RUC/Rapid Refresh Review

NCEP Production Suite Review - 2007

NOAA/ESRL/GSD/AMB
Stan Benjamin
Steve Weygandt
Bill Moninger
John M. Brown
Kevin Brundage
Dezso Devenyi
Georg Grell
Ming Hu
Brian Jamison
Steven Peckham
Susan Sahm
Tom Schlatter
Tanya Smirnova
Tracy Lorraine Smith
NCEP/EMC – Geoff Manikin
NCEP/NCO

Major transitions:

- RUC13 change package – ~3Q 2008
  – radar reflectivity assimilation, TAMDAR, mesonet, RUC/WRF physics
- Rapid Refresh - JIF for ~4Q 2009

Fresh, tasty results - dev/testing for RUC, observation impact studies, Rapid Refresh -- GSI, WRF

http://ruc.noaa.gov

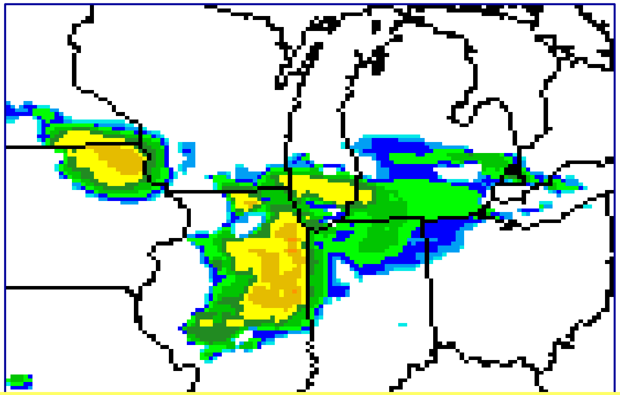
http://rapidrefresh.noaa.gov/rr

Tues 11 Dec 2007

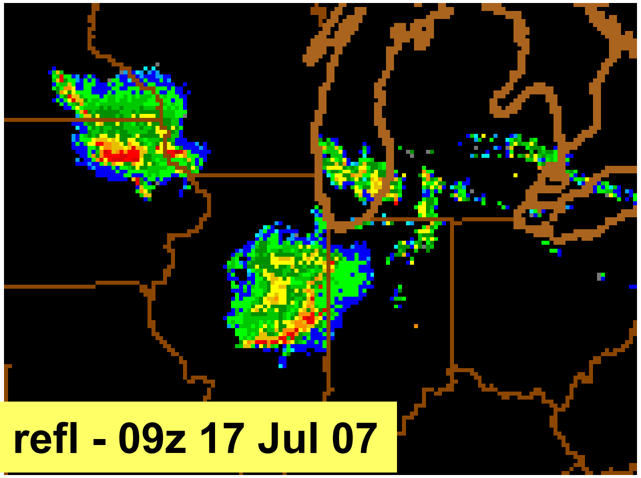
NCEP

Earth System Research Laboratory
SCIENCE, SERVICE & STEWARDSHIP

RUC Upgrade at NCEP - Spring 2008



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



Obs 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

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

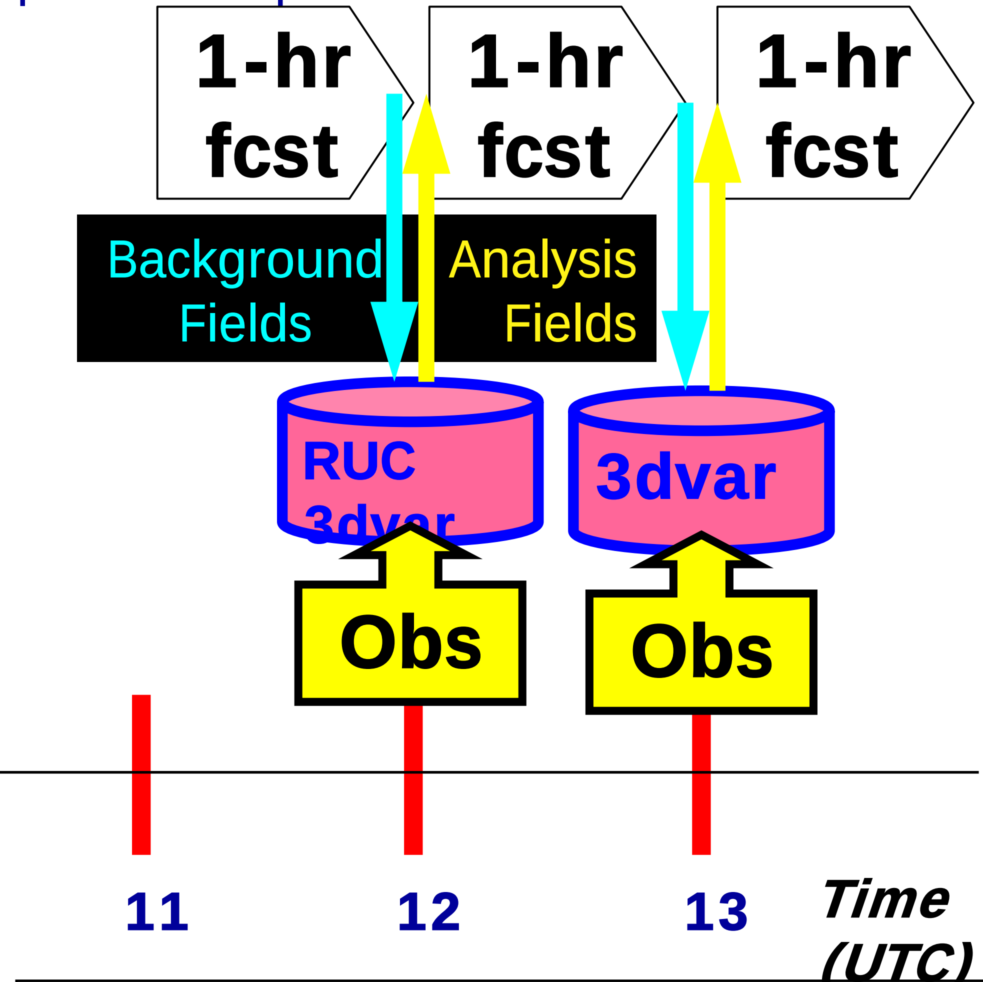
Early 2008 Changes for oper RUC upgrade

- 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

New observations assimilated -- RUC upgrade

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



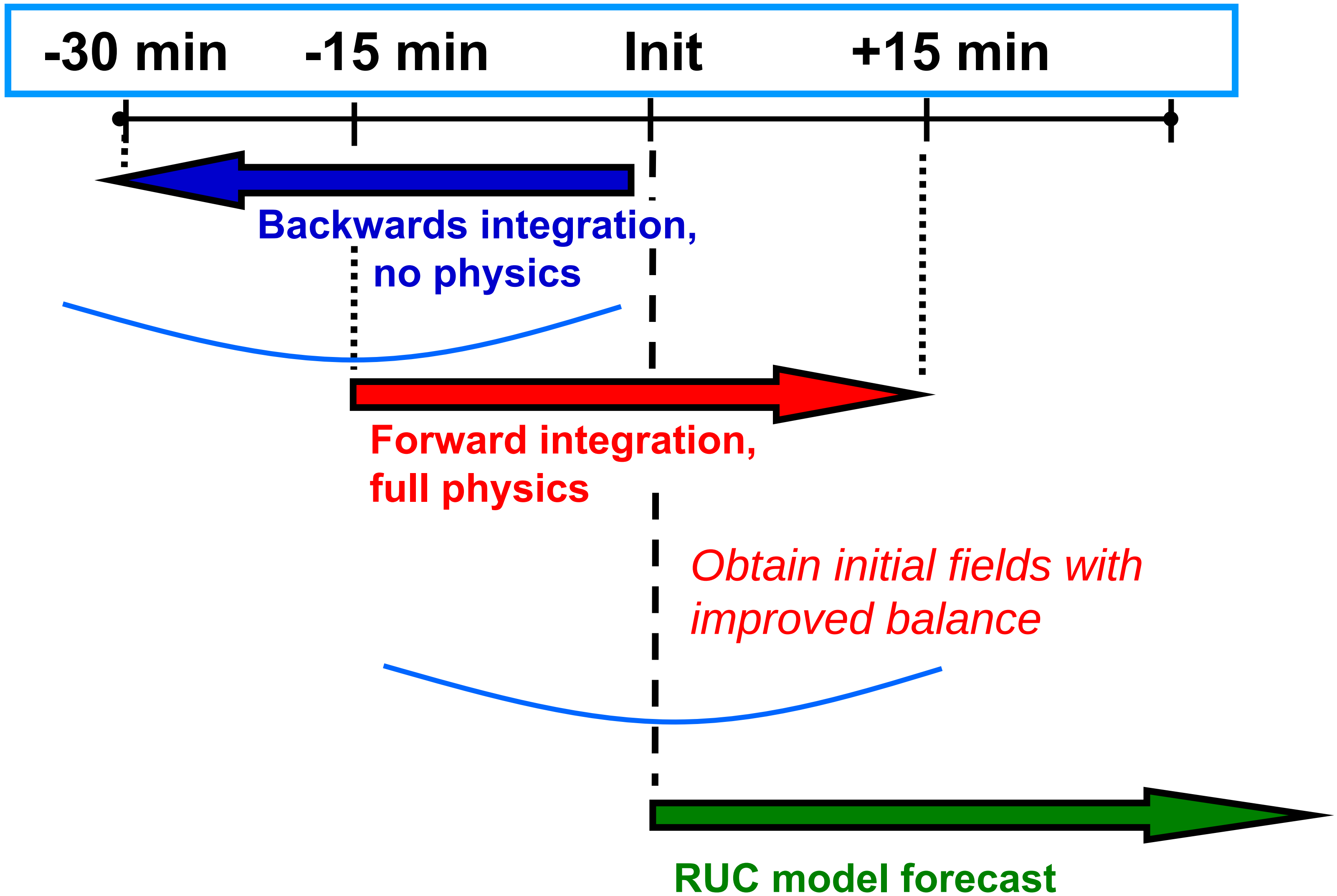
Hourly obs in 2008 RUC

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	1km

RUC Hourly Assimilation Cycle

RUC Diabatic Digital Filter Initialization (DDFI)

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

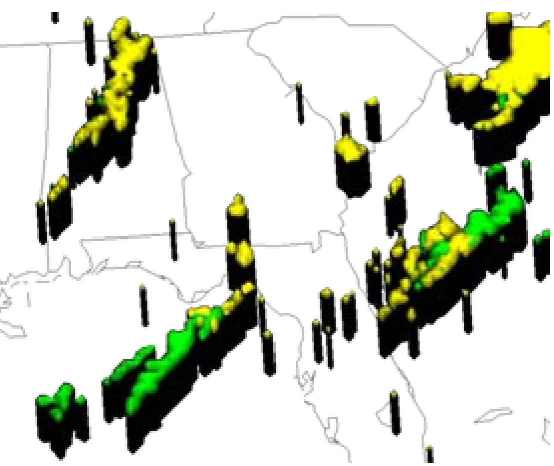


Diabatic Digital Filter Initialization (DDFI)

New - add assimilation of radar data

-30 min   -15 min   Init   +15 min

Backwards integration, no physics



Forward integration, full physics

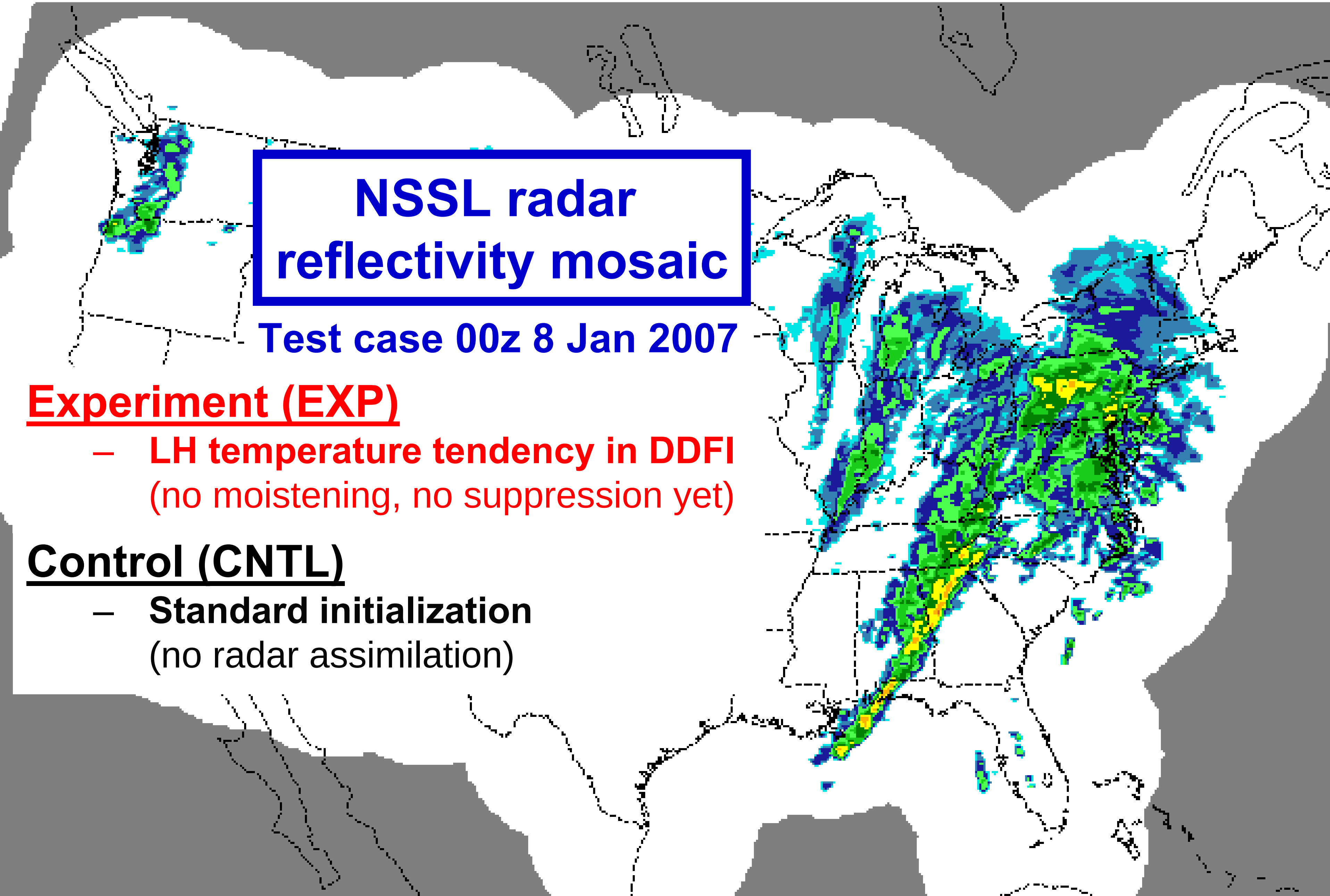
Specify 3-d latent heating from radar reflectivity, lightning data (where available)

Obtain initial fields with improved balance, vertical circulations associated with ongoing convection

RUC model forecast

Radar reflectivity assimilation in RUC

RUC radar assimilation test case



NSSL radar reflectivity mosaic

Test case 00z 8 Jan 2007

Experiment (EXP)

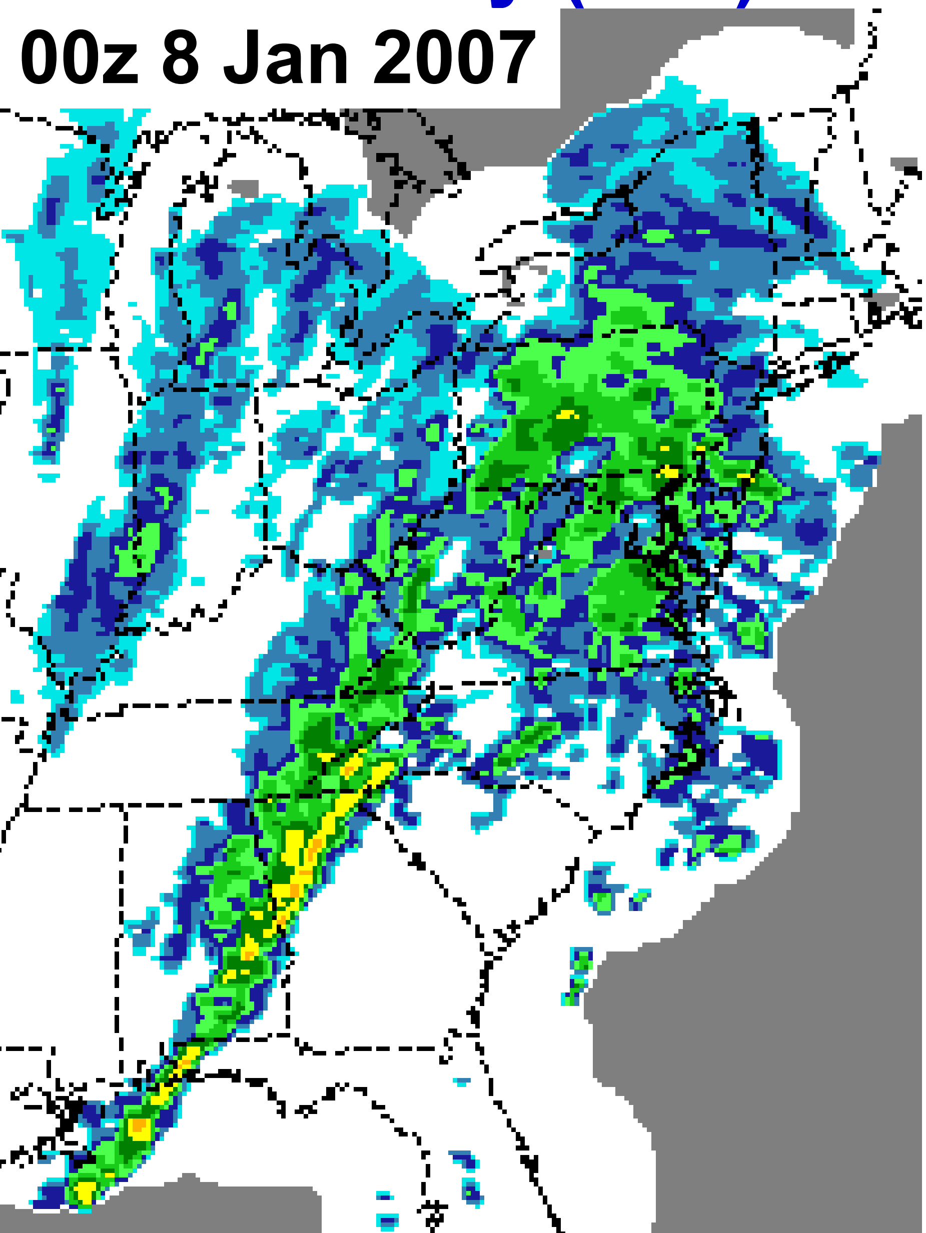
- **LH temperature tendency in DDFI**
  (no moistening, no suppression yet)

Control (CNTL)

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

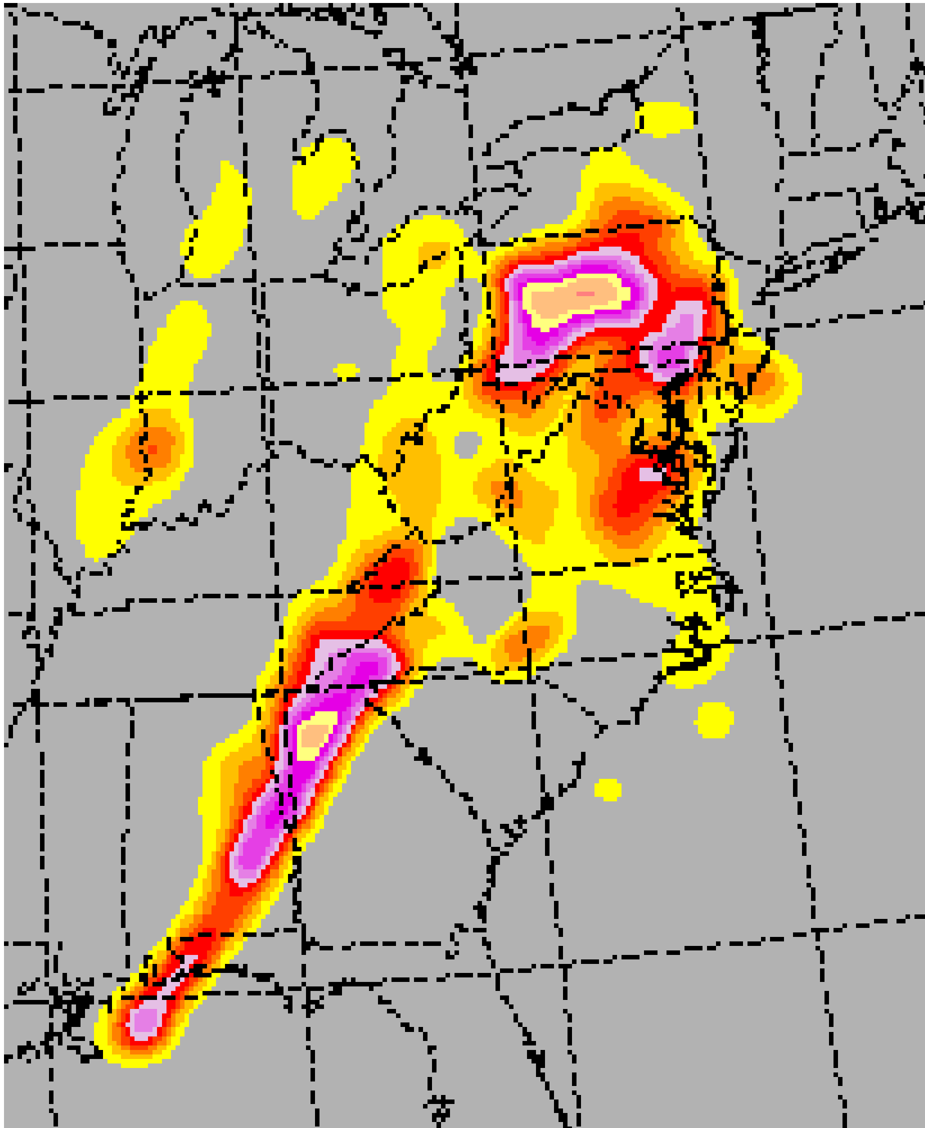
NSSL 3-km radar reflectivity (dbz)

00z 8 Jan 2007



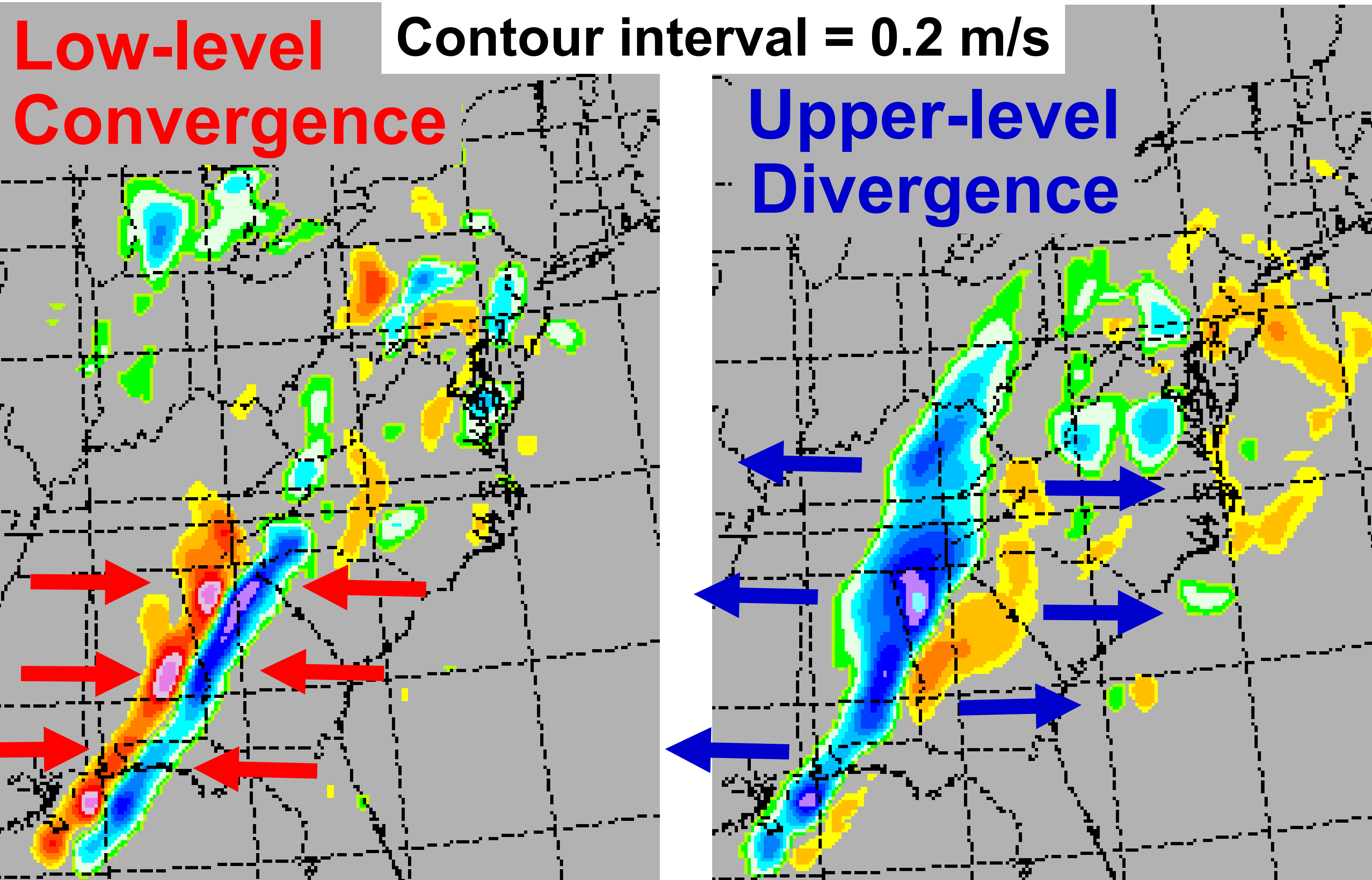
K=15 LH temp. tend. (K / 15 min)

Contour interval = 0.5 K

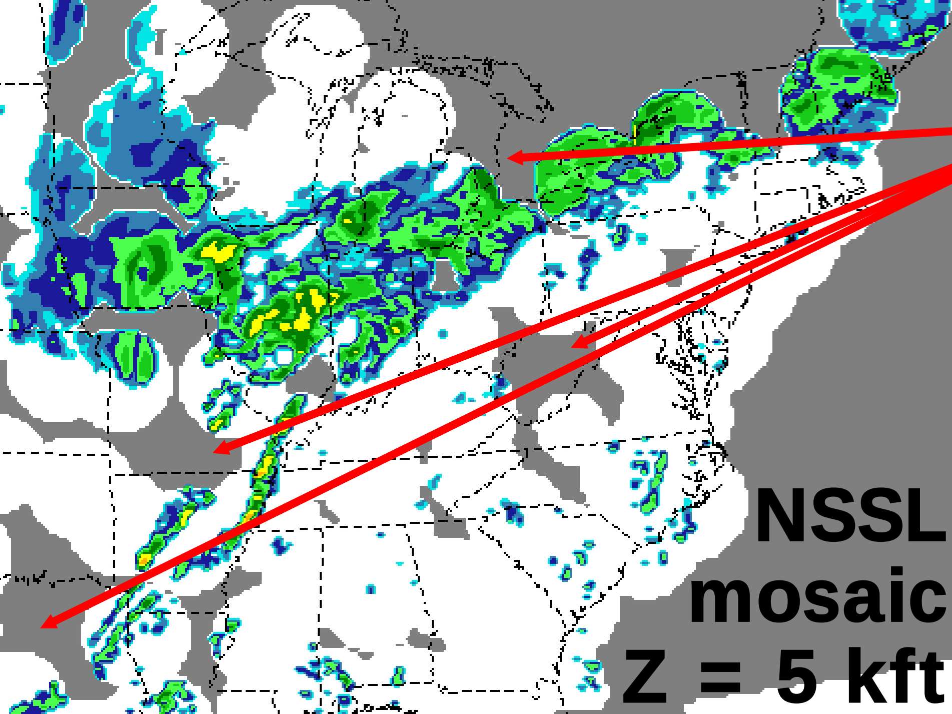


K=15 U-comp. diff (EXP - CNTL)

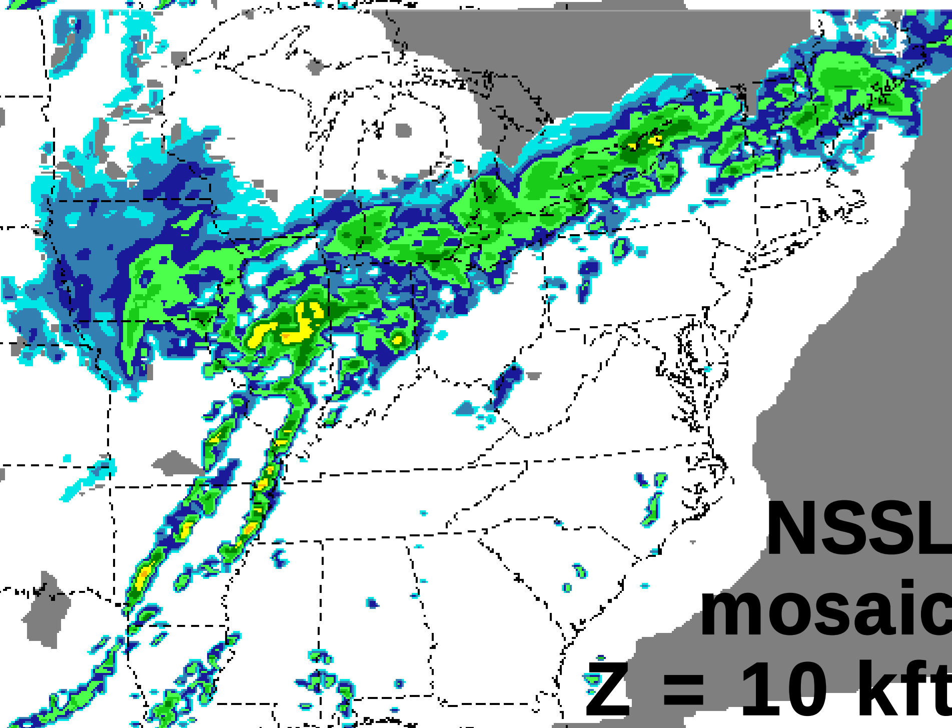
K=35 U-comp. diff (EXP - CNTL)



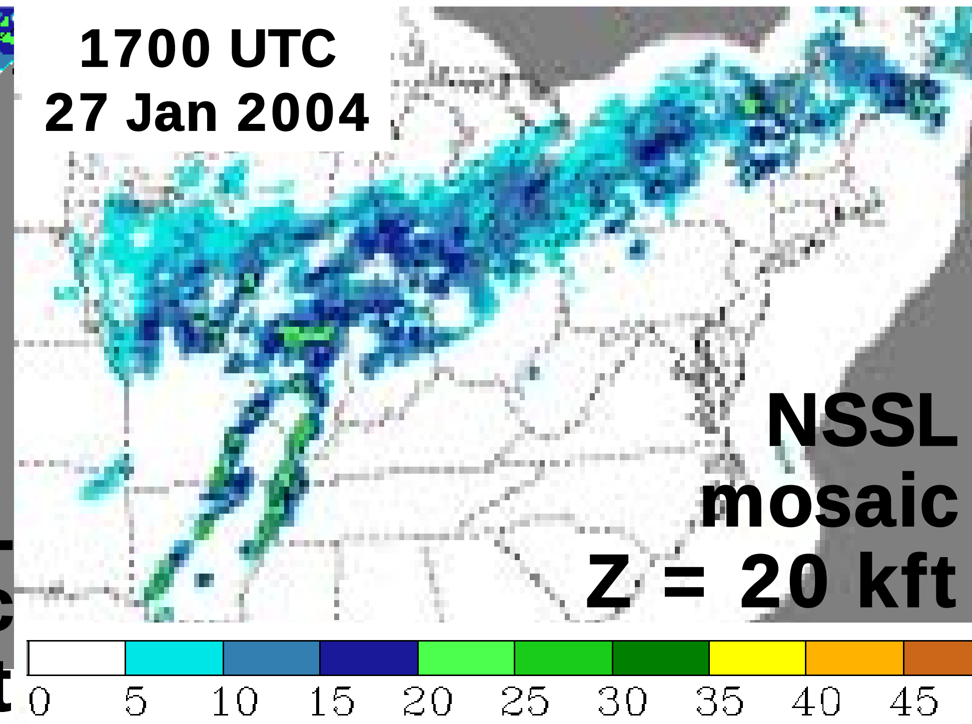
Data gap regions
(larger at low levels)



Latent heating in diabatic forward DFI step specified *only* where 3-d radar data available

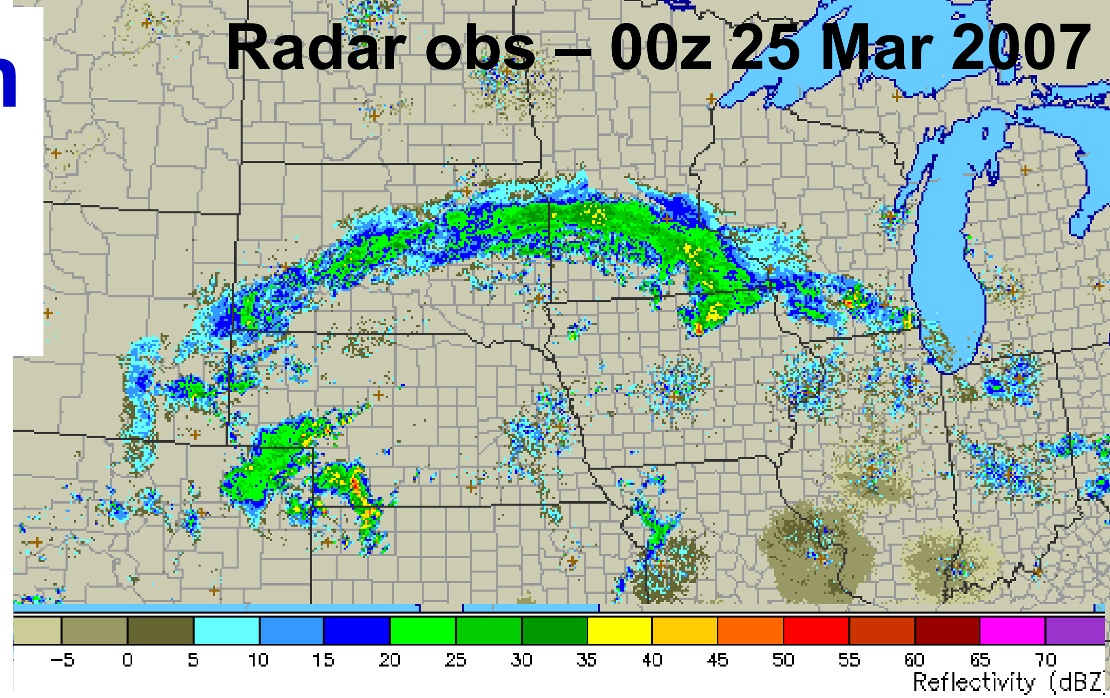


1700 UTC
27 Jan 2004

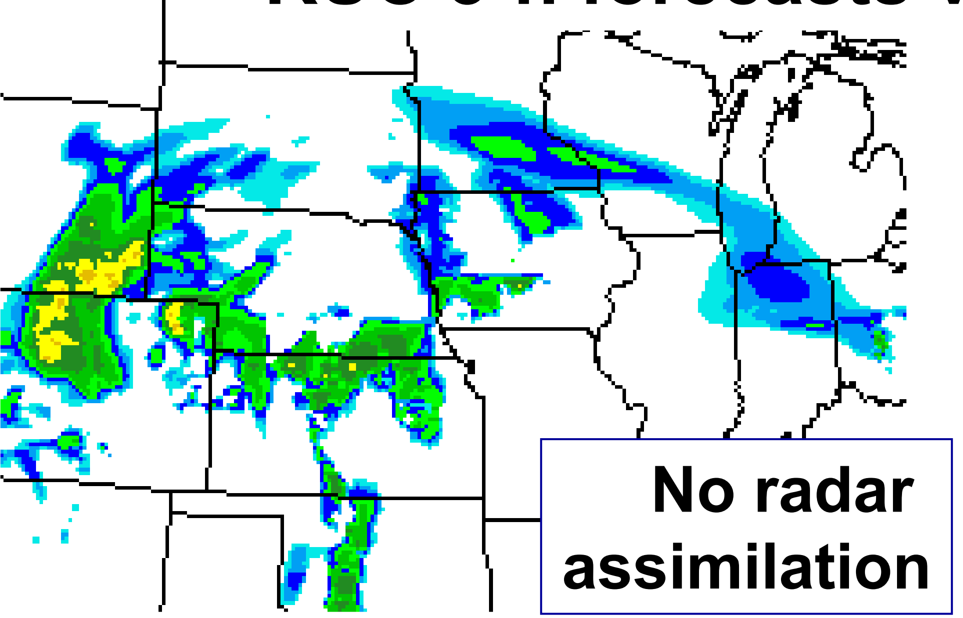


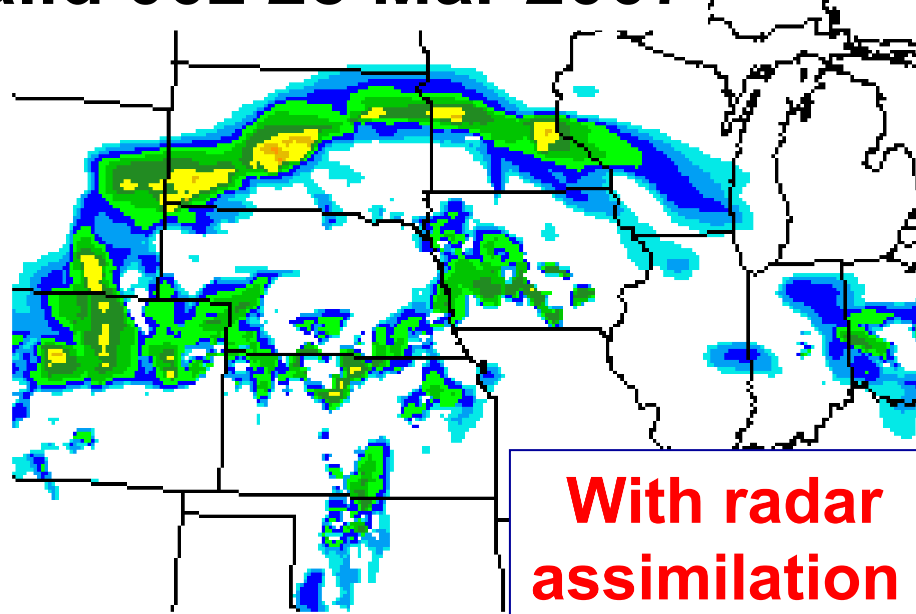
Radar assimilation in RUC - winter storm example

Also, added simulated radar reflectivity field to RUC output



RUC 3-h forecasts valid 00z 25 Mar 2007





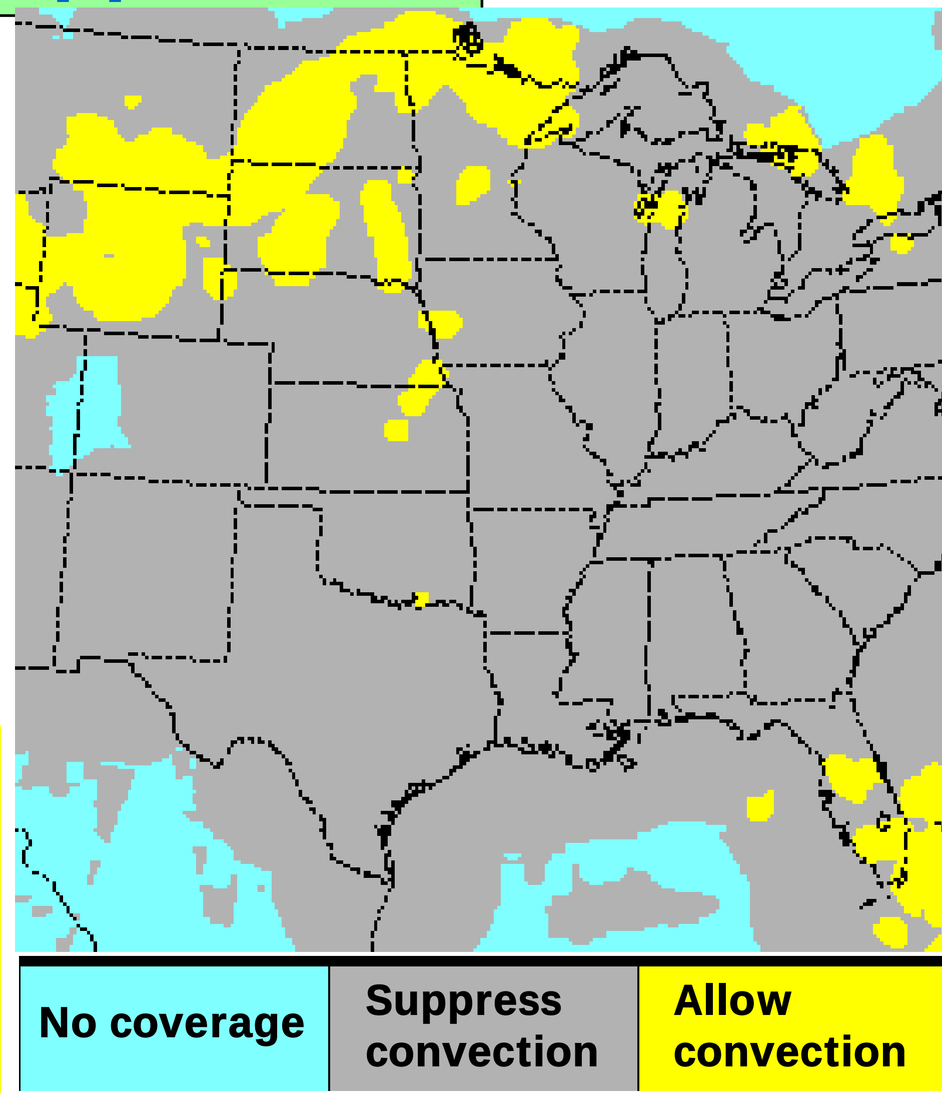
Radar reflectivity assimilation

Part 2 – convection suppression

• Define suppression areas as follows:

• No reflectivity > 20 dbZ within 100 km
• Depth of radar coverage > 300 hPa
• Augmented by GOES fully clear areas

**Design in RUC model:
Specify min cap depth
as 0 hPa to limit convection
in DFI step and first 30 min
in actual forecast**

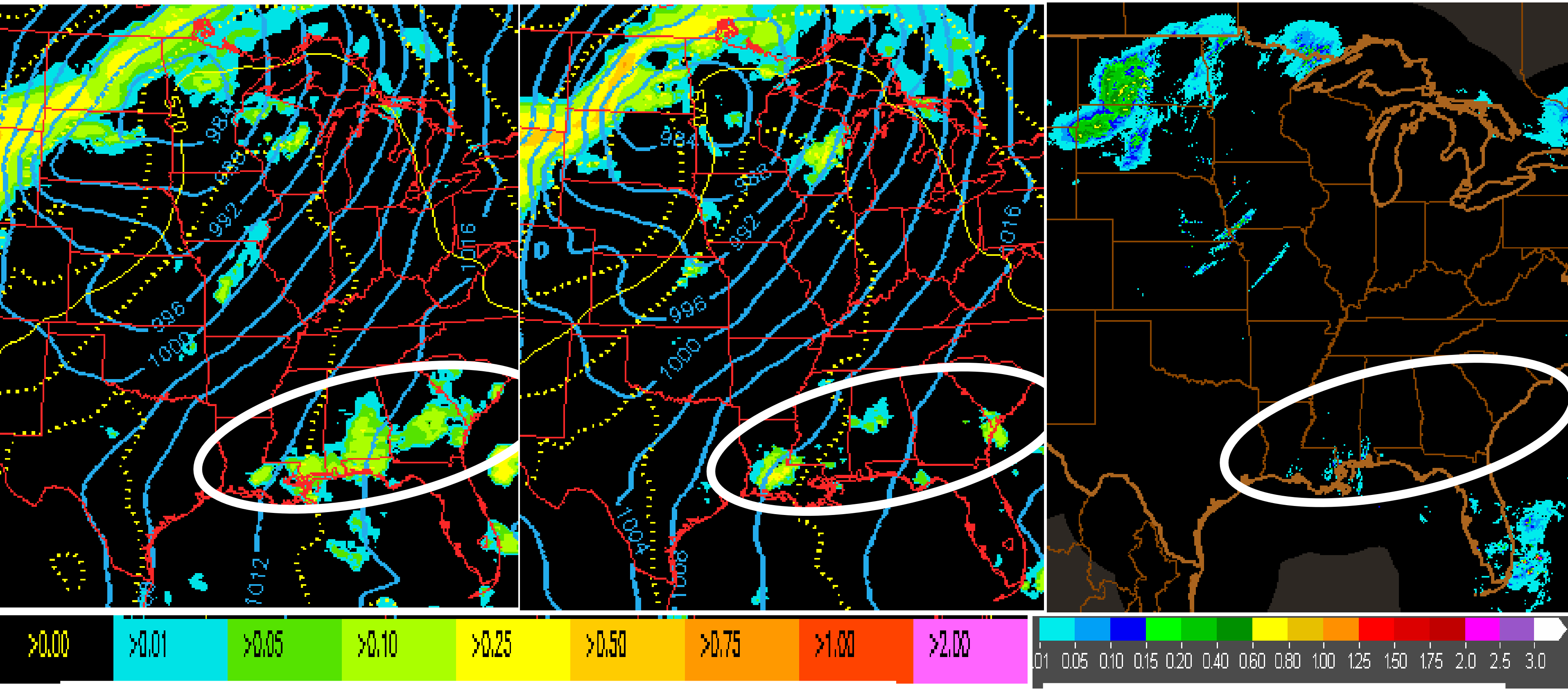


Convective suppression example

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? –***

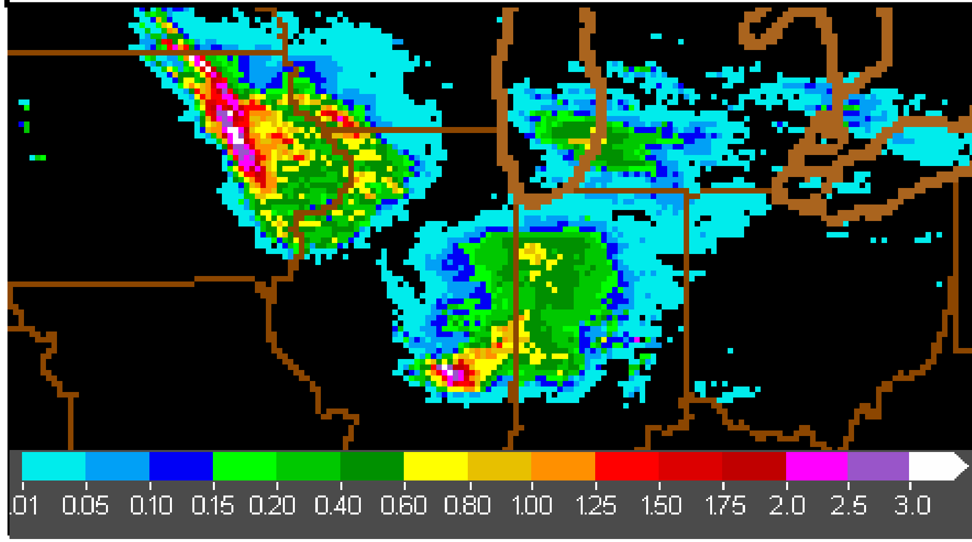
Reduces latent heating, vert. motion in erroneous conv areas

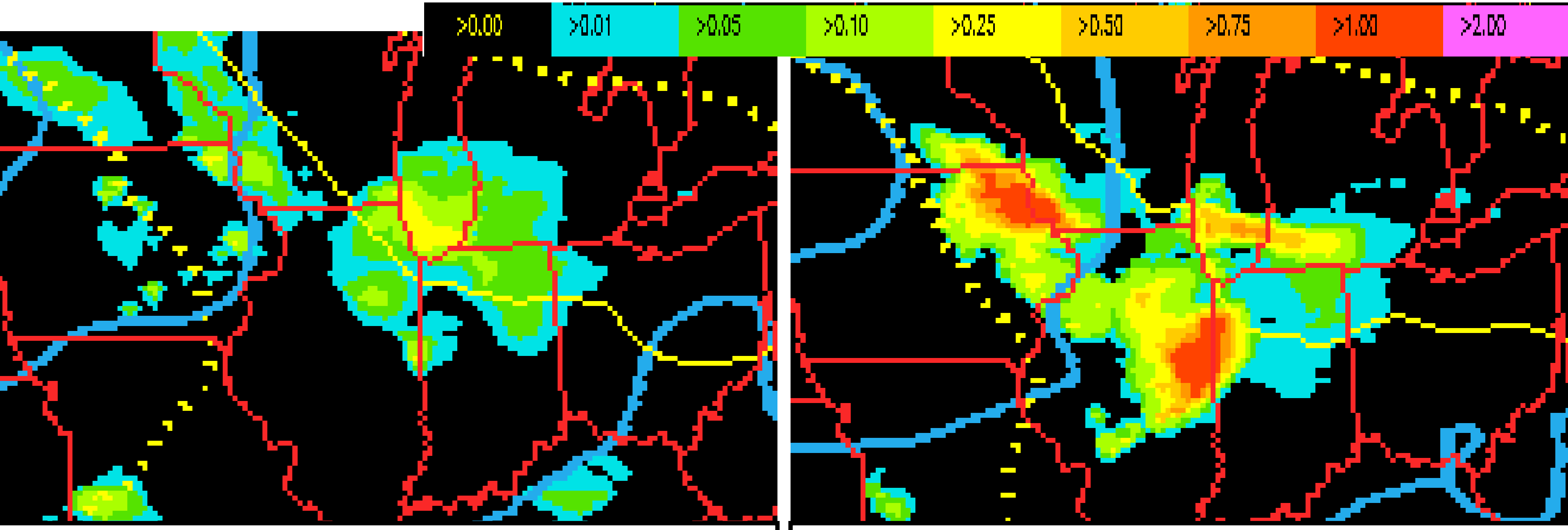
Overall effect of RUC radar assimilation -

RUC3h QPF

-Overnight convection example - 09-12z July 06

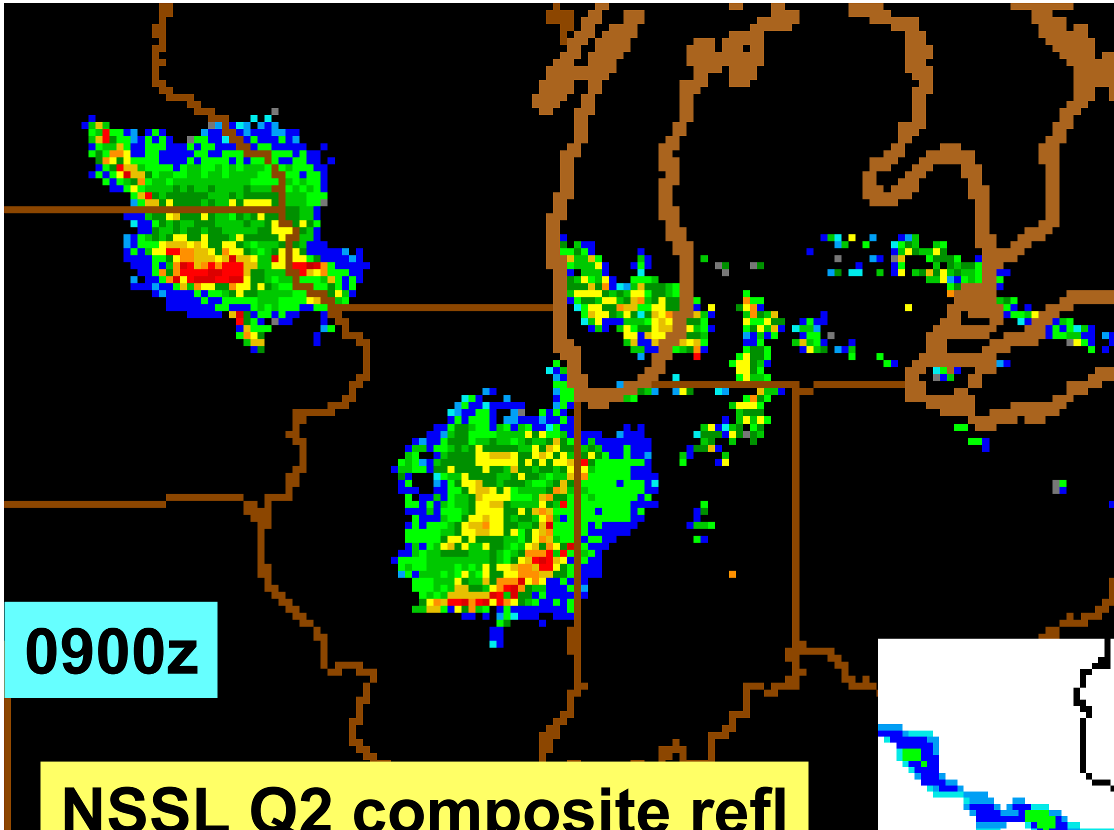
NSSL 12z 3-h accum. Precip.





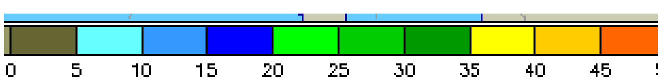
No radar assimilation

w/ Radar assimilation

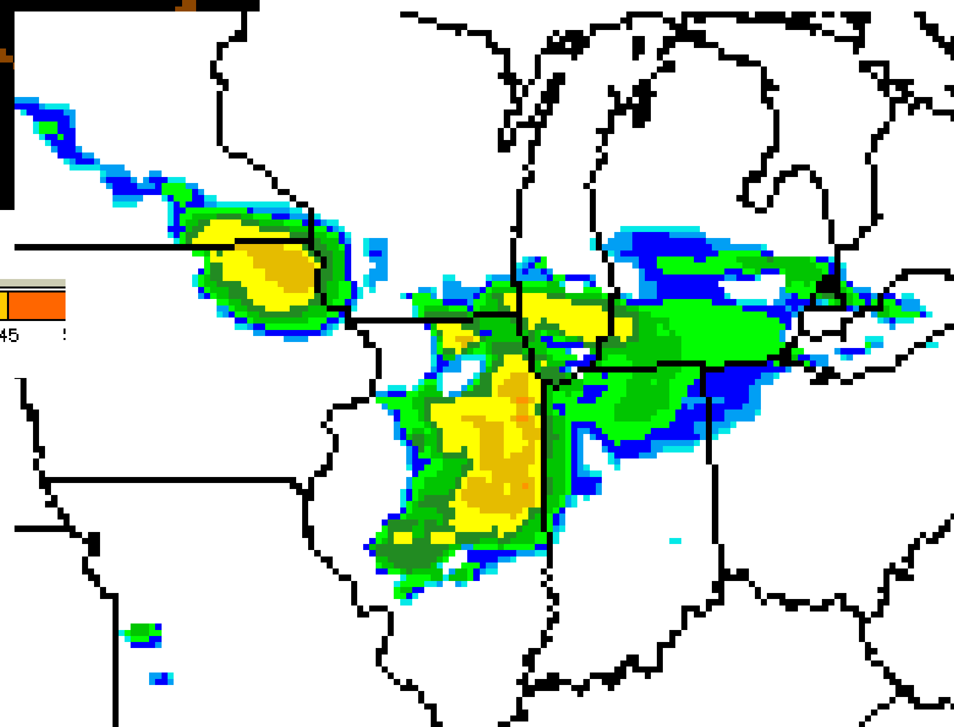


0900z

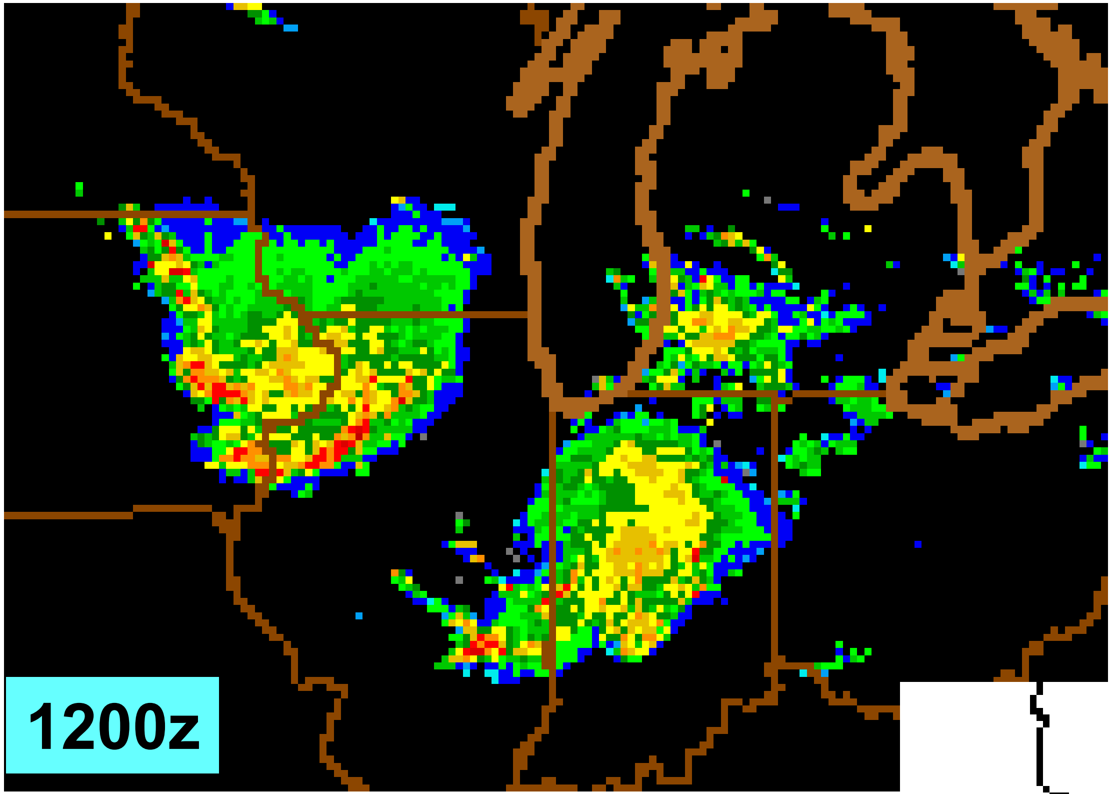
NSSL Q2 composite refl



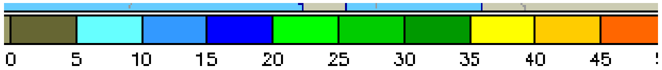
RUC "analysis" composite reflectivity (actually 1h fcst)
- fairly good agreement



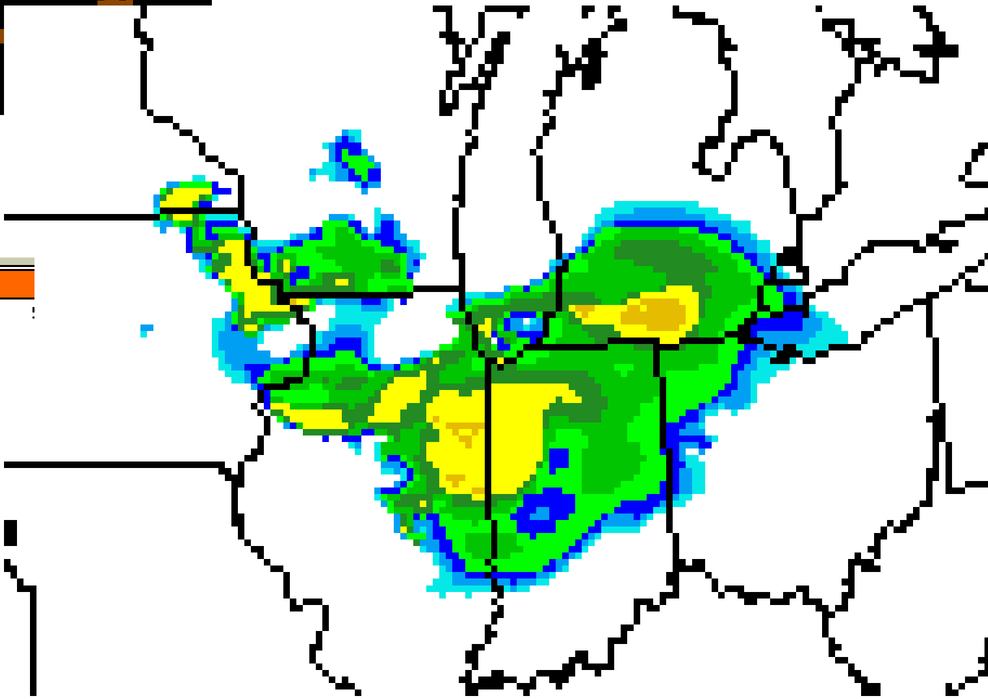
0900z reflectivity
Tues 17 July 2007



NSSL Q2 composite refl

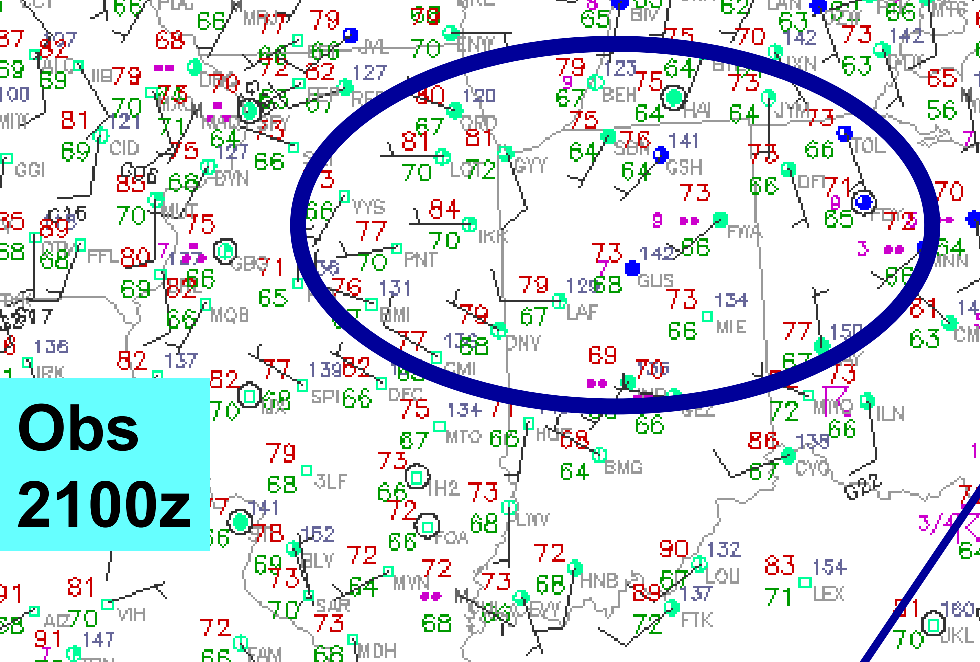


RUC 3h forecast composite refl

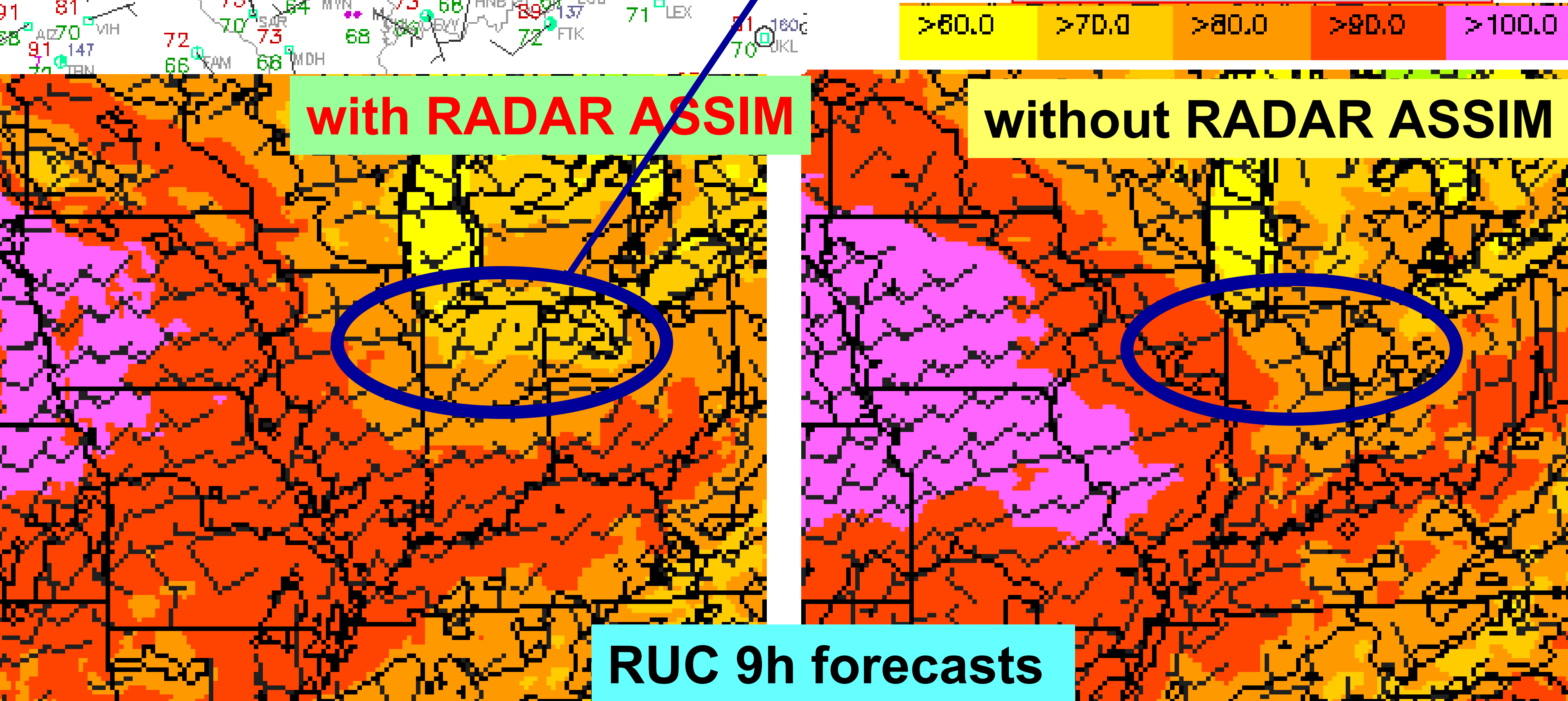


Valid 1200z
Tues 17 July 2007

Evaporative cooling - improved cold pool with radar assim

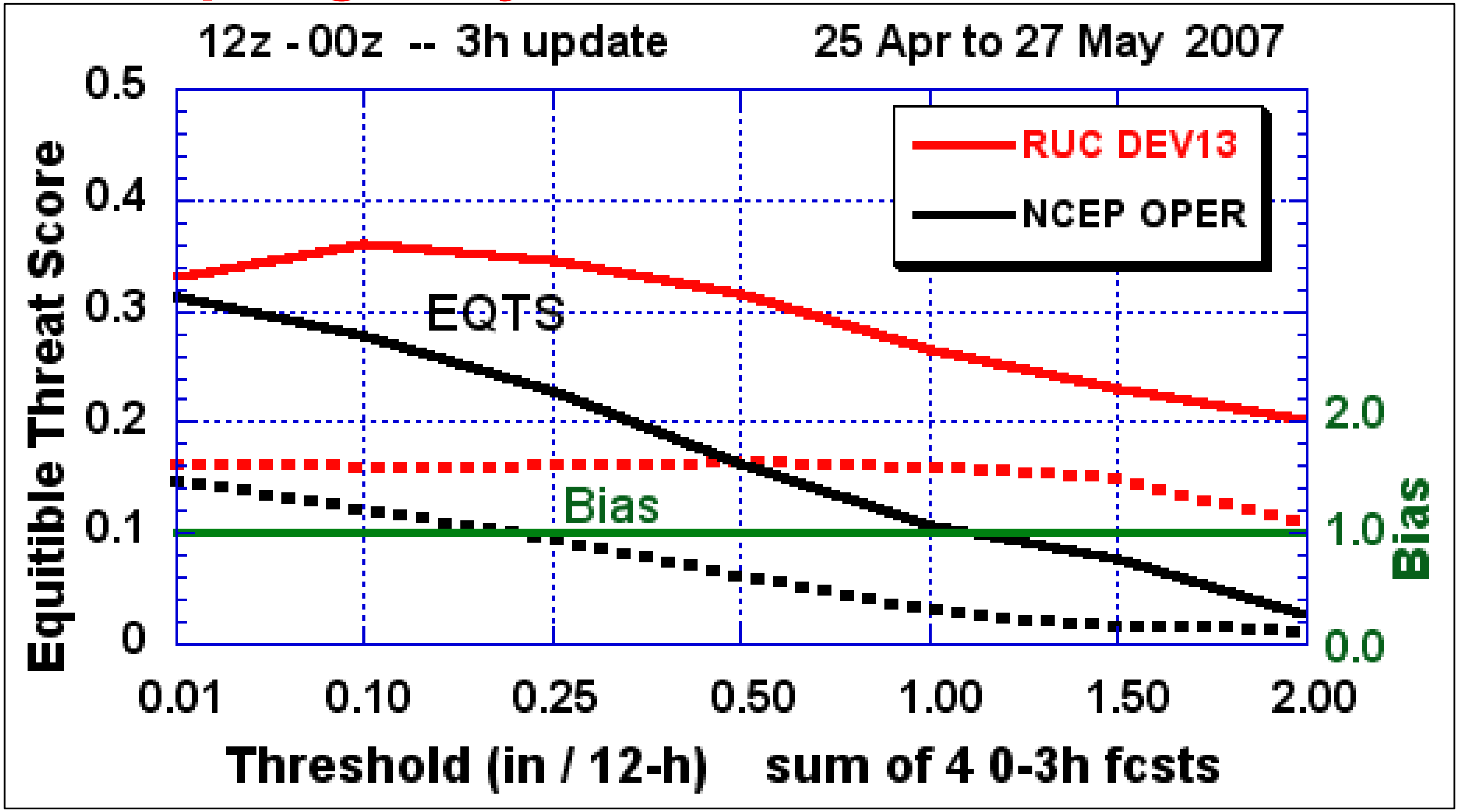


Sfc Temp – 21z
Tues 17 July 2007



Radar assimilation impact on 3-h precipitation skill scores

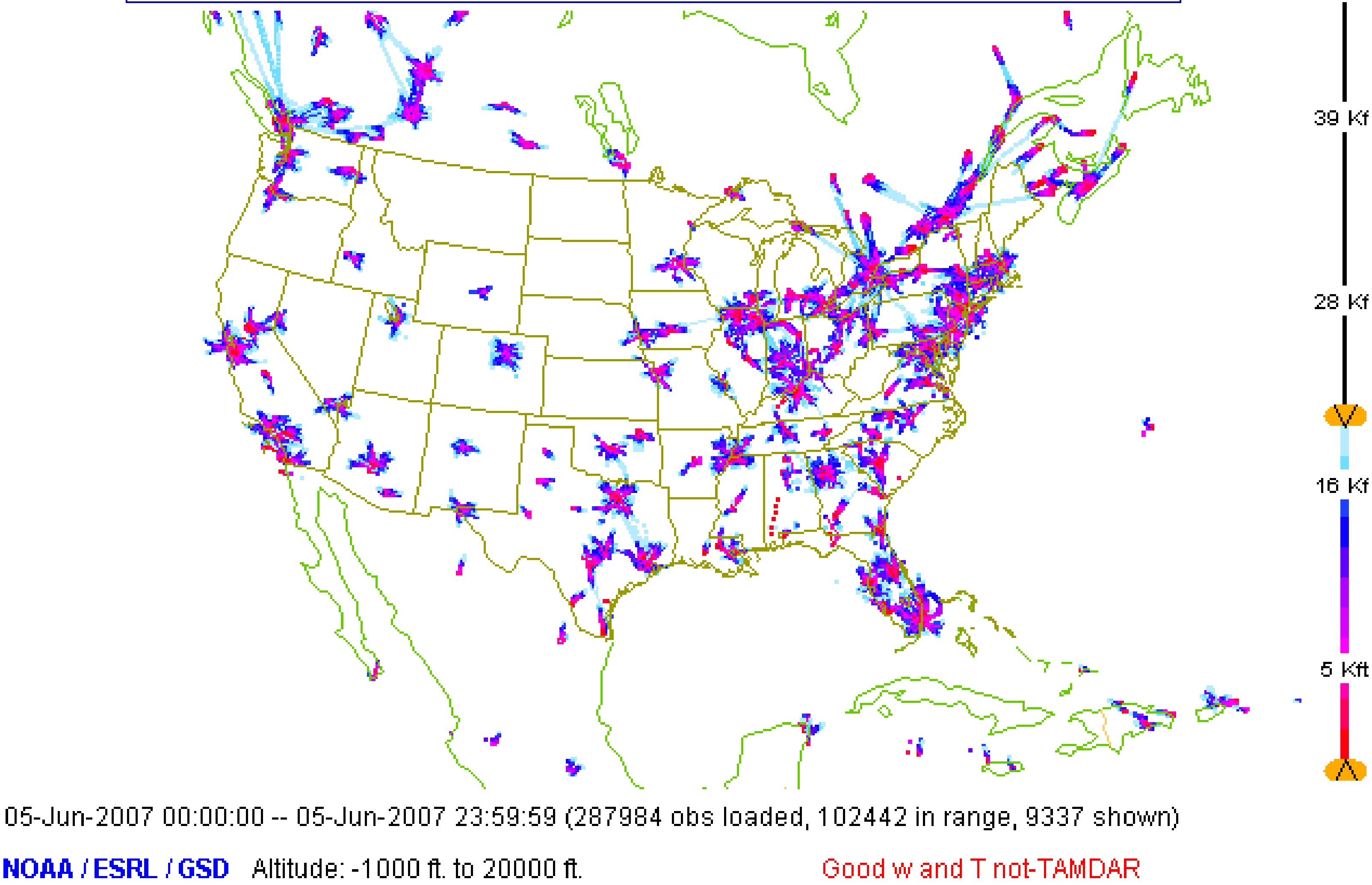
- Significant improvement in ETS and bias
- Spring - daytime



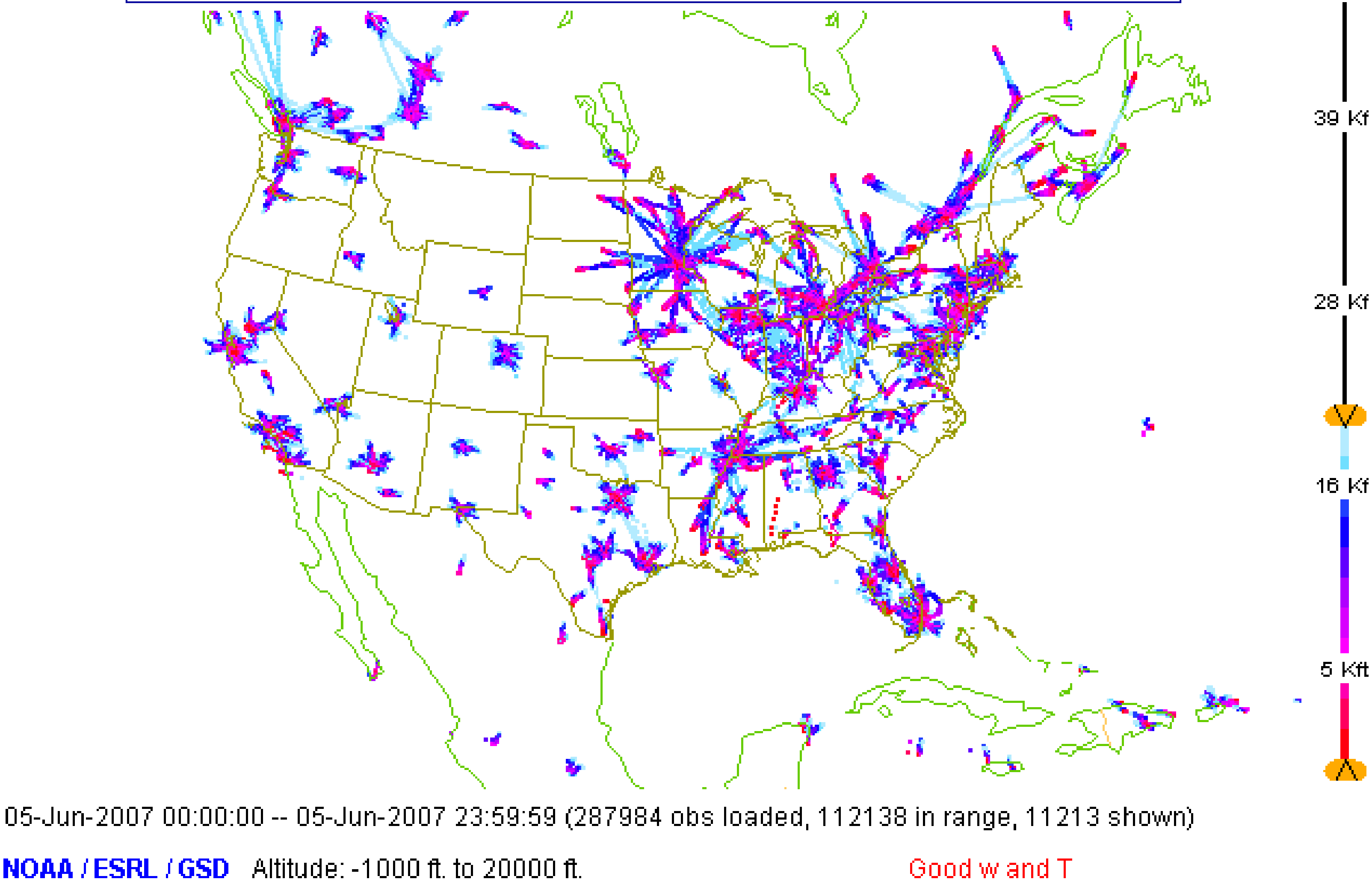
(On RUC assimilation of TAMDAR data) - AMDAR and TAMDAR definitions

- **“AMDAR” (Automated Meteorological Data and Recording) – 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

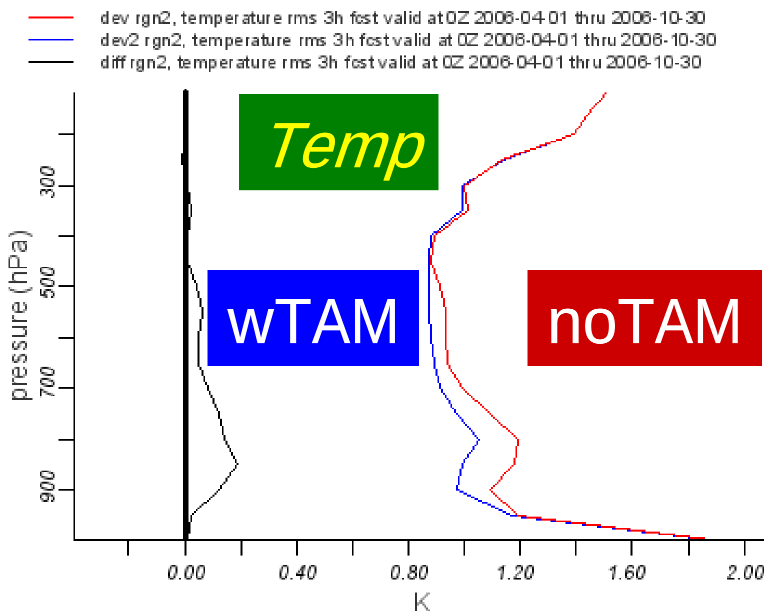
Aircraft coverage is limited to major hubs below 20 Kft, (without TAMDAR)

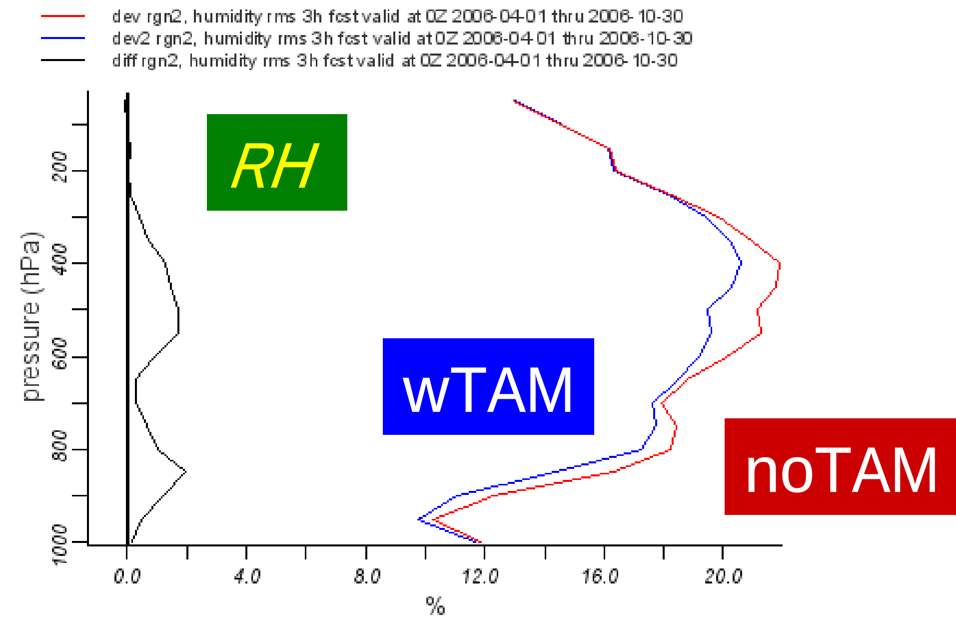


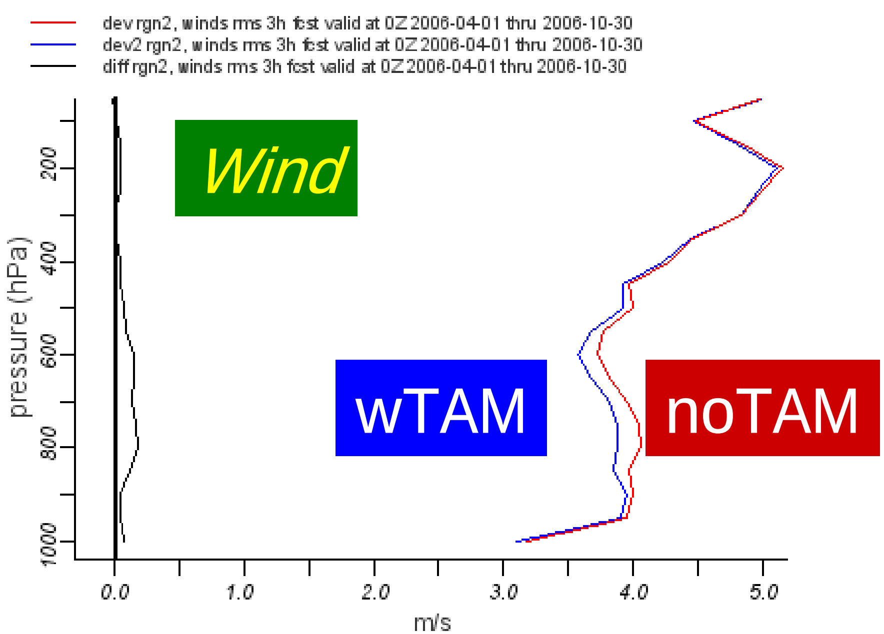
Below 20 Kft, with TAMDAR – better regional coverage in the Midwest



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

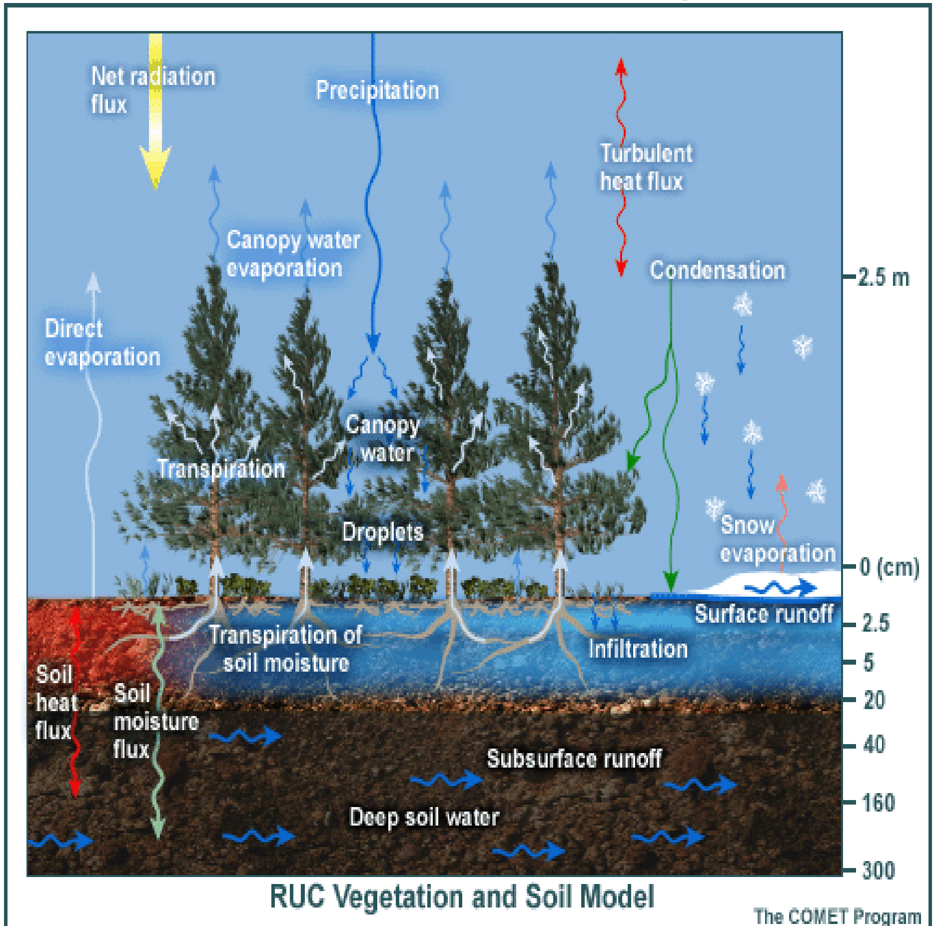
Network	uselist	total	% low 10m spd bias
UrbaNet	357	810	44
Citizens	659	3422	19
AWS	2207	5226	43
OK-Meso	80	116	69
GoMOOS	10	11	91
MesoWest	454	972	47
RAWS	826	1696	49
METAR	1284	2069	62
WXforYou	20	97	21

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.

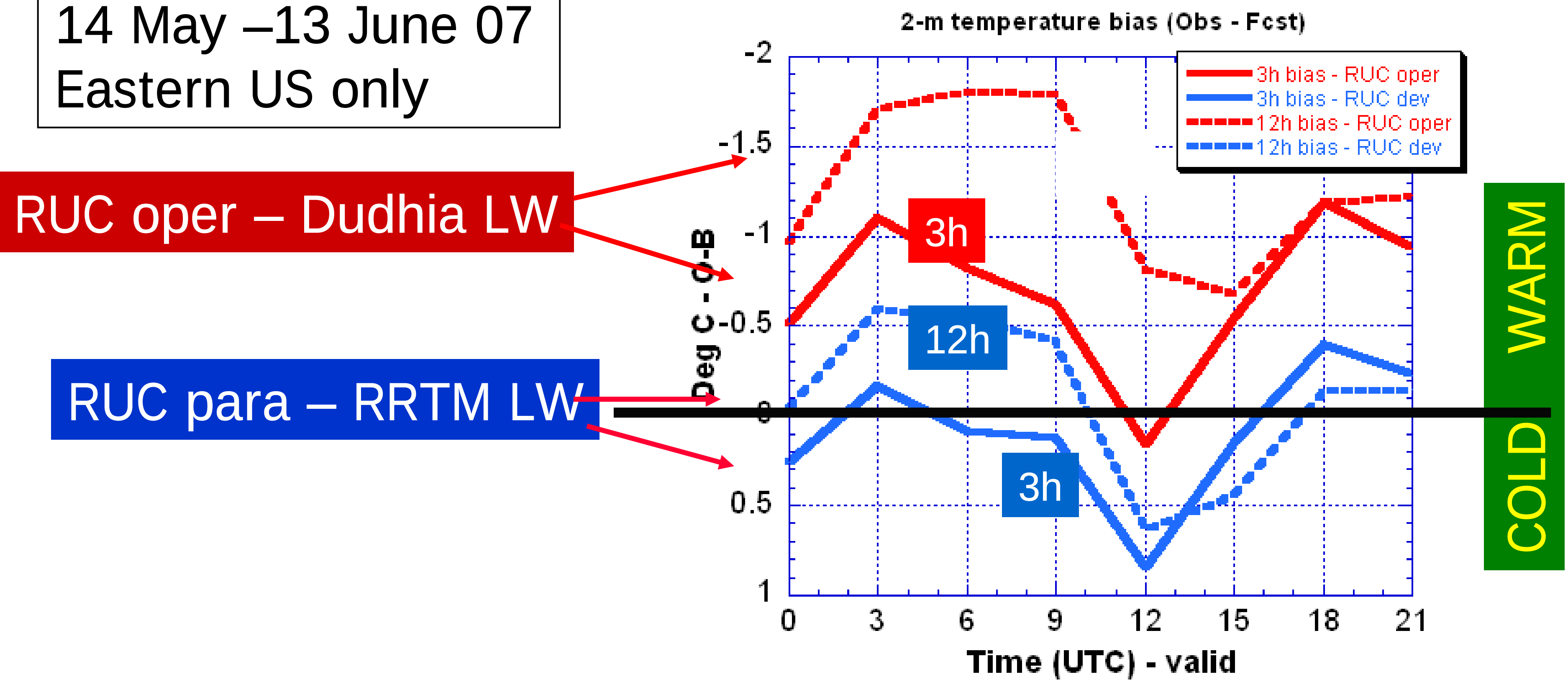
Result - More accurate 2m temps over snow cover, extreme cold temps removed.

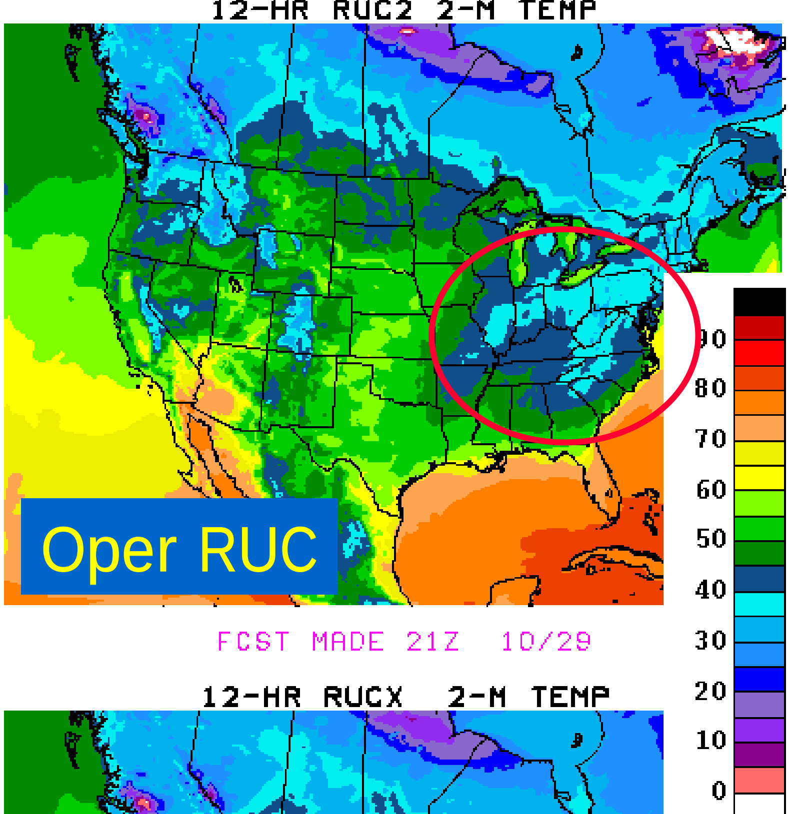
RRTM Longwave Radiation in RUC Upgrade
Effect on 2-m temperature forecasts

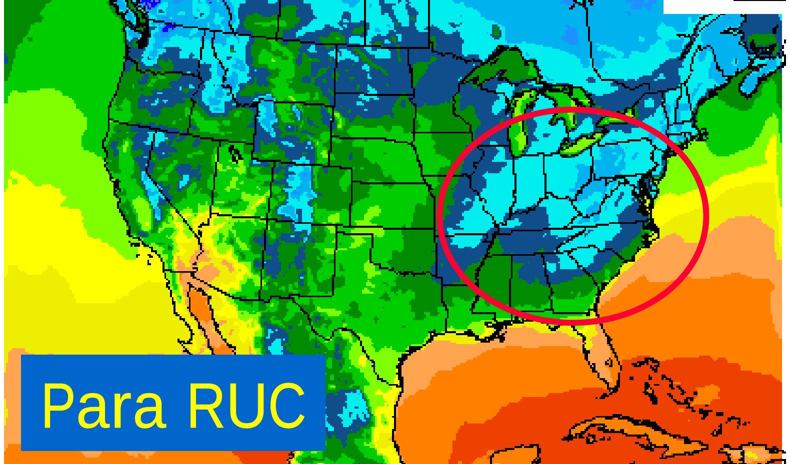
- Much decreased warm bias near surface

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

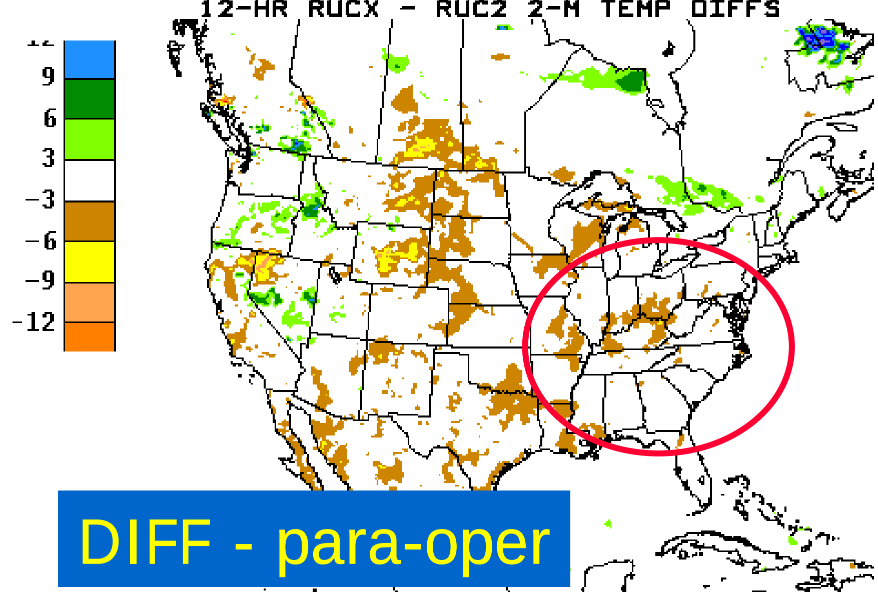
2-m temp bias (obs – forecast)



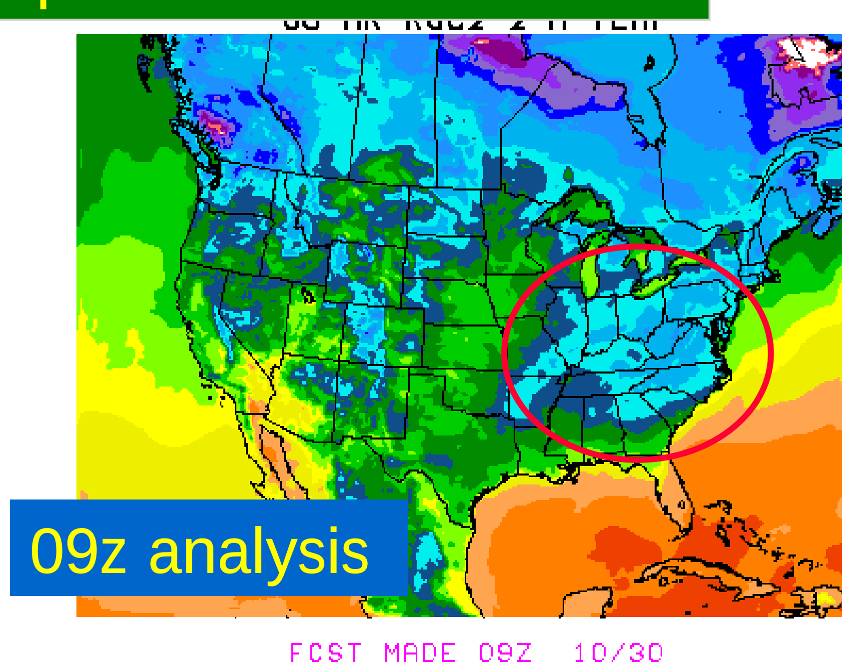




12h fcst – valid 09z 30 Oct



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



Grell-Devenyi Convection

2007 Changes to address recent issues

Non-local subsidence warming

- 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).

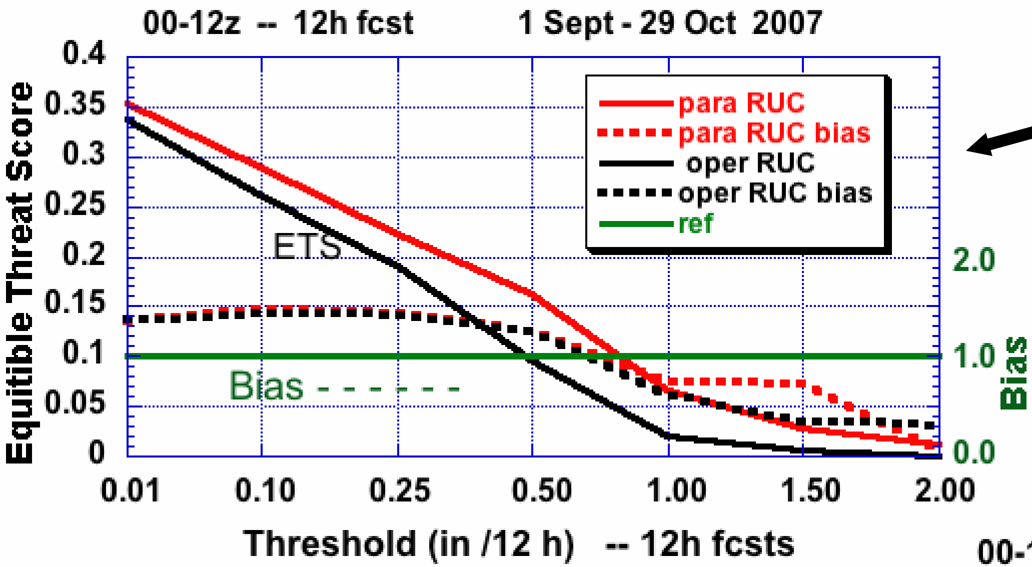
Reduce weight given to Arakawa-Schubert closure

- Result: Reduces the high spatial coverage bias of small amounts

Use smaller depth for cap adequate to deny convective initiation

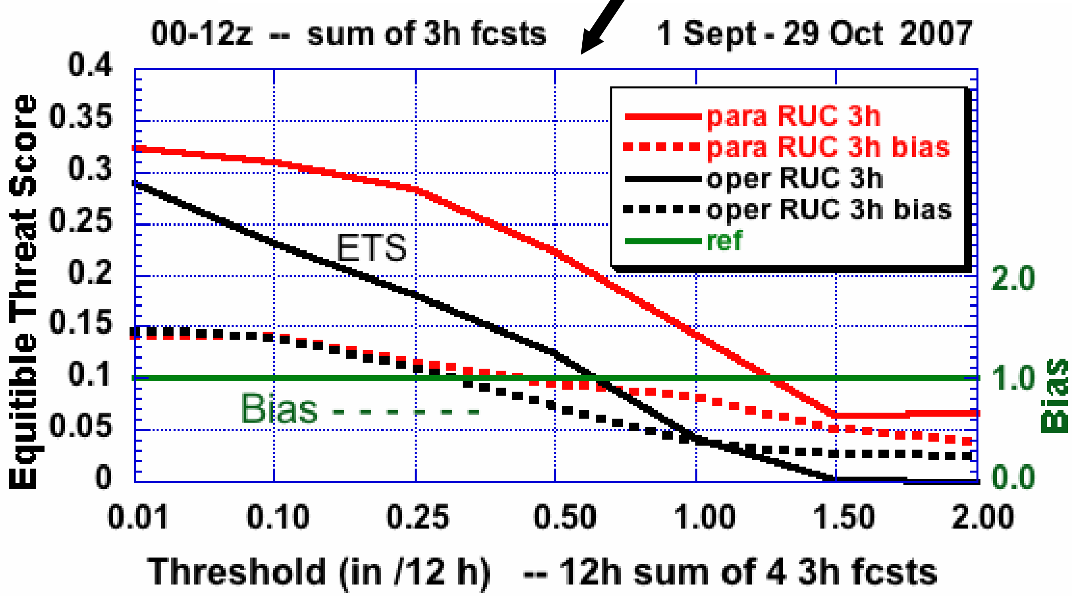
- Result: convection starts later in diurnal cycle

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

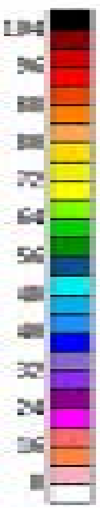
- Post-processing – add reflectivity fields, improved RTMA downscaling

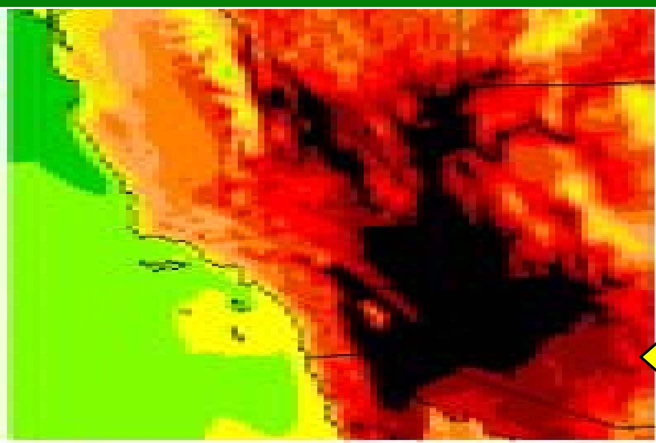
RUC parallel web site:
http://www.emc.ncep.noaa.gov/mmb/ruc2/para

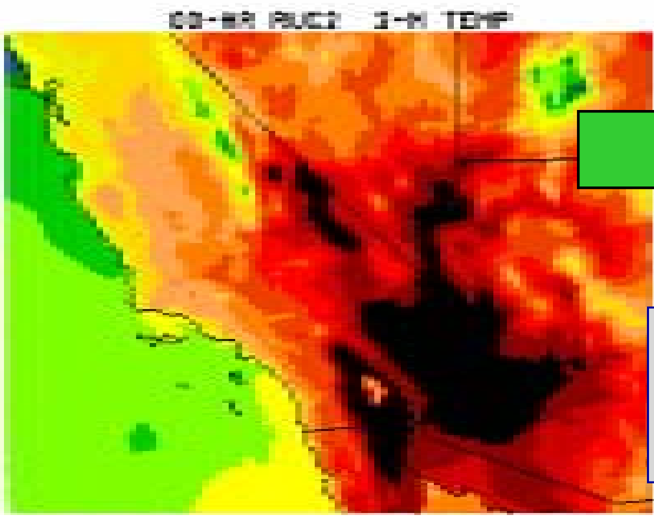
RUC-RTMA downscaling

2008 change - improved cold valleys

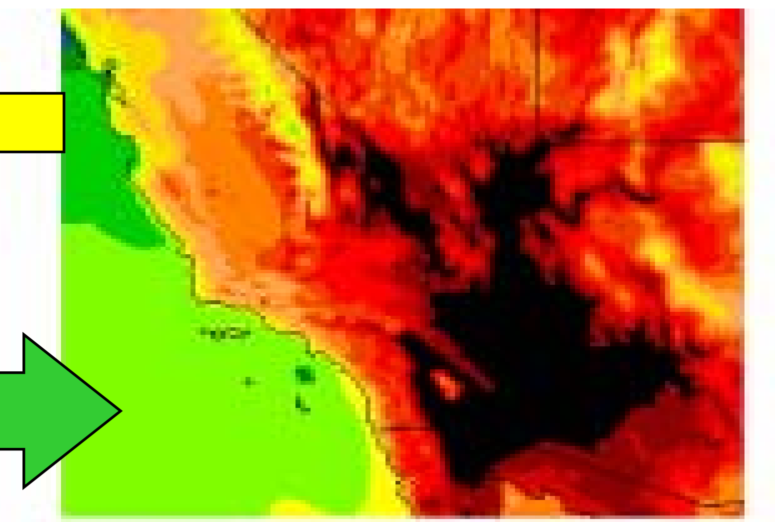
RUC post code used (w/ mods)
for RTMA downscaling







RTMA 2dVAR update



RUC-RTMA downscaling
Goal- CONUS RTMA background

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

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

Spring 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 all seasons, 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

Rapid Refresh status

11 Dec 07

Development, testing, results on

- Planned domain
- RR-WRF model configuration
- GSI for Rapid Refresh
- Rapid Refresh cycling

http://rapidrefresh.noaa.gov/rr

Includes

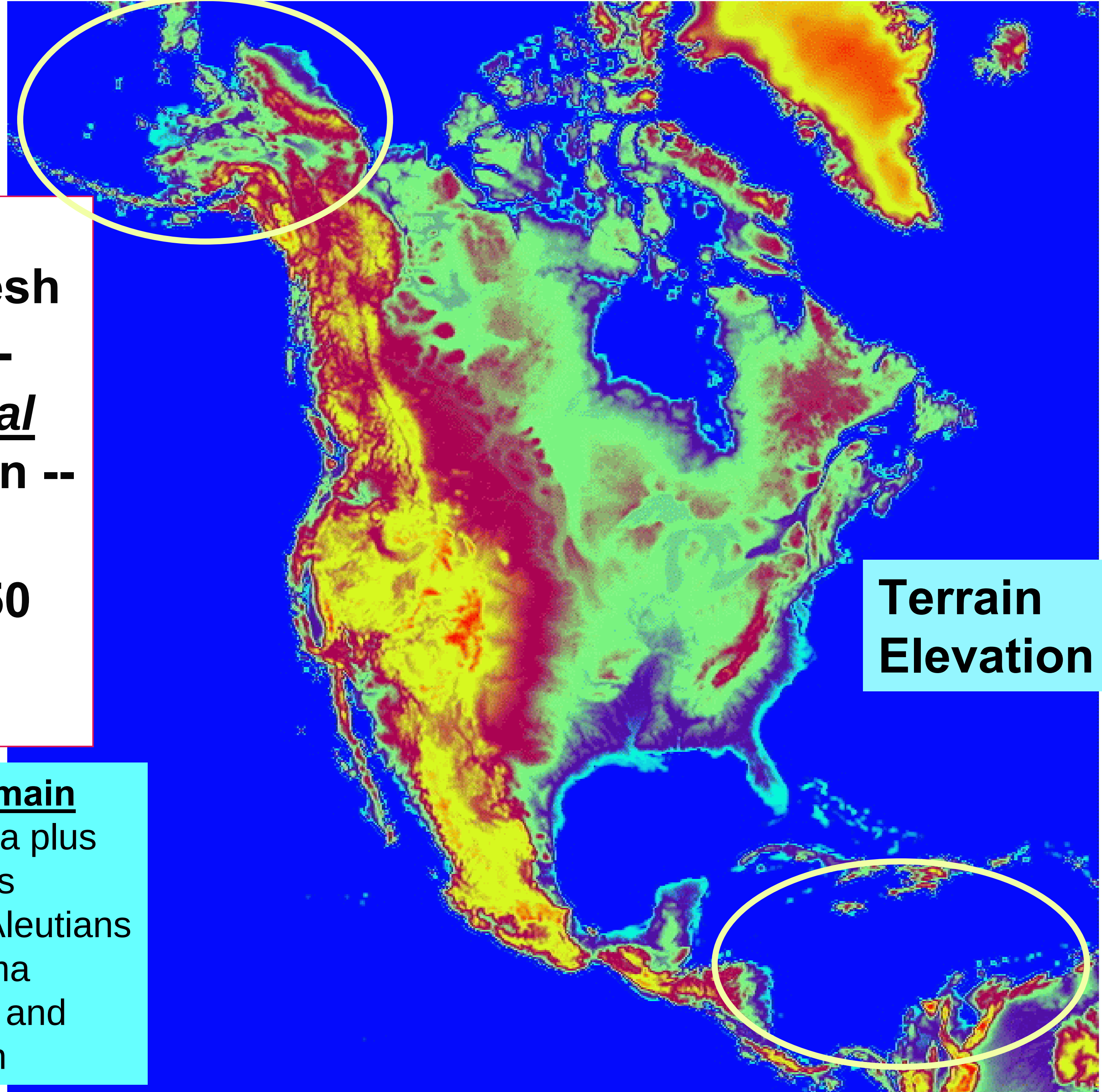
- lots of information
- real-time experimental products

Recent RUC/RR summary

http://ruc.noaa.gov/amb/2007_Oct_Review.pdf

Rapid Refresh *domain* -
Almost final
configuration --

649x648x50 grid pts



Terrain Elevation

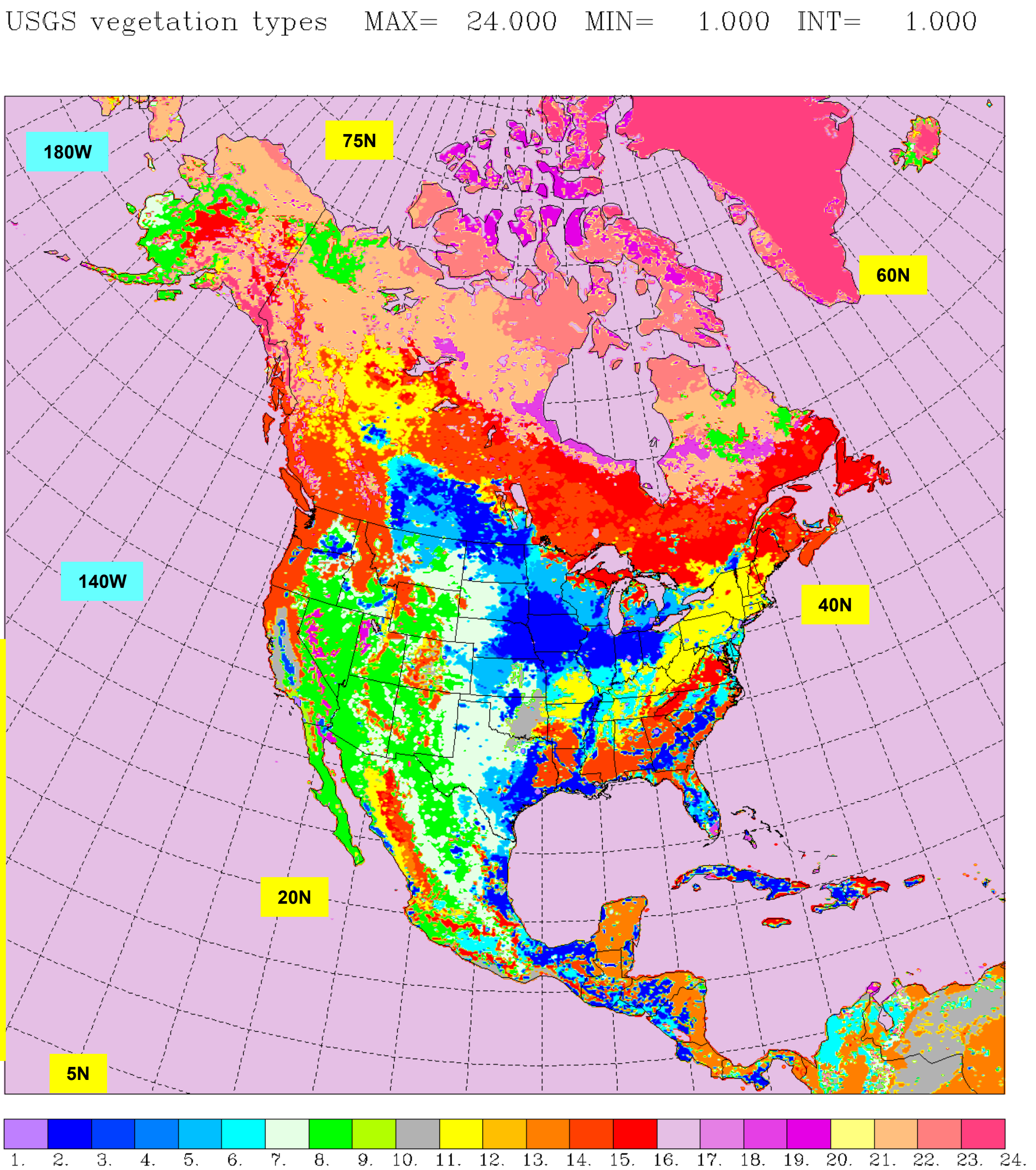
Constraints on domain

- Continental Alaska plus coastal margins
- Dutch Harbor in Aleutians
- Isthmus of Panama
- US Virgin Islands and most of Caribbean

Rapid Refresh

- USGS veg types

- Lat/lon



Latitude/longitude corner points

UL	56.24	+170.06
UR	61.44	- 4.64
LL	1.06	-128.50
LR	2.80	-65.75

RR vs. RUC grid points

Horizontal

• **RUC**	**451 x 301**	**- 13km**
• **RR**	**649 x 648**	**- 13km**
	(about 3x increase)	

Vertical

• **RUC**	**50 hybrid θ-σ levels**
• **RR**	**50 σ levels**

NCEP/GSD Agreement on Rapid Refresh - signed 12 September 2007

- **2009 – Initial Rapid Refresh – Phase 1**
  - Model - WRF-ARW, Rapid Refresh physics
  - Data assimilation – GSI with RR-developed enhancements
  - Submitted for operations (JIF) by Sept 2009
- **2012 – Ensemble Rapid Refresh – Phase 2**
  - 6 members, 3 each using ARW and NMM
  - Model (ARW, NMM) and GSI will use ESMF framework, not WRF framework
  - Model/assimilation systems from GSD and NCEP

RUC to Rapid Refresh

• **CONUS domain (13km)**	→	• **North American domain (13km)**
• **RUC model**	→	• **WRF model (RR version) <u>(ARW dynamic core)</u>**
• **RUC 3DVAR**	→	• **GSI (Gridpoint Statistical Interpolation)** (incl. RR enhancements)

RR version of WRF model

ARW core

Physics ***(those from RUC are in red)***

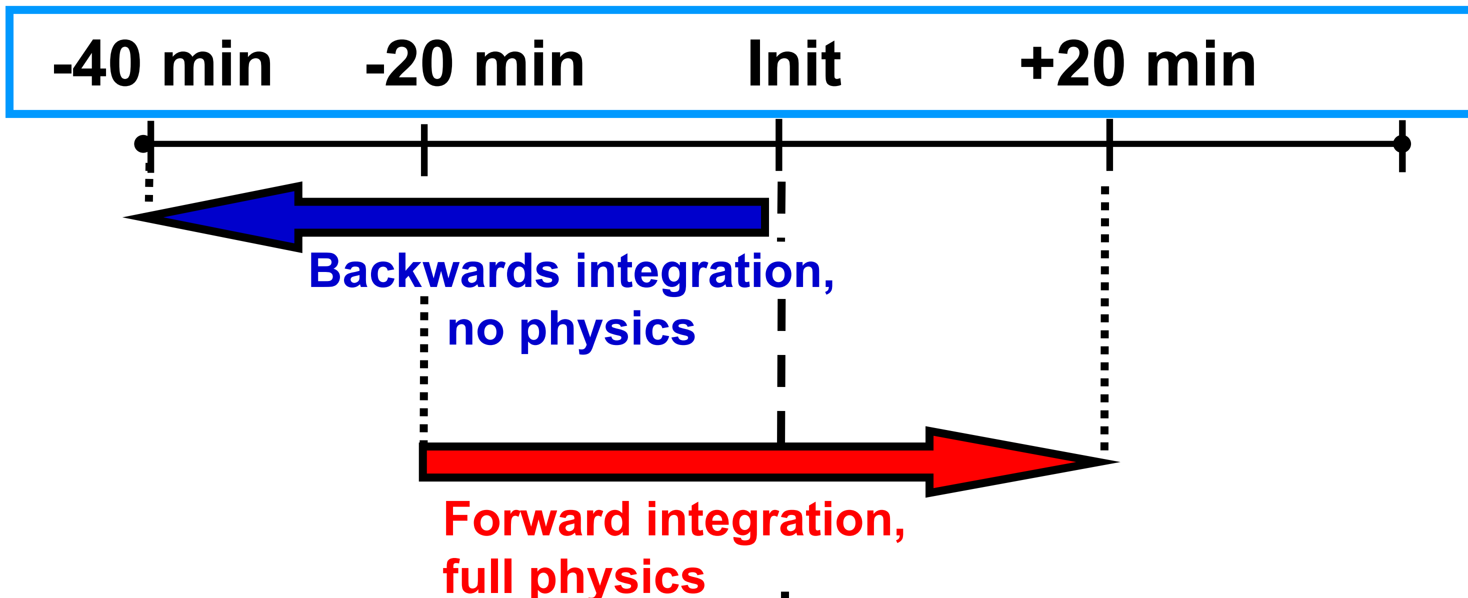
- **Grell-Devenyi convection**
- **MYJ (NCEP/NAM) surface layer and**
  turbulent vertical mixing above surface layer
- **NCAR-Thompson microphysics**
- **Diabatic Digital Filter Initialization (DFI)**
  - similar to that in RUC model
- **GFDL radiation (longwave and shortwave,**
  with cloud effects)
- **RUC Land-Surface Model** **(diversity from Noah LSM**
  in anticipation of ensemble RR by 2012)

Result: Physics behavior similar to that of RUC, preferred for aviation applications and convective environment

Diabatic Digital Filter Initialization (DDFI), used in RUC

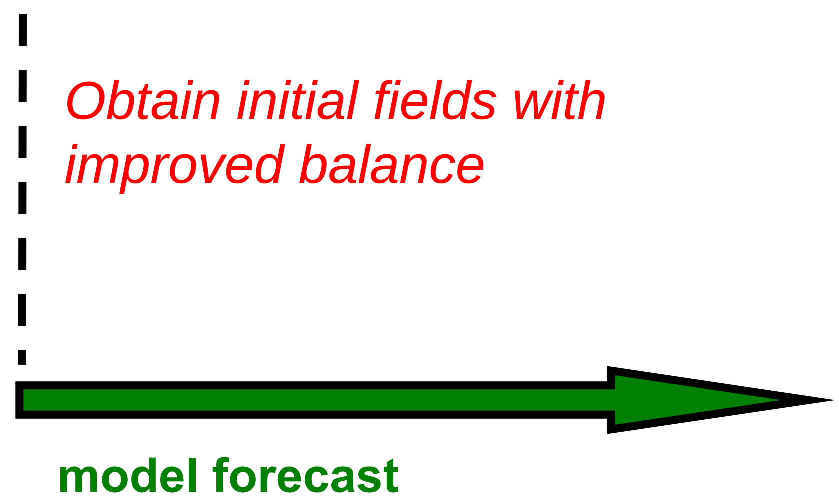
- Application into WRF - **recently completed for ARW**

(Tanya Smirnova, Steven Peckham)



Function of DFI: Remove high-frequency oscillations (particularly, gravity waves) from the initial state for the forecast

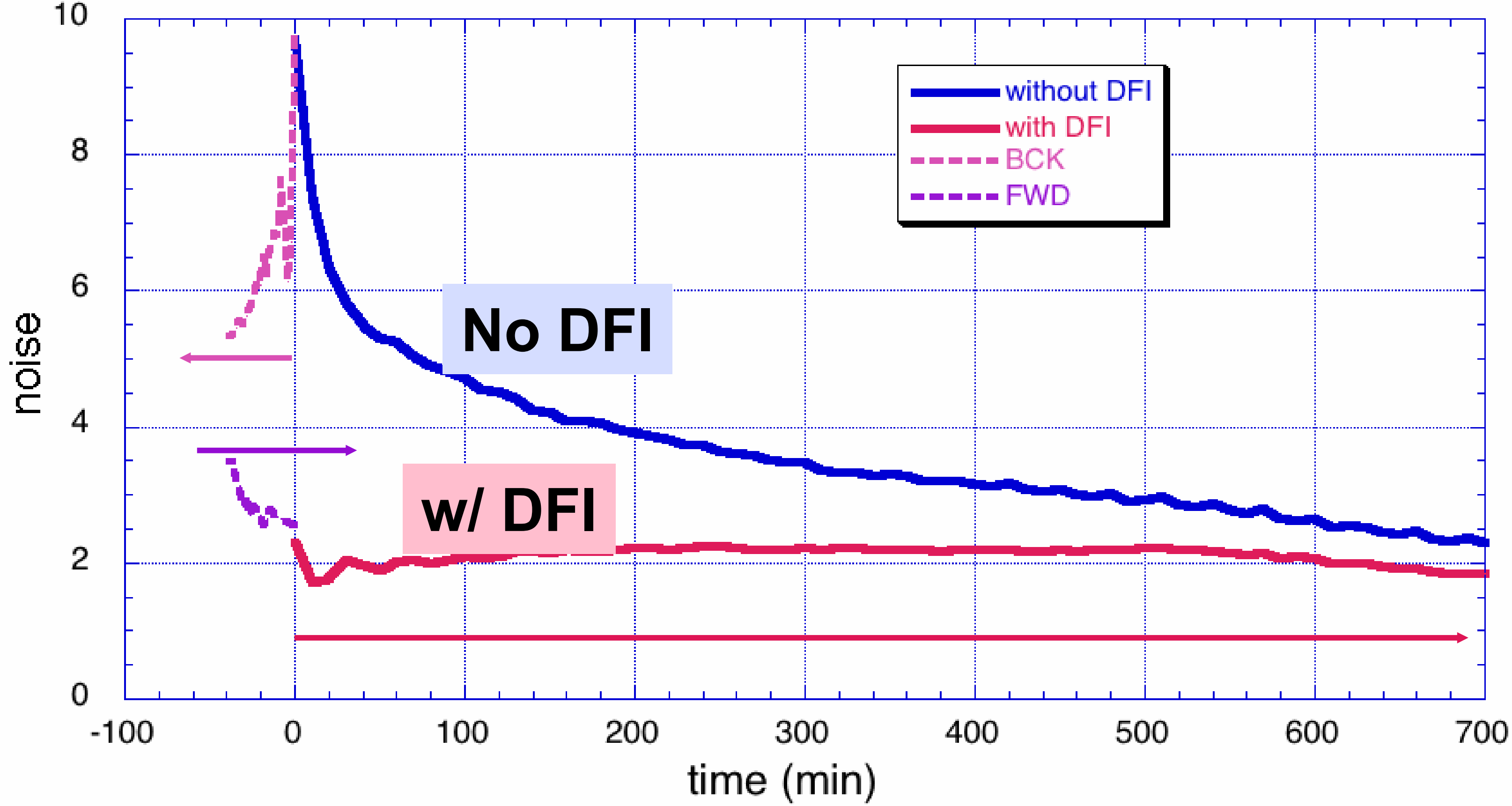
$\Rightarrow$ creates smoother background for next analysis



Quiter forecasts in WRF using DFI

Noise = mean absolute sfc pressure tendency (hPa/h)

$$\overline{\left|\frac{\partial p_{sfc}}{\partial t}\right|}$$

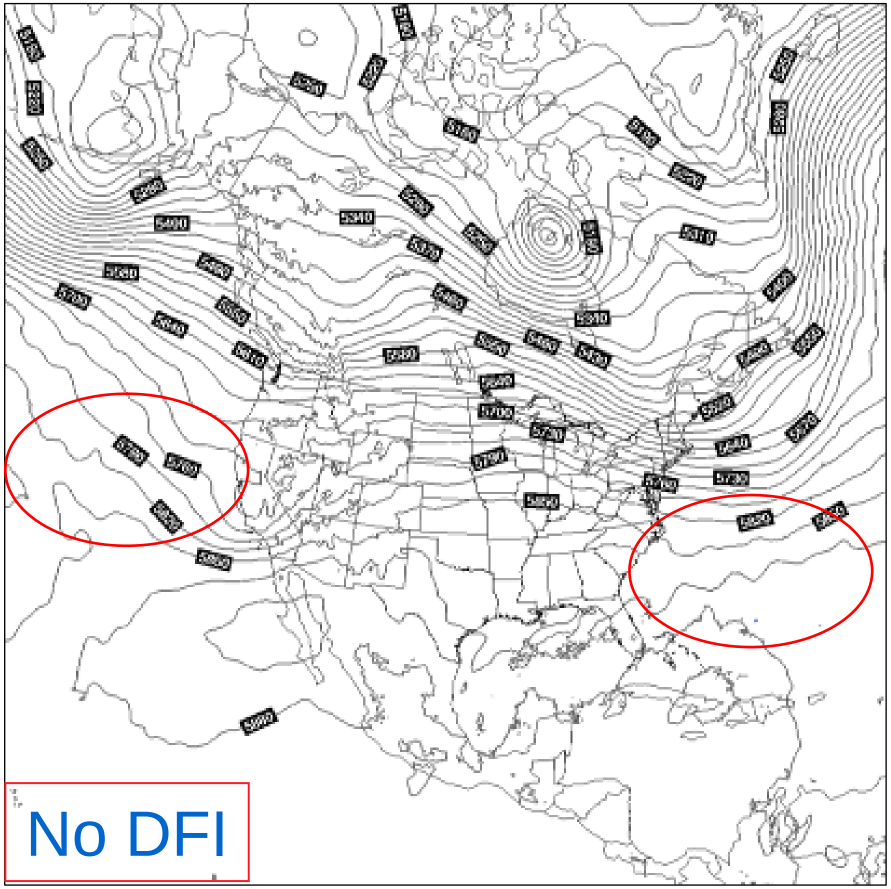


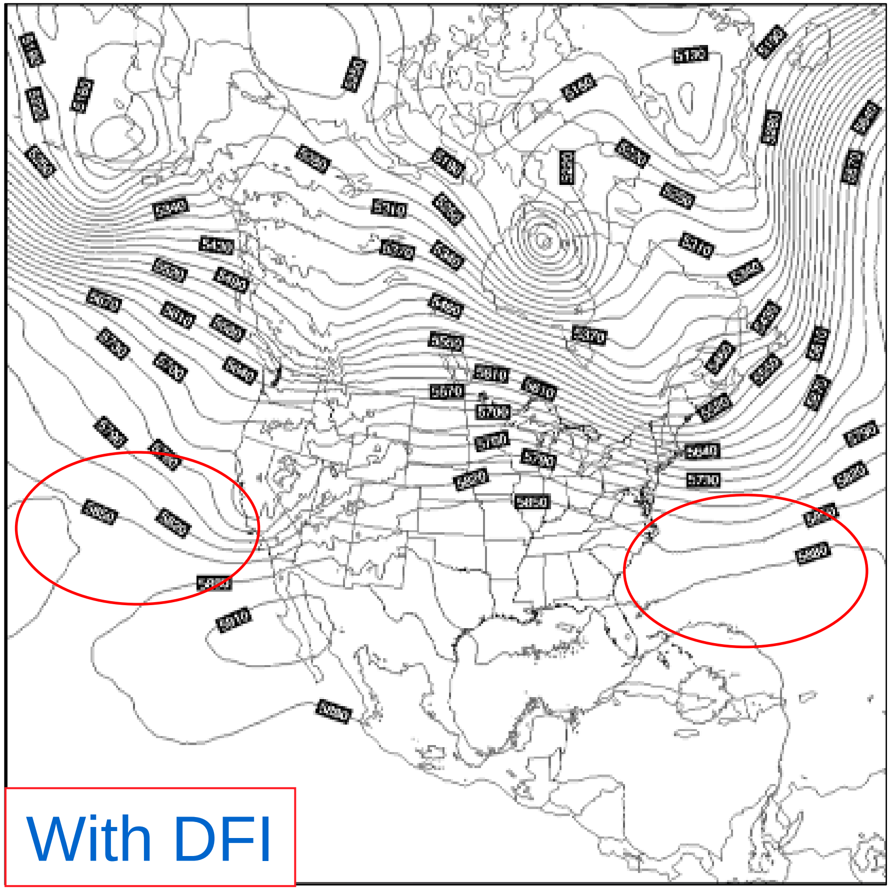
Using WRF-13km Rapid Refresh over N. American domain

Successful for reducing noise in 1h WRF fcst, as with RUC

500mb Height 3-h Fcst for 03Z 30 Oct 07
Rapid Refresh WRF

Away from terrain and convection,
height contours are smoother with DFI





Diabatic Digital Filter Initialization (DDFI)

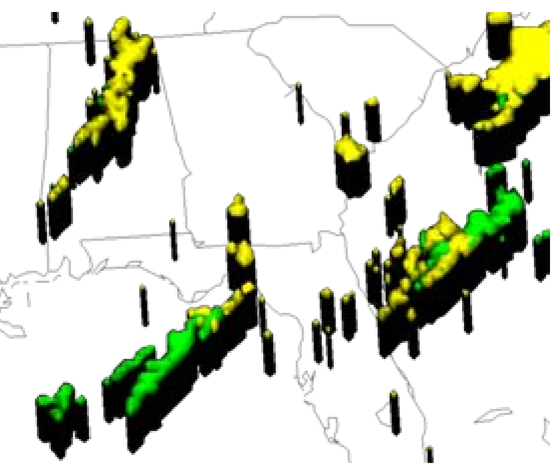
RUC-2008 - add assimilation of radar data

To be used in Rapid Refresh also

-30 min -15 min Init +15 min

Backwards integration,
no physics

Forward integration,
full physics



Apply latent heating from radar reflectivity, lightning data

Obtain initial fields with improved balance, vertical circulations associated with ongoing convection

RUC/RR model forecast

Application of GSI for RR
(Gridpoint Statistical Interpolation)

- GSI adapted from global Spectral Statistical Interpolation (SSI) toward unified NCEP analysis
  - Used for operationally in GFS, NAM, RTMA
  - Primary development by NCEP/EMC and NASA/GMAO (via JCSDA), ESRL/GSD now collaborating on regional GSI
- Includes satellite radiance assimilation package
  - Not in current RUC, critical for large oceanic coverage in RR
- Work with EMC on RR application of GSI:
  1) Use of background from ARW w/ 5 hydrometeor types
  2) Cloud analysis (satellite, METAR, radar, LTG obs)
  3) Surface obs assimilation (PBL depth, coast-lines)
  4) Force convection from radar, lightning data in model DDFI

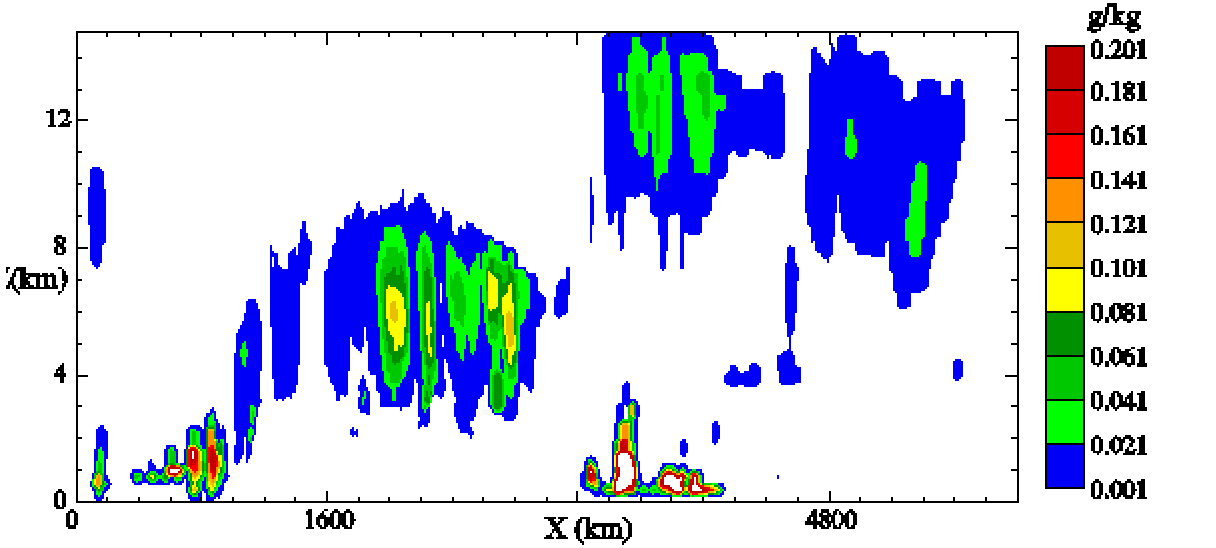
"RUC specific" enhancement in GSI for Cloud analysis

- Uses techniques from RUC, ARPS cloud analysis
- Utilizes METAR, satellite, radar data
- Modifies background cloud, hydrometeor, water vapor fields

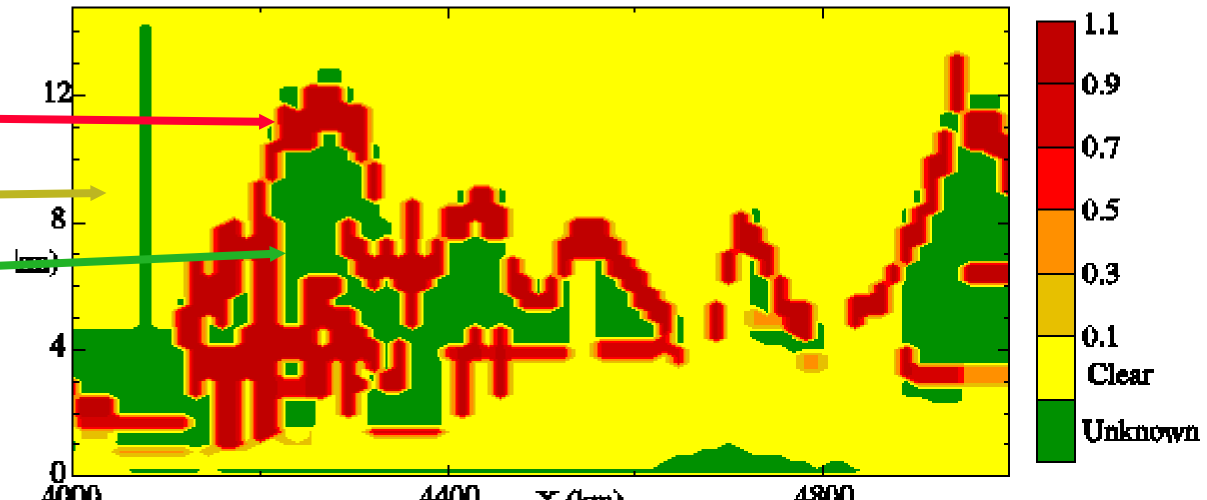
- Cycled testing within GSI framework
- Parallelized version for inclusion in full GSI

Updating cycled cloud / hydrometeor fields with METAR, satellite, radar observations

Background Cloud water + cloud ice



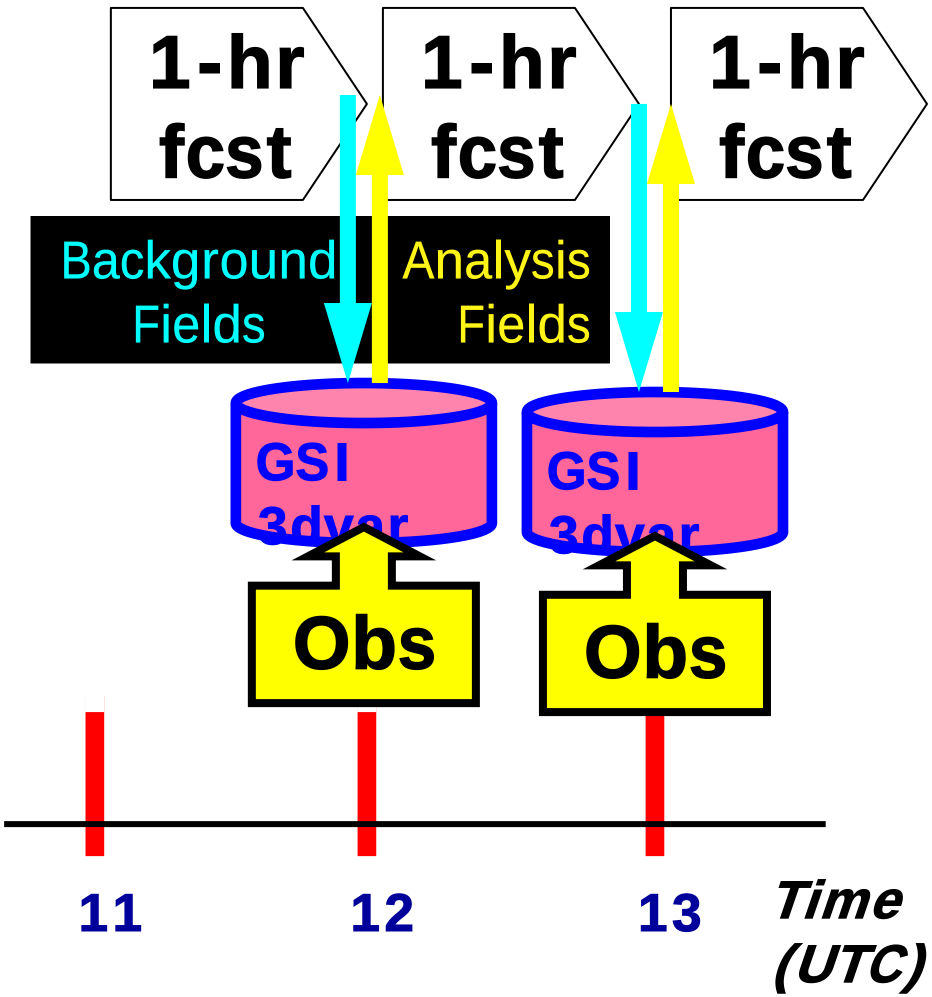
Cloud assessment (YES/ NO/ UNKNOWN) from observations (METAR/sat/radar)



(based on RUC cloud analysis w/ METAR, GOES, 1h fcst)

RR Hourly Assimilation Cycle

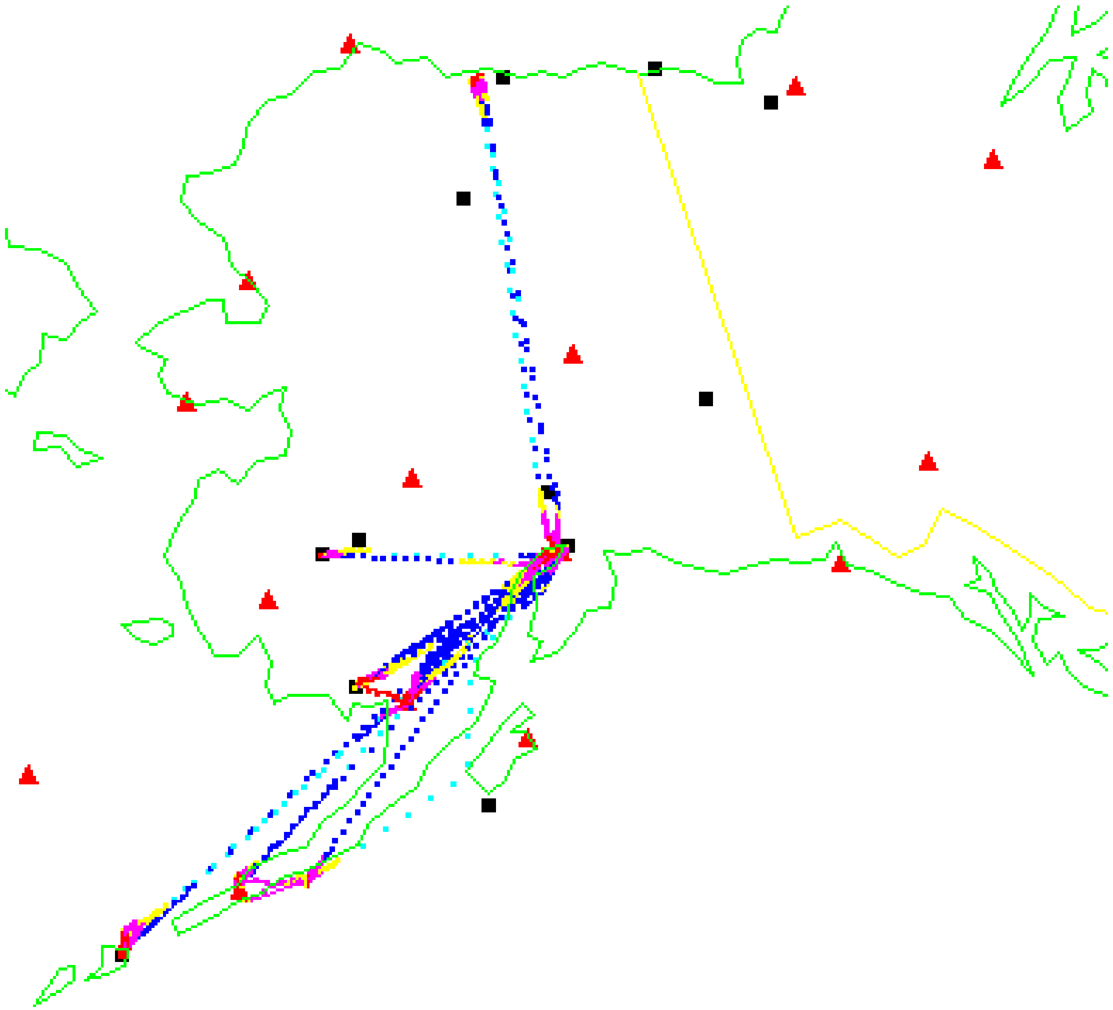
Cycle hydrometeor, soil temp/moisture/snow plus atmosphere state variables



Hourly obs

Data Type	**~Number**
Rawinsonde (12h)	150
NOAA profilers	35
VAD winds	120-140
PBL – prof/RASS	~25
Aircraft (V,temp)	3500-10000
TAMDAR (V,T,RH)	200-3000
Surface/METAR	2000-2500
Buoy/ship	200-400
GOES cloud winds	4000-8000
GOES cloud-top pres	10 km res
GPS precip water	~300
Mesonet (temp, dpt)	~8000
Mesonet (wind)	~4000
METAR-cloud-vis-wx	~1800
AMSU-A/B/GOES radiances	
Radar reflectivity/ lightning	1km

Pen Air TAMDAR Data, 22 Oct 2007
(1520 Observations)

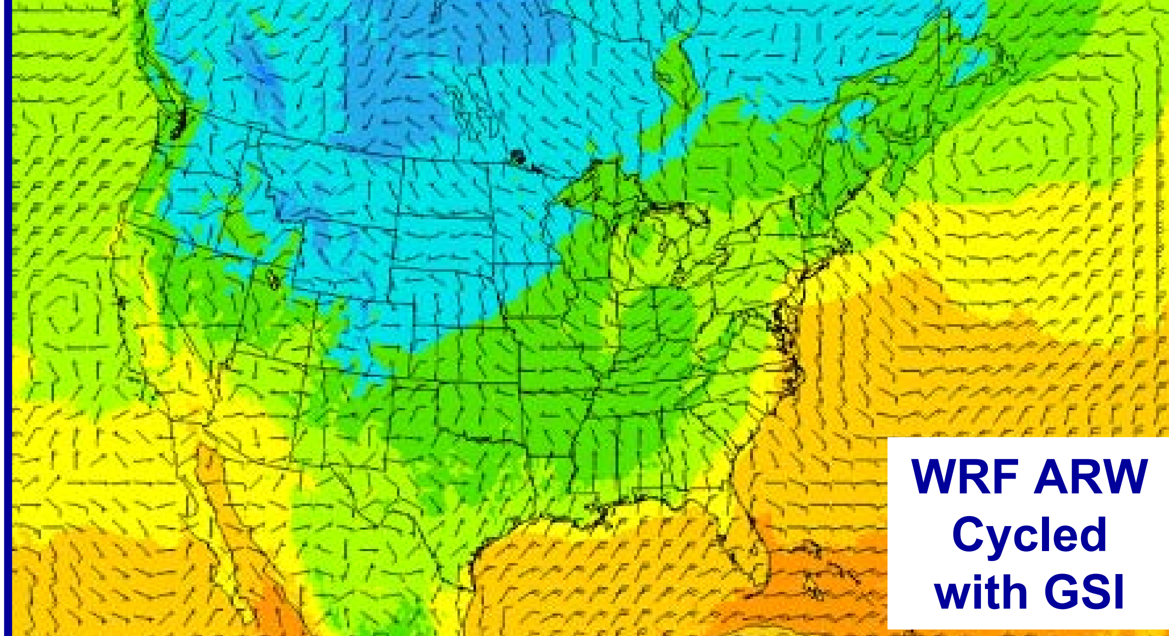


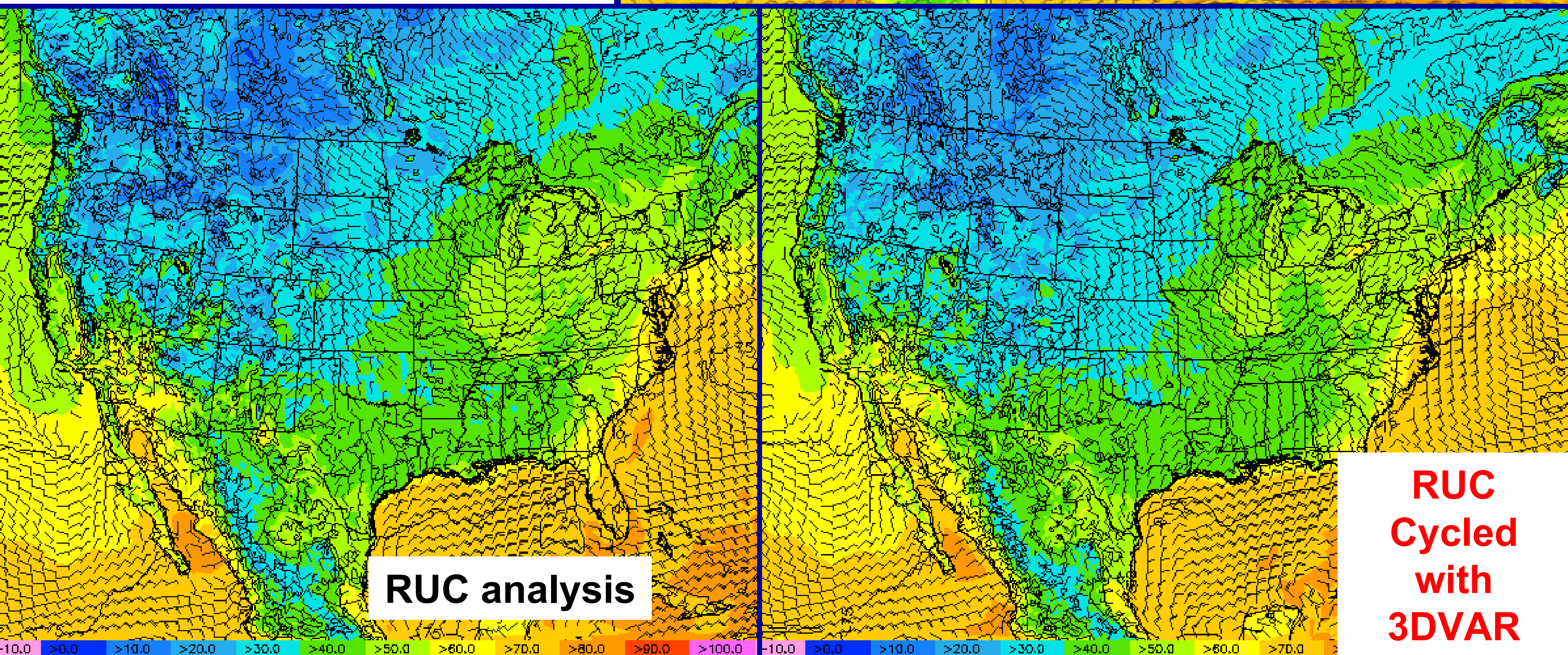
Current status - RR testing
11 Dec 2007

- **2 versions running at this time over full RR domain**
  - 6h cycle Rapid Refresh using GSI
    - RUC observation (prepBUFR) file only
  - cold start Rapid Refresh - no cycle
    - GFS initial conditions
- **3h CONUS RR cycle for RUC comparison**
- **Expected status by January 2008**
  - 3h cycle Rapid Refresh using GSI
    - using full Rapid Refresh prepBUFR observations including satellite radiance data

GSI- WRF cycled forecasts - initial comparisons with RUC

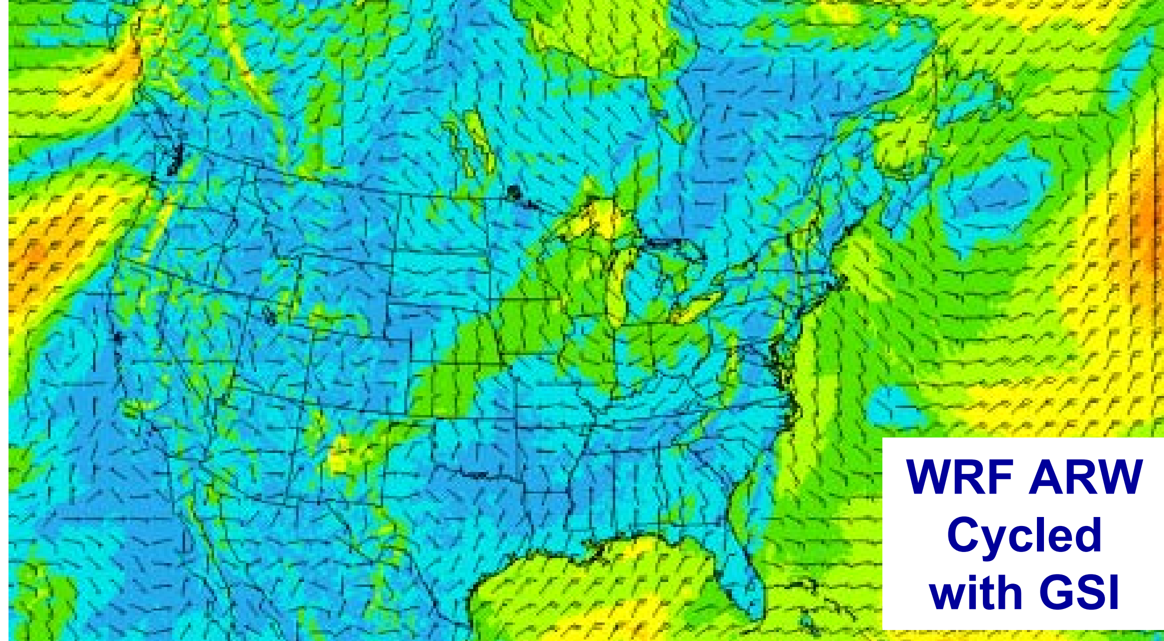
6-h fcst surface temp. v12z 27 Oct 2007

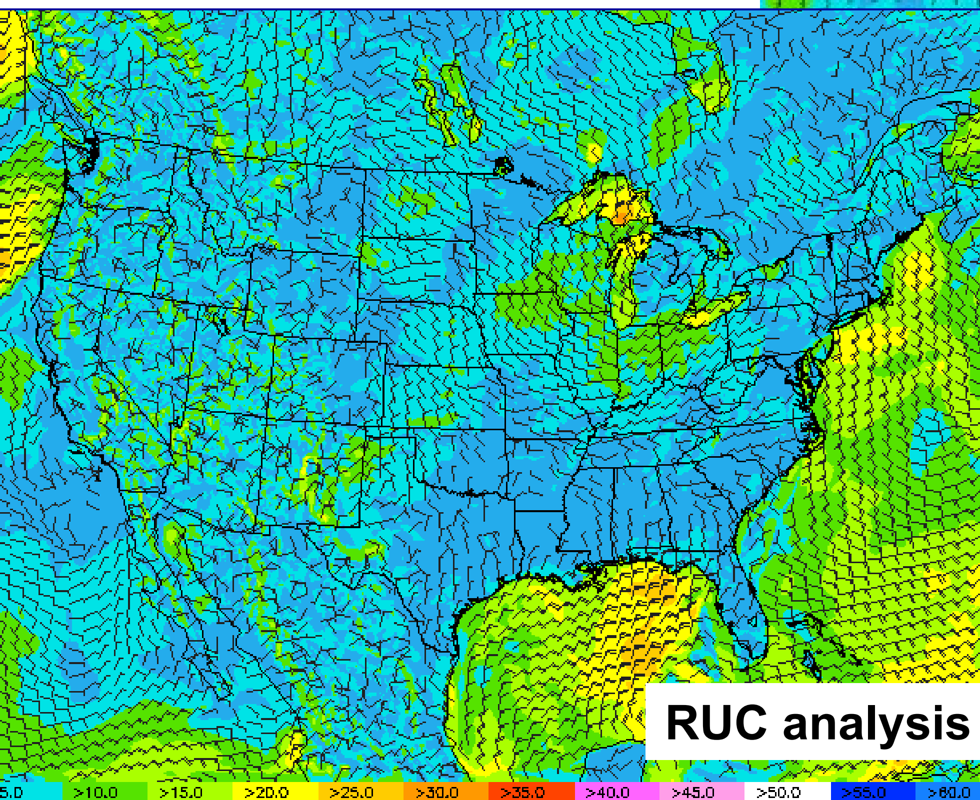


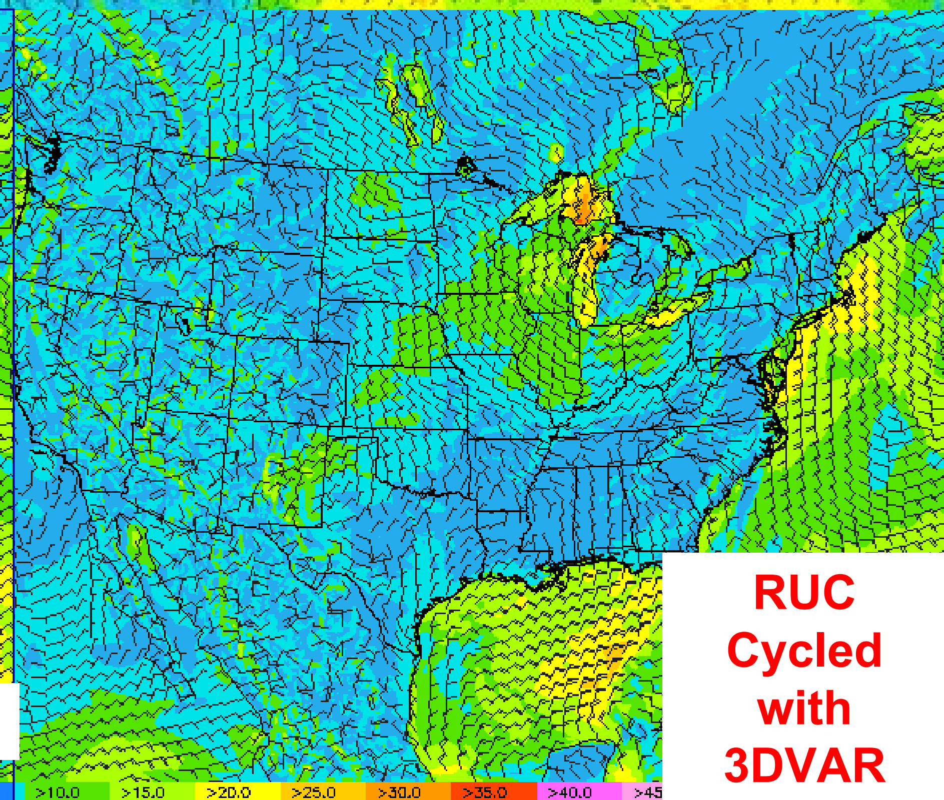


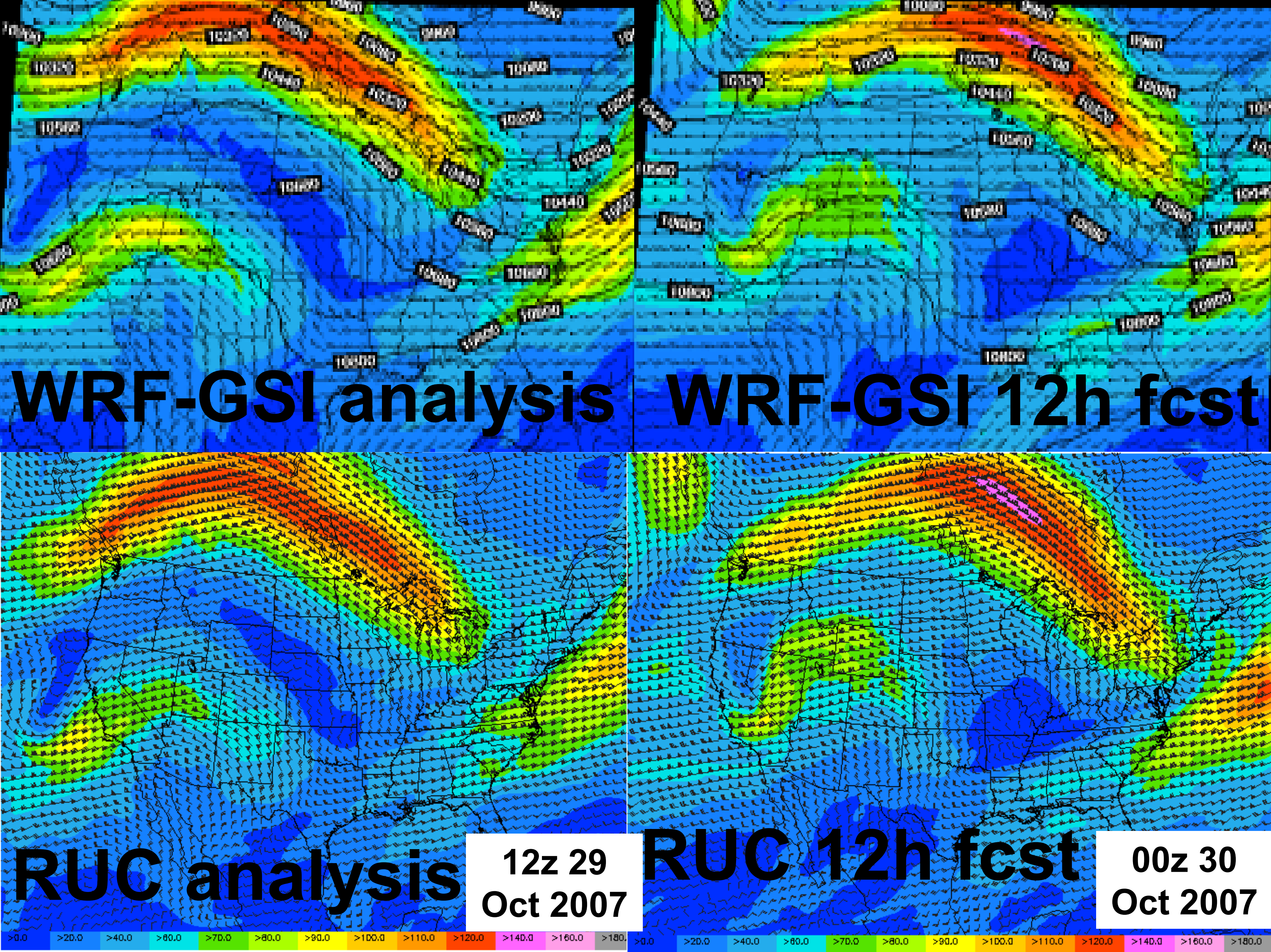
GSI- WRF cycled forecasts - initial comparisons with RUC

6-h fcst 10-m wind valid 12z 27 Oct 2007



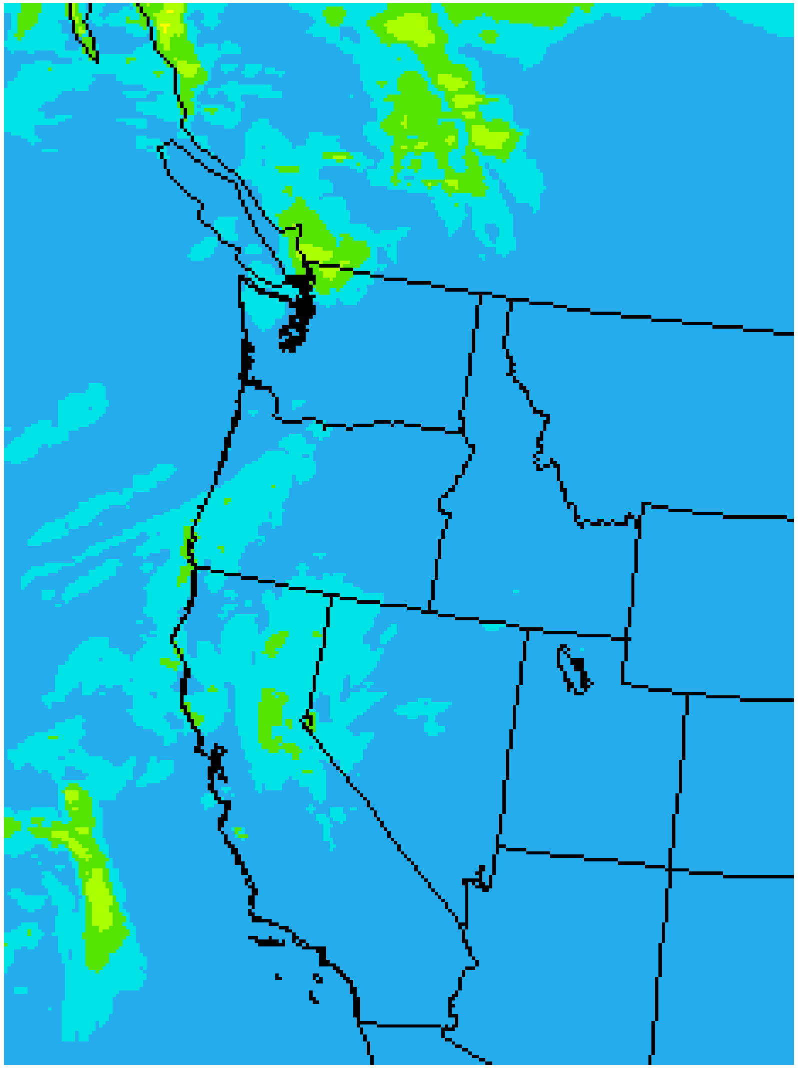




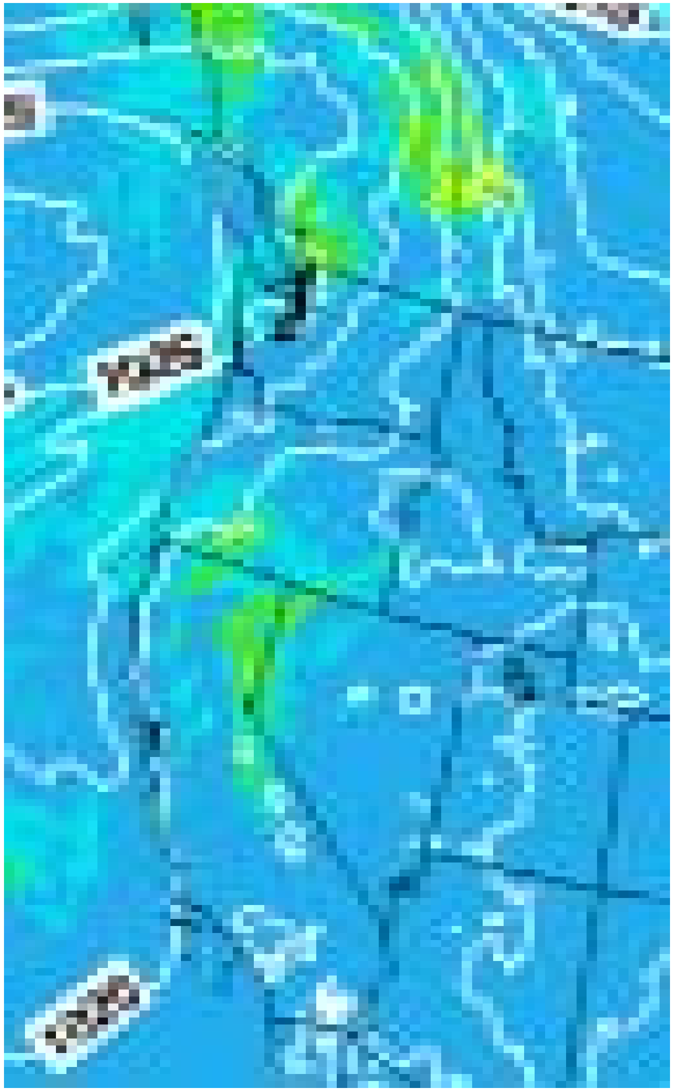

WRF-GSI analysis
WRF-GSI 12h fcst
RUC analysis
12z 29
Oct 2007
RUC 12h fcst
00z 30
Oct 2007
>0.0
>20.0
>40.0
>60.0
>70.0
>80.0
>90.0
>100.0
>110.0
>120.0
>140.0
>160.0
>180.0

CONUS Rapid Refresh domain (3-h cycle)

RUC cycled
12-h forecast

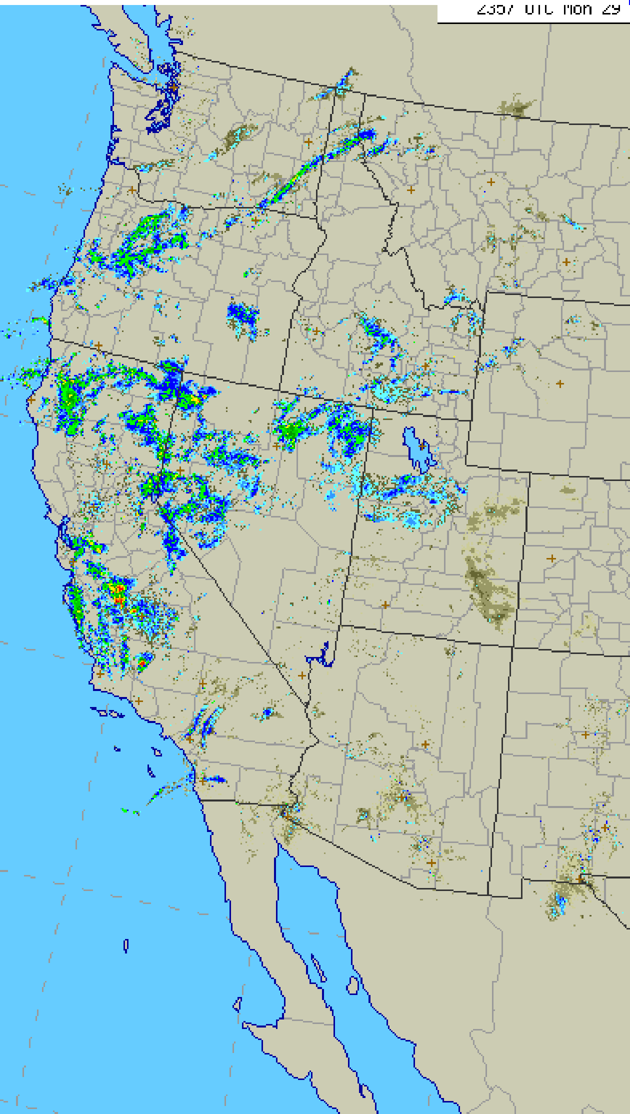


GSI- WRF cycled
12-h forecast

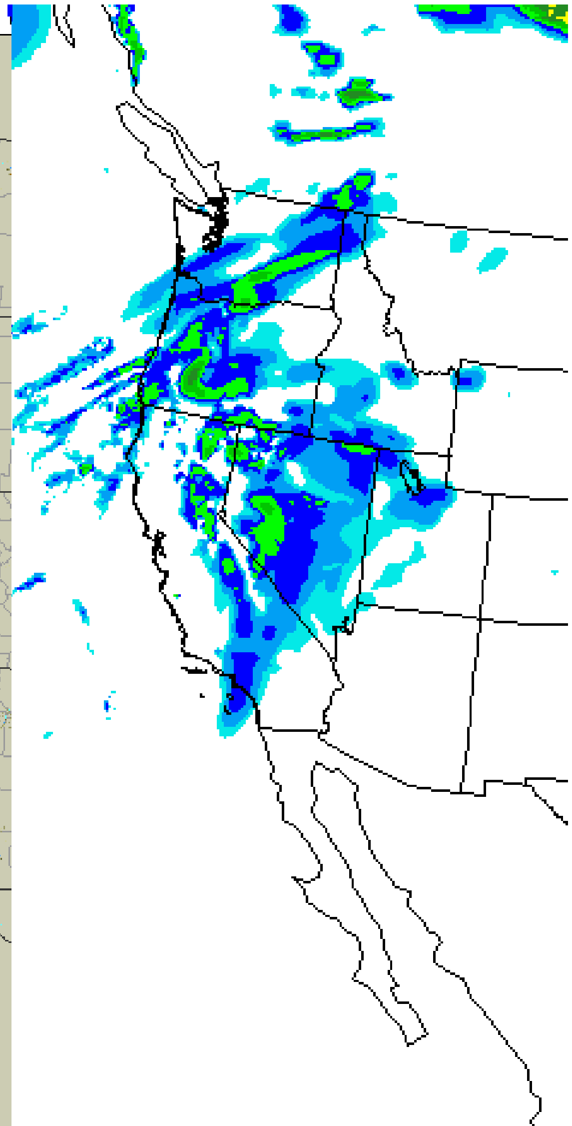


CONUS Rapid Refresh domain (3-h cycle)

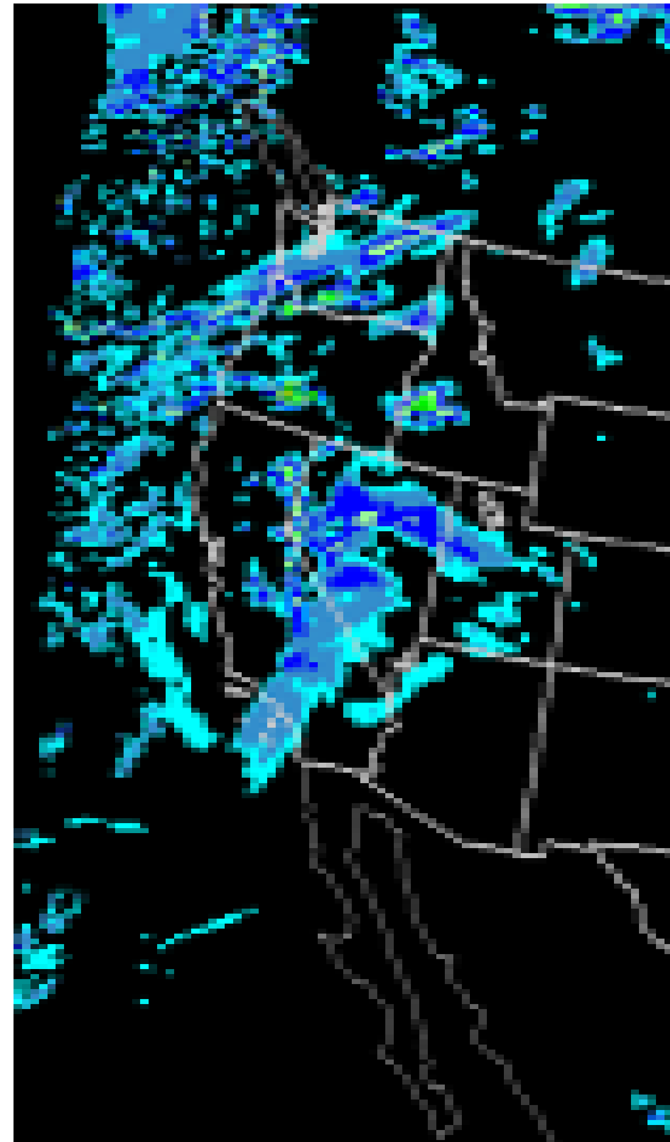
Radar mosaic
00z 30 Oct 2007



RUC cycled
12-h forecast

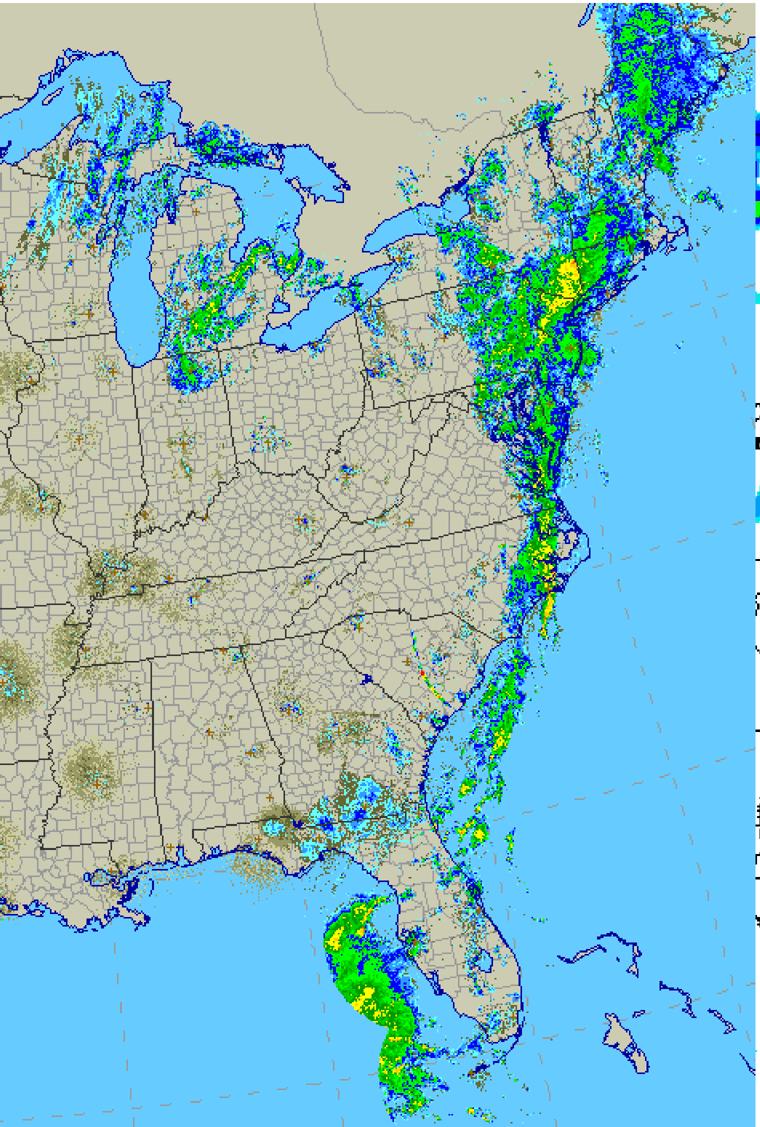


GSI- WRF cycled
12-h forecast

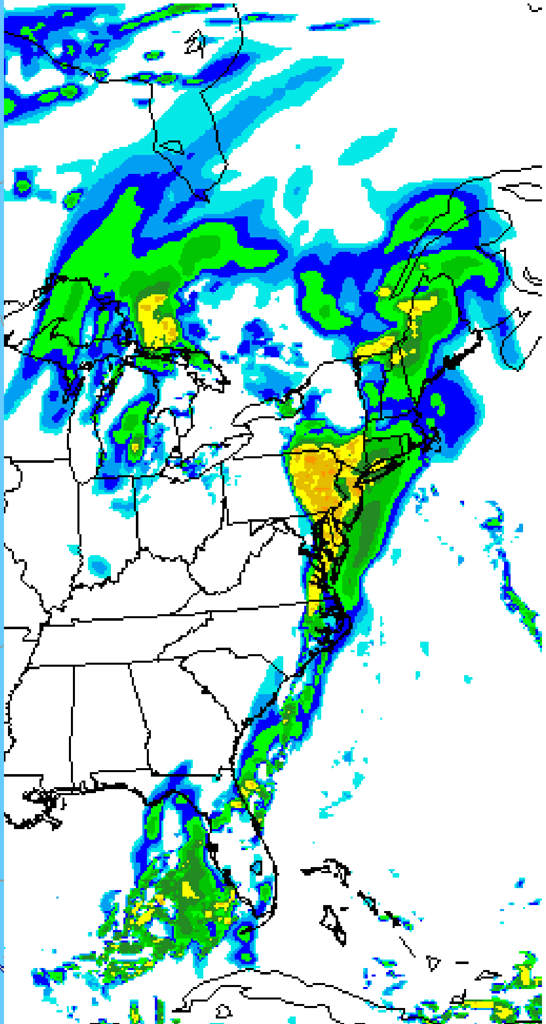


Full Rapid Refresh domain (6-h cycle)

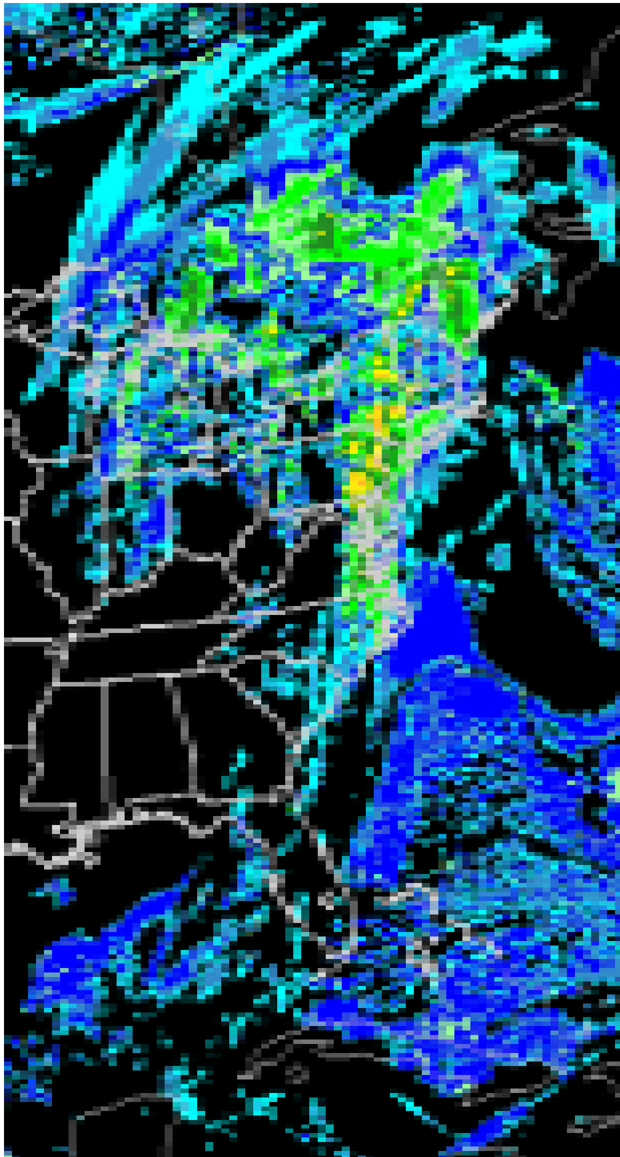
Radar mosaic
12z 27 Oct 2007



RUC cycled
6-h forecast



GSI- WRF cycled
6-h forecast



Rapid Refresh output

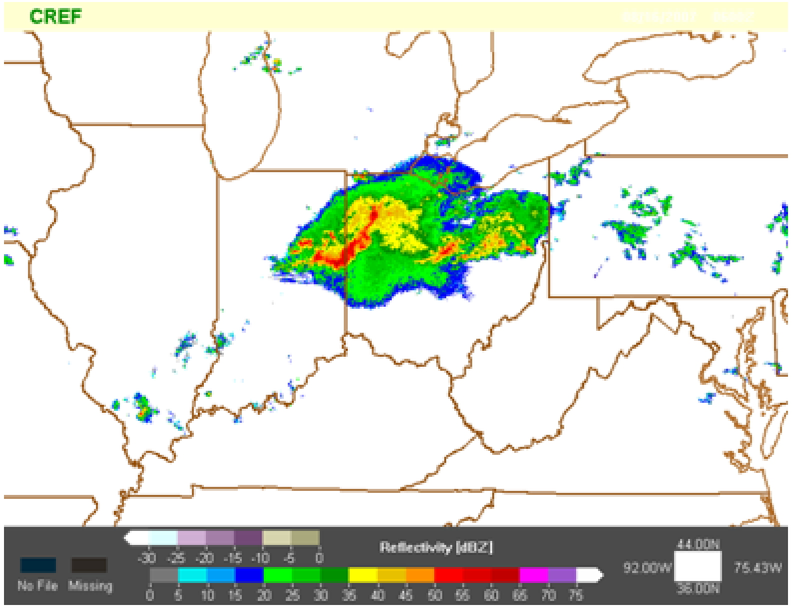
- **Use of NCEP WRFpost (unified post)**
  – Will add RUC diagnostics including advanced visibility, ceiling diagnostics, reflectivity for Thompson microphysics, etc.

- **Output will be available on**
  – Full RR domain, and
  – Current RUC grids (#130 (13km), #252 (20km)) to ensure compatibility with current RUC data
  – Other subsets (Alaska is likely)

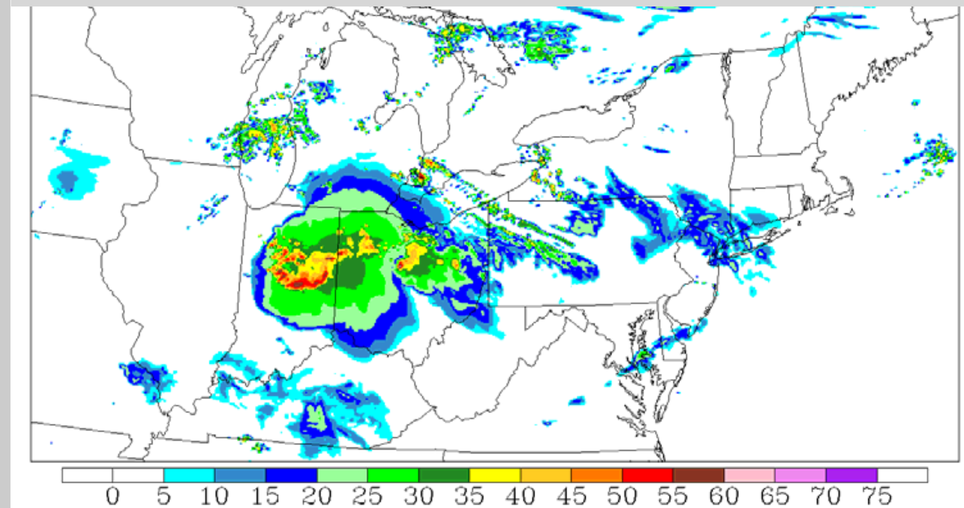
Proposed 3km HRRR (Hi-Res Rapid Refresh)

Nest initialized w/ Radar-Enhanced RUC/RR

NSSL verification

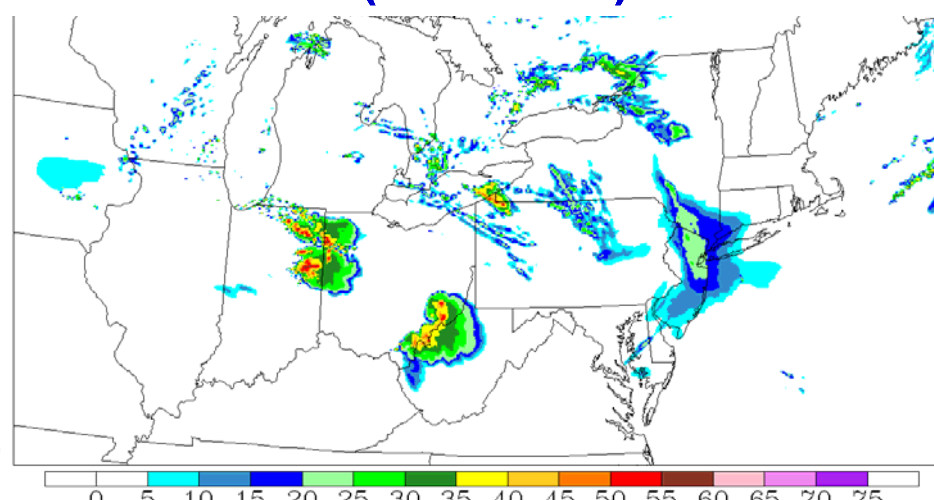


HRRR 3-km run initialized From radar-enhanced RUC



- **Much improved convection forecast from HRRR (*but* only if HRRR nested within radar-enhanced RR/RUC)**

Cold start (no radar) 3-km run



6-h forecasts valid 00z 16 Aug 2007

Flow-following (i.e. θ-σ) Finite-volume Icosahedral Model FIM

(Development at NOAA/ESRL-Boulder, planned for EMC-ESMF-global-ensemble dynamic component)

Icosahedral grid

Grid = Hexagons, with 12 embedded pentagons

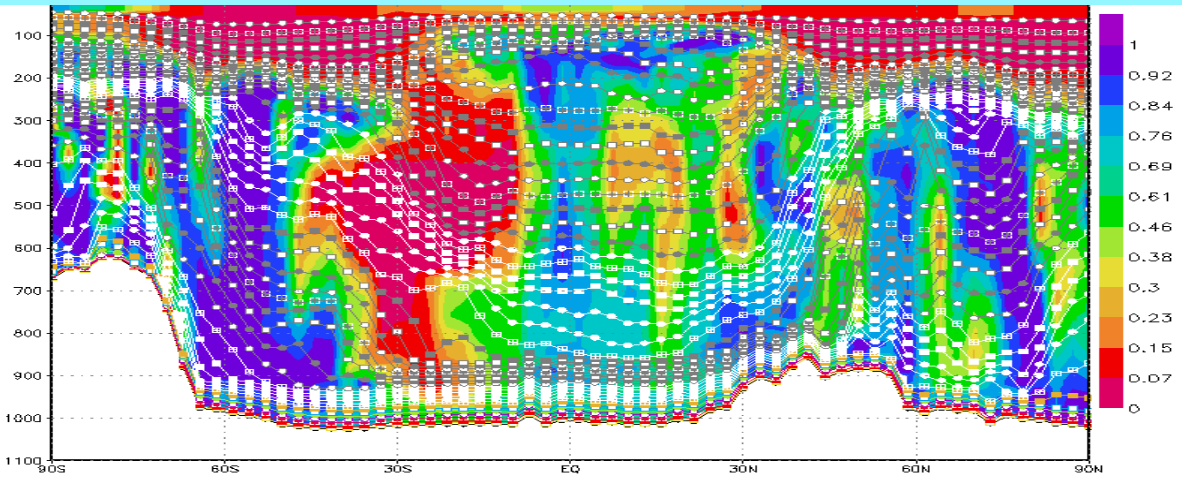
No pole singularities- better representation of circulations in polar regions

Adaptive, hybrid-isentropic vertical coordinate (similar to HYCOM, RUC) -- I

Accurate/conservative transport of atmospheric constituents (water vapor, chemical constituents, aerosols, etc.)

Physics - GFS, very soon - add WRF physics/chem

FIM Vertical cross section of coordinate surfaces and RH along 110E long

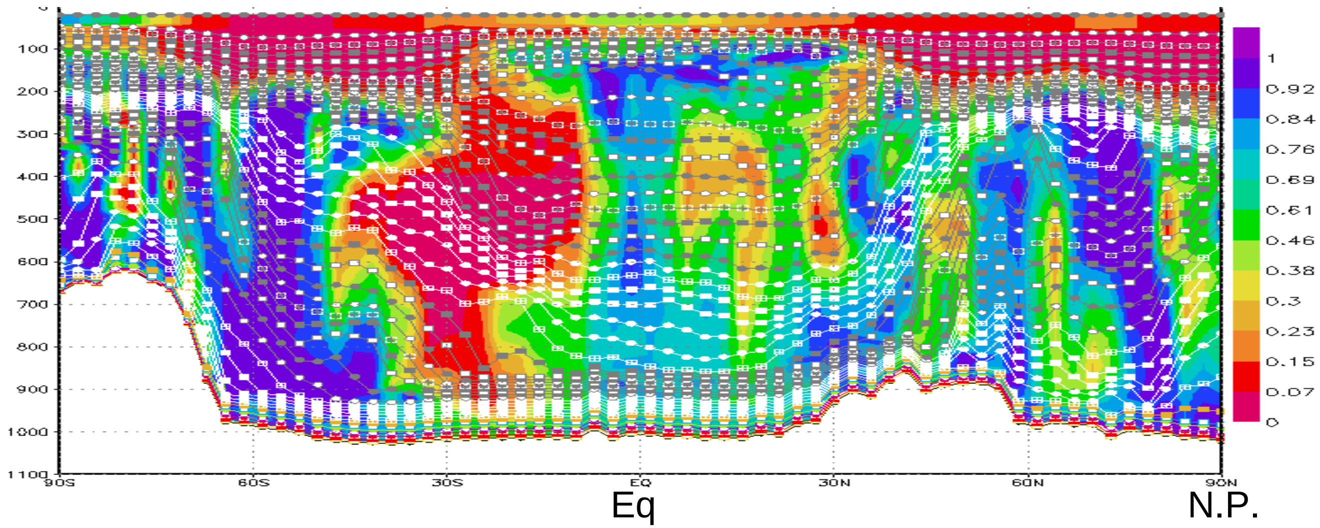


S.Pole Equator N. Pole

FIM combines 3 unique features (continued)

Adaptive, hybrid-isentropic vertical coordinate (similar to HYCOM ocean model) -- accurate and conservative long-range transport of atmospheric constituents (water vapor, chemical constituents, fine dust particles, etc.)

Vertical cross section of coordinate surfaces and relative humidity (image) along 110E longitude



Finite-Volume numerical procedures -- conservation of fundamental physical quantities (mass, momentum, water vapor, etc.)

- **FIM successfully tested on several real-data cases at 15km and 30km resolution (50 levels) after extensive testing and development**
- **Full physics (NCEP-GFS) implemented and tested extensively**
- **Tests of FIM with both θ-σ hybrid and σ vertical coordinates, now with acceptably equal performance using GFS physics**
- **Plan to run and verify real-time multi-day forecasts beginning late December 2007 using GFS initial conditions**
- **Also about to start**
  - Incorporation of WRF physics and WRF-chem (Grell)
  - ESMF dynamic core from FIM (Henderson)

RUC/Rapid Refresh Development and Testing

Major transitions:

- RUC13 change package –Spring 2008
  - – radar reflectivity assimilation
  - - TAMDAR
  - - Improved radiation, convection physics in RUC
- Rapid Refresh JIFed for ops by 9/09
  - WRF ARW, GSI, North America
- Ensemble Rapid Refresh
  - proposed by 2012, to use ESMF framework
- High-Res Rapid Refresh (HRRR) – RR nest proposed to NCEP by 2012
  - 3km hourly updated 12h forecast
  - In testing at GSD
  - NE Corridor → CONUS, AK

http://ruc.noaa.gov

http://rapidrefresh.noaa.gov/rr