

Hydrometeor assimilation using hourly updated satellite cloud retrievals over N. America in the Rapid Refresh

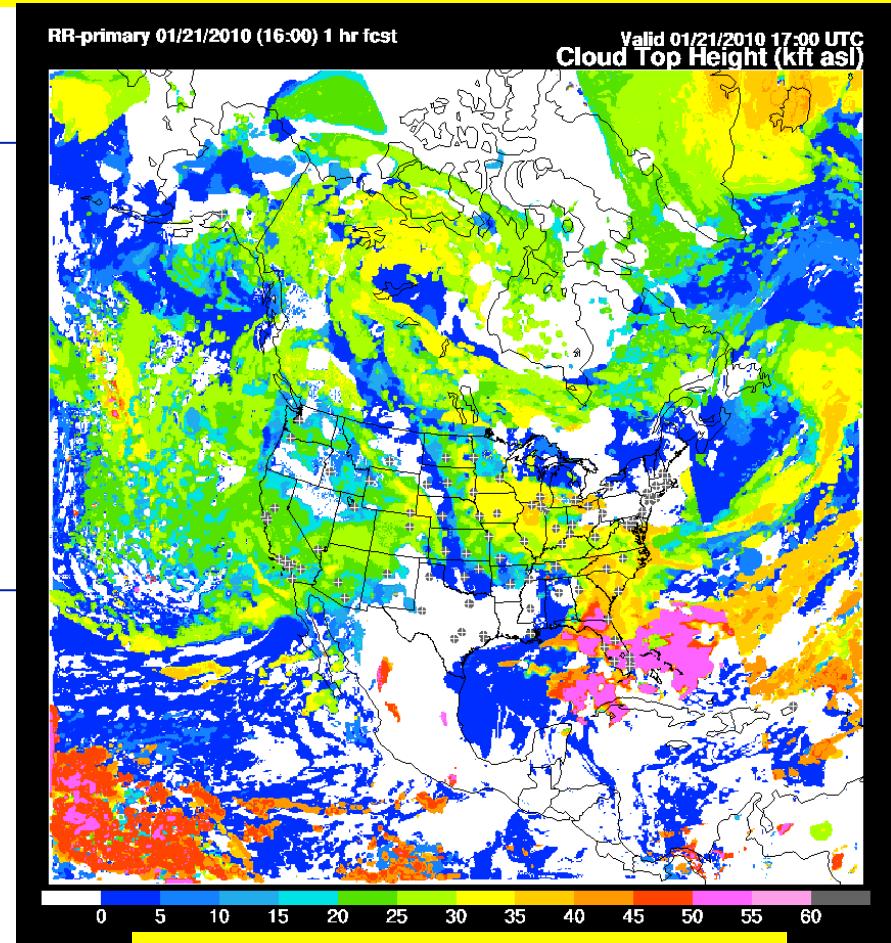
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Thurs 21 Jan 2010



Analyzed cloud-top height
Rapid Refresh
17z today – 21 Jan 2010



Earth System Research Laboratory
SCIENCE, SERVICE & STEWARDSHIP

RUC to Rapid Refresh (RR)

- CONUS domain (13km)

→ North American domain (13km)

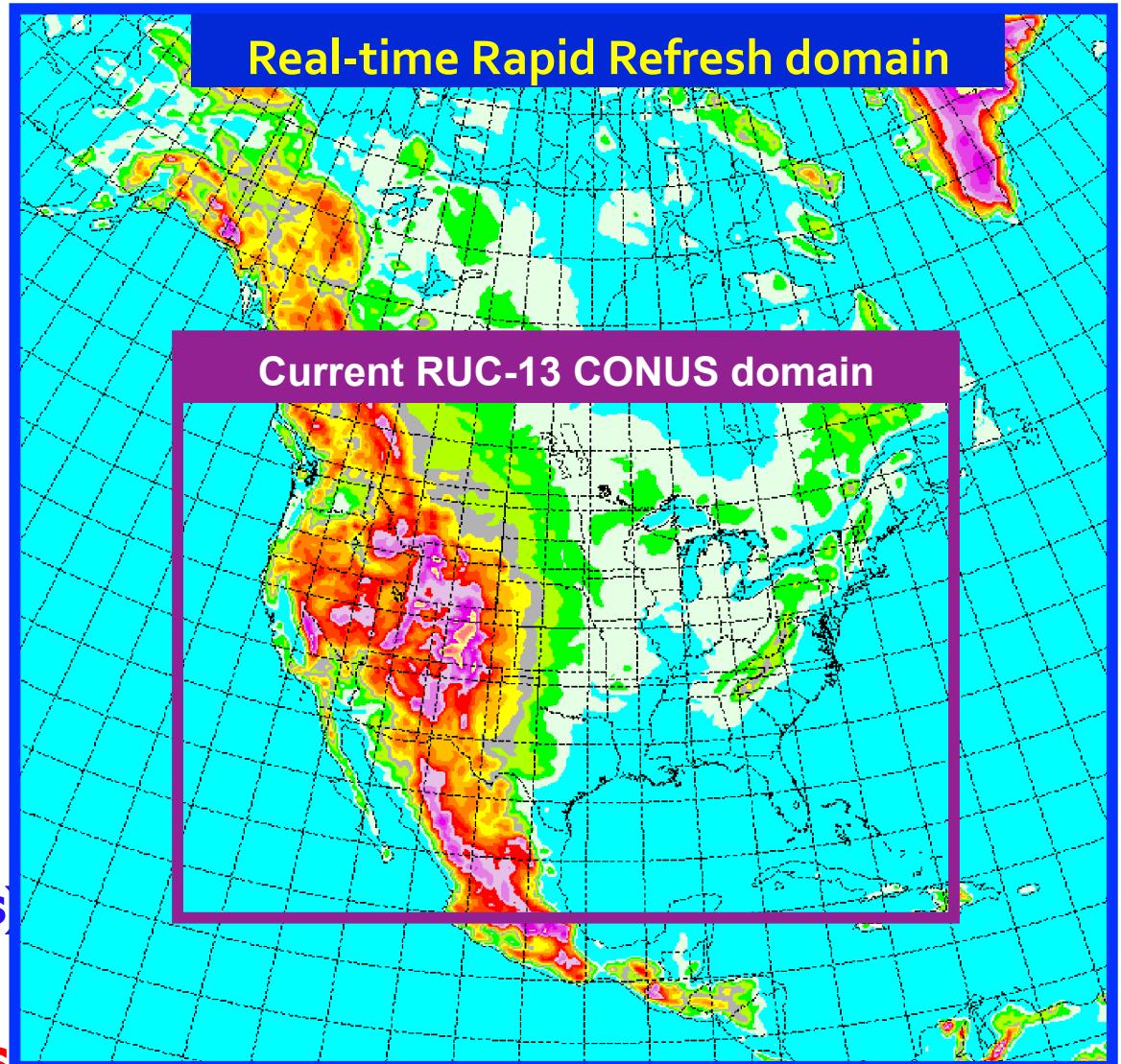
- RUC model

→ WRF model
(RR version)
(ARW dynamic core)

- RUC 3DVAR

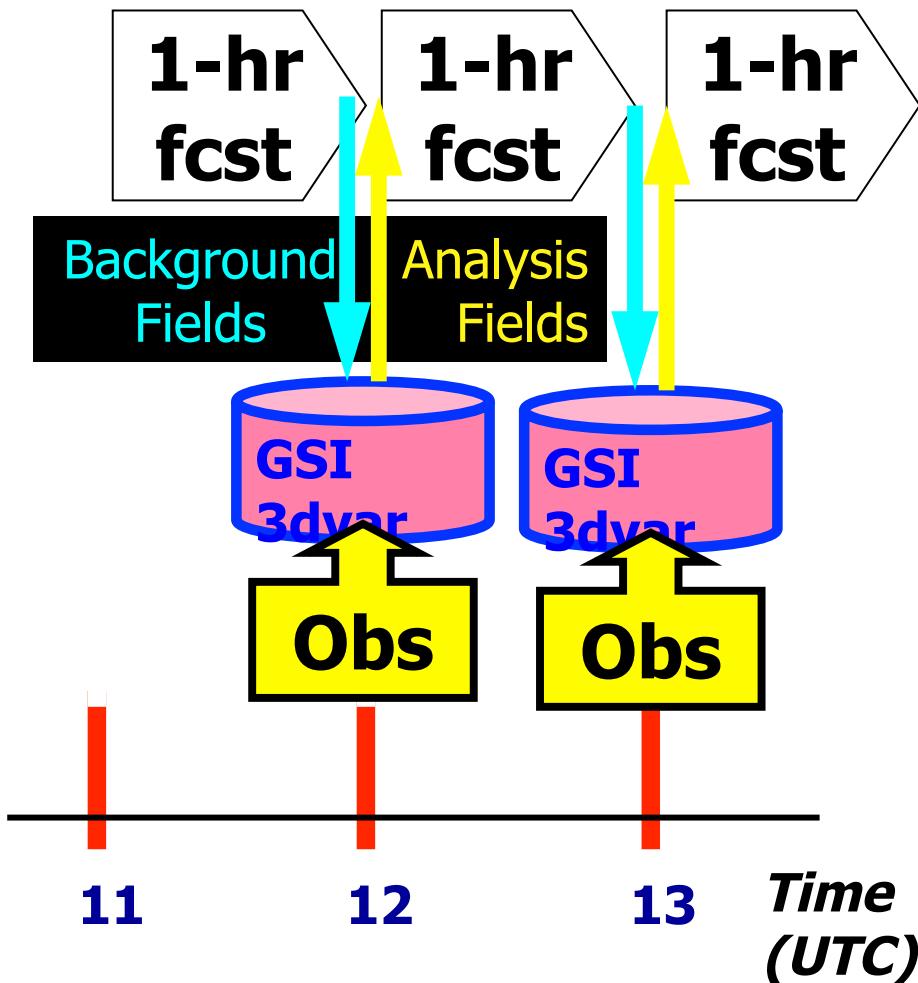
→ GSI
(+ RR enhancements)

↓
Cloud Analysis



RUC/Rapid Refresh Hourly Assimilation Cycle

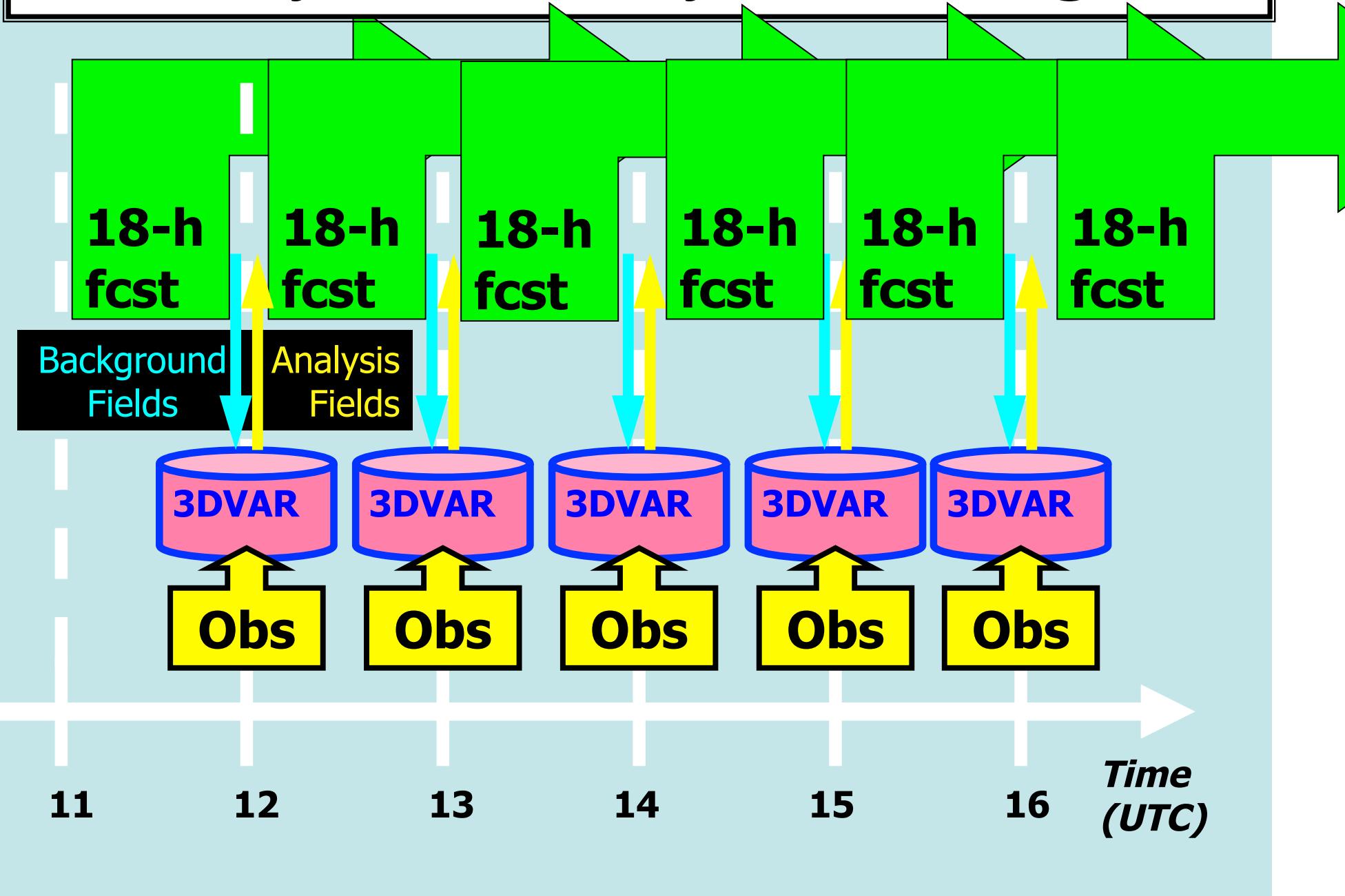
Cycle hydrometeor, soil temp/moisture/snow
plus atmosphere state variables



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 - RRonly	
Radar reflectivity/ lightning	
	1km

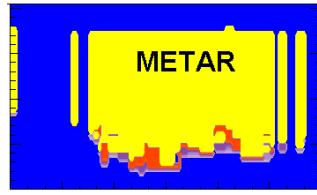
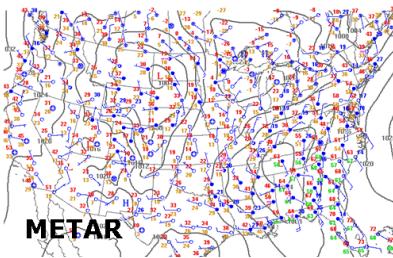
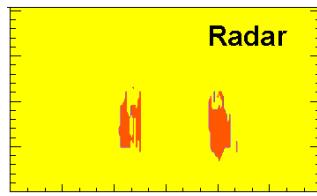
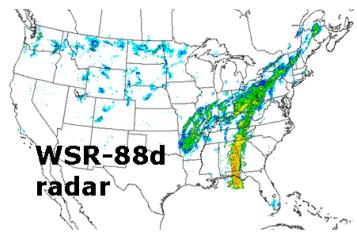
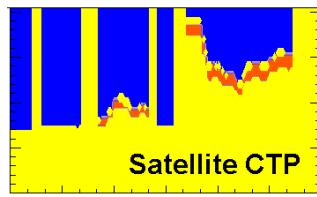
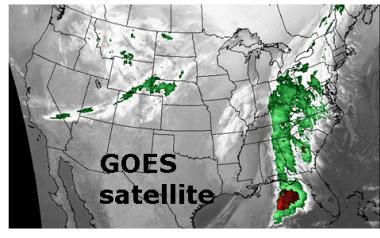
RUC Hourly Assimilation Cycle - fall 2009 @ NCEP



Cloud Analysis in GSI for RR

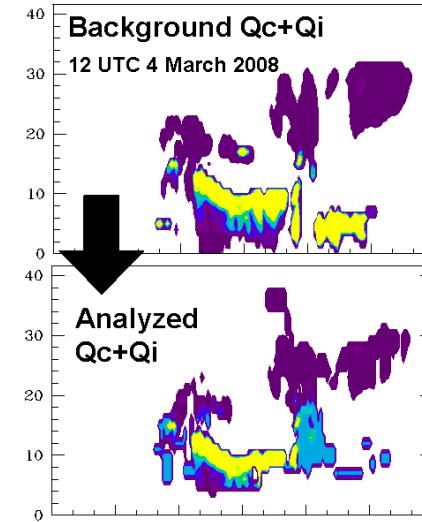
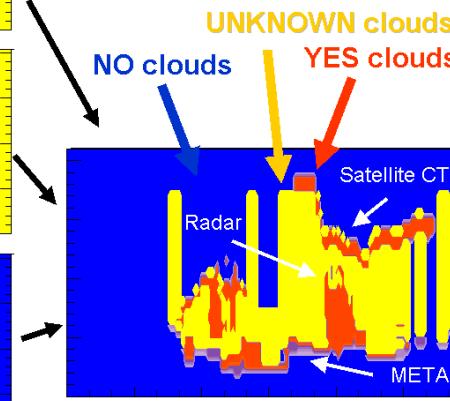
- Gridpoint Statistical Interpolation (GSI)
 - NCEP operational data analysis
 - GFS, NAM, RTMA, et al
- Add RUC-like features in GSI for designed for aviation and severe storm application
 - Cloud analysis (satellite, METAR, radar obs)
 - RUC-design modifications for surface assimilation
 - Assimilation of radar and lightning data (generate latent heating tendency for application in model DFI)

Cloud analysis schematic



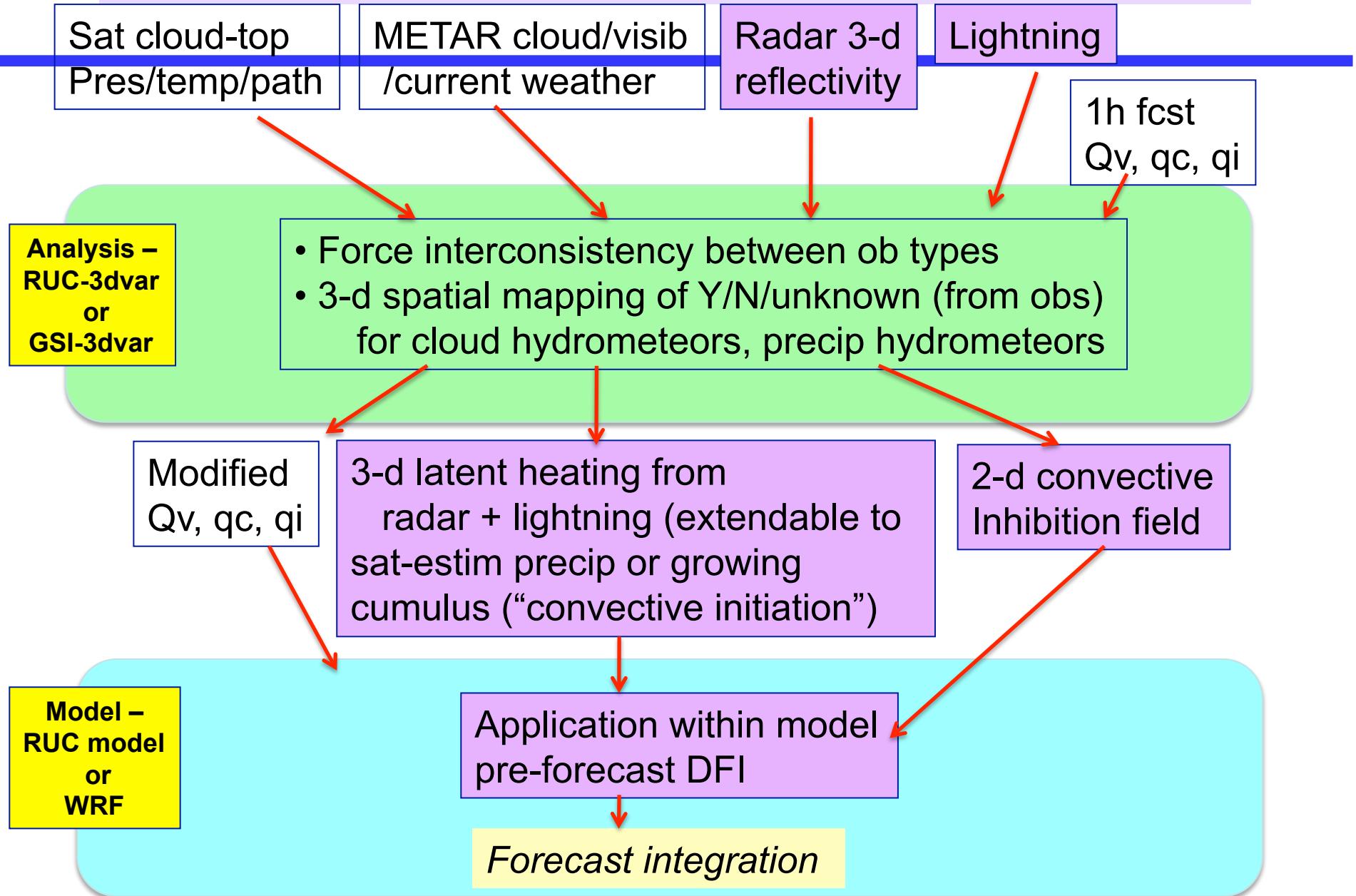
observation

Cloud designation from observations



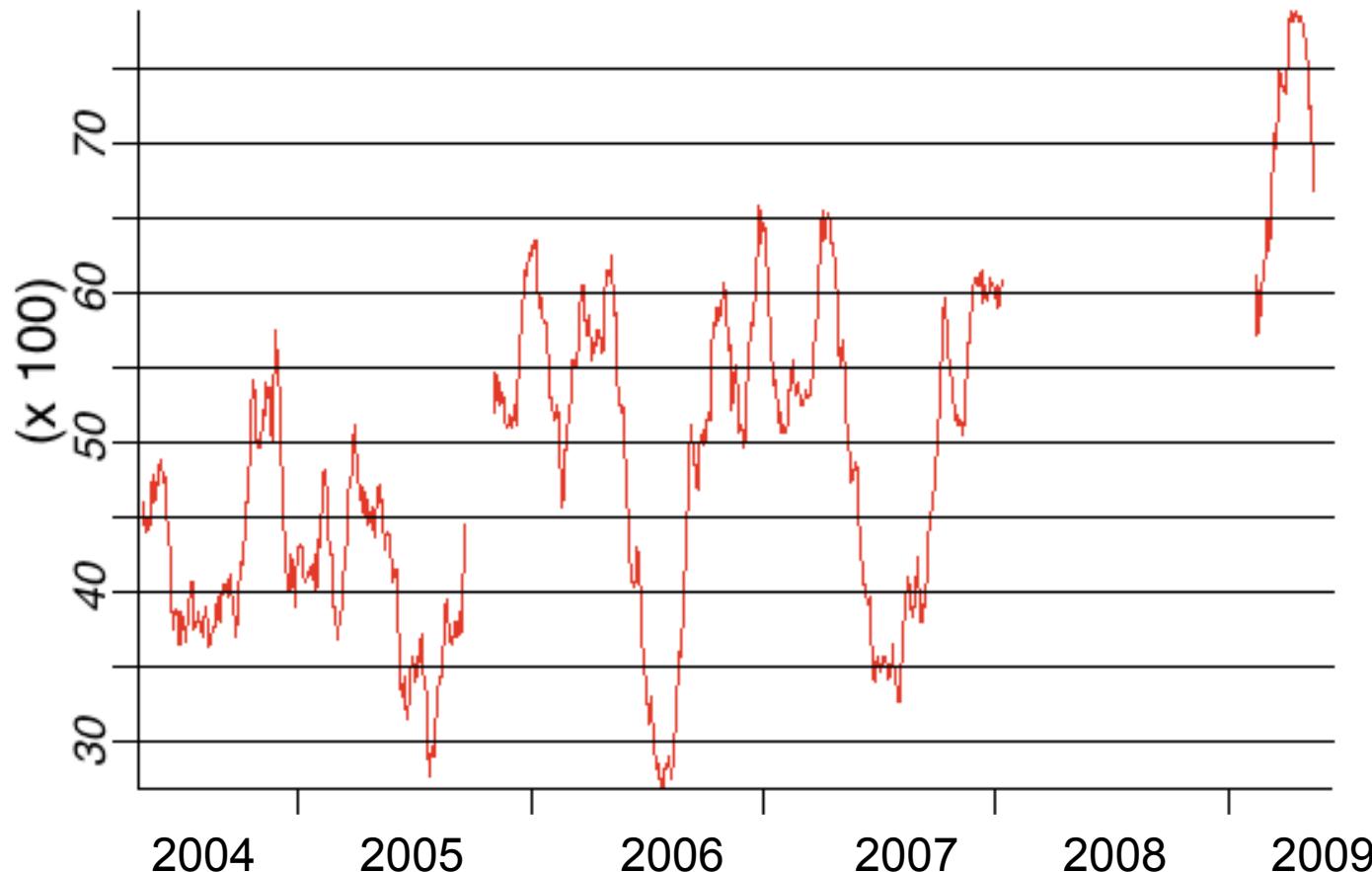
- Uses METAR, satellite, radar, lightning data
- Updates RR 1h-fcst RR hydrometeor, water vapor fields
- Generates latent heating from radar and lightning data

Flow for RUC/RR hydrometeor assimilation



RUC 3h forecast of 1000' ceiling (IFR flight conditions)

-probability of detection - verification against METAR observations over US every 3 h

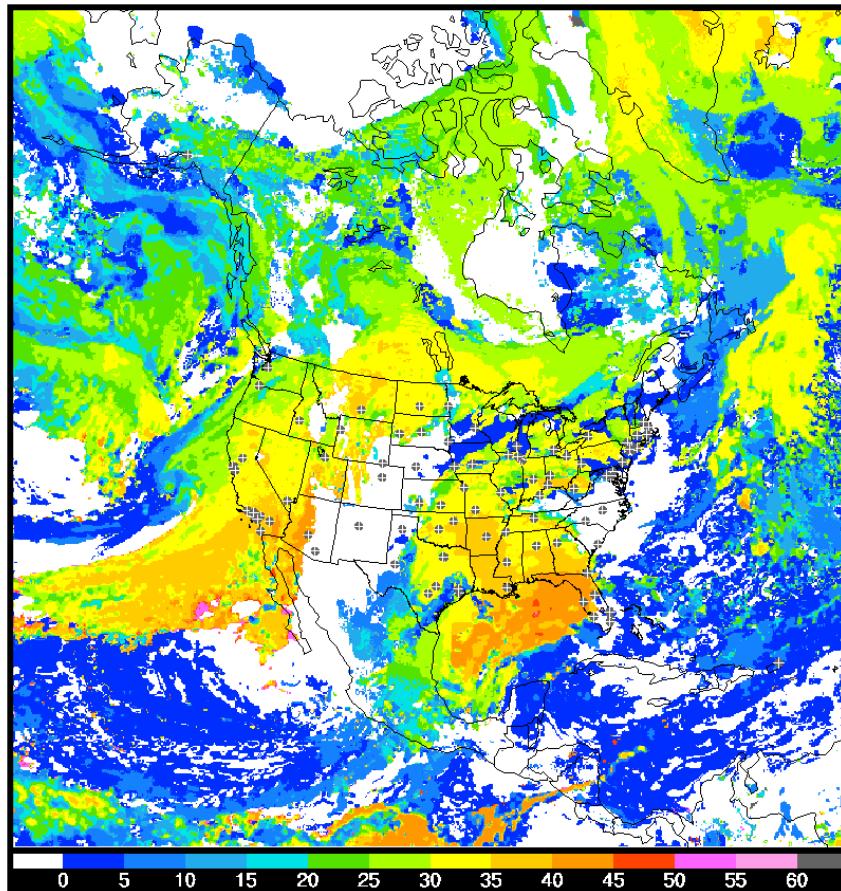


Improvements in GOES-cloud and METAR assimilation in Nov 2008 and March 2009 have led to major improvement in NCEP RUC cloud forecasts

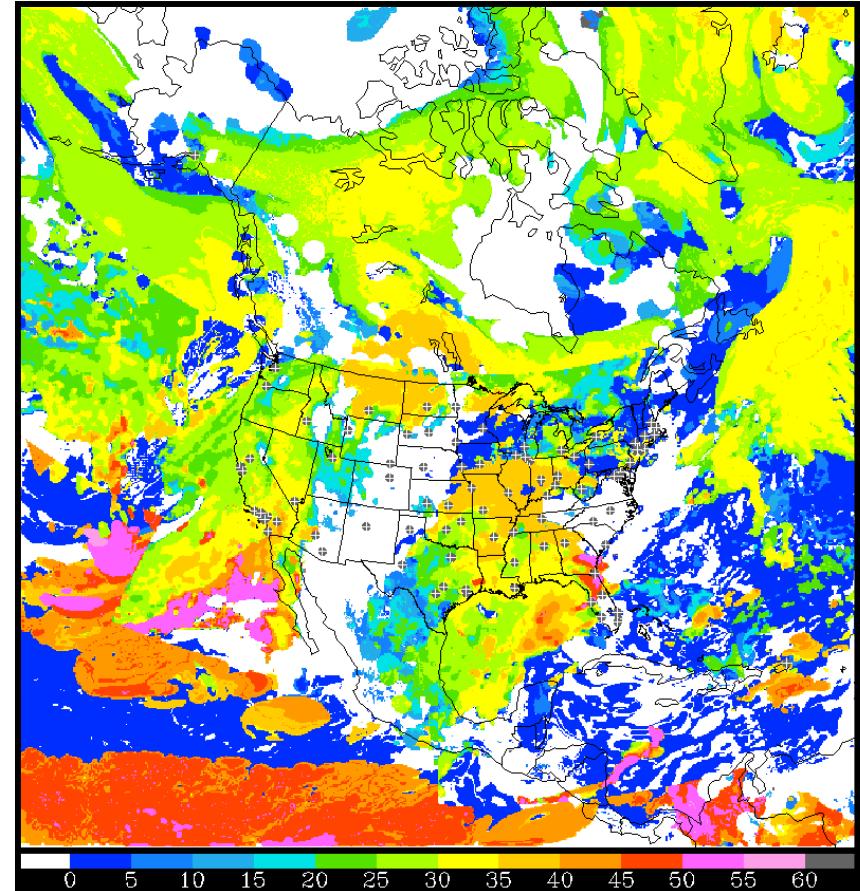
Recent development: use of NASA Langley satellite cloud data

Cloud Top Height Analysis

RR with NASA data - over
full RR domain



RR with NESDIS data- only
over RUC domain



Recent development: Bug fixes and Calibration

- Bug fixes and calibration are key to improve the impact of the cloud analysis. Many details need to be considered:
 - ✓ Compare to the RUC cloud analysis results
 - ✓ Match Rapid Refresh grids
 - ✓ Focus on aviation rules
 - ✓ Consider cloud observation features
- Will show the bug fixes and calibration results first

Real-time comparison of cloud analysis impact

- Optimize and calibrate RR cloud analysis
 - ✓ compare results to RUC, fix deep details in algorithm
 - ✓ calibration period: Oct. 24 - Nov. 9, 2009
- Sync two parallel RR cycle running at GSD:
 - ✓ oprRR, devRR: 1-h partial cycling, GSI+cloud analysis
- Turned off cloud analysis in devRR for 4-13 Jan 2010
 - ✓ **oprRR: GSI + cloud analysis**
 - ✓ **devRR: GSI only (NO cloud analysis)**

Cloud analysis verification: Cloud Ceiling

Cloud Ceiling:

Cloud ceiling is reported as part of the METAR used for flight planning by pilots worldwide. 500, 1000, 3000 feet cloud ceiling is used to decide if the weather is better than Basic Visual flight rules (VFR) Weather Minimums

Probability of Detection (POD):

$$POD = \frac{\text{Detection hit the target}}{\text{sum of all target to be detected}} \cdot 100\%$$

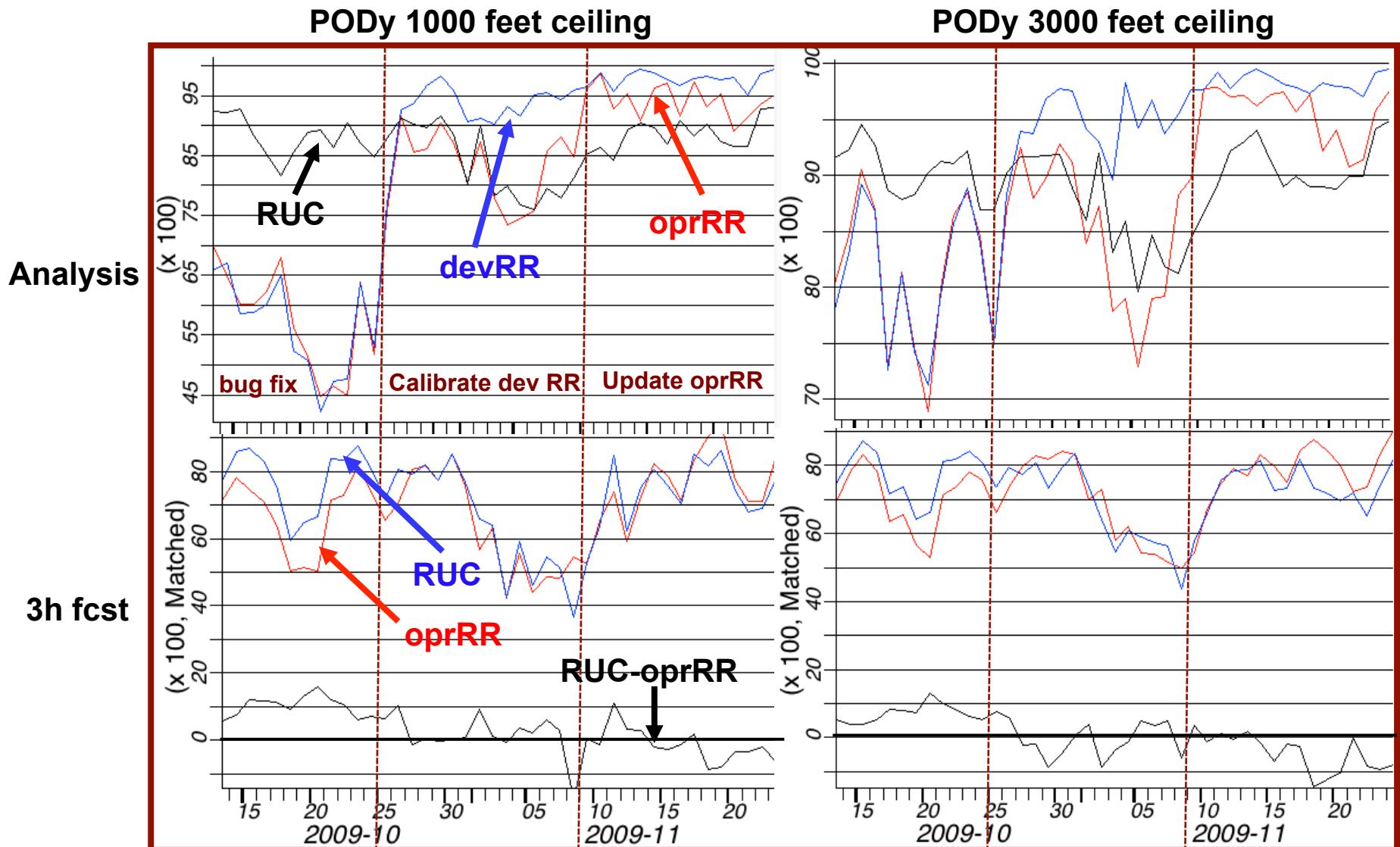
POD yes for 500, 1000, and 3000 feet cloud ceiling:

$$PODy = \frac{\text{forecast cloud ceiling under } 500/1000/3000 \text{ feet}}{\text{sum of all observed cloud ceiling under } 500/1000/3000 \text{ feet}} \cdot 100\%$$

PODy higher, better

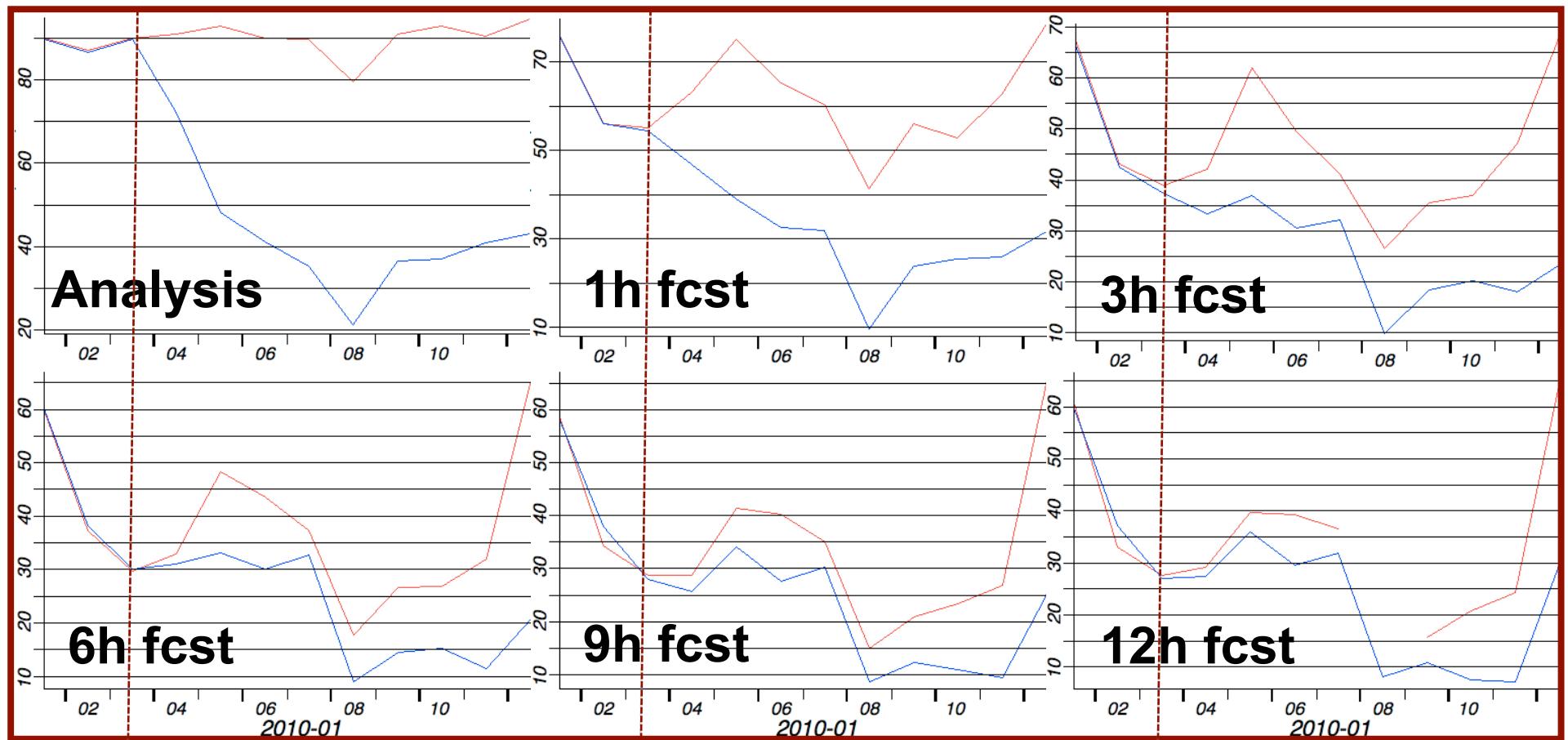
Cloud analysis calibration period

Oct. 24 - Nov. 9, 2009



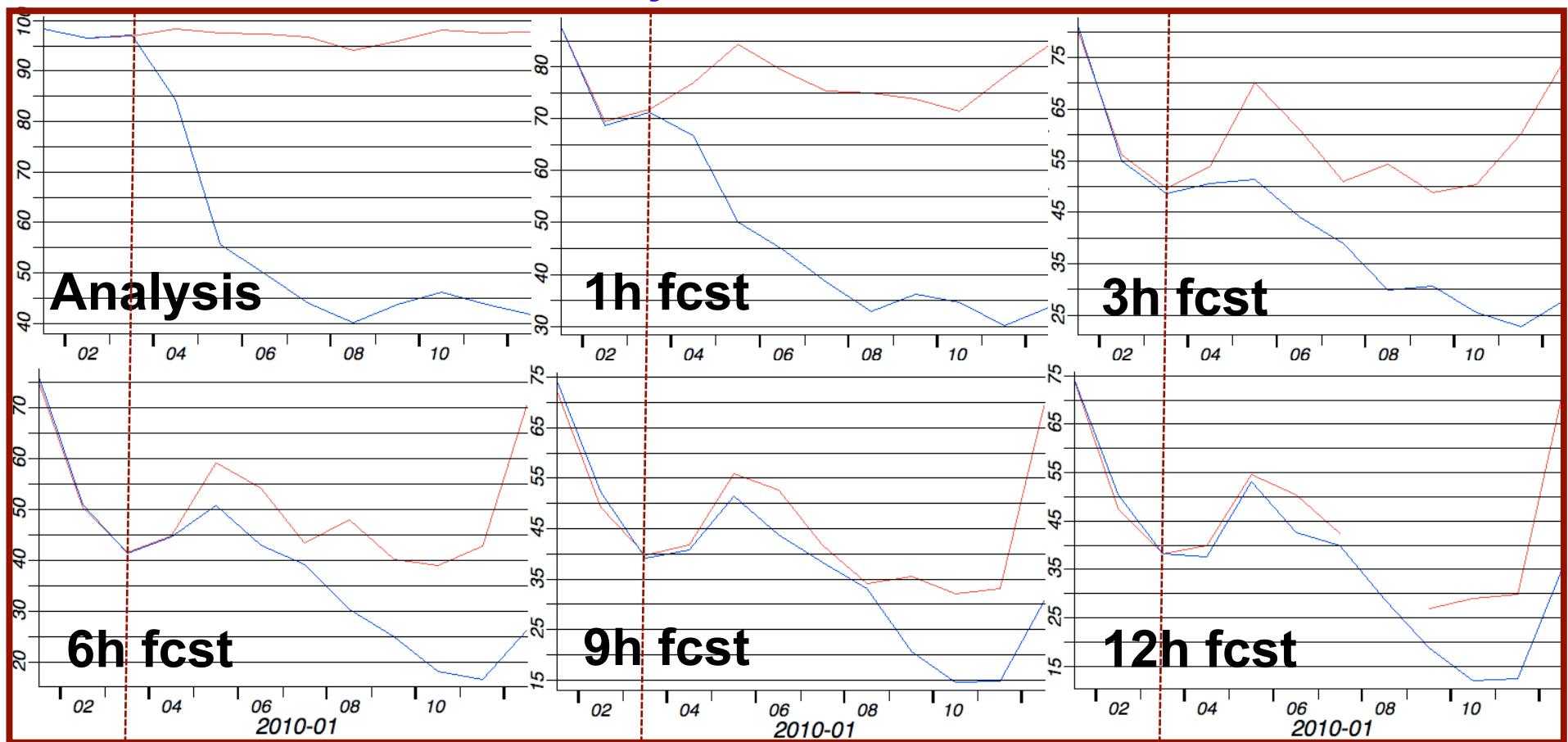
Cloud Analysis Verification: PODy 500 ft. ceiling -- LIFR

— oprRR:with cloud analysis
— devRR: no cloud analysis after Jan 4, 2010



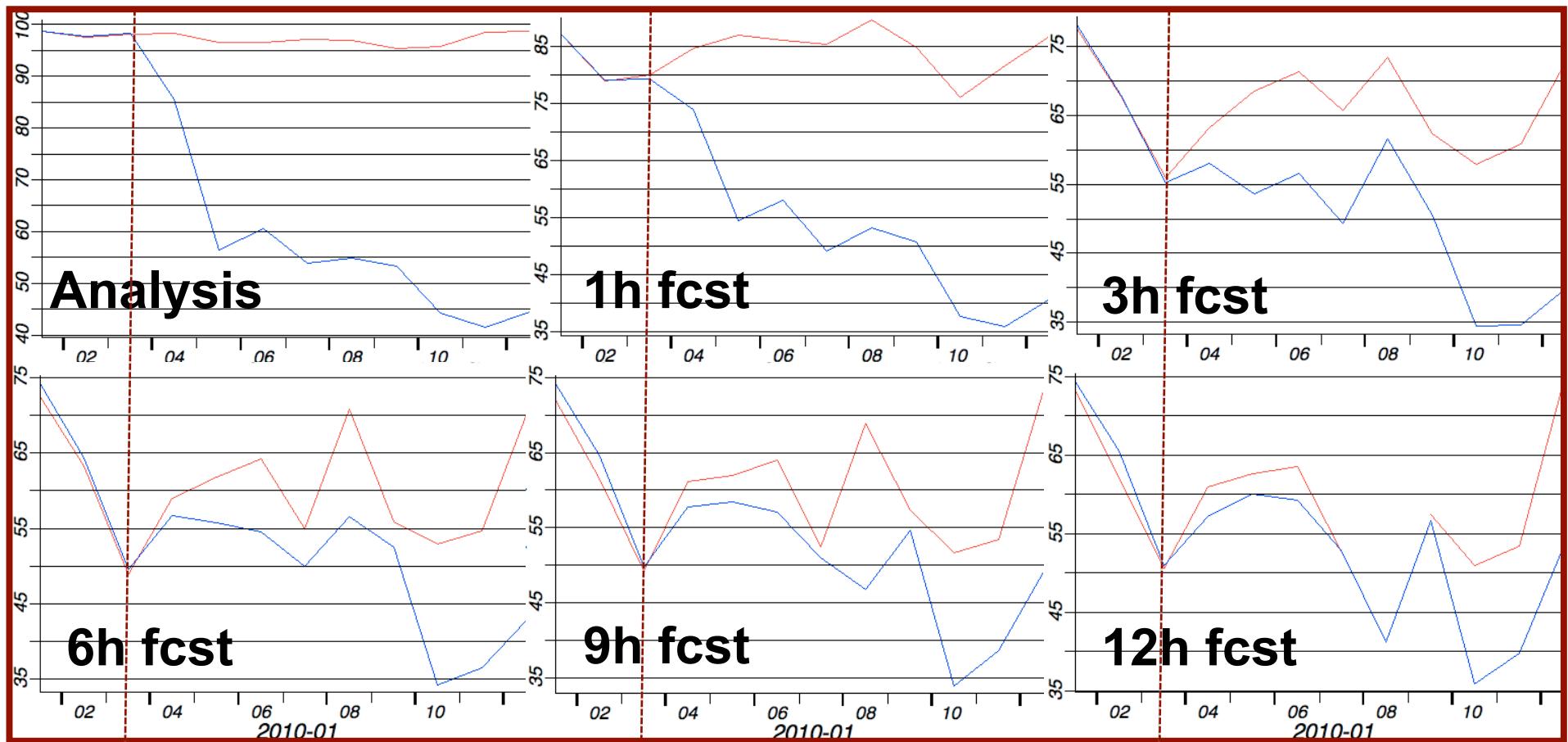
Cloud Analysis Verification: PODy 1000 ft. ceiling -- IFR

— oprRR:with cloud analysis
— devRR: no cloud analysis after Jan 4, 2010



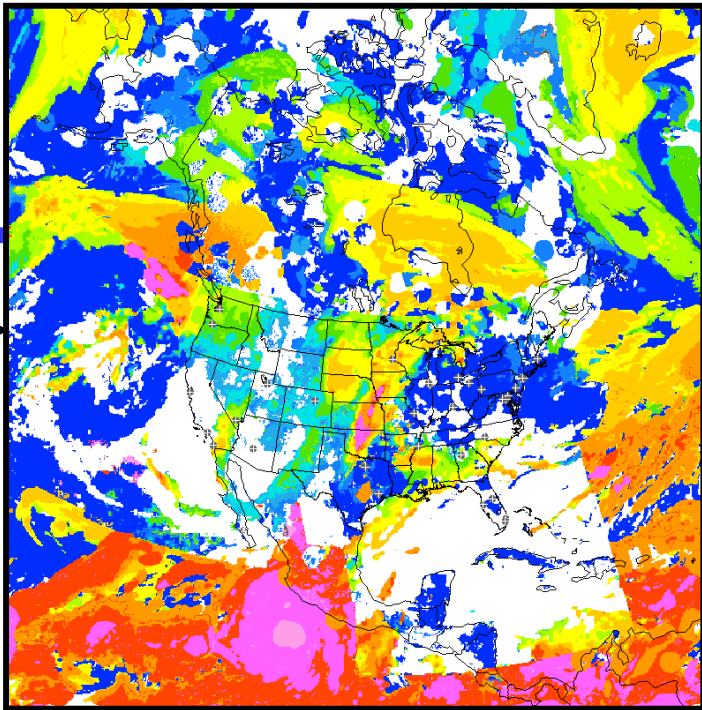
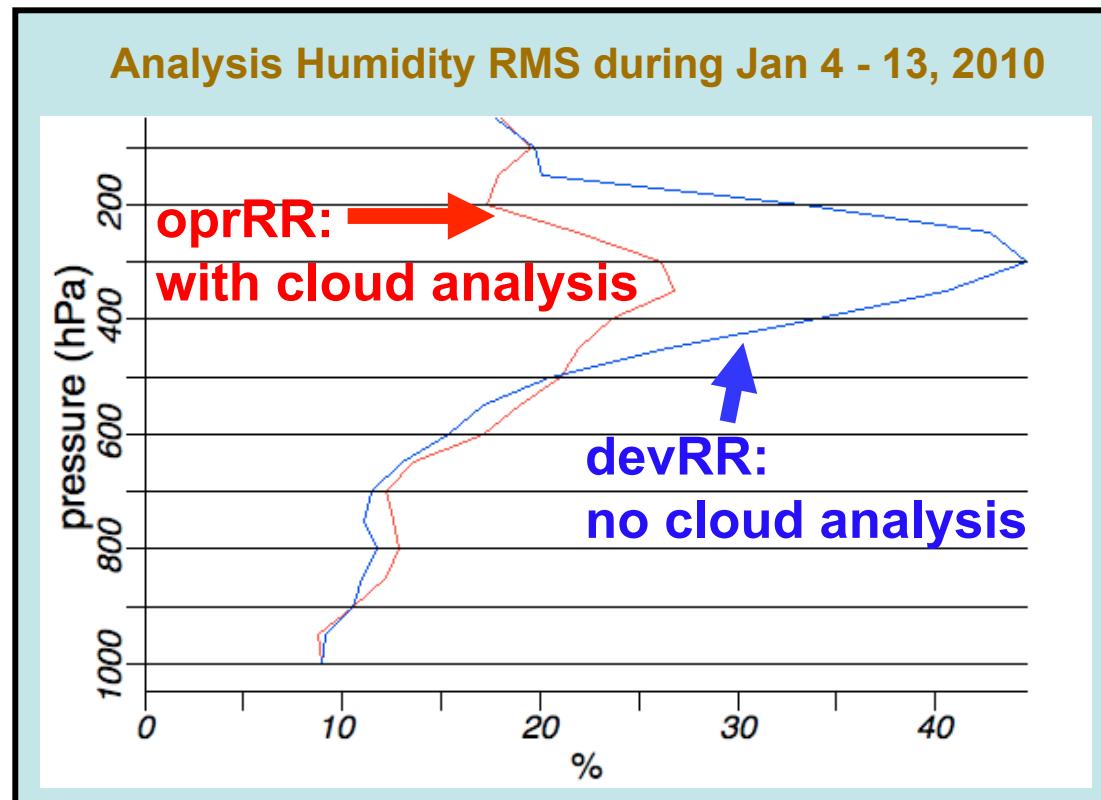
Cloud Analysis Verification: PODy 3000 ft. ceiling -- MVFR

— oprRR:with cloud analysis
— devRR: no cloud analysis after Jan 4, 2010

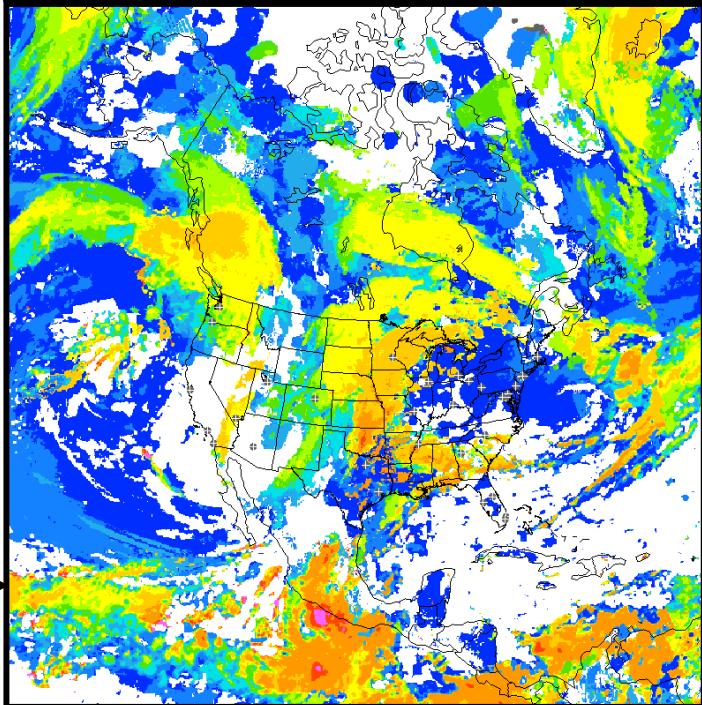


Cloud Analysis Verification: Impact to moisture analysis

RR with NESDIS data-
only over RUC domain

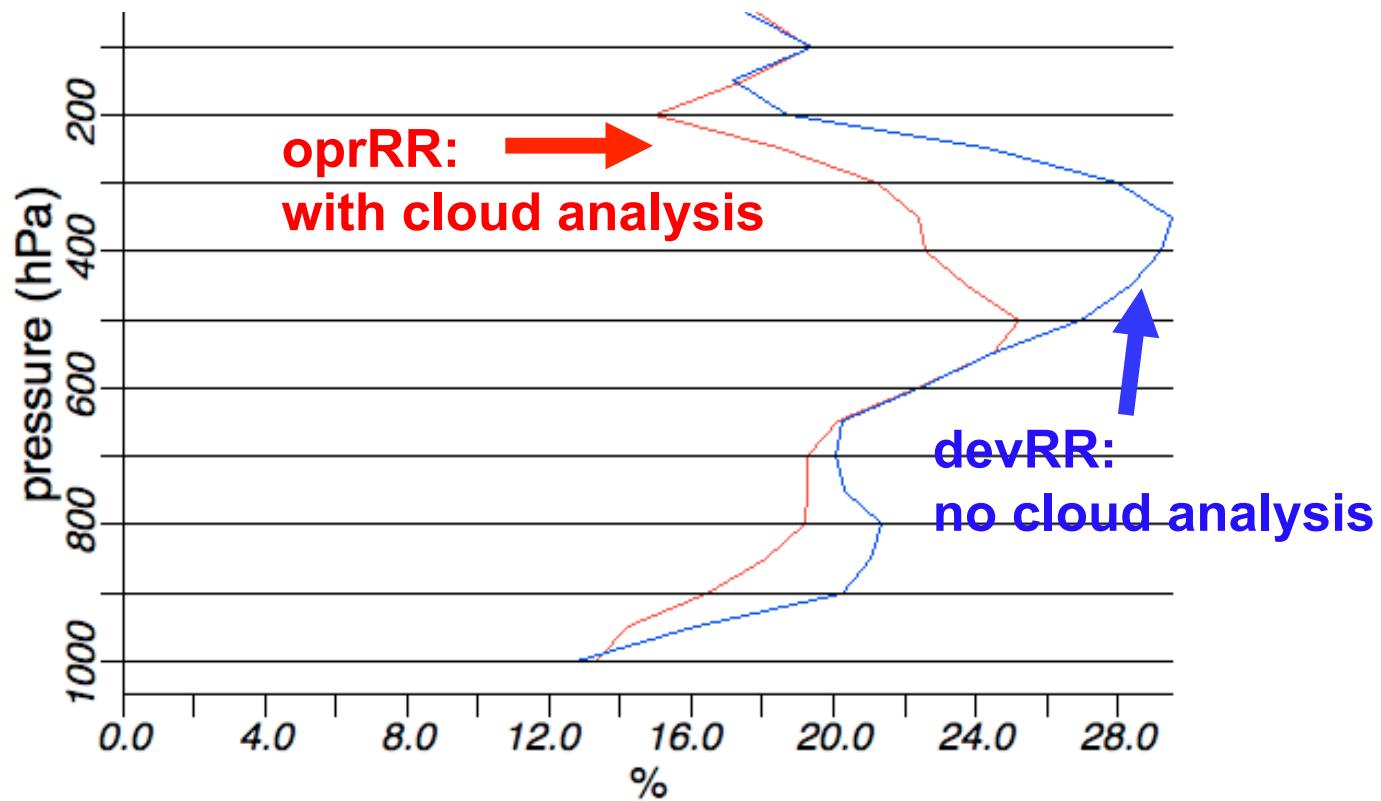


RR with NASA data - over
full RR domain



Cloud Analysis Verification: Impact to moisture forecast

1-h Forecast Humidity RMS during Jan 4 - 13, 2010

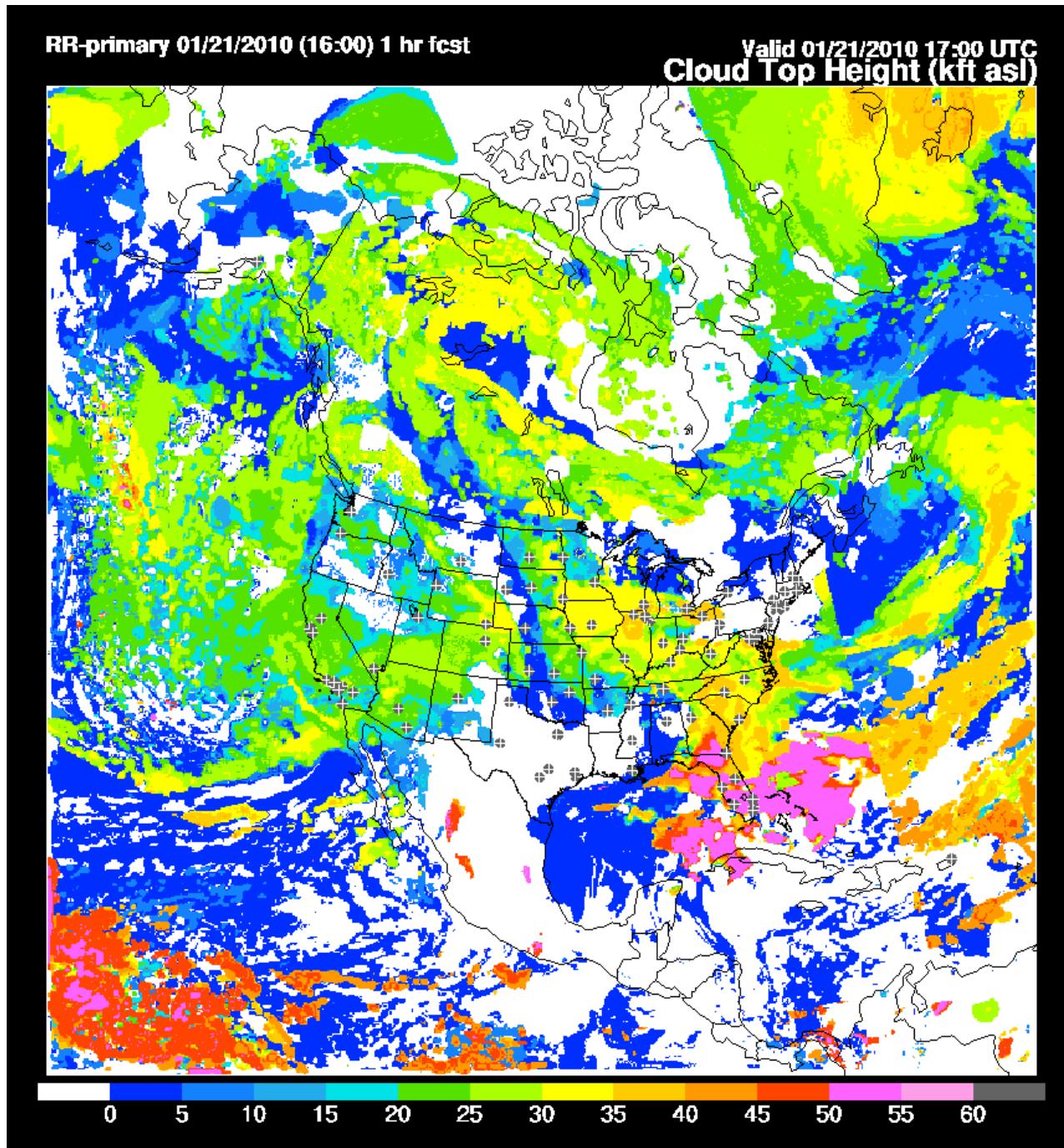


Summary and Ongoing cloud analysis work

- Cloud analysis clearly improved ceiling analysis and forecast during winter time
- Has positive impact to moisture field
- Further calibration for cloud top, visibility, and hydrometeors
- More comparison and verification based on
 - ✓ Different season, data type, and analysis method
- Implementation new cloud products: water and ice path field
- Improve analysis of “black stratus” ($T_{Cloud} > T_{Skin}$) in Alaska

Future: Variational analysis of clouds

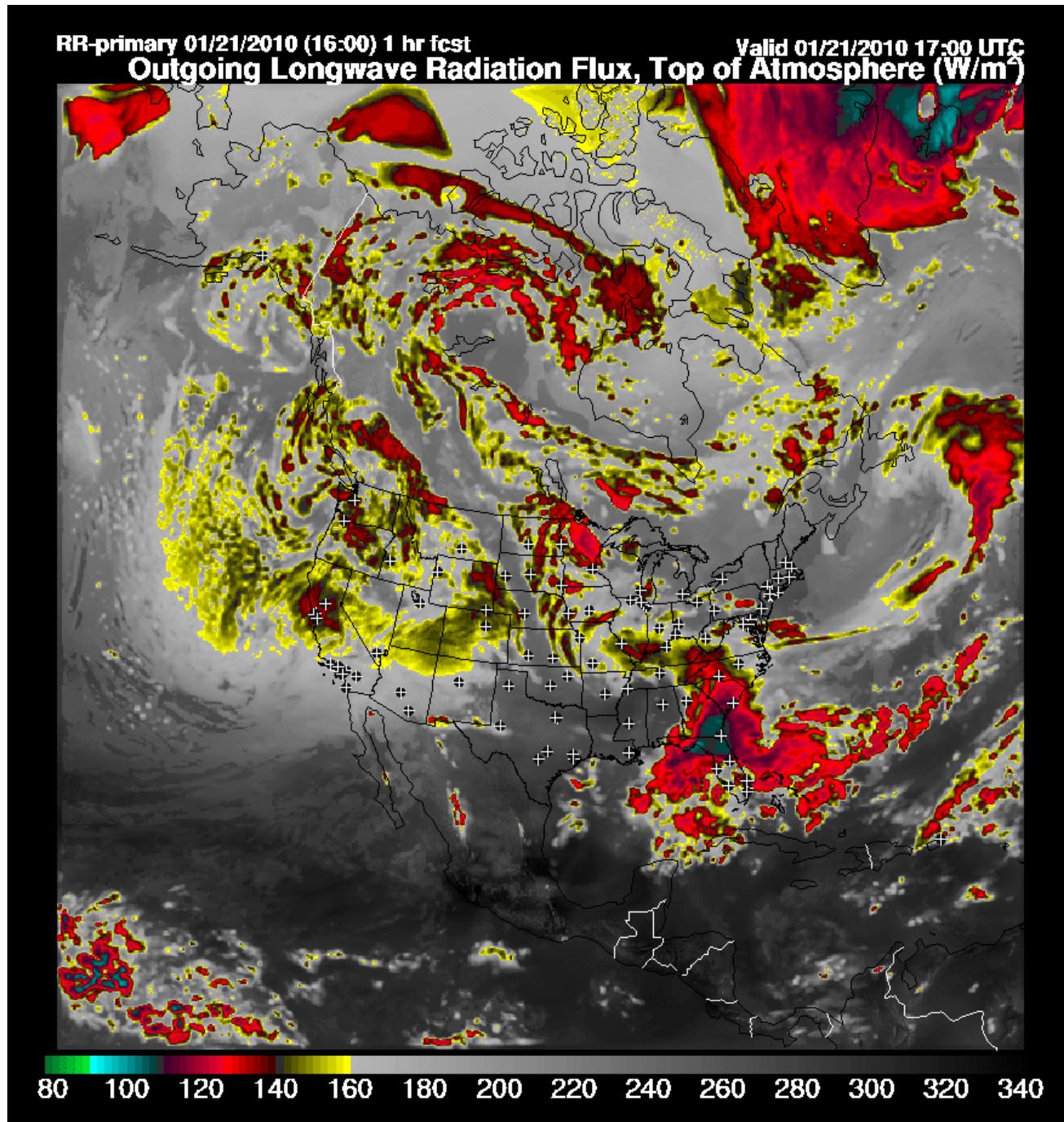
- Possibilities of Analysis variables
 - Total water content ($qc + qi + qr + qs + qg + qv$)
 - Normalized RH w.r.t. total water but not precip condensate
 $= ((qv + qc + qi) / qs(bkg))$
 - Corresponds to RH* (Holm) for water vapor – $(qv / qs(bkg))$
 - Condensate only ($qc + qi + qr + qs + qg$)
 - Cloud condensate ($qc + qi$) and precipitation condensate ($qr + qs + qg$)
 - Cloud condensate ($qc + qi$)
 - Binary cloud indicator (Y/N)
 - Cloud fraction (0-1) (related to qc, qi ; but not to qr, qs, qg)



17z today
21 Jan 2010

Rapid Refresh
Cloud top height

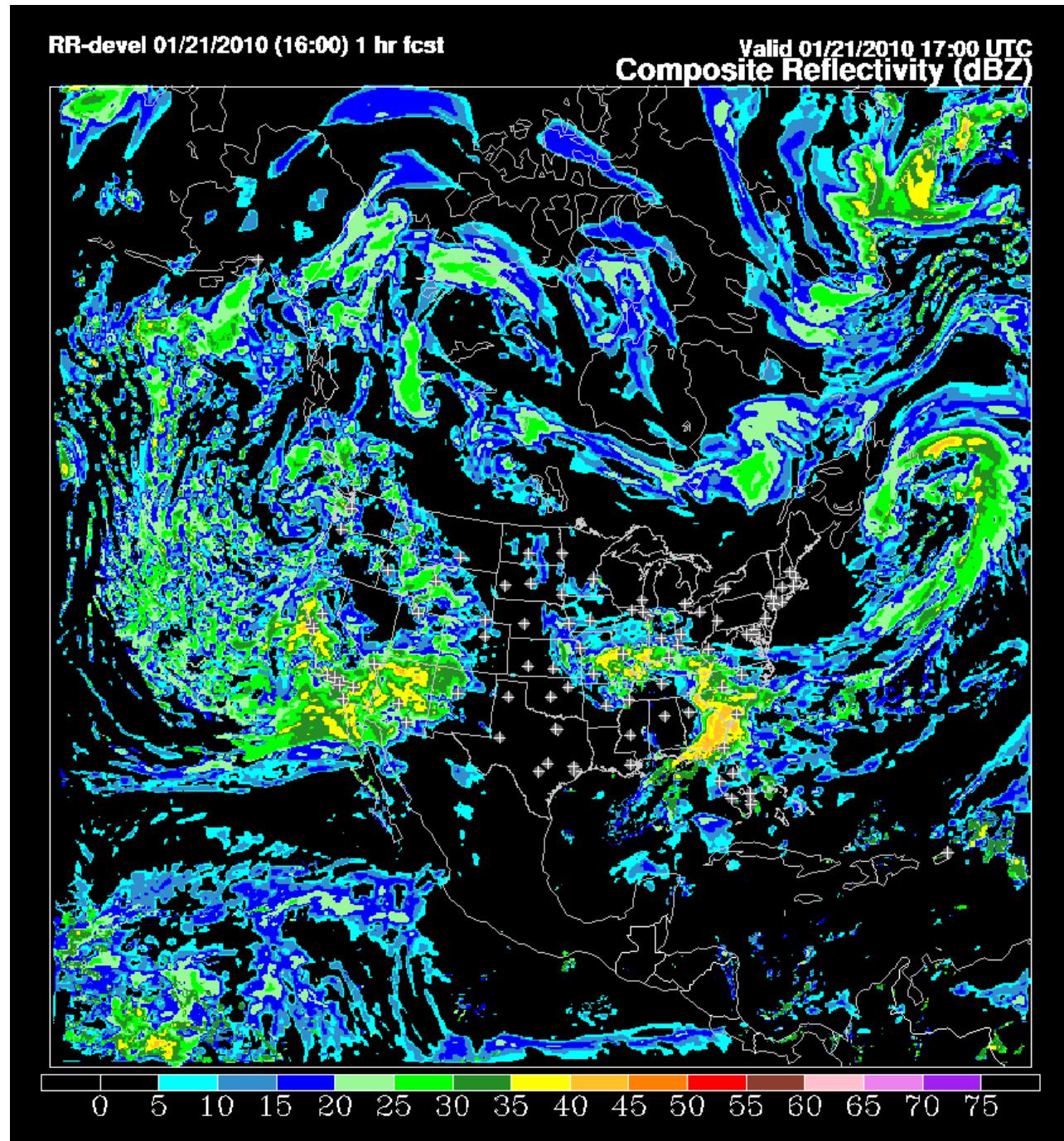
Hourly assimilation
of GOES cloud-top
pressure/temp,
retrieved liquid/ice
water path
(from NASA LaRC)



17z today
21 Jan 2010

Rapid Refresh
Outgoing LW rad

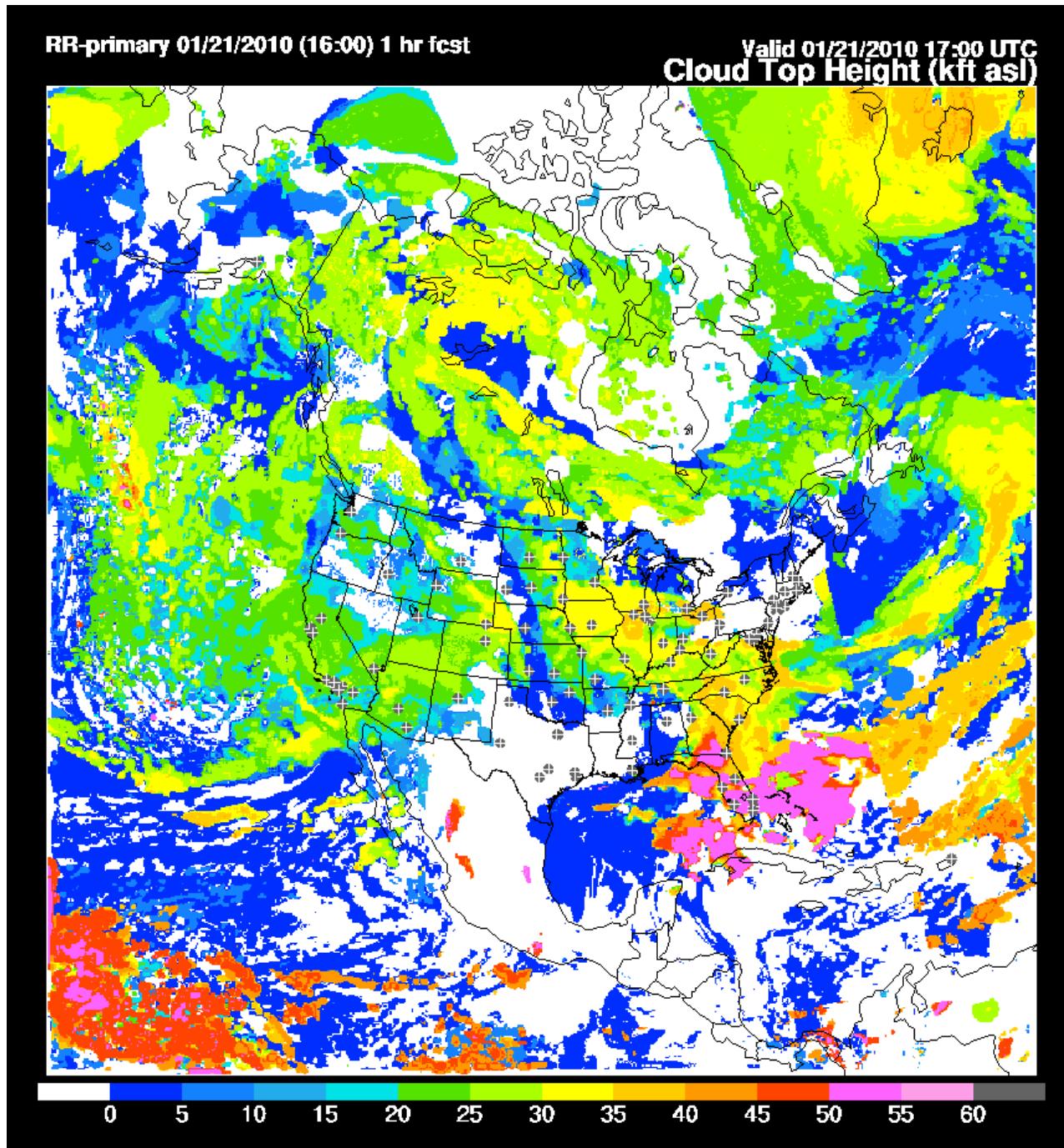
Hourly assimilation
of GOES cloud-top
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water path
(from NASA LaRC)



17z today
21 Jan 2010

Rapid Refresh
reflectivity

Hourly assimilation
of GOES cloud-top
pressure/temp,
retrieved liquid/ice
water path
(from NASA LaRC)



17z today
21 Jan 2010

Rapid Refresh
Cloud top height

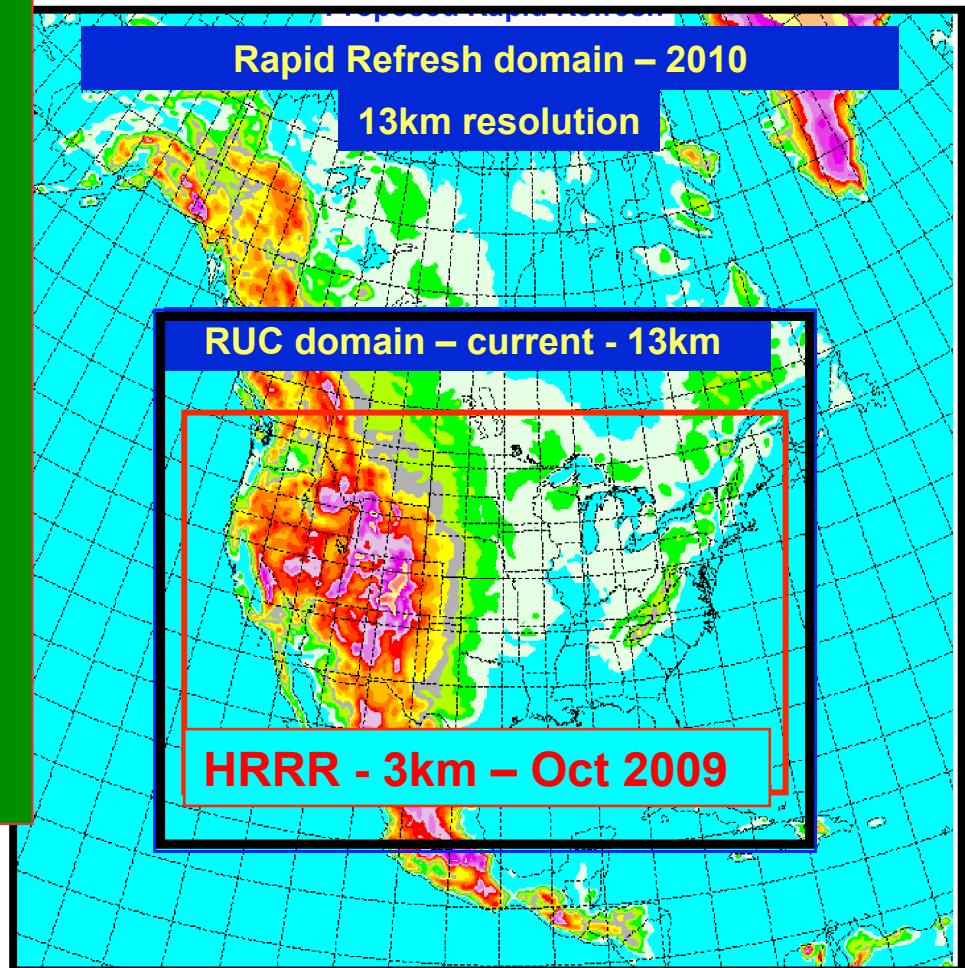
Hourly assimilation
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RUC/Rapid Refresh / HRRR

Hourly updated NWP runs over US / North America:

- Rapid Update Cycle - RUC
 - upgrade @ NCEP – 11/17/08
 - radar reflectivity assim
 - improve cloud retention – Mar09
 - Oper RUC out to 18h – fall 09
- Rapid Refresh - RR
 - now running experimentally at NOAA/ESRL/GSD
 - to be implemented @ NCEP in 2010
- High-Res Rapid Refresh (HRRR) –
 - 3km hourly updated 12h forecast
 - In testing at GSD initialized by radar-enhanced RUC

<http://ruc.noaa.gov>
<http://rapidrefresh.noaa.gov>
<http://ruc.noaa.gov/hrrr>

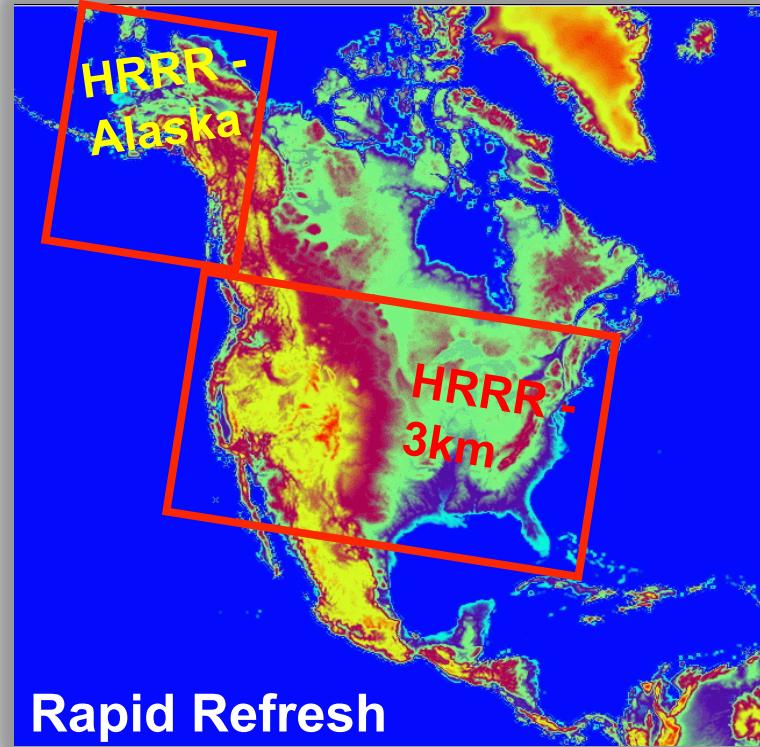


Future plans for ≤1h updated NWP

2010 – Rapid Refresh operational at NCEP
2012 – Operational (NCEP)
CONUS-wide High Resolution Rapid Refresh nested inside RR
2013 – Ensemble RR - NARRe (~6 members, ARW, NMM cores)
2014 – Add operational Alaska HRRR
2013-15 – Ensemble CONUS HRRR - HRRRe (6 members)
2017 – Global Rapid Refresh (GRR)

Incorporation of inline chemistry – 2012-15

- Assimilation of radial wind, new satellite, phased-array radar, CASA, new regional aircraft, chemistry obs...
- Frequency from 60min → 30 → 15min
- 1h EnKF + 1h hybrid 4dvar/EnKF
- Improved nowcast/blend/NWP
- Ensemble-based post-processing



Applications:

Aviation, severe wx,
Hydrology, energy, air quality, fire weather, volcanoes/hazards, etc.

Firm NCEP plans

Plans in development