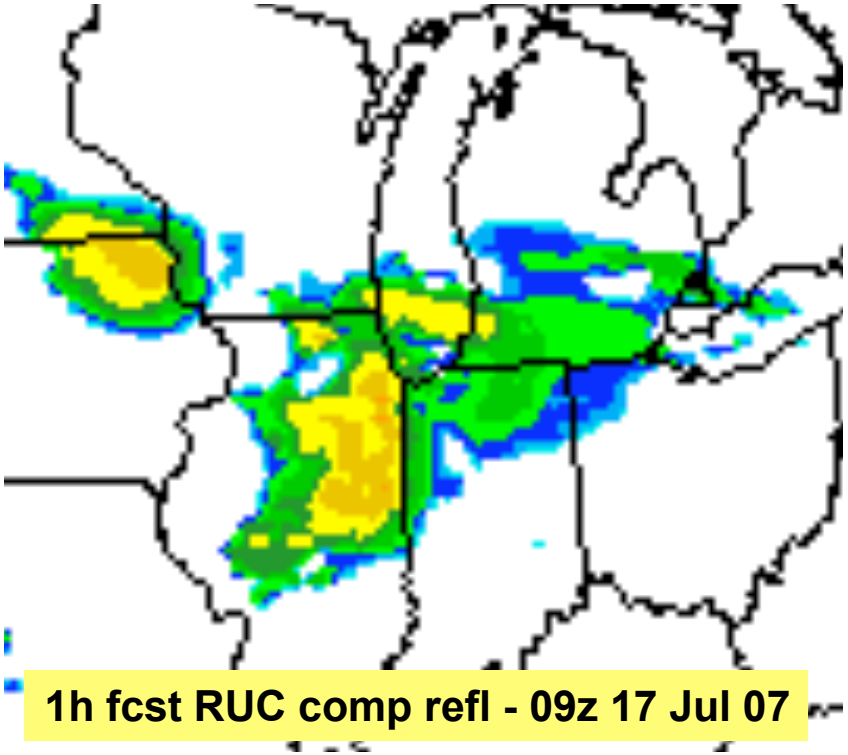
RUC Upgrade at NCEP - Early 08



1h fcst RUC comp refl - 09z 17 Jul 07

RUC 13 change package

- Components
  - Assimilation of new obs - radar reflectivity, TAMDAR wind/temp/RH, mesonet winds
  - Improved surface, precip, reflectivity forecasts
- Status
  - in real-time parallel testing at NCEP (since Aug 2007)
  - Real-time and retrospective tests by 2Q FY08.
  - Implementation by 3Q FY08.

NCEP RUC parallel web site:
http://www.emc.ncep.noaa.gov/mmb/ruc2/para
Comparisons between para and oper RUC

Early 2008 Changes for oper RUC upgrade

- Assimilation
  - Use of **radar reflectivity** in RUC diabatic digital filter initialization in RUC model
  - **Mesonet winds** using mesonet station uselist
  - **TAMDAR aircraft** observations
    (TAMDAR impact parallel RUC tests at GSD)
- Model physics
  - RRTM longwave radiation - eliminates sfc warm bias
  - Mod to Grell-Devenyi – decrease areal coverage, non-local subsidence warming
  - Mod to RUC land-sfc model – fresh snow density - nighttime temps over snow cover
- Post-processing – add reflectivity fields, improved RTMA downscaling

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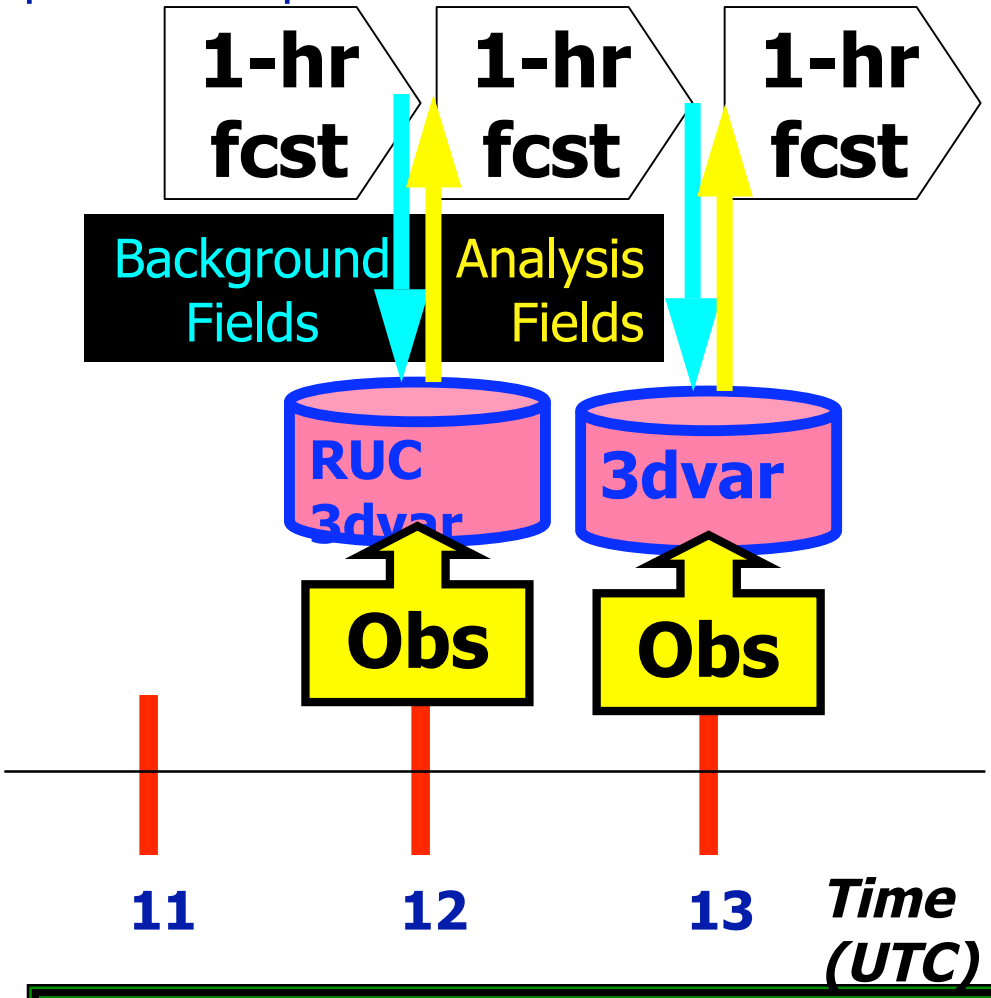
New observations assimilated -- RUC upgrade

Cycle hydrometeor, soil temp/moisture/snow plus atmosphere state variables



Hourly obs in 2008 RUC

Data Type	~Number
Rawinsonde (12h)	80
NOAA profilers	30
VAD winds	110-130
PBL – prof/RASS	~25
Aircraft (V,temp)	1400-7000
→ **TAMDAR (V,T,RH)**	0 - 800
Surface/METAR	1800-2000
Buoy/ship	100- 200
GOES cloud winds	1000-2500
GOES cloud-top pres	10 km res
GPS precip water	~300
Mesonet (temp, dpt)	~7000
→ **Mesonet (wind)**	2000-4000
METAR-cloud-vis-wx	~1600
→ **Radar reflectivity**	2km

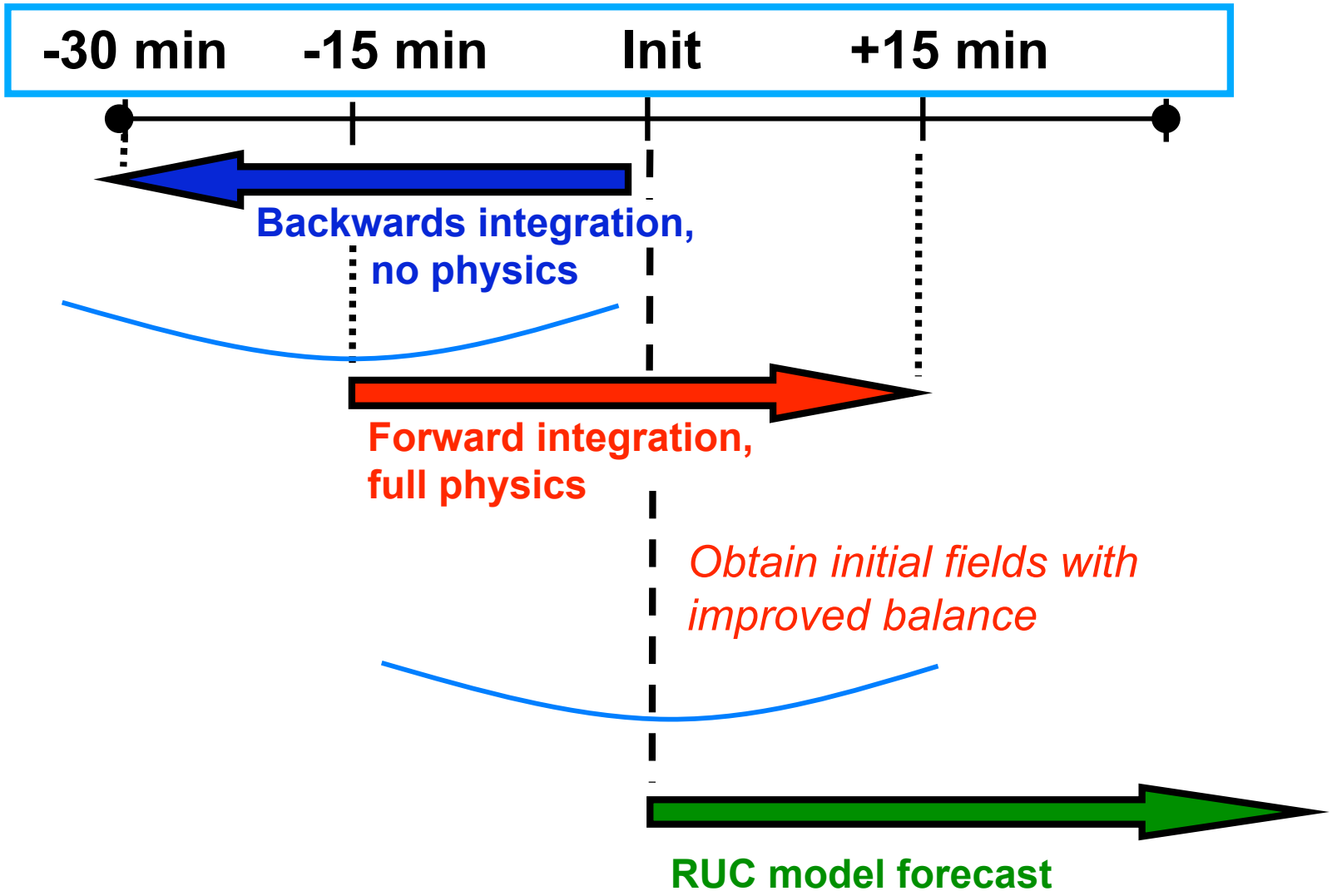
RUC Hourly Assimilation Cycle

RUC reflectivity assimilation procedure

1. **Force precipitation in areas with radar echoes**
   - Specify 3D latent heat from reflectivity
   - Apply latent heat within forward integration of diabatic digital filter initialization (DDFI)
   - Replace temperature tendency from cumulus parameterization and explicit microphysics
   - Moisten echo region, do not add hydrometeors
2. **Suppress convection in echo-free areas**
   - Create convective suppression mask (> 300 mb deep layer > 100 km from existing convection
   - Inhibit cumulus parameterization during DDFI and 1st 30 min. of model integration

RUC Diabatic Digital Filter Initialization (DDFI)

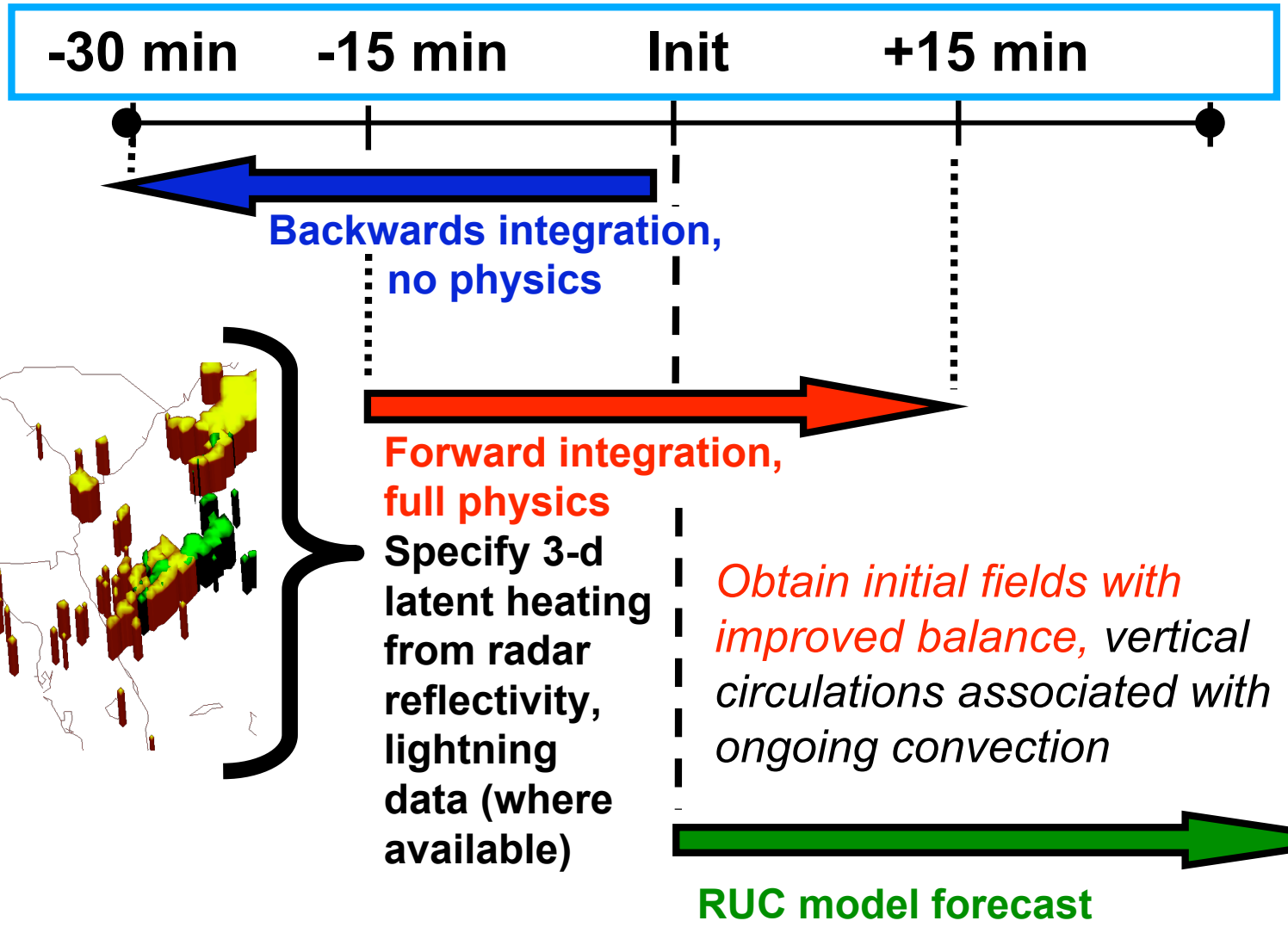
Initial DFI in RUC model at NCEP - 1998 - adiabatic DFI
Diabatic DFI introduced - 2005, 2006



Radar reflectivity assimilation in RUC

Diabatic Digital Filter Initialization (DDFI)

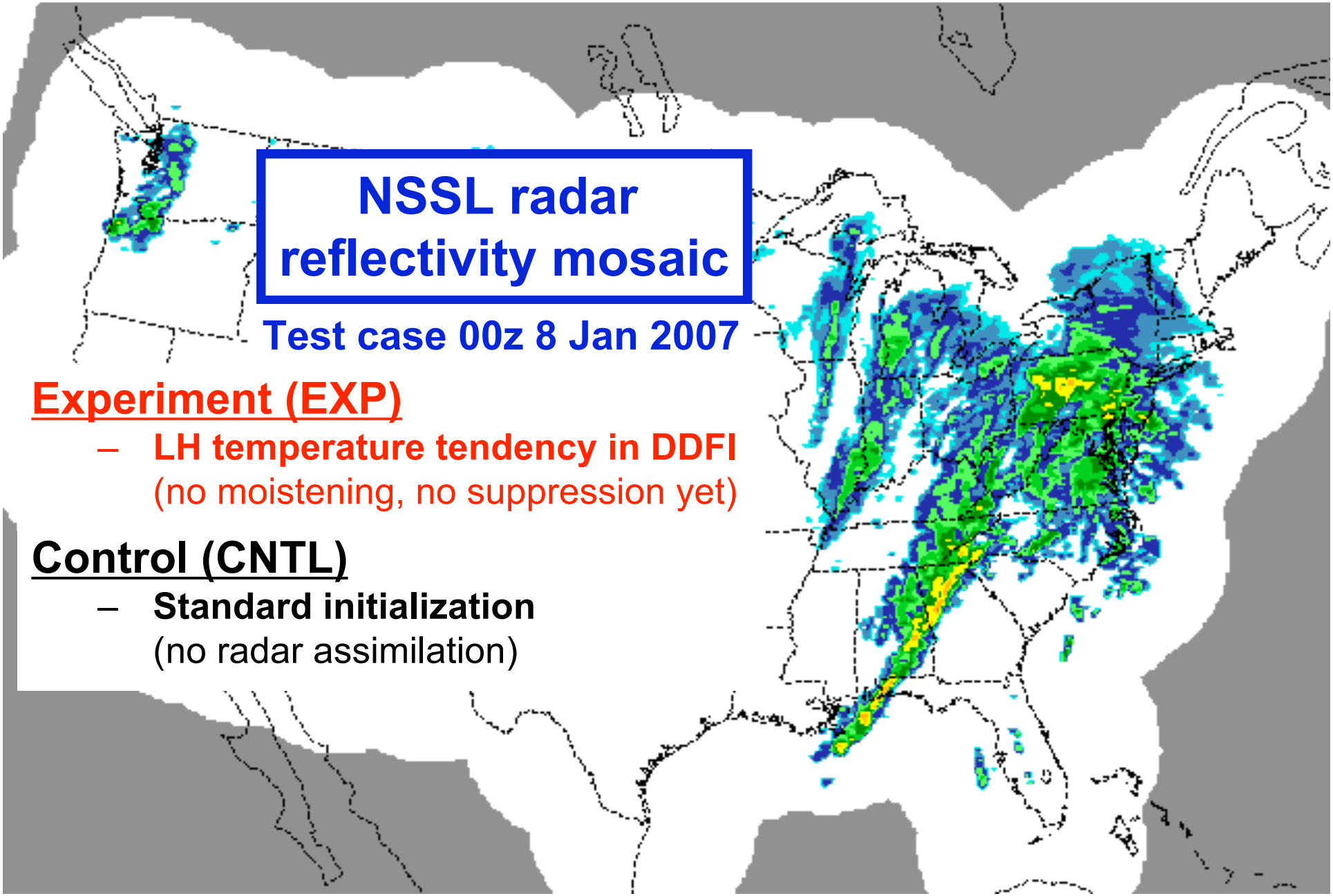
New - add assimilation of radar data



Advantages of radar assimilation procedure

1. **Minimal shock to model**
   - Coherent wind, temperature and moisture fields evolve in response to heating within DDFI
2. **Very little additional computer cost**
   - DDFI already used to control noise
3. **Independent of model or physics packages**
   - Is being added to WRF (for Rapid Refresh)

RUC radar assimilation test case



Experiment (EXP)

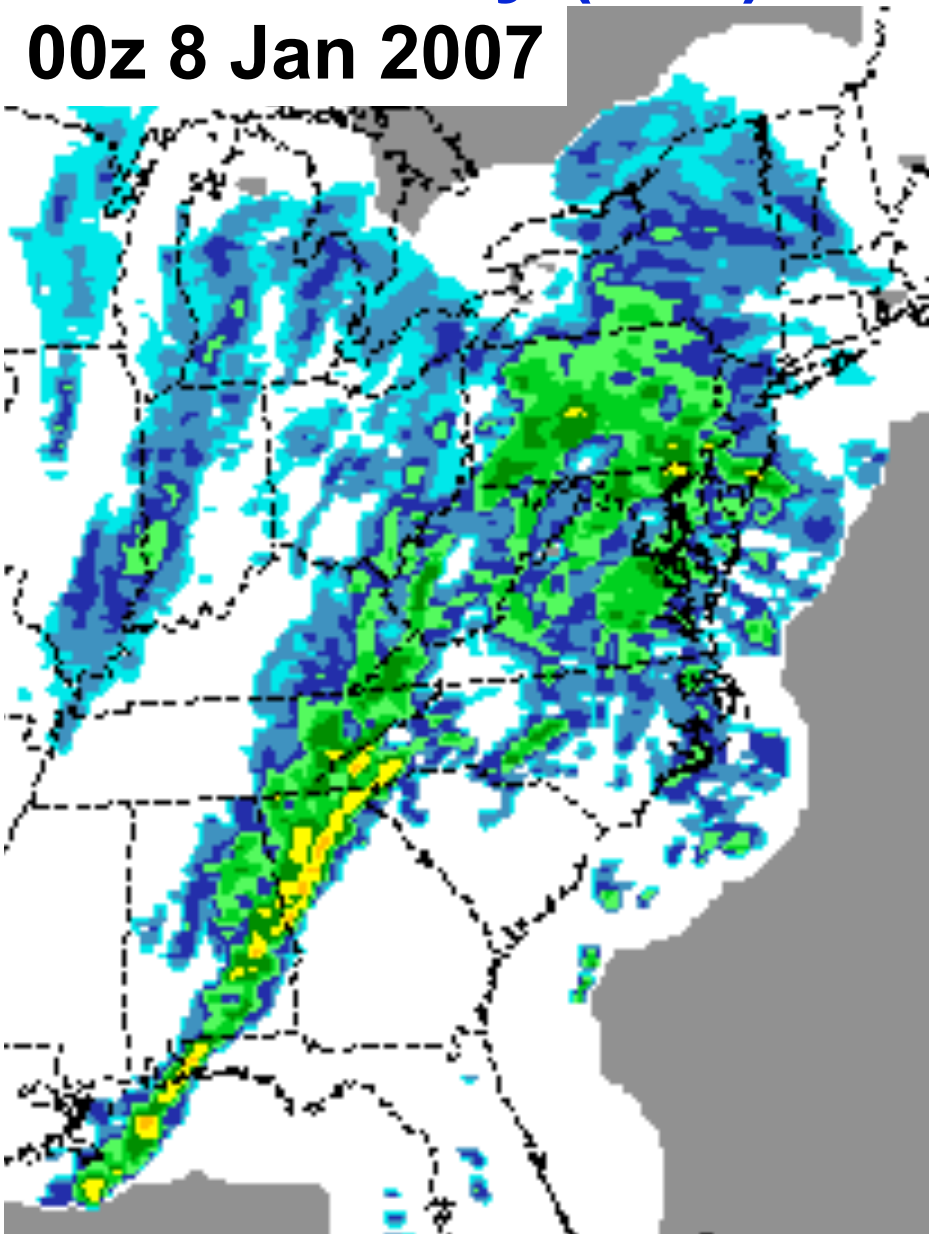
- **LH temperature tendency in DDFI**
  (no moistening, no suppression yet)

Control (CNTL)

- **Standard initialization**
  (no radar assimilation)

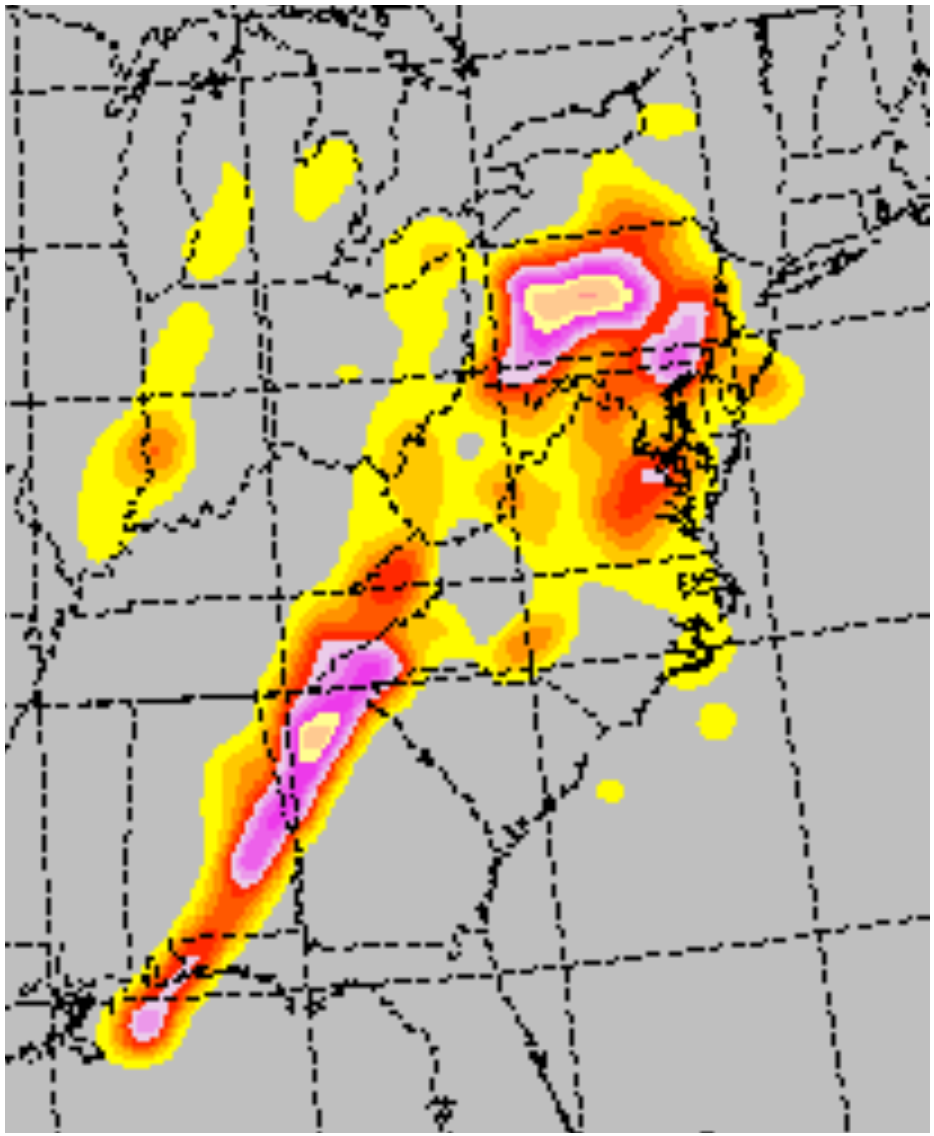
NSSL 3-km radar reflectivity (dbz)

00z 8 Jan 2007



K=15 LH temp. tend. (K / 15 min)

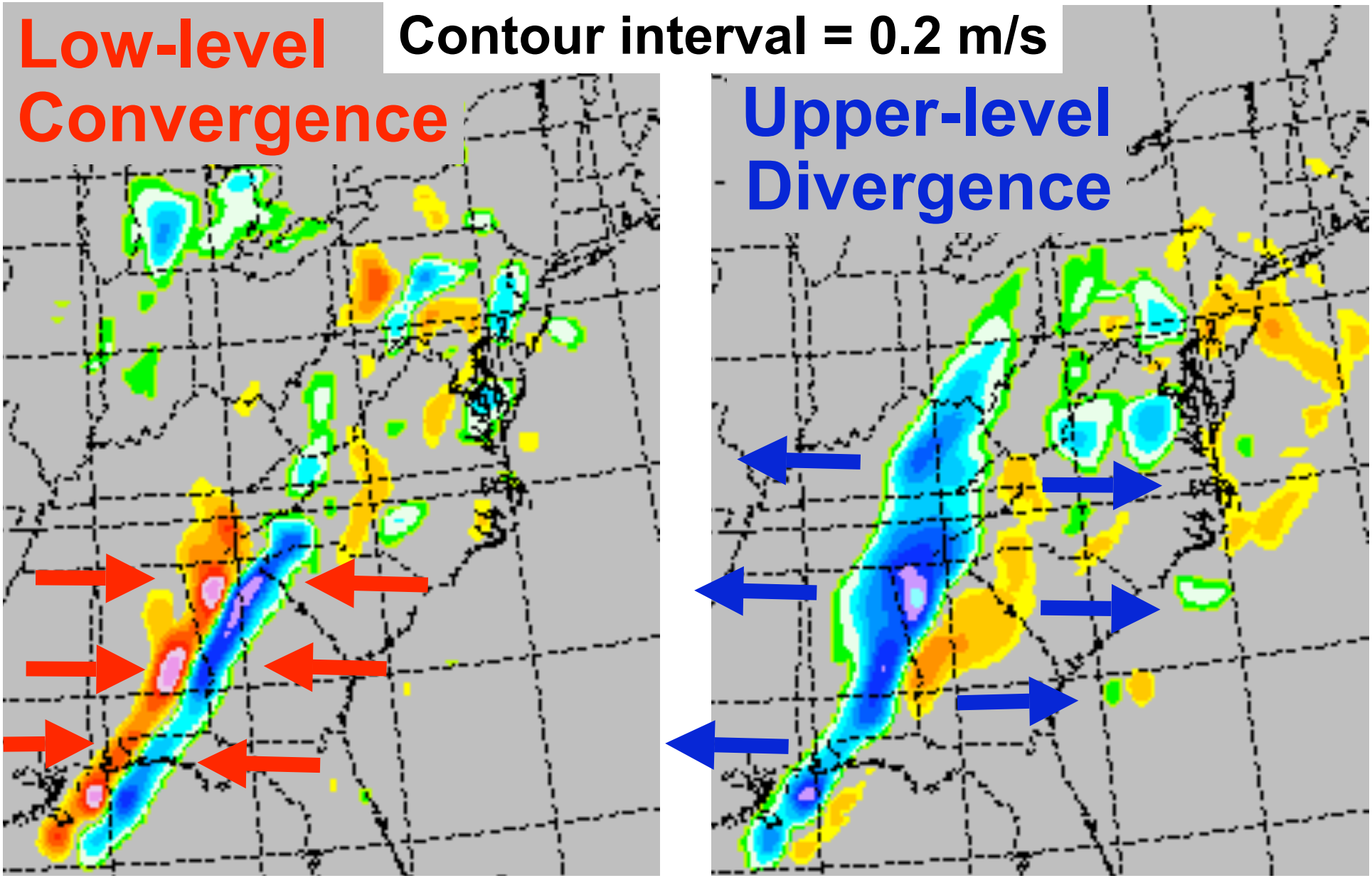
Contour interval = 0.5 K

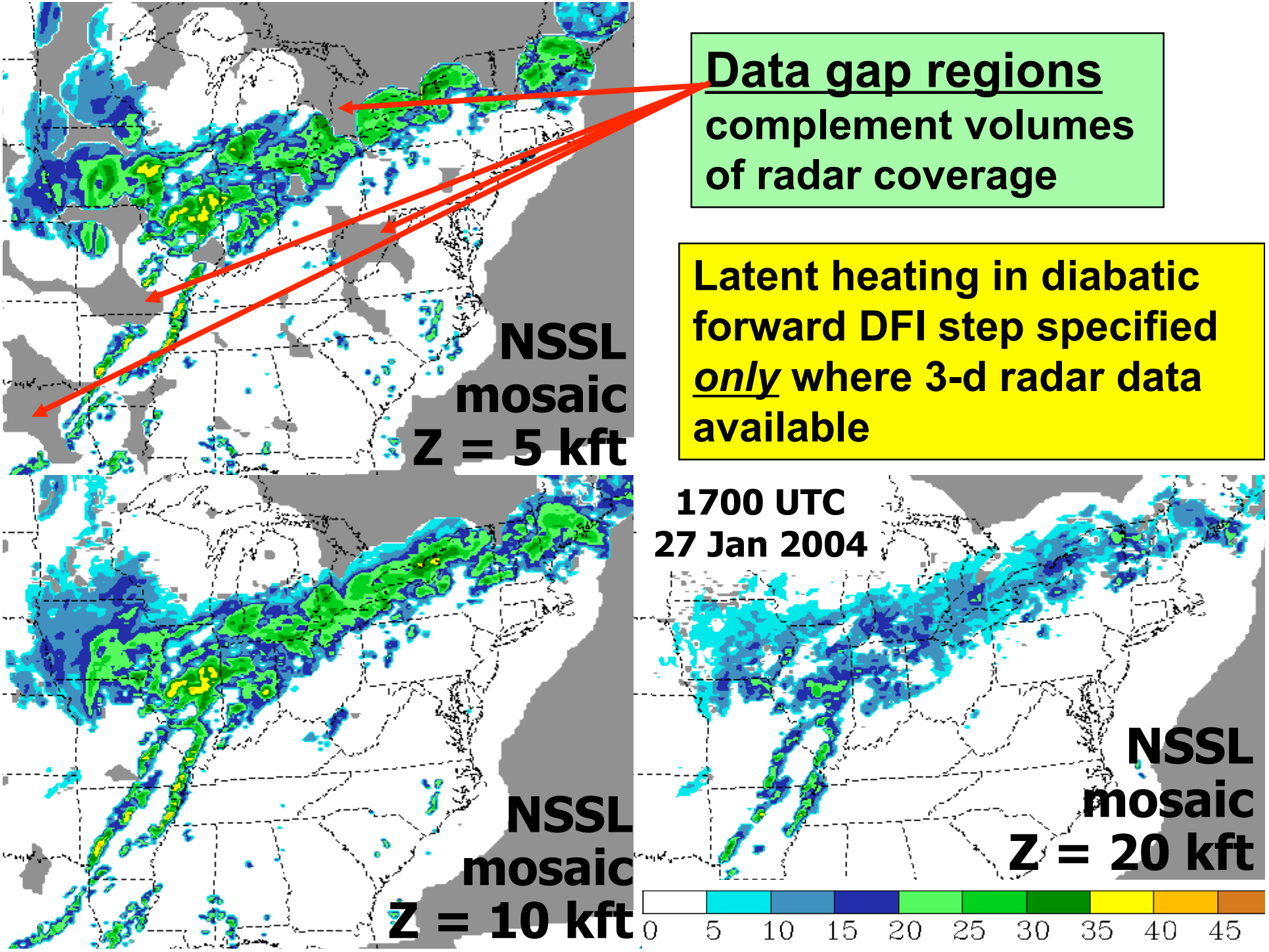


K=15 U-comp. diff (EXP - CNTL)

K=35 U-comp. diff (EXP - CNTL)

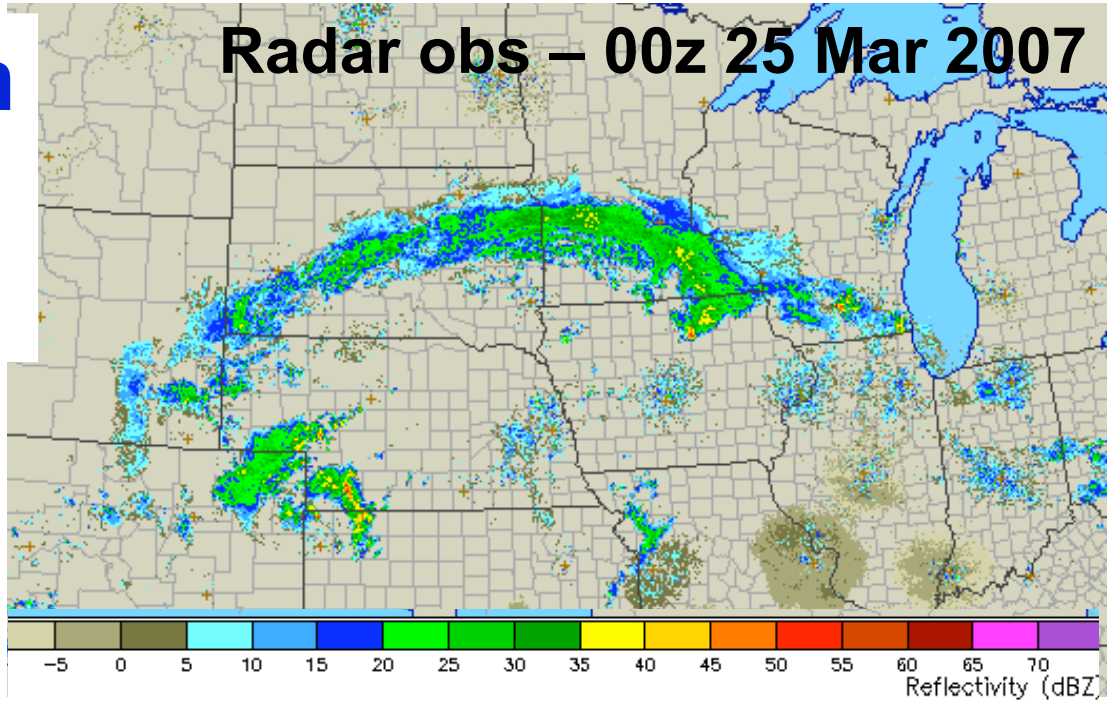
Contour interval = 0.2 m/s



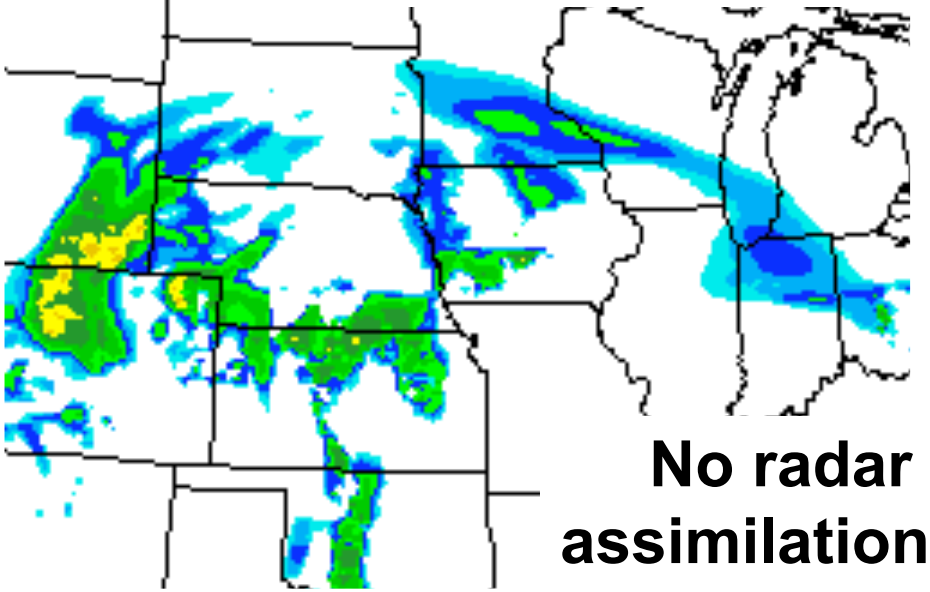

Data gap regions
complement volumes
of radar coverage
Latent heating in diabatic
forward DFI step specified
only where 3-d radar data
available
NSSL
mosaic
Z = 5 kft
NSSL
mosaic
Z = 10 kft
1700 UTC
27 Jan 2004
NSSL
mosaic
Z = 20 kft
0
5
10
15
20
25
30
35
40
45

Radar assimilation in RUC - winter storm example

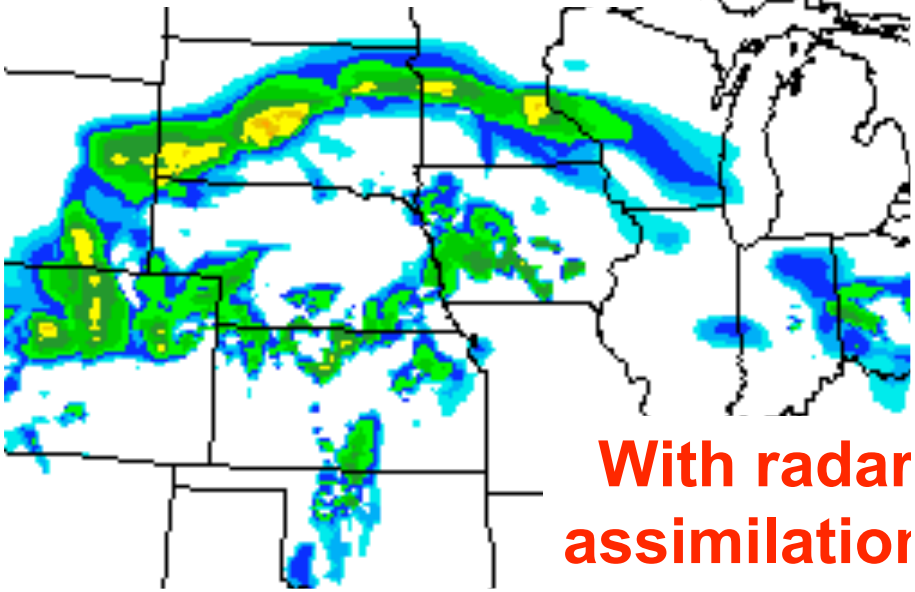
Also, added simulated radar reflectivity field to RUC output



RUC 3-h forecasts valid 00z 25 Mar 2007



No radar assimilation



With radar assimilation

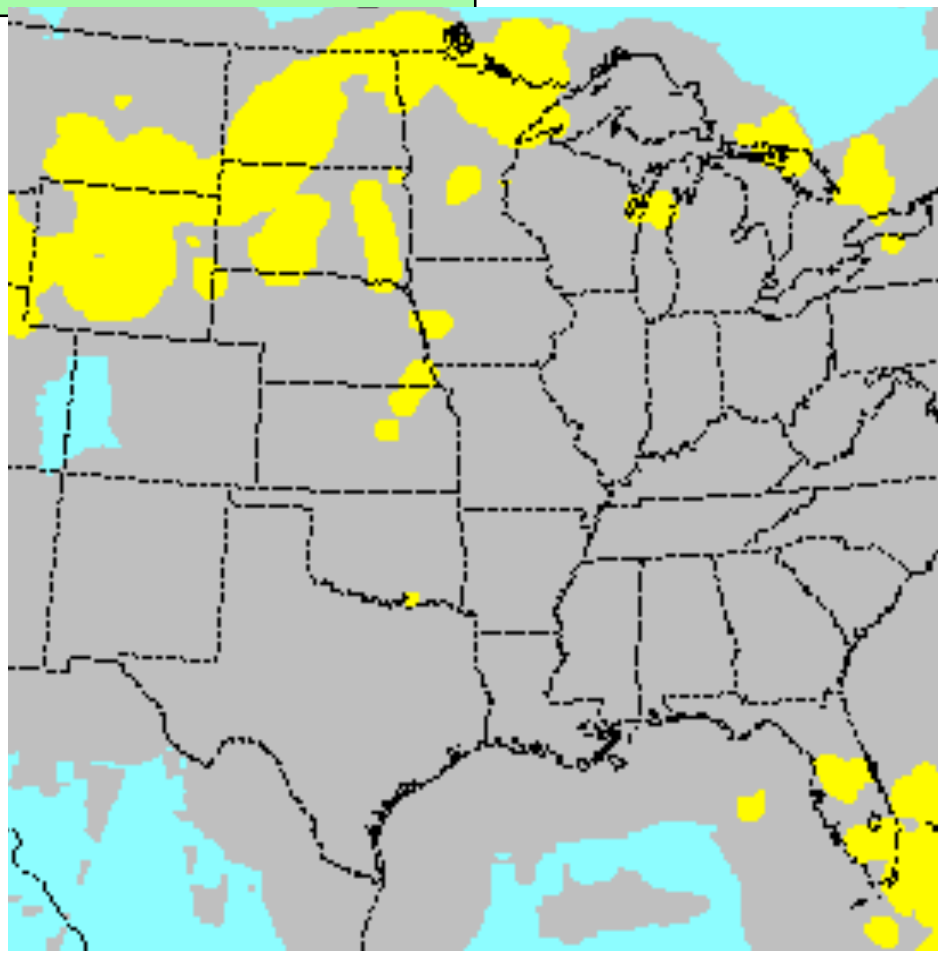
Radar reflectivity assimilation

Part 2 – convection suppression

- **Define suppression areas as follows:**

- **No reflectivity > 20 dbZ within 100 km**
- **Depth of radar data > 300 hPa**
- **Complemented by GOES fully clear areas**

Design in RUC model: Specify minimum cap depth as 0 hPa in DFI step and first 30 min in actual forecast



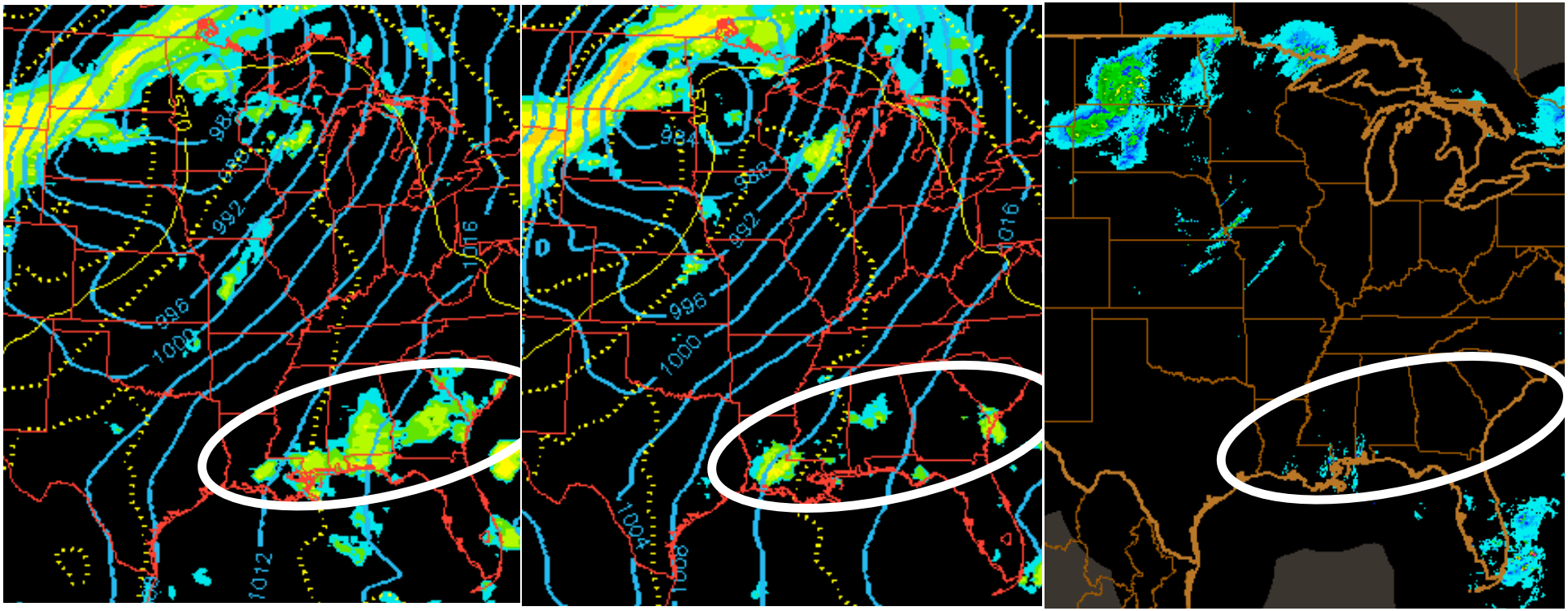
No coverage	Suppress convection	Allow convection

Convective suppression example

Control - radar assim without suppression

Add conv suppression to radar assimilation

NSSL 3-h precipitation



Real-time 3-h forecasts valid 15z 7 June 2007

Valid 15z 7 June 2007

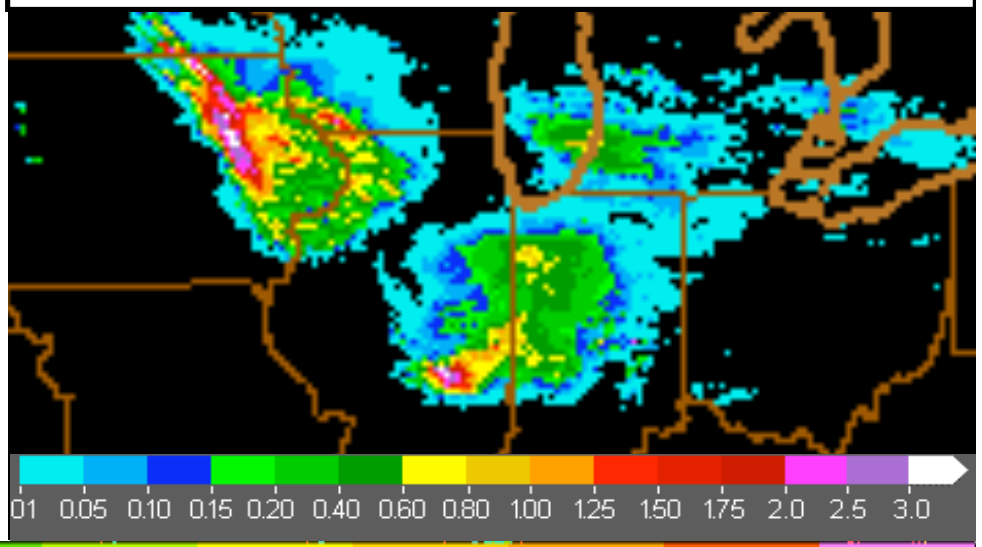
convective suppression - *How does it work? –*

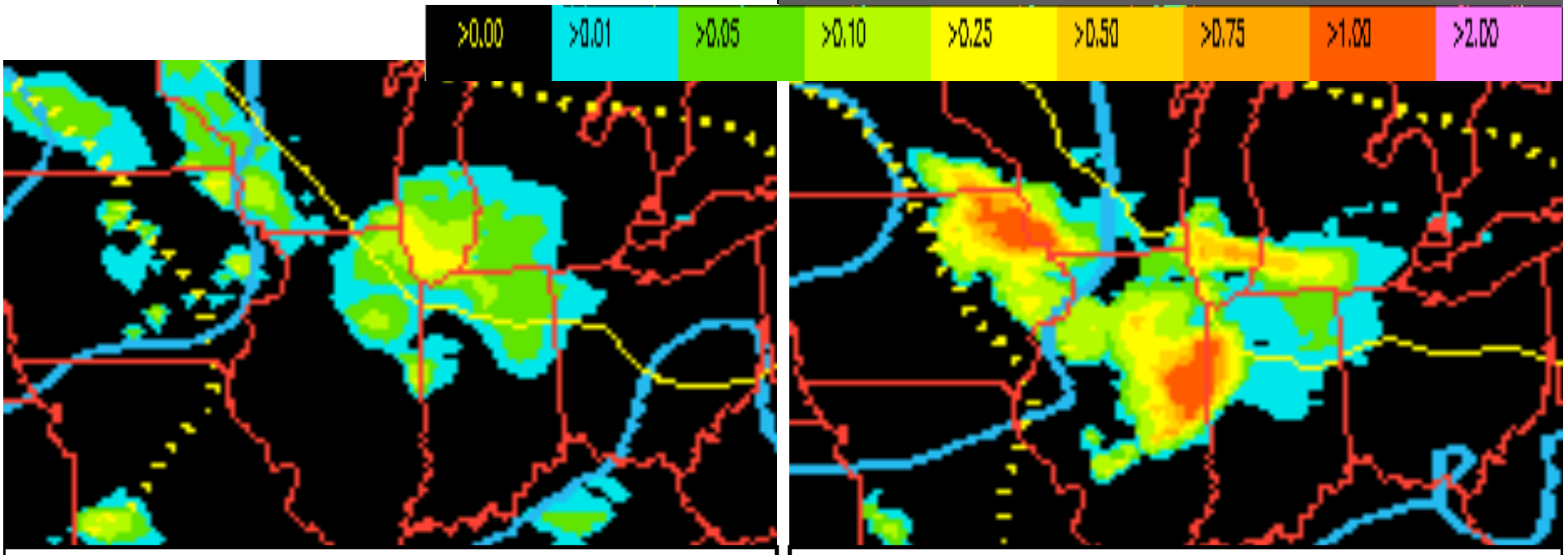
Reduces latent heating, vert. motion in erroneous conv areas

Overall effect of RUC radar assimilation

- Overnight convection example

NSSL 12z 3-h accum. Precip.

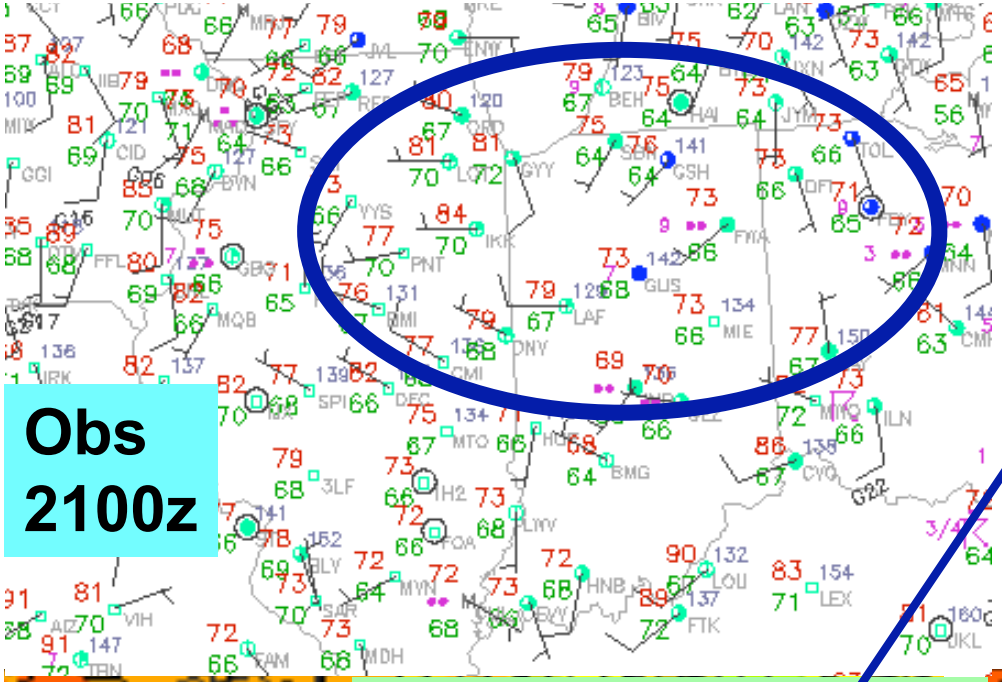




No radar assimilation

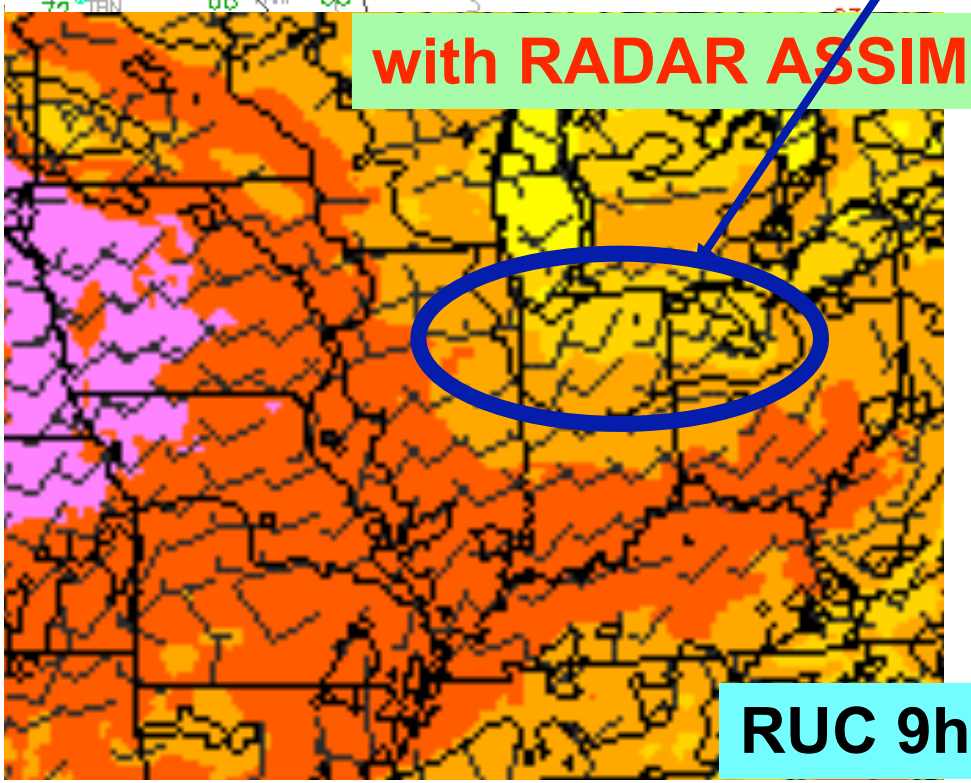
Radar assimilation

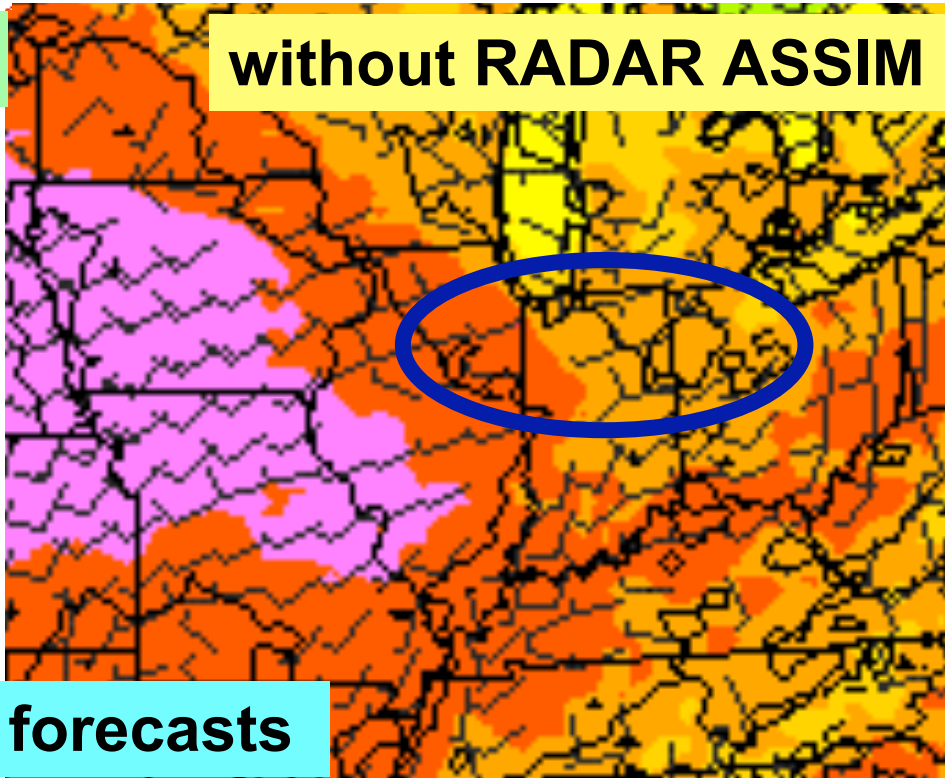
Evaporative cooling - improved cold pool with radar assim



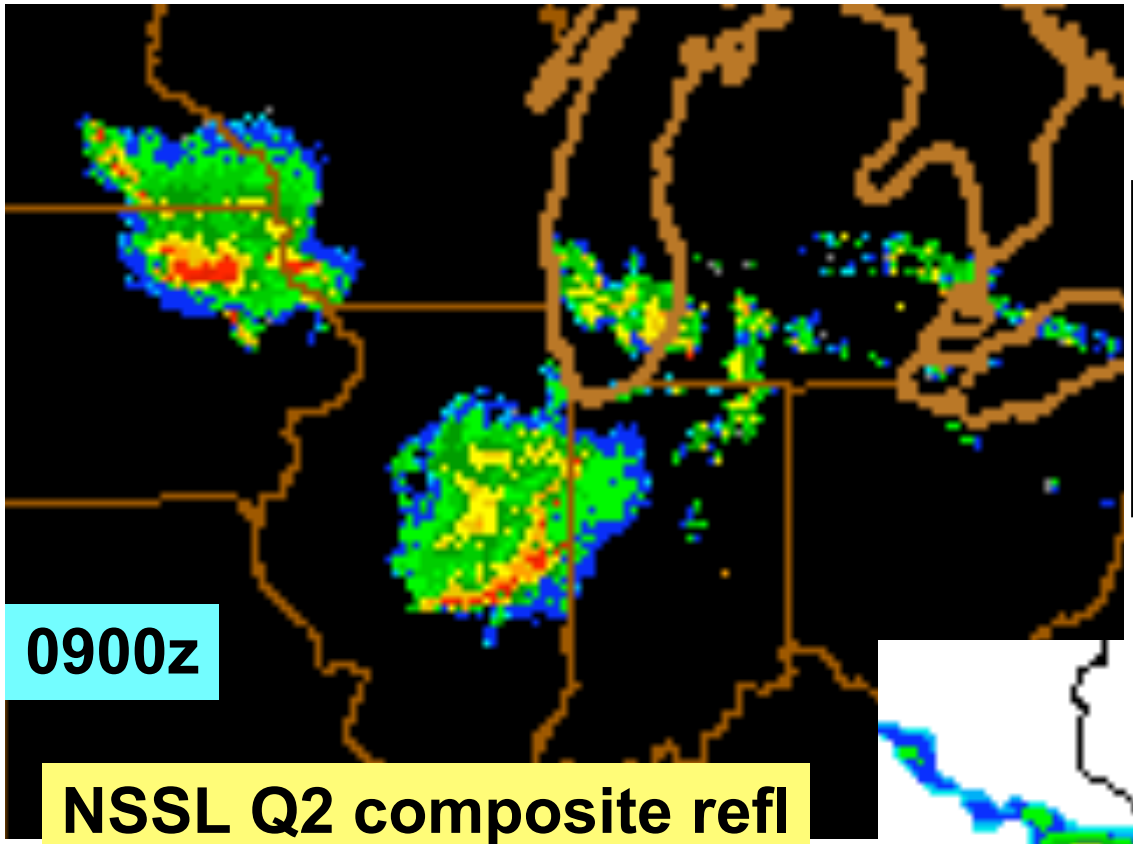
Sfc Temp – 21z
Tues 17 July 2007

>60.0 >70.0 >80.0 >90.0 >100.0



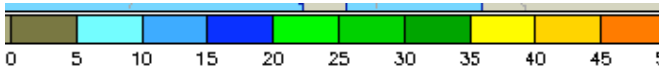


RUC 9h forecasts

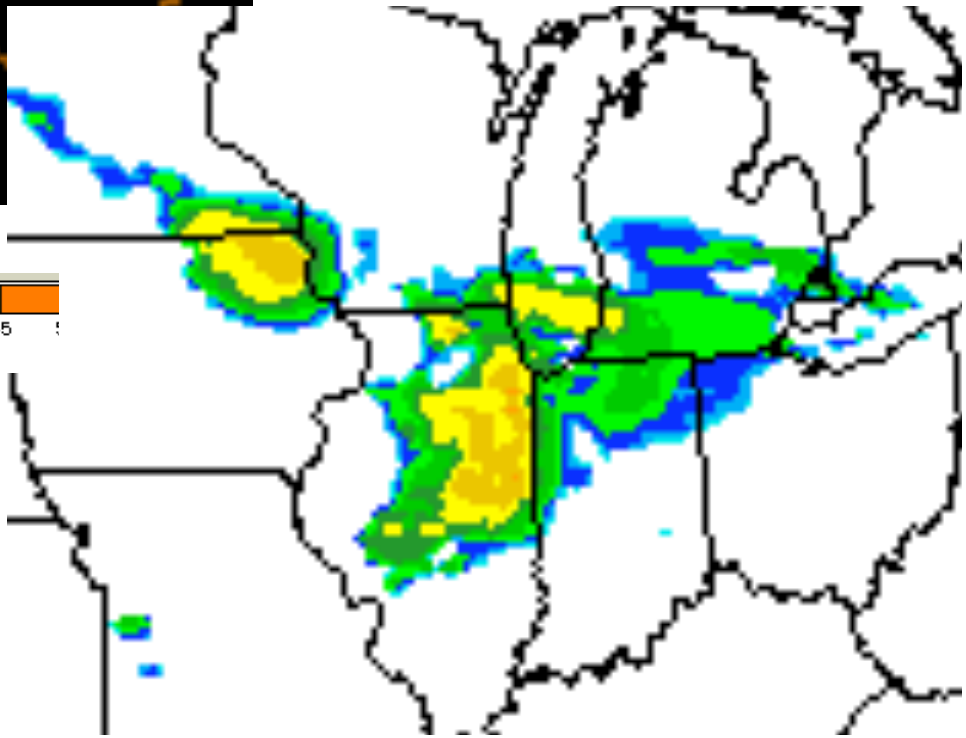


0900z

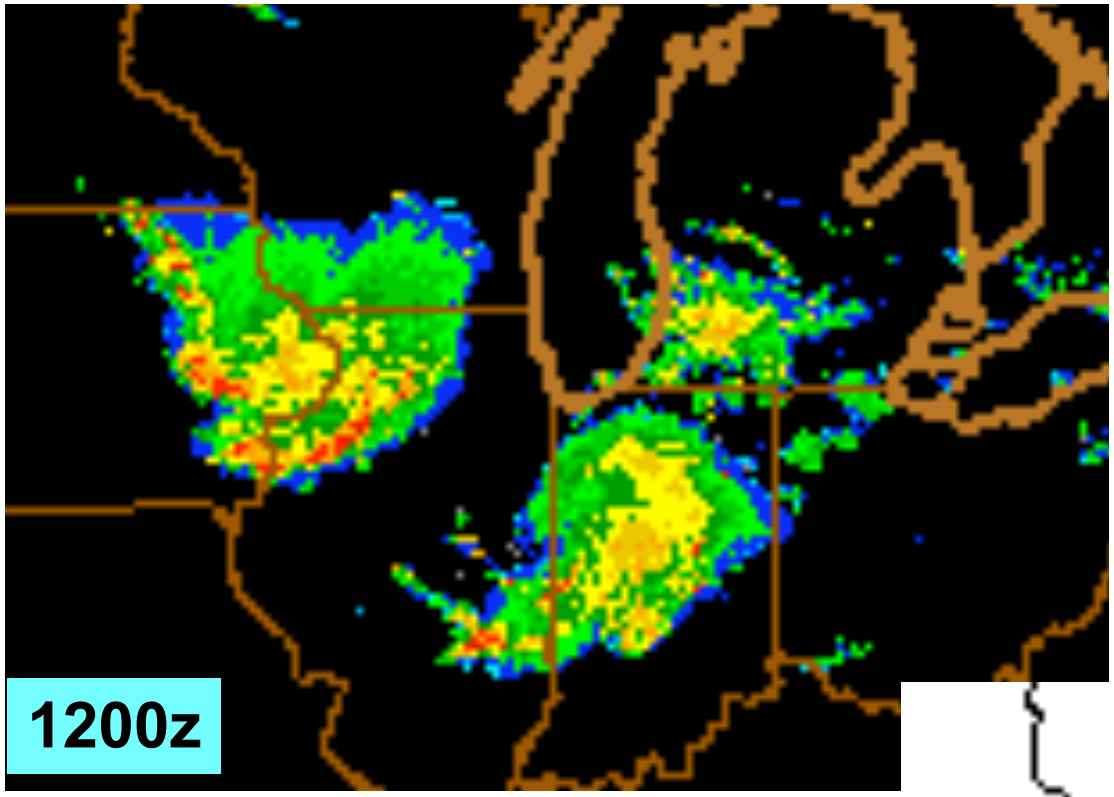
NSSL Q2 composite refl



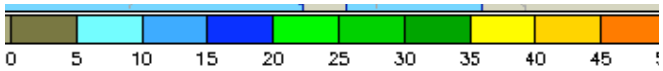
RUC "analysis"
composite reflectivity
(actually 1h fcst)
- fairly good agreement



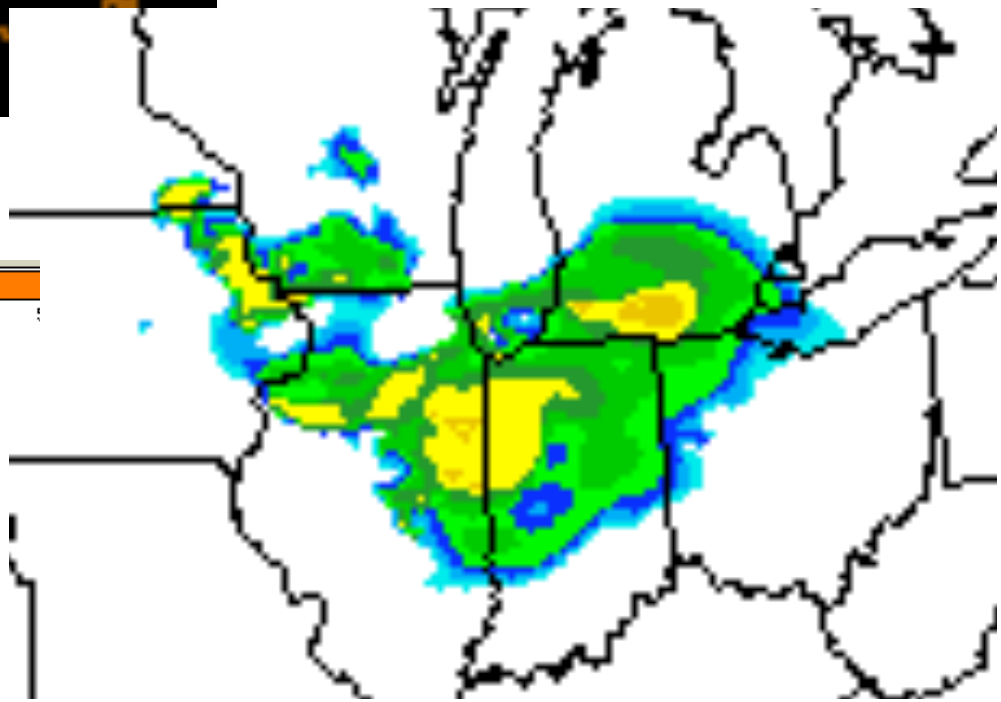
0900z reflectivity
Tues 17 July 2007



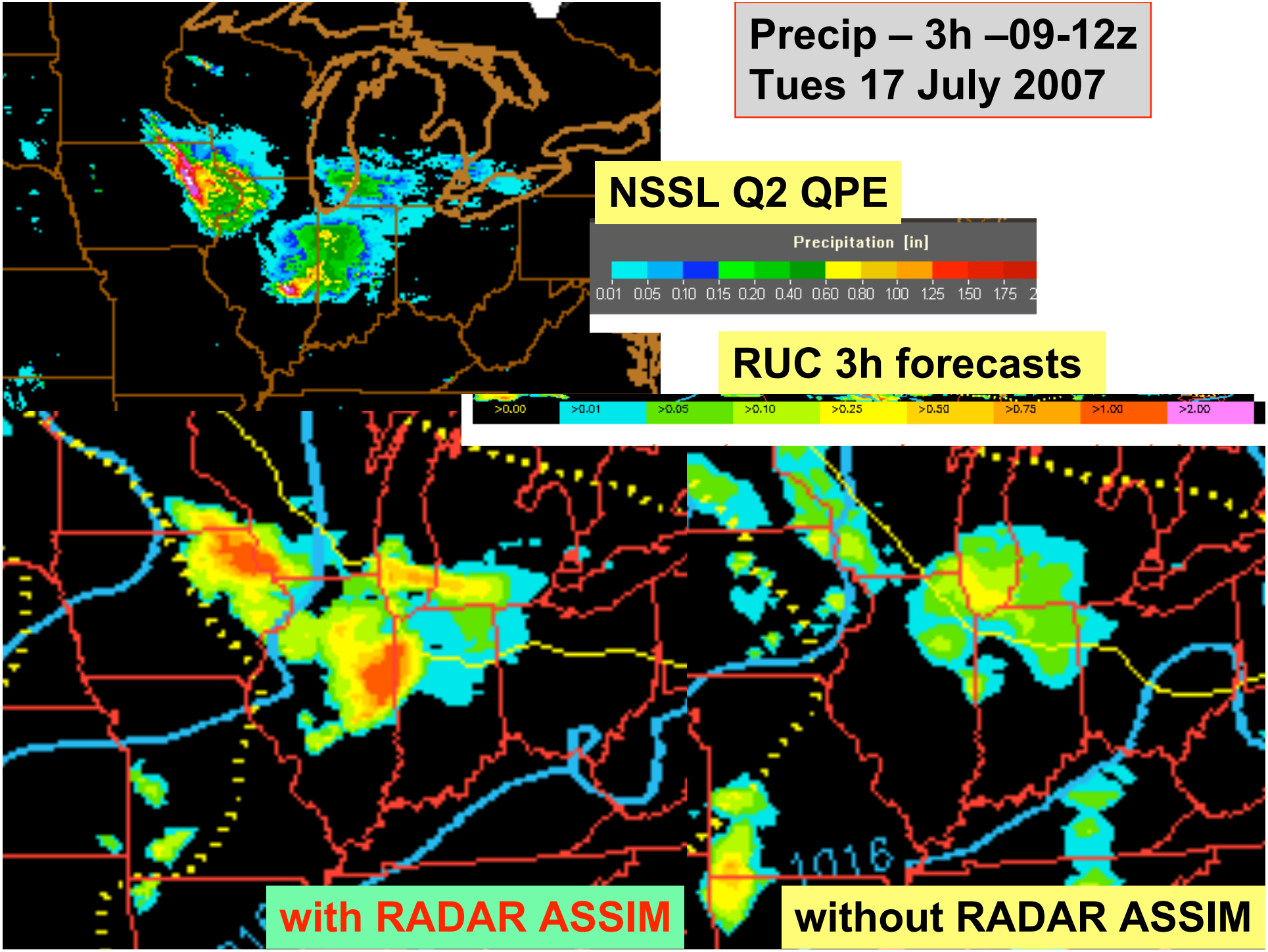
NSSL Q2 composite refl



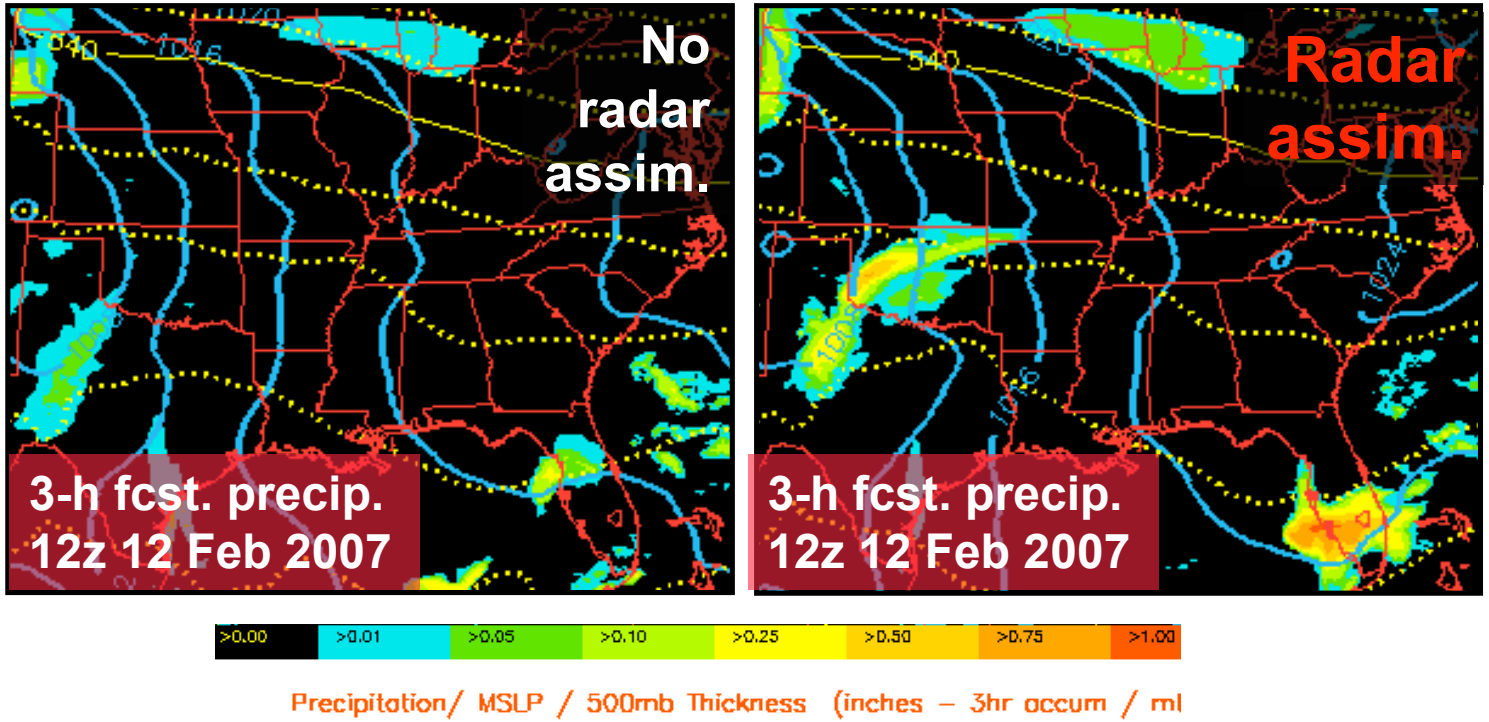
RUC 3h forecast composite refl



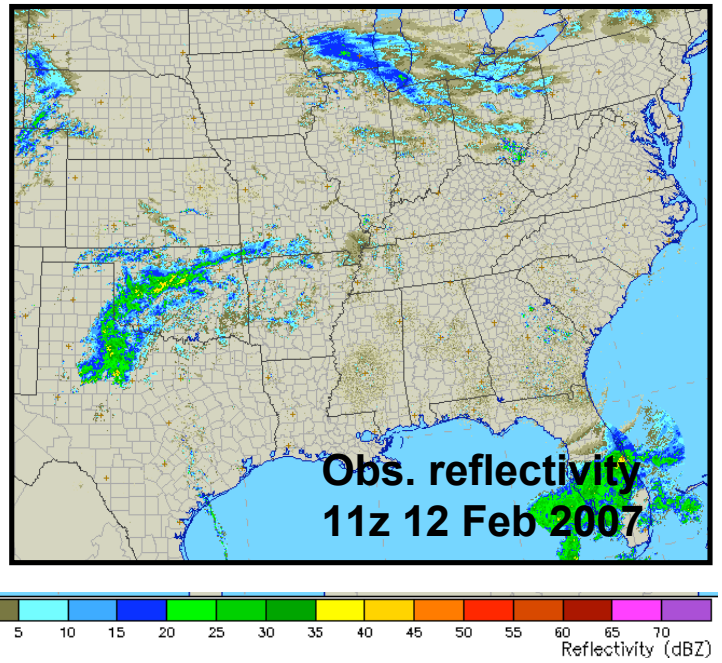
Valid 1200z
Tues 17 July 2007


Precip – 3h –09-12z
Tues 17 July 2007
NSSL Q2 QPE
Precipitation [in]
0.01 0.05 0.10 0.15 0.20 0.40 0.60 0.80 1.00 1.25 1.50 1.75 2
RUC 3h forecasts
>0.00 >0.01 >0.05 >0.10 >0.25 >0.50 >0.75 >1.00 >2.00
with RADAR ASSIM
without RADAR ASSIM

3-h fcst accum. precip. from RUC with and without radar assimilation



Real-time case from 09z 12 Feb 2007

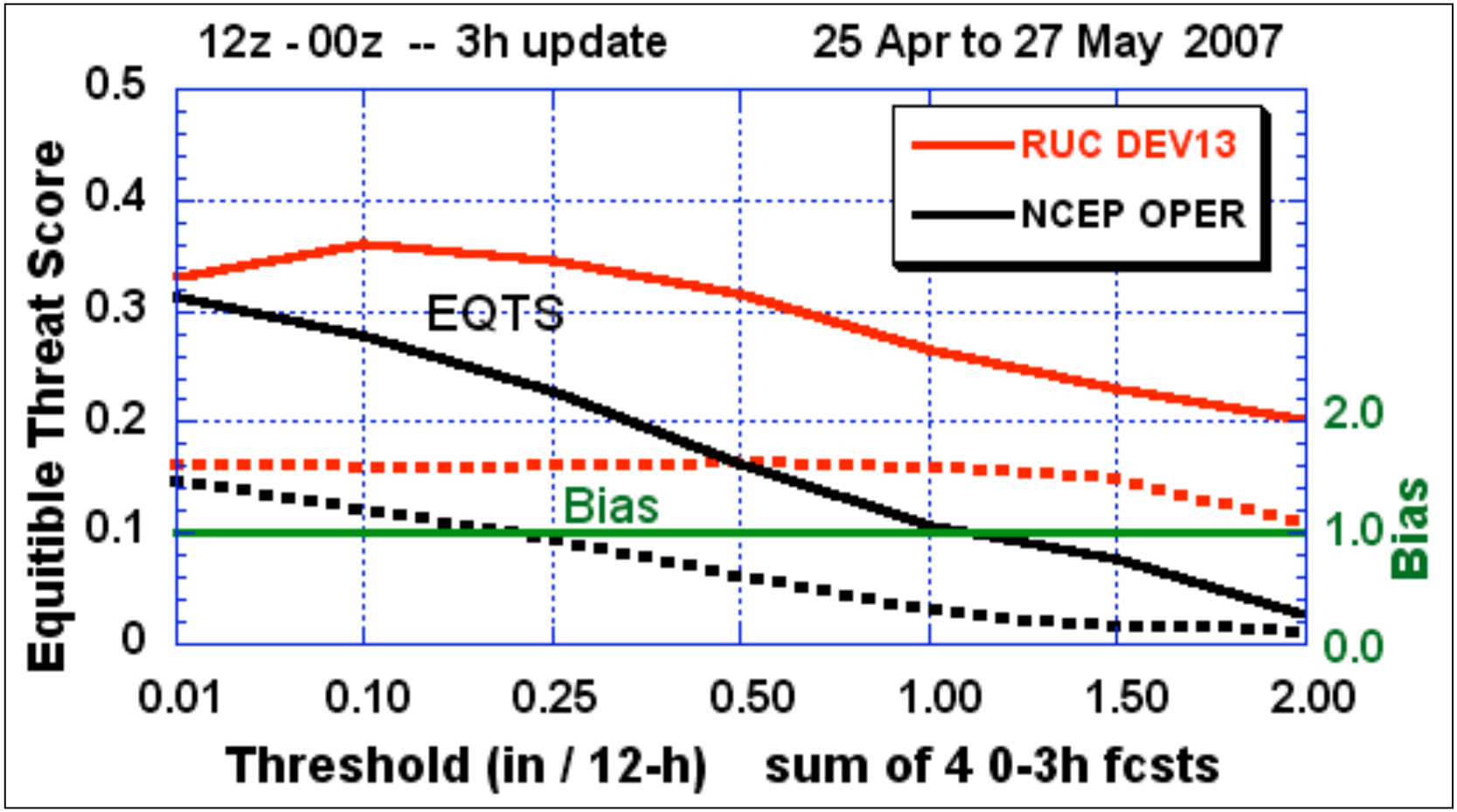


RUC Radar refl assim w/ DDFI

- effective on winter as well as summer events

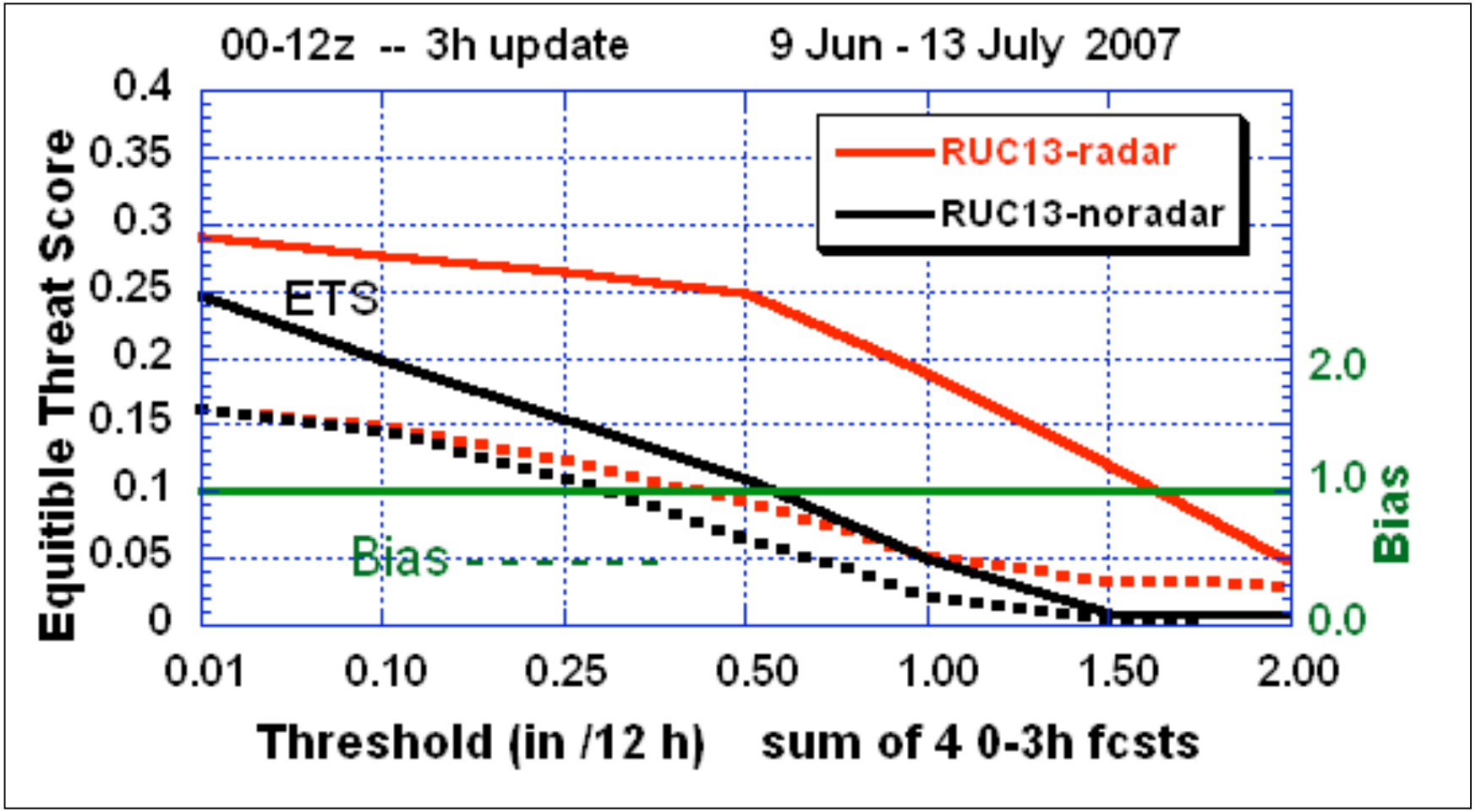
Radar assimilation impact on 3-h precipitation skill scores

- Significant improvement in ETS and bias
- Spring - daytime



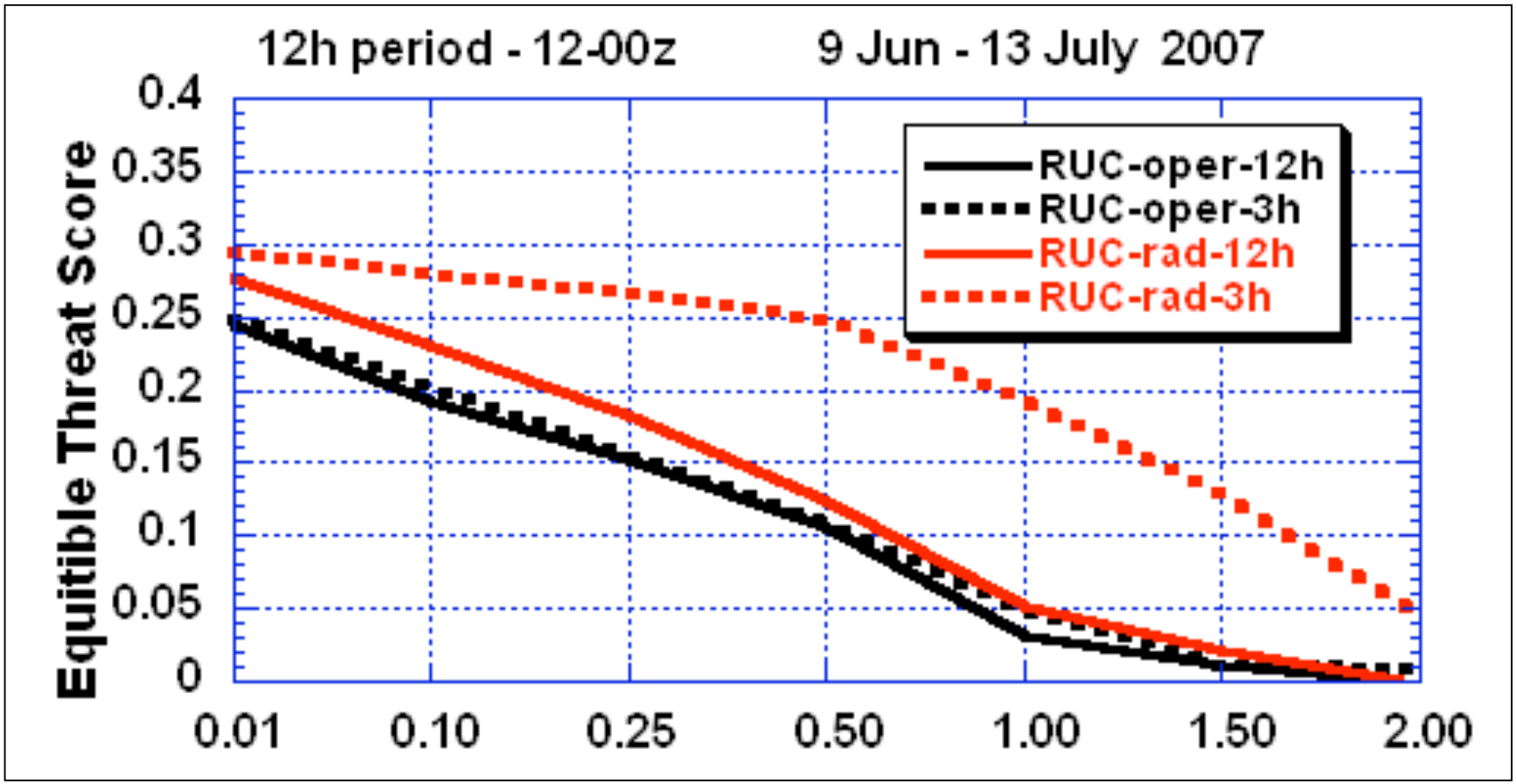
Radar assimilation impact on 3-h precipitation skill scores

- ***Summer - overnight***



Radar assimilation impact on 3-h precipitation skill scores

- 4 x 0-3h vs. 1x0-12h
- Summer - daytime

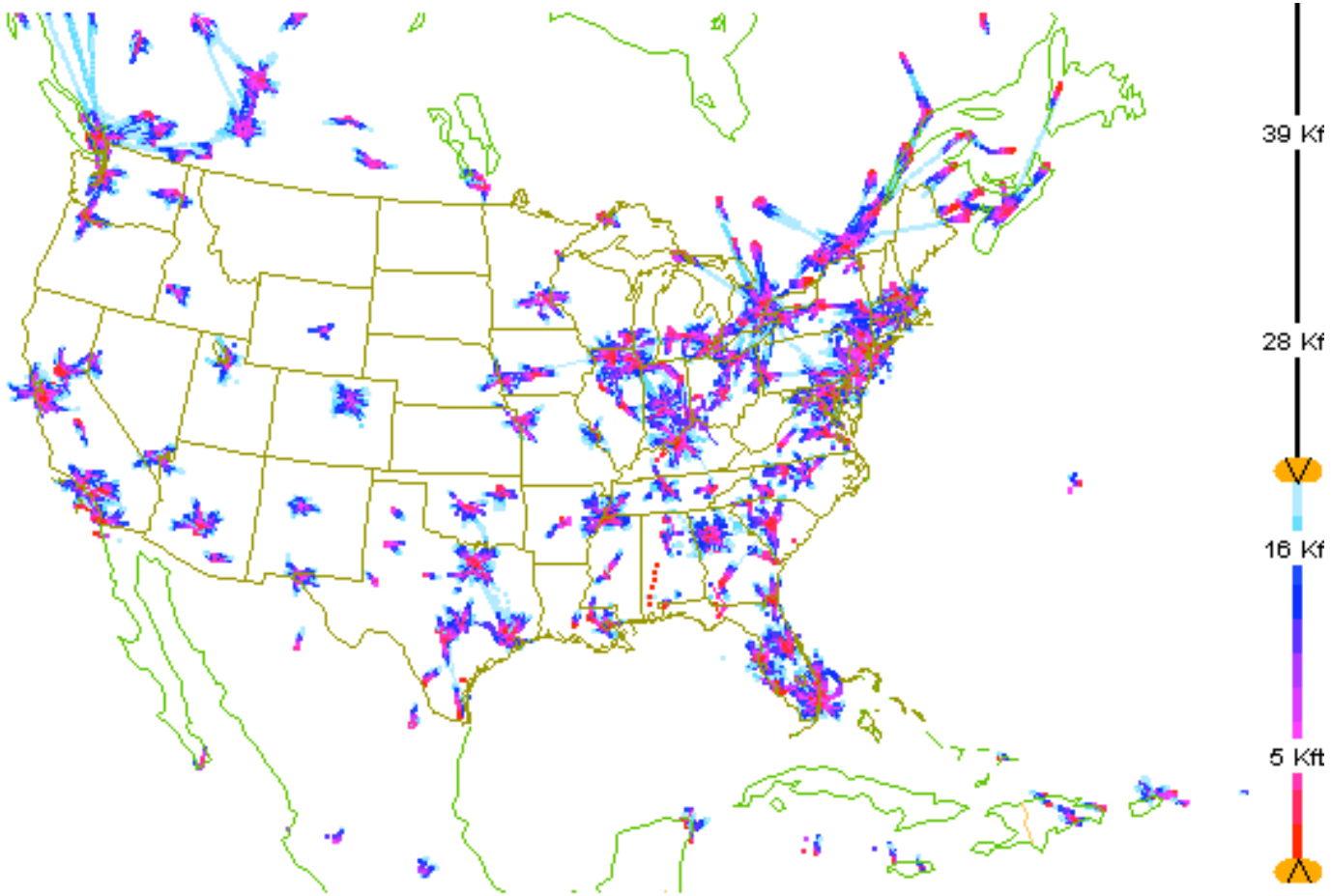


(On RUC assimilation of TAMDAR data) - AMDAR and TAMDAR definitions

- **"AMDAR" (Automated Meteorological Data and Recording) – are automatically sent from commercial aircraft, mostly large jets**

- **"TAMDAR" (Tropospheric AMDAR) – automatic reports from (currently) ~50 turboprops flying regionally in the US Midwest**
  - Provided by AirDat LLC
  - Agreement between Northwest Airlines (Mesaba – regional subsidiary) and AirDat LLC
  - New agreement between NWS/FAA and AirDat for use of TAMDAR

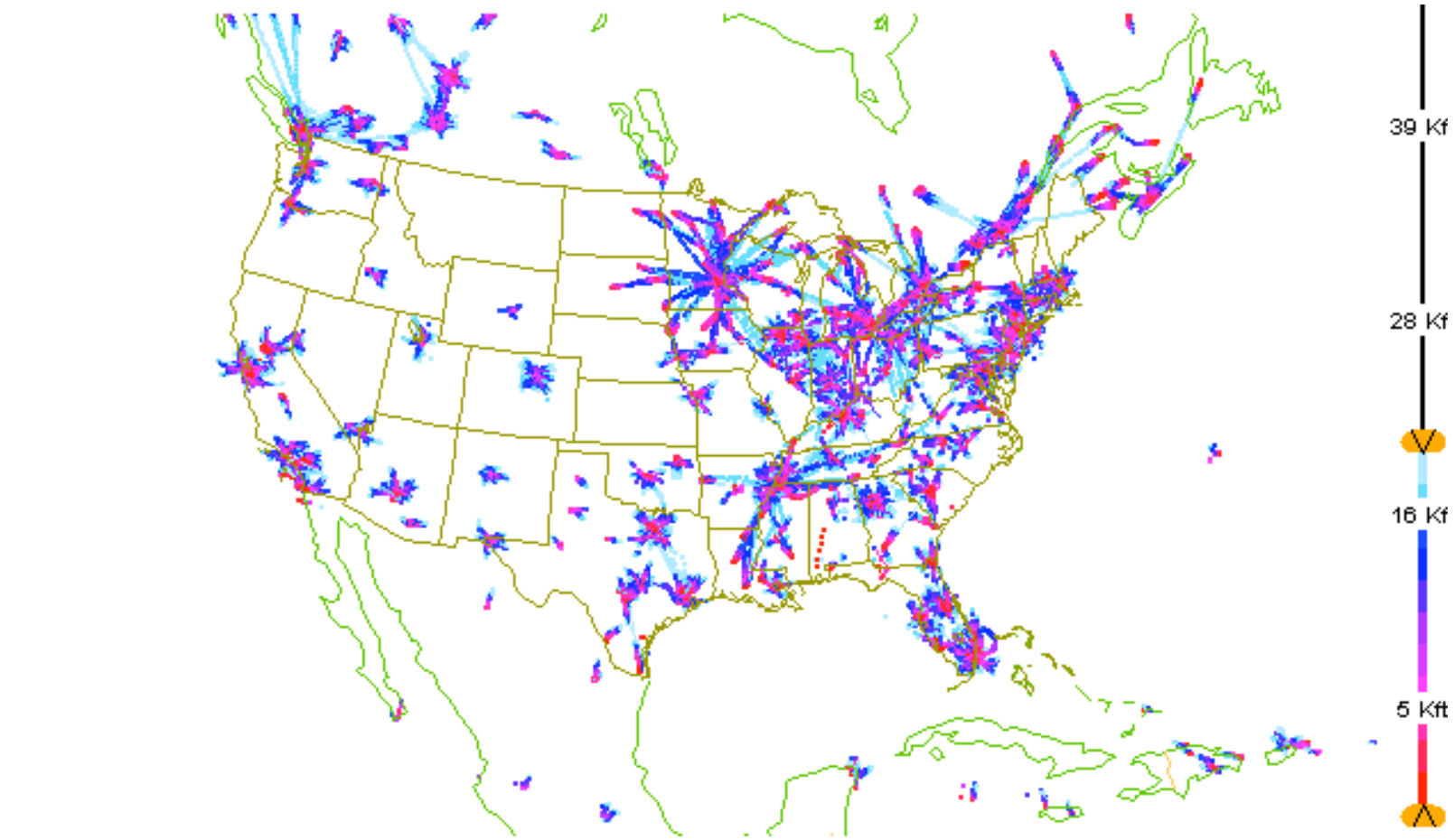
Aircraft coverage is limited to major hubs below 20 Kft,
(without TAMDAR)



05-Jun-2007 00:00:00 -- 05-Jun-2007 23:59:59 (287984 obs loaded, 102442 in range, 9337 shown)

NOAA / ESRL / GSD Altitude: -1000 ft. to 20000 ft. Good w and T not-TAMDAR

Below 20 Kft, with TAMDAR – better regional coverage in the Midwest



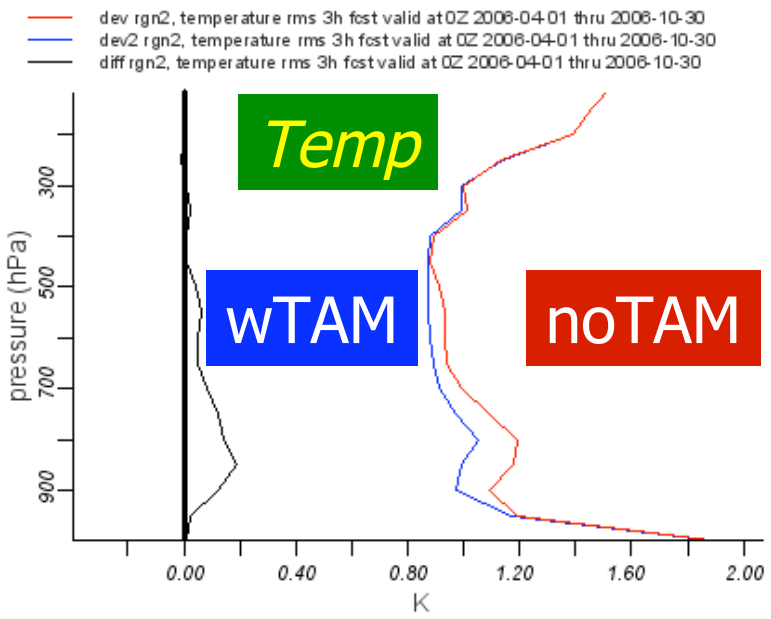
05-Jun-2007 00:00:00 -- 05-Jun-2007 23:59:59 (287984 obs loaded, 112138 in range, 11213 shown)

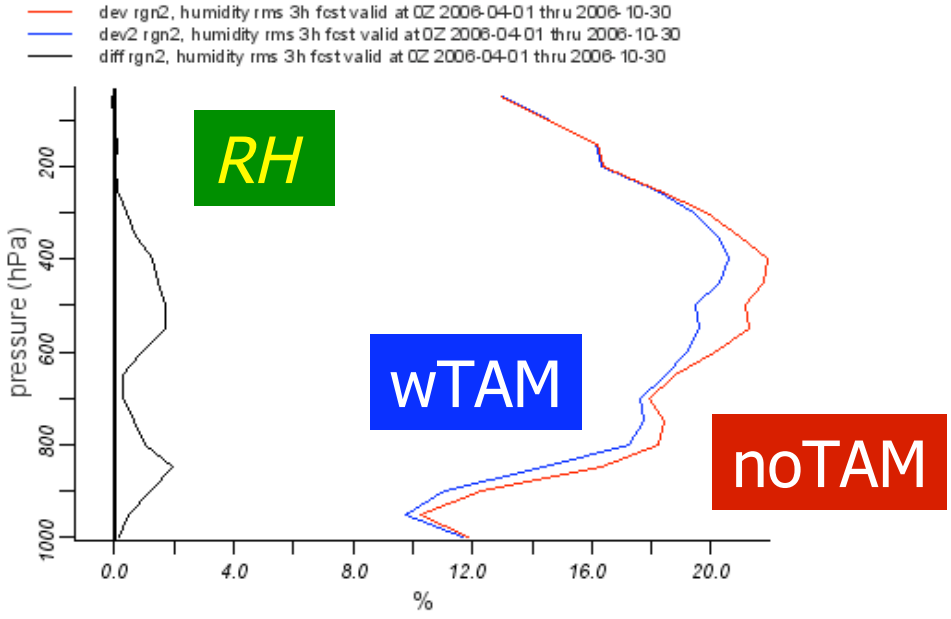
NOAA / ESRL / GSD Altitude: -1000 ft. to 20000 ft. Good w and T

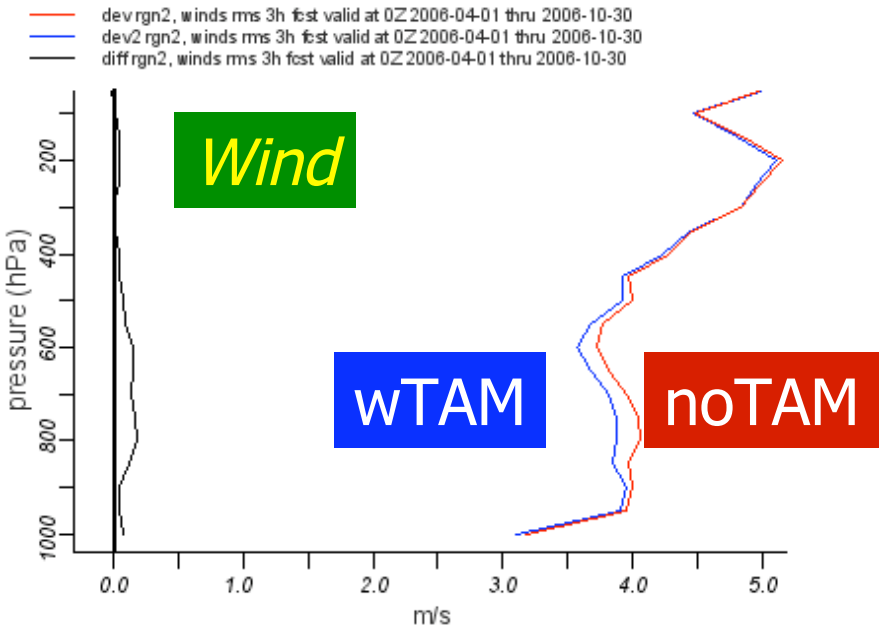
TAMDAR Variables

- **TAMDAR measures temperature and winds aloft, as does the rest of the AMDAR fleet**
- **In addition, TAMDAR measures**
  - **water vapor**

3h Fcst errors – RUCdev (no TAMDAR), RUCdev2 (w/ TAMDAR)







TAMDAR – regional aircraft with V/T/RH obs

GSD impact study with RUC parallel cycles

- 2005-2007 (ongoing)
- 10-30% reduction in RH, temperature, wind fcst error w/ TAMDAR assimilation

Mesonet station wind uselist: ~4400 out of 12,100 stations

Basis:

* mean wind speed diff from RUC 1h forecast < 1.0 m/s
  (over 10-day period in October 2007 - 18-21z-daytime)
* All winds used from METAR, RAWS, OK-Meso,
  other selected providers

Network	uselist	total	% low 10m spd bias
UrbaNet	357	810	44
Citizens	659	3422	19
AWS	2207	5226	43
OK-Meso	80	116	69
GoMOOS	10	11	91
MesoWest	454	972	47
RAWS	826	1696	49
METAR	1284	2069	62
WXforYou	20	97	21

RUC change package – ***use of mesonet winds***

- Assimilate mesonet winds from accepted **station** uselist
  - Developed from 10-day period database of wind speed differences between surface stations and RUC 1h forecasts
  - Allows about additional wind observations to be used hourly in RUC from ~4400 stations on use list (out of 12000)
  - Primary mesonet providers (e.g., Citizens Weather, AWS) have common siting problems
    - Mesonet winds turned off for RUC13 implementation in 2005, not used yet in NAM or RTMA for same reason
  - New RUC treats each mesonet station separately
  - GSD-derived mesonet station uselist will be available to RTMA and NAM

Early 2008 Changes for oper RUC upgrade

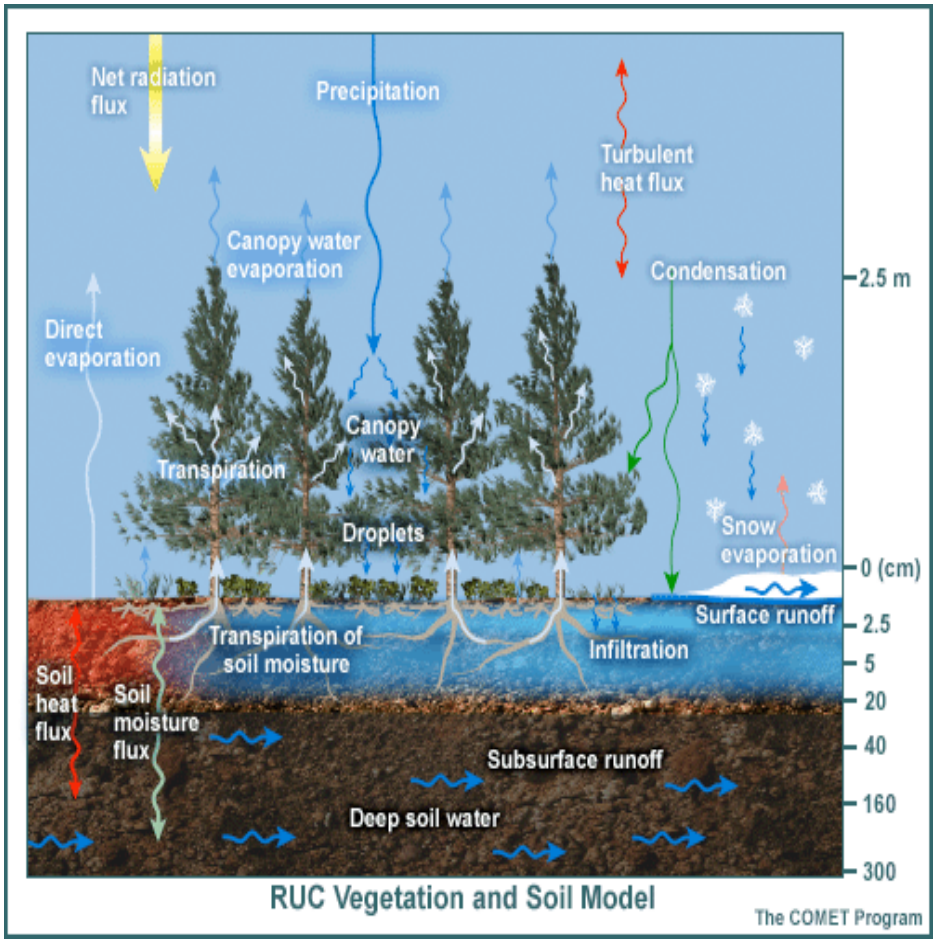
- Assimilation
  - Use of **radar reflectivity** in RUC diabatic digital filter initialization in RUC model
  - **Mesonet winds** using mesonet station uselist
  - **TAMDAR aircraft** observations
    (TAMDAR impact parallel RUC tests at GSD)

- Model physics
  - RRTM longwave radiation - eliminates sfc warm bias
  - Mod to Grell-Devenyi – decrease areal coverage, non-local subsidence warming
  - Mod to RUC land-sfc model – fresh snow density - nighttime temps over snow cover

- Post-processing – add reflectivity fields, improved RTMA downscaling

RUC parallel web site:
http://www.emc.ncep.noaa.gov/mmb/ruc2/para

RUC land-surface model
- change for RUC upgrade



Problem: RUC gave too cold 2-m temperature at night over land cover.

Solution: Increased density of snow on ground to ≥100 kg/m3 (from ≥50 kg/m^3) to reduce cold bias over fresh snow cover when temps are ≤ -15C.

Result - More accurate 2m temps over snow cover, extreme cold temps removed.

RRTM Longwave Radiation in RUC Upgrade
Effect on 2-m temperature forecasts

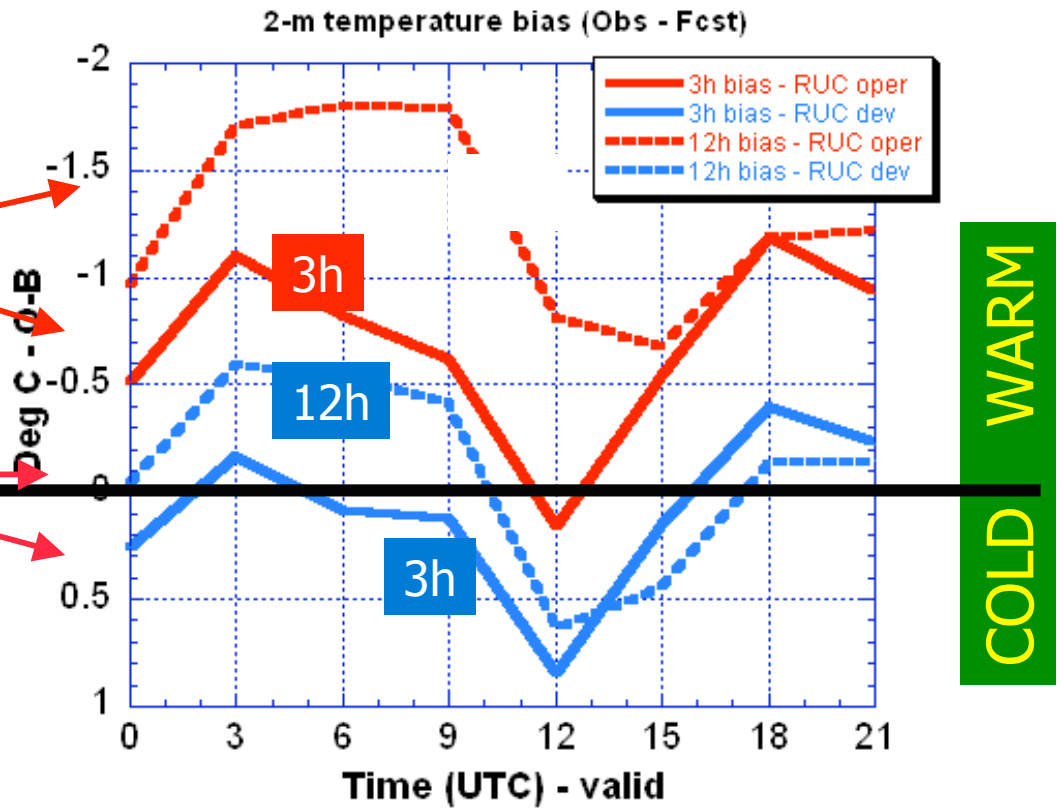
- Much decreased warm bias near surface

1-month comparison
14 May –13 June 07
Eastern US only

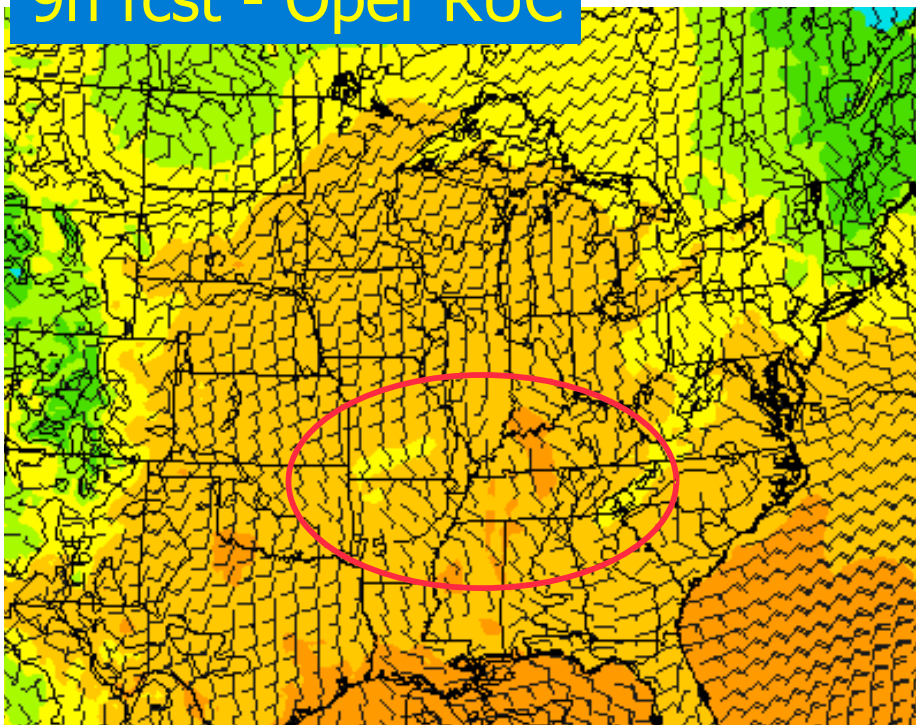
RUC oper – Dudhia LW

RUC para – RRTM LW

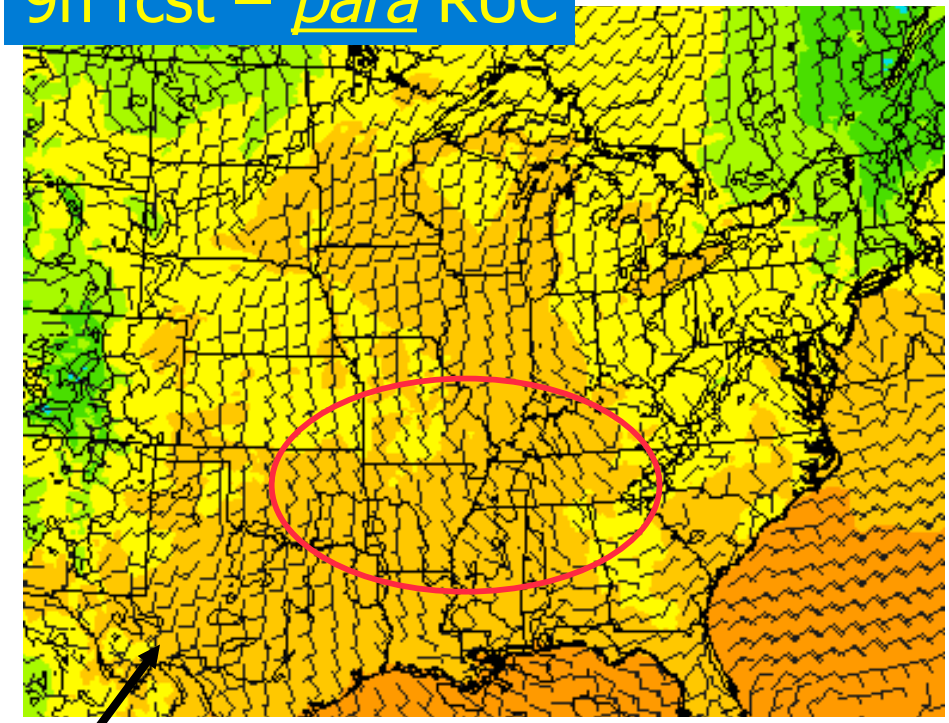
2-m temp bias (obs – forecast)



9h fcst - Oper RUC



9h fcst – *para* RUC

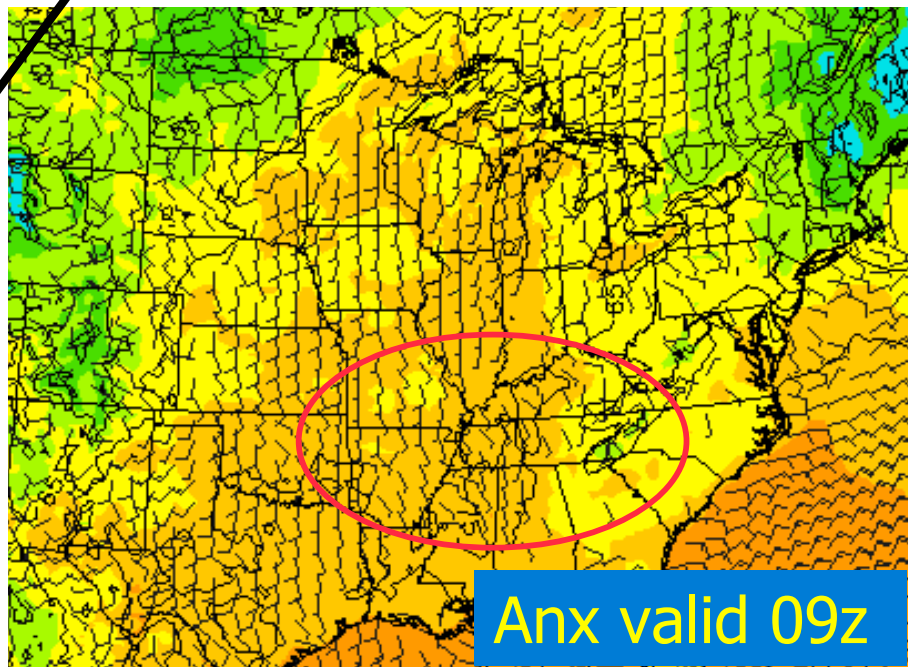


Surface Temperature / Winds (°F / Kn

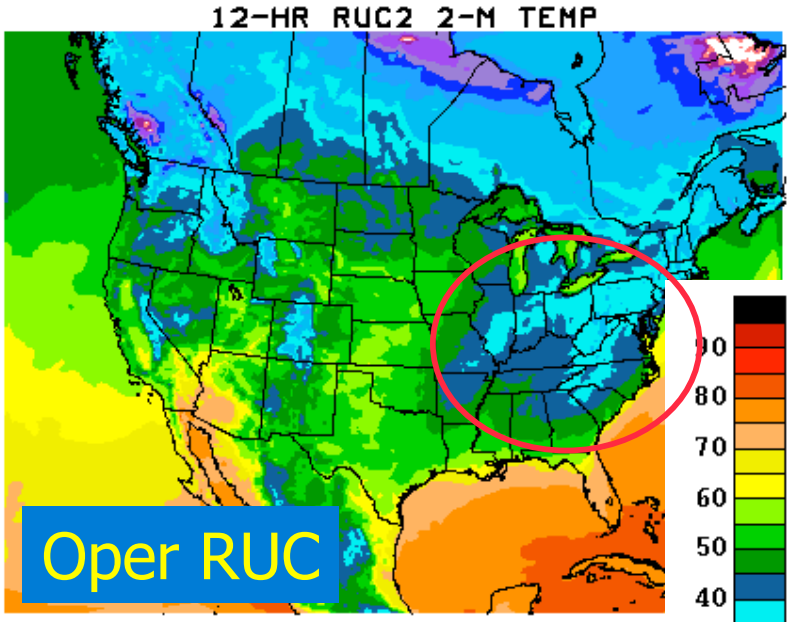
9–hr fcst valid 06–Sep–07 09:00Z

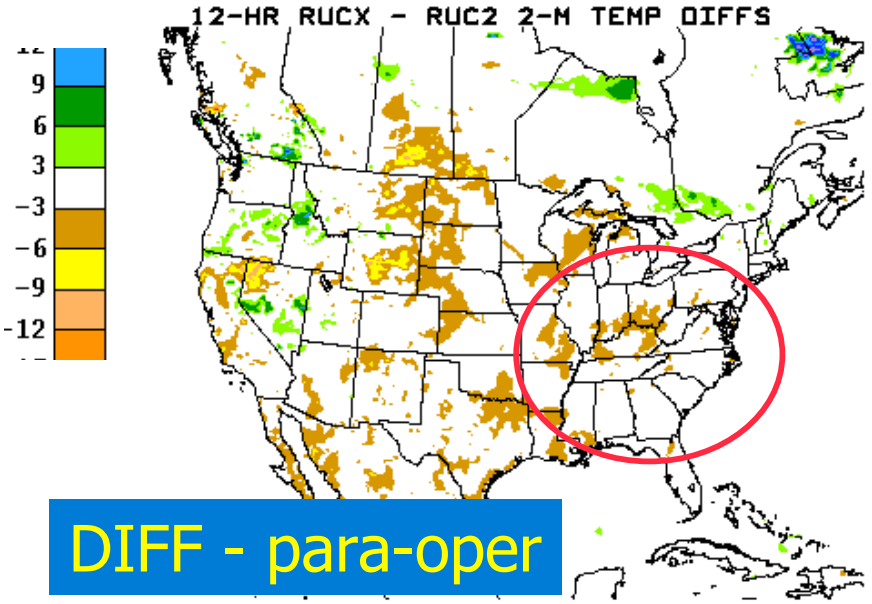
6 Sept 2007

Better 2m temp forecast
From para RUC w/ RRTM LW

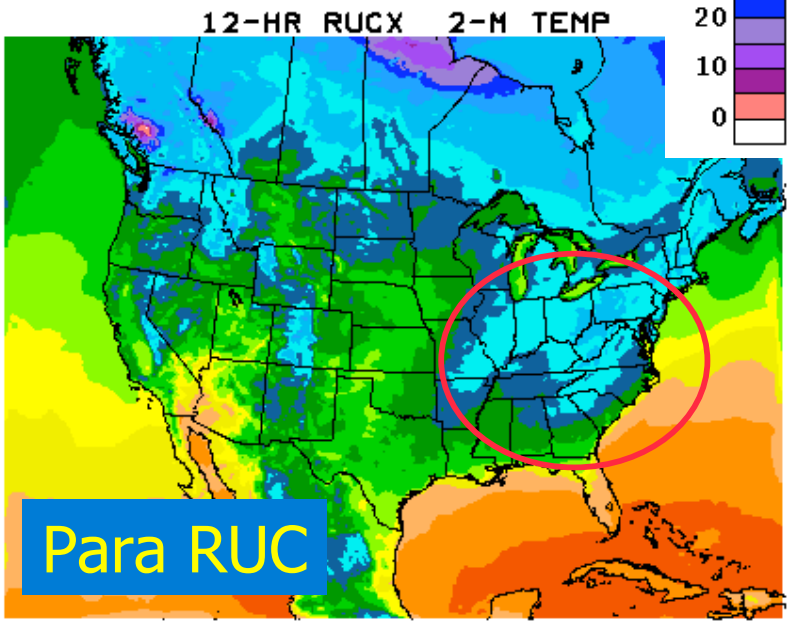


Anx valid 09z

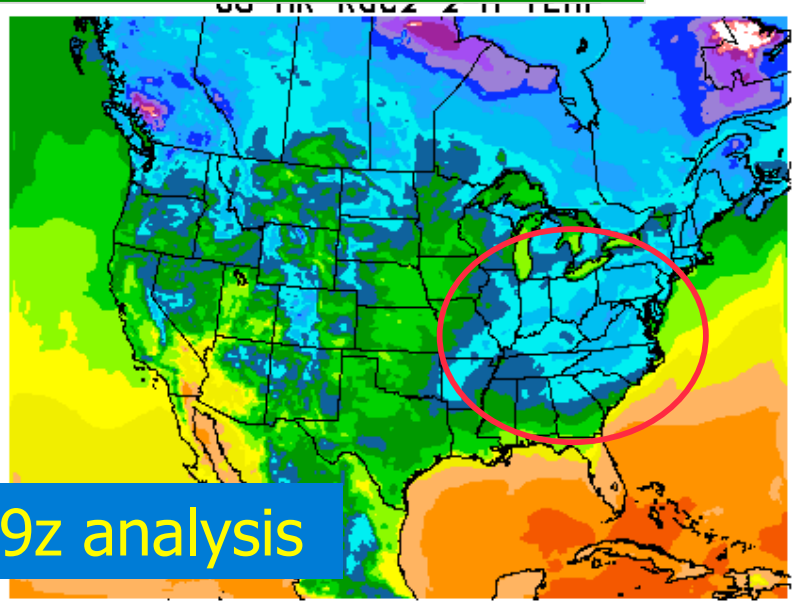




Better 2m temp forecast
From para RUC w/ RRTM LW



12h fcst – valid 09z 30 Oct



Grell-Devenyi Convection

Problems in Oct-2007 NCEP operational RUC

- Excessive coverage of small precipitation amounts

- Heating-induced convective initiation too early in the day

- Despite detrainment of cloud hydrometeors, seldom initiates much grid-scale precipitation (drying at mid levels)

- Cold pools too weak; too slow (or nil) propagation of convective systems

- Fundamental issue: scale-separation between convection and larger scales (fundamental assumption) becomes less distinct at $\Delta x \leq 20$km.

Grell-Devenyi Convection

Changes to address these issues

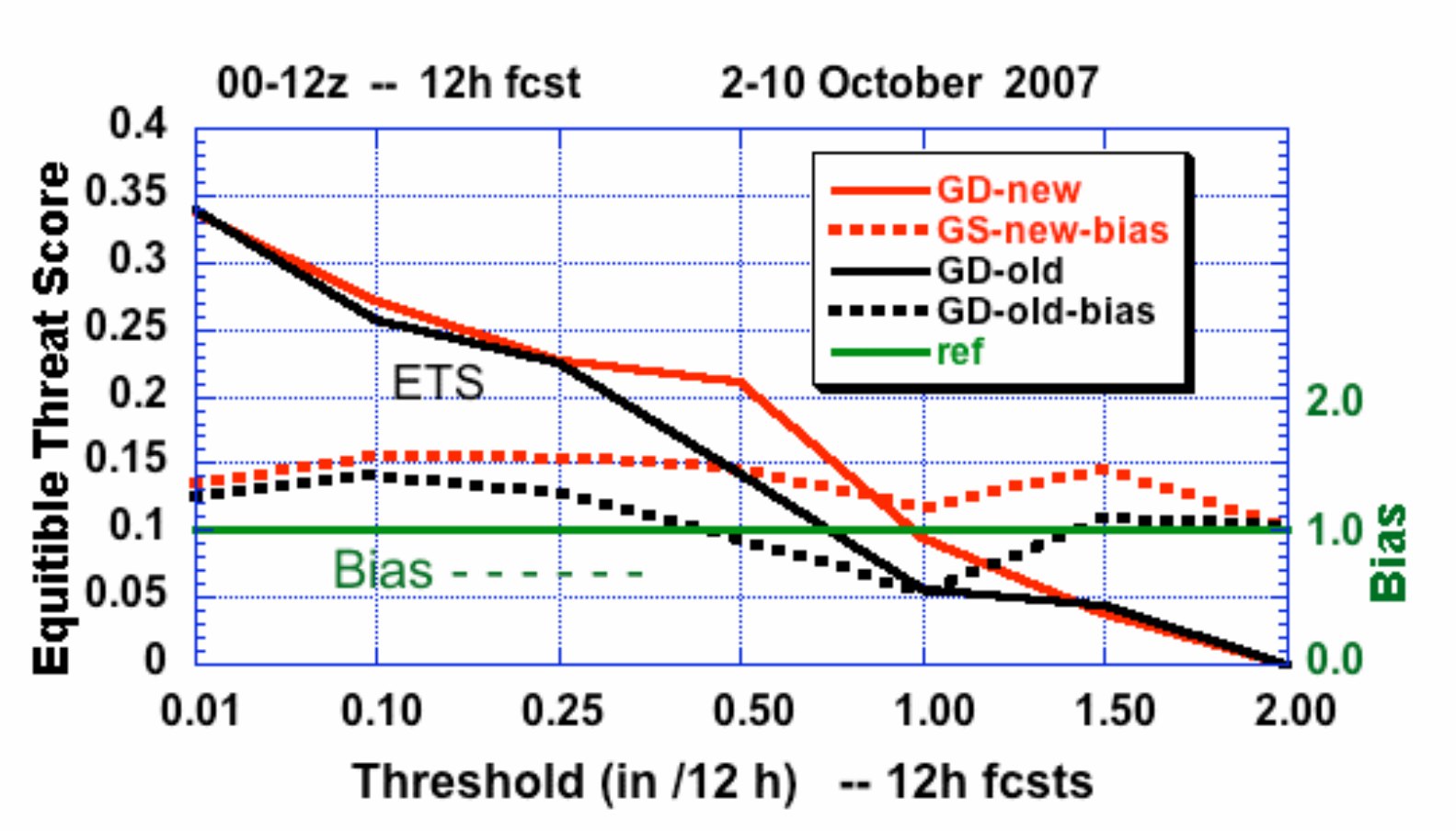
Reduce weight given to Arakawa-Schubert closure
Result: Reduces the high spatial coverage bias of small amounts

Use smaller depth for cap adequate to deny convective initiation

Result: convection starts later in diurnal cycle

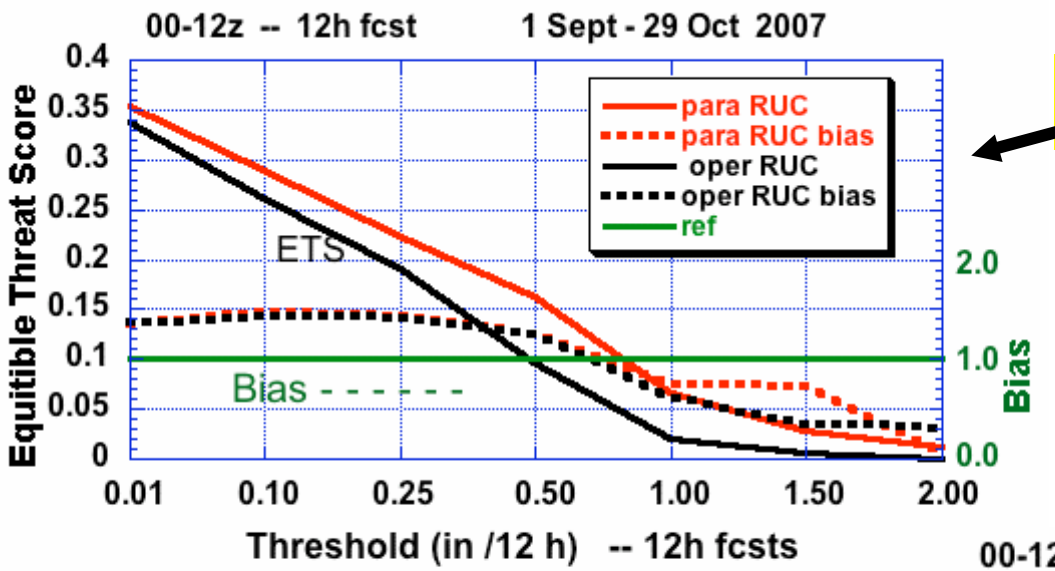
No longer treat individual grid columns independently: spread "compensating subsidence" into adjacent grid columns => contributes to more realistic initiation of grid-scale precip (and associated subcloud evaporation and cooling).

Grell-Devenyi Convection-- effect of non-local subsidence warming



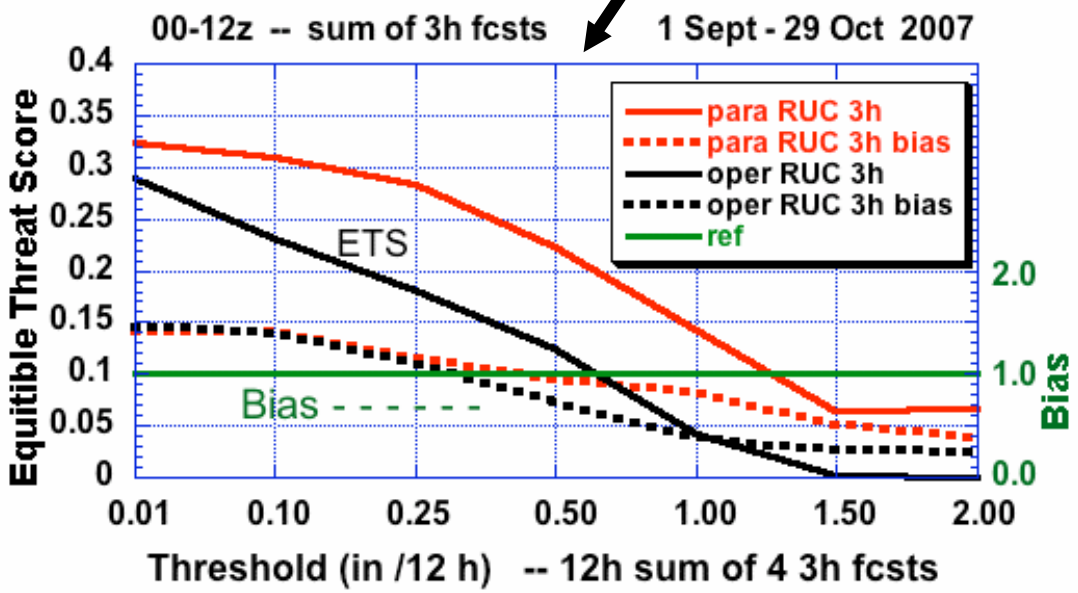
Adds further to the improvement shown on the next slide ….→

Overall improvement in precip forecasts - parallel RUC vs. NCEP oper RUC



12h forecast

3h forecast



Large improvements due to

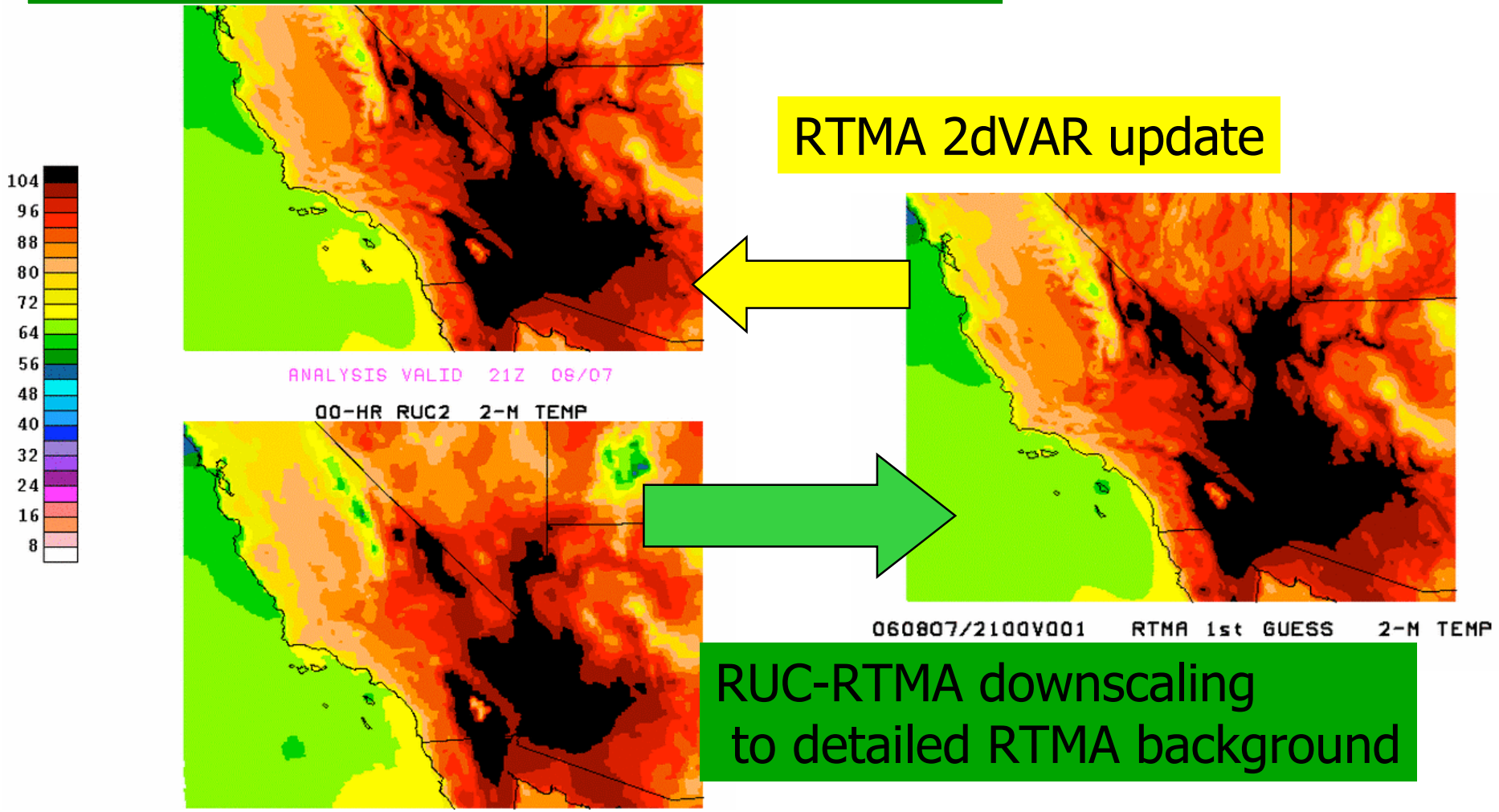
- **Radar reflectivity assimilation**
- **Improvements in Grell-Devenyi scheme**
- **Other para changes**

Early 2008 Changes for oper RUC upgrade

- Assimilation
  - Use of **radar reflectivity** in RUC diabatic digital filter initialization in RUC model
  - **Mesonet winds** using mesonet station uselist
  - **TAMDAR aircraft** observations
    (TAMDAR impact parallel RUC tests at GSD)
- Model physics
  - RRTM longwave radiation - eliminates sfc warm bias
  - Mod to Grell-Devenyi – decrease areal coverage, non-local subsidence warming
  - Mod to RUC land-sfc model – fresh snow density - nighttime temps over snow cover
- Post-processing – add reflectivity fields, improved RTMA downscaling

RUC parallel web site:
http://www.emc.ncep.noaa.gov/mmb/ruc2/para

RUC-RTMA downscaling
2008 change - improved cold valleys
RUC post code used (w/ mods)
for RTMA downscaling



RTMA 2dVAR update

RUC-RTMA downscaling
to detailed RTMA background

http://www-frd.fsl.noaa.gov/pub/papers/Benjamin%202007e/cp.pdf

Early 2008 Changes for oper RUC upgrade

- Assimilation
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RUC parallel web site:
http://www.emc.ncep.noaa.gov/mmb/ruc2/para

Early 2008 Changes for oper RUC upgrade - forecast performance improvements

- Surface temperature and winds
  - Much lower bias, all times of day and seasons

- Precipitation, reflectivity
  - Much improved QPF, new reflectivity product consistent with reflectivity observations
- Ceiling and visibility

- Lower tropospheric temperature, RH in eastern US

- Improved RTMA downscaling and accuracy

RUC parallel web site:
http://www.emc.ncep.noaa.gov/mmb/ruc2/para