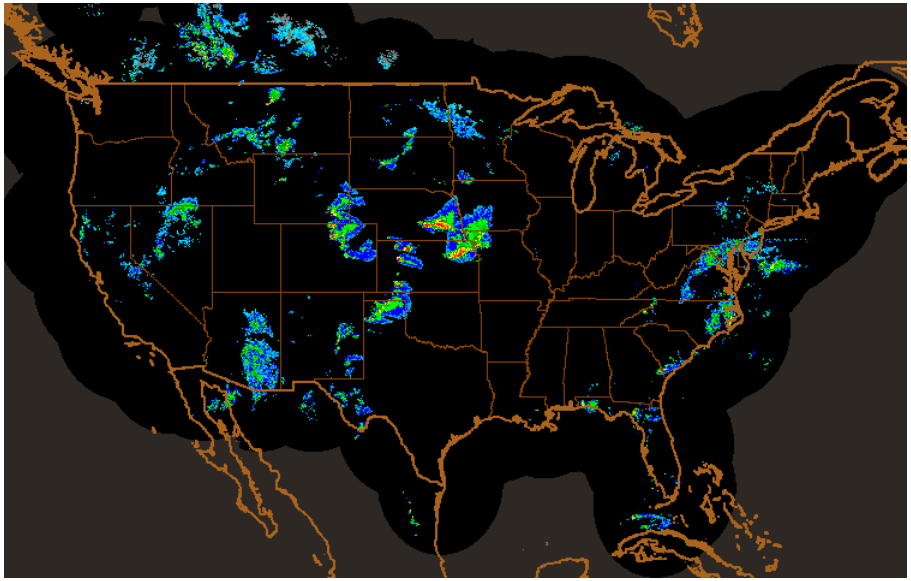
HRRR radial velocity assimilation

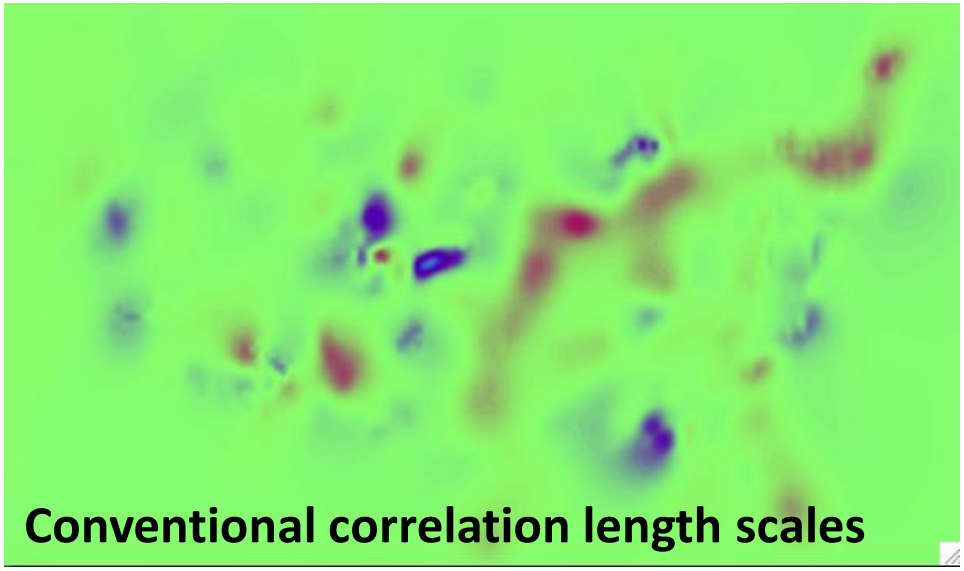
Expt. Name	RAP reflectivity	3-km Pre-fcst	HRRR 3-km reflectivity	HRRR radial Velocity	Comments
CONTROL	Radar DFI	Yes	Yes	**None**	RAPv2/ HRRRv1 operational
NOrap, PREhrrr	**NO Radar DFI**	Yes	**NO**	**None**	Pre-fcst only
NO rap NO hrrr	**NO Radar DFI**	**NO**	**NO**	**None**	Cold start
YESrap/hrrr Vr 2-pass	Radar DFI	Yes	Yes	**2nd GSI pass Vr, Short-scl**	3-km VR assim

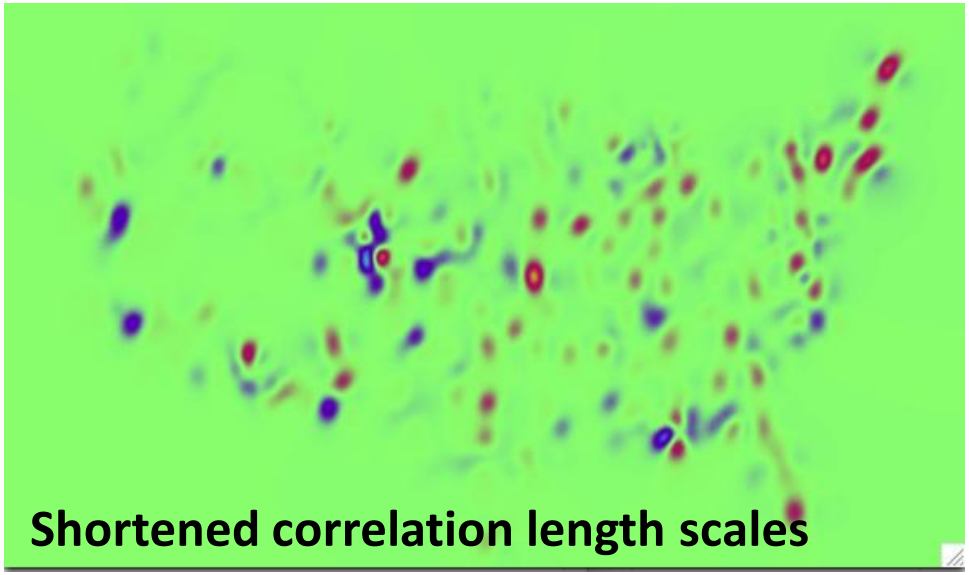
HRRR radial velocity assimilation

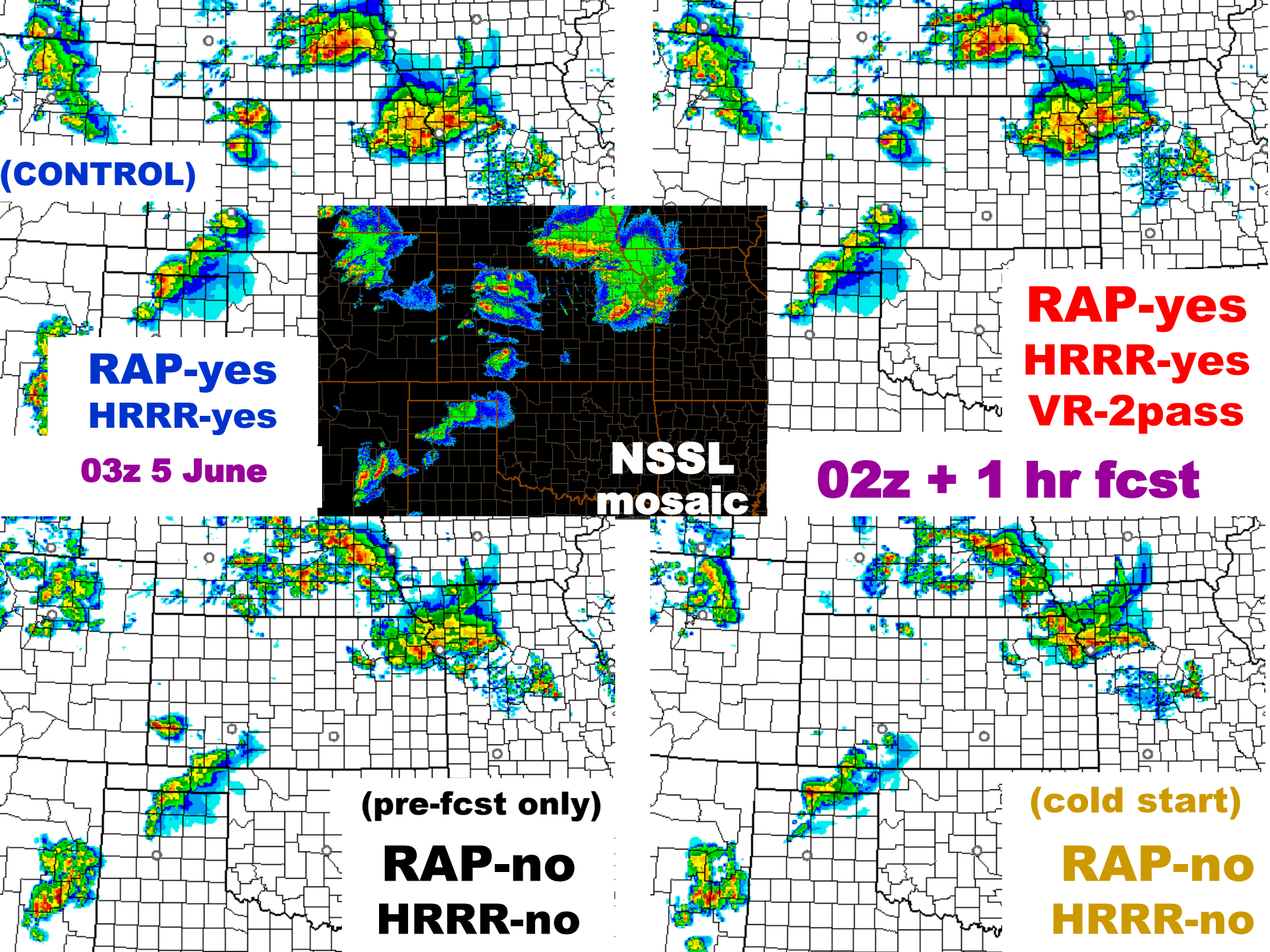
02z V-comp increments from 2nd pass of GSI (with level 2 radial velocity and VAD only)

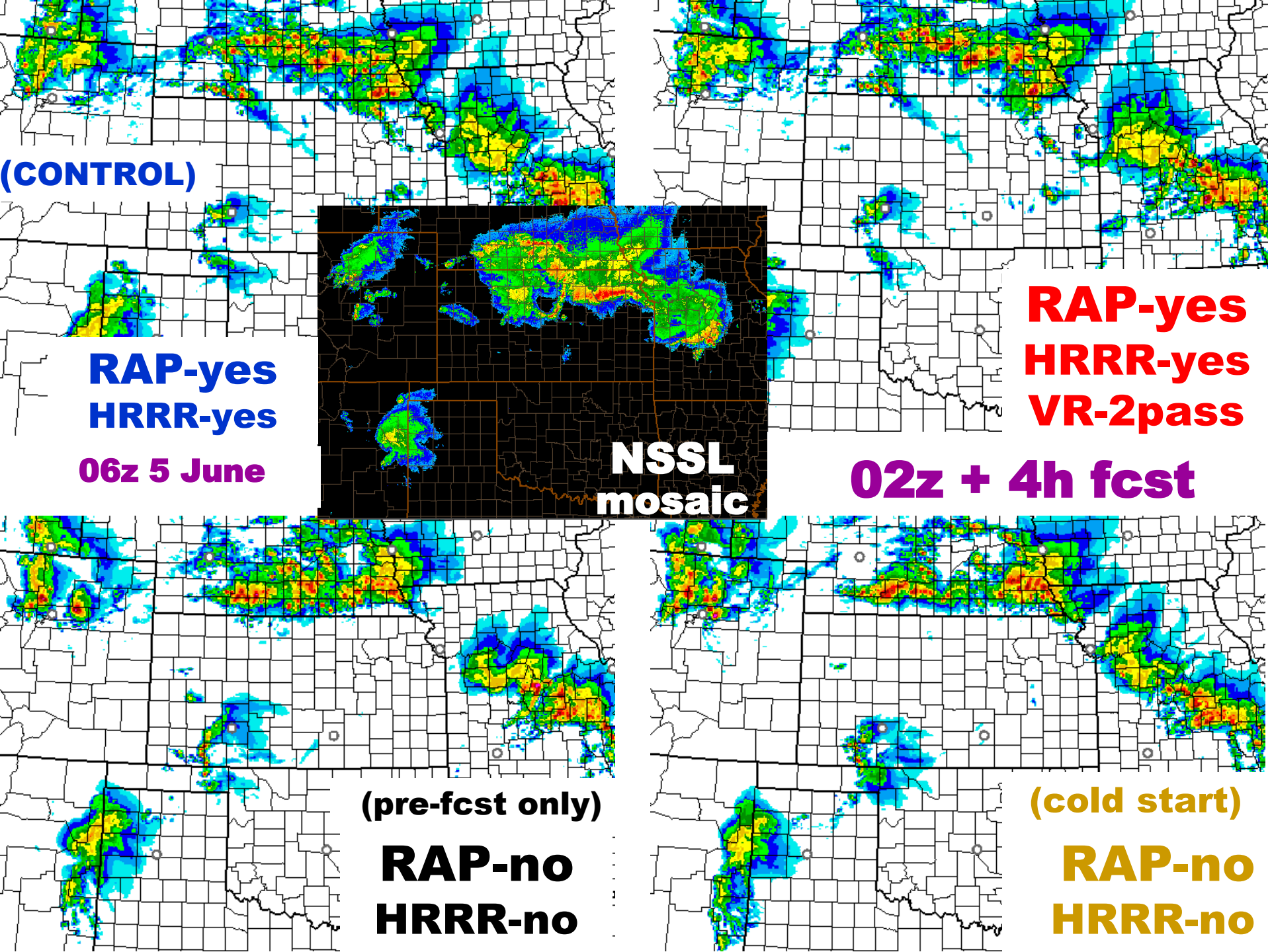
K = 5
Max / min ~ + / - 8 m/s
lue < 0, maroon > 0)







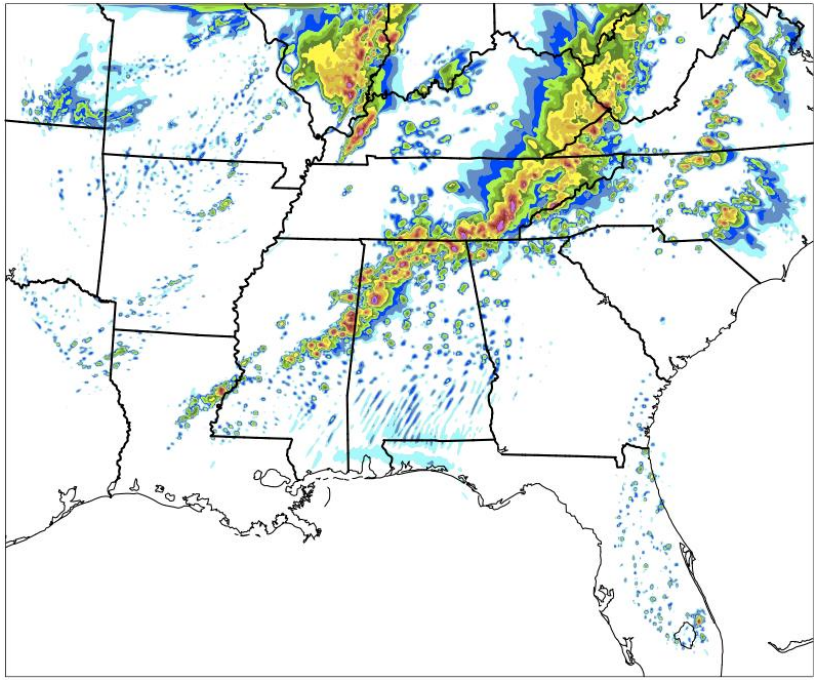

(CONTROL)
RAP-yes
HRRR-yes
03z 5 June
NSSL
mosaic
RAP-yes
HRRR-yes
VR-2pass
02z + 1 hr fcst
(pre-fcst only)
RAP-no
HRRR-no
(cold start)
RAP-no
HRRR-no


(CONTROL)
RAP-yes
HRRR-yes
06z 5 June
NSSL
mosaic
RAP-yes
HRRR-yes
VR-2pass
02z + 4h fcst
(pre-fcst only)
RAP-no
HRRR-no
(cold start)
RAP-no
HRRR-no

HRRR Ensemble Retrospective Testing: 27 April 2011

David Dowell

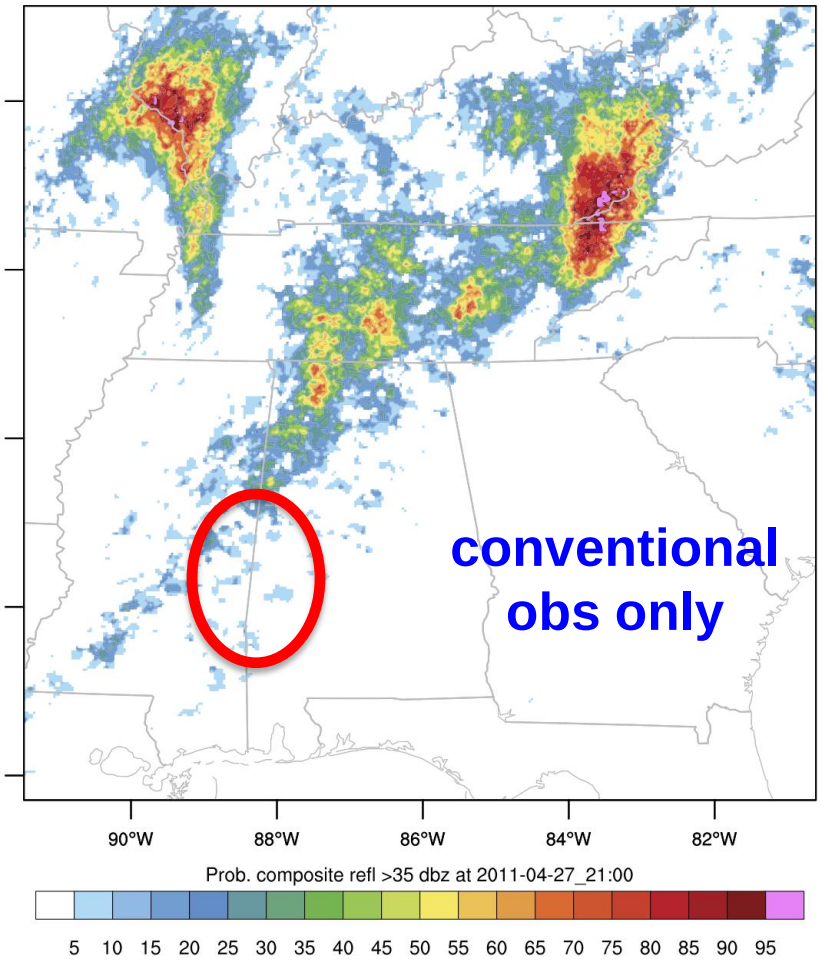
- Southeast US domain
- 40 ensemble members initialized from GFS ensemble
- Hourly ensemble Kalman filter (EnKF) data assimilation
  control experiment: conventional observations only
  radar DA experiment: conventional obs plus MRMS reflectivity obs
- Cycling for ~1 day, ensemble forecasts every 3 hours

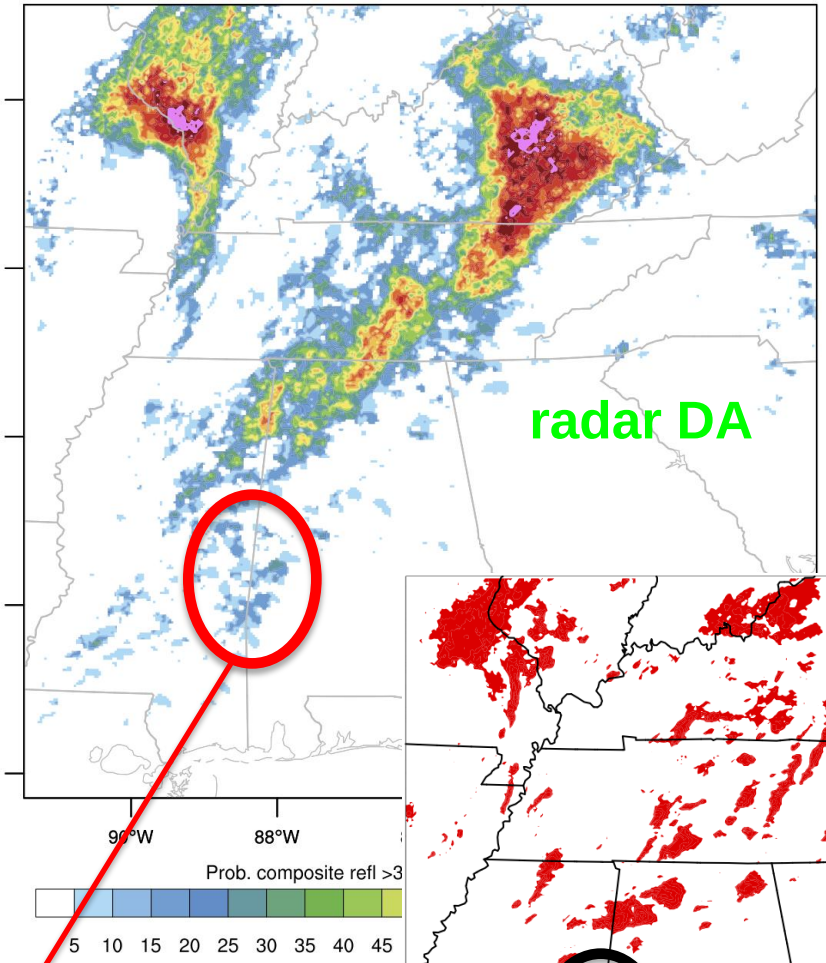


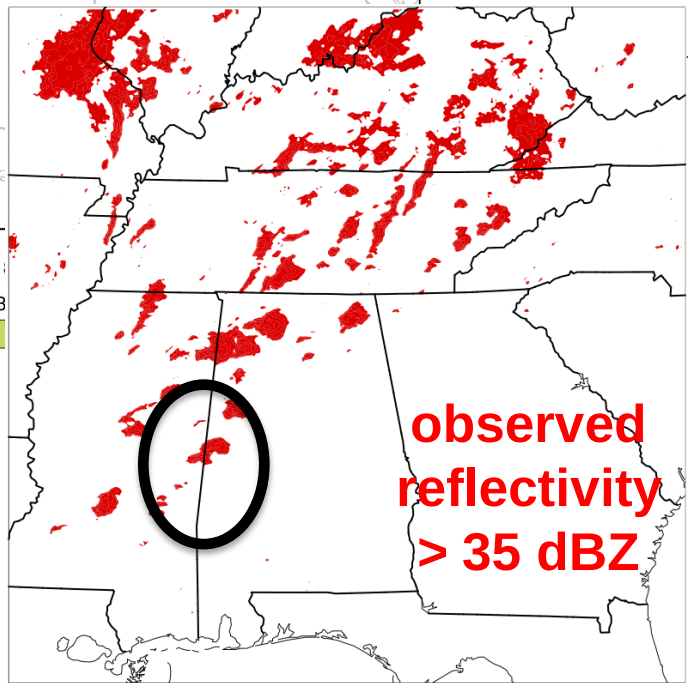
ABC 33/40 Birmingham, AL

Acknowledgments: VORTEX-SE, L. Lei, J. Whitaker, H. Winterbottom, N. Yussouf

Probability of Reflectivity > 35 dBZ
3-h Ensemble* Forecast Following Cycling for 12 h



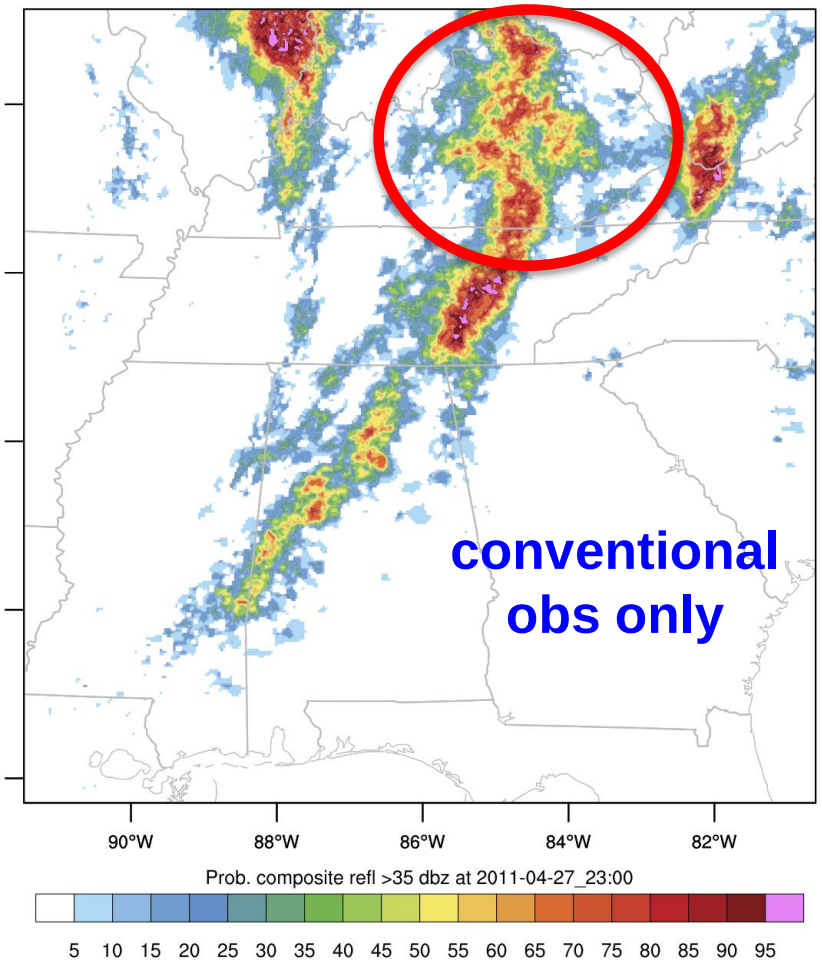


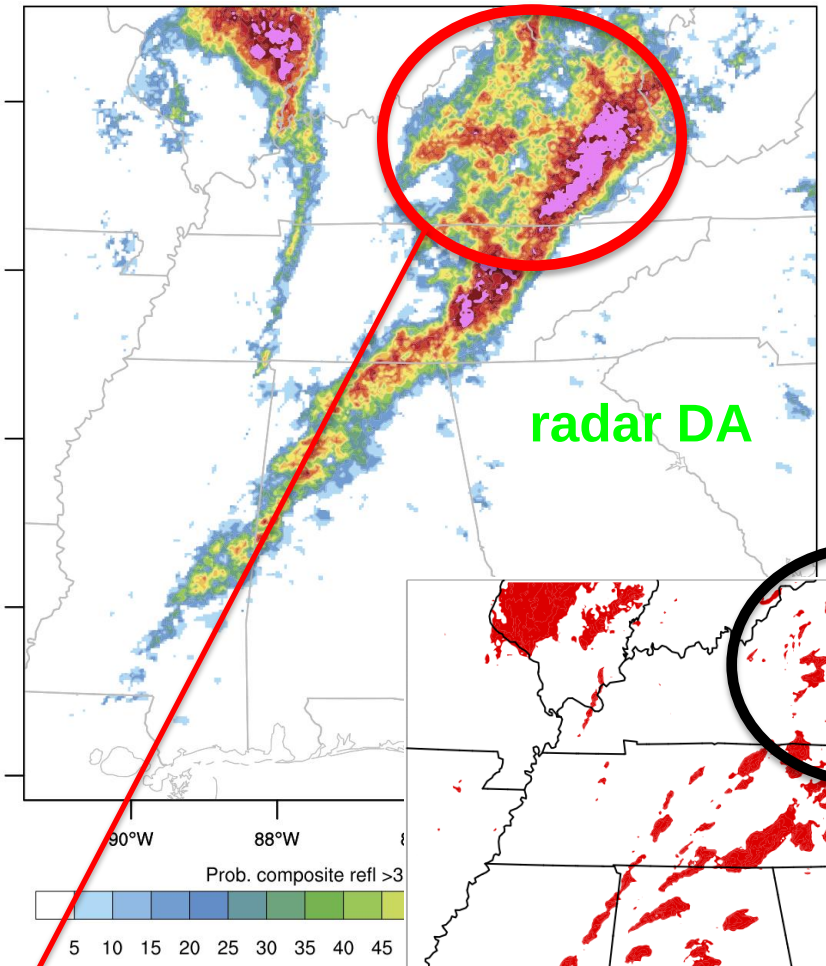


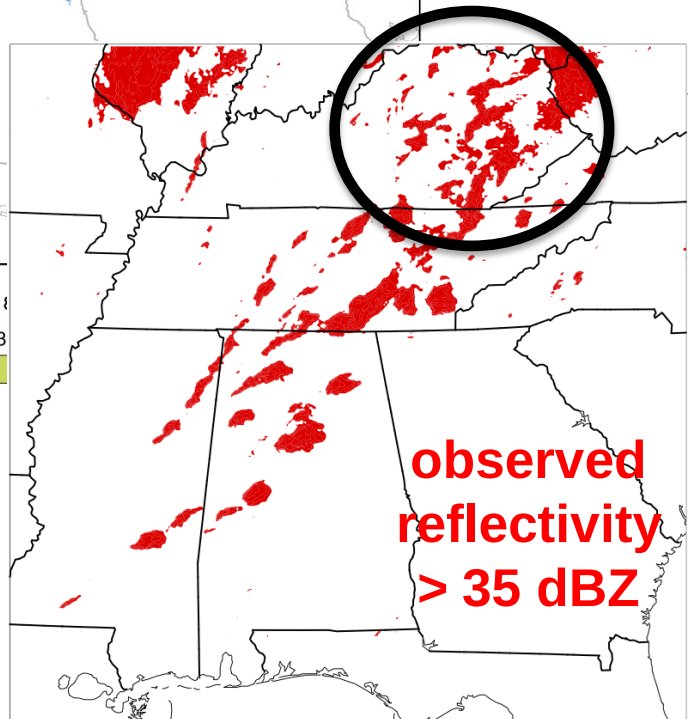
increased probability in region of developing Tuscaloosa storm

*12 Ensemble Members

Probability of Reflectivity > 35 dBZ
2-h Ensemble* Forecast Following Cycling for 15 h







consolidation of higher probabilities over eastern Kentucky

*12 Ensemble Members

Rapid Refresh and HRRR Radar Assimilation

Summary:
RAP and HRRR use three-dimensional observed radar reflectivities as a proxy for latent heating through specification (replacement) of the model's microphysics temperature tendencies

Advantages:
Computationally inexpensive that can run "in-line" with model integration and offers several adjustable parameters for case/user specific applications

Often improves short-term forecast skill including reflectivity and precipitation

Limitations:
Can lead to high forecast bias (precip, reflectivity) early in forecast period in some strongly-forced situations or during periods of decaying convection

Convective suppression is limited in capability for explicit convection applications…mesoscale forcing dominates

Ongoing work: 3-km HRRR radial velocity assimilation, storm-scale ensemble DA (with NSSL, PSD, NCAR, CAPS)