Assimilation of AIRS SFOV retrievals in the Rapid Refresh model system

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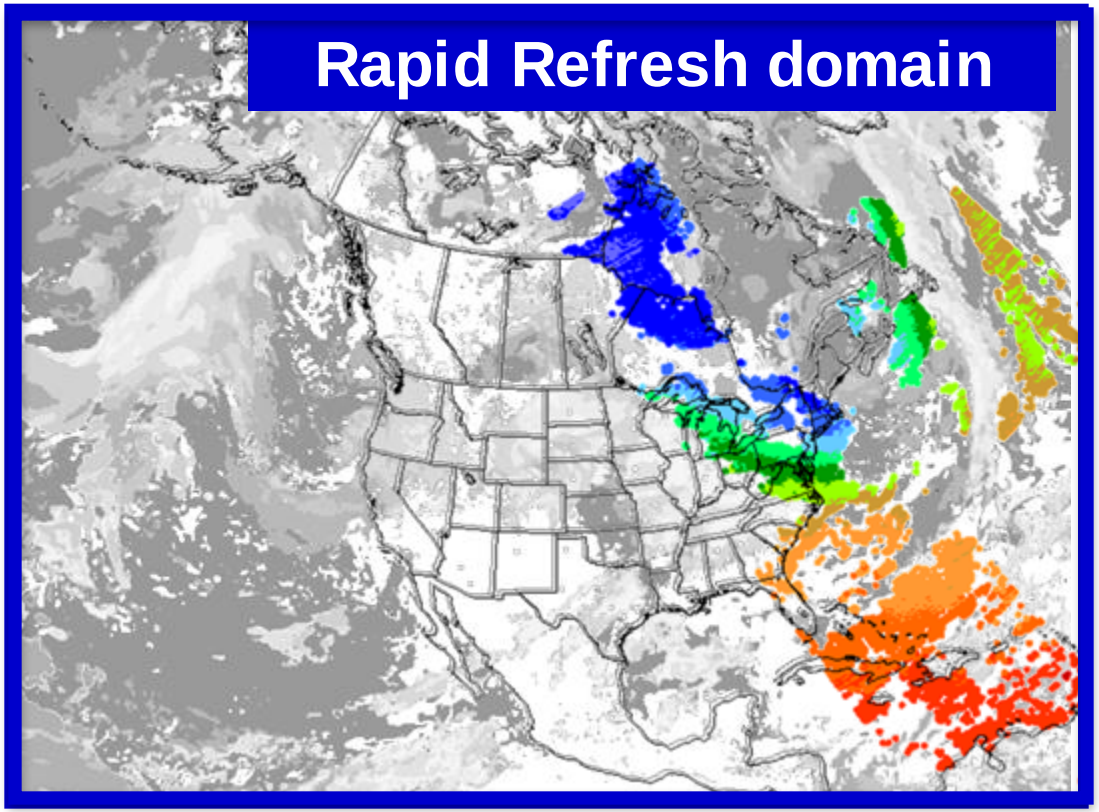

AIRS 500-mb retrieved temperature, grey-scaled RR cloud-top analysis

Earth System Research Laboratory
SCIENCE, SERVICE & STEWARDSHIP

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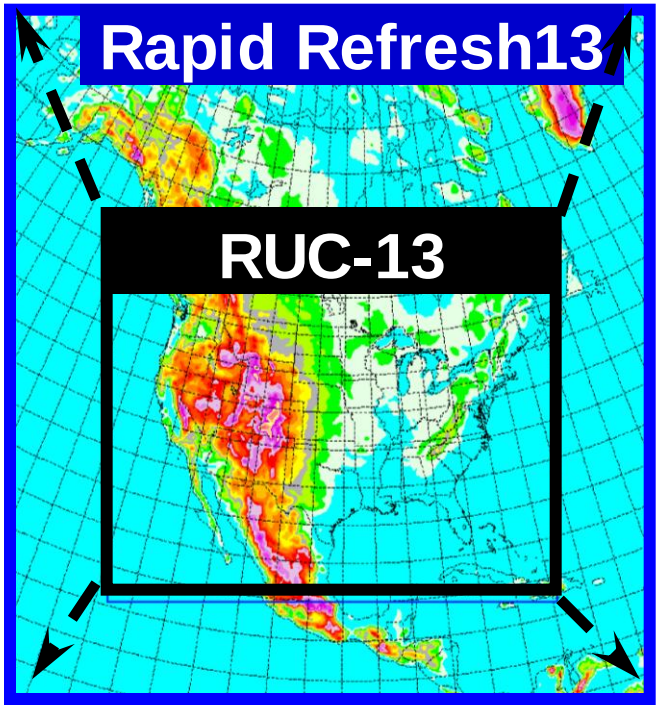
Talk Outline

1. Background on Rapid Refresh system
2. AIRS SFOV data coverage and assessment
3. Retro experiment design, impact benchmarking
4. Initial SFOV temperature experiments
5. SFOV moisture experiments with bias correction
6. Bias correction for SFOV temperatures
7. Ongoing work and future plans

1. Background on Rapid Refresh

RUC → Rapid Refresh transition

- **Advanced community codes (ARW and GSI)**
- **Retain key features from RUC** analysis / model system **(hourly cycle, cloud analysis, radar DFI assimilation)**
- **Domain expansion** → consistent fields over all of North America
- **RAP guidance for aviation, severe weather, energy applications**



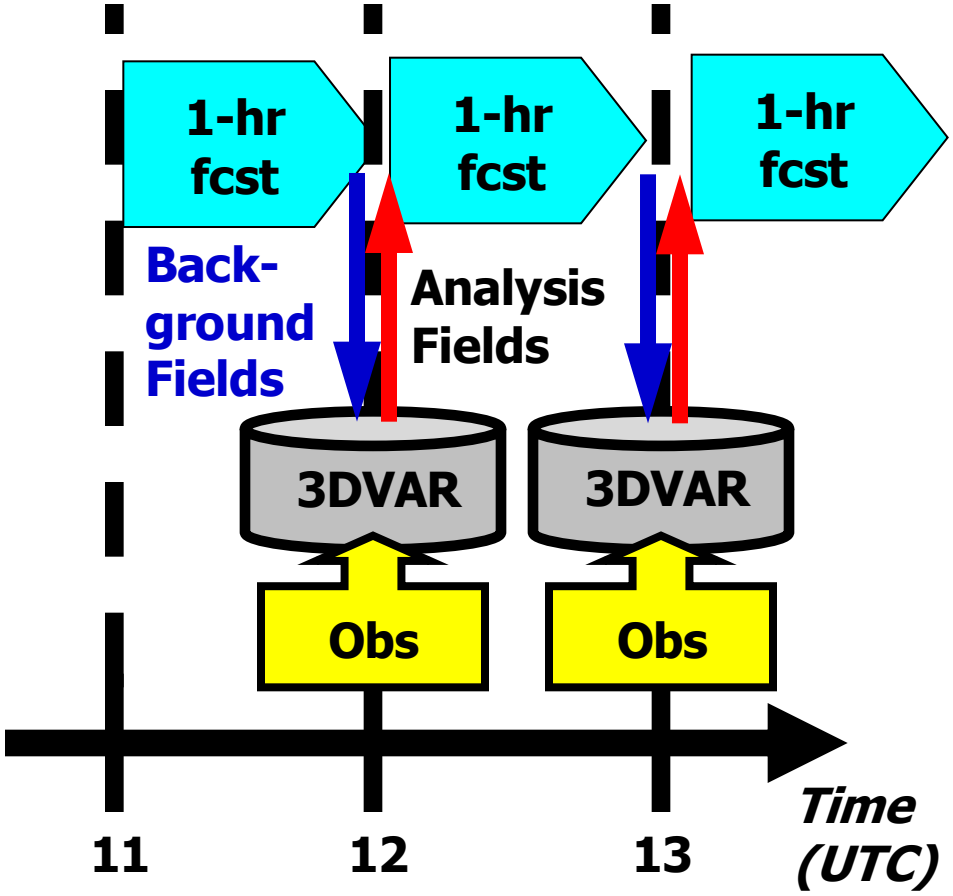
Status /implementation

- **NCO 30-day evaluation ongoing**
- **NCEP operational implementation planned for 13 March 2012**

Rapid Refresh Real-time system

Partial cycle atmospheric fields – introduce GFS information 2x per day

Fully cycle all LSM fields



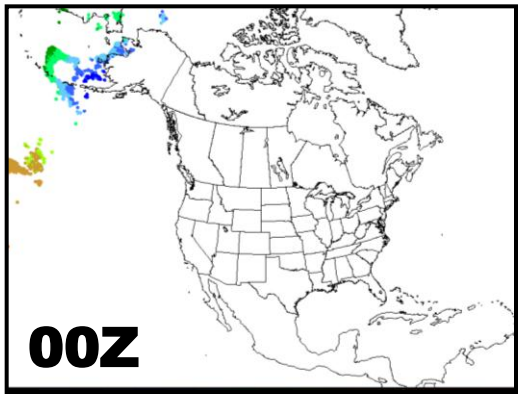
Data types – counts/hr

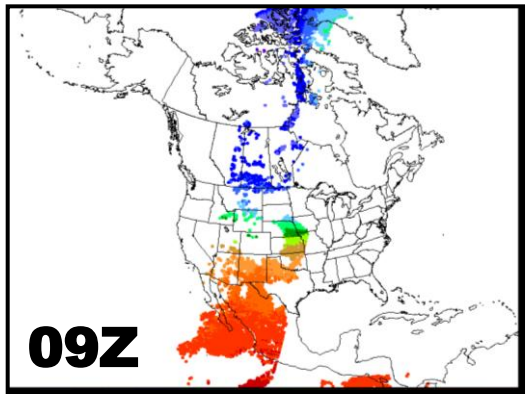
Rawinsonde (12h)	150
NOAA profilers	35
VAD winds	~130
PBL profilers / RASS	~25
Aircraft (V,T)	3500 – 10,000
TAMDAR	200 – 3000
METAR surface	2000 -2500
Mesonet (T,Td)	~8000
Mesonet (V)	~4000
Buoy / ship	200-400
GOES cloud winds	4000-8000
METAR cloud/vis/wx	~1800
GOES cloud-top P,T	10 km res.
satellite radiance	~5,000
Radar reflectivity	1 km res.

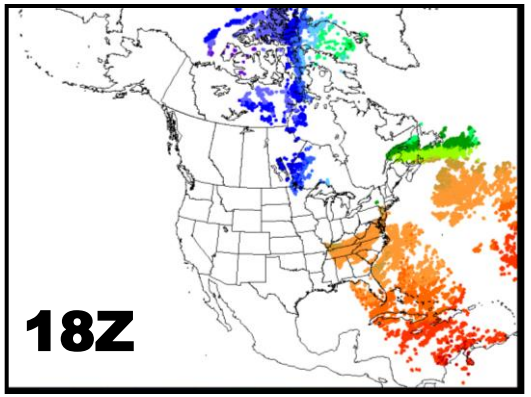
2. AIRS SFOV Data Assessment

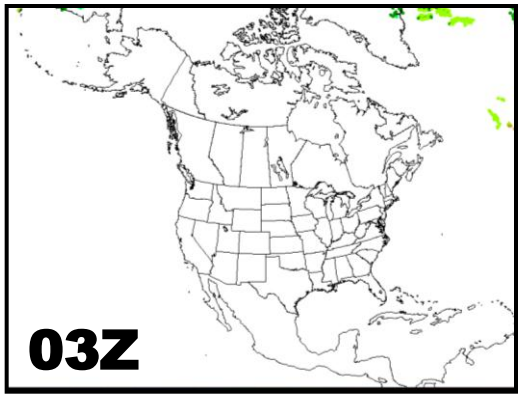
- Launched in May 2002 on NASA Earth Observing System (EOS) polar-orbiting Aqua platform
- Twice daily, global coverage
- 13.5 km horizontal resolution (Aumann et al. 2003)
- 2378 spectral channels (3.7-15.4 μm)
- Single Field of View (SFOV) soundings are derived using CIMSS physical retrieval algorithm (Li et al. 2000)
- Clear sky only soundings

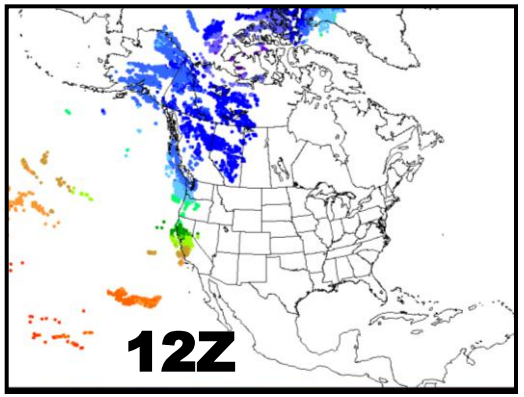
AIRS SFOV Coverage in RAP

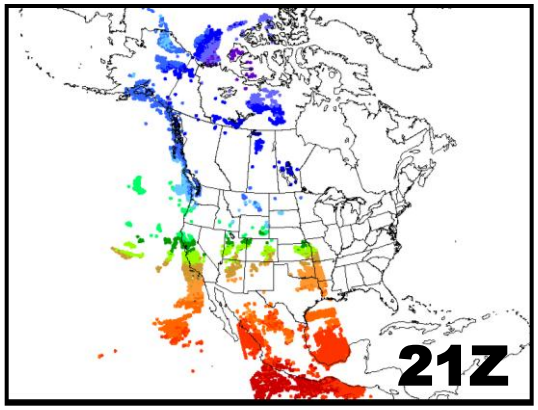


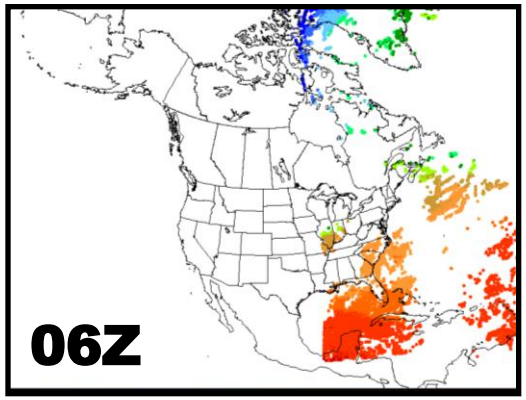


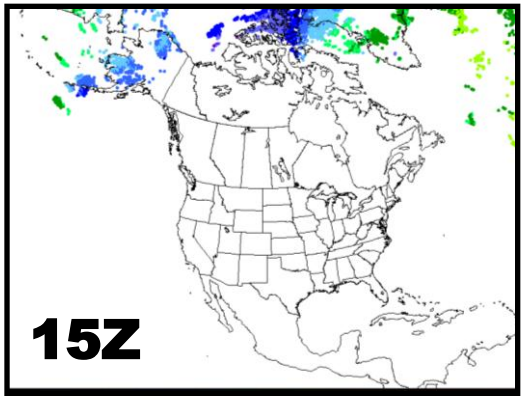










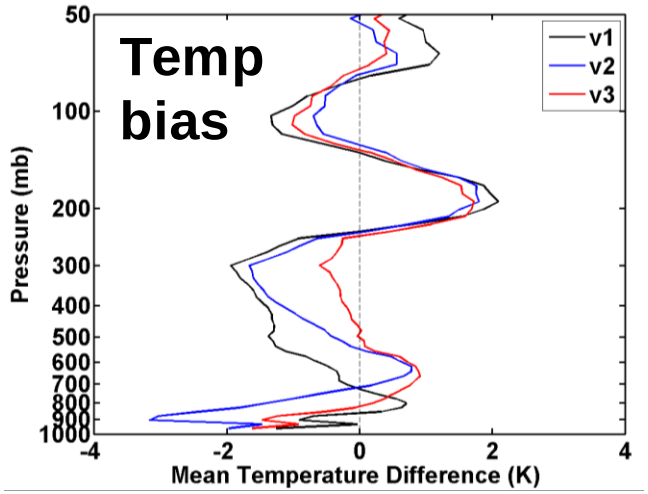


500 mb Temperature 8 May 2010

Compare AIRS SFOV with Raobs

Conditions for matched profiles:

3-h time window, less than 15 km horizontal distance under clear-sky

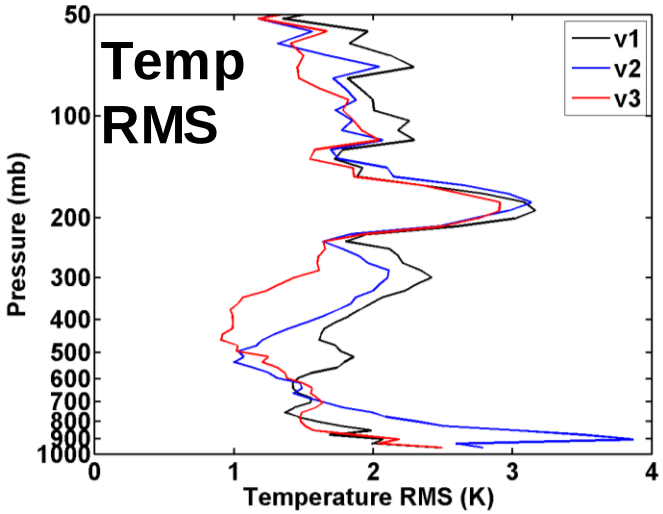


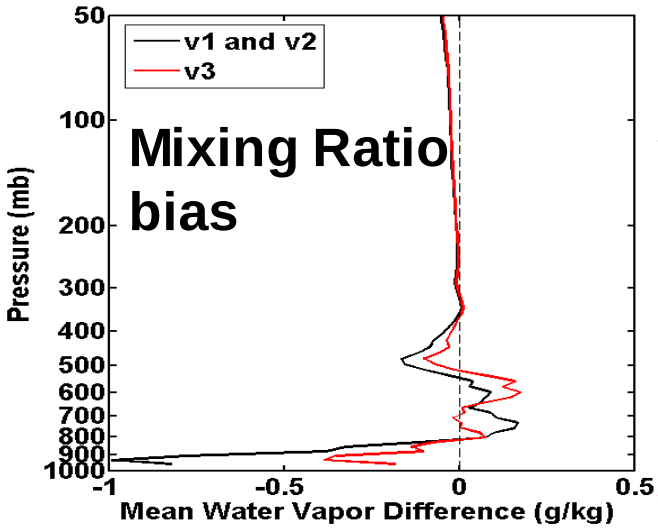
3 SFOV data sets obtained from UW CIMSS:

V1 – first set

V2 – improved

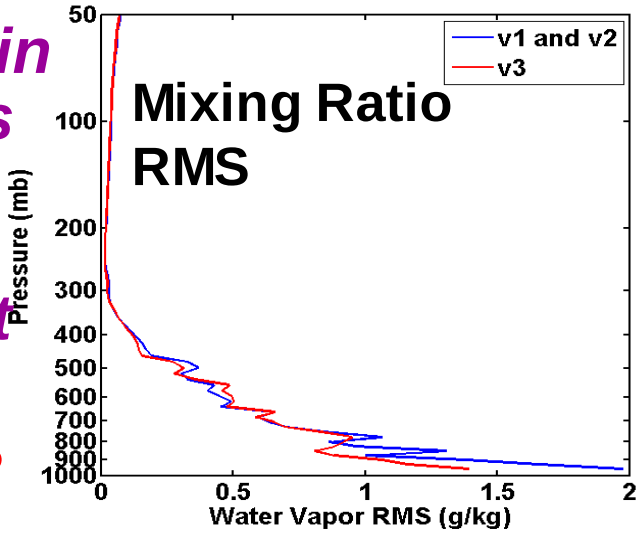
V3 – best set



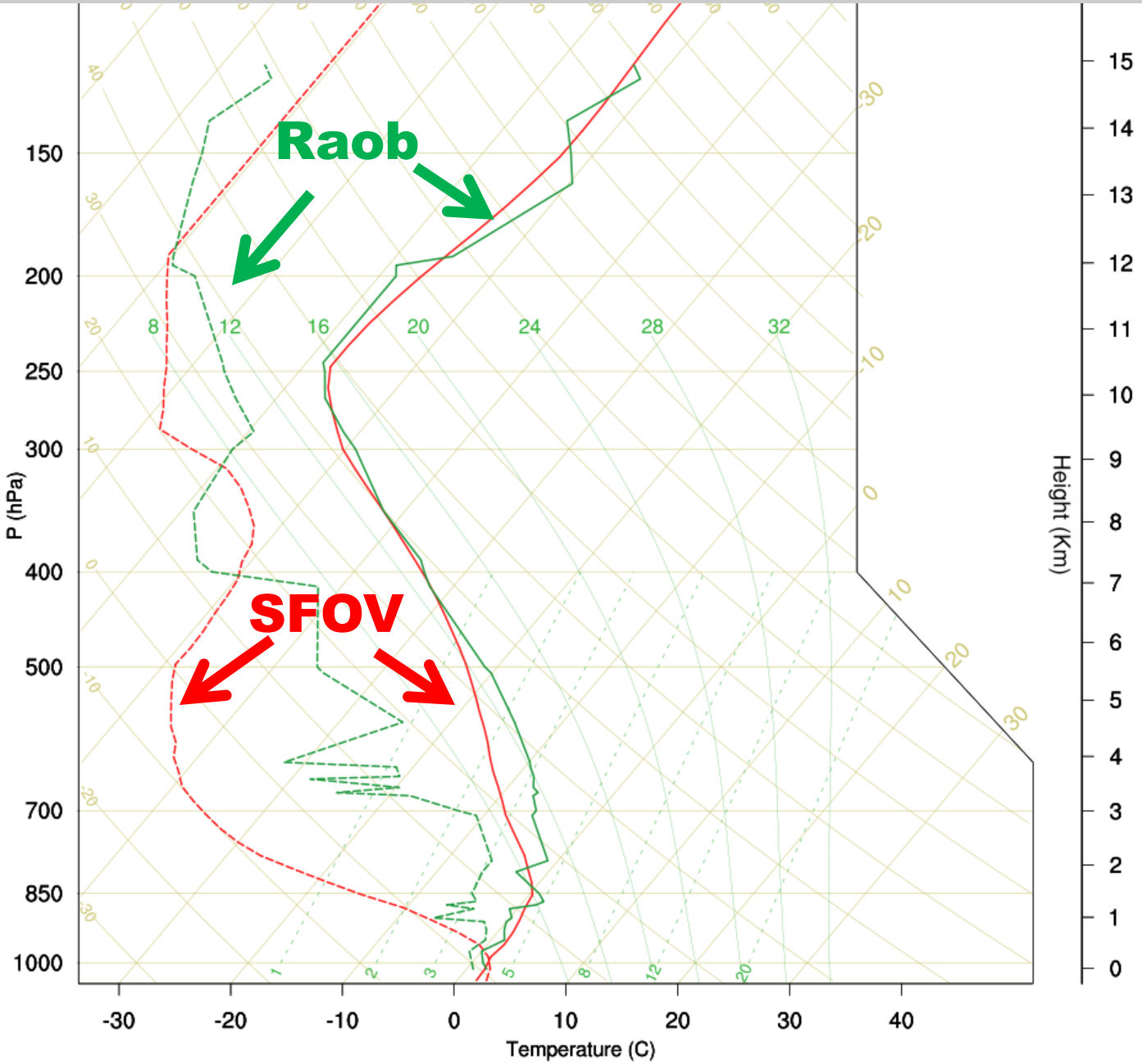


Improvements in SFOV retrievals has lead to more positive forecast impact

→ All results Shown from V3



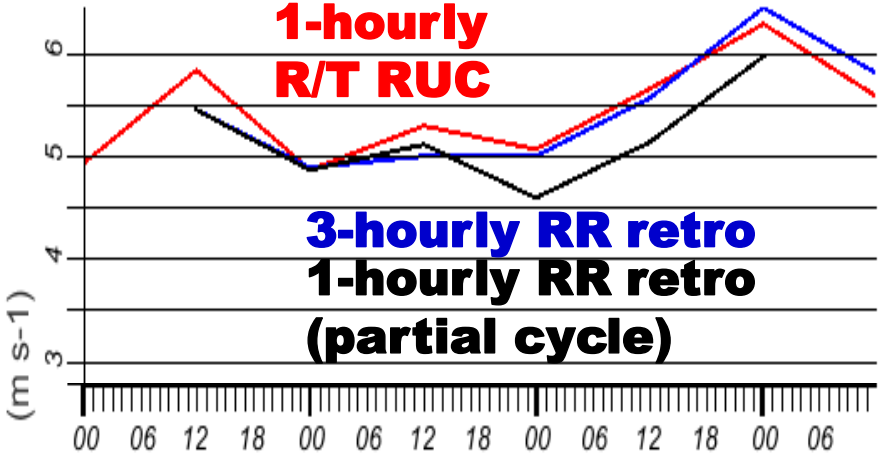
Compare AIRS SFOV with Raobs



3. Experiment Design / Benchmarking

- 9 day retro period (8-16 May 2010)
- Use 3-h cycle, no partial cycling
- Benchmark against R/T and perform raob denial

Assimilate full mix of observations



12-h fcst wind RMS Error
(100-1000 mb mean)

RMS error impact	Raob denial retro run	Benj. et al. MWR 2010
6-h fcst T	0.06 K	0.05 K
12-h fcst T	0.11 K	0.15 K
6-h fcst RH	0.77%	1.25 %
12-h fcst RH	1.11%	1.75%
6-h fcst wind	0.13 m/s	0.1 m/s
12-h fcst wind	0.17 m/s	0.18 m/s

3-h RR retro cycle results as expected

-- 1-h RR slightly better

-- 3-h RR similar to R/T RUC

Raob denial results closely match previous OSE study

4. Initial SFOV T Experiments

Variations in details of SFOV T assimilation

CNTL – std obs - No AIRS SFOV

FULL T – std. obs + SFOV T (50-1000 mb)

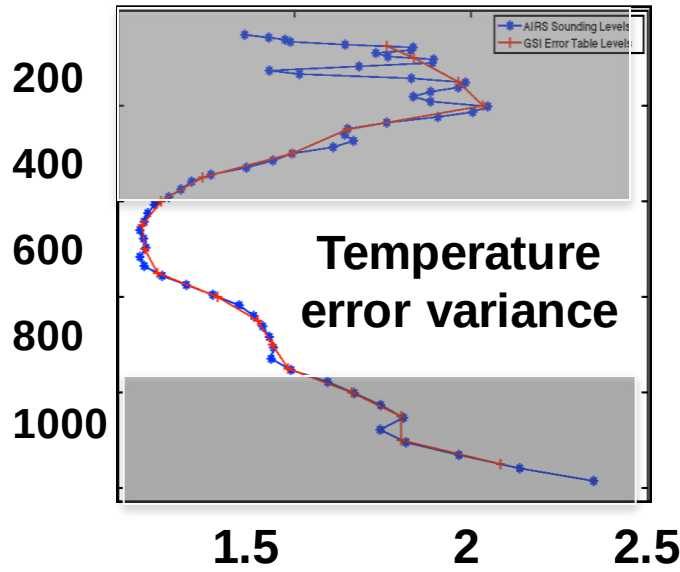
MID T – std. obs + SFOV T (400-800 mb)

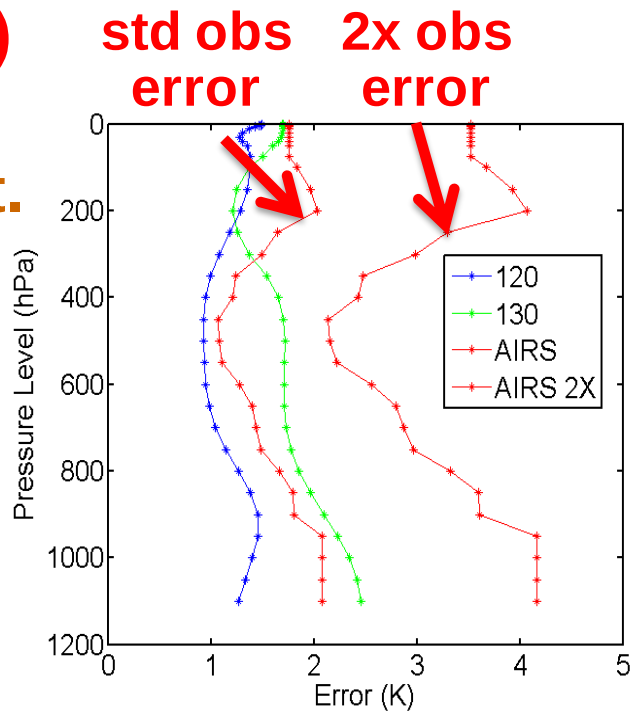
DBL Err – std. obs + SFOV T (400-800 mb)
2X standard temperature error variance

THIN – thinning 60-km horiz., 50 mb vert.

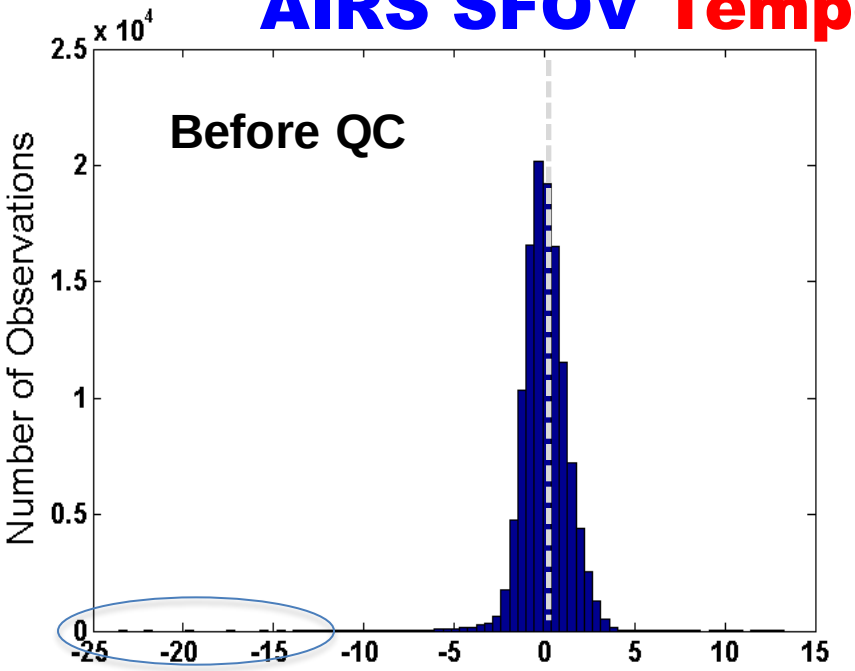
NEW T DATA – 60-km horiz, 50 mb vert.
2X std. error (400-800 mb)

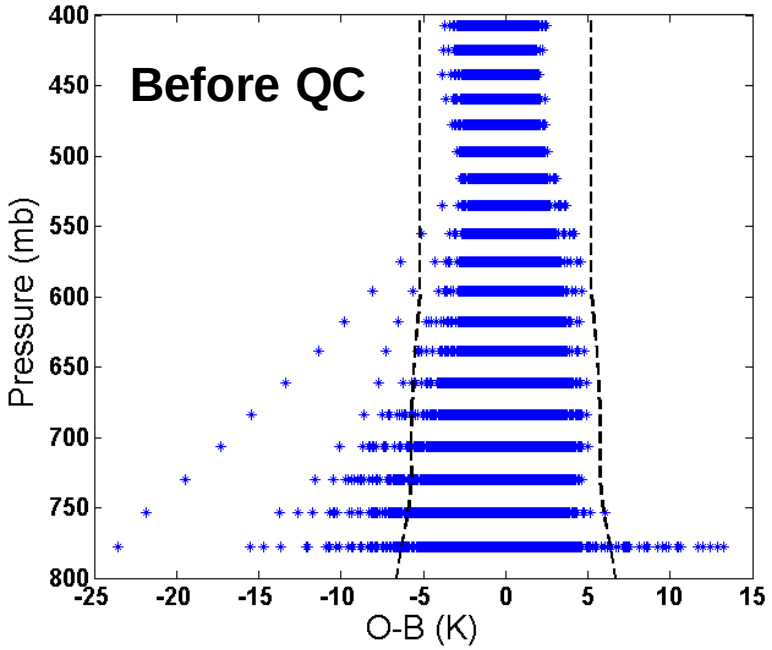
NEW T QC – Reject for abs(O-B) > 4 K

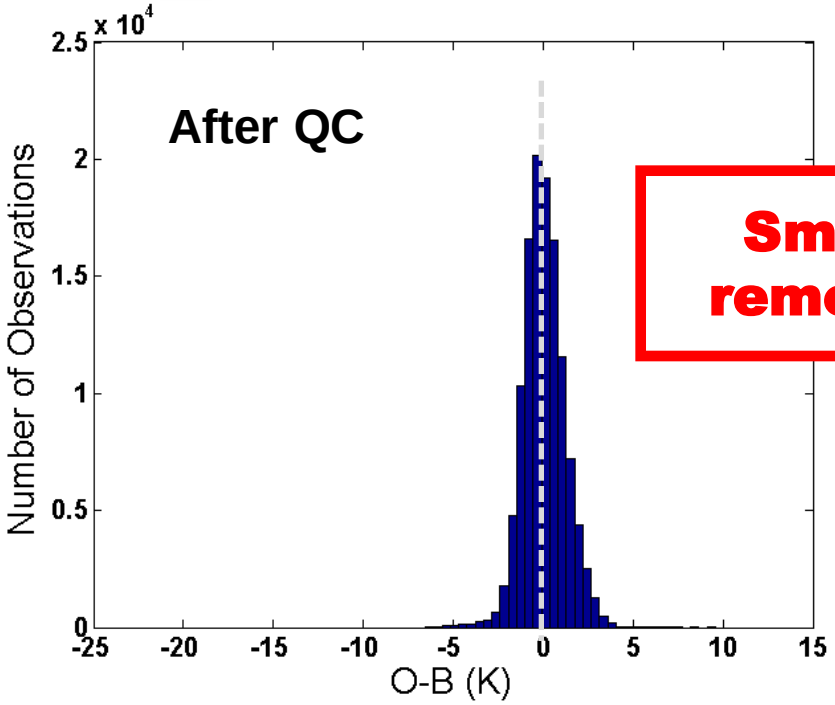




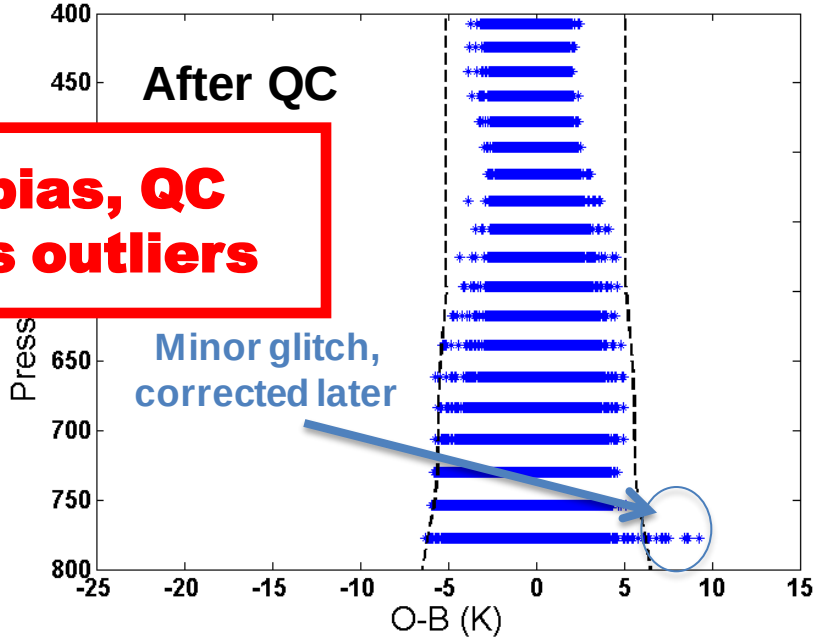
AIRS SFOV Temperature Innovations







Small bias, QC removes outliers

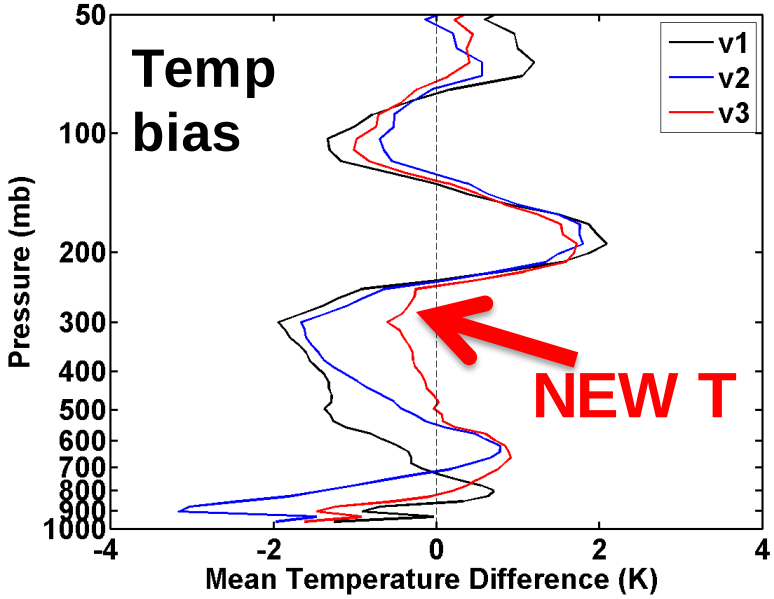


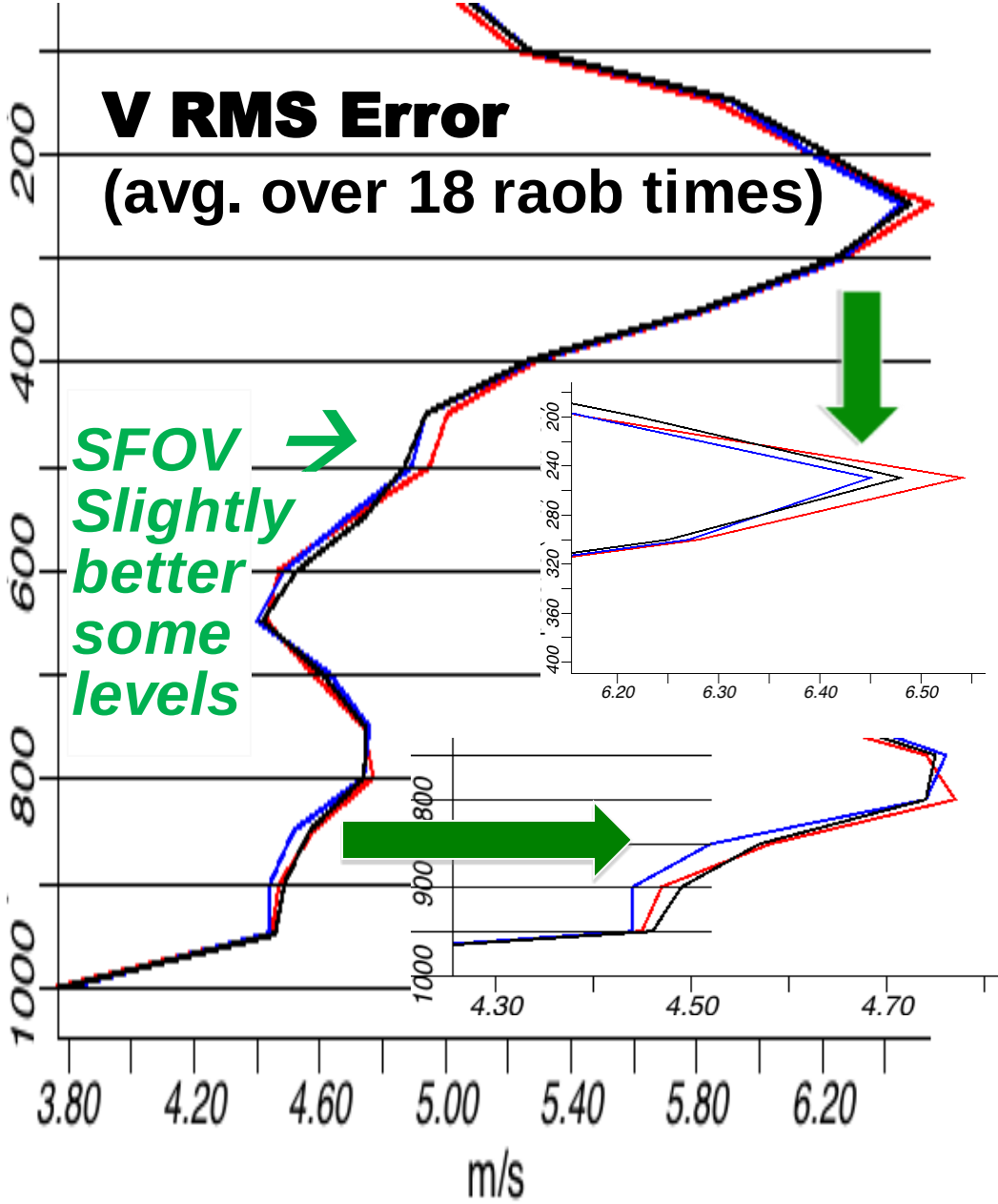
+12-h forecast wind errors (against raobs)

CNTL (control run)
Conventional data)

NEW T (CNTL + AIRS SFOV T)
400-800 mb, 2x std. obs error
60 km/50 mb horiz/vert thinning

NEW T QC (CNTL + SFOV T)
Above + reject for abs(O-B) > 4 K



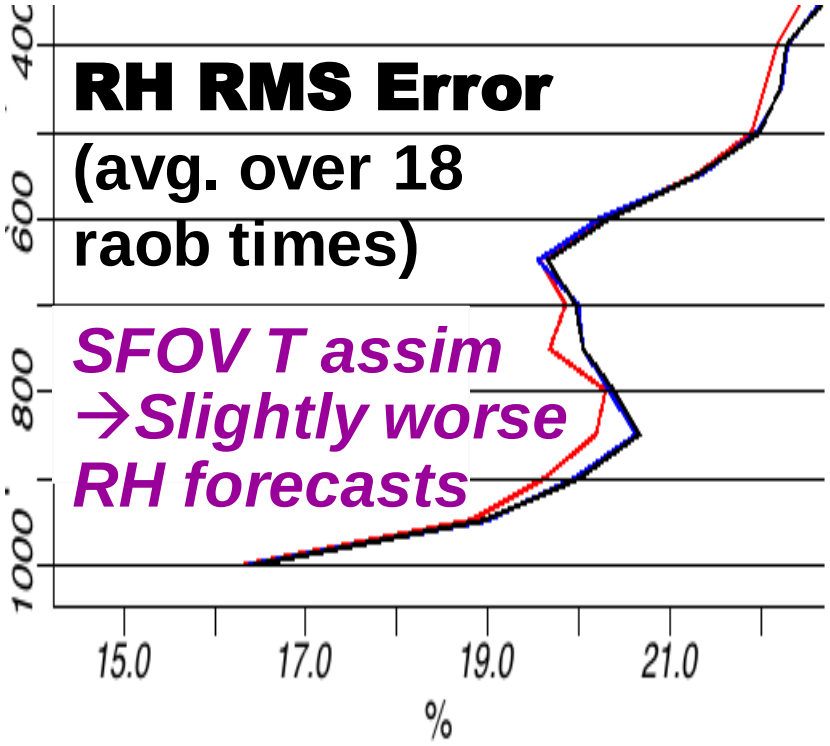


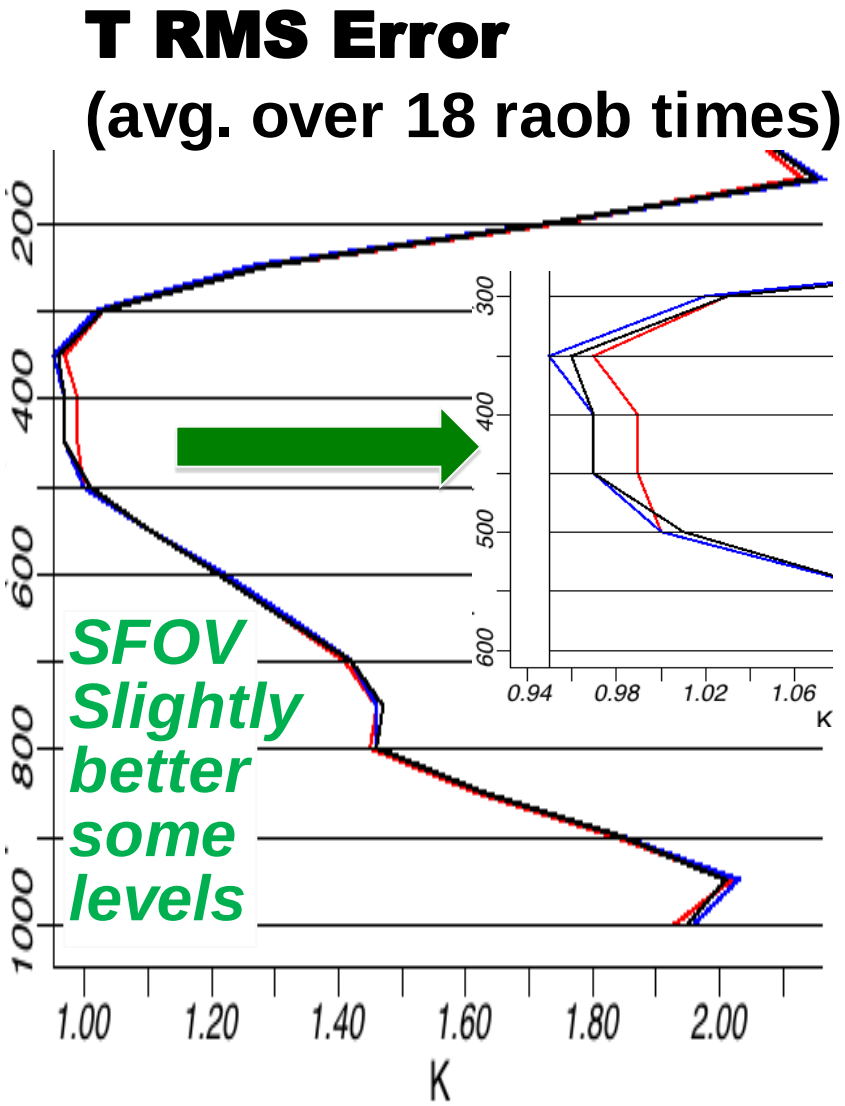
+12-h fcst T and RH errors (against raobs)

CNTL (control run)
Conventional data)

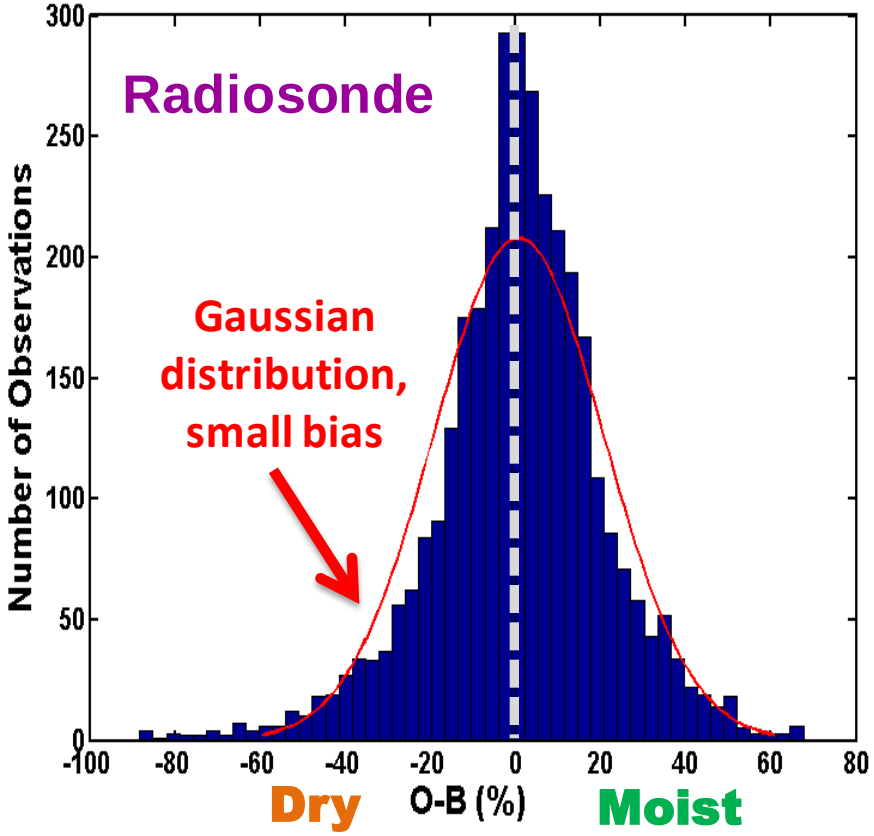
NEW T (CNTL + AIRS SFOV T)
400-800 mb, 2x std. obs error
60 km/50 mb horiz/vert thinning

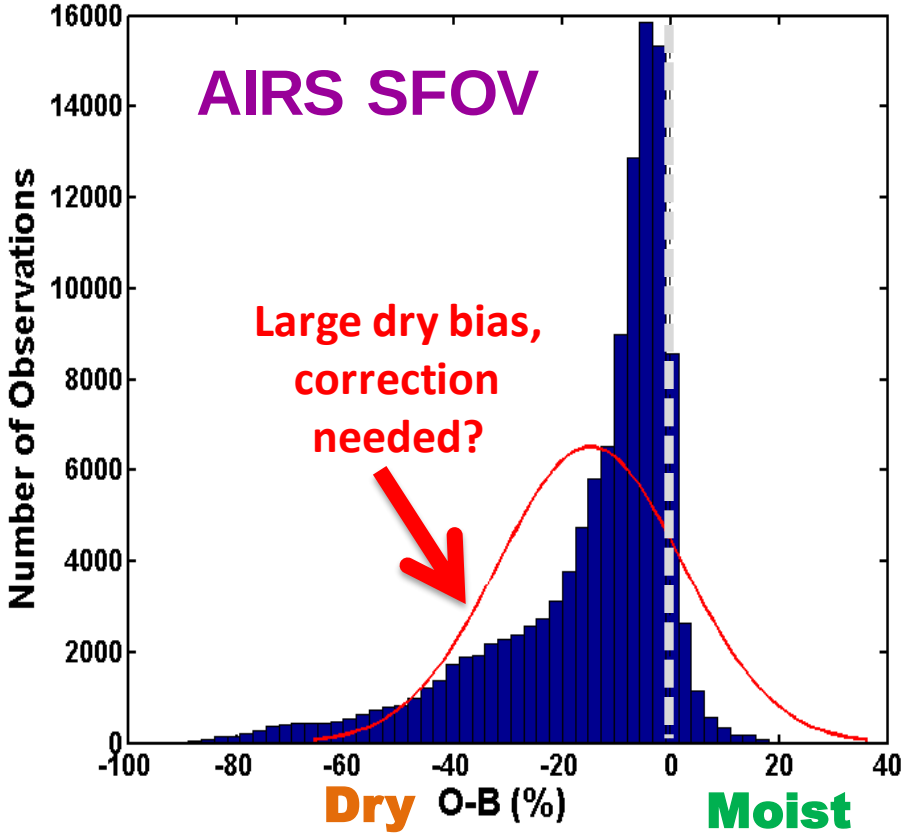
NEW T QC (CNTL + SFOV T)
Above + reject for abs(O-B) > 4 K





Histograms of moisture innovations (O-B): radiosonde vs. SFOV retrievals

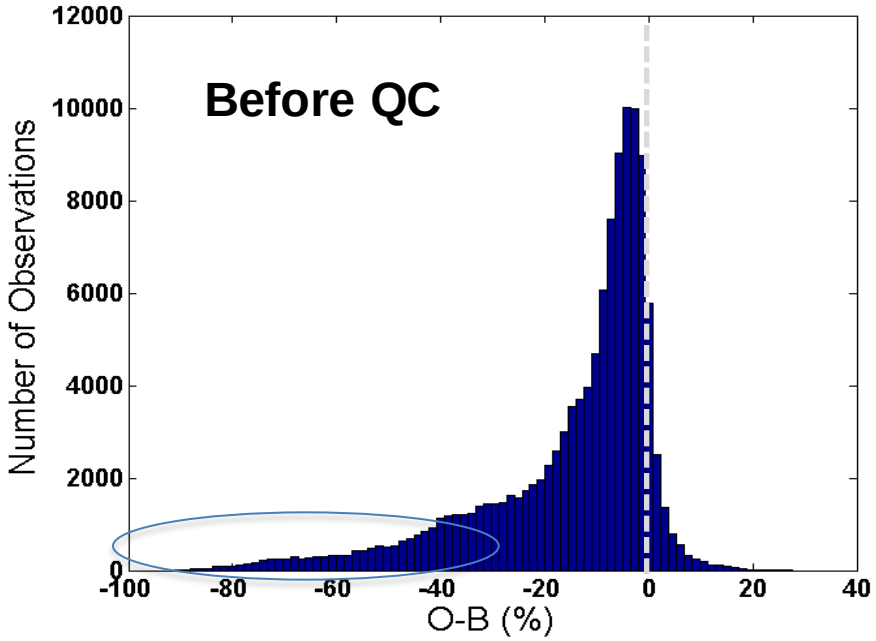


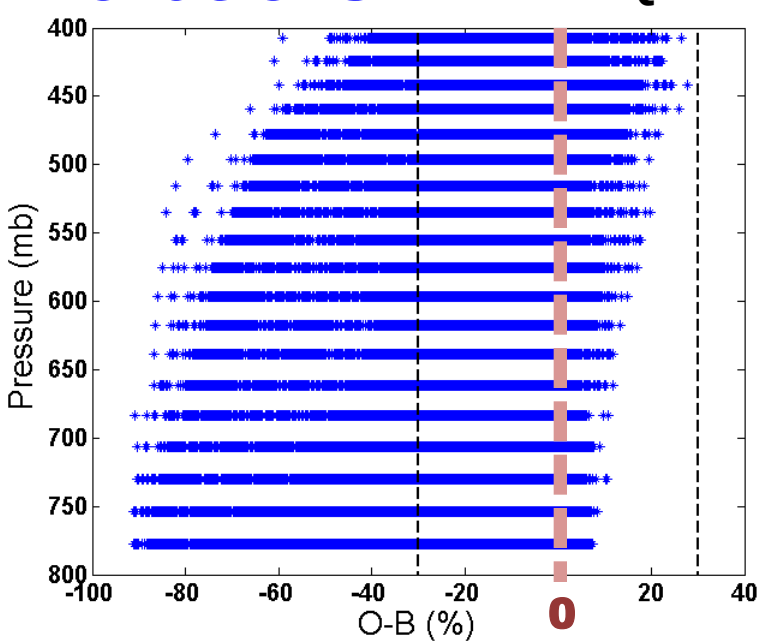


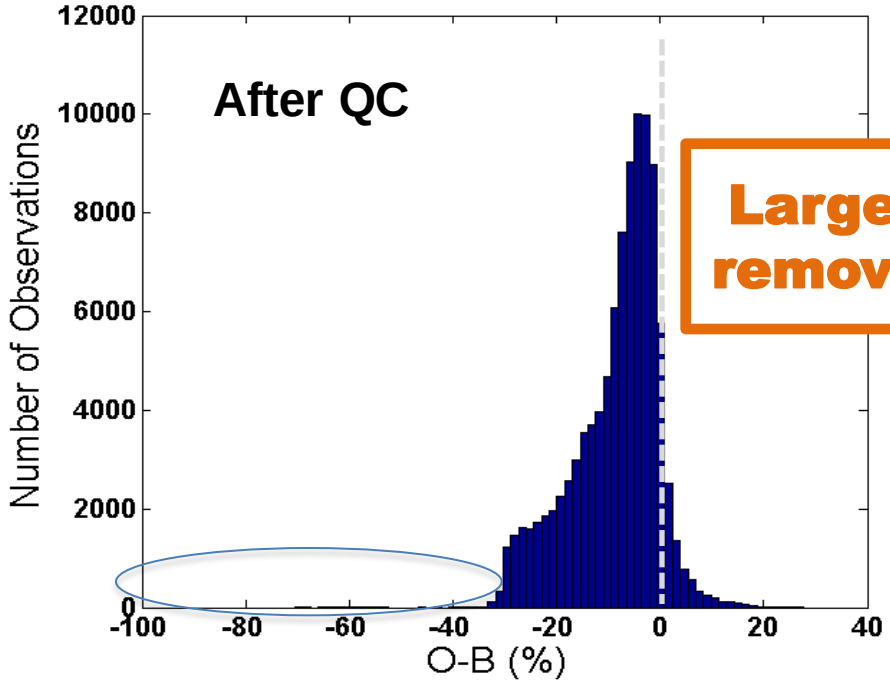
Scientific question:

Should mean moisture innovation for retrievals restricted to clear air columns be near zero?

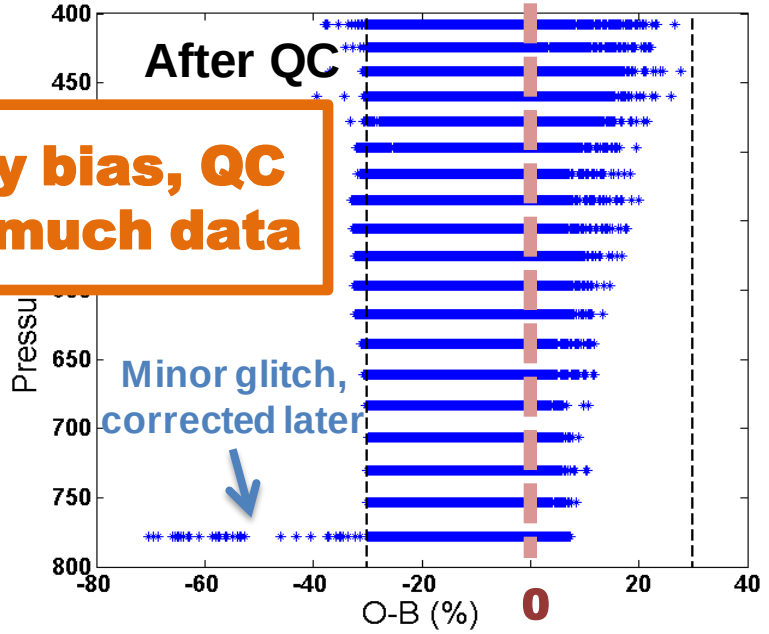
AIRS SFOV Moisture Innovations



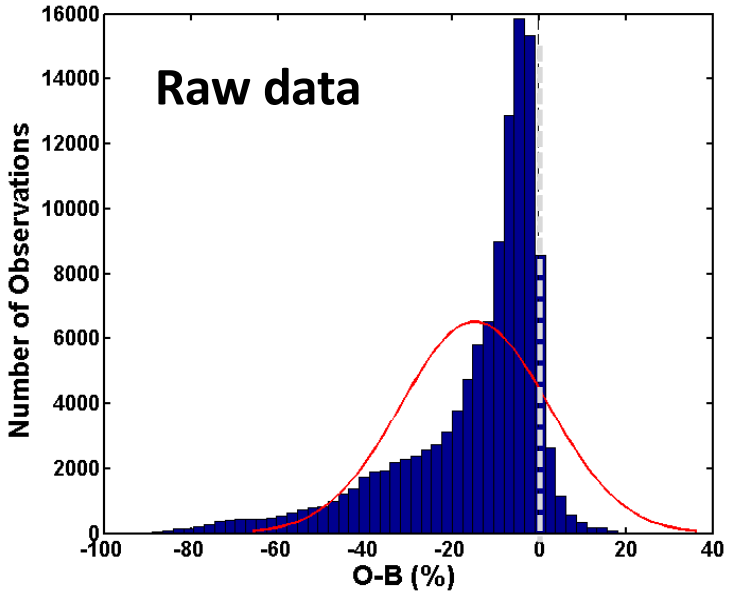


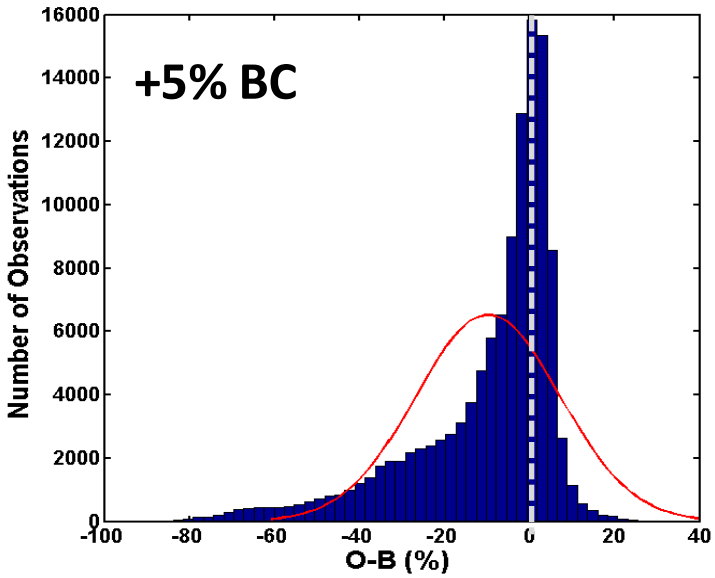


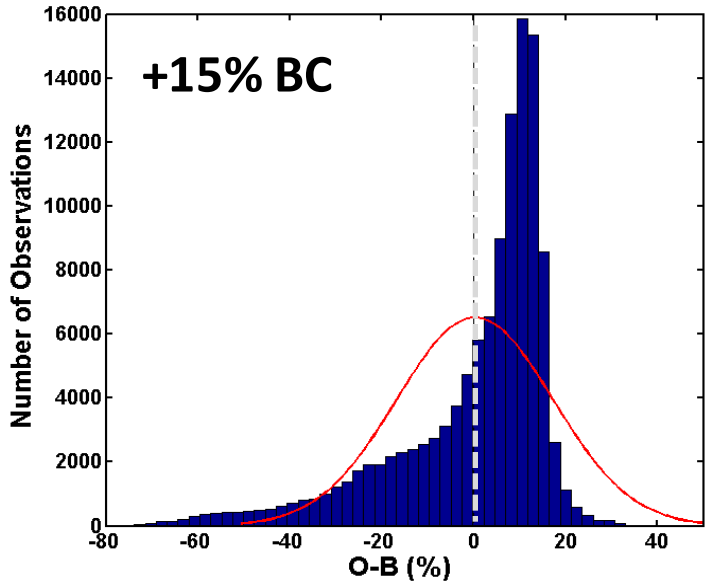
Large dry bias, QC removes much data

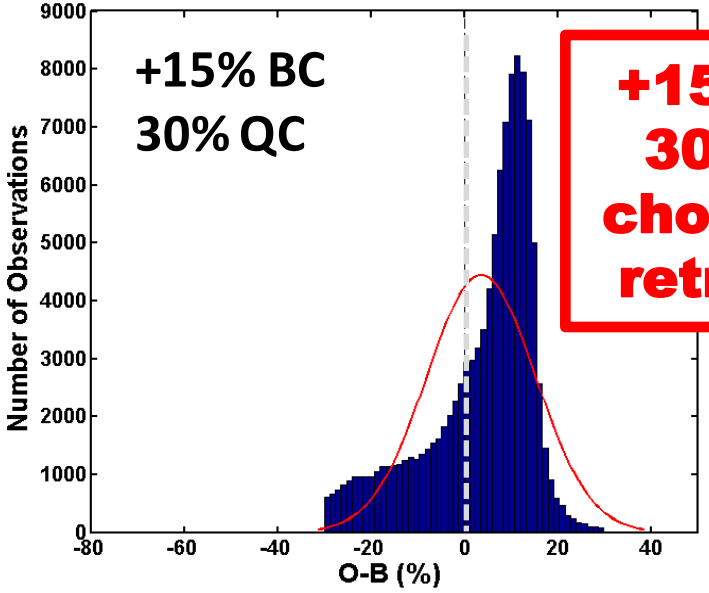


Apply bias correction (BC) and gross QC (QC) to AIRS SFOV moisture innovations







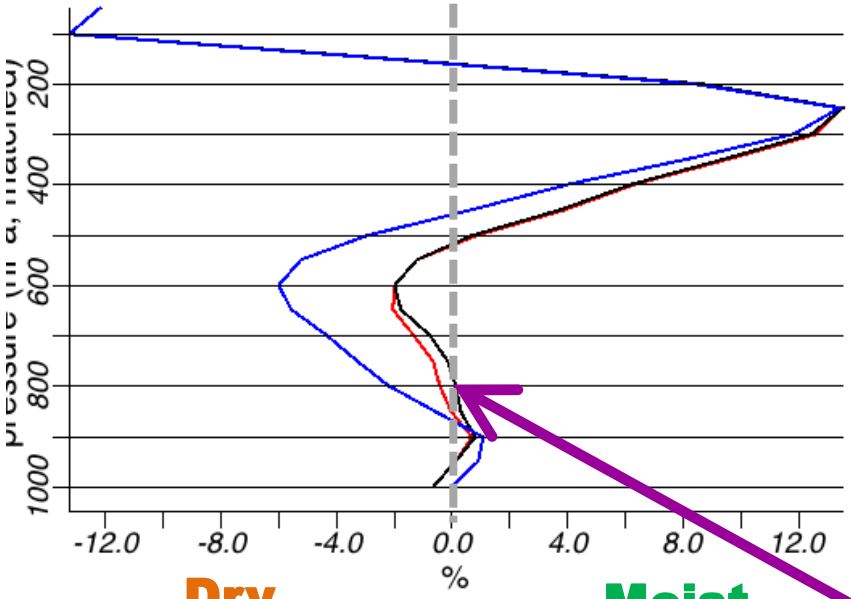


+15% BC, 30% QC chosen for retro test

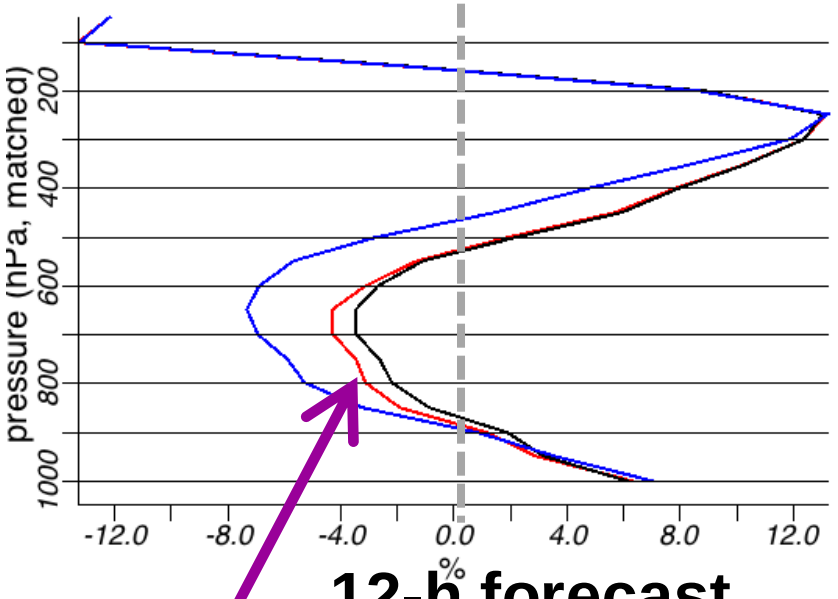
Retrospective runs for SFOV moisture with and w/o bias correction (BC)

- **Control (no SFOV Qv)**
  - conventional data, no SFOV retrieval
- **SFOV Qv w/o BC (30% gross QC, no bias correct)**
  - Control + water vapor (400-800 mb), using 30% as errors for all levels, rejecting any residual larger than 30%, rejecting all near surface data (under 150 mb period)
- **SFOV Qv WITH BC (30% QC + 15% bias correct)**
  - Same as “SFOV QV w/o BC” except add bias correction (+15% of first guess saturation specific humidity)

Impact of SFOV moisture on bias relative to radiosonde moisture



Dry Analysis Moist



12-h forecast

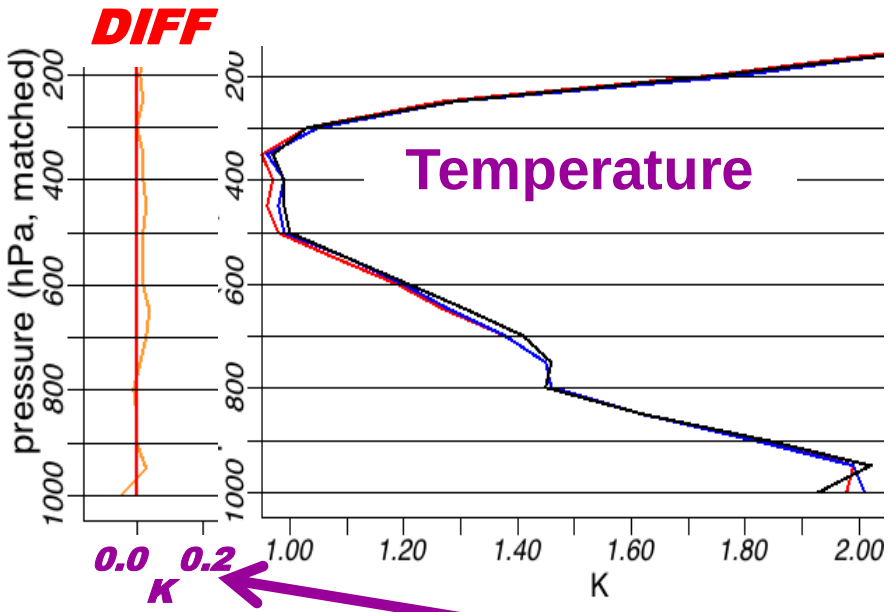
Control (no SFOV Qv)

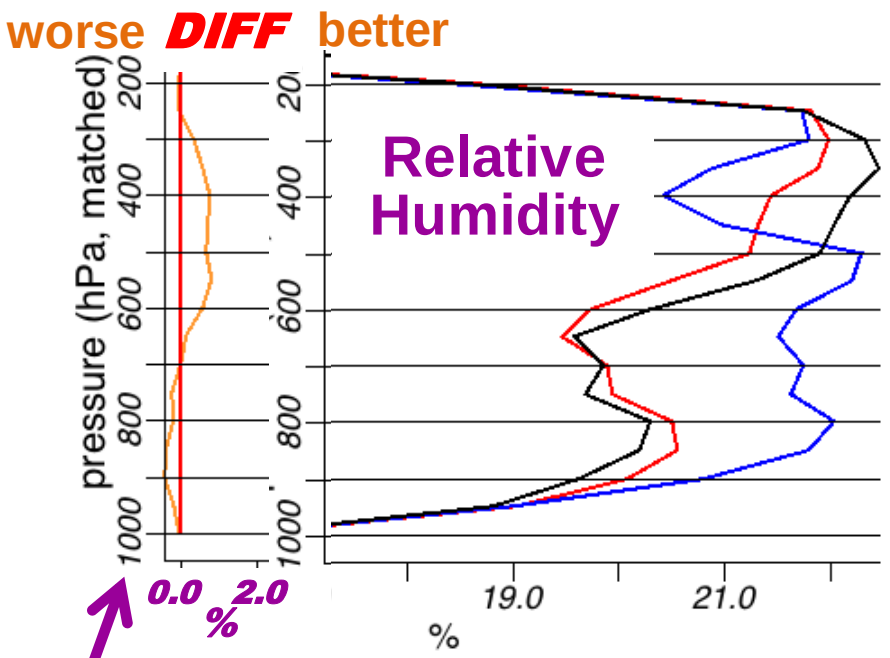
SFOV Qv w/o bias correct

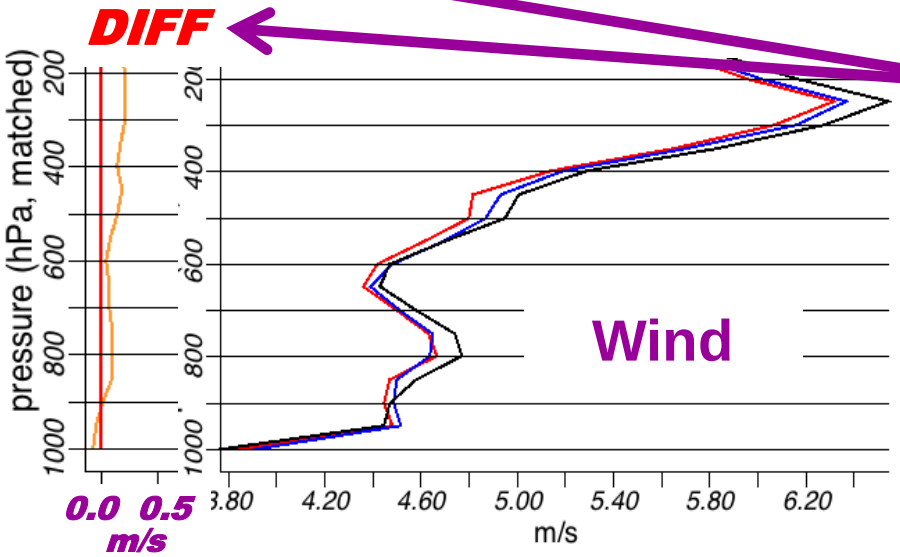
SFOV Qv WITH bias correct

SFOV bias correction procedure significantly reduces analysis and forecast dry bias

Impact of SFOV moisture on +12-h forecast RMS errors relative to raobs







SFOV with bias correction better than control for nearly all level and all variables

Control (no SFOV Qv)

SFOV Qv w/o bias correct

SFOV Qv WITH bias correct

CNTL

vs.

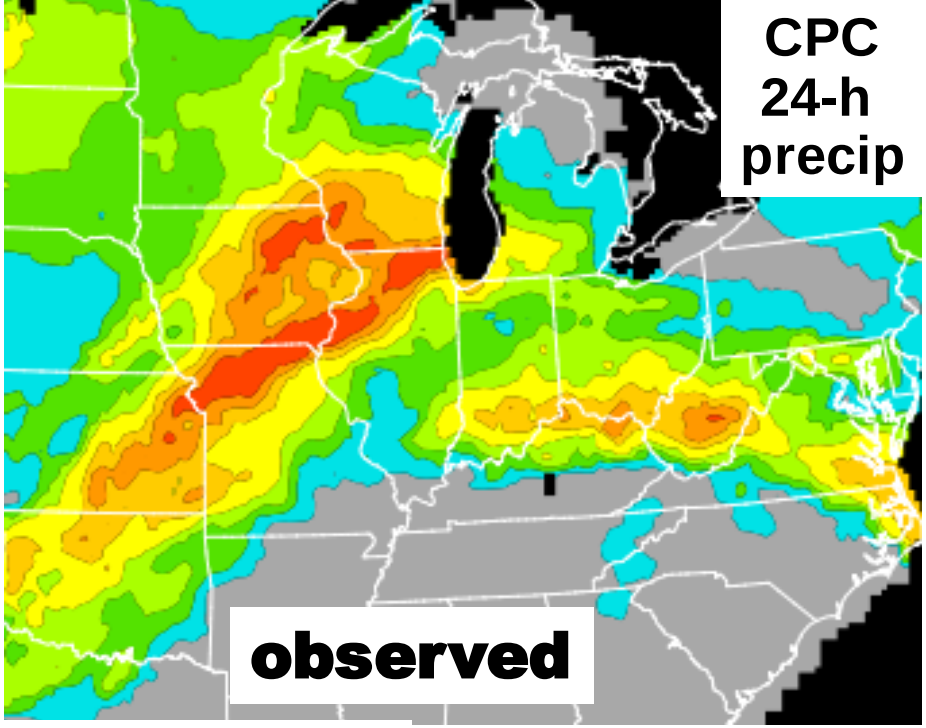
SFOV

T + Q bc

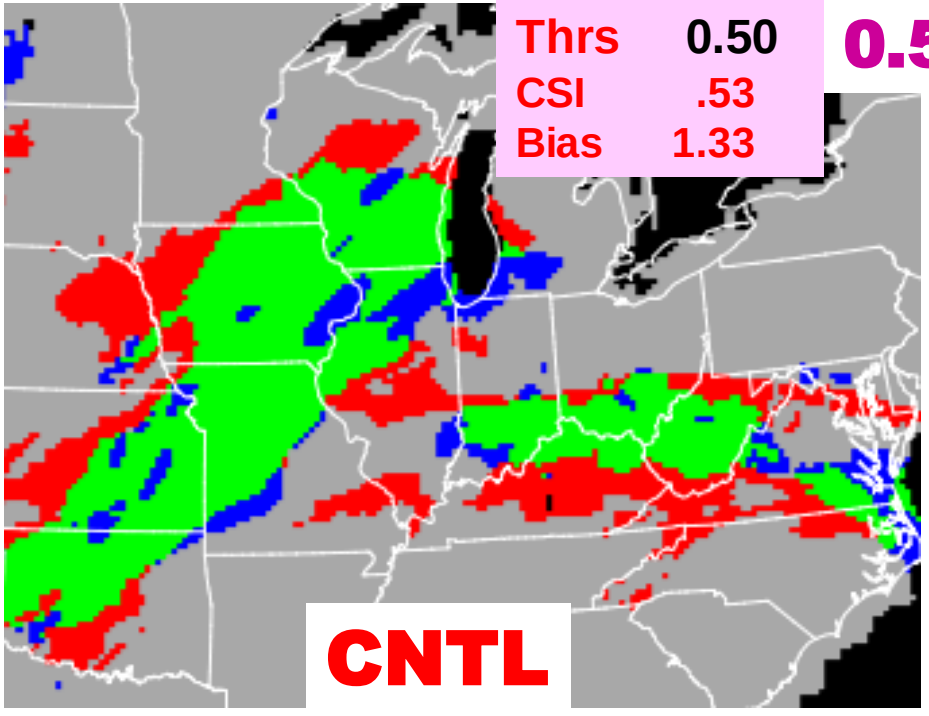
24-h precip. verif

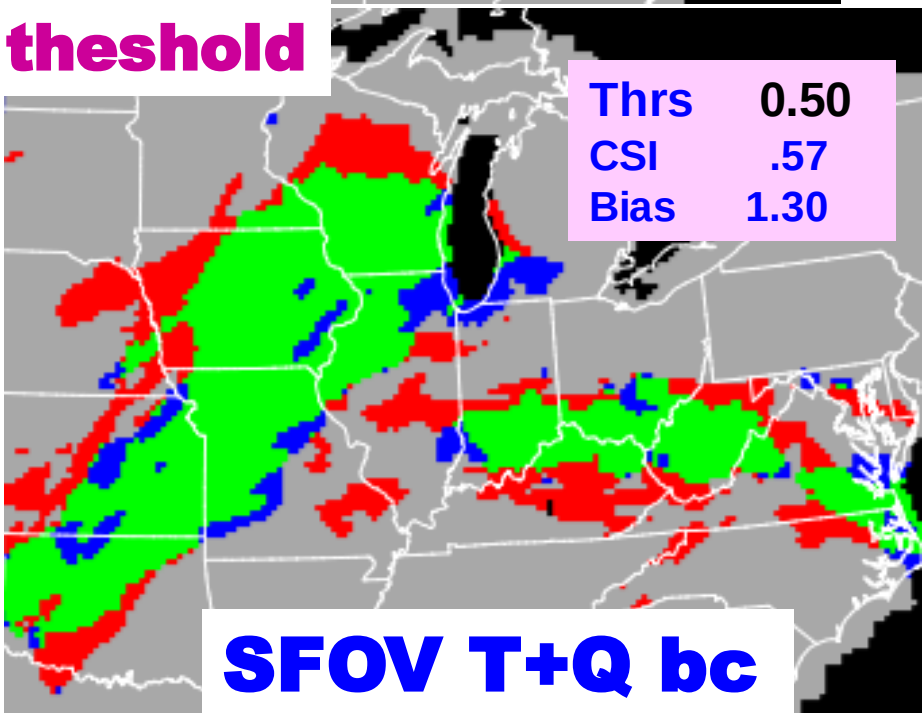
2 x 12h fcst ending 12z 13 May 2011

Verified on common 13-km grid



0.5" theshold

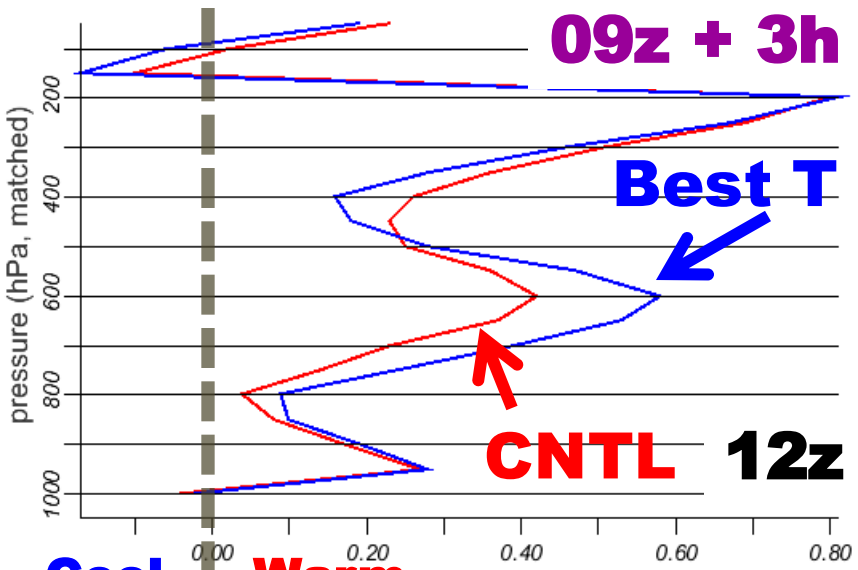


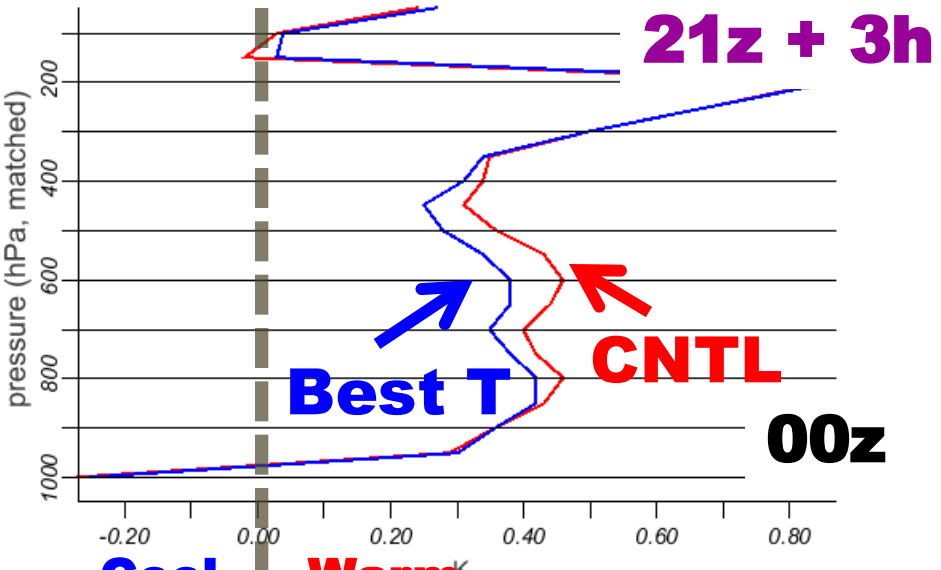


Summary of Moisture Experiments

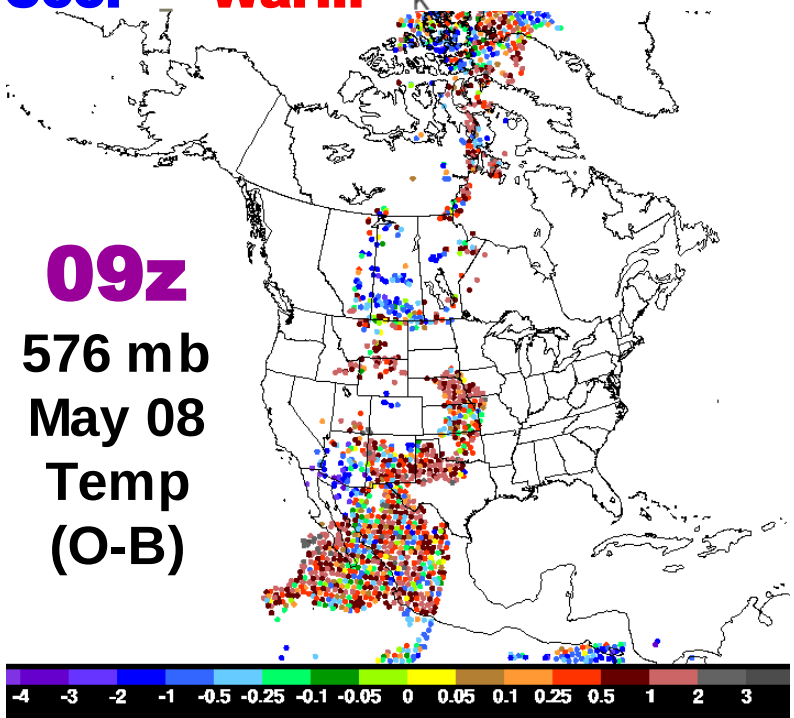
- SFOV moisture innovations have dry bias compared with the background, also non-Gaussian distribution
  - -- Dry innovation bias more pronounced at low levels
  - -- Analsyis with SFOV moisture dry compared to raobs
- Bias correction (BC) and gross quality control (QC) check applied to the SFOV moisture data
  - → Improved innovation distribution
  - → Greatly reduced dry bias in relative humidity for analysis and forecast
  - → Significant improvement in relative humidity forecast skill from inclusion of bias correction
  - → With BC and QC, SFOV moisture data improve forecasts for nearly all fields and levels

+3h fcst T bias (vs. raobs) – diurnal aspects



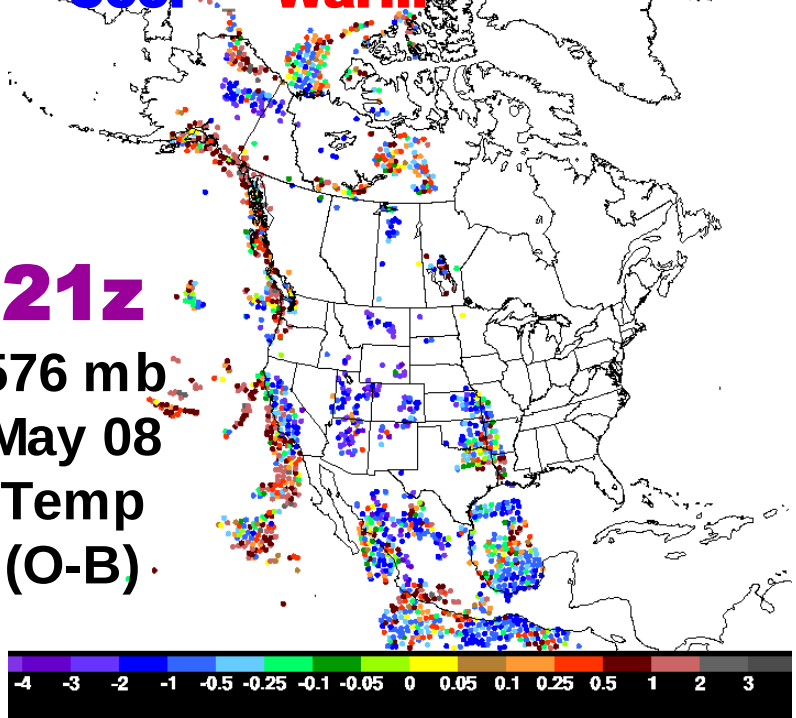


Cool Warm K



09z
576 mb
May 08
Temp
(O-B)

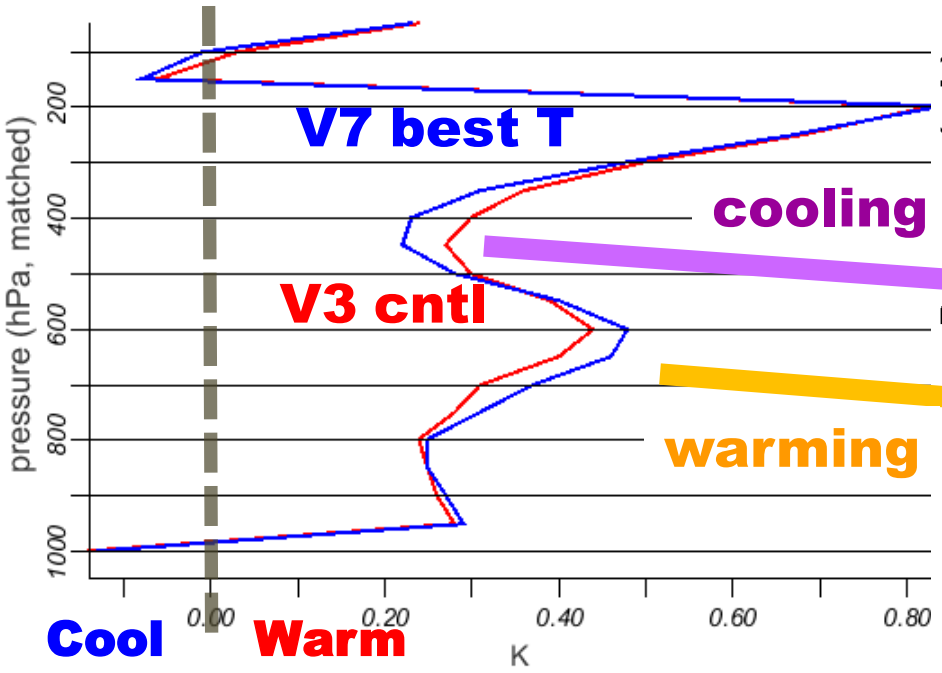
Cool Warm K



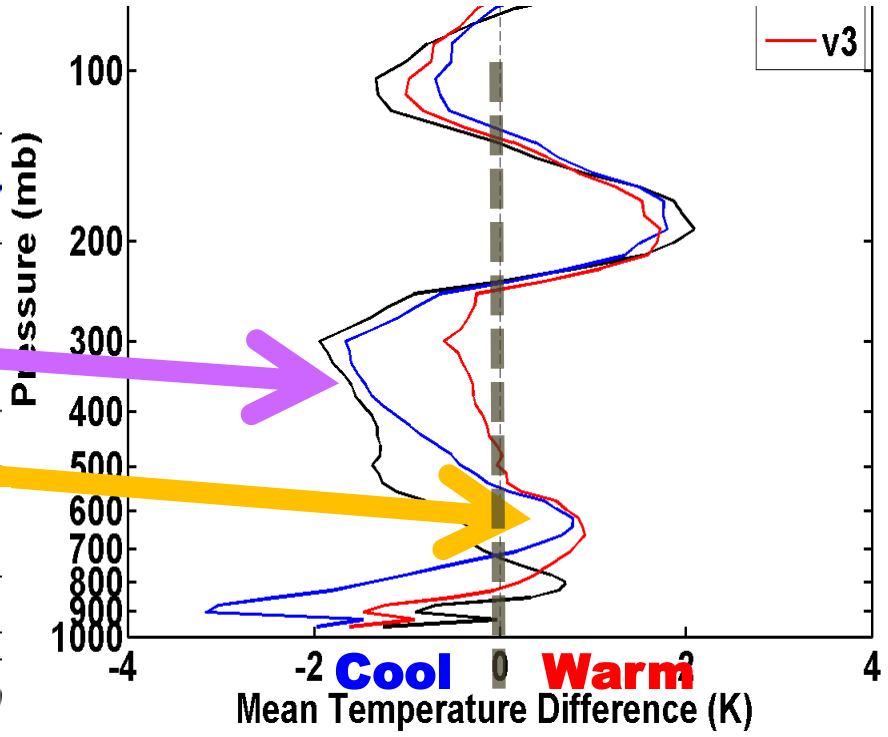
21z
576 mb
May 08
Temp
(O-B)

Overall T bias (vs. raobs) – no diurnal aspects

+3h fcst T bias (00z,12z)

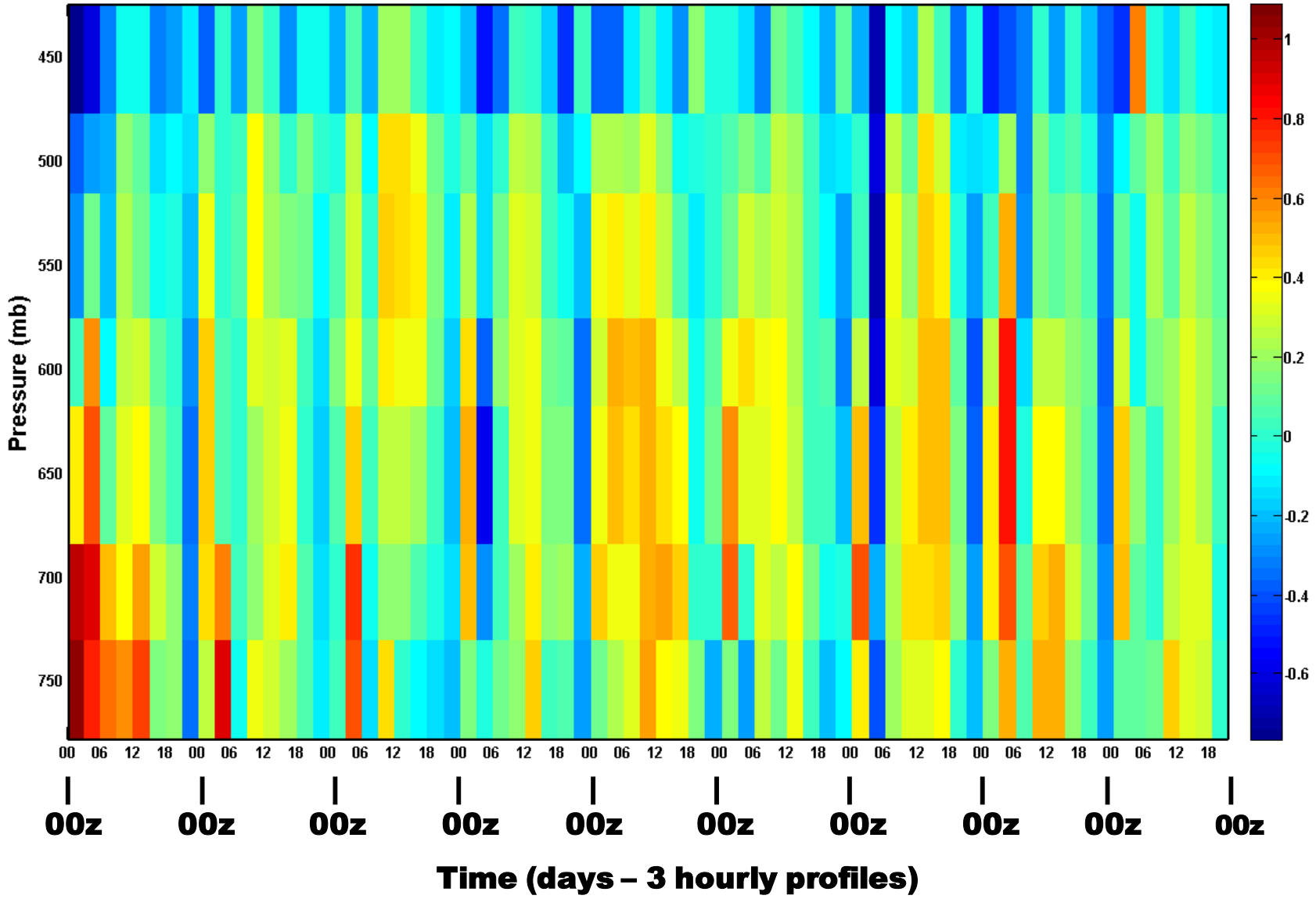


Comparison of SFOV T to radiosonde data

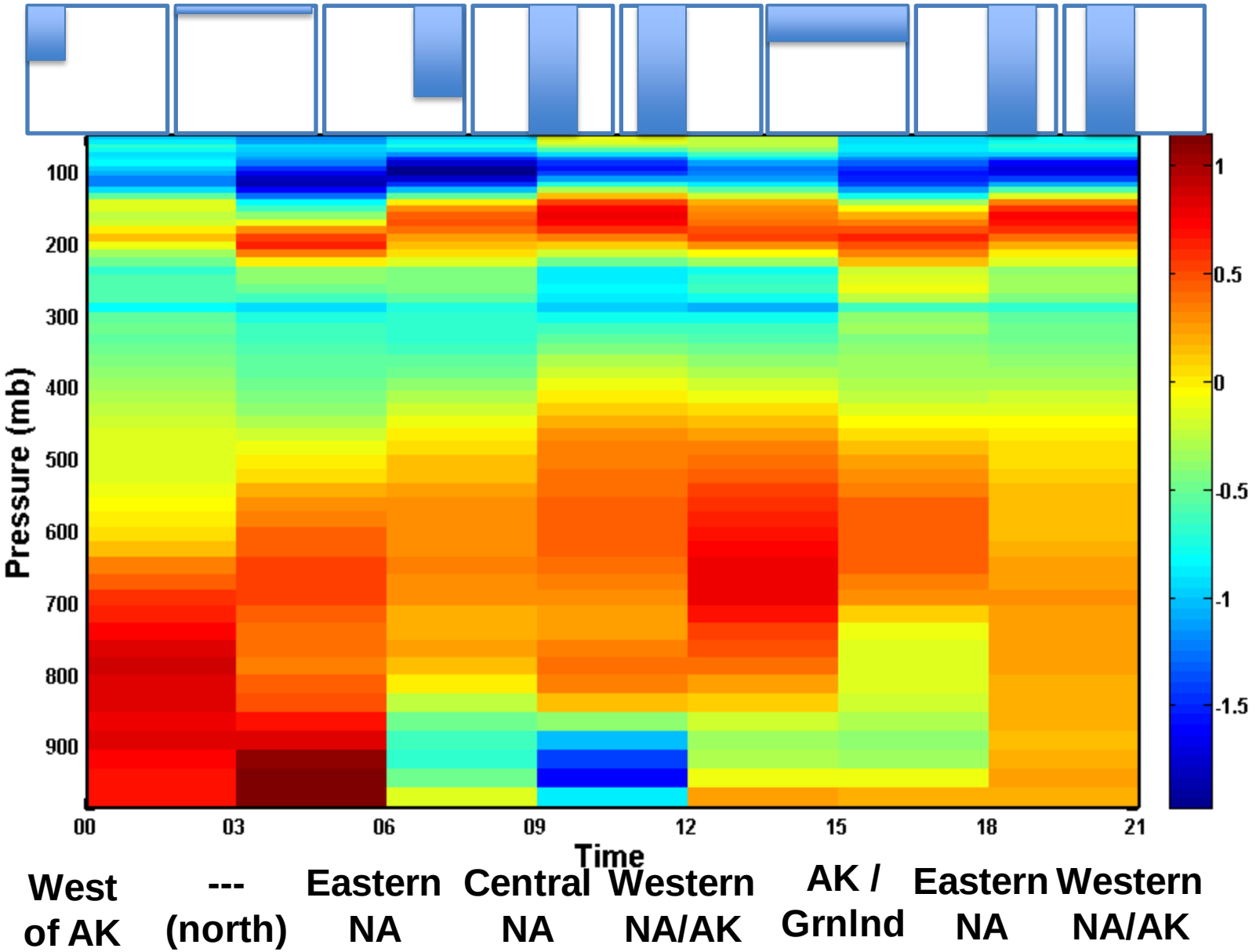


- Correspondence between raob comparison, fcst impact
- Overall average masks diurnal signal
- Model bias as well as observation bias

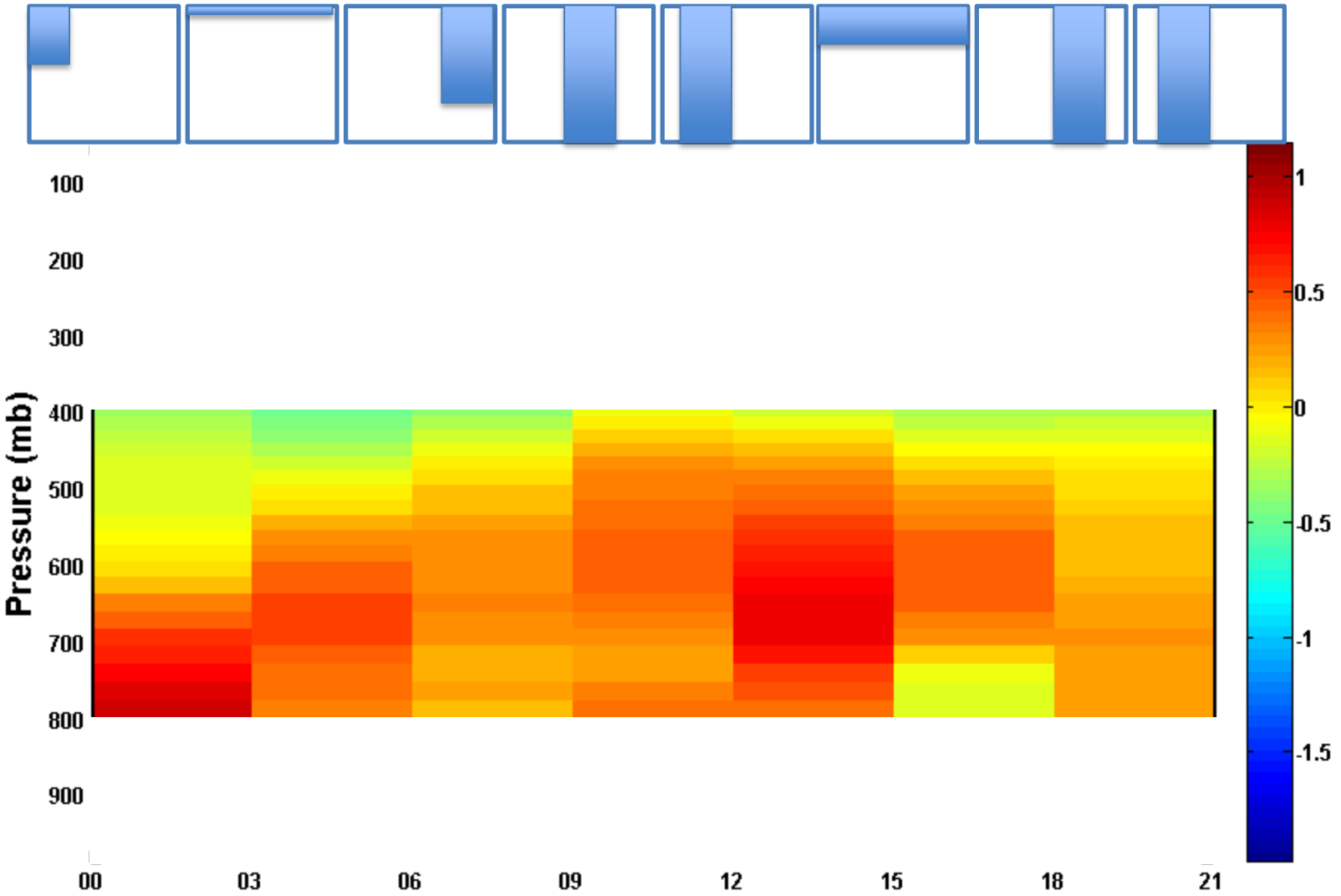
Time height X-section of horizontal avg. SFOV T innovation (O-B)



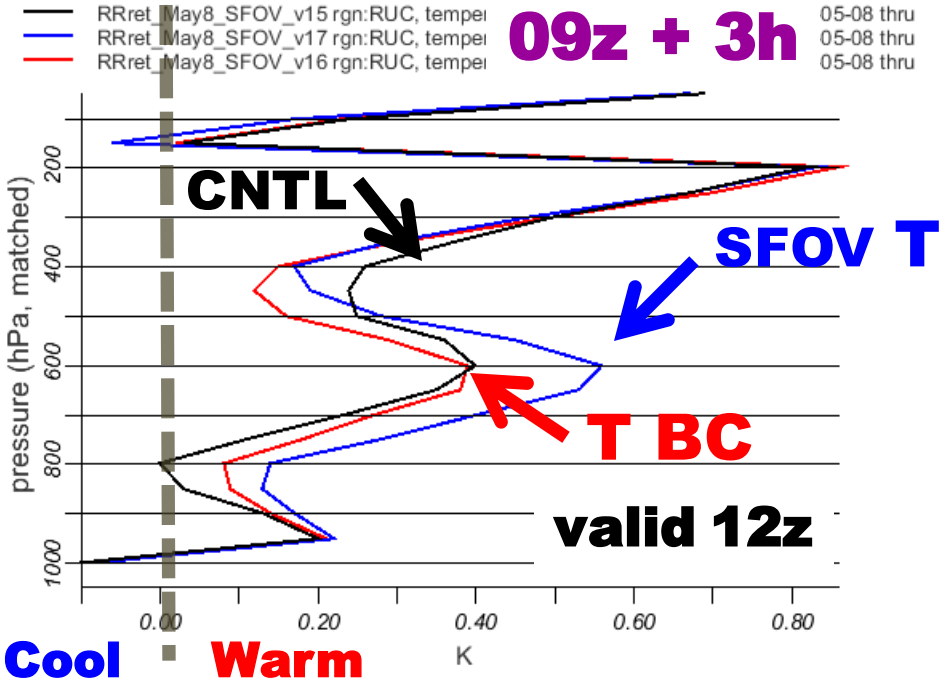
Diurnal aspect to horizontal avg. SFOV T (O-B)

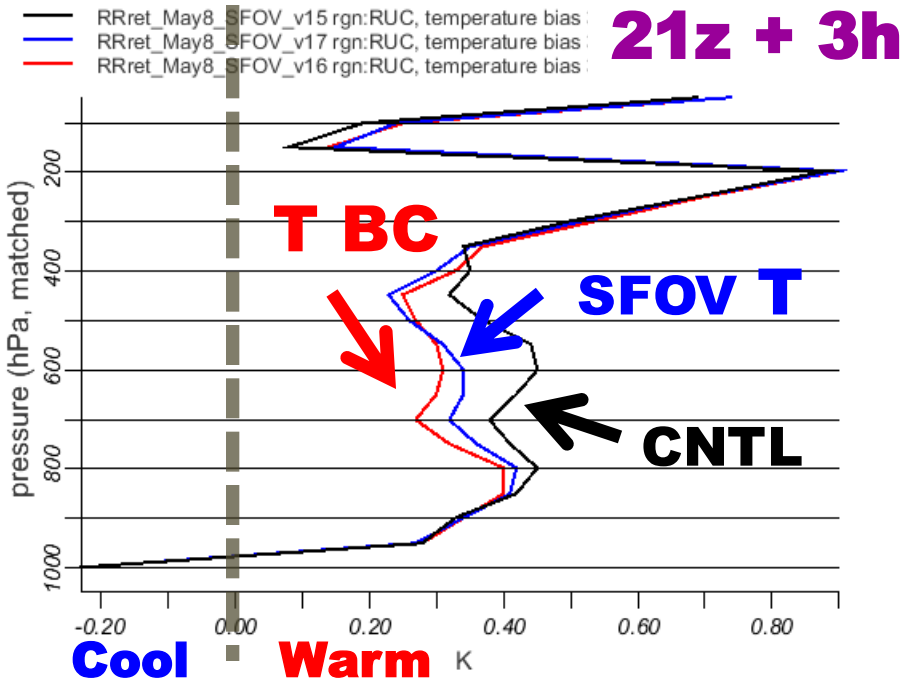


Diurnal aspect to horizontal avg. SFOV T (O-B)



+3h fcst T bias (vs. raobs) – evaluation of impact of T bias correction



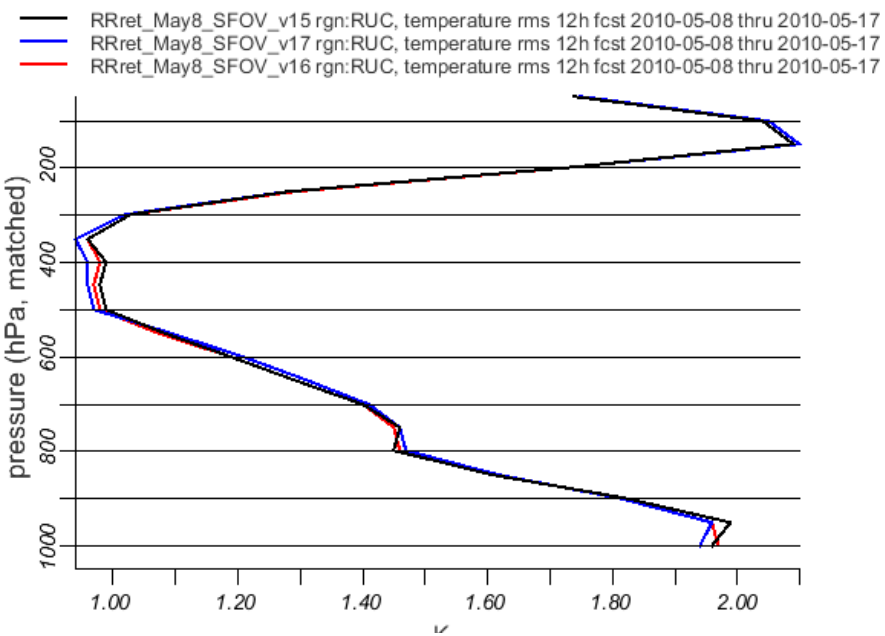


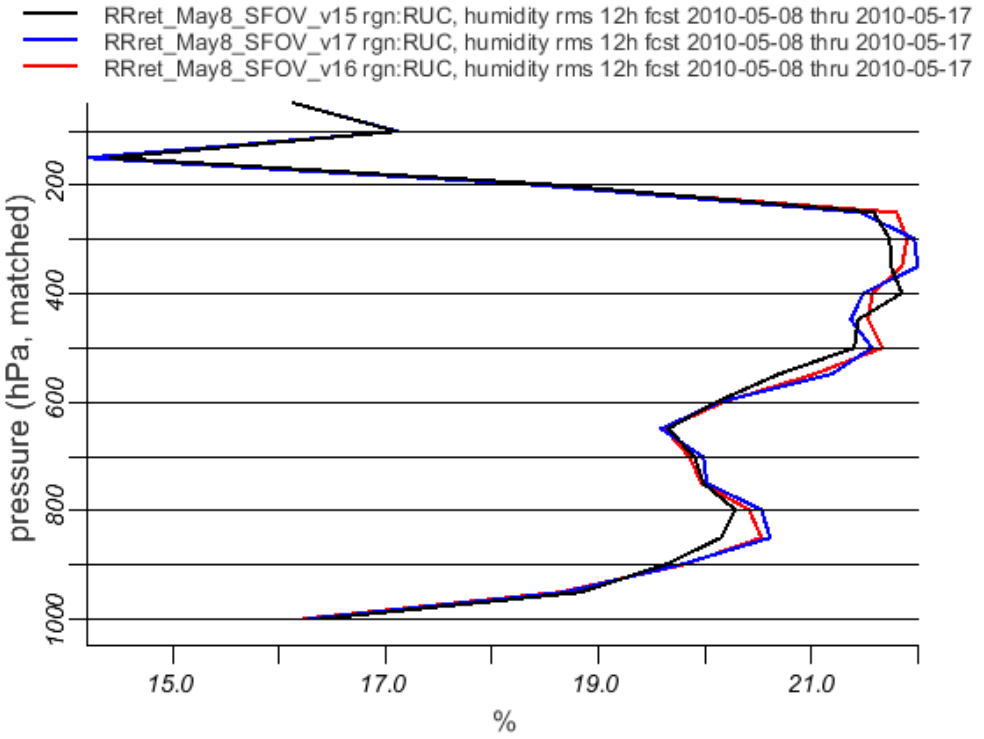
→ **First attempt at T bias correction**

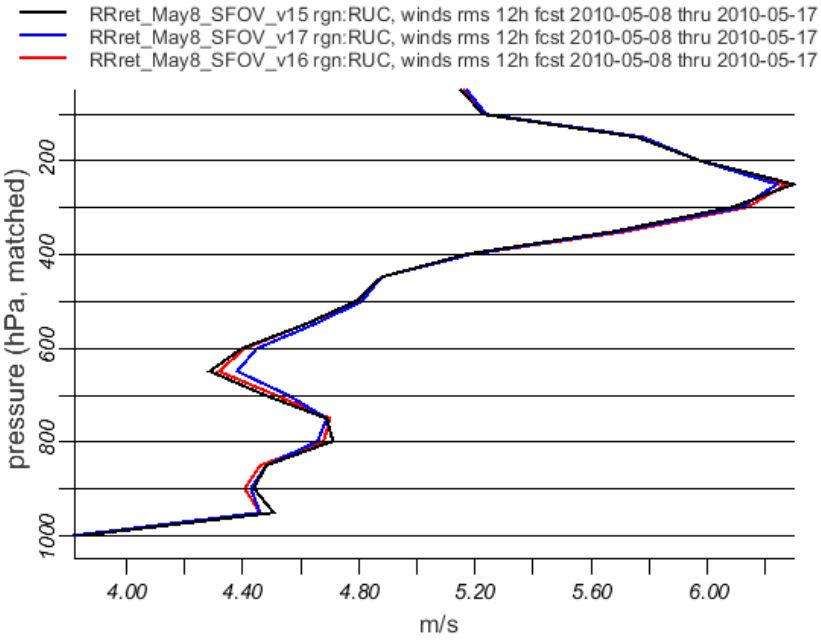
– Improvement in mid-level T bias at 12z

– Slightly larger departure from CNTL bias at 00z

12-h forecast RMS Error







CNTL

SFOV T

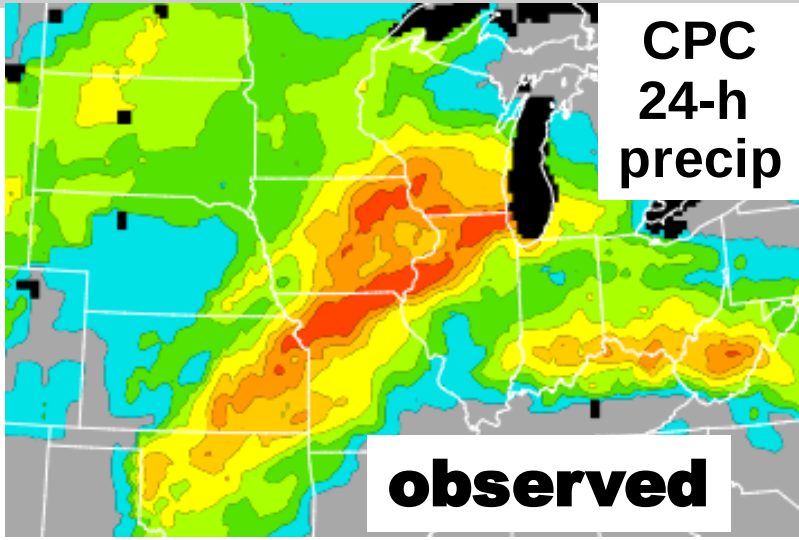
T bias correct

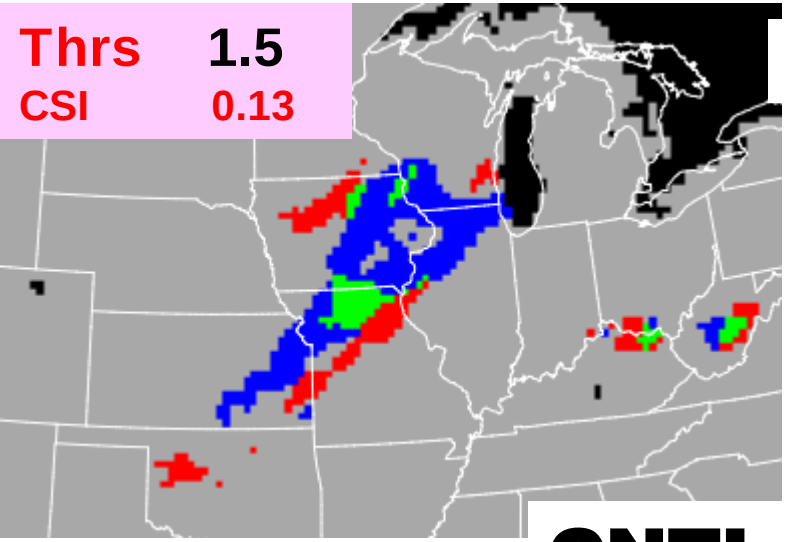
Sample Precipitation Impact

CNTL vs. AIRS Ex. 2 24-h precip. verif

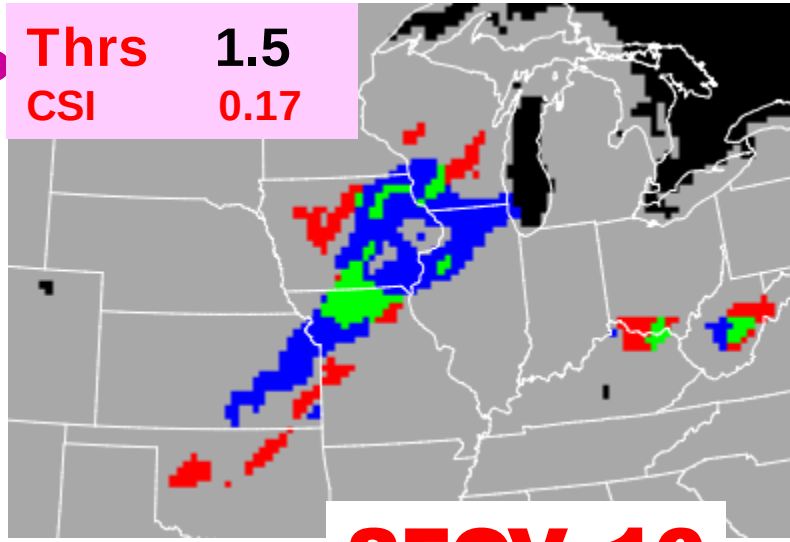
2 x 12h fcst ending 12z 13 May 2010

Verified on common 20-km grid





1.5 ” thesho



Summary and Future Work

Results so Far

Initial SFOV T assimilation yielded slight improvement after several modifications (mid-level only, data thinning, larger observation error, enhanced QC)

SFOV moisture assimilation gives modest forecast improvement after implementation of simple bias correction / QC algorithm

Analysis of SFOV T innovations revels diurnal bias pattern pattern relative to RAP background, which has its own (mostly warm) bias relative to observations

Ongoing and future work for 2011-2012

Initial SFOV T assimilation with simple bias correction shows bias reduction for 12z, but not 00z.

Further evaluation of SFOV T bias (possibly using aircraft data for verification) and refinement of T bias correctuion

Addition assimilation experiments with bias correction, including nested HRRR runs from RAP with SFOV temp. and moisture