EVALUATION OF A GPSRO & IR TEMPERATURE & RADIANCE DATASET FOR CONTINUED CLARREO STUDIES

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OUTLINE

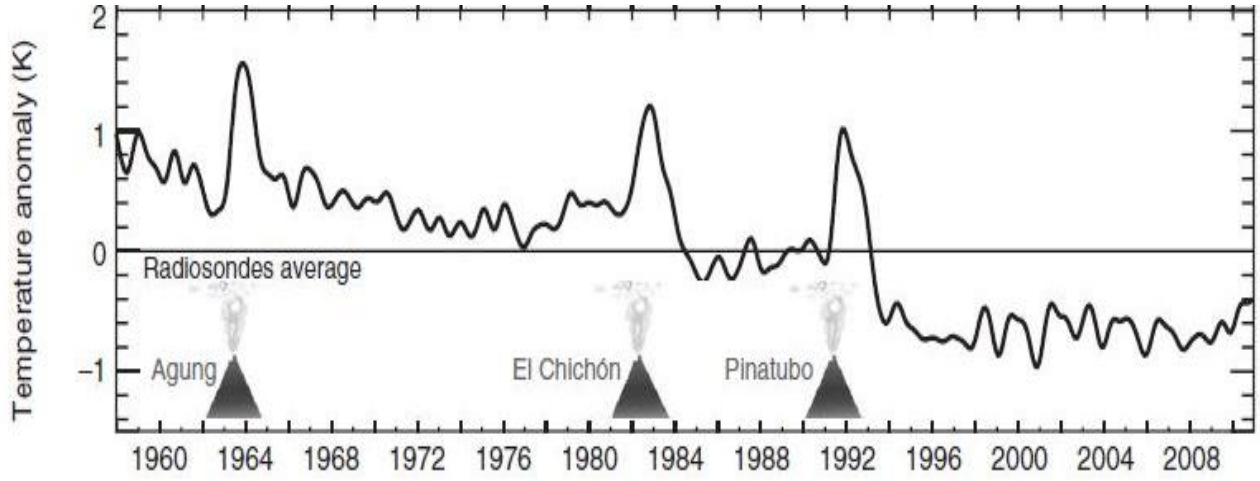
- Motivation: Stratospheric Temp. Trends
- CLARREO climate benchmark concept
- Space/Time L2 Matchup Approach
- Spatial Analysis
- Temporal Analysis
- Vertical Analysis
- Radiance Assessment Climate Zones
- Conclusions

Motivation:
Monitoring Stratospheric Temperature

Advanced Review

Stratospheric temperature trends: our evolving understanding

Dian J. Seidel,[1]* Nathan P. Gillett,[2] John R. Lanzante,[3] Keith P. Shine[4] and Peter W. Thorne[5]



- 50 year radiosonde Strat. Temperature record: cooling 1958-1995 then stable since 1996.

Stratospheric Satellite Trends

Advanced Review

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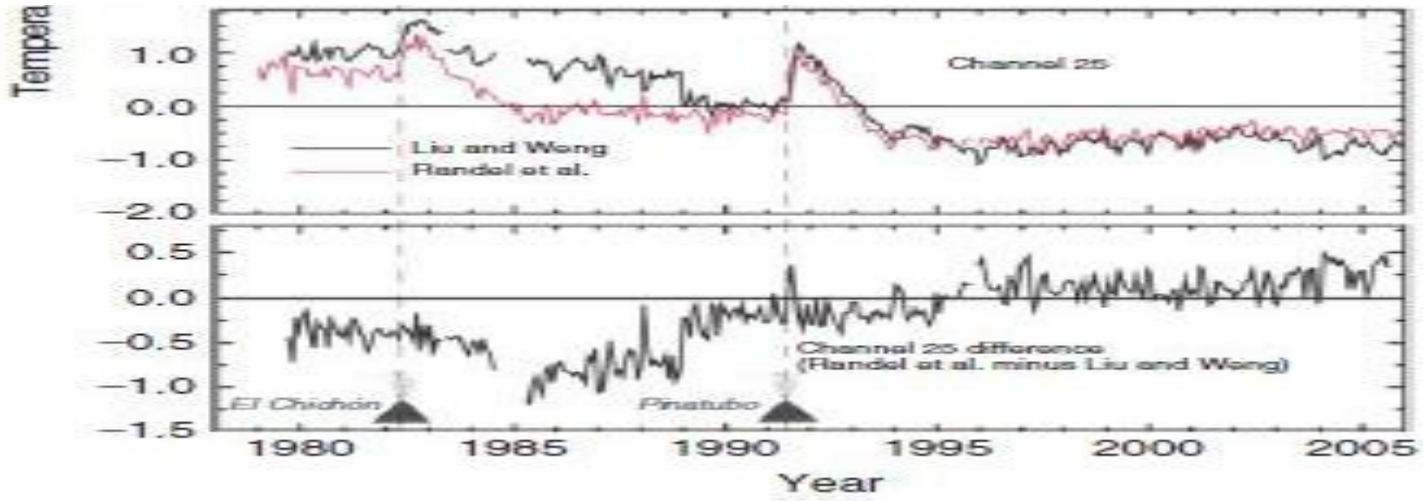

- 30 year SSU satellite record:
  seems to confirm radiosonde trend in Stratosphere with significant analysis uncertainties.

Stratospheric Temperature Weighting Functions: dR/dp

Heritage Sounders

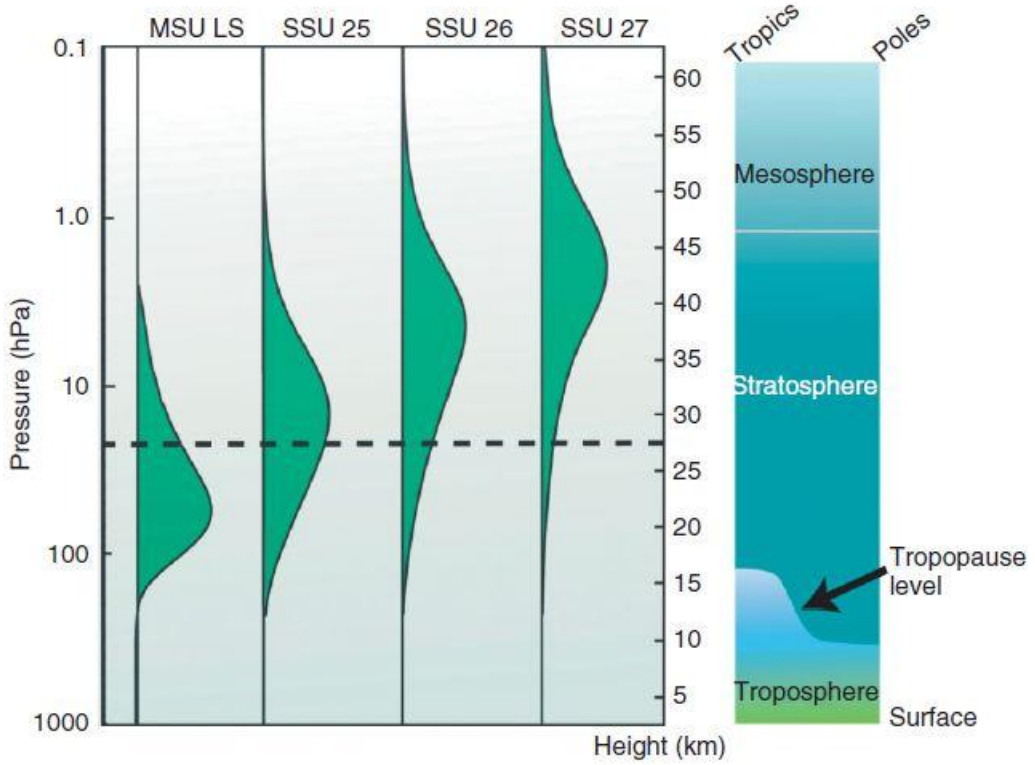

FIGURE 2 | Vertical sampling of satellite and radiosonde observations of stratospheric temperature. *Left*: vertical weighting functions for satellite Microwave Sounding Unit (MSU) and Stratospheric Sounding Unit (SSU) stratospheric temperature observations as a function of pressure (left axis) and height (right axis). The dashed line at about 27 km (30 hPa) indicates the typical maximum height of historical global radiosondes data coverage (Figure 1). *Right*: schematic of atmospheric vertical structure and its latitudinal variation. (Modified from Climate Change Science Program Synthesis and Assessment Product 1.1[4])

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- Dashed line indicates upper limit of radiosonde data (30 mb).
- **Can we use GPS RO and hyperspectral IR to provide a new reference for these trends? Yes!! (But we need to demonstrate how.)**

CLARREO IR and GPS Benchmark Concept

- GPS and IR have independent SI traceability paths (Time standard vs Temperature standard)

- GPS and IR have unique sampling characteristics which are complementary.

- A combined IR and GPS dataset could be used to assess the accuracy of a UTLS temperature climatology in either dataset individually.

- These are essential elements for making irrefutable claims about atmospheric temperature trends.

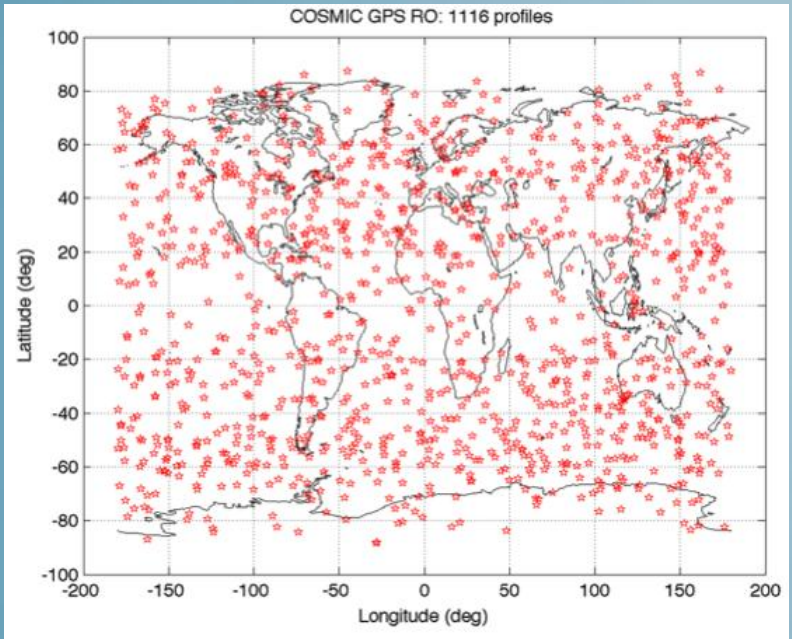
This study uses UCAR processing of the COSMIC GPS Radio Occultation observations.

CHAMP: 2001-2006

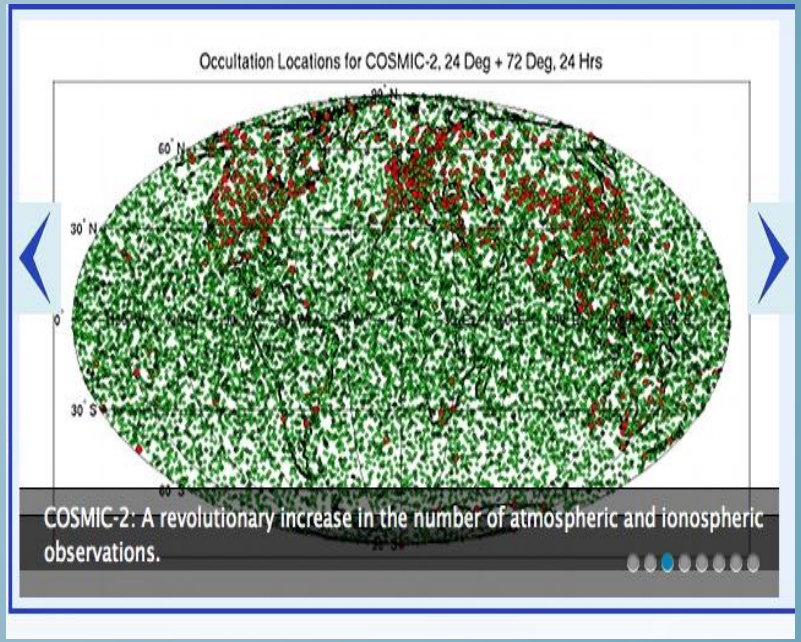
COSMIC-I: 2006-2014

COSMIC-II: 2015 +

COSMIC-I



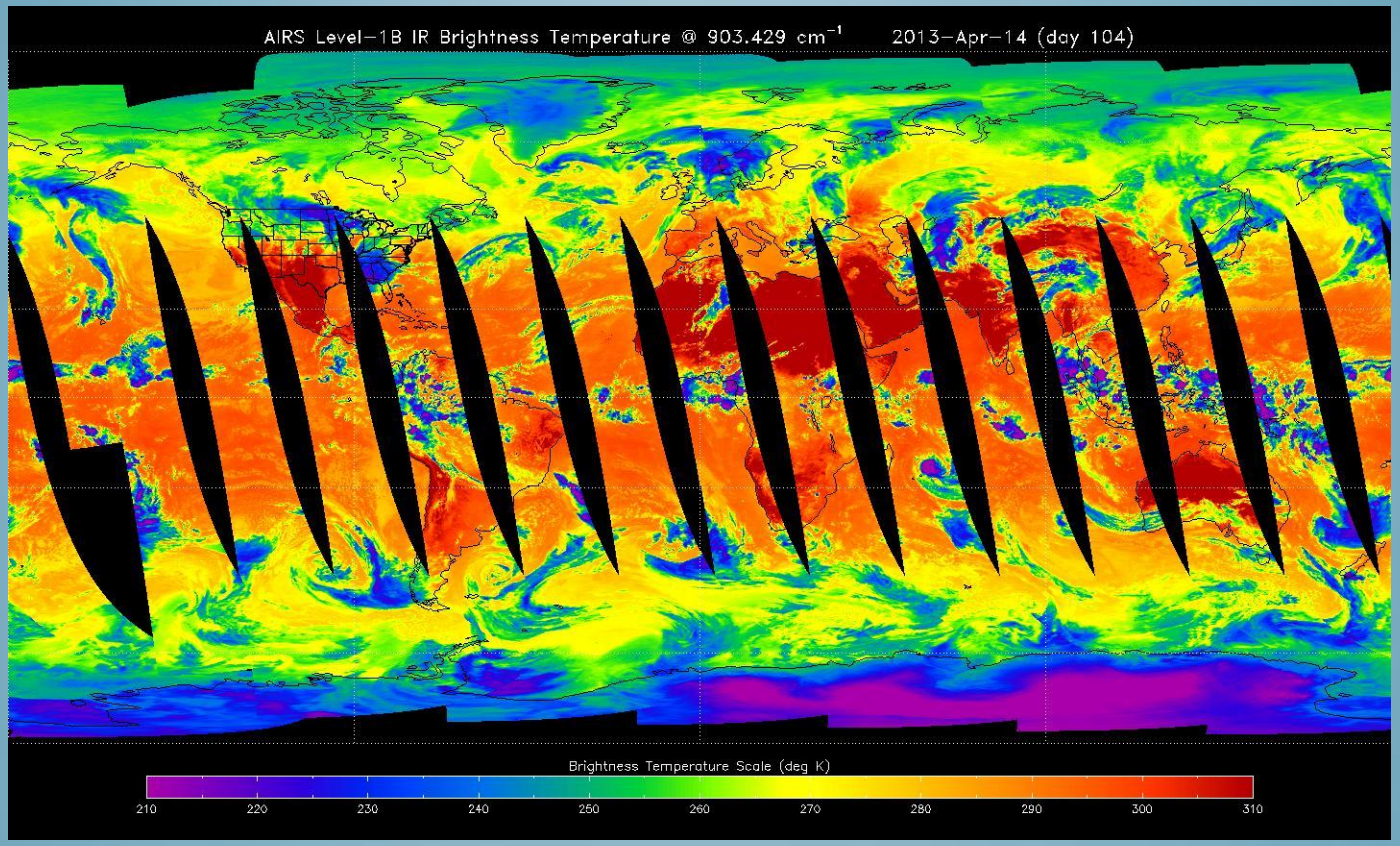
COSMIC-II



COSMIC-I: ~ 1,000 vertical Temperature profiles per day
COSMIC-II: ~ 12,000 vertical Temperature profiles per day

COSMIC stated "dry" temperature accuracy is 0.1 K
in the range 30 mb to 300 mb (above the effect of H2O)

AIRS



COSMIC-I: ~ 1,000 vertical Temperature profiles per day

AIRS: ~ 324,000 vertical Temperature profiles per day

AIRS L1B accuracy is ~ 0.2 K but AIRS L2 Temperature accuracy is TBD.

Spatial/Temporal L2 Matchup

File-based Matchup Method

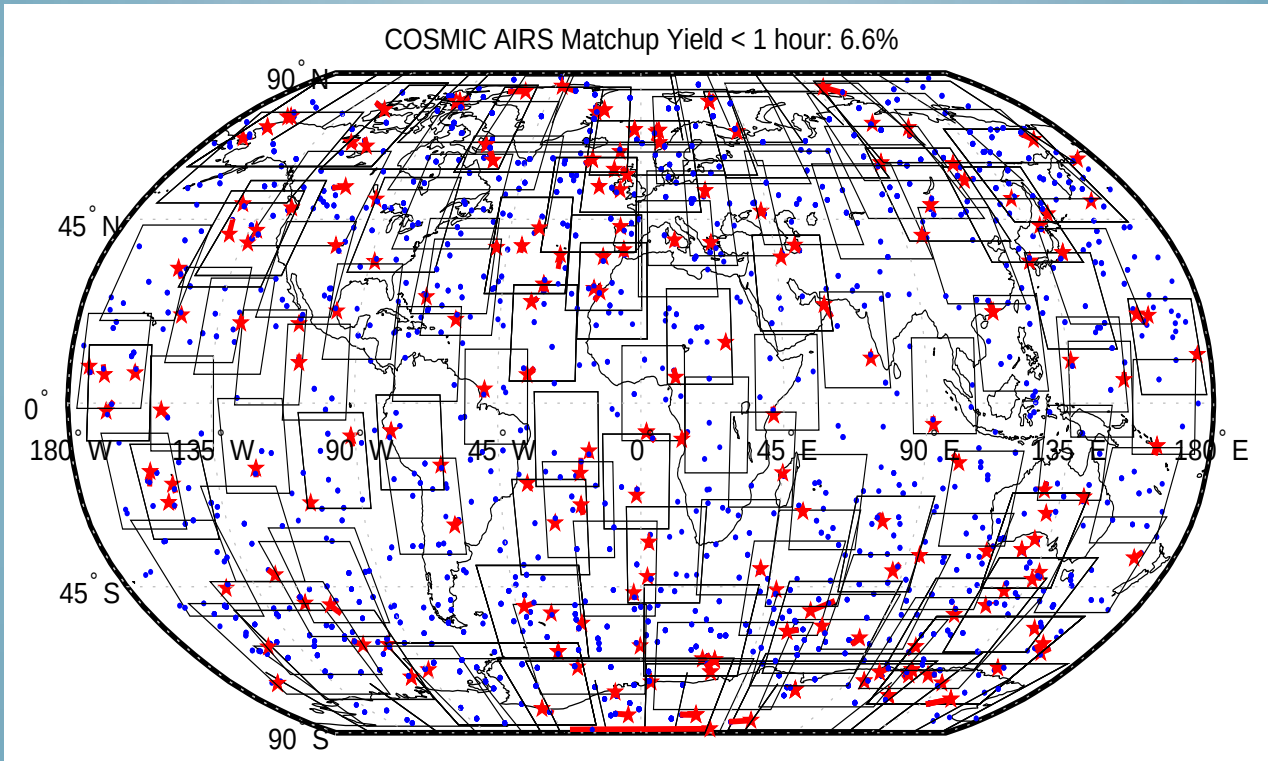
1) **Step through each COSMIC data file.**

2) **Find sounding data granule where COSMIC profile lat/lon is within granule bounding box.**

3) **Check that COSMIC profile is within 1 hour of sounding granule (if not then reject profile).**

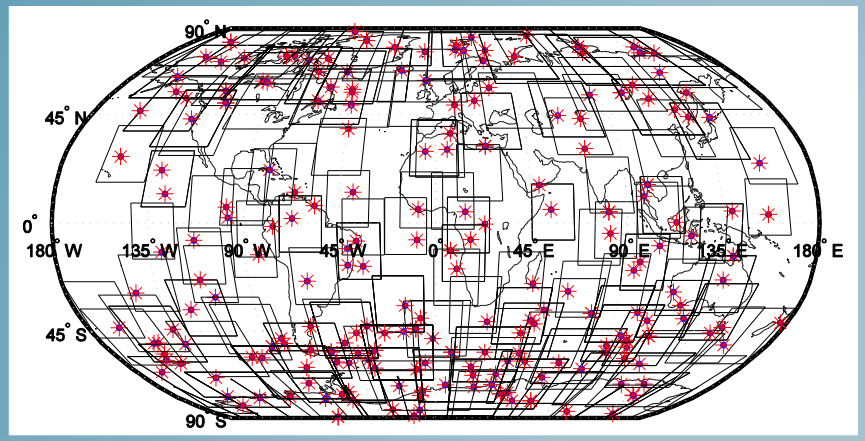
4) **Record COSMIC profile data file and sounding data file as a "matchup".**

AIRS and COSMIC L2 Matchup



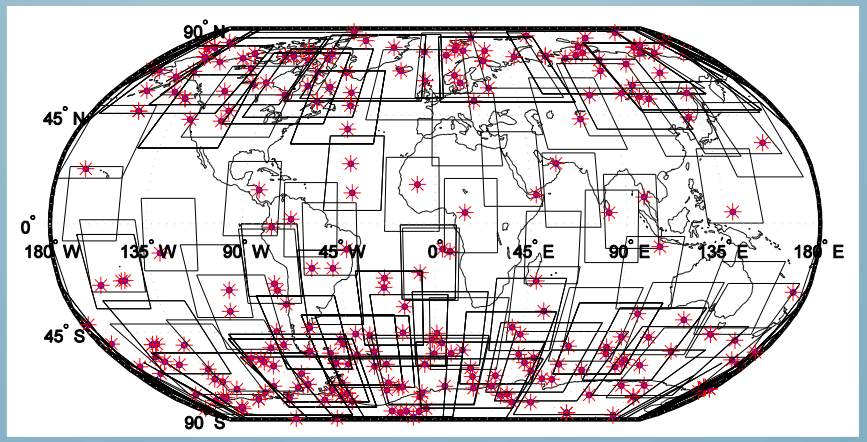
6% OF THE COSMIC PROFILES ON THIS DAY ARE WITHIN 1 HOUR OF A COINCIDENT AIRS OBSERVATION.

THIS MATCHUP CAN BE MADE WITH ALL SOUNDERS: AIRS, IASI-A, IASI-B, CRIS-NPP, … CRIS-J1, CRIS-J2, …

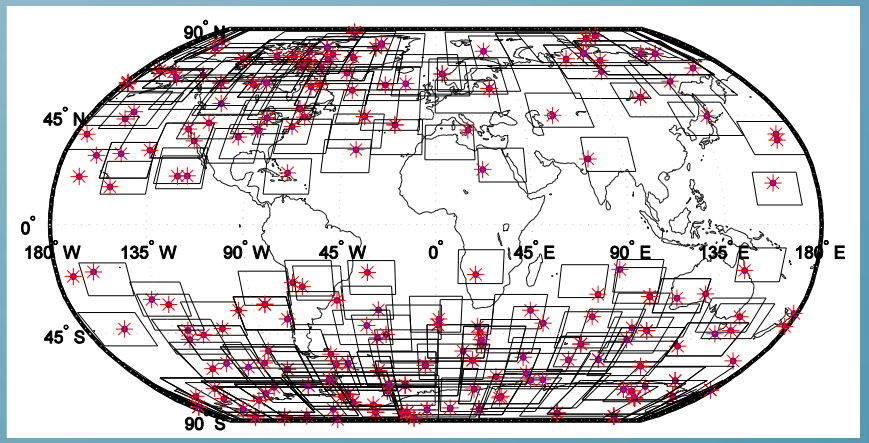


AIRS/Aqua

CrIS/NPP



IASI/Metop-A



Spatial Analysis

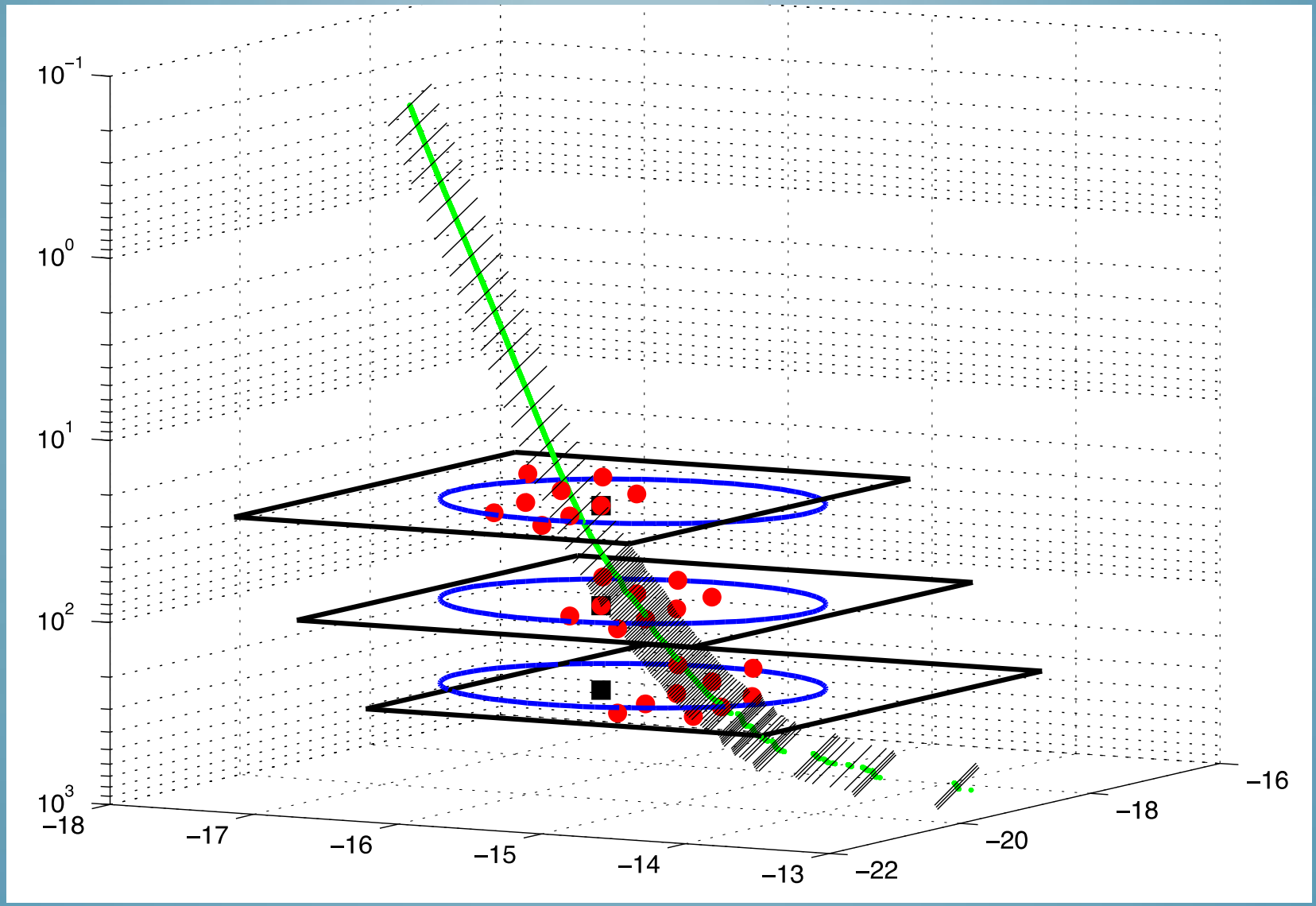
Consider three spatial matchup methods:

1) **Closest sounding to the COSMIC 100 mb level**
   Note: the perigee point reported in the COSMIC profile file header can be hundreds of km away from the 100 mb level!

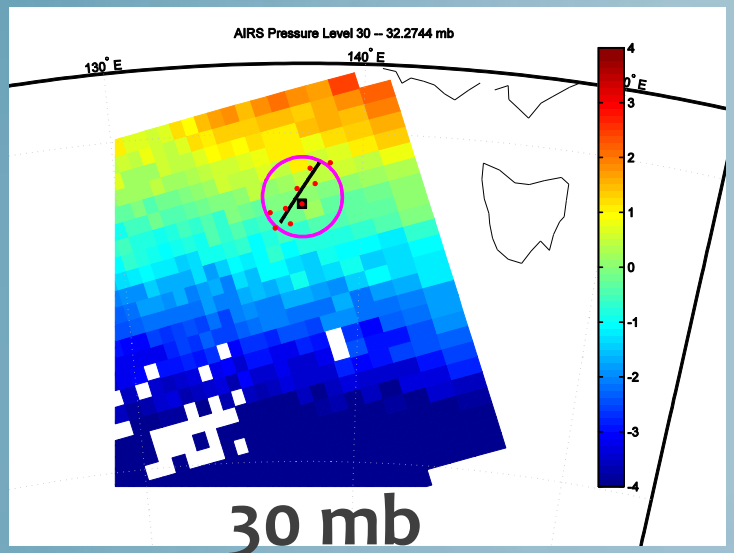
2) **Circle of radius 150 km center centered on closest sounding (approx. accounts for horizontal averaging).**

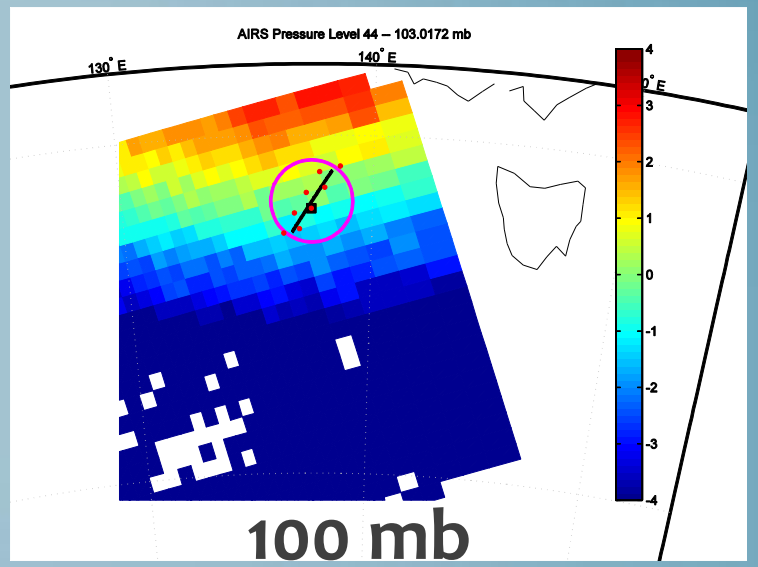
3) **Ray path "ribbon" method**
   (accounts for both horizontal averaging (300 km) and GPS RO profile lat/lon change versus height (500 km).

GPS RO Profile matchup with IR sounding (30, 100, 300 mb)

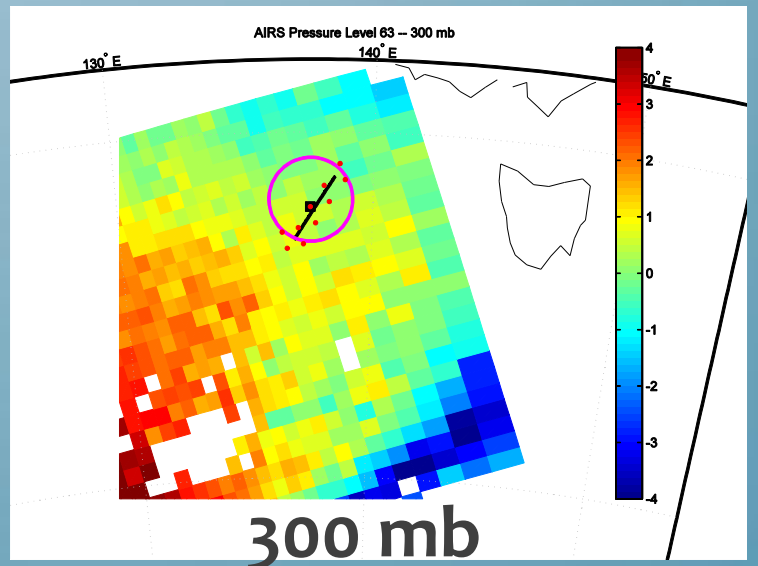


GPS RO Profile matchup with IR sounding (30, 100, 300 mb)

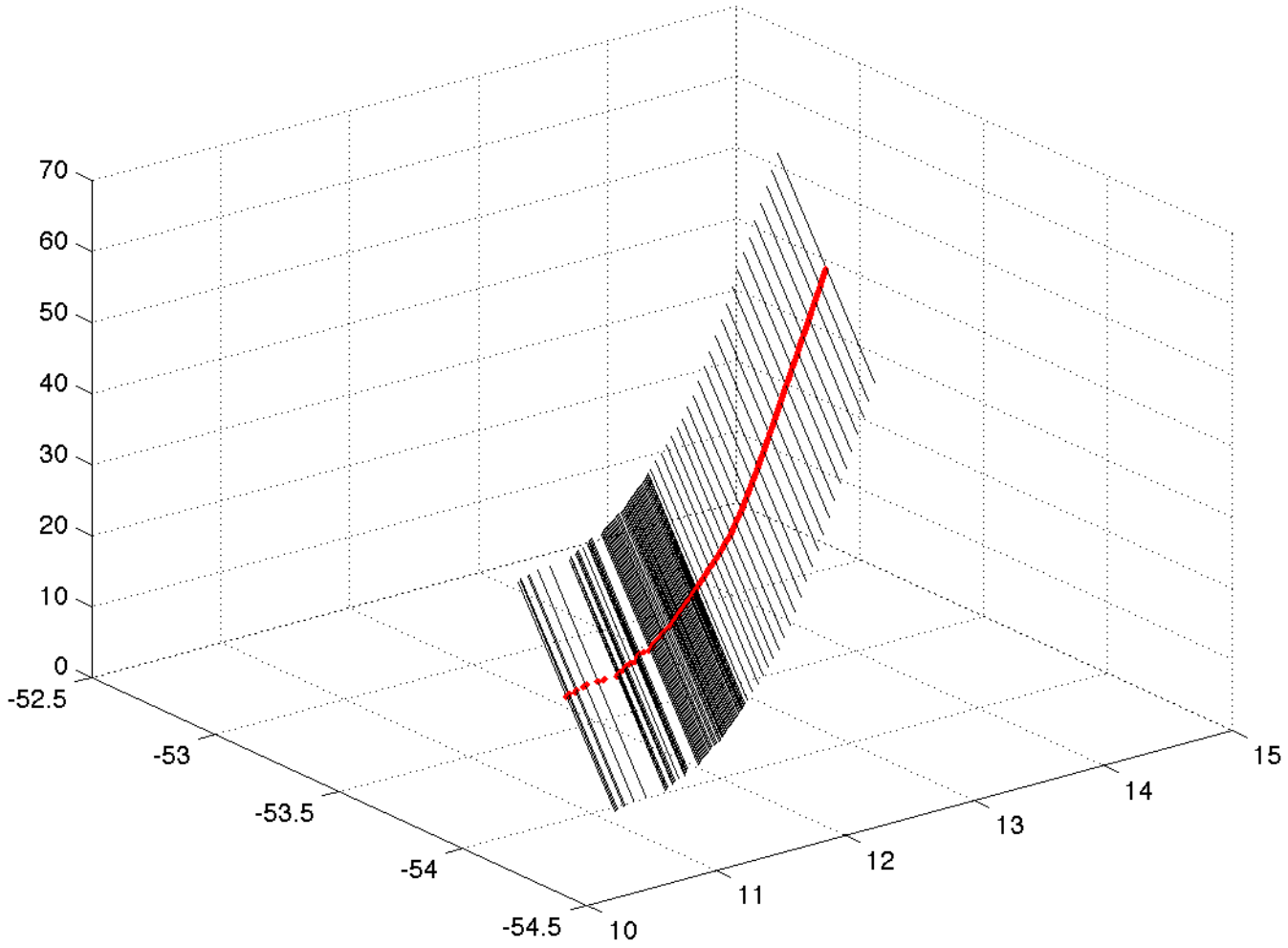




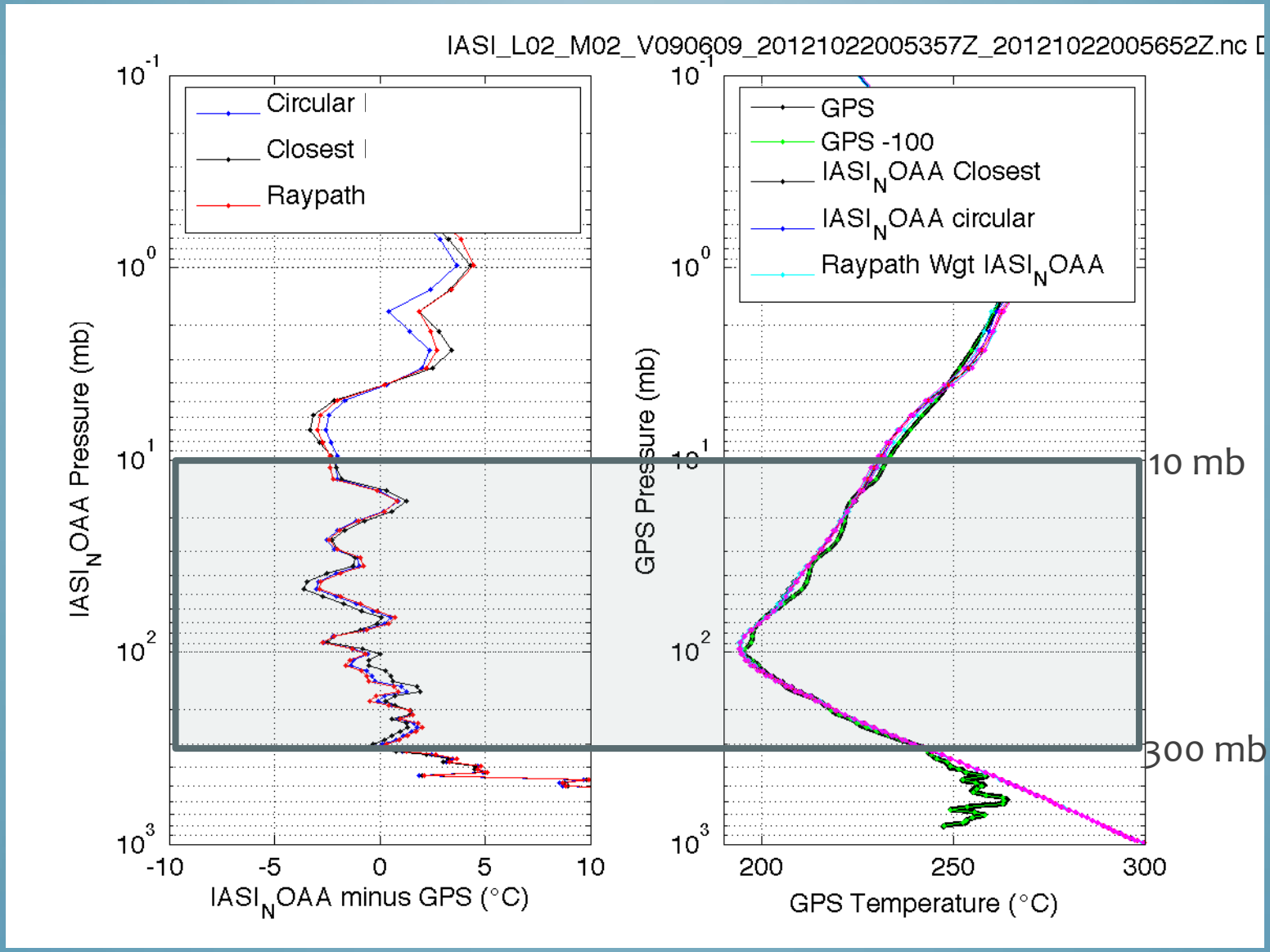
- The black square is the closest IR profile to the COSMIC at 100 mb.
- The pink circle has radius of 150 km centered at the closest profile.
- The black line is the ray path and the red dots are the ray path IR soundings



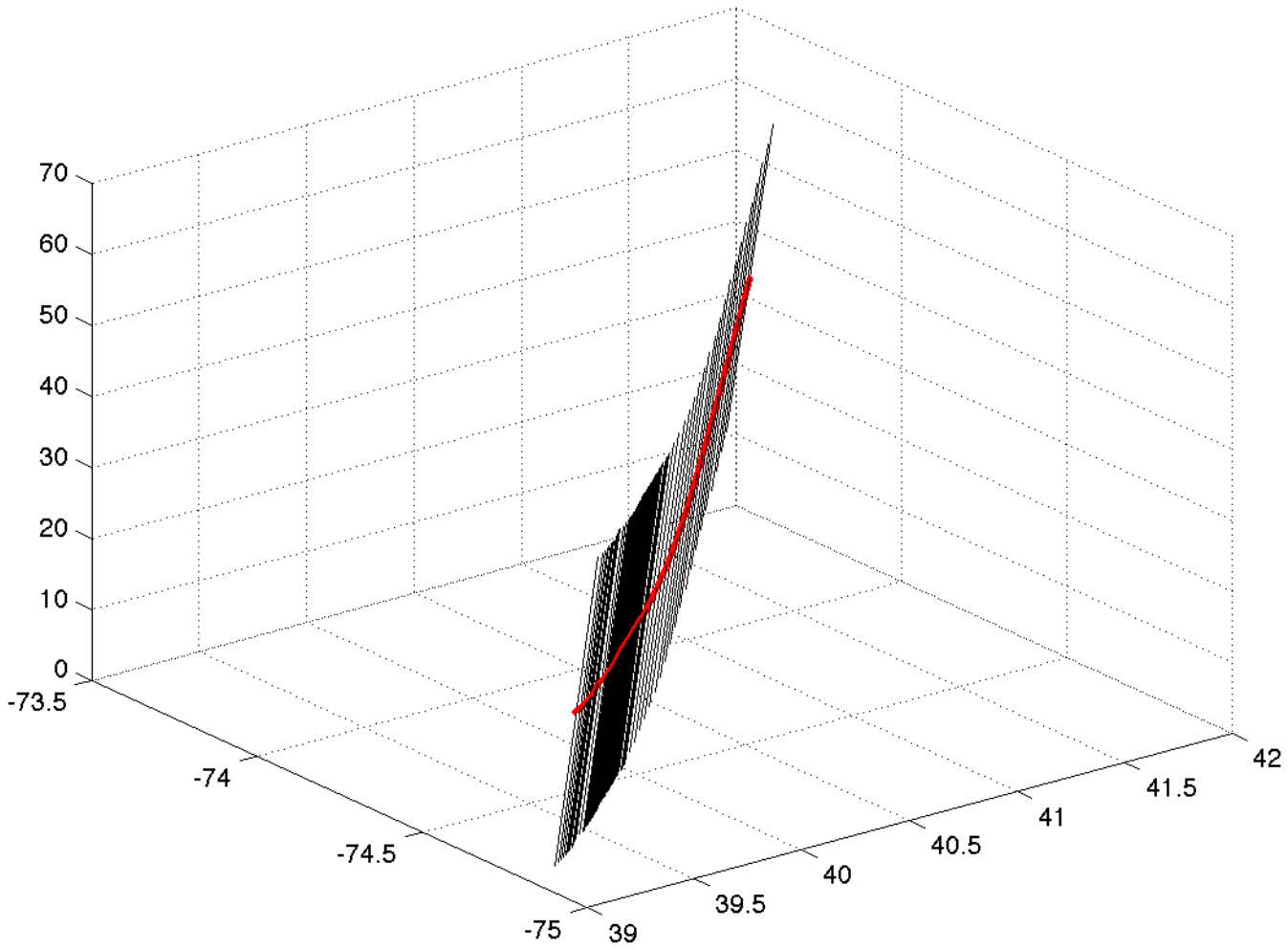
Example #1: “typical COSMIC”



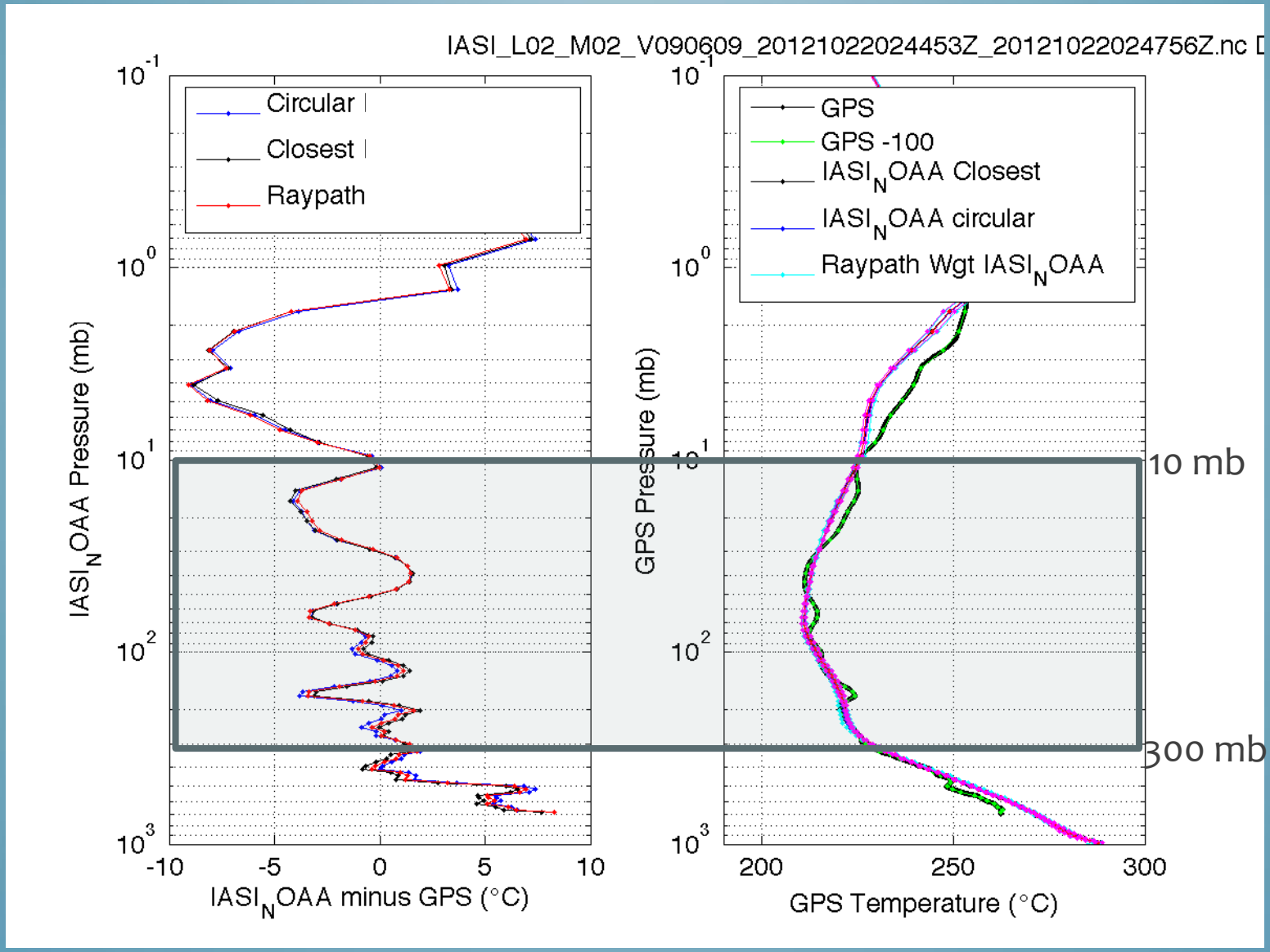
Example #1: “typical COSMIC”



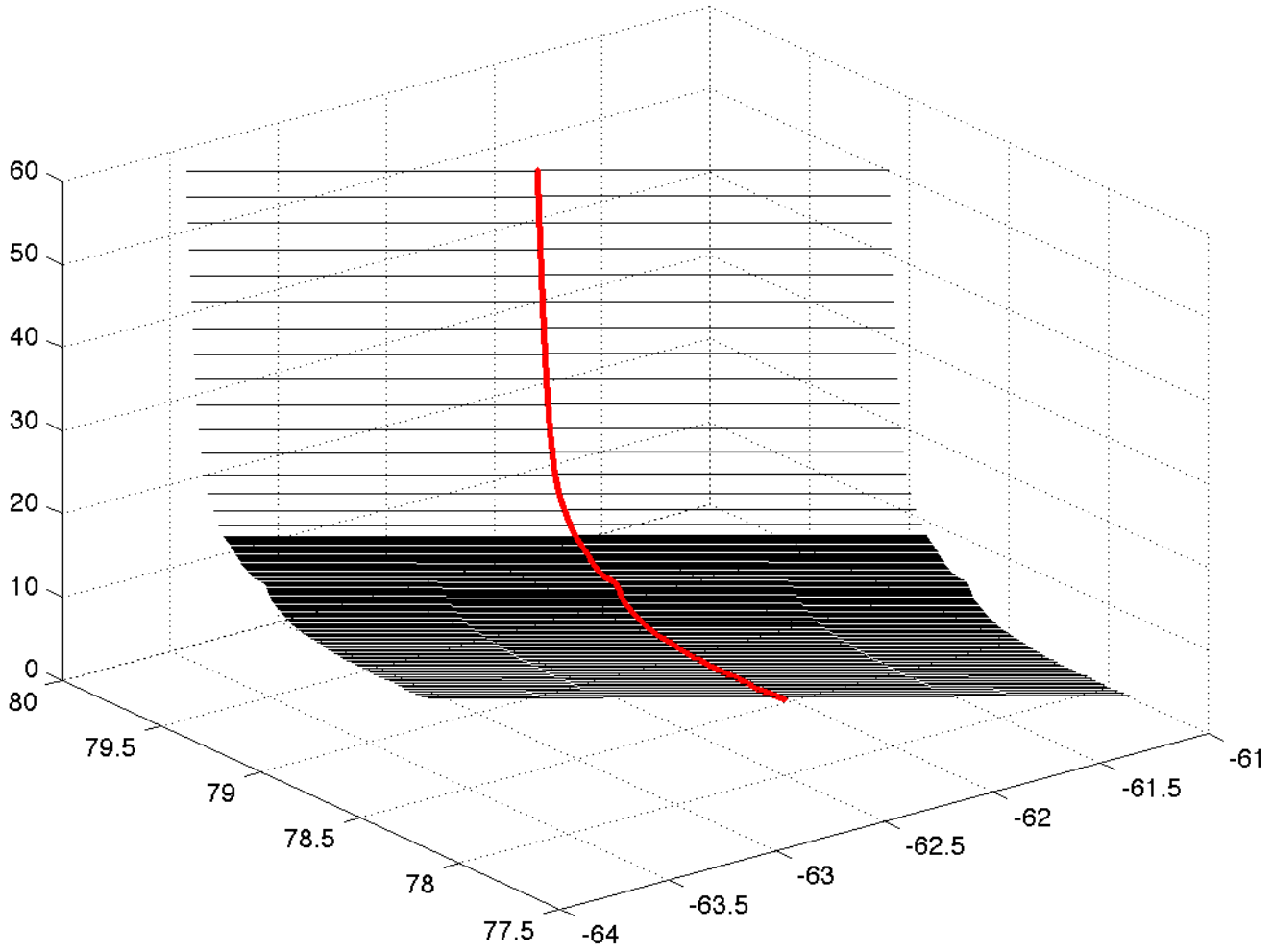
Example #2: “vertical COSMIC”



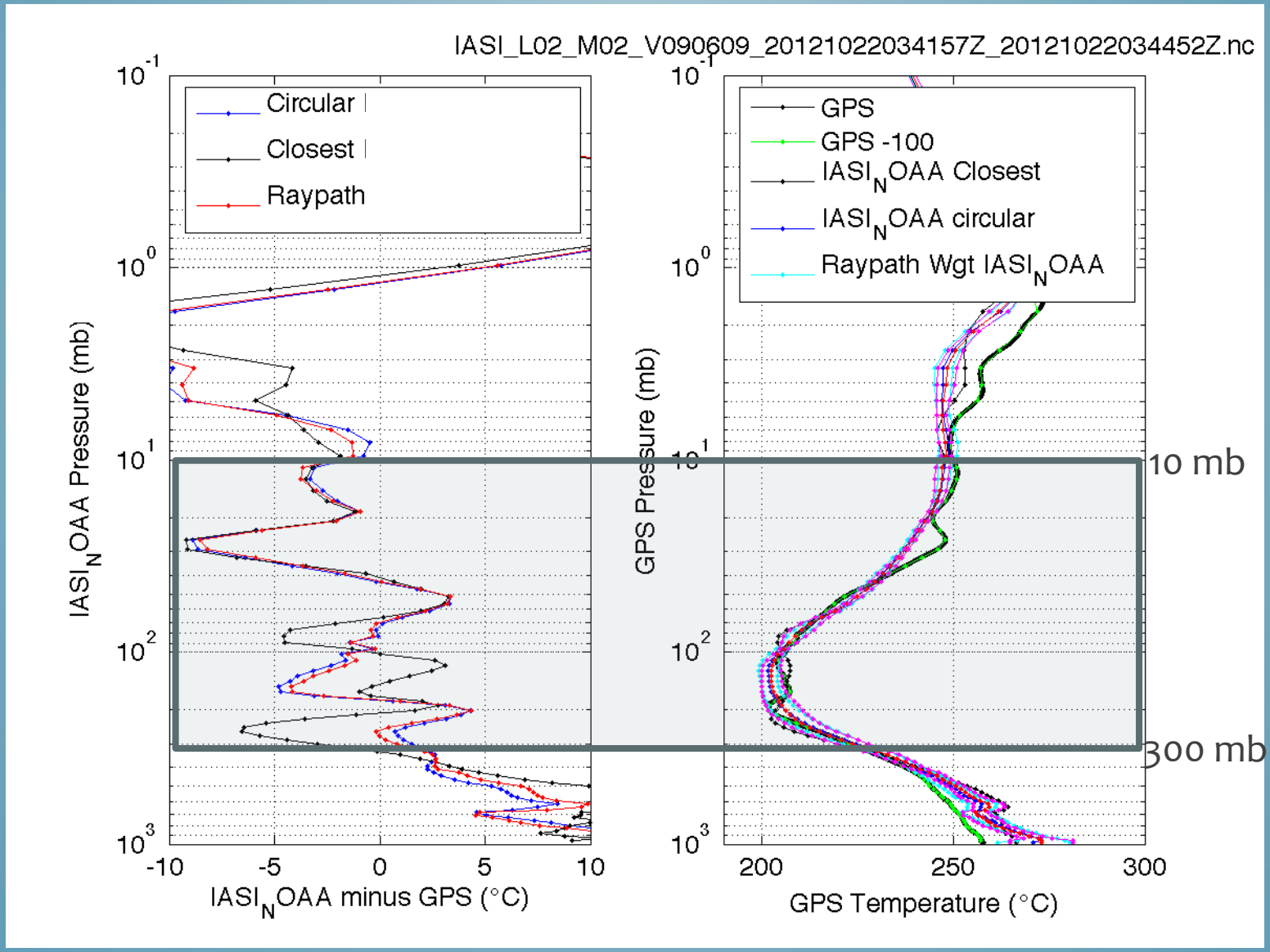
Example #2: “vertical COSMIC”



Example #3: “flat COSMIC”

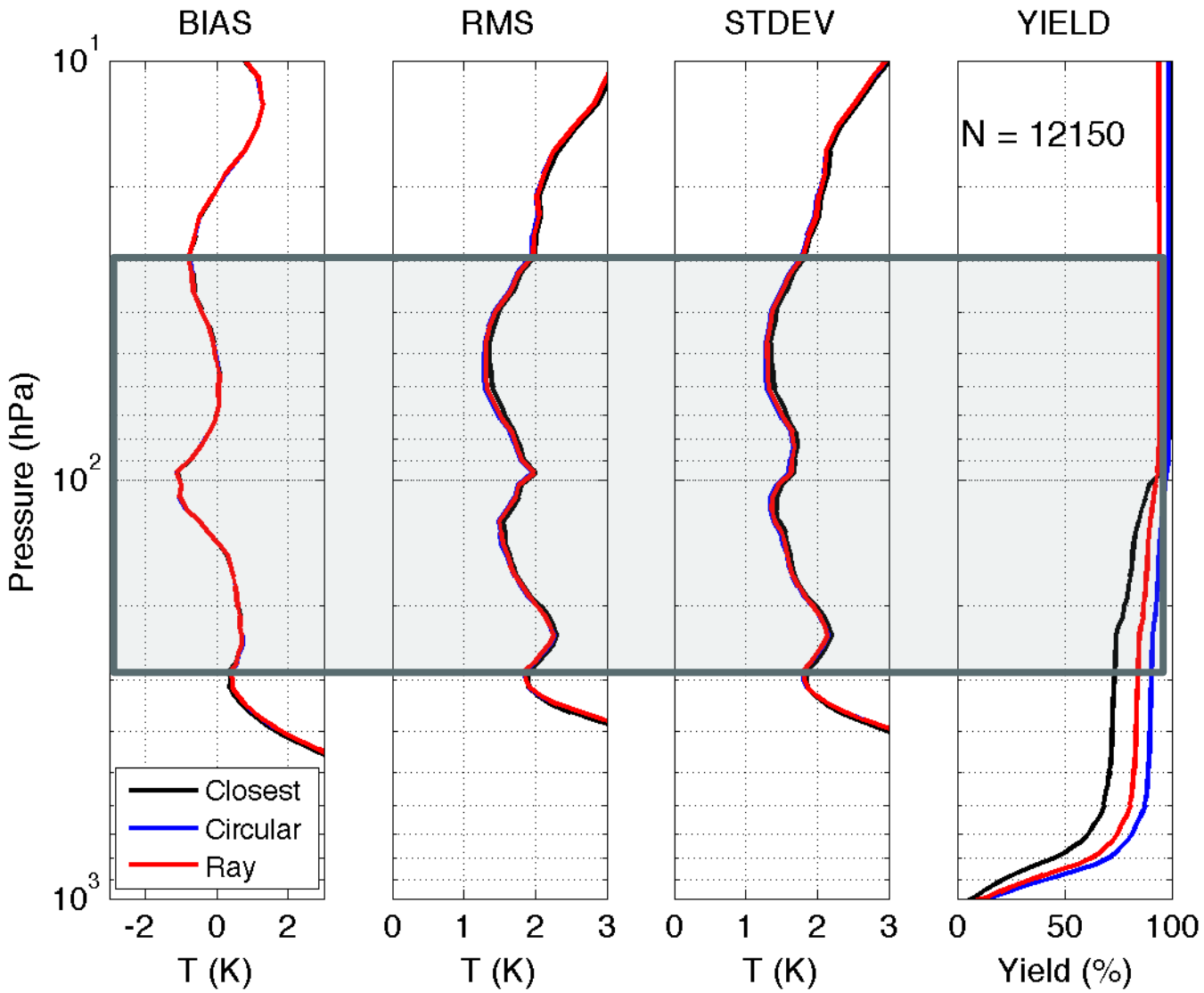


Example #3: “flat COSMIC”



AIRS - COSMIC (90S-90N) GLOBAL

(1 day)



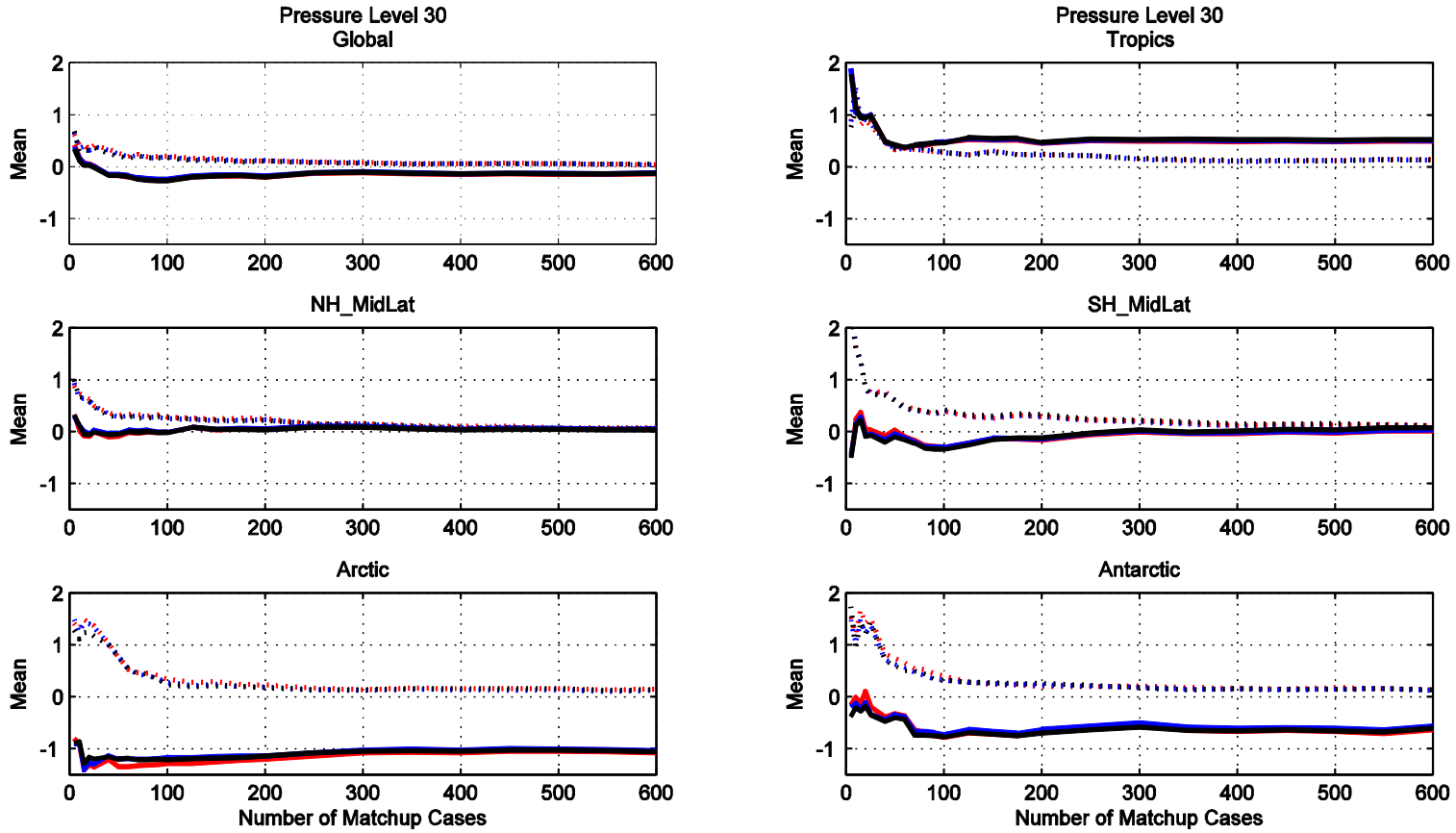
- On daily or longer averages the horizontal resolution effects are minor.

Temporal Analysis

Uncertainty in the Estimated Bias & RMS

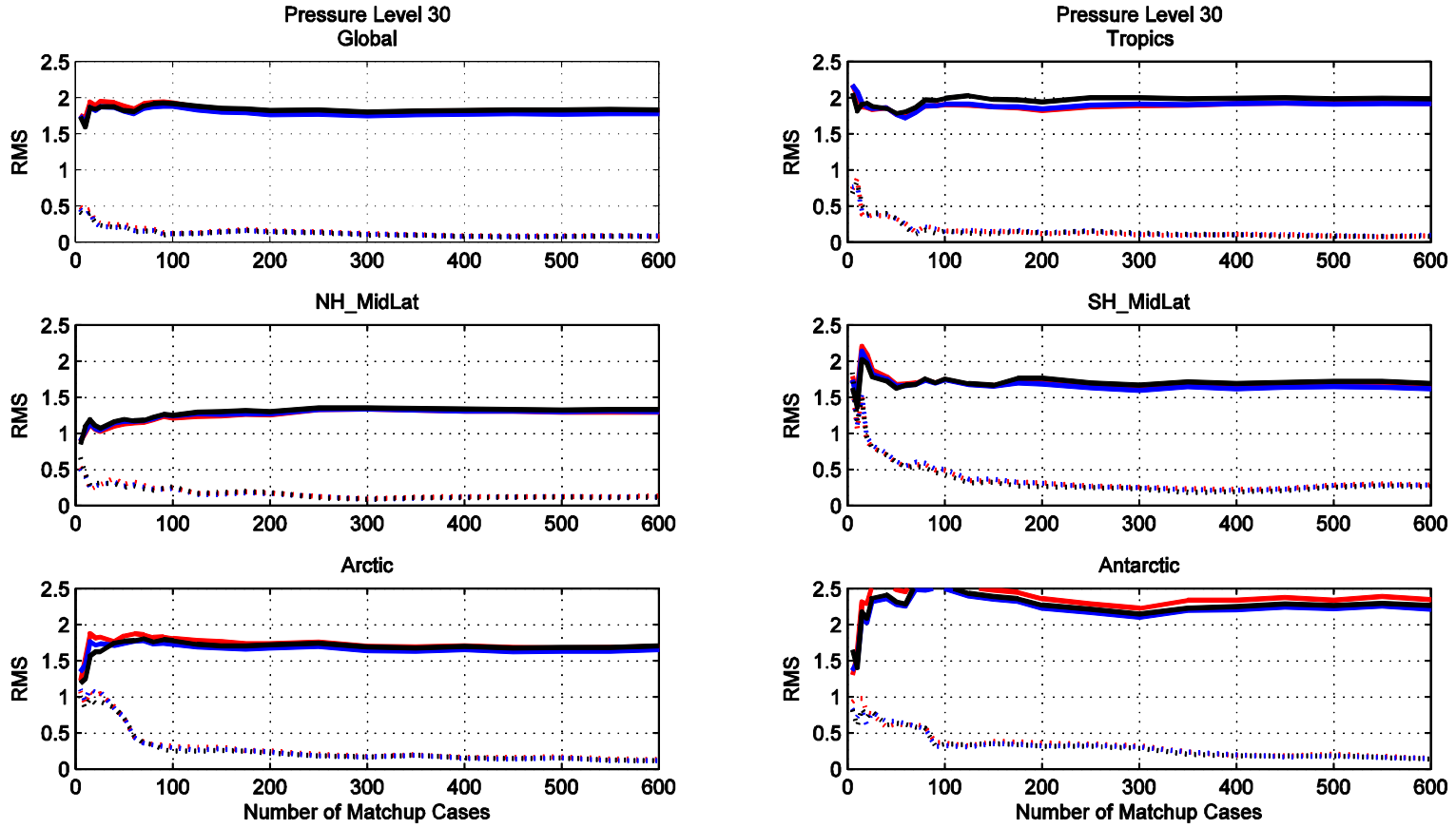
as a function of number of samples (time)

Temporal Analysis: Uncertainty in the Estimated Bias
AIRS – COSMIC Temperature (30 mb level)



- 100 samples (1.5 days) for statistical fluctuations in bias to damp out
- 300 sample (5 days) to converge to stable bias value

Temporal Analysis: Uncertainty in the Estimated RMS AIRS – COSMIC Temperature (30 mb level)



- 100 samples (1.5 days) for statistical fluctuations in RMS to damp out
- 300 sample (5 days) to converge to stable RMS value

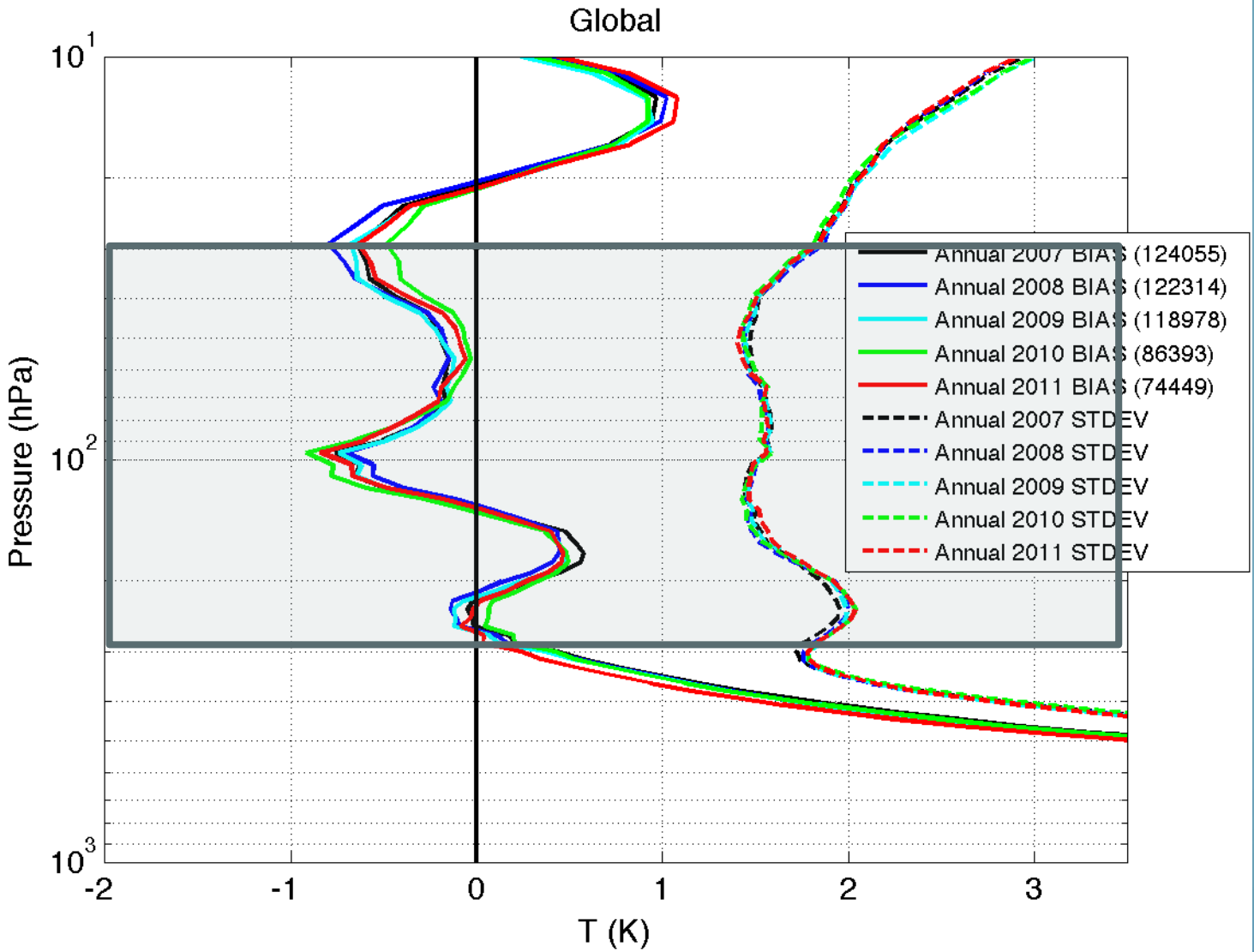
AIRS – COSMIC L2 Temperature

5 Year Statistical Summary

2007-2011

AIRS - COSMIC (90S-90N) GLOBAL

(Annual)

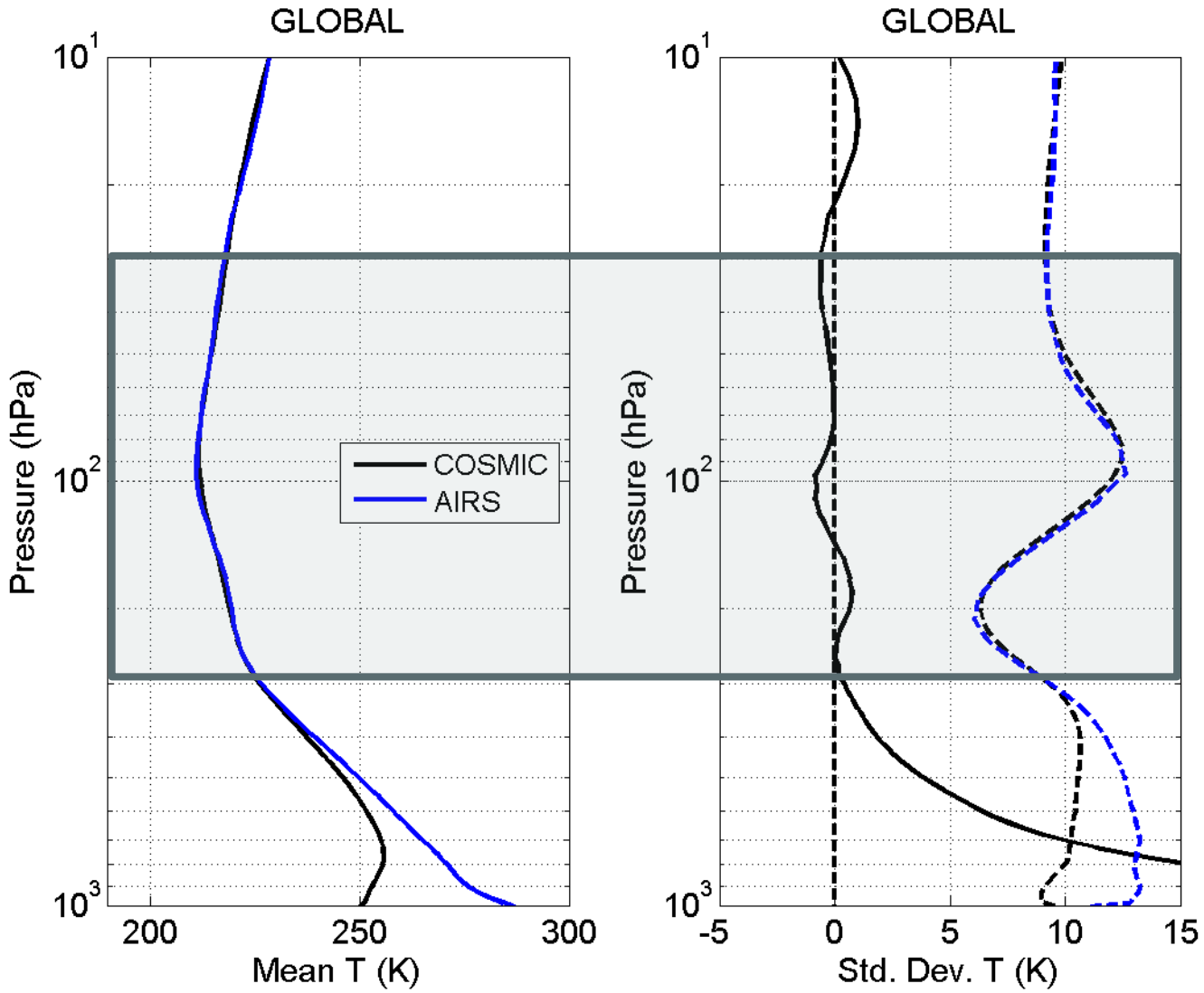


- Inter-annual varibility of Temperature bias is small (<0.1K)
- Individual sample errors are about 1.5K at full vertical resolution.

AIRS - COSMIC (90S-90N)

GLOBAL

(90 day)

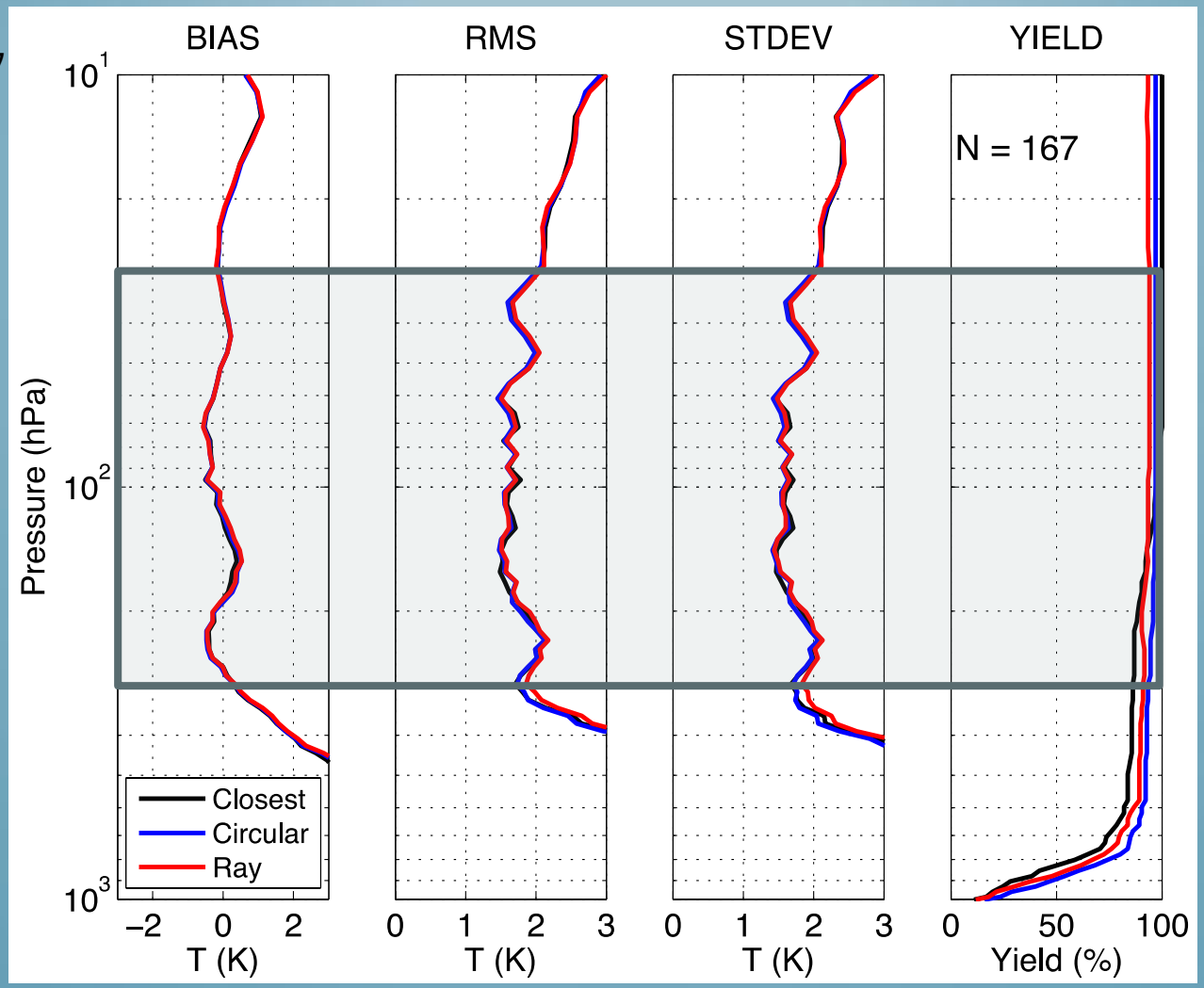


- AIRS mean bias "error" shows vertical structure.
- "Natural Variability" estimates are very consistent.

Vertical Resolution Analysis

1 POINT BOXCAR SMOOTHER
SMOOTHED DIFFS 100 LEVEL - GLOBAL

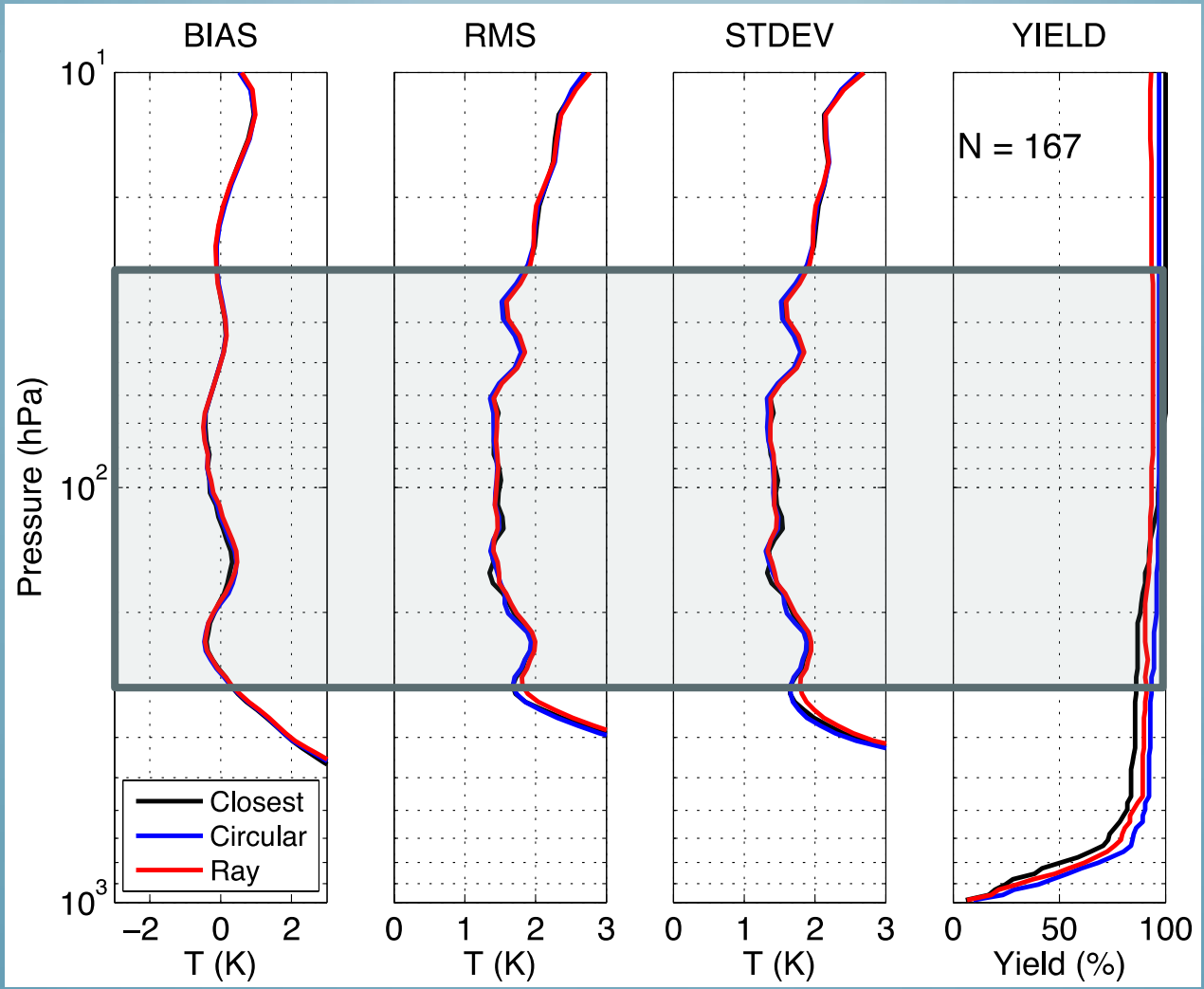
Day 292 2007



- AT FULL VERTICAL RESOLUTION THE BIAS ERROR → 0.5K & RMS→ 1.5K

3 POINT BOXCAR SMOOTHER
SMOOTHED DIFFS 100 LEVEL - GLOBAL

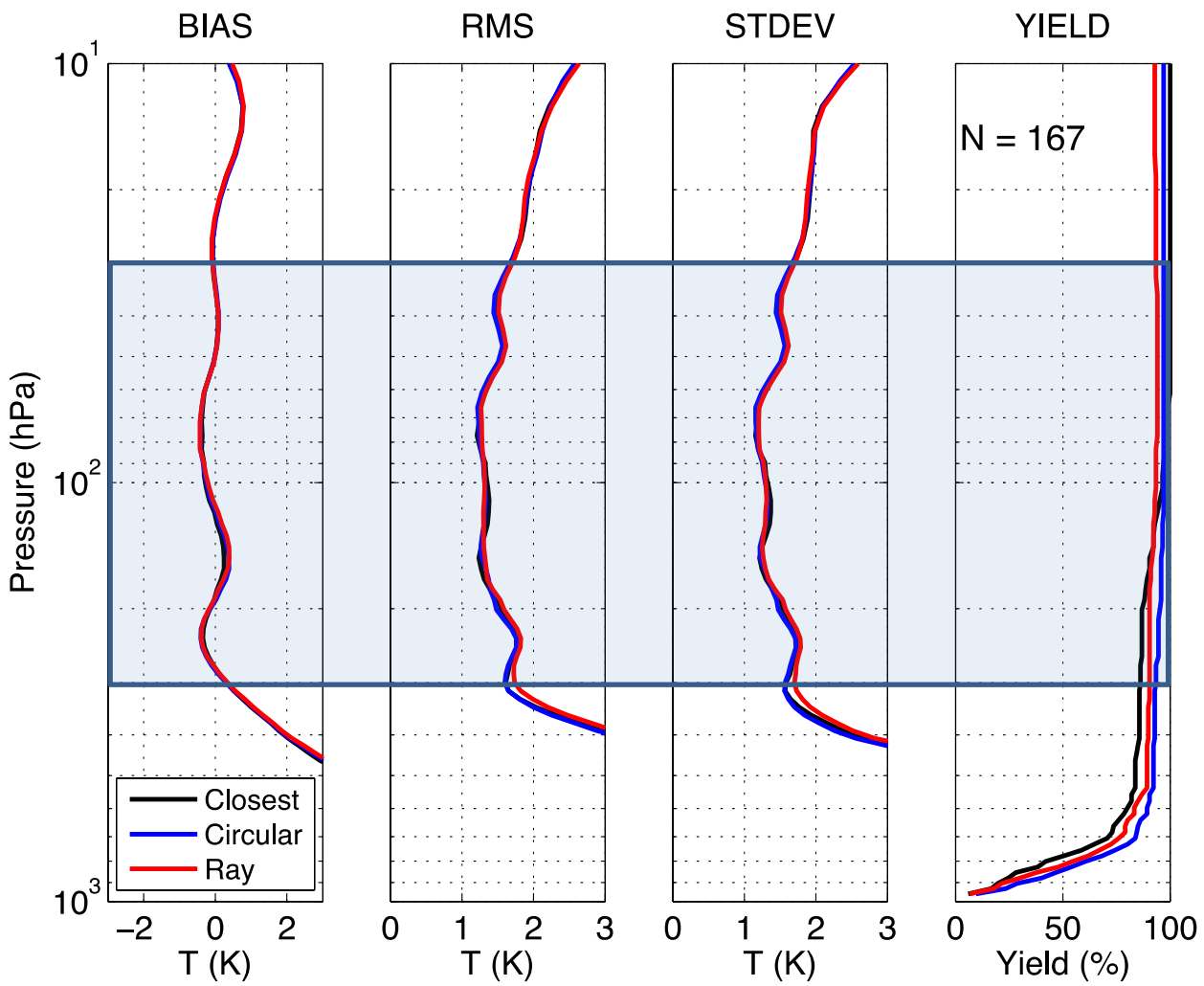
Day 292 2007



- VERTICAL SMOOTHING MATCHES COSMIC AND AIRS RESOLUTIONS

5 point boxcar smoother
Smoothed Diffs 100 Level - Global

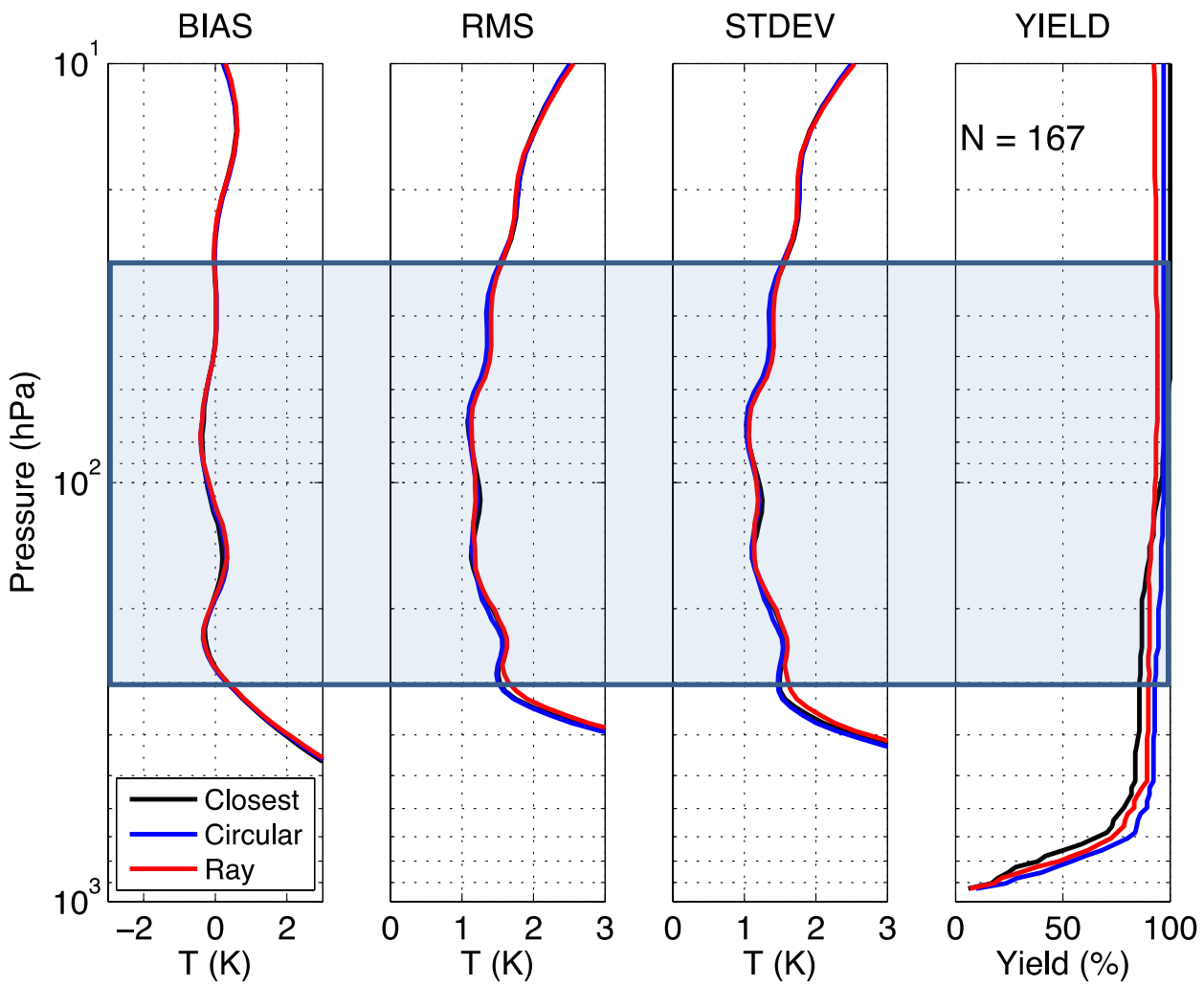
Day 292 2007



- **AT AIRS VERTICAL RESOLUTION THE BIAS ERROR → 0.3K & RMS→ 1.2K**

7 point boxcar smoother
Smoothed Diffs 100 Level - Global

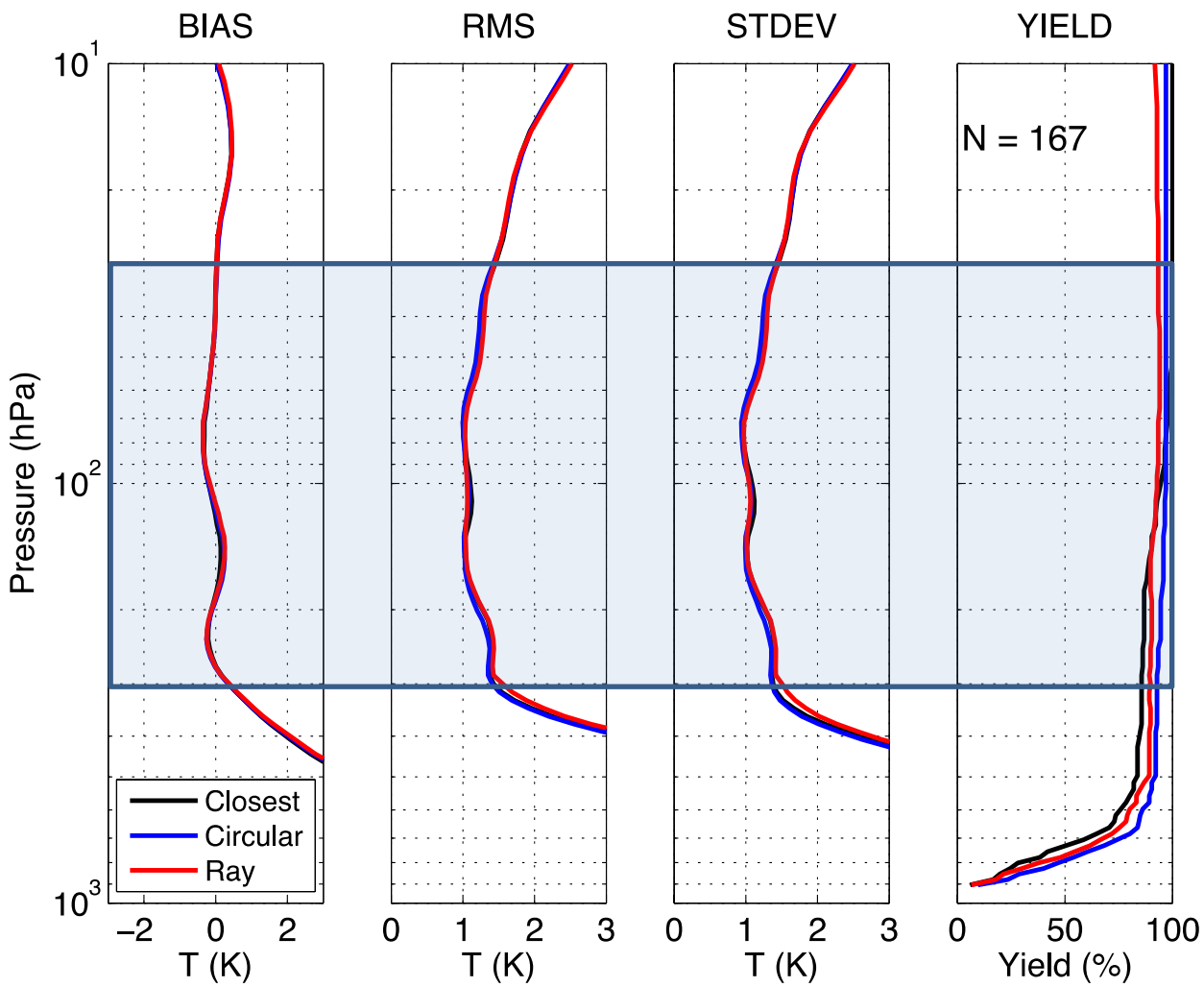
Day 292 2007



- **BOTH COSMIC AND AIRS VERTICAL RESOLUTION ARE SMOOTHED HERE.**

9 point boxcar smoother
Smoothed Diffs 100 Level - Global

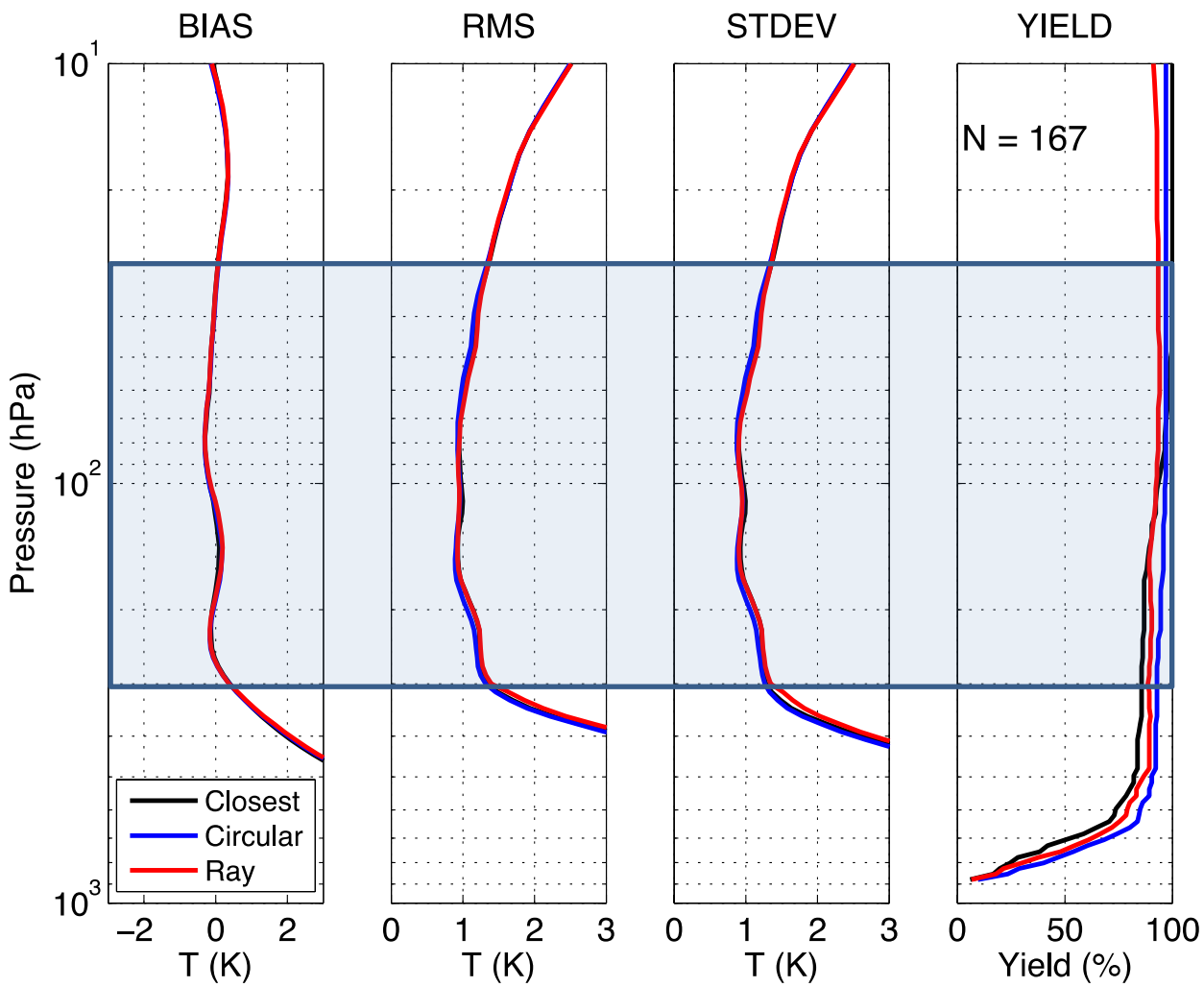
Day 292 2007



- **FURTHER SMOOTHING CONTINUES TO REDUCE BIAS AND RMS.**

11 point boxcar smoother
Smoothed Diffs 100 Level - Global

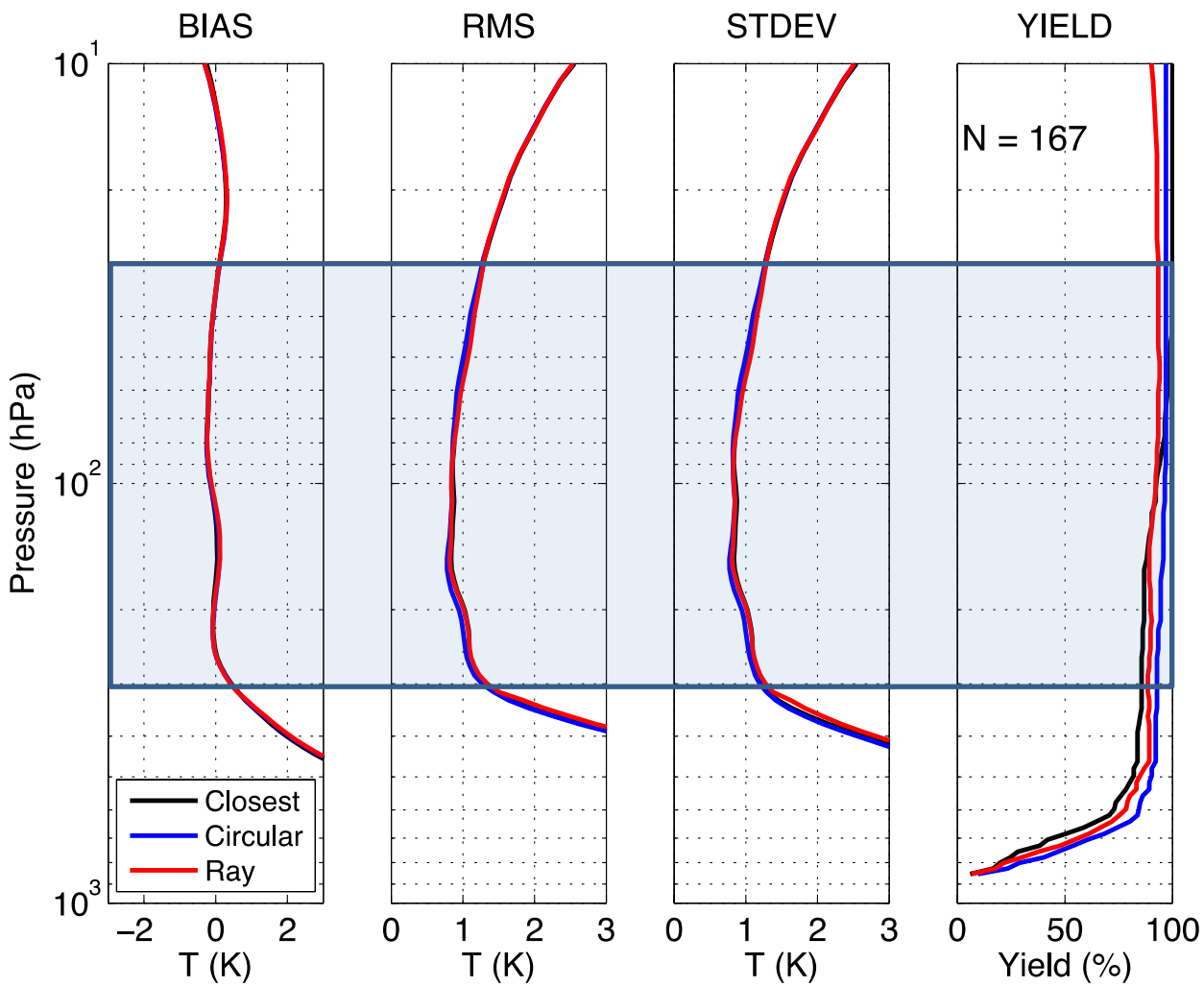
Day 292 2007



- **FURTHER SMOOTHING CONTINUES TO REDUCE BIAS AND RMS.**

13 point boxcar smoother
Smoothed Diffs 100 Level - Global

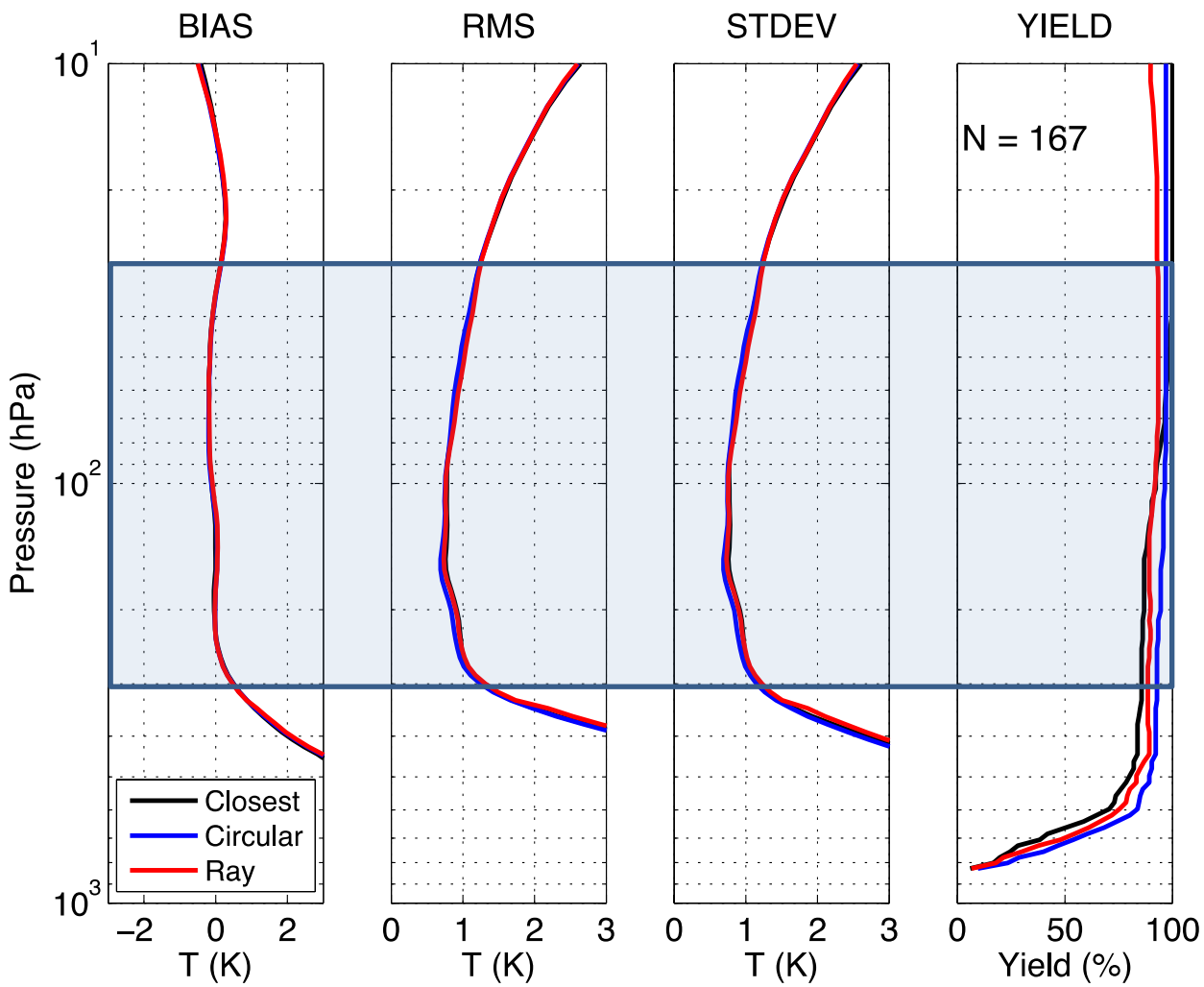
Day 292 2007



- **FURTHER SMOOTHING CONTINUES TO REDUCE BIAS AND RMS.**

15 point boxcar smoother
Smoothed Diffs 100 Level - Global

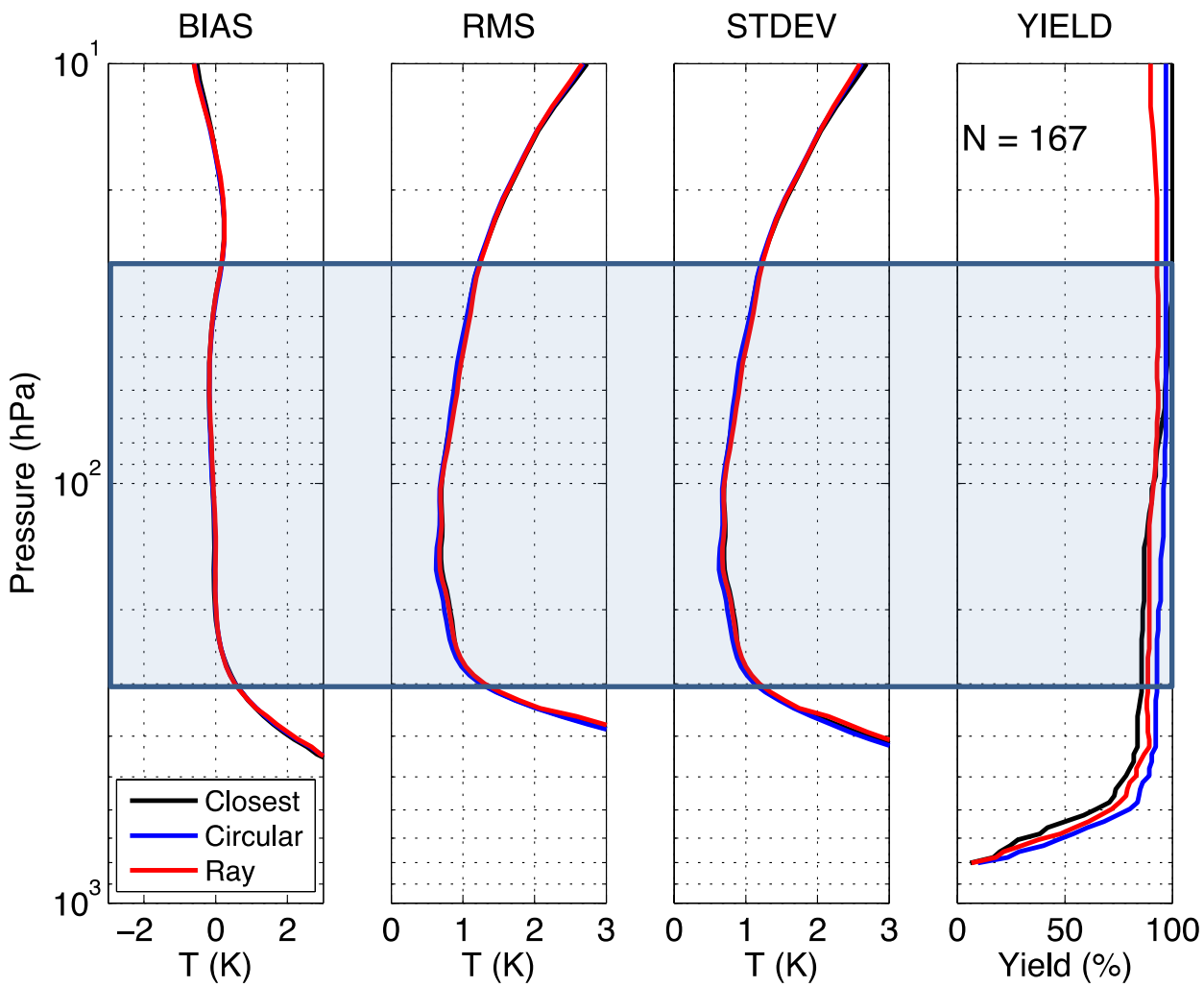
Day 292 2007



- **FURTHER SMOOTHING CONTINUES TO REDUCE BIAS AND RMS.**

17 point boxcar smoother
Smoothed Diffs 100 Level - Global

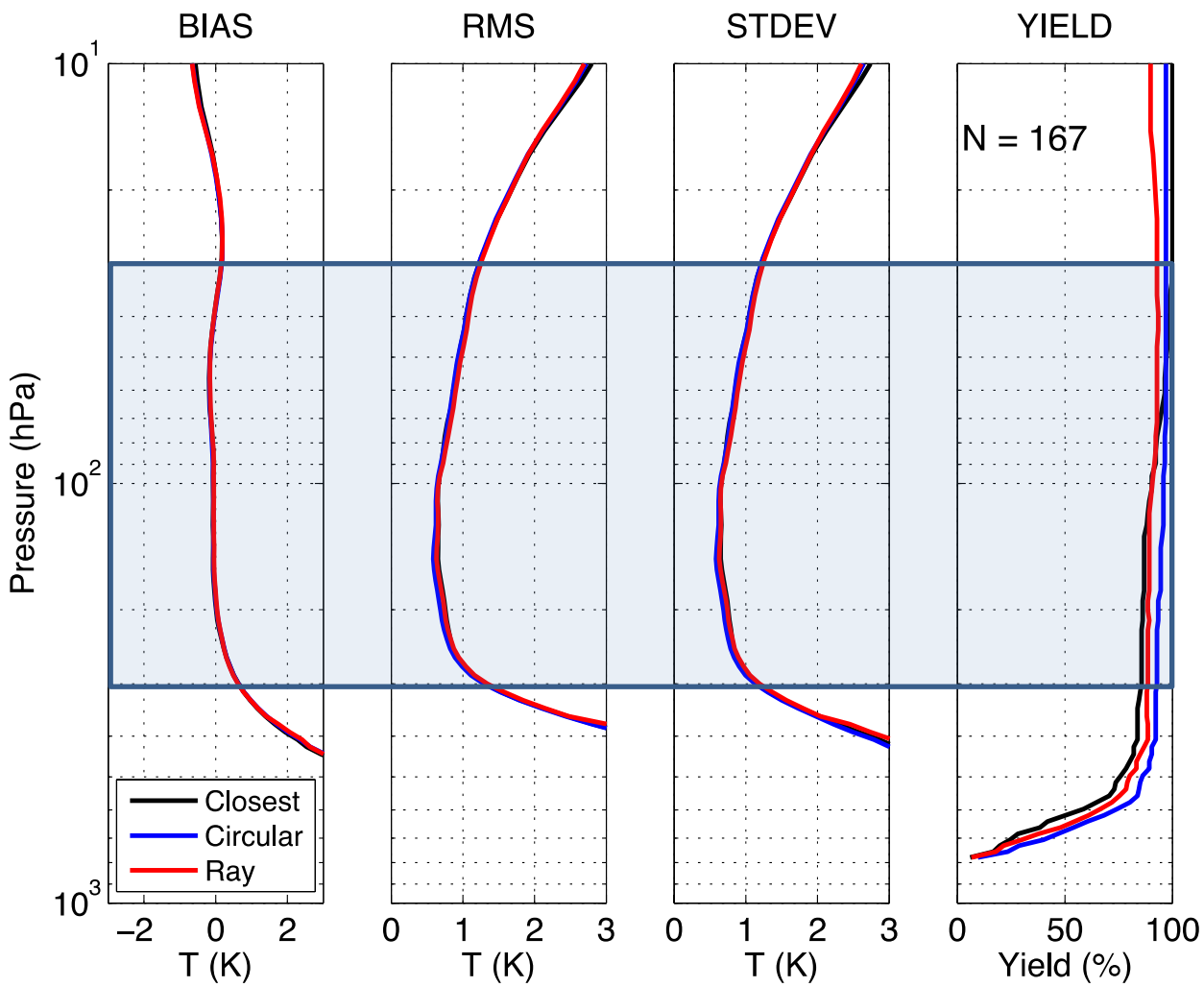
Day 292 2007



- **FURTHER SMOOTHING CONTINUES TO REDUCE BIAS AND RMS.**

19 point boxcar smoother
Smoothed Diffs 100 Level - Global

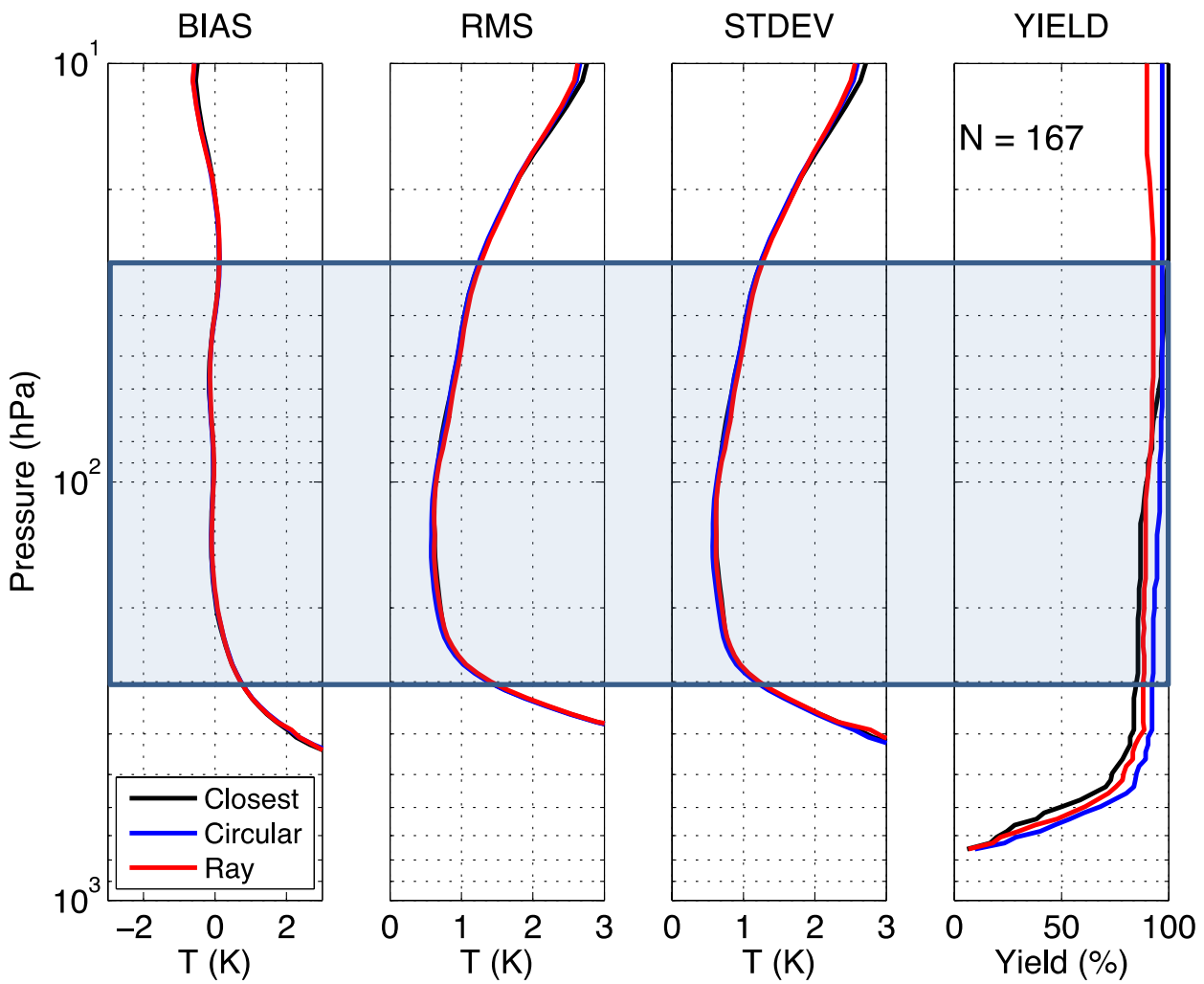
Day 292 2007



- **FURTHER SMOOTHING CONTINUES TO REDUCE BIAS AND RMS.**

21 point boxcar smoother
Smoothed Diffs 100 Level - Global

Day 292 2007



- **AT LOW VERTICAL RESOLUTION THE BIAS ERROR → ZERO & RMS→ 0.5K**

Radiance Analysis

Stratospheric Temperature Weighting Functions: dR/dp

Legacy Stratospheric Sounders

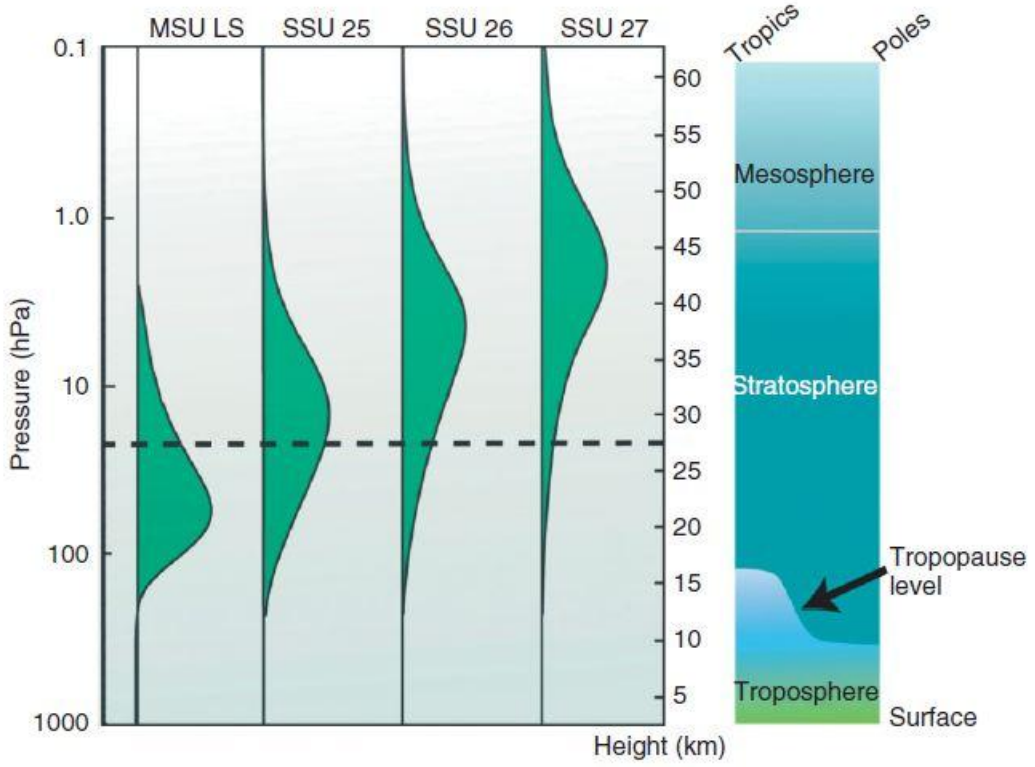
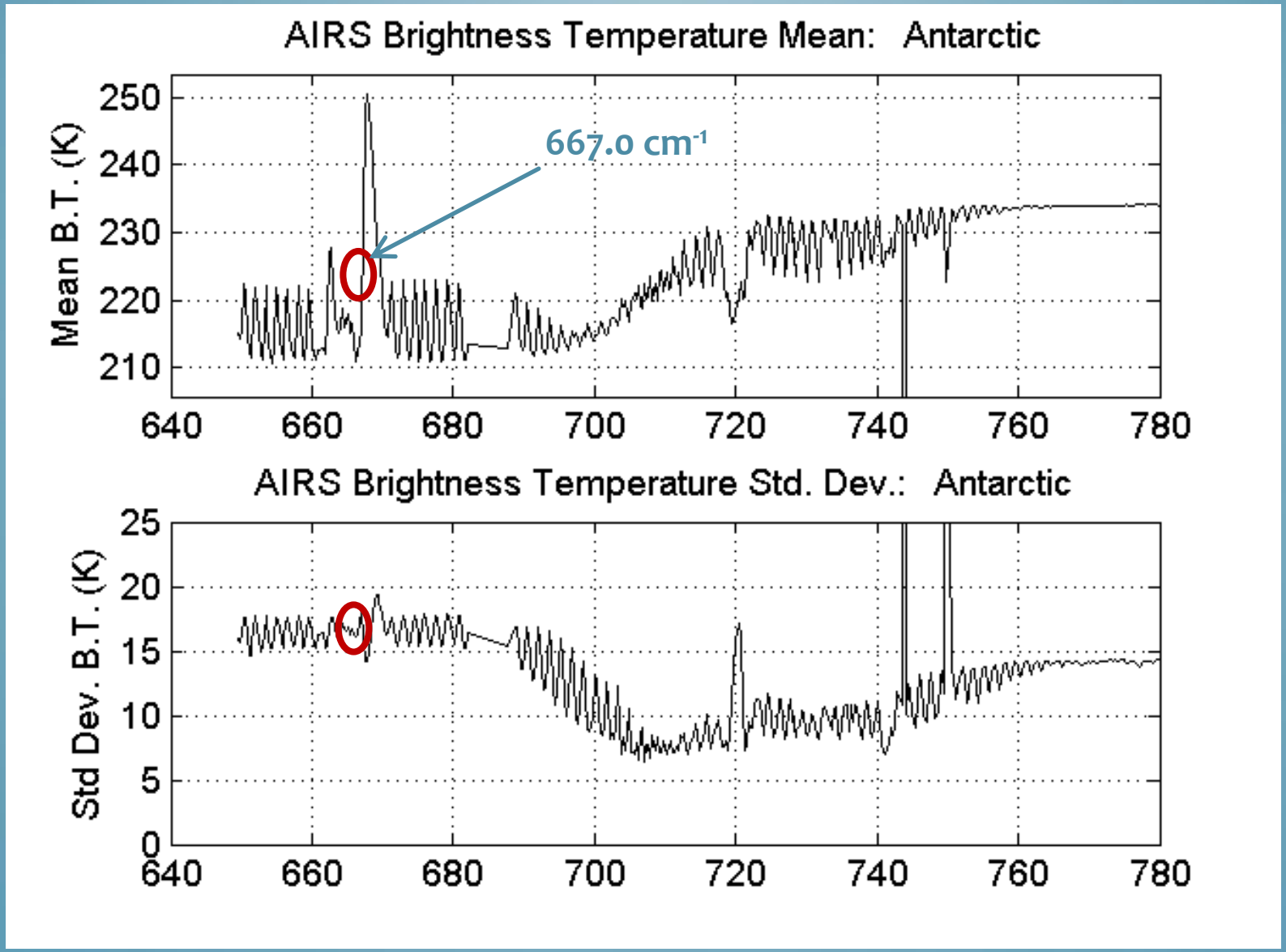


FIGURE 2 | Vertical sampling of satellite and radiosonde observations of stratospheric temperature. *Left*: vertical weighting functions for satellite Microwave Sounding Unit (MSU) and Stratospheric Sounding Unit (SSU) stratospheric temperature observations as a function of pressure (left axis) and height (right axis). The dashed line at about 27 km (30 hPa) indicates the typical maximum height of historical global radiosondes data coverage (Figure 1). *Right*: schematic of atmospheric vertical structure and its latitudinal variation. (Modified from Climate Change Science Program Synthesis and Assessment Product 1.1[4])

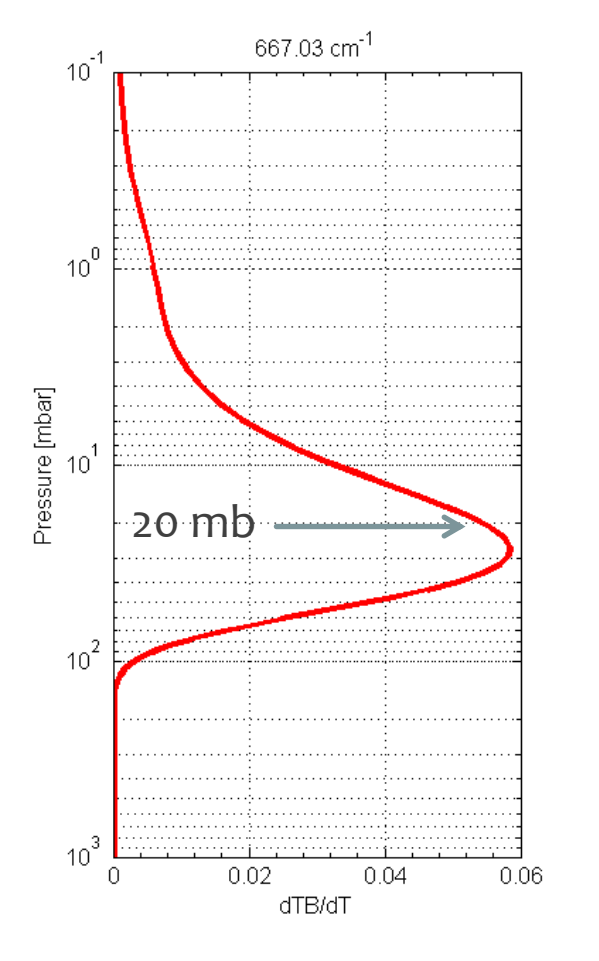
WIREs Clim Change 2011 vol 2 pp592–616 DOI: 10.1002/wcc.125

- IR emission sensitivity depends on T(p), gas concentrations, gas absorption cross-sections, pressure, spectral resolution

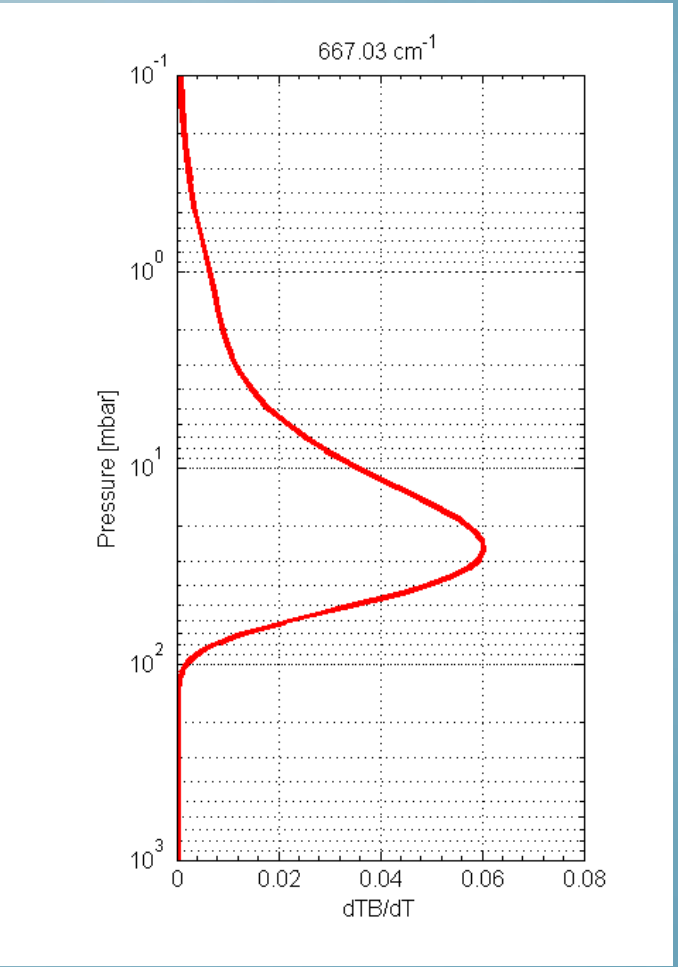
AIRS Brightness Temperature IR Spectra: Antarctica



AIRS IR Temperature Weighting Functions



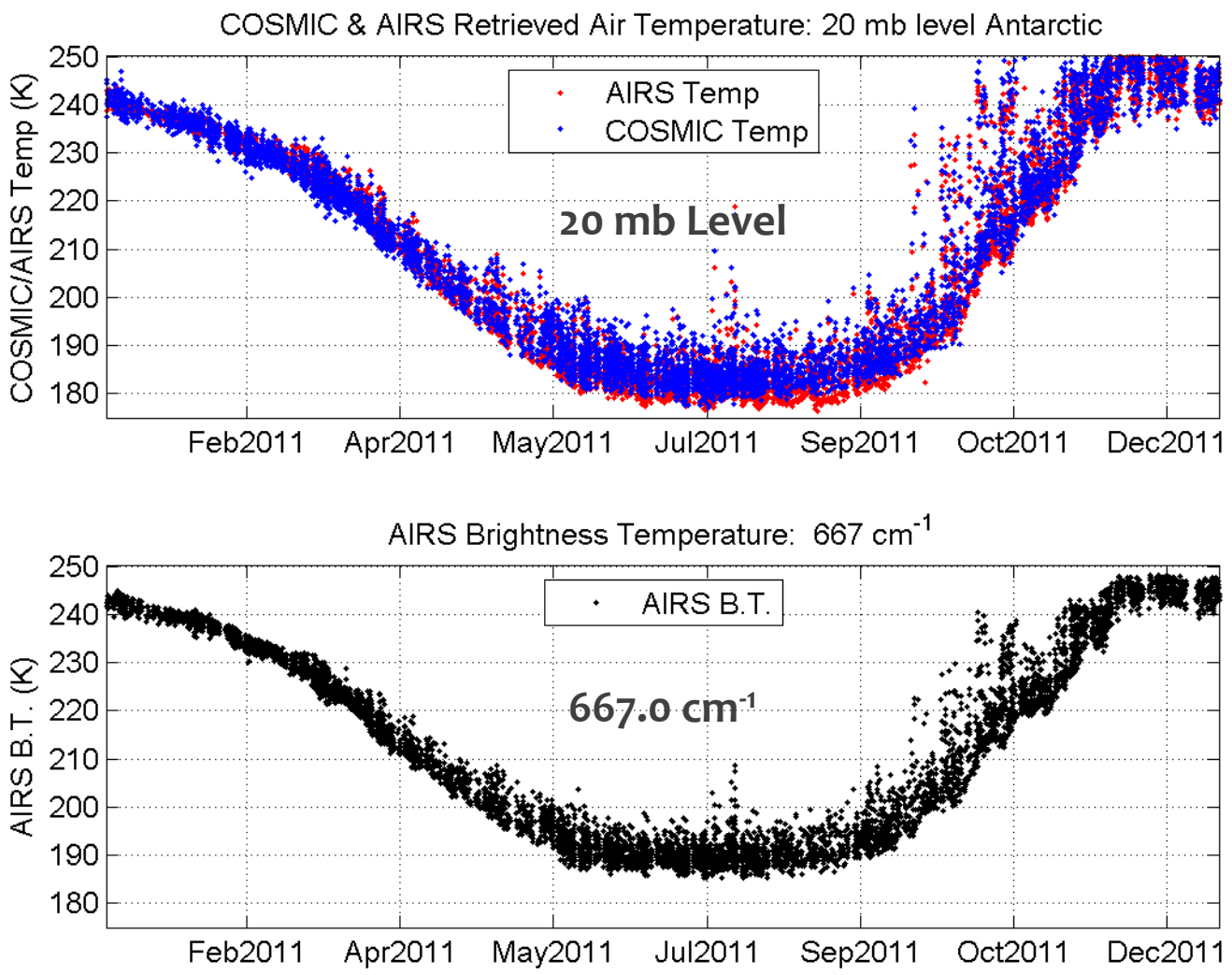
Subarctic Winter



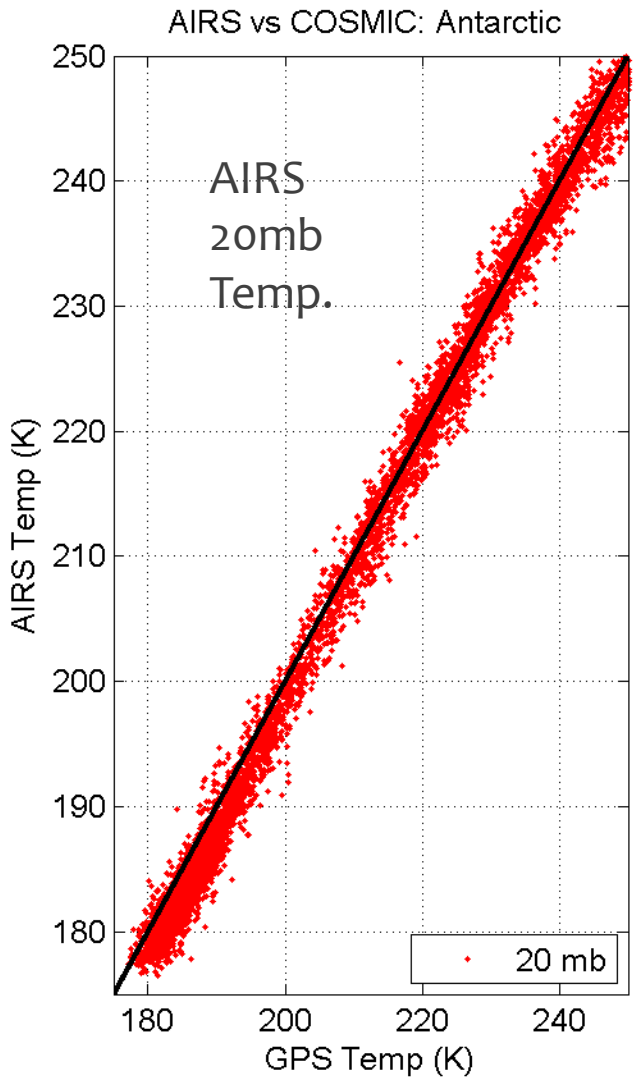
Tropical

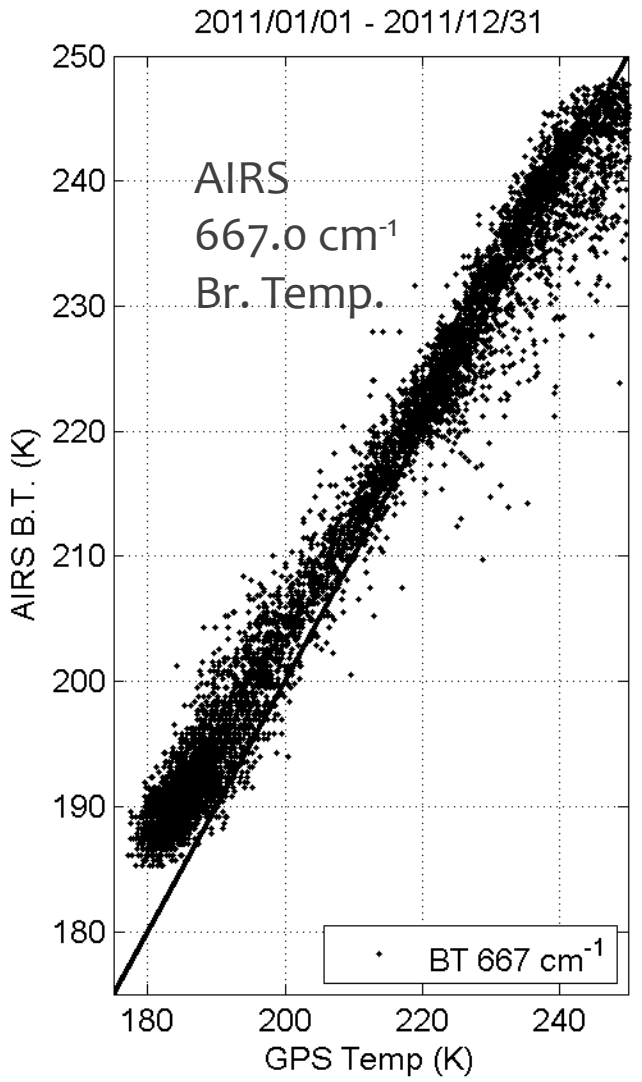
- Computed using the SARTA RTM for the 667.0 cm-1 channel
- Peak is between 20 mb and 30 mb. Compare with 20 mb T levels.

AIRS vs COSMIC Time Series 2011: Antarctica



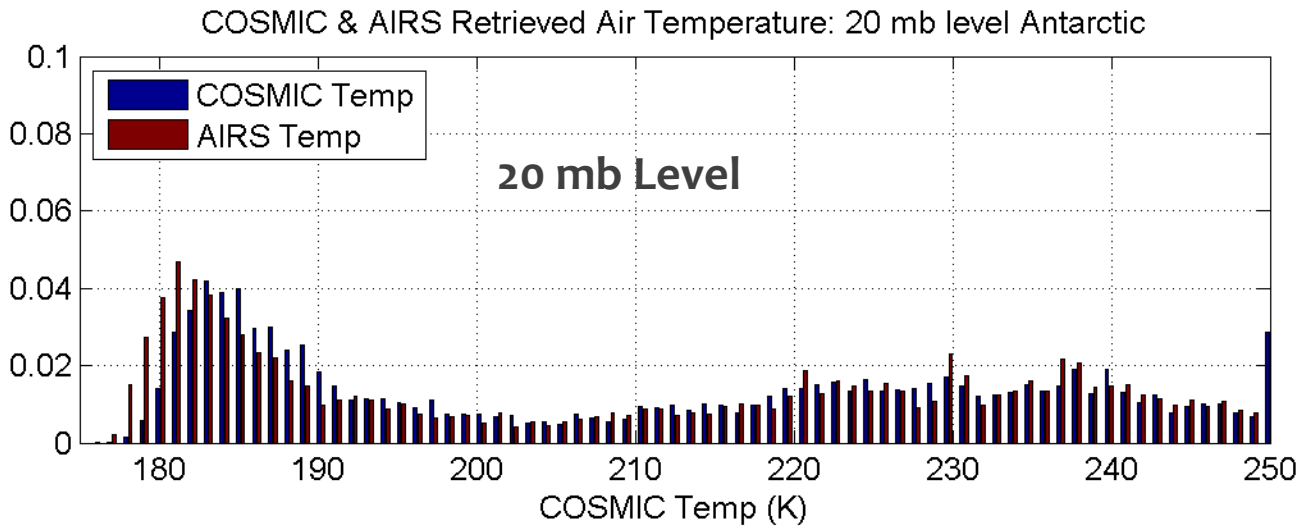
AIRS/COSMIC Scatterplot 2011: Antarctica

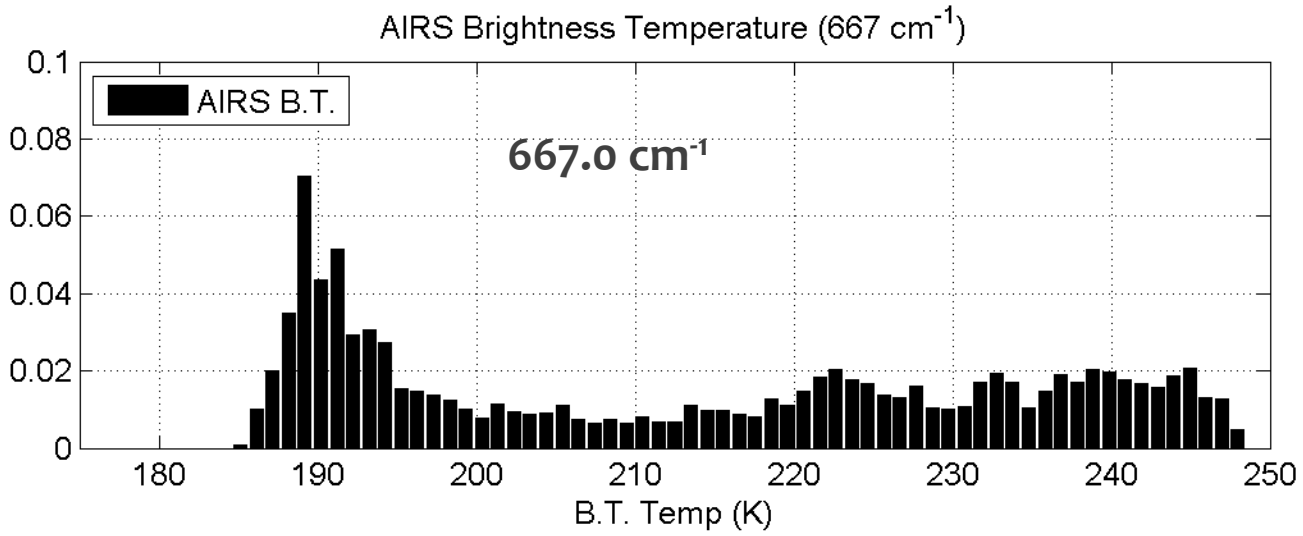




This matched dataset allows for detailed correlation of GPS temperature and both IR retreived temperrature (left) and IR brightness temperature (right).

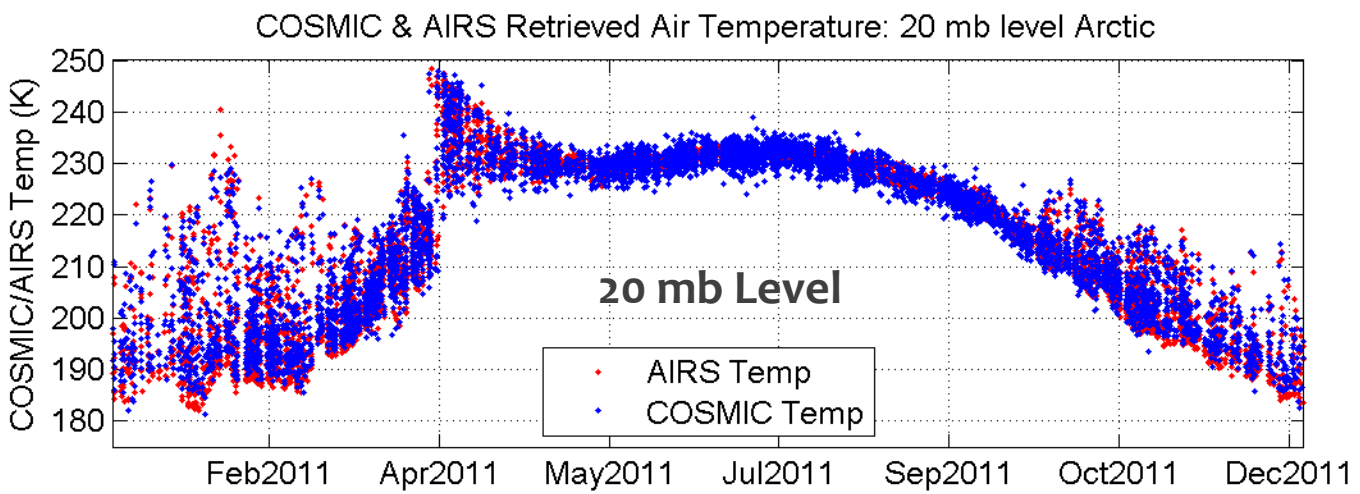
AIRS/COSMIC PDF 2011: Antarctica

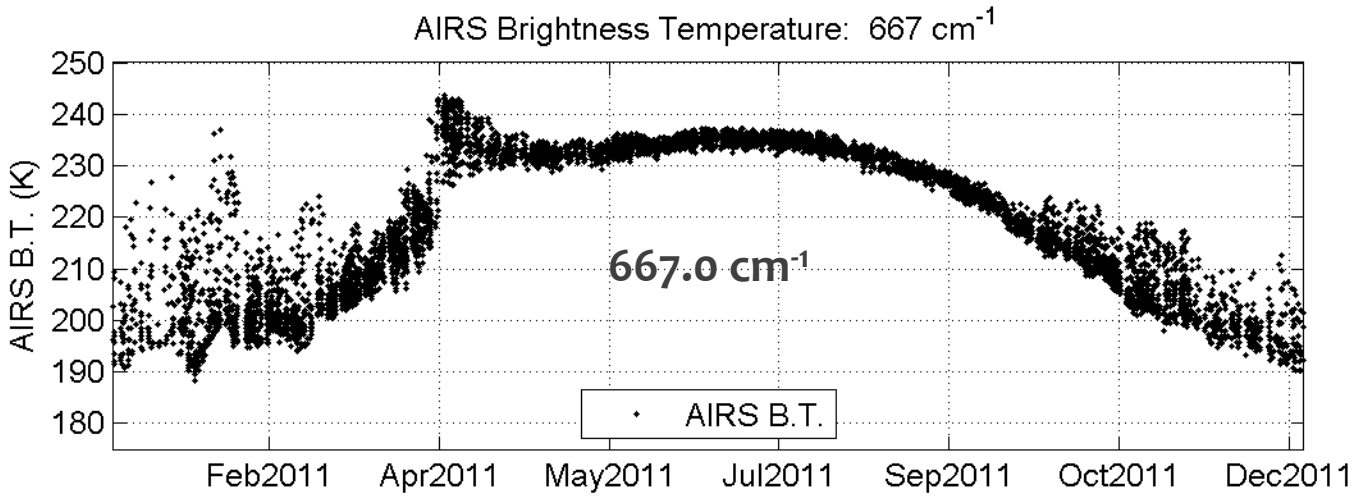




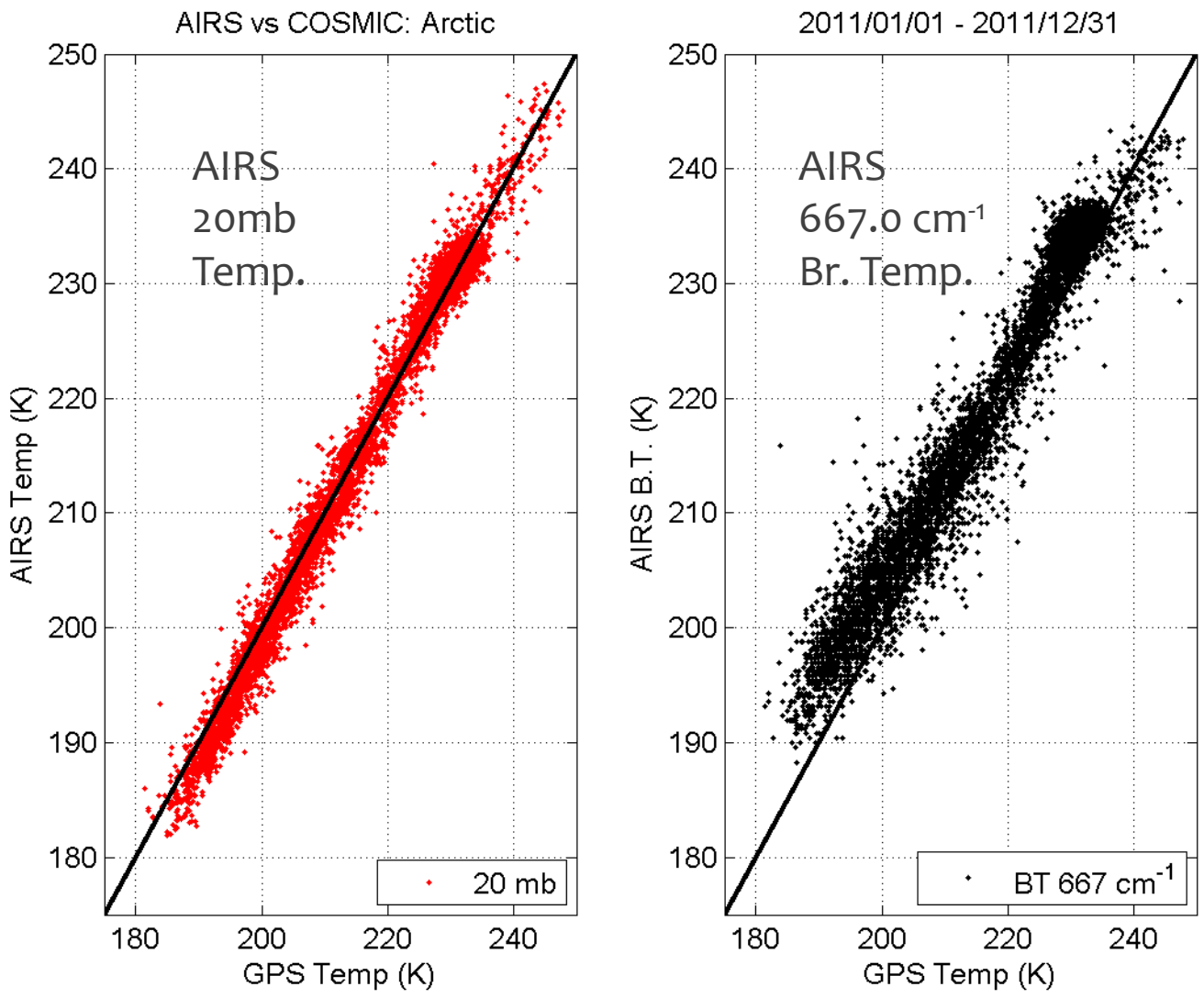
Similarity of IR B.T. PDF to retrieved Stratospheric temperature is encouraging.

AIRS vs COSMIC Time Series 2011: Arctic

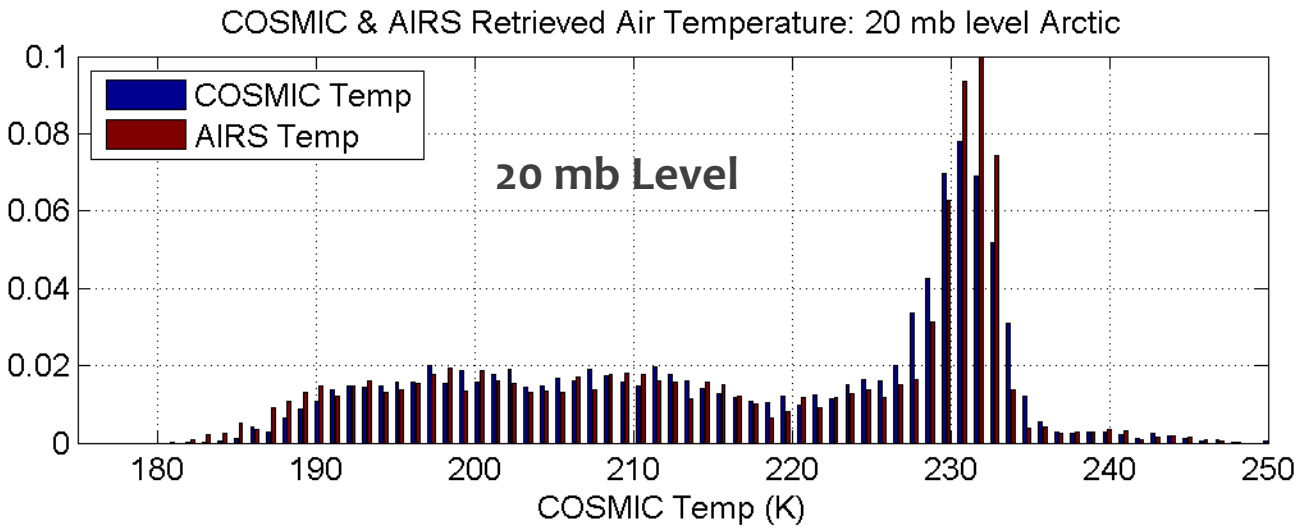


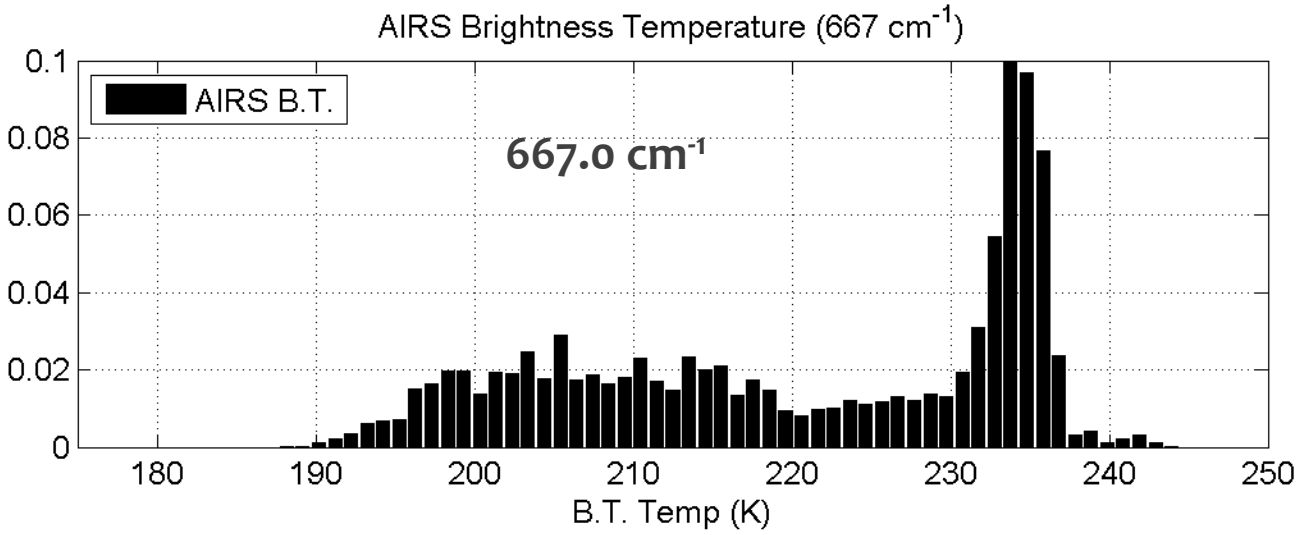


AIRS/COSMIC Scatterplot 2011: Arctic



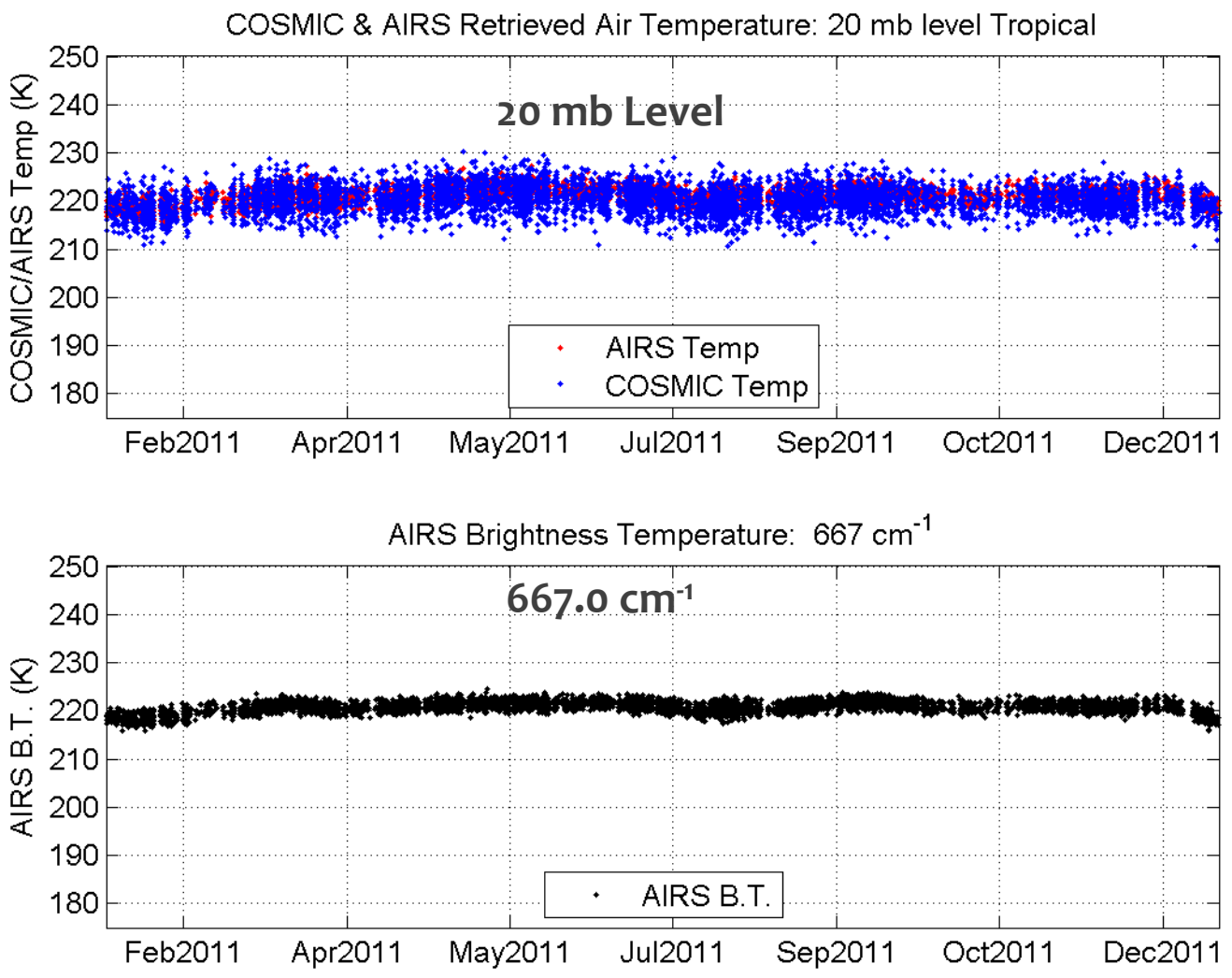
AIRS/COSMIC PDF 2011: Arctic



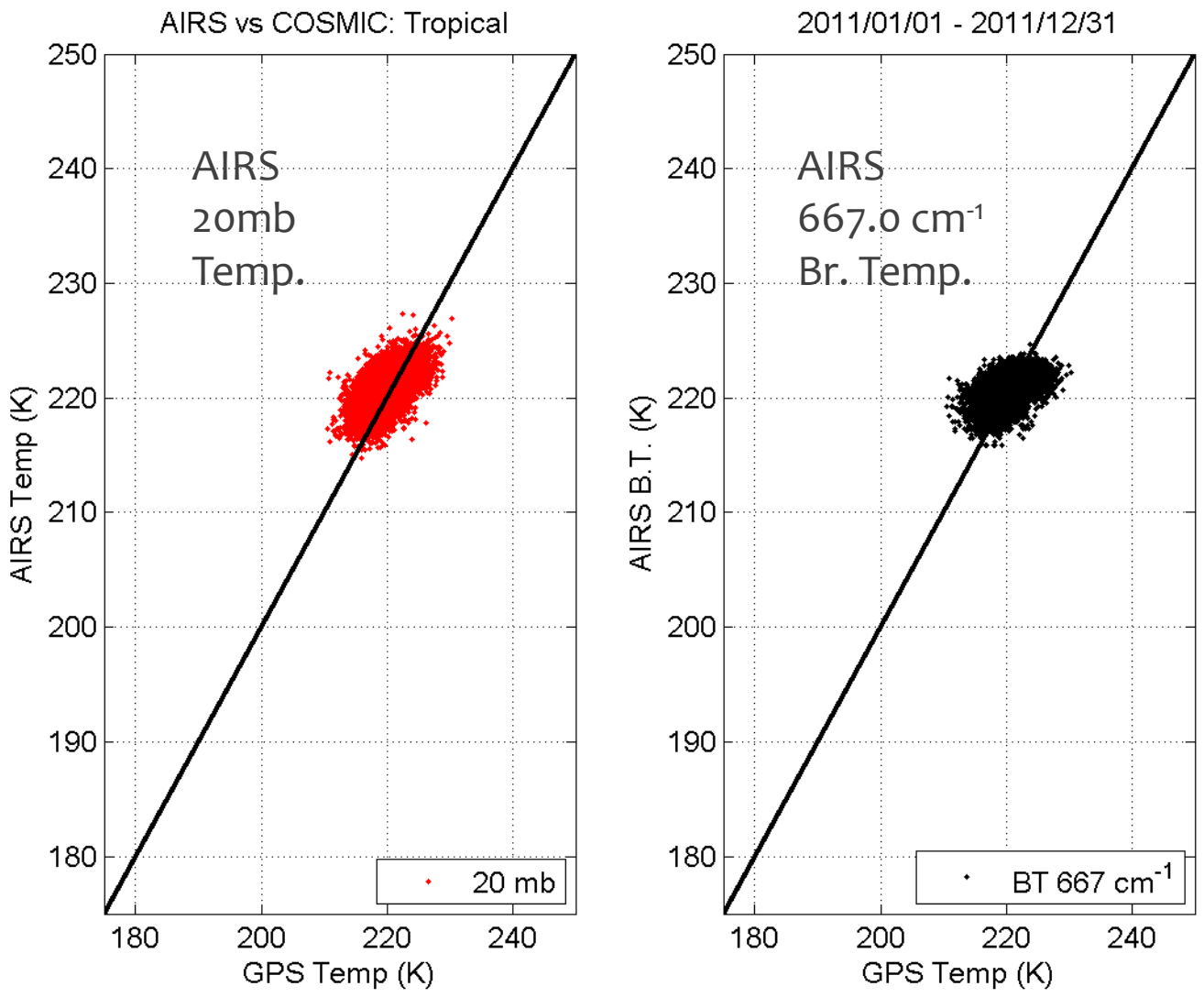


In the Arctic, the IR Brightness Temperature PDF appears to have very similar information with an apparent scaling and shift

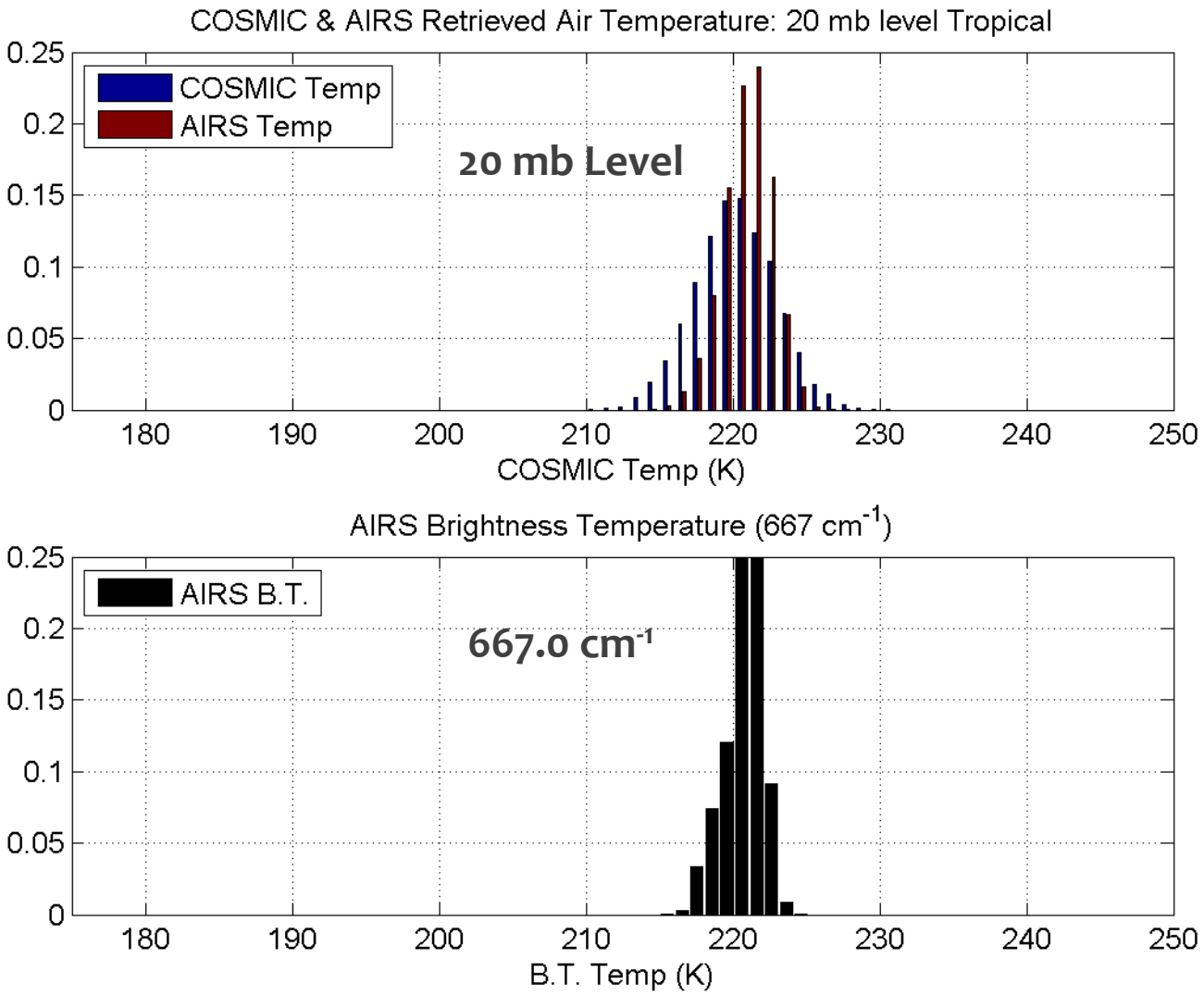
AIRS vs COSMIC Time Series 2011: Tropics



AIRS/COSMIC Scatterplot 2011: Tropics



AIRS/COSMIC PDF 2011: Tropics



In the tropics the IR Brightness Temperature has less variance than either the retrieved GPS or retreived AIRS temperature.

CONCLUSIONS

1. Coincidentally, GPS RO and Hyperspectral IR records began about ten years ago (CHAMP 2001, AIRS 2002).

2. Comparison of COSMIC and AIRS retrieved temperature profiles in the period 2007-2011 show excellent agreement at low vertical resolution.

3. The UW has created a matched L2 dataset of COSMIC RO refractivity and retrieved temperature profiles and AIRS infrared radiance and retrieved profiles.

4. This dataset is being used to develop methodologies for working with similar products expected from CLARREO to help in assessment of atmospheric temperature trends.