

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

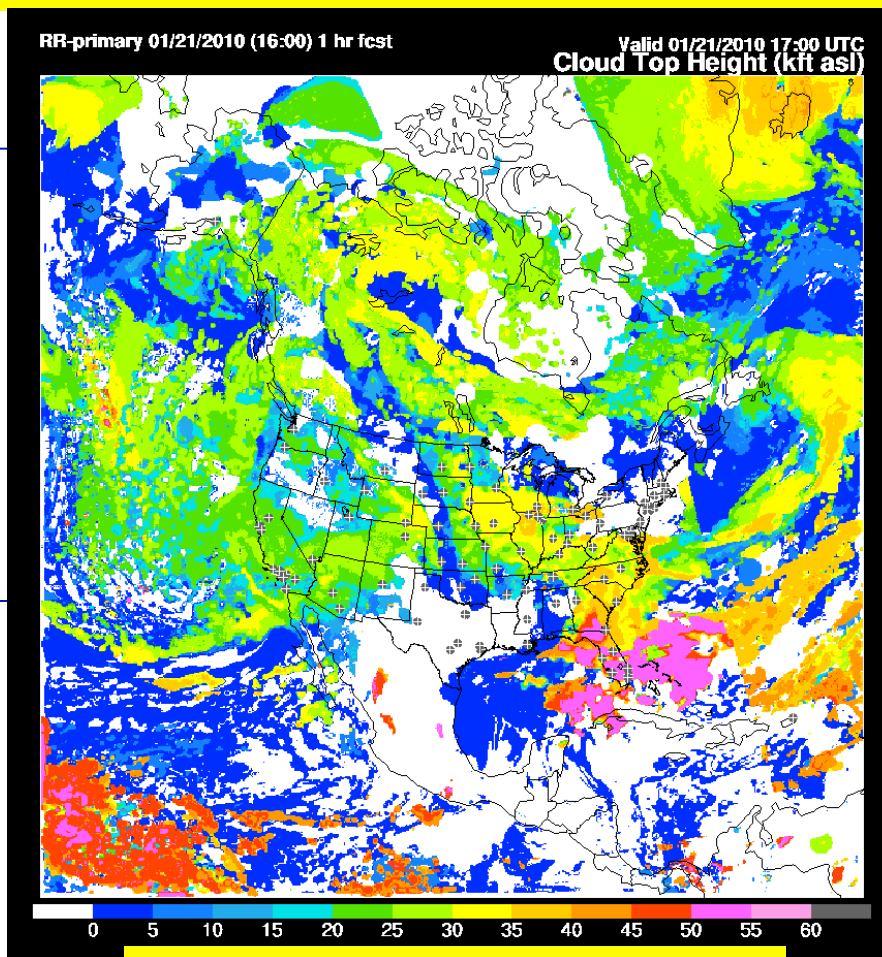
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**Thurs 21 Jan 2010**



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)

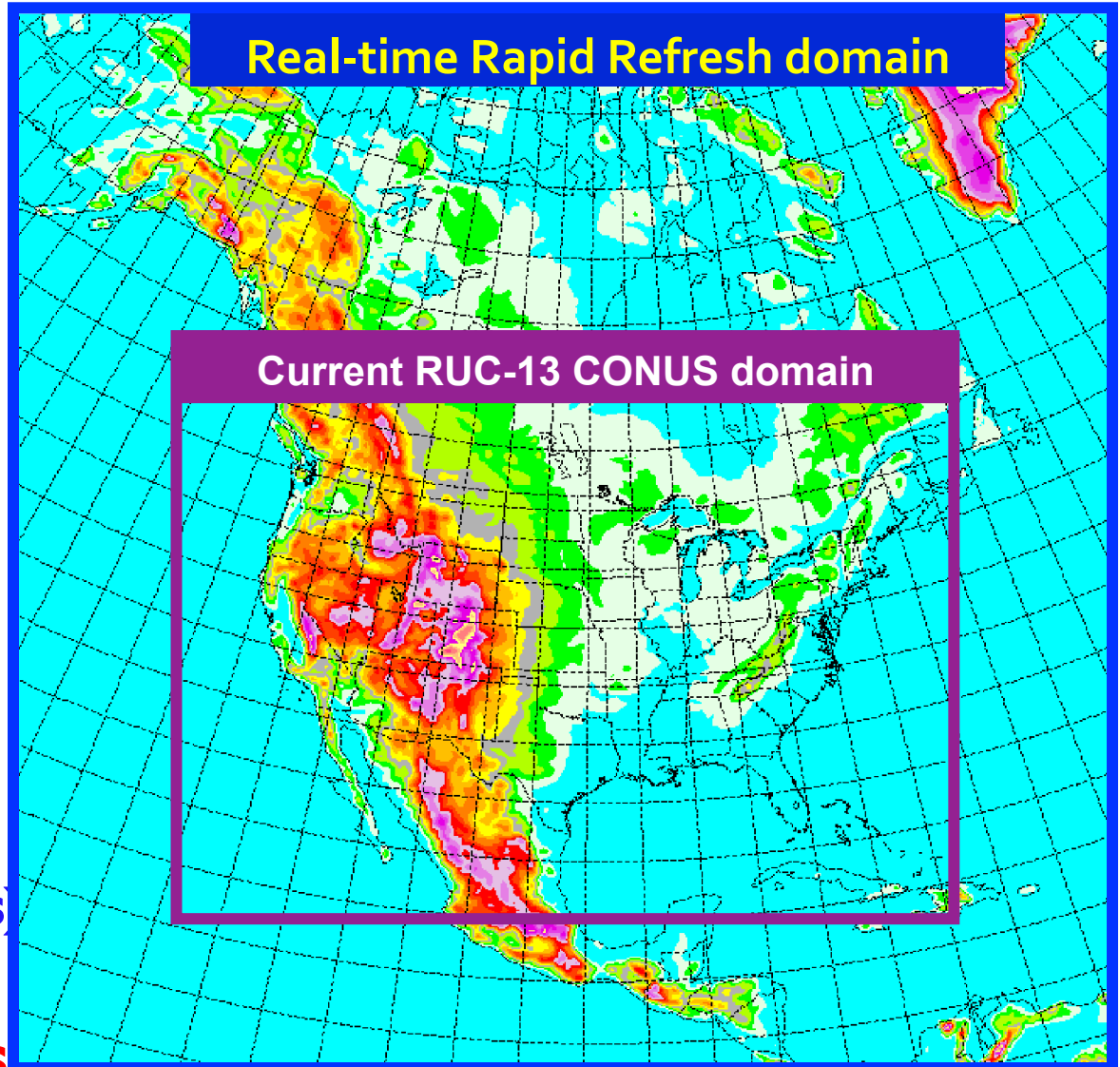
- RUC model

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

- RUC 3DVAR

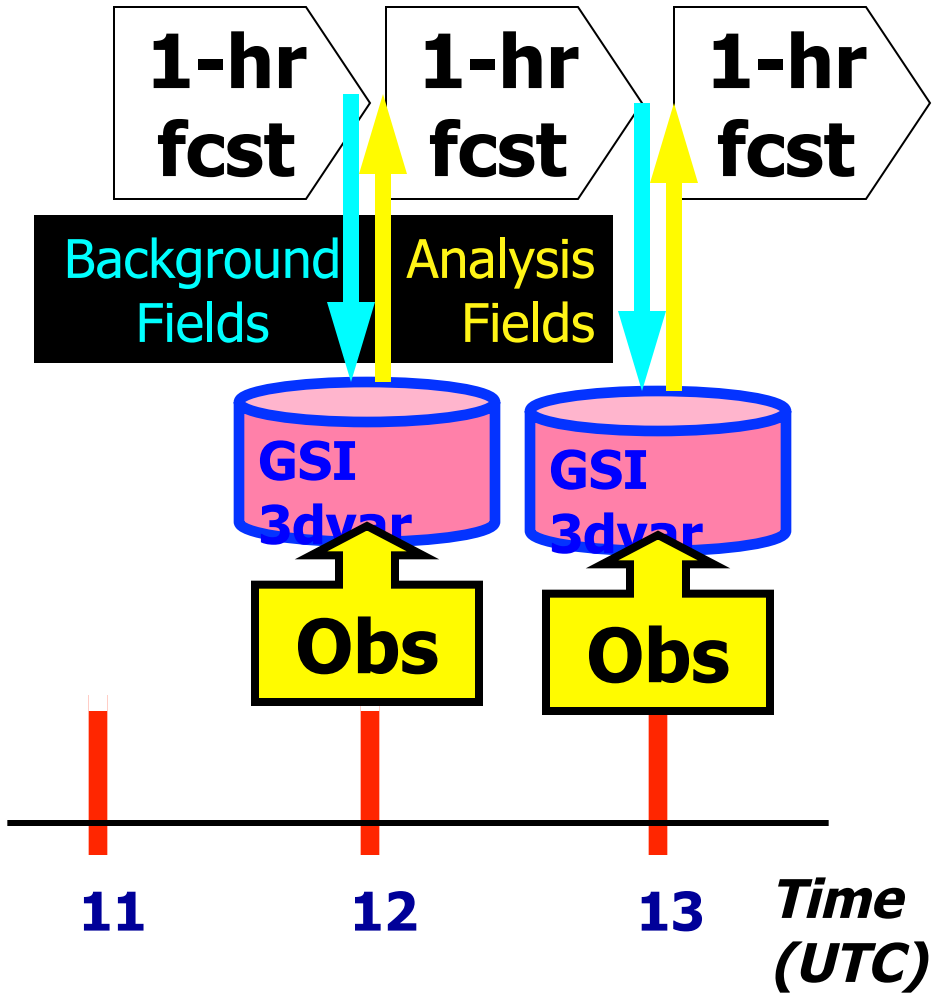
➔ GSI  
(+ RR enhancements)

↓  
Cloud Analysis



# RUC/Rapid Refresh Hourly Assimilation Cycle

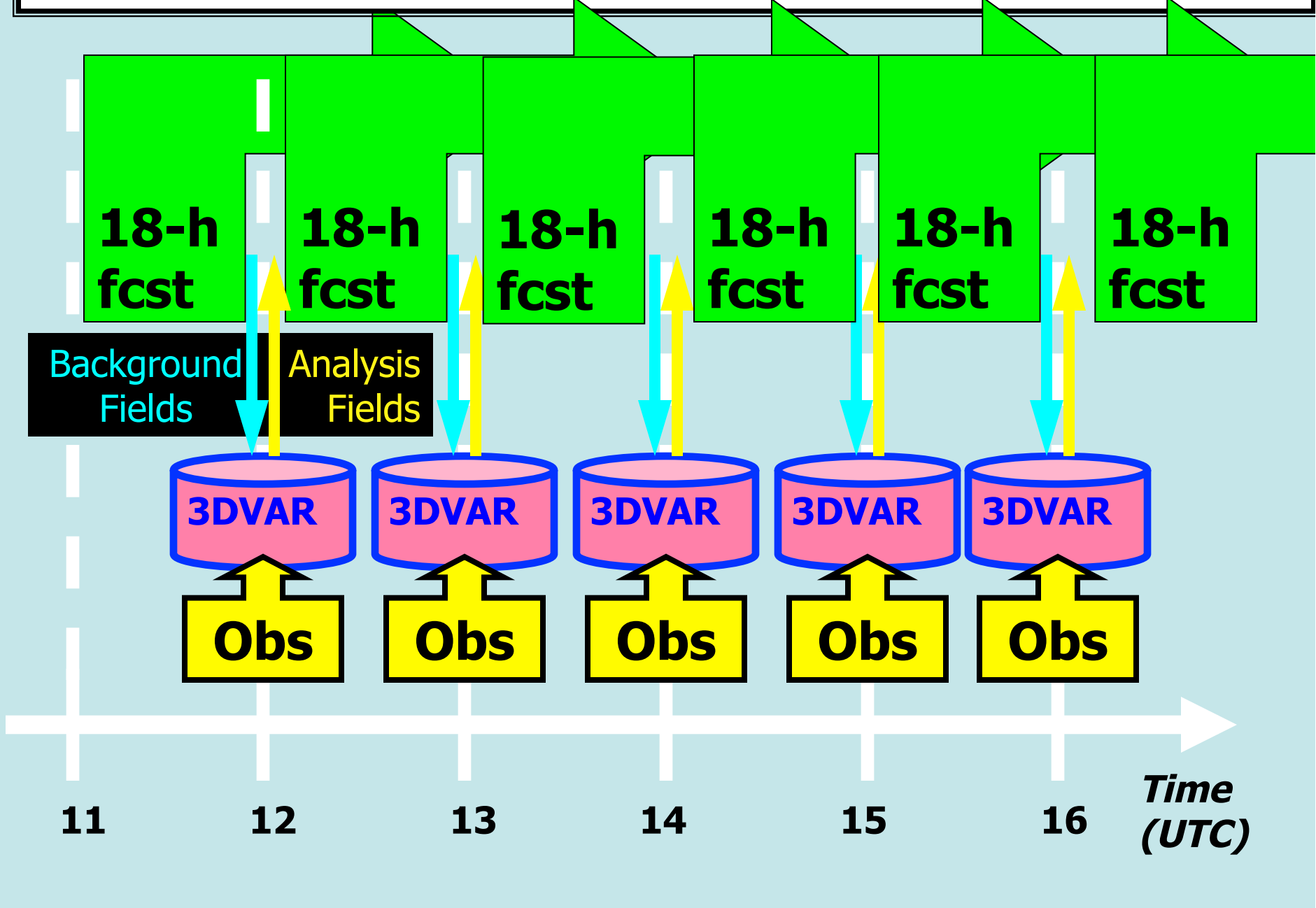
Cycle hydrometeor, soil temp/moisture/snow plus atmosphere state variables



## Hourly obs

<b>Data Type</b>	<b>~Number</b>
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 - <i>RRonly</i>	
Radar reflectivity/ lightning	1km

# RUC Hourly Assimilation Cycle - fall 2009 @ NCEP

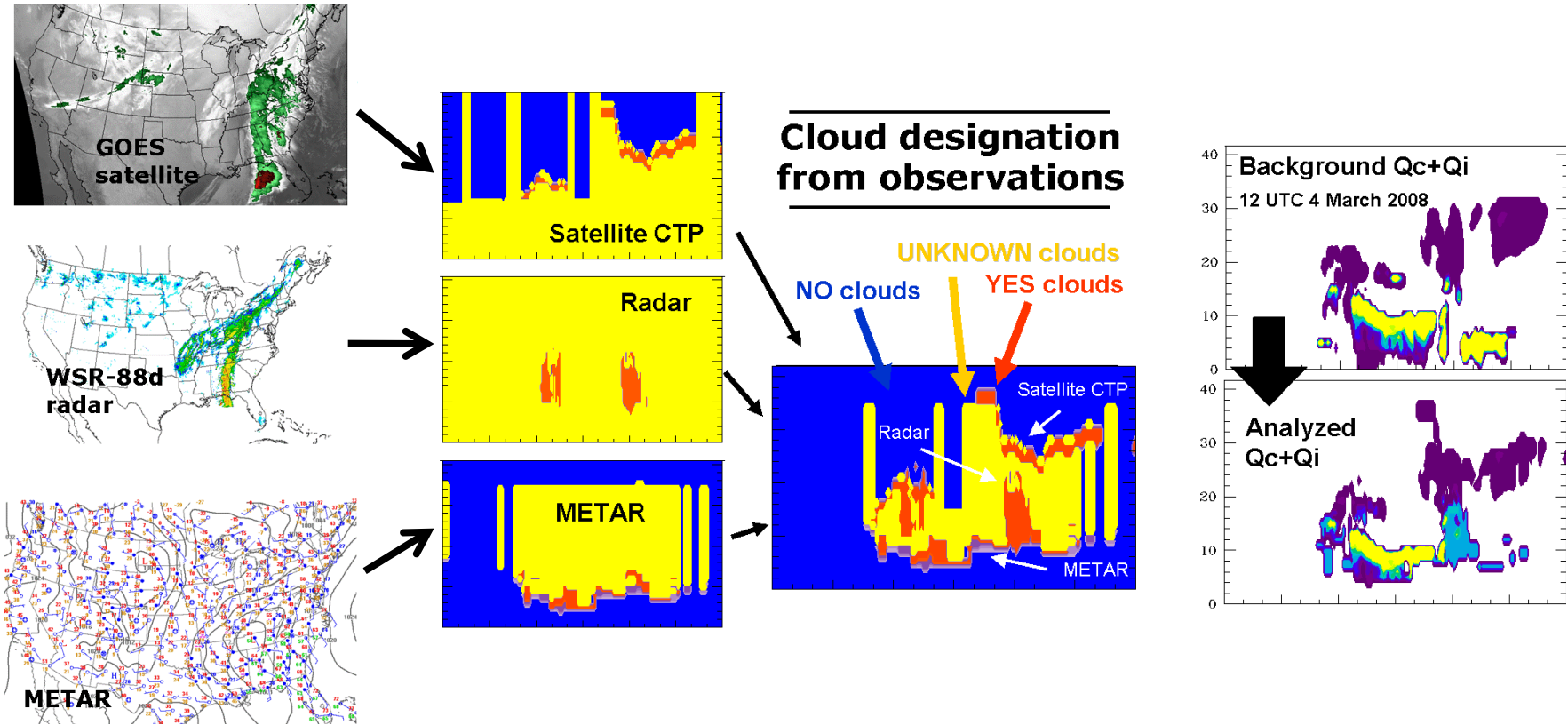


# Cloud Analysis in GSI for RR

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- 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)

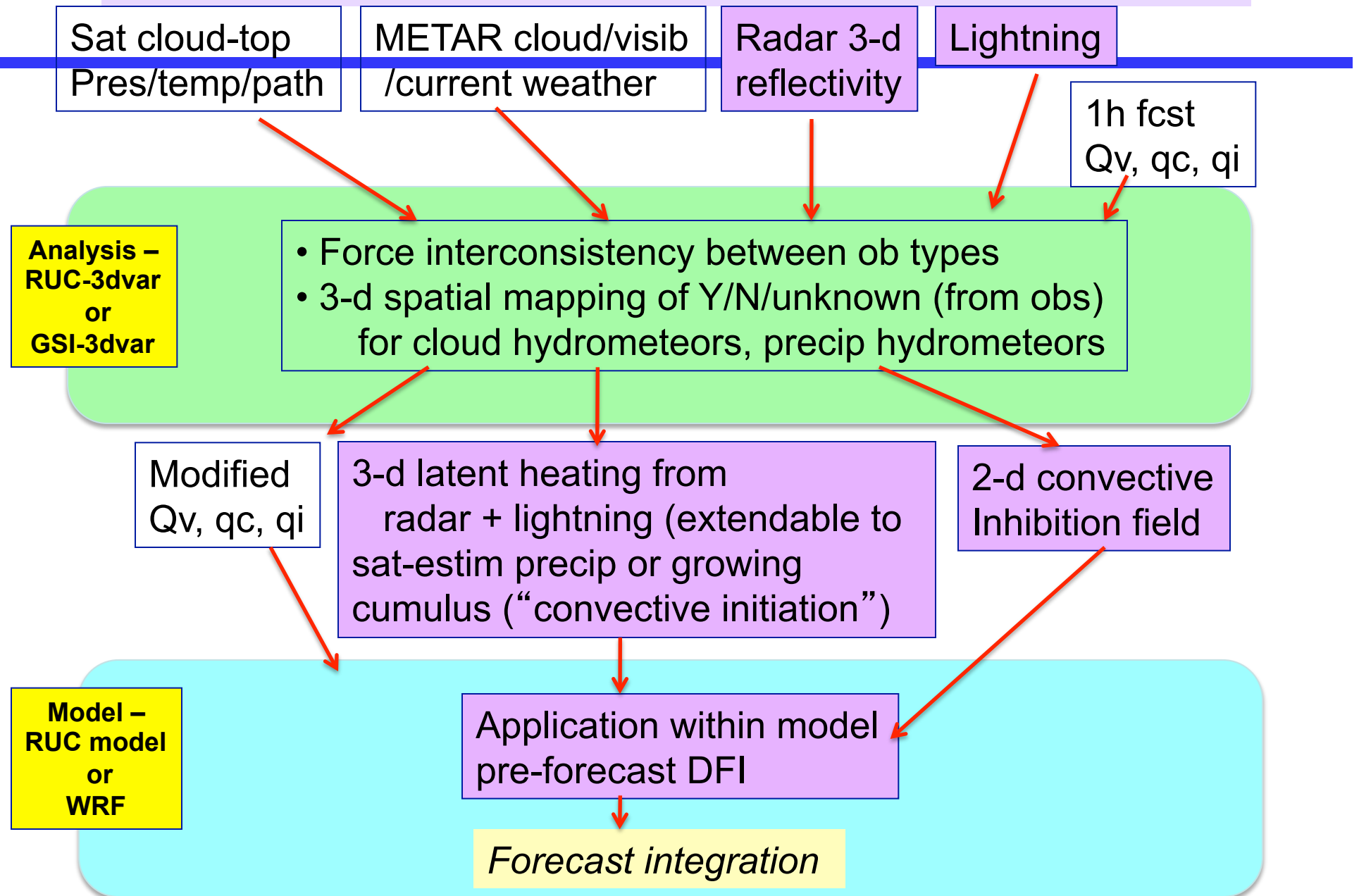
# Cloud analysis schematic



observation

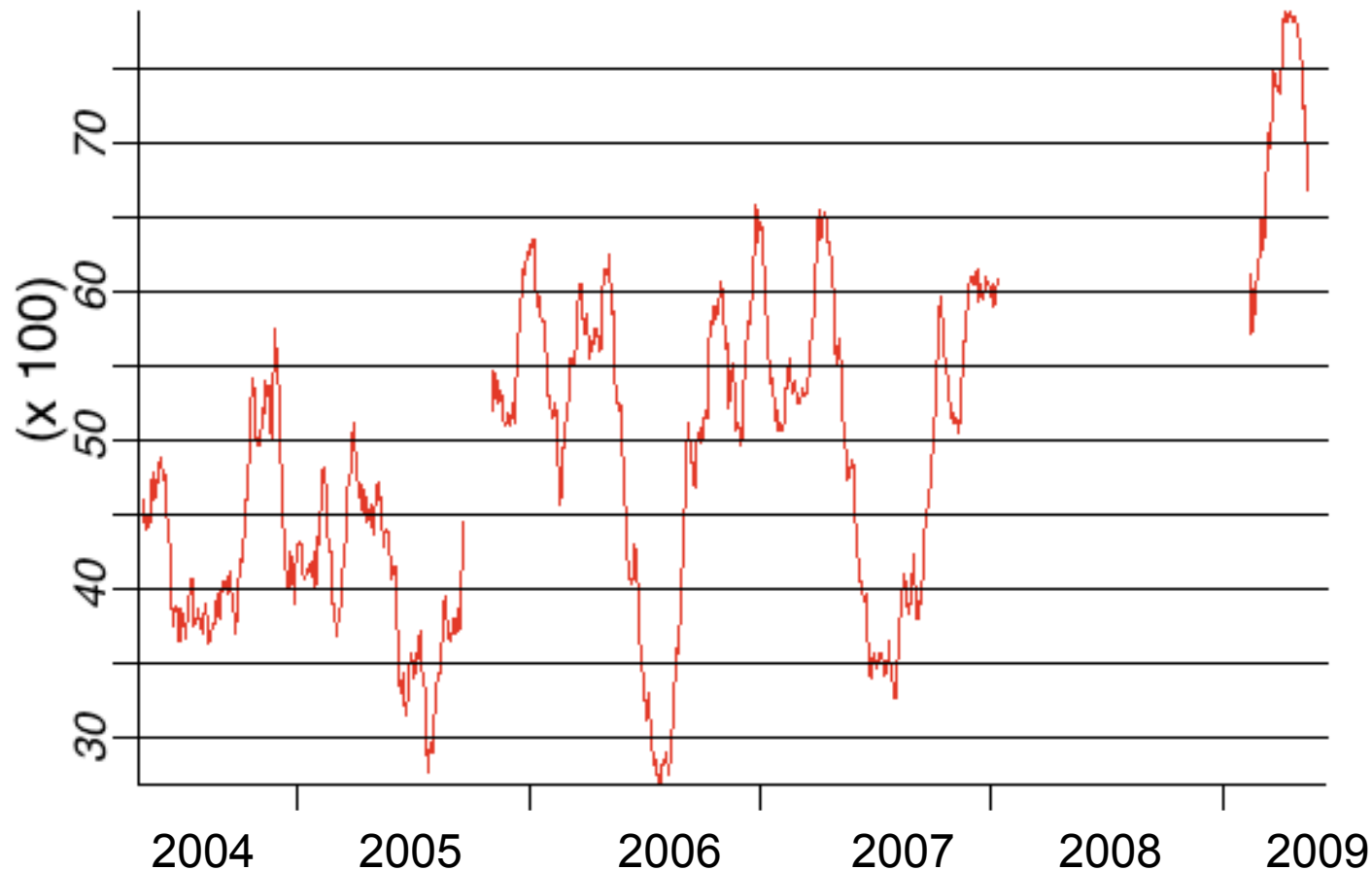
- Uses METAR, satellite, radar, lightning data
- Updates RR 1h-fcst RR hydrometeor, water vapor fields
- Generates latent heating from radar and lightning data

# 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

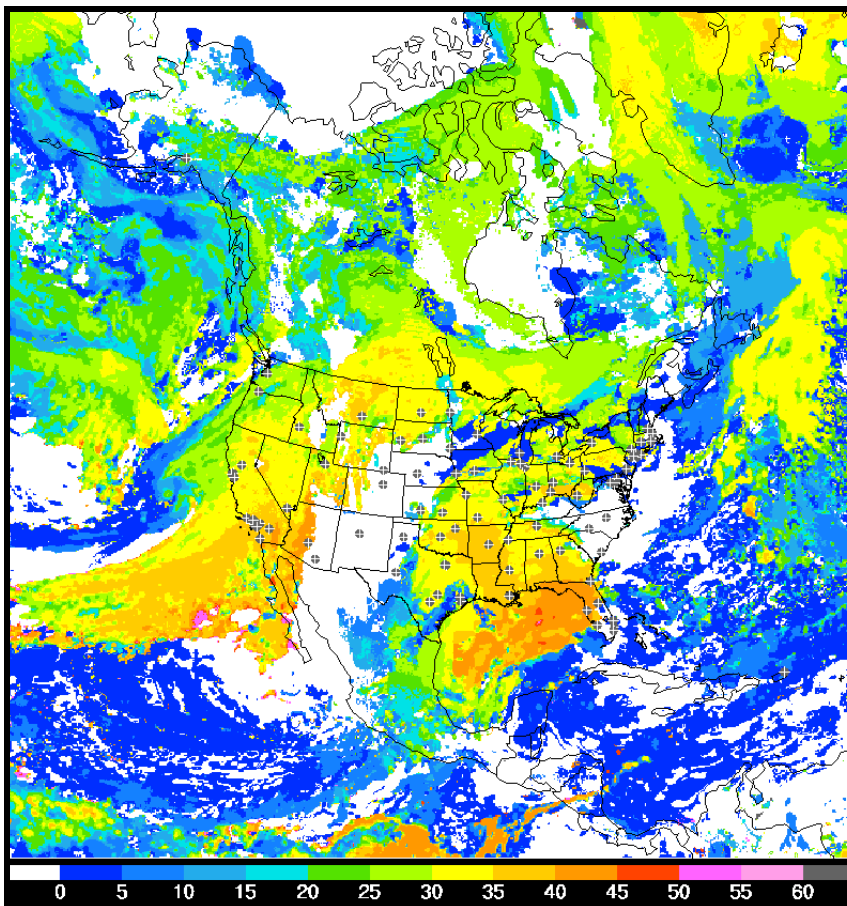


Recent development:  
use of NASA Langley satellite cloud data

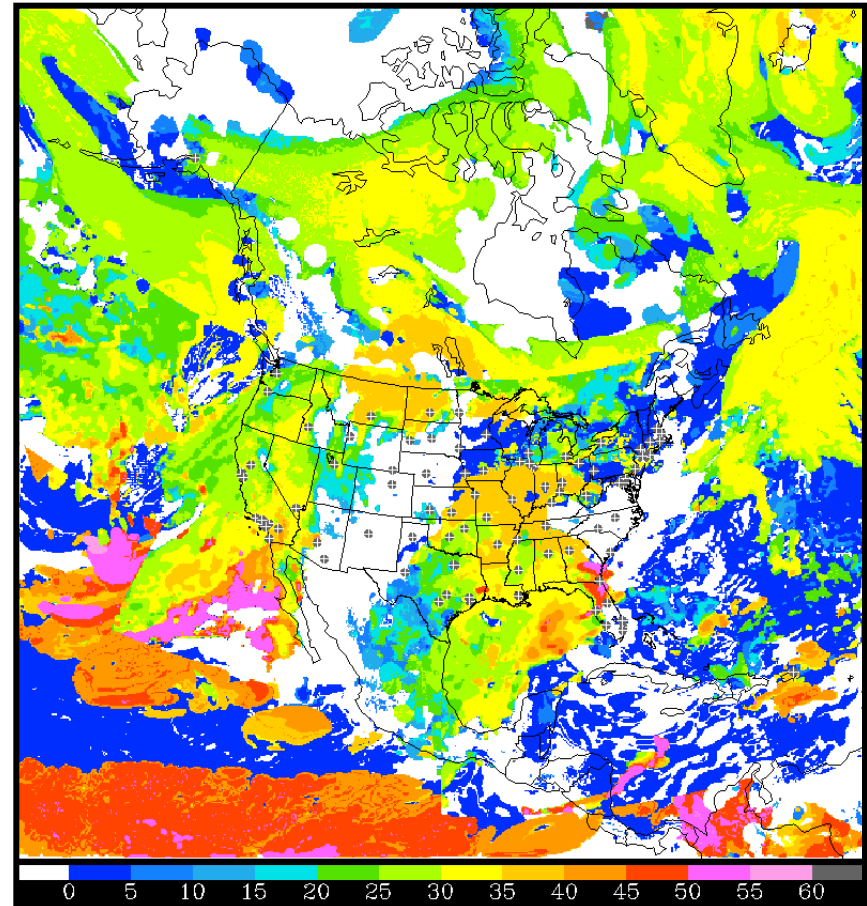
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## Cloud Top Height Analysis

**RR with NASA data - over  
full RR domain**



**RR with NESDIS data- only  
over RUC domain**



# Recent development: Bug fixes and Calibration

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- 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

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- 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

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## 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):

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

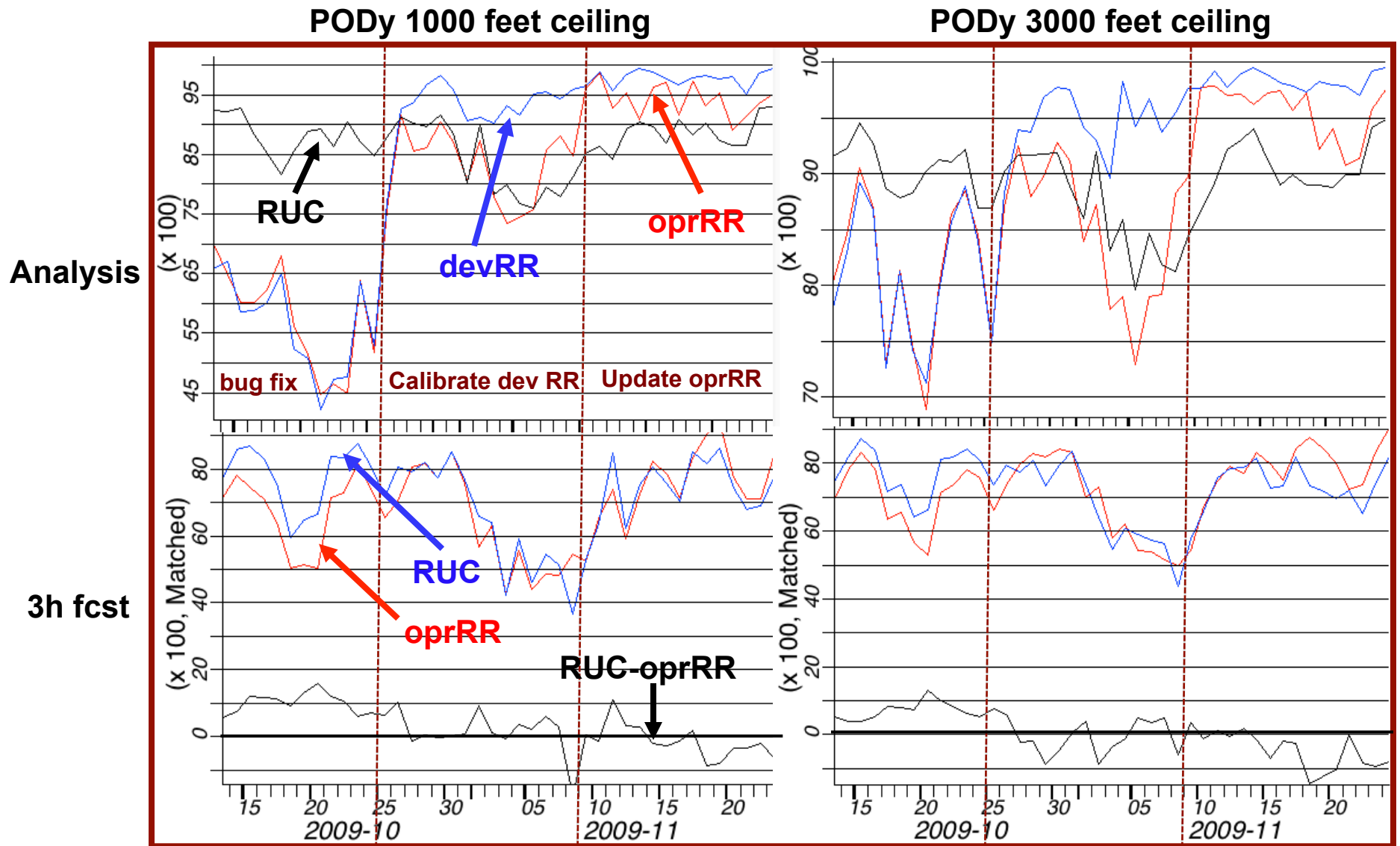
POD yes for 500, 1000, and 3000 feet cloud ceiling:

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

**POD<sub>y</sub> higher, better**

# Cloud analysis calibration period

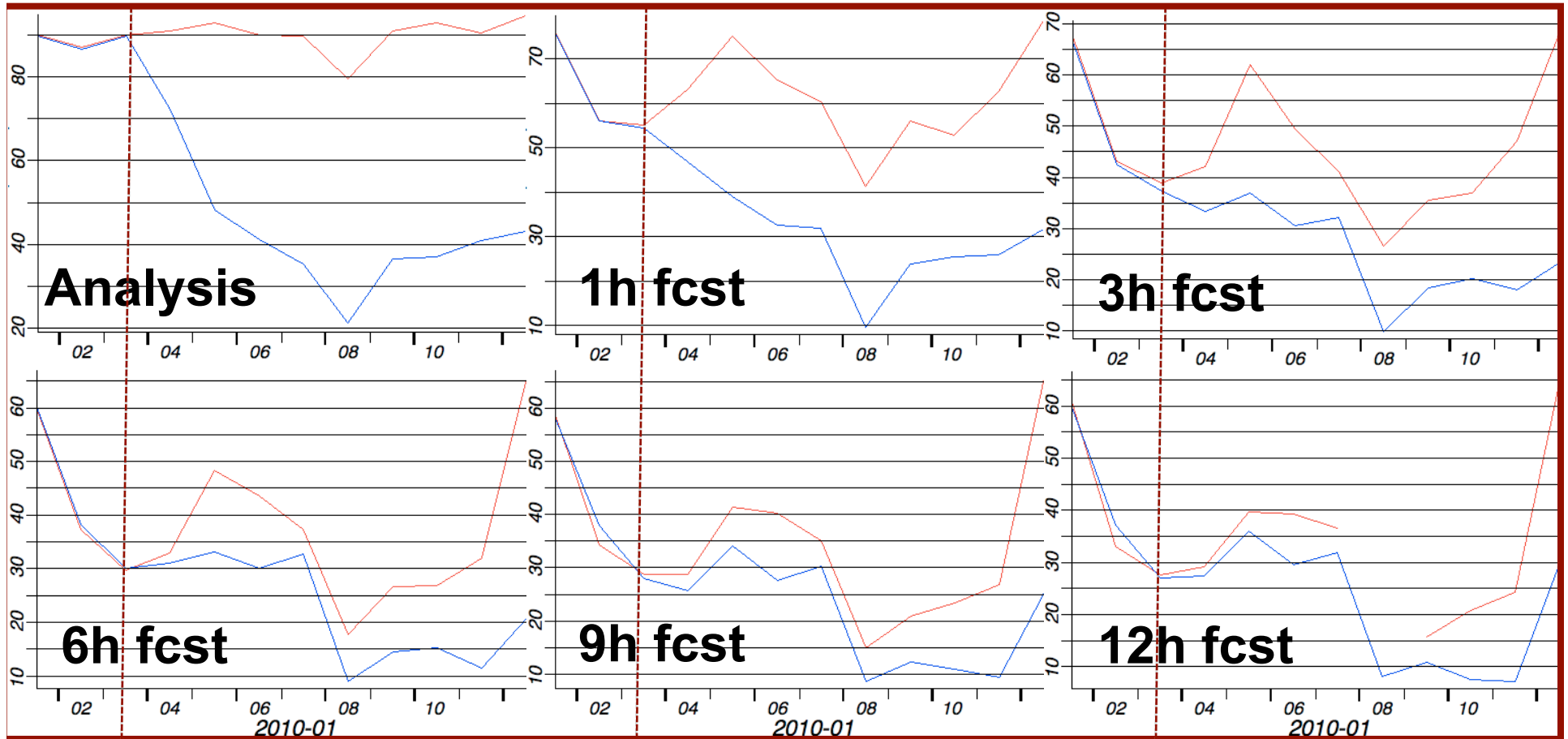
Oct. 24 - Nov. 9, 2009



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

— oprRR:with cloud analysis

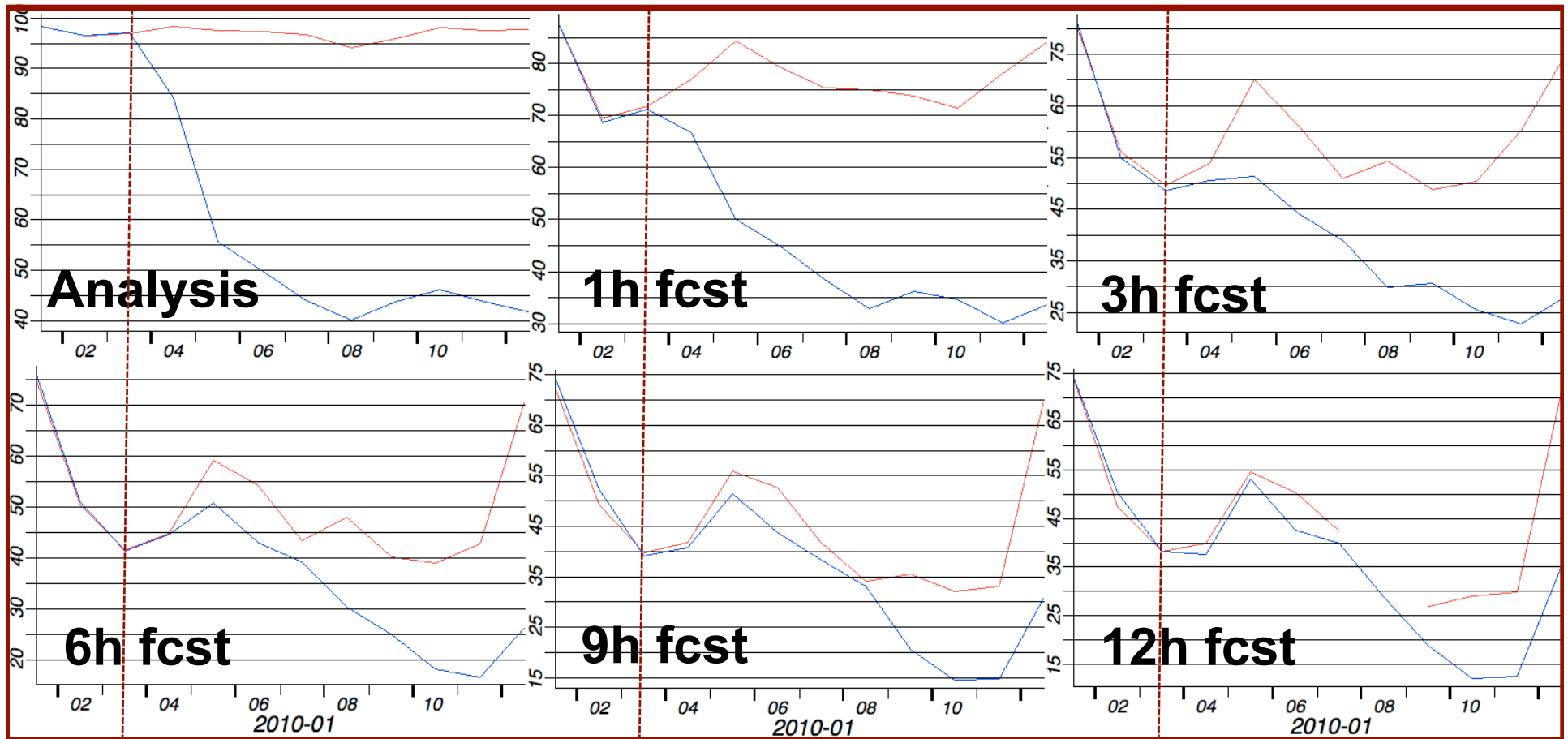
— devRR: no cloud analysis after Jan 4, 2010



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

— oprRR:with cloud analysis

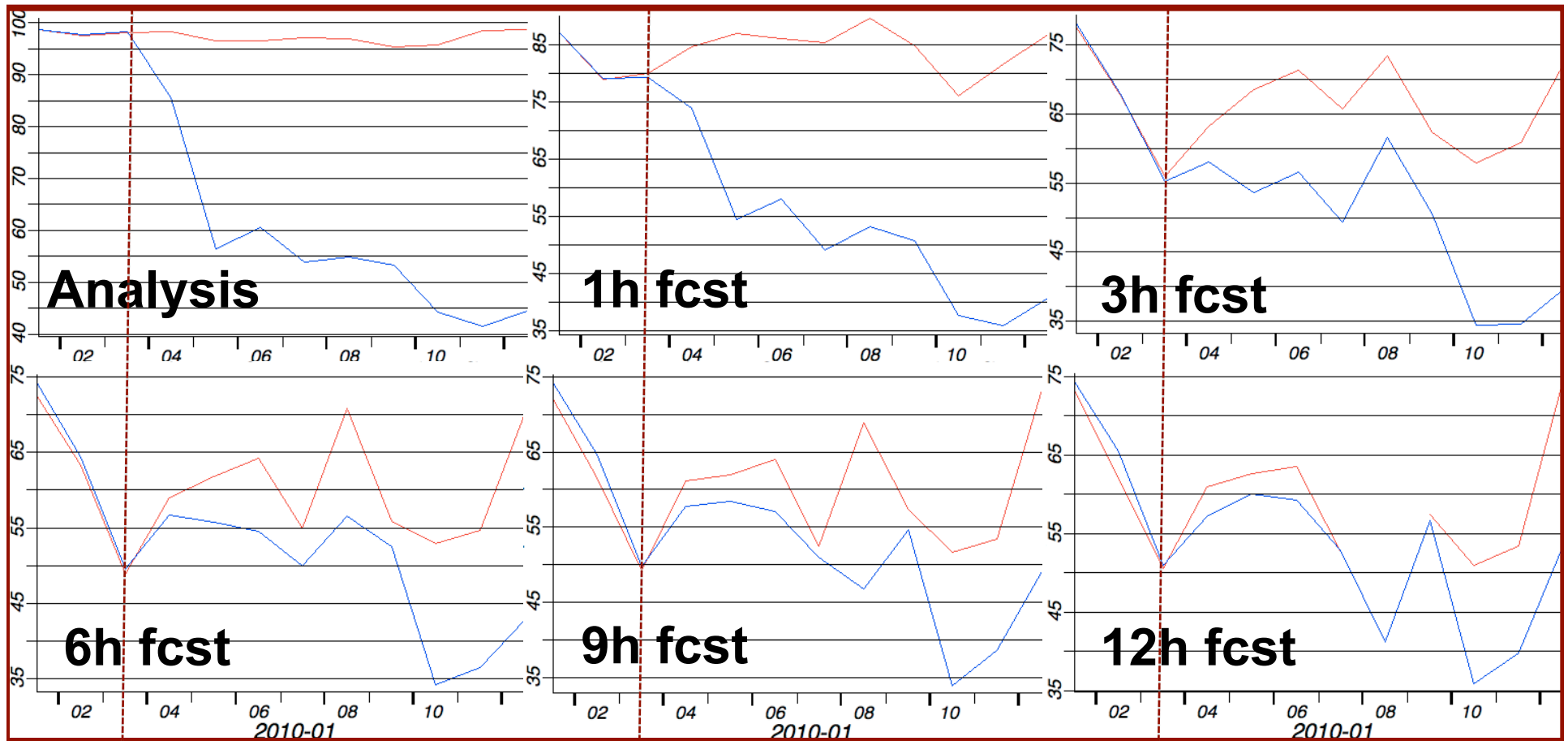
— devRR: no cloud analysis after Jan 4, 2010



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

— oprRR:with cloud analysis

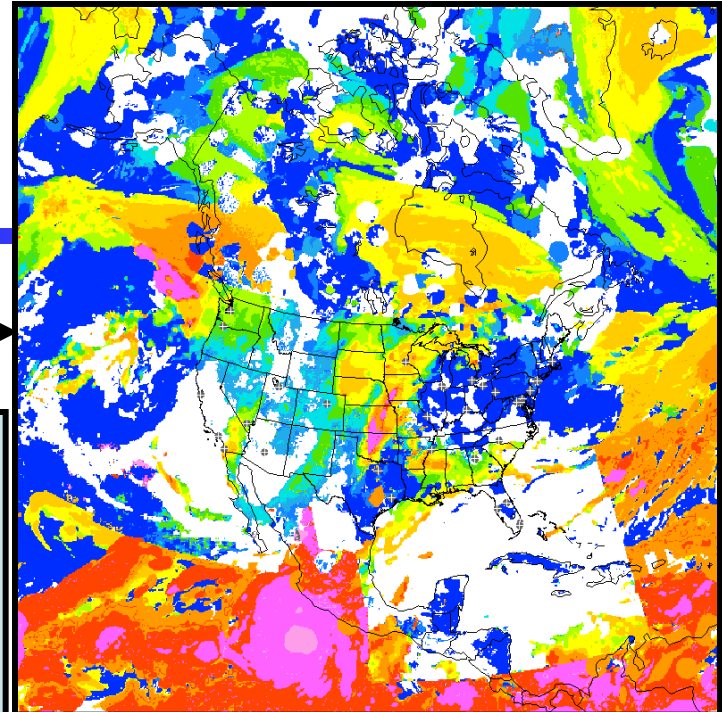
— devRR: no cloud analysis after Jan 4, 2010



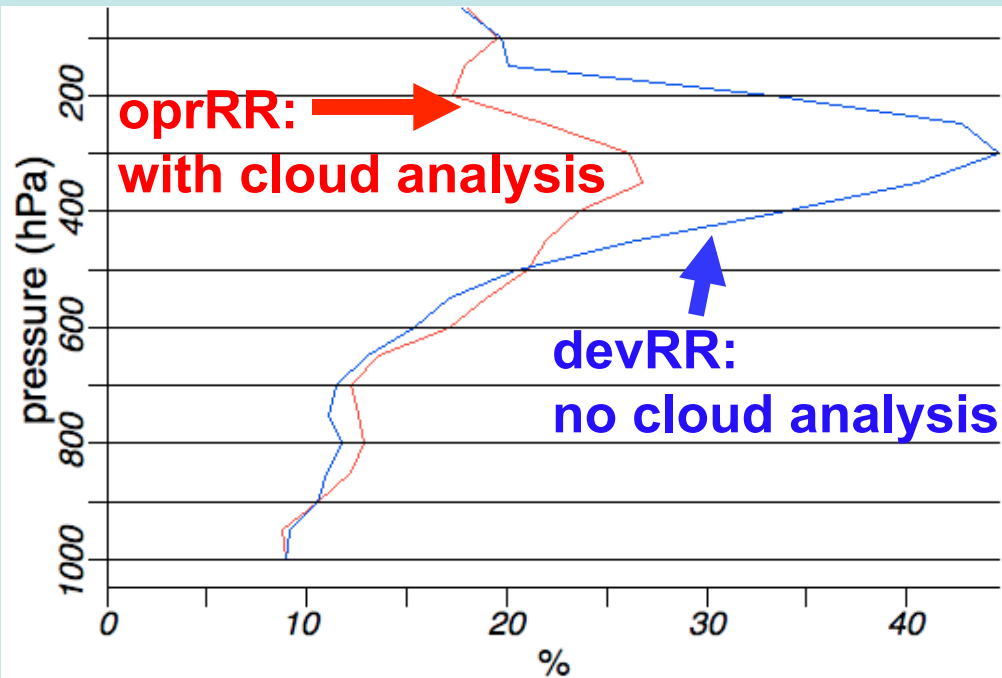


# Cloud Analysis Verification: Impact to moisture analysis

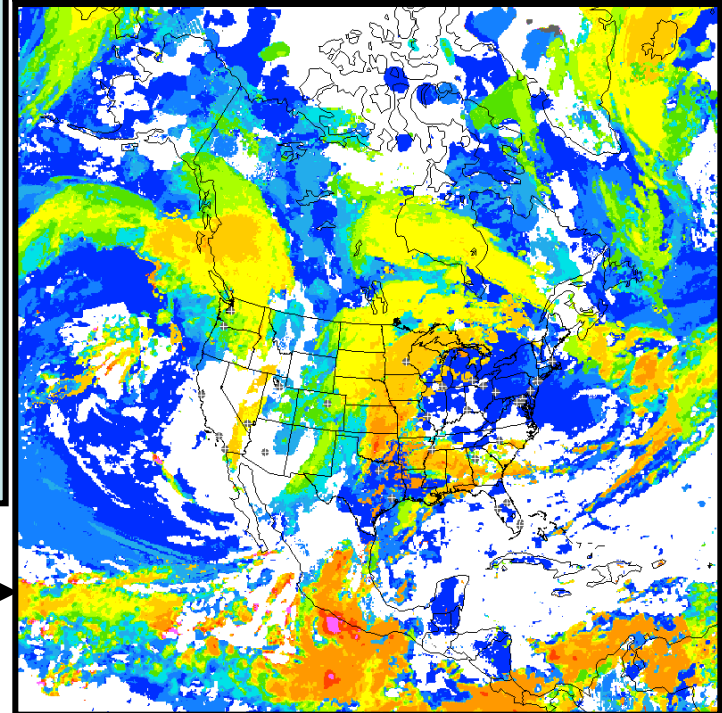
RR with NESDIS data-  
only over RUC domain



Analysis Humidity RMS during Jan 4 - 13, 2010

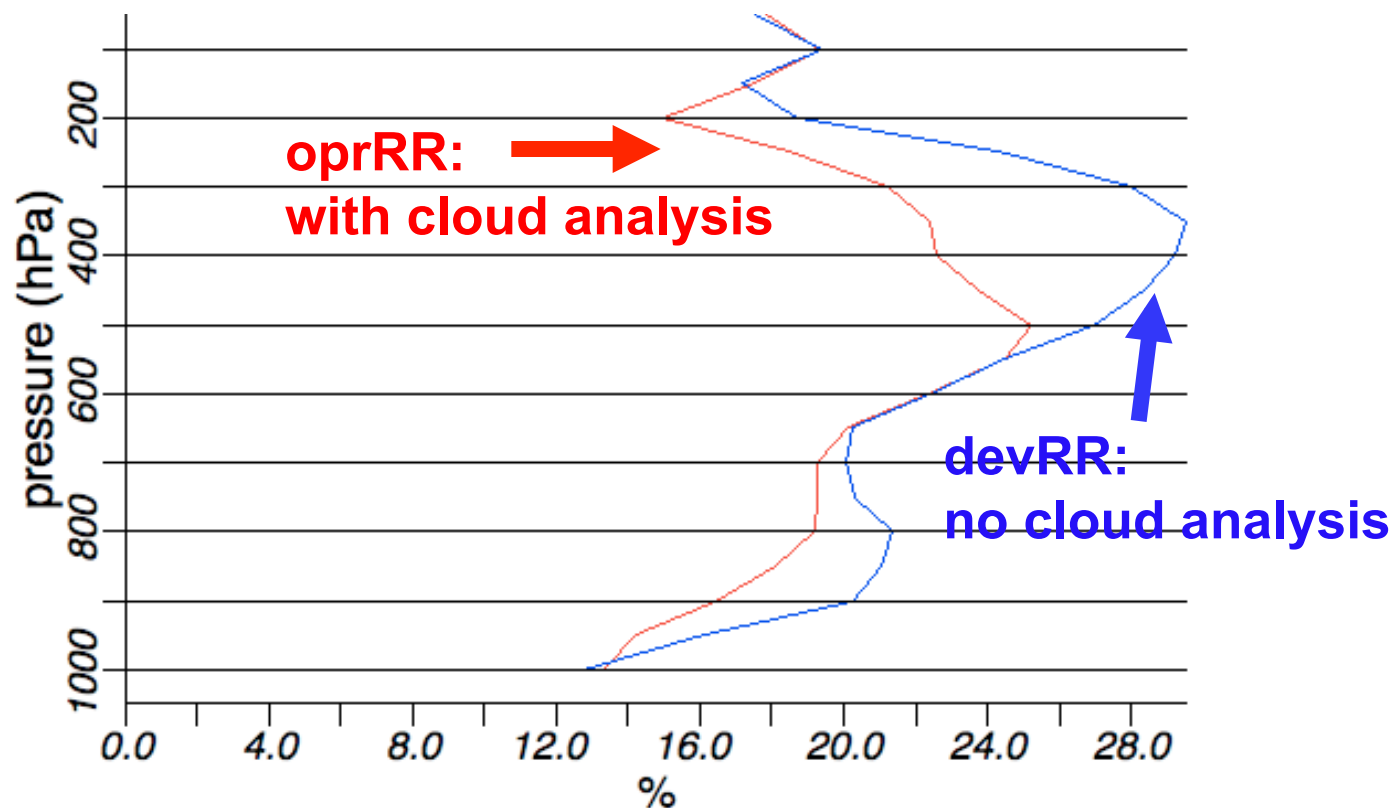


RR with NASA data - over  
full RR domain



# Cloud Analysis Verification: Impact to moisture forecast

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



# Summary and Ongoing cloud analysis work

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- 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” ( $T_{cld} > T_{skin}$ ) in Alaska

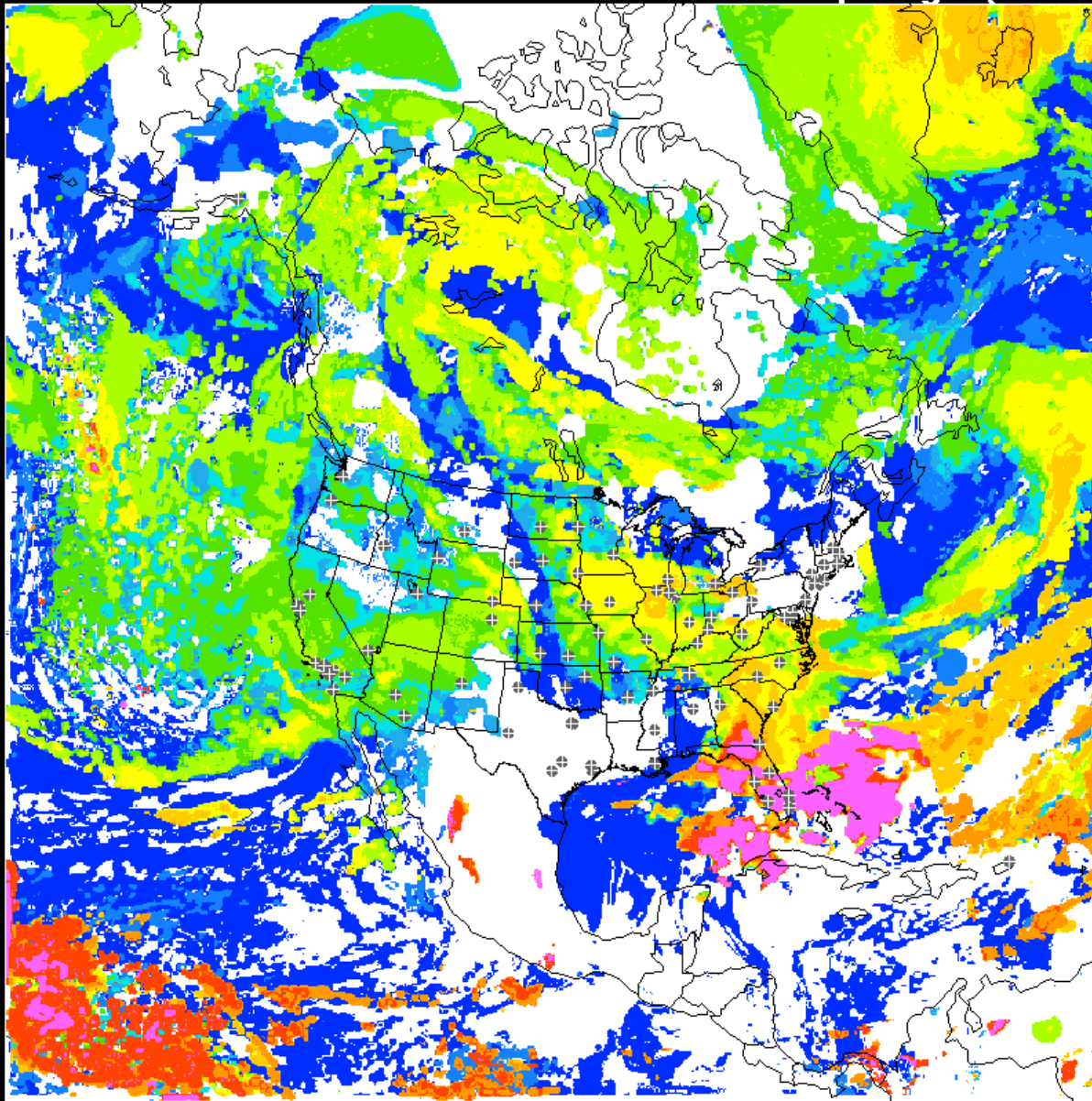
# Future: Variational analysis of clouds

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- Possibilities of Analysis variables
  - Total water content ( $q_c + q_i + q_r + q_s + q_g + q_v$ )
  - Normalized RH w.r.t. total water but not precip condensate  
=  $((q_v + q_c + q_i) / q_s(\text{bkg}))$ 
    - Corresponds to  $RH^*$  (Holm) for water vapor –  $(q_v / q_s(\text{bkg}))$
  - Condensate only ( $q_c + q_i + q_r + q_s + q_g$ )
  - Cloud condensate ( $q_c + q_i$ ) and precipitation condensate ( $q_r + q_s + q_g$ )
  - Cloud condensate ( $q_c + q_i$ )
  - Binary cloud indicator (Y/N)
  - Cloud fraction (0-1) (related to  $q_c, q_i$ ; but not to  $q_r, q_s, q_g$ )

RR-primary 01/21/2010 (16:00) 1 hr fcst

Valid 01/21/2010 17:00 UTC  
Cloud Top Height (kft asl)



17z today  
21 Jan 2010

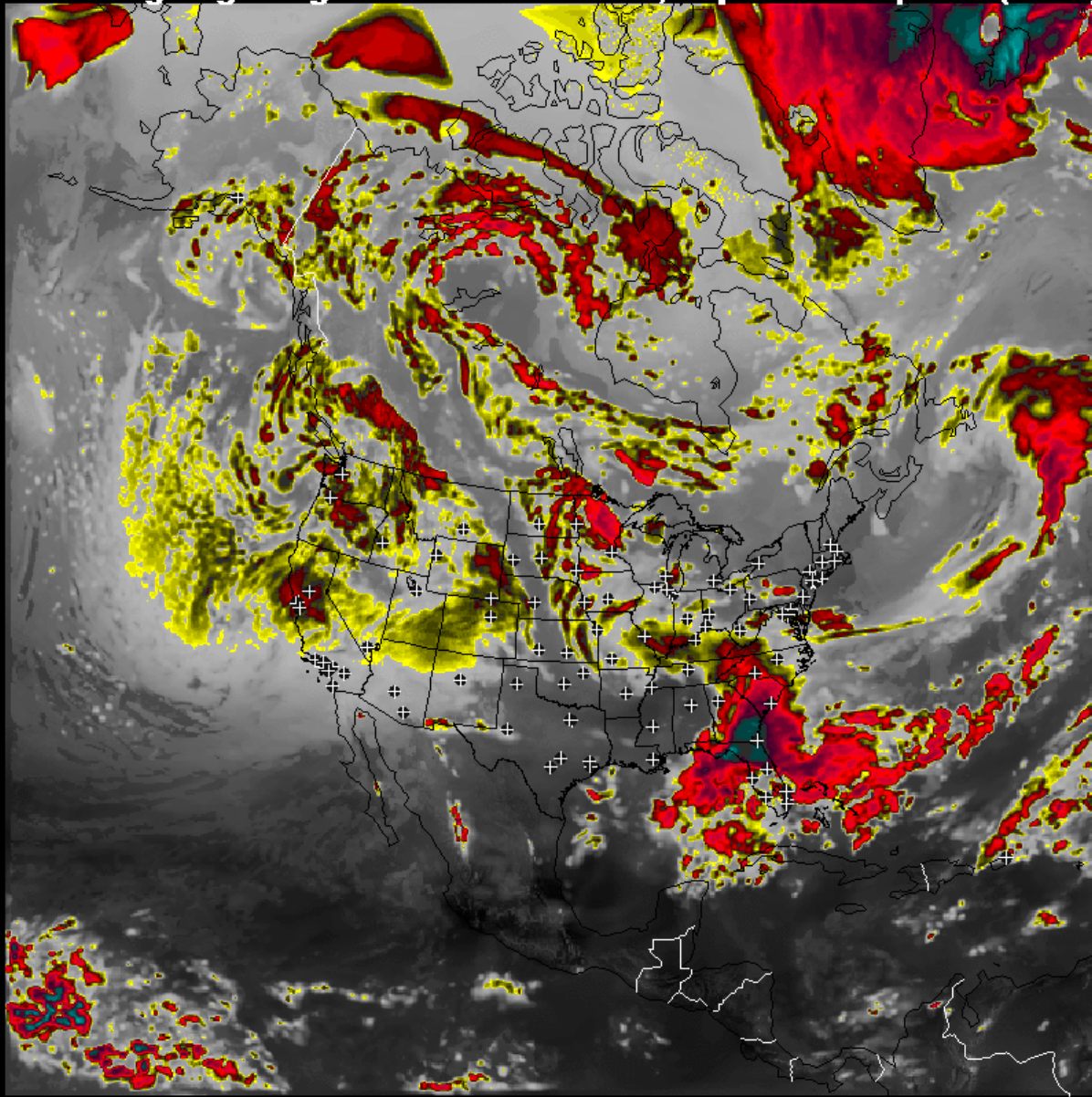
Rapid Refresh  
Cloud top height

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

RR-primary 01/21/2010 (16:00) 1 hr fcst

Valid 01/21/2010 17:00 UTC

**Outgoing Longwave Radiation Flux, Top of Atmosphere (W/m<sup>2</sup>)**



80 100 120 140 160 180 200 220 240 260 280 300 320 340

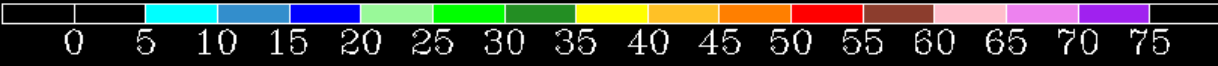
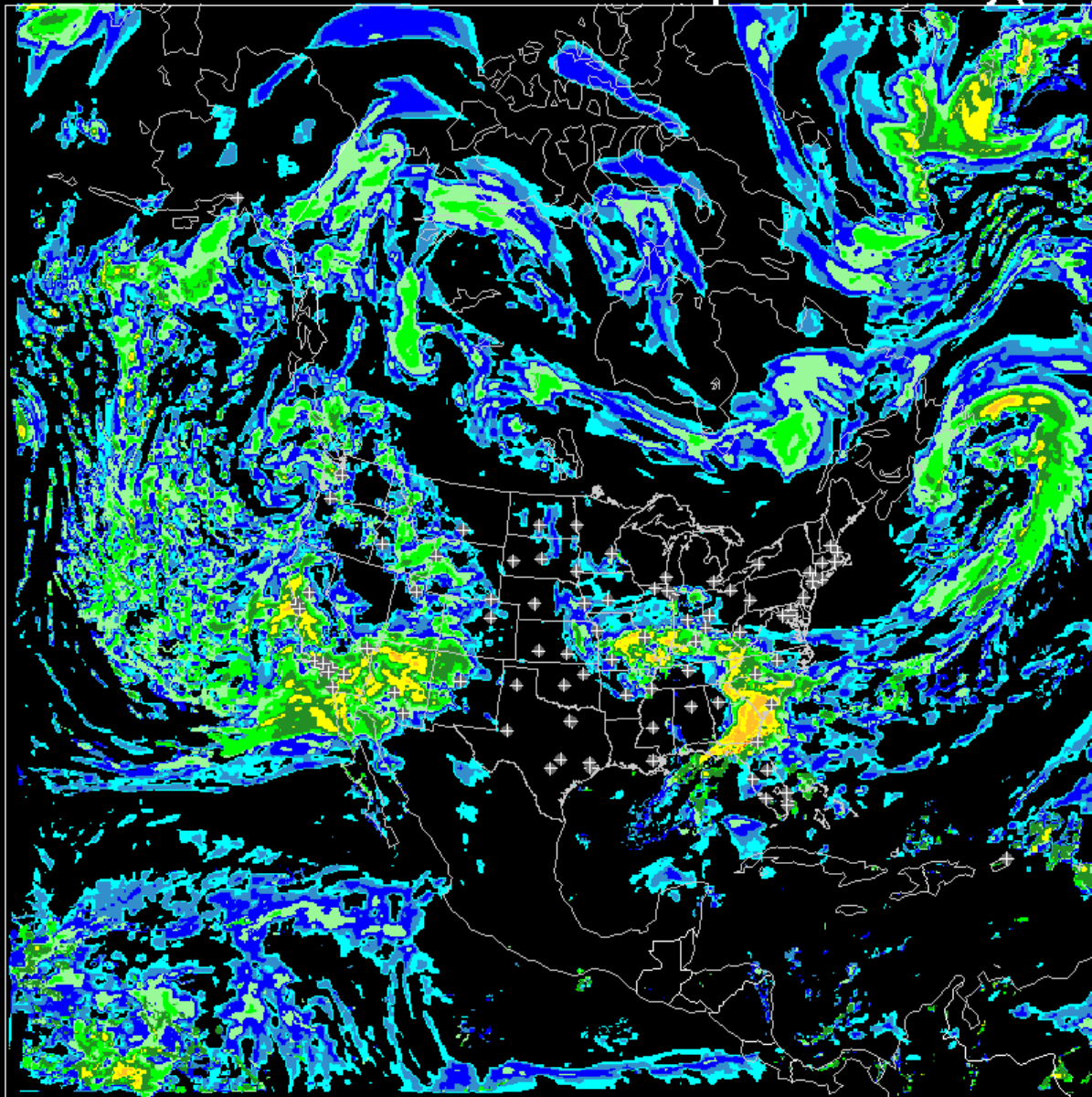
17z today  
21 Jan 2010

Rapid Refresh  
Outgoing LW rad

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

RR-devel 01/21/2010 (16:00) 1 hr fcst

Valid 01/21/2010 17:00 UTC  
Composite Reflectivity (dBZ)



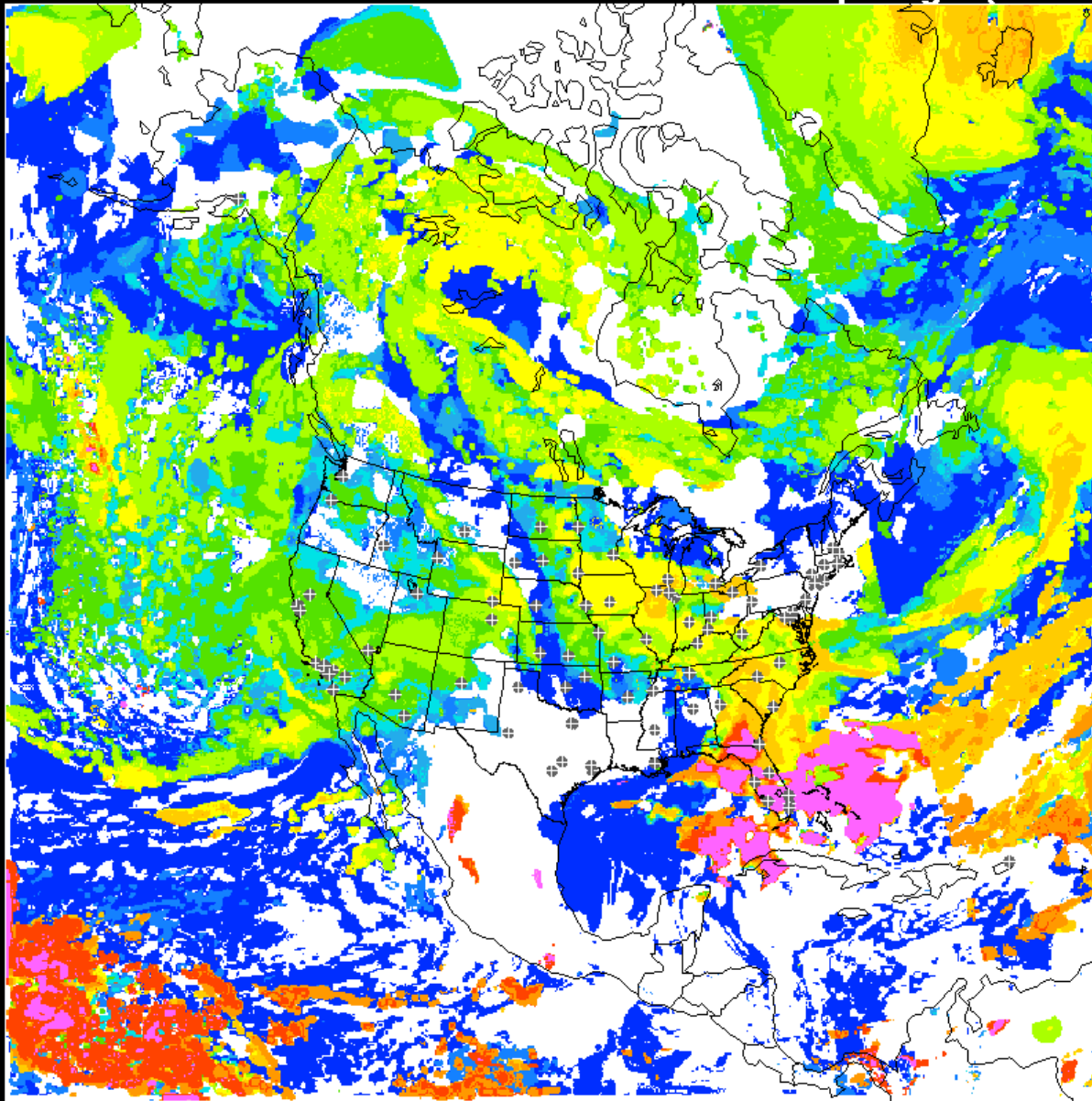
17z today  
21 Jan 2010

Rapid Refresh  
reflectivity

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

RR-primary 01/21/2010 (16:00) 1 hr fcst

Valid 01/21/2010 17:00 UTC  
Cloud Top Height (kft asl)



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)



# RUC/Rapid Refresh / HRRR

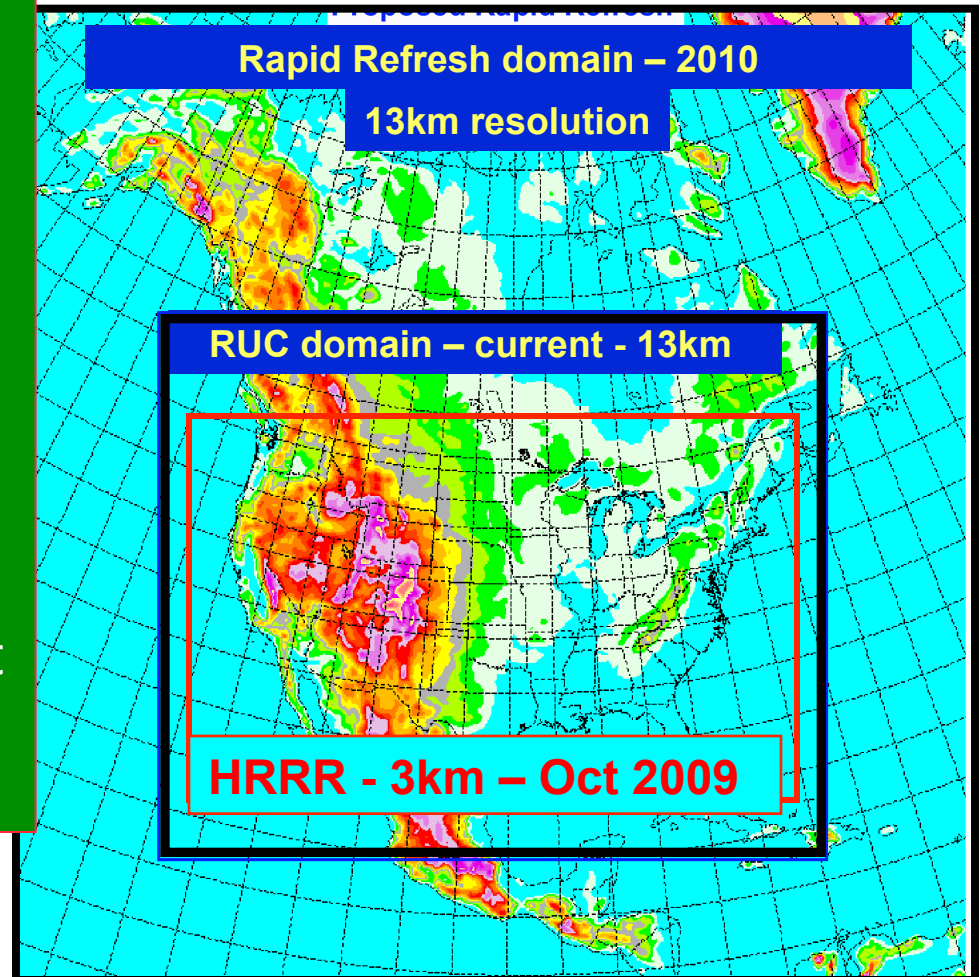
Hourly updated NWP runs over US / North America:

<http://ruc.noaa.gov>

<http://rapidrefresh.noaa.gov>

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

- 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



# Future plans for $\leq 1$ h 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)

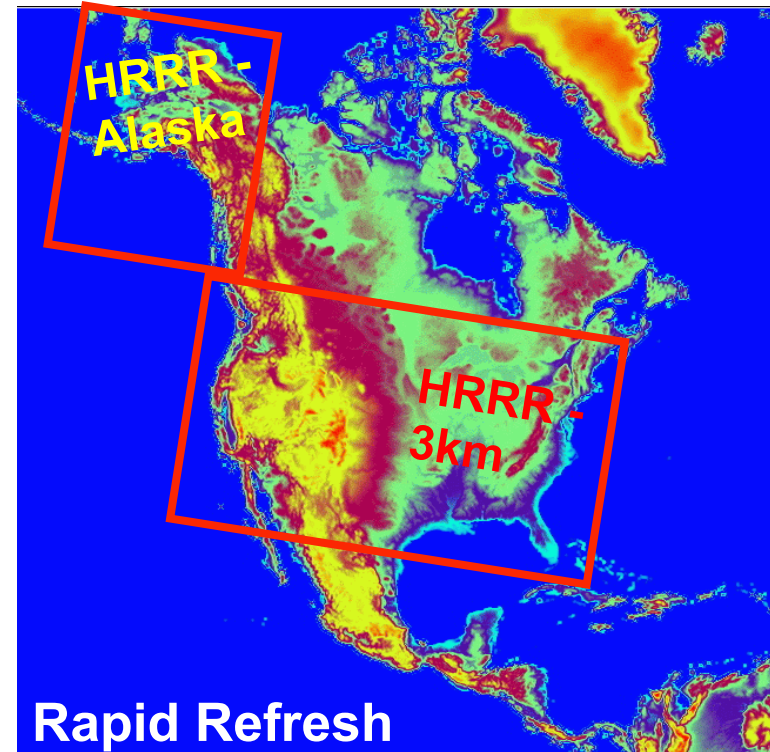
2014 – Add operational  
Alaska HRRR

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  $\rightarrow$  30  $\rightarrow$  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**