Performance of CrIS on Suomi-NPP

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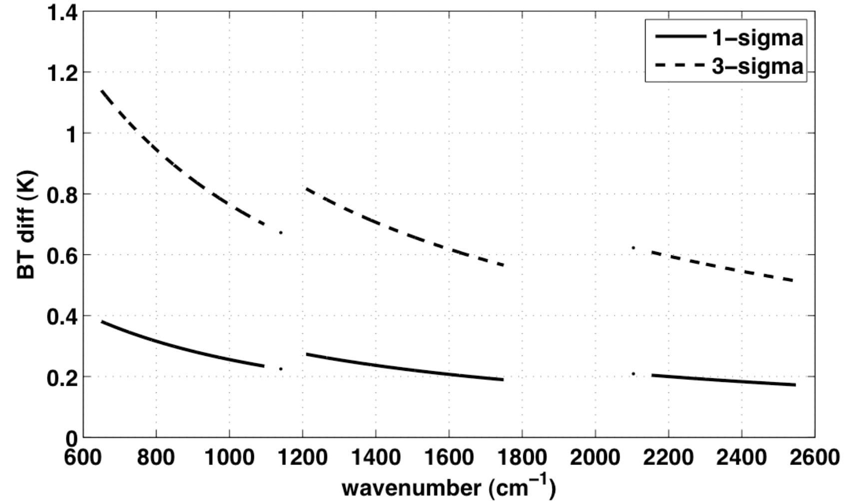
CrIS Radiometric Uncertainty Specification

- **CrIS Radiometric Uncertainty specification** (circa 1990) is primarily driven by weather applications. Expressed as 1-sigma percent radiance uncertainty with respect to Planck 287K radiance [i.e. 100•dR/B(287K)]:
  - Longwave: 0.45%
  - Midwave: 0.58%
  - Shortwave: 0.77%

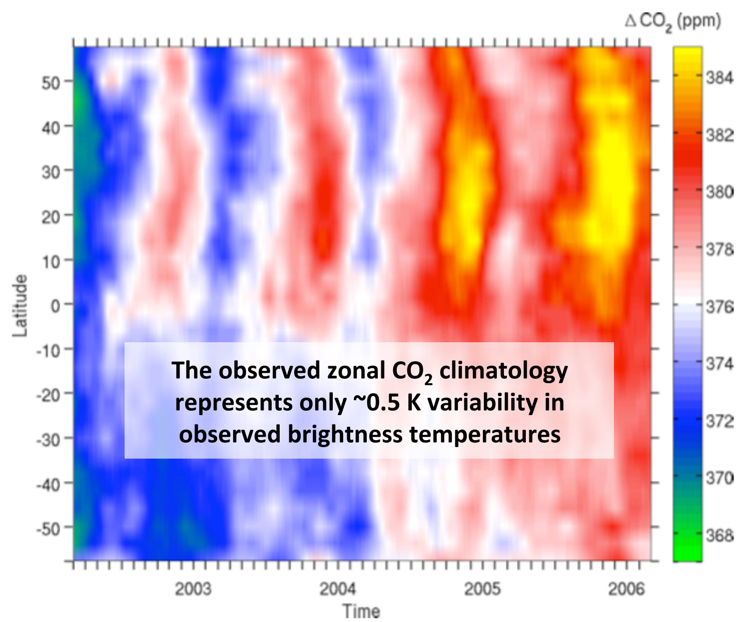
  for B(233K) to B(287K)

CrIS Radiometric Uncertainty spec, expressed as 1 and 3 sigma brightness temperature differences



- **Climate and NWP Applications** often require better accuracy

E.g. CO_2 as measured by AIRS, c/o L. Strow:



Radiometric Uncertainty Budget
with component uncertainties based on pre-launch analysis/testing

On-orbit calibration equation:

$$R_{Earth}(\nu_{user}) = SRA\left[SA^{-1}\left(\mathrm{Re}\left\{\frac{C'_{Earth}(\nu_{sensor}) - \langle C'_{Space}(\nu_{sensor})\rangle}{\langle C'_{ICT}(\nu_{sensor})\rangle - \langle C'_{Space}(\nu_{sensor})\rangle}\right\} R_{ICT}(\nu_{sensor})\right)\right]$$

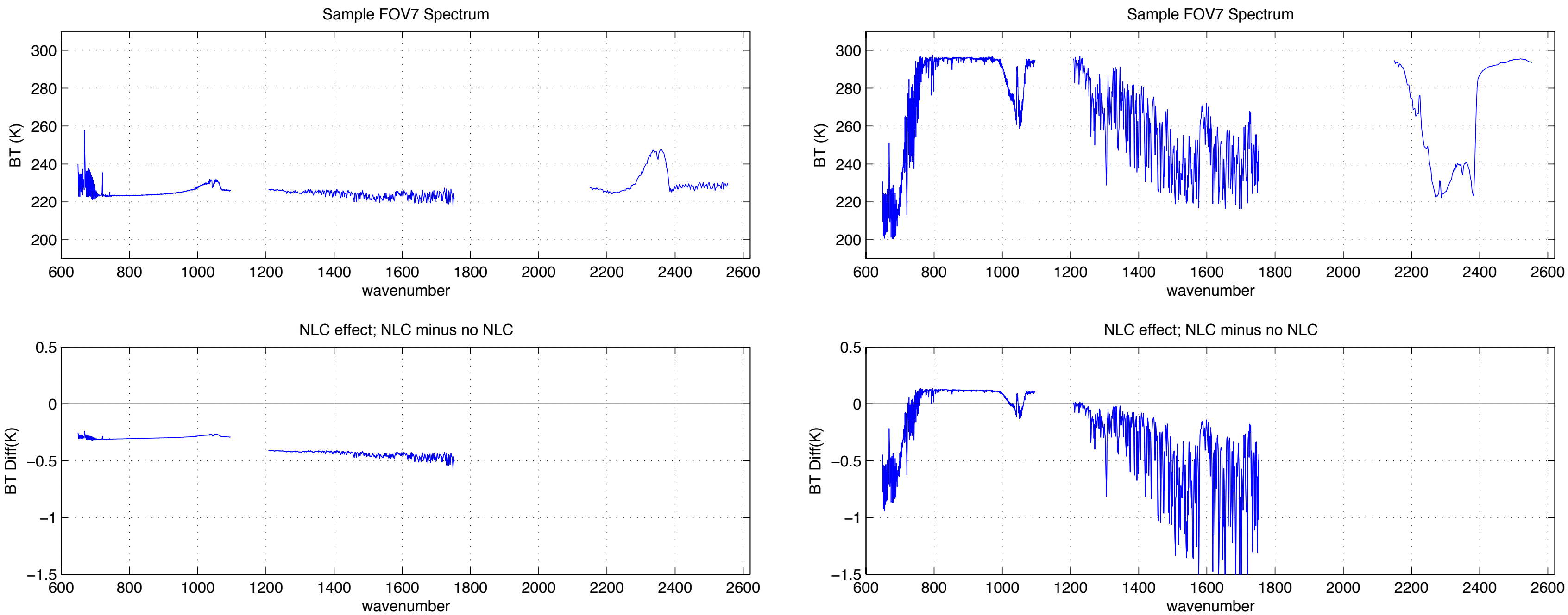
with $R_{ICT} = \varepsilon_{ICT} B(T_{ICT}) + (1-\varepsilon_{ICT}) R_{ICT,Reflected}$ $\quad C' = C / (1 - a_2 V_{DC})$

Parameter	1-σ uncertainty	3-σ uncertainty	Source/Comment
T_{ICT} (K)	37.5 mK	112.5 mK	Bomem/ITT eng. estimate (w/o known readout issue)
ε_{ICT} ( )	0.01	0.03	Independent measurement (TSSR) at 2500 cm^{-1} plus Analysis
$T_{refl,measured}$ (K)	0.5 K	1.5 K	Temperature monitored components (Frame, OMA, BS, ICT Baffle)
$T_{refl,modelled}$ (K)	2 K	6 K	Worst case estimate of unmonitored SSM Baffle T variations
a_2 (1/counts)	9.6% Longwave 15.5% Midwave	28.8% Longwave 46.5% Midwave	DM and ECT view analysis

Other contributions, such as scan mirror polarization and stray light, are not included here. Other studies, by ITT/Exelis, show these do not contribute significantly to the total RU.

Non-Linearity Correction

Example corrections:

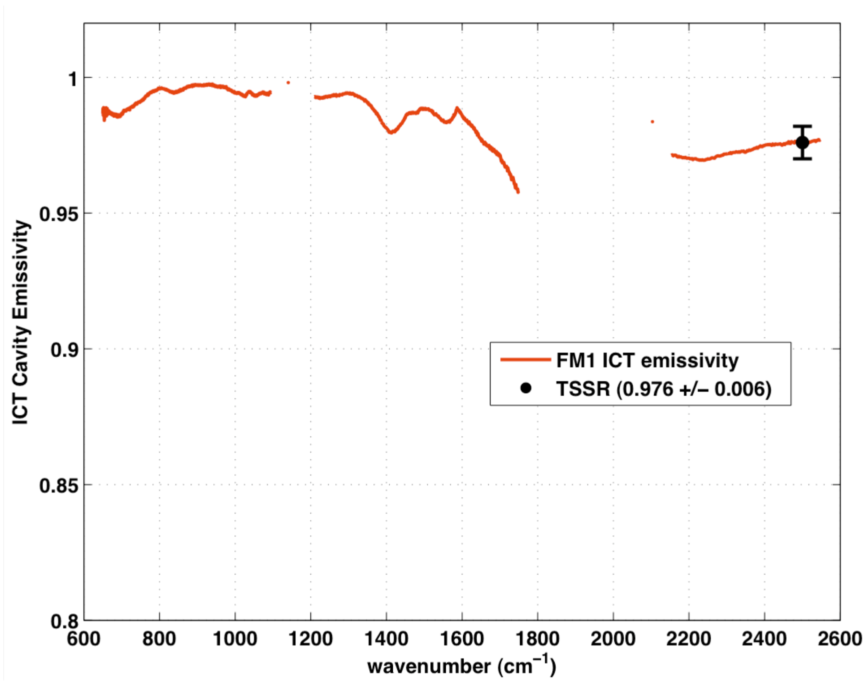


- The CrIS RU budget and SDR algorithm did not originally include NL contributions; Significant quadratic NL realized for LW and MW (MCT) bands and characterized only with system level TVAC testing. SW band (InSb) is linear.
- The correction is FOV#, band, wavenumber, and scene dependent
- The NL magnitude was observed to change between TVAC cycles, particularly for certain MW FOVs.
- Post-launch, the on-orbit NL has been characterized using harmonic out-of-band analysis of ICT views and FOV-2-FOV consistency analysis of Earth views.

ICT Predicted Radiance

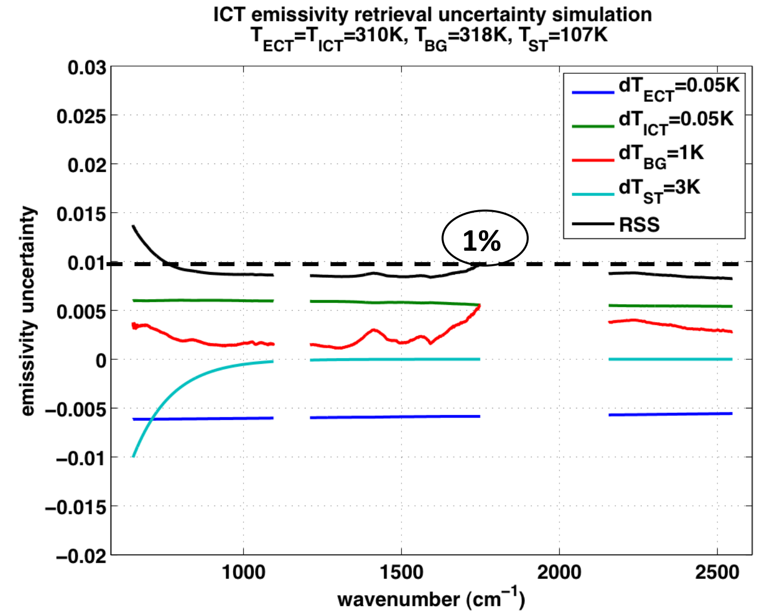
$$R_{ICT} = \varepsilon_{ICT}\, B(T_{ICT}) + (1-\varepsilon_{ICT})\, R_{ICT,Reflected}$$

ICT Emissivity

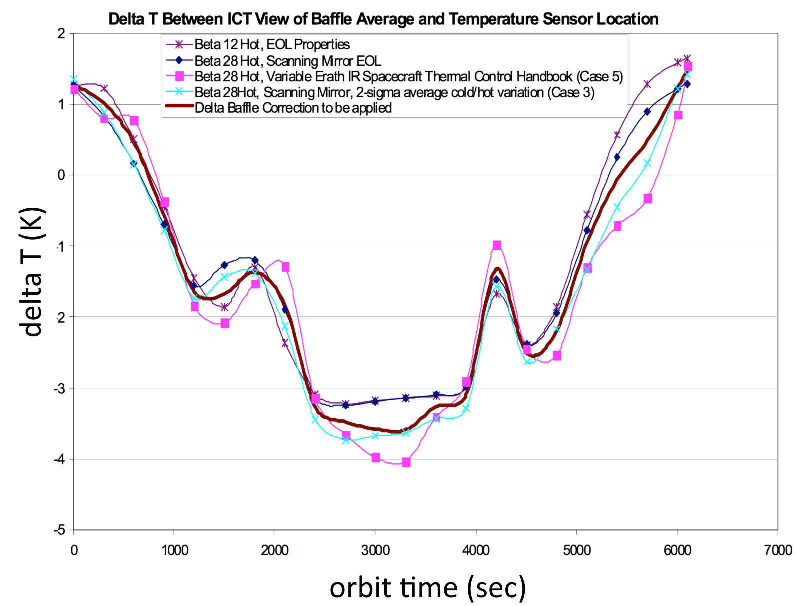


- Prediction includes a modeled component of the reflected radiance which varies with orbit phase
- Effect is expected to be small, but largest for warm scenes in SW band and edge of MW band

ICT Emissivity Uncertainty

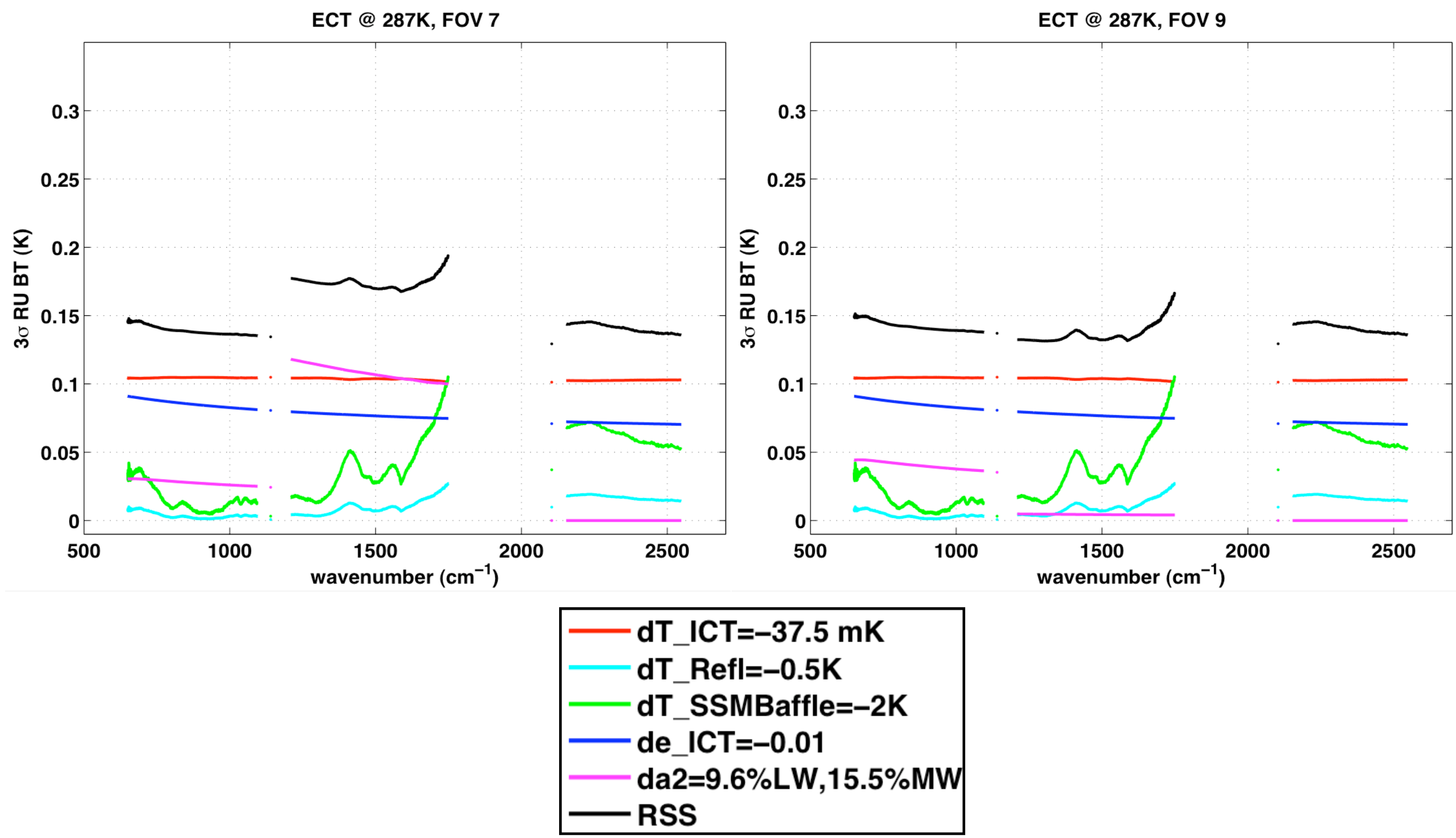


$T_{refl,\ modeled}$



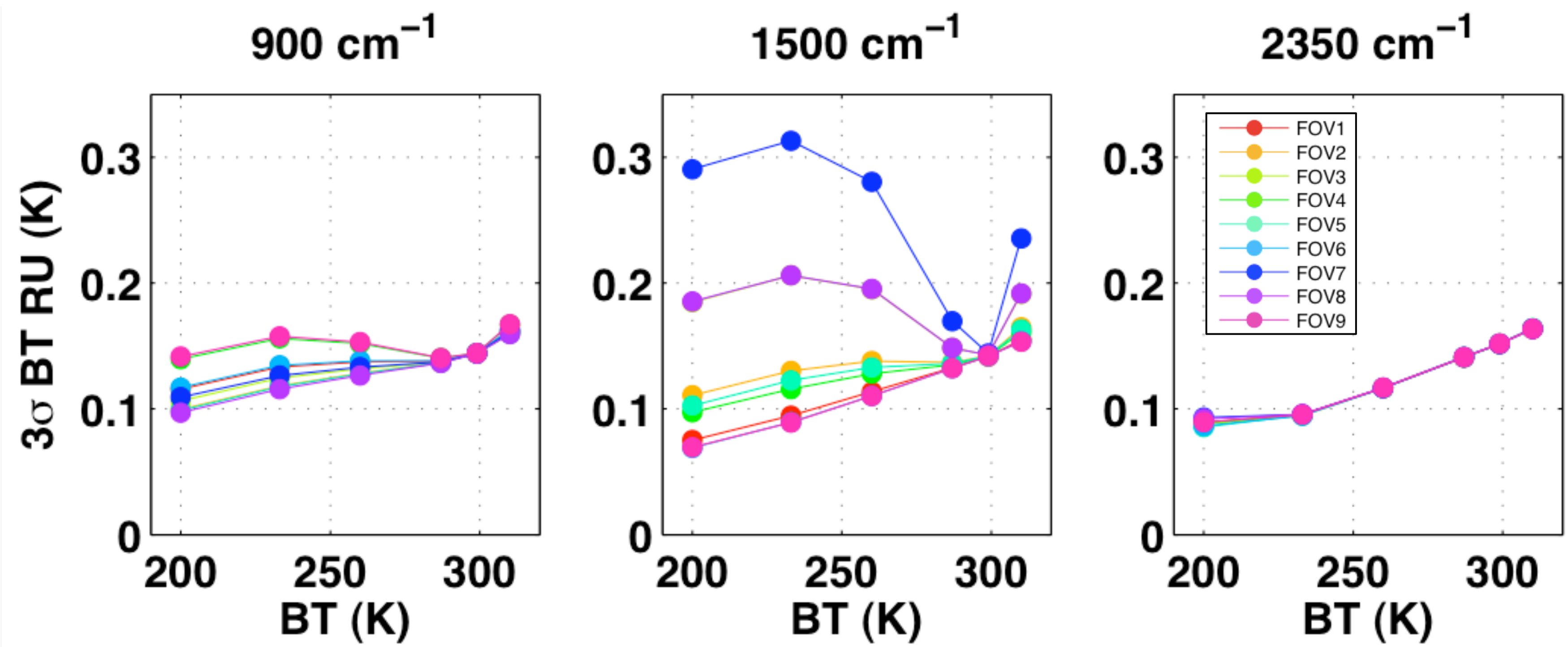
Pre-launch estimates of CrIS Radiometric Uncertainty based on TVAC testing

Examples for FOVs 7 and 9 for ECT@287K



Pre-launch estimates of CrIS Radiometric Uncertainty based on TVAC testing

versus scene temperature for all FOVs for ~mid-band spectral channels

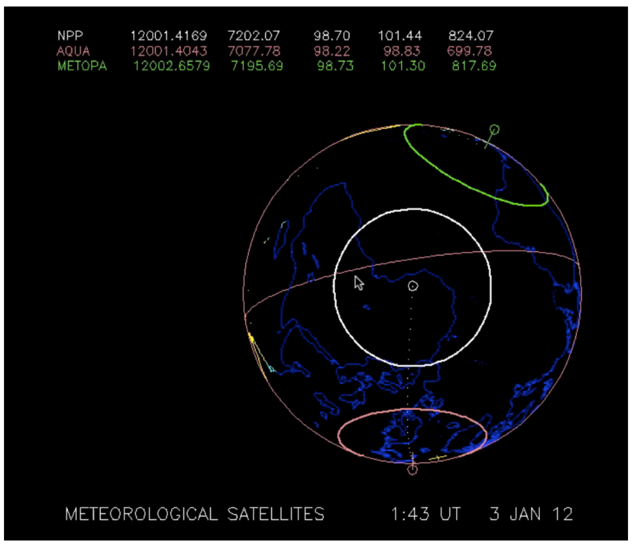


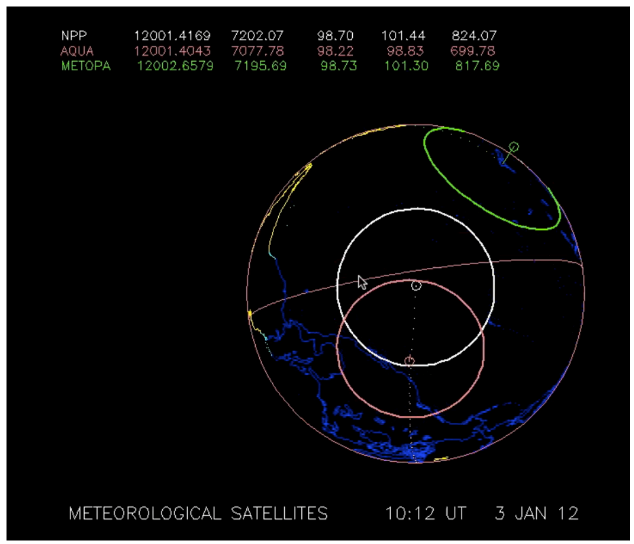
- Predicted behavior in the Shortwave (linear) band is dominated by T_{ICT} uncertainty
- Deviations in the Longwave and Midwave bands are due to FOV dependent nonlinearity

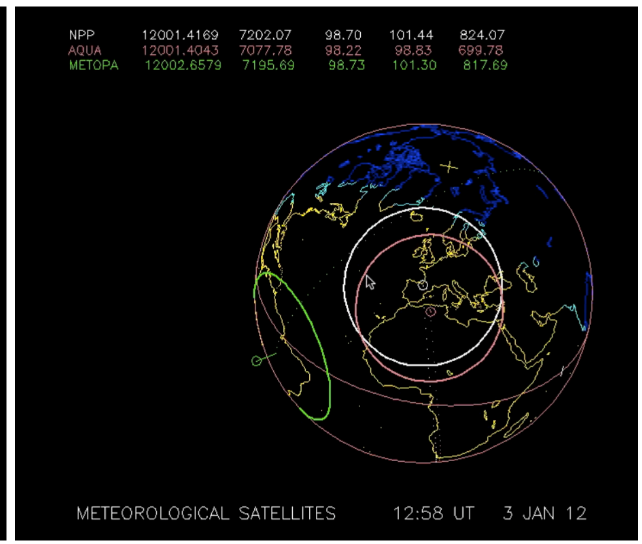
U.Wisc Post-Launch Cal/Val Tasks

1. Internal consistency checks on Radiometric Calibration
2. Radiometric Non-linearity Refinement and Evaluation
3. Radiometric Noise assessment
4. Variable artifact assessment using Principle Component Analysis
5. Early broadband comparisons with GOES and other GEOs
6. Clear sky Observed minus Calculated Analysis
7. Internal consistency checks on spectral calibration, spectral self-apodization correction and resampling
8. Analysis of non-uniform scene effects on the ILS
9. **SDR evaluations using SNO comparisons with AIRS** and IASI
10. **CrIS/VIIRS Radiance Comparisons**
11. ICT Environmental Model Evaluation and Refinement
12. In-orbit RU Estimation

Suomi-NPP/Aqua/METOP-A orbit animation



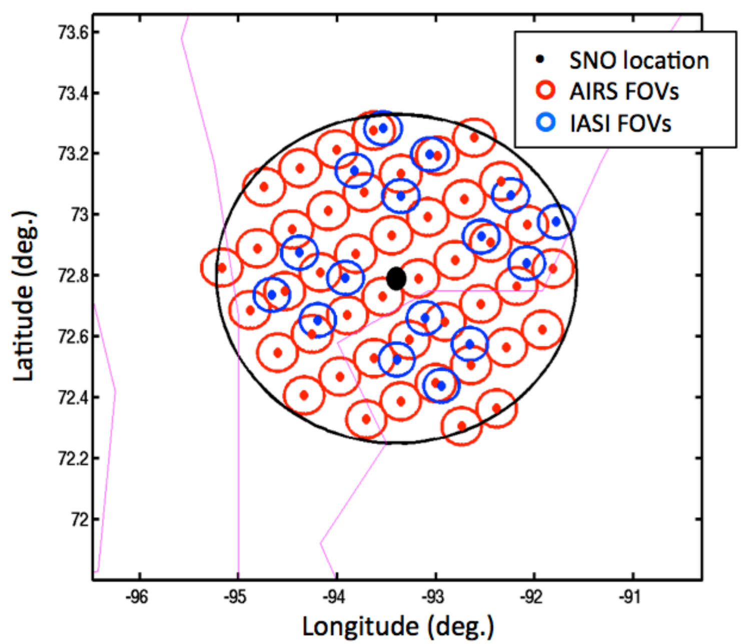


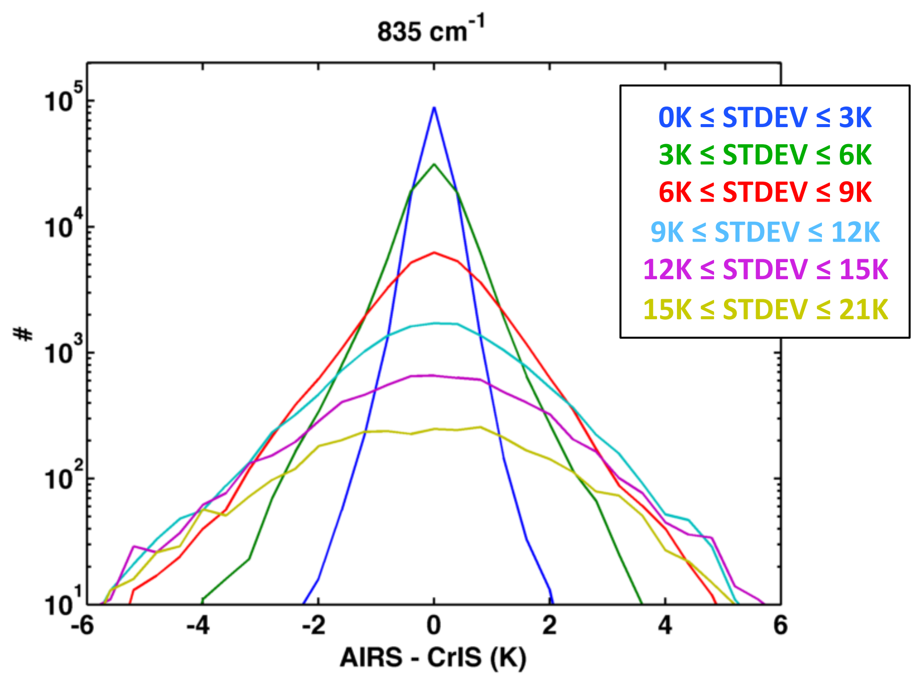


“Big Circle SNO” approach

Comparison approach follows our previous SNO type analyses (e.g. Tobin et al. CALCON2010)

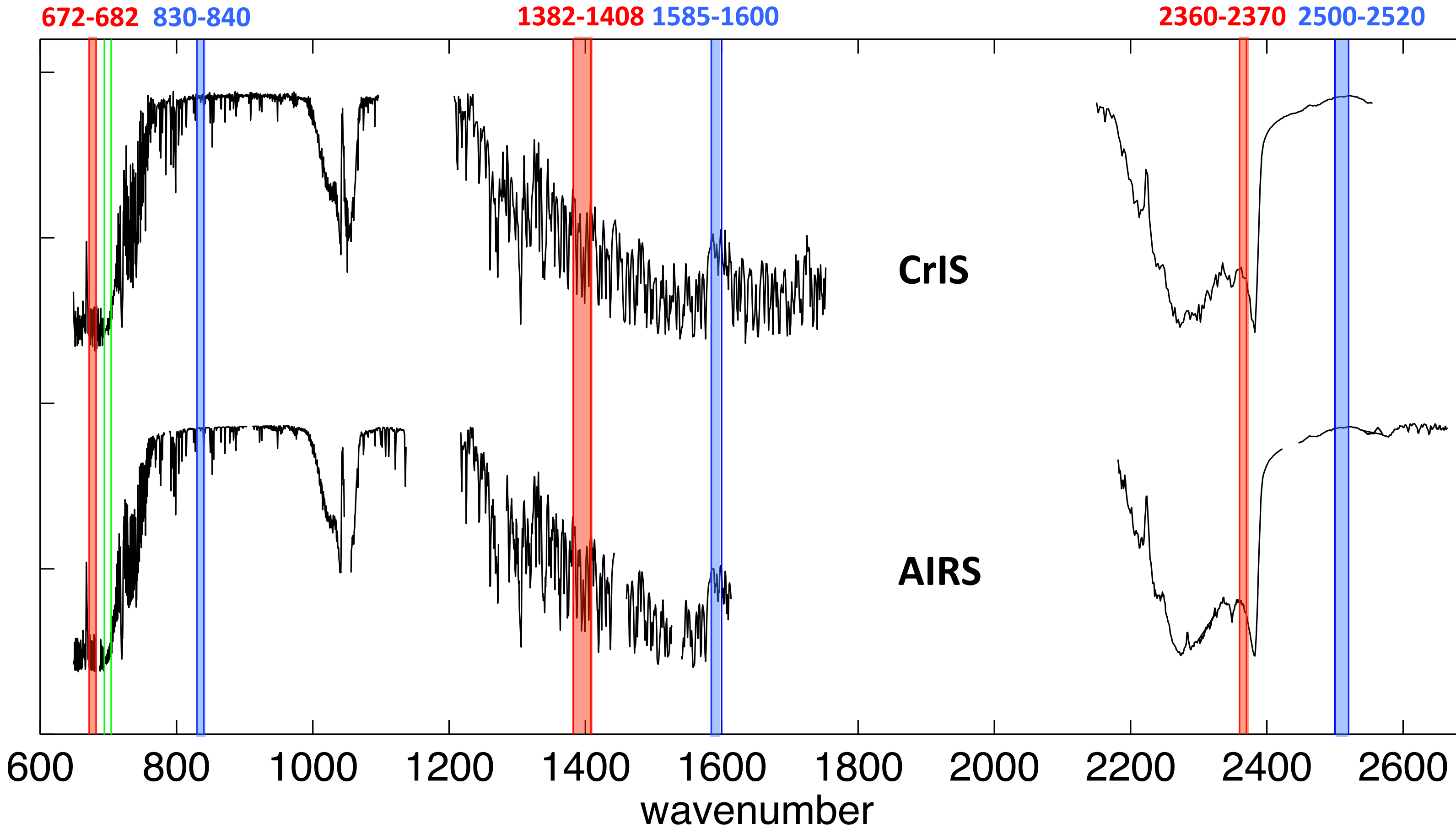
- AIRS and CrIS data within large ellipsoids gathered (~100 km diameter at nadir)
- Mean spectra and StdDev of spectra recorded
- Data screened by time matchup and view angle and weighted by scene variability to compute biases and associated uncertainties
- Advantage of this type of analysis is that the comparisons are not dependent on knowledge of the atmospheric state, radiative transfer algorithms, cloud screening, surface characterization, precise gelocation, …



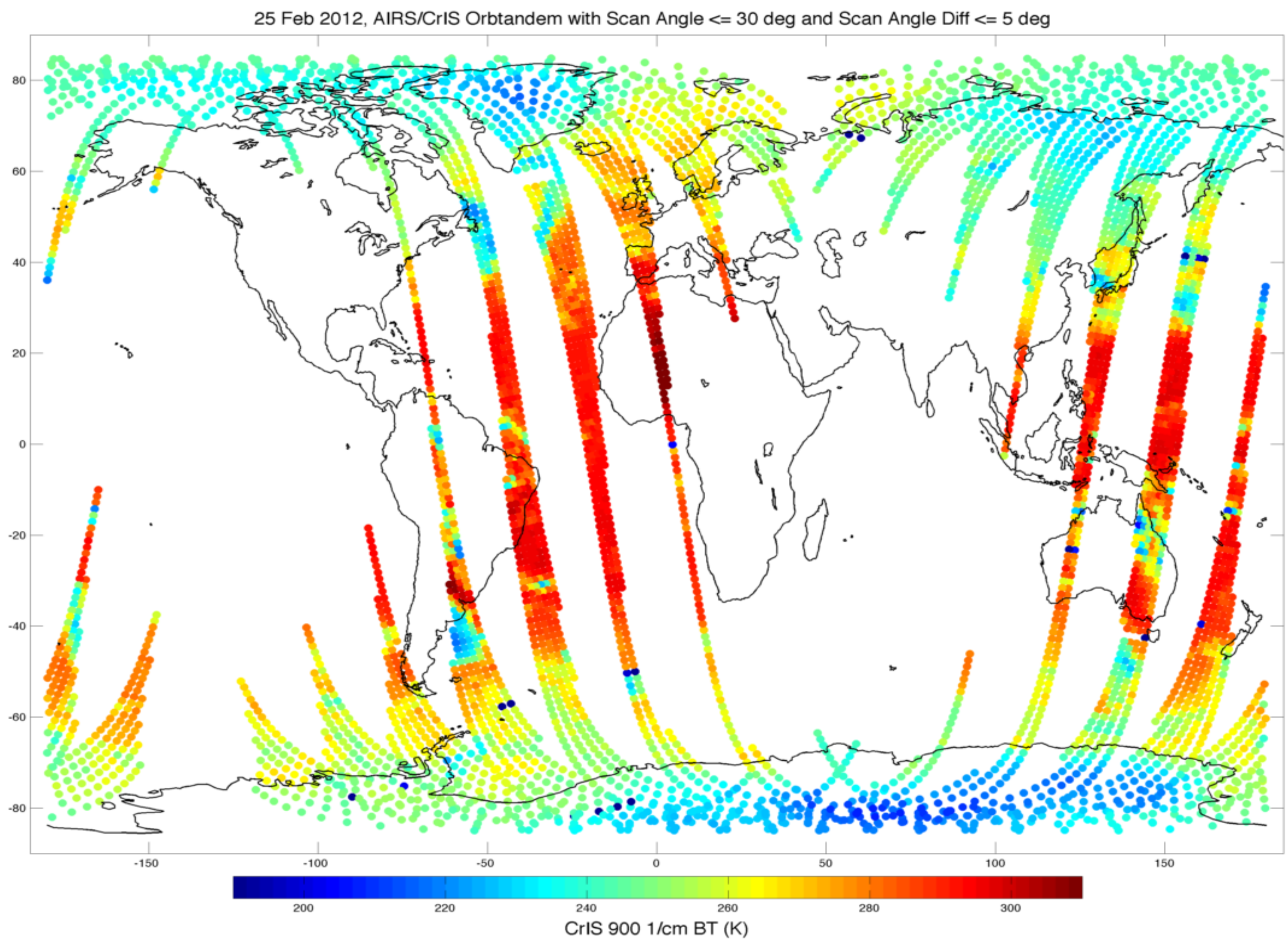


Selected wavenumber regions

- To *largely* avoid the AIRS L1B SRF issues, comparisons shown here are performed for representative ~10 cm^{-1} regions, selected for sensitivity to CrIS nonlinearity and the CrIS ICT environmental model:



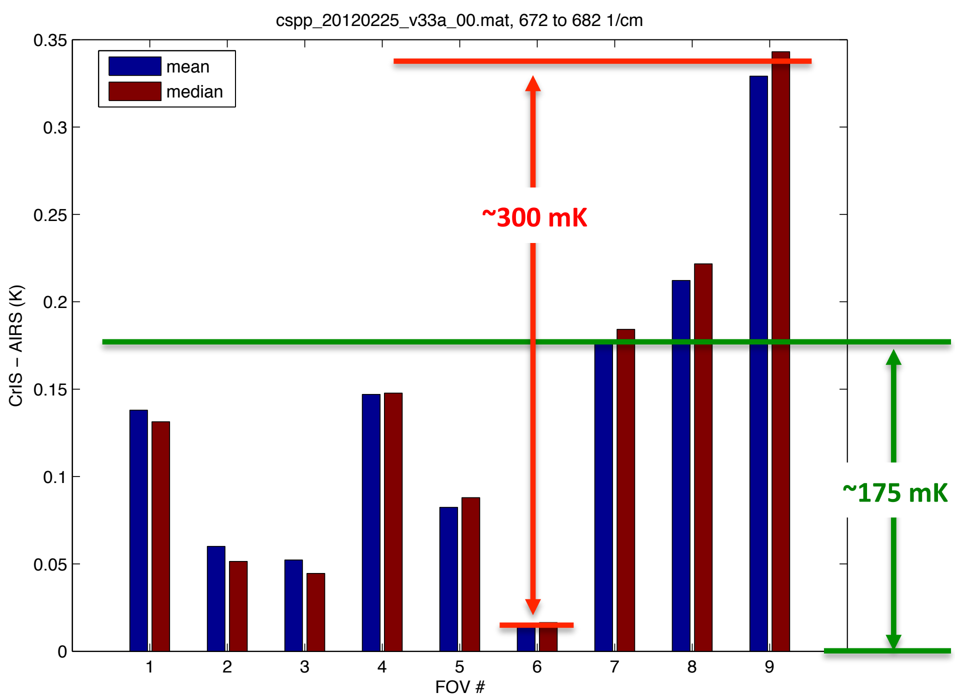
25 Feb overlaps
for scan_angles <= 30 deg & scan_angle_dif <= 5 deg



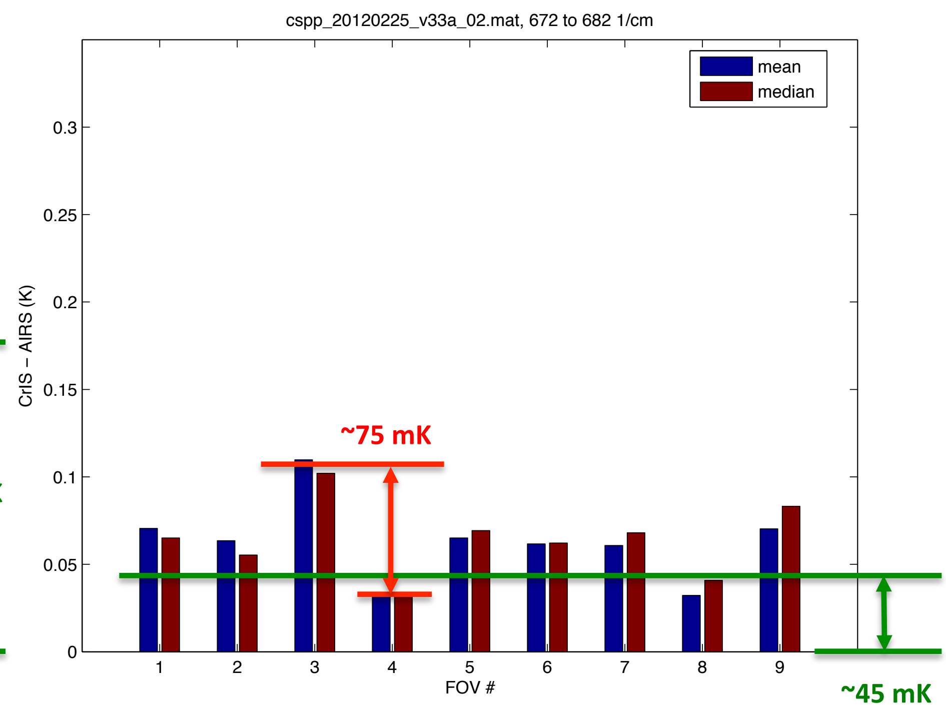
LW band, by CrIS FOV#

Feb 25 AIRS/CrIS comparisons

TVAC (v32) a_2 values



On-orbit (v33) a_2 values

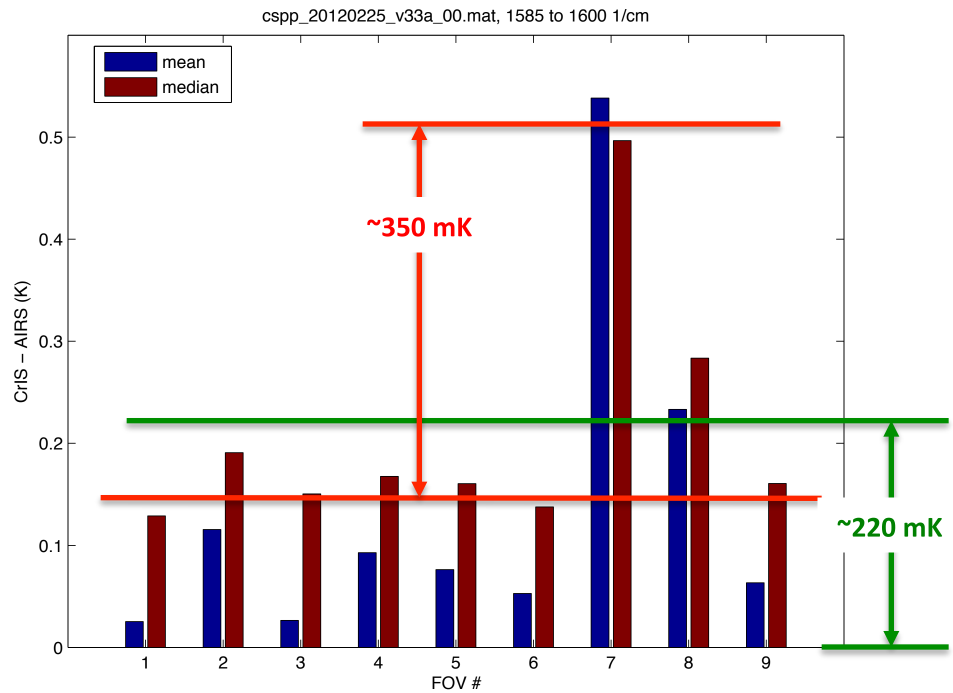


LW at 675 cm^{-1}: **FOV-2-FOV range** and **median difference from AIRS**

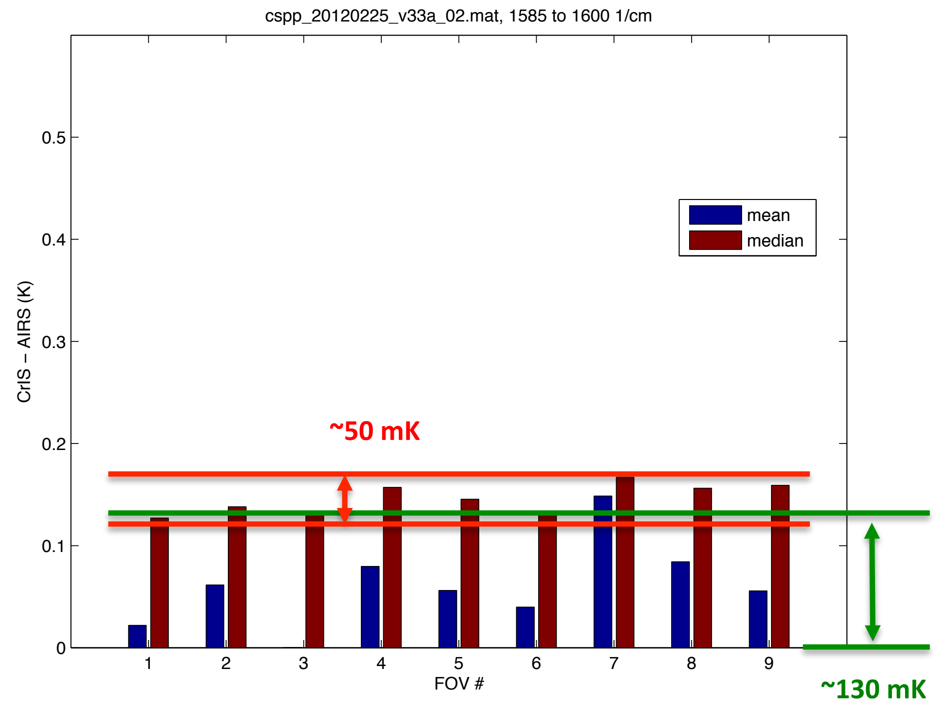
MW band, by CrIS FOV#

Feb 25 AIRS/CrIS comparisons

TVAC (v32) a_2 values

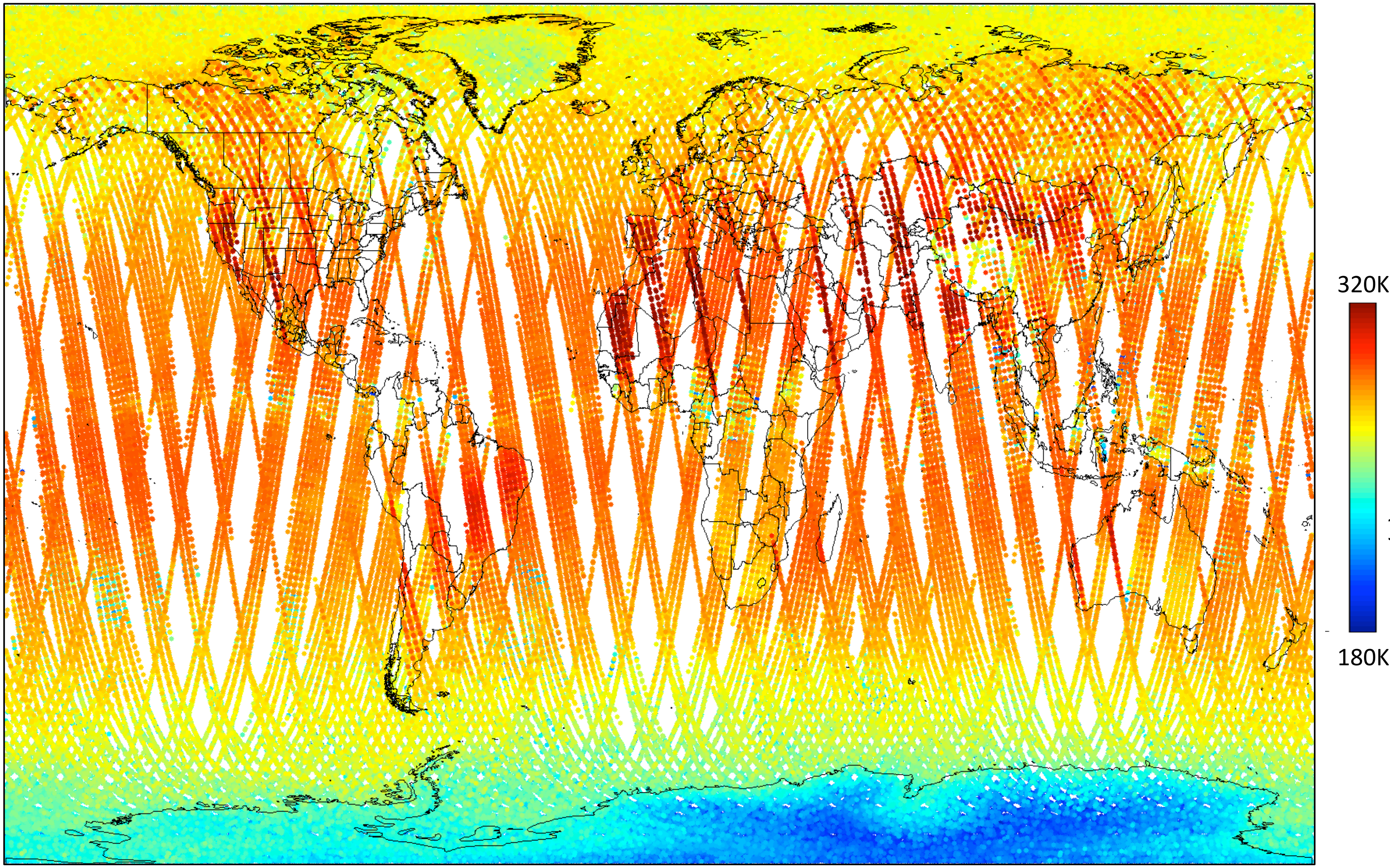


On-orbit (v33) a_2 values



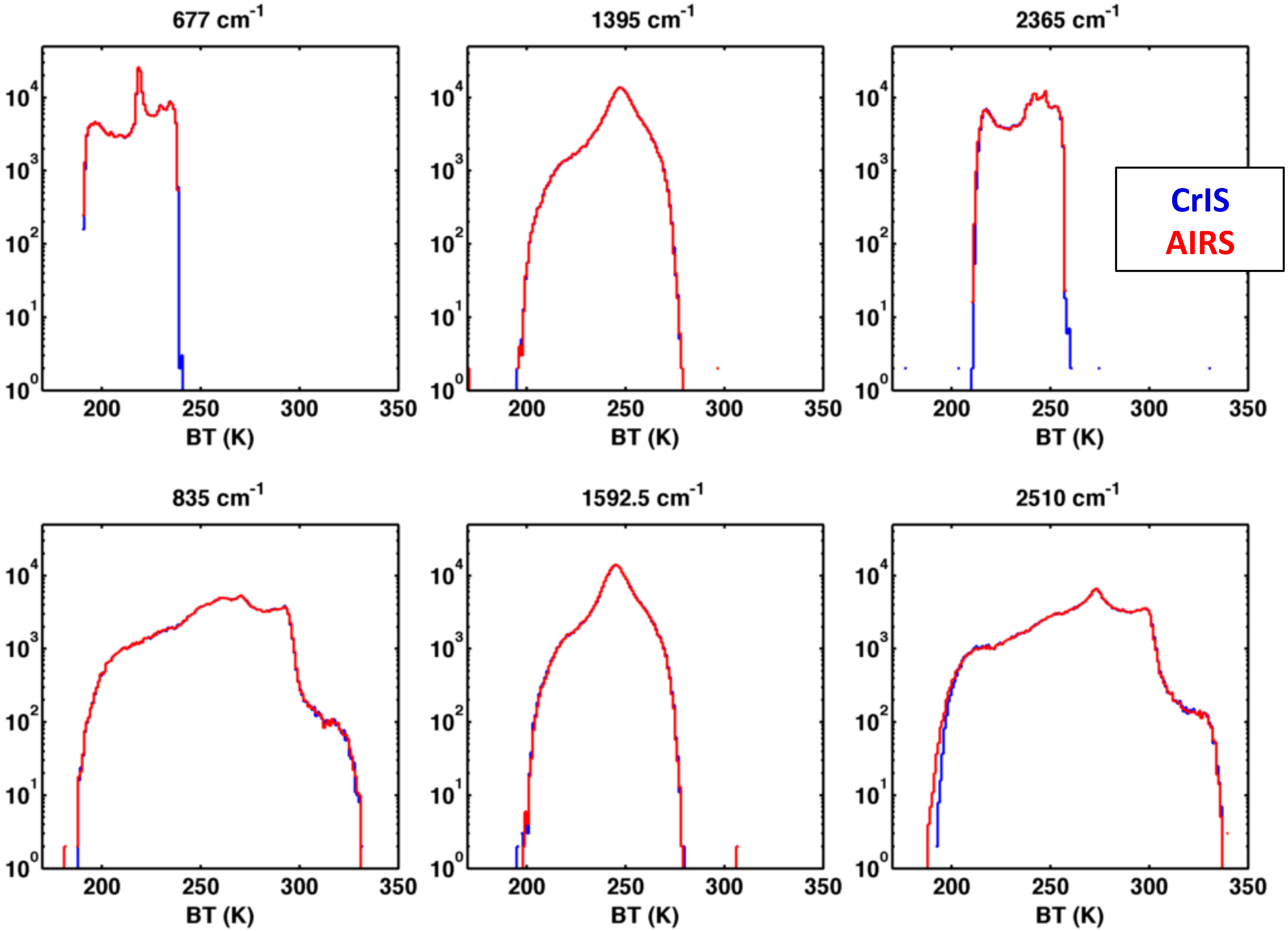
MW at 1590 cm^{-1}: **FOV-2-FOV range** and **median difference from AIRS**

CrIS/AIRS dataset, 1 April to 19 August

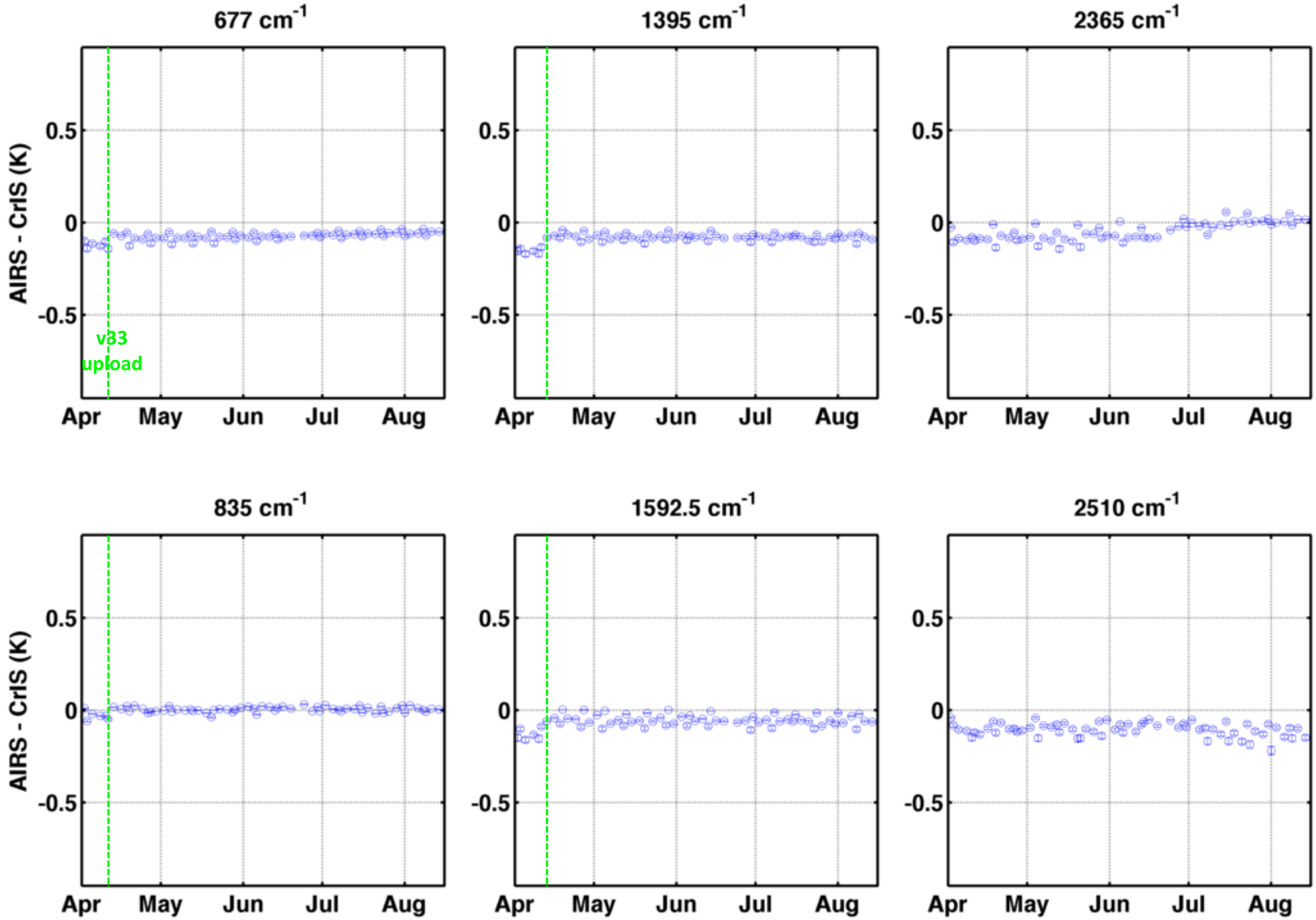


- 275,307 “big circle” samples, 1 April to 19 August
- Scan angles ≤ 30°; Scan angle difference ≤ 3°; Time Diff <= 20 min
- AIRS data is L1B v5; CrIS data is ADL (CSPP v1.1)

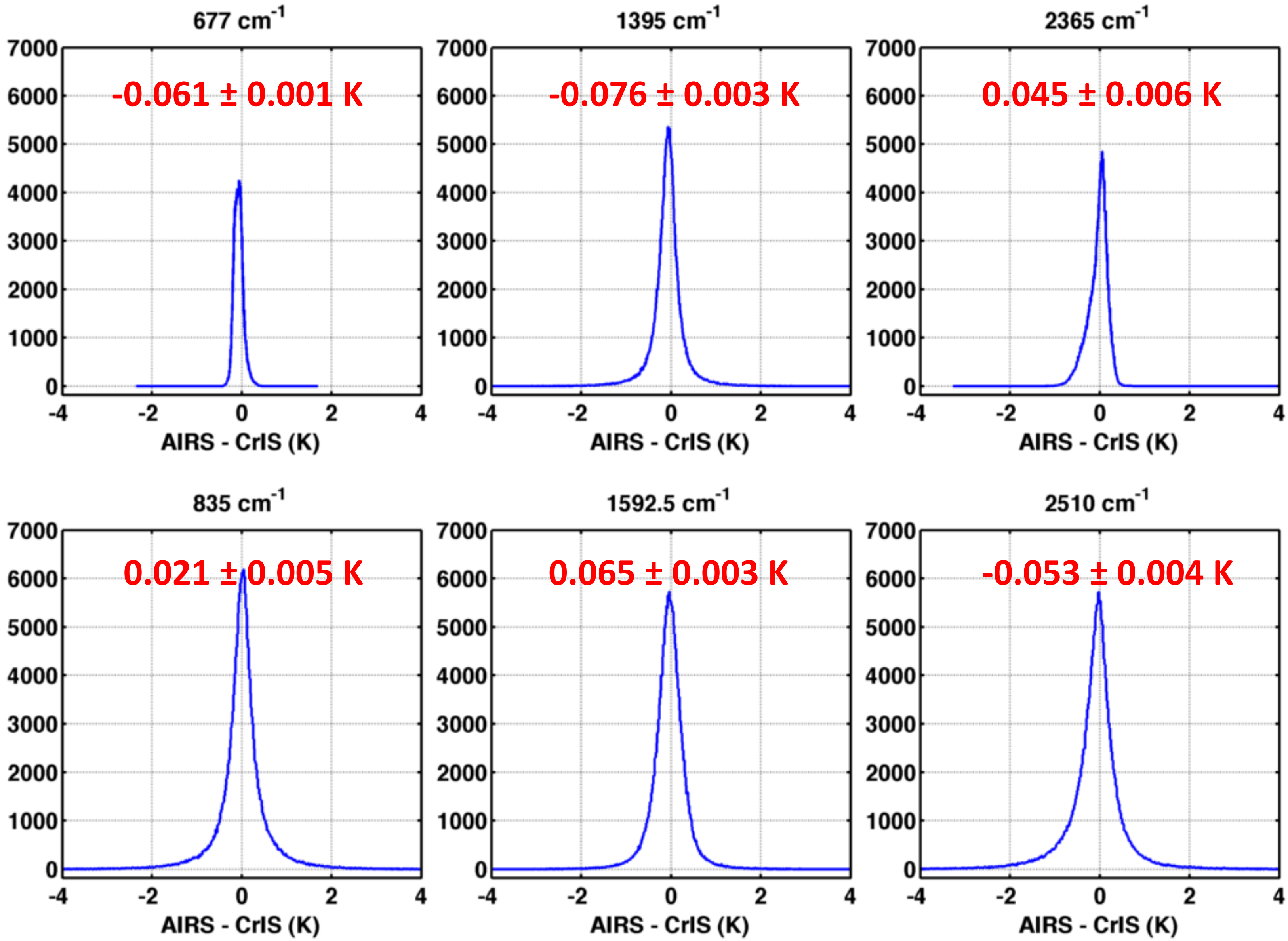
BT Distributions



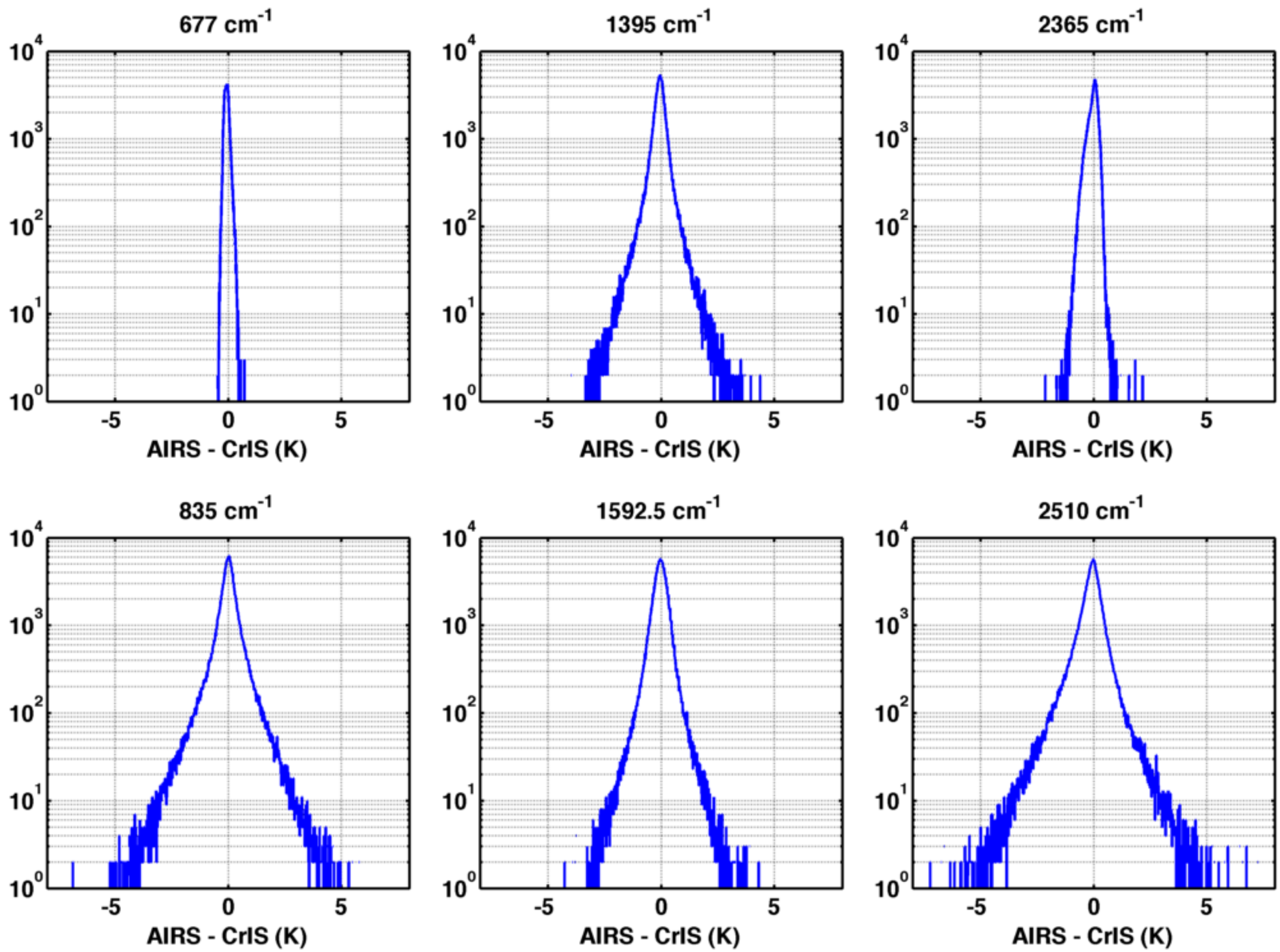
Daily Mean Differences



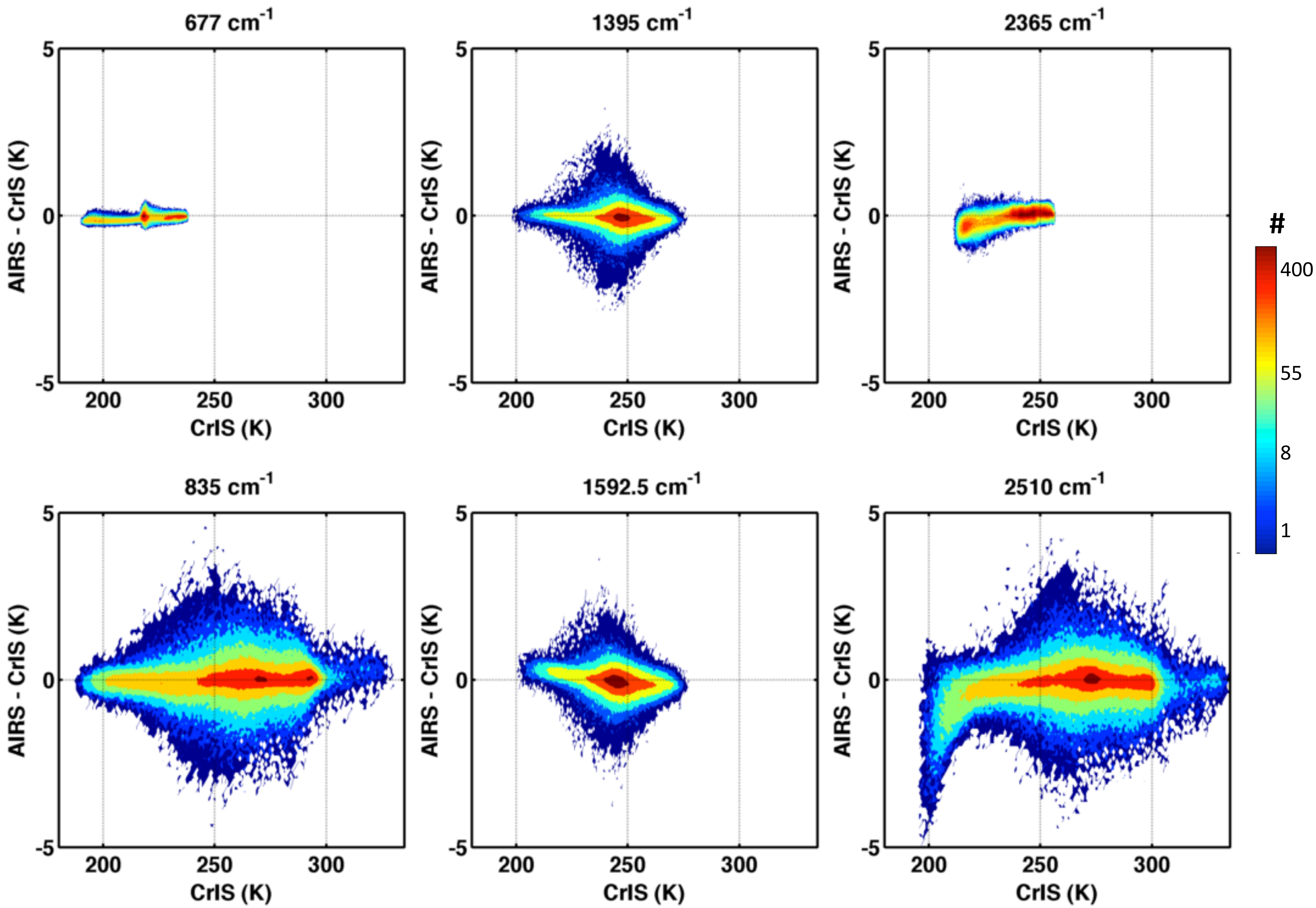
BT Difference Distributions, 19 Apr – 19 Aug



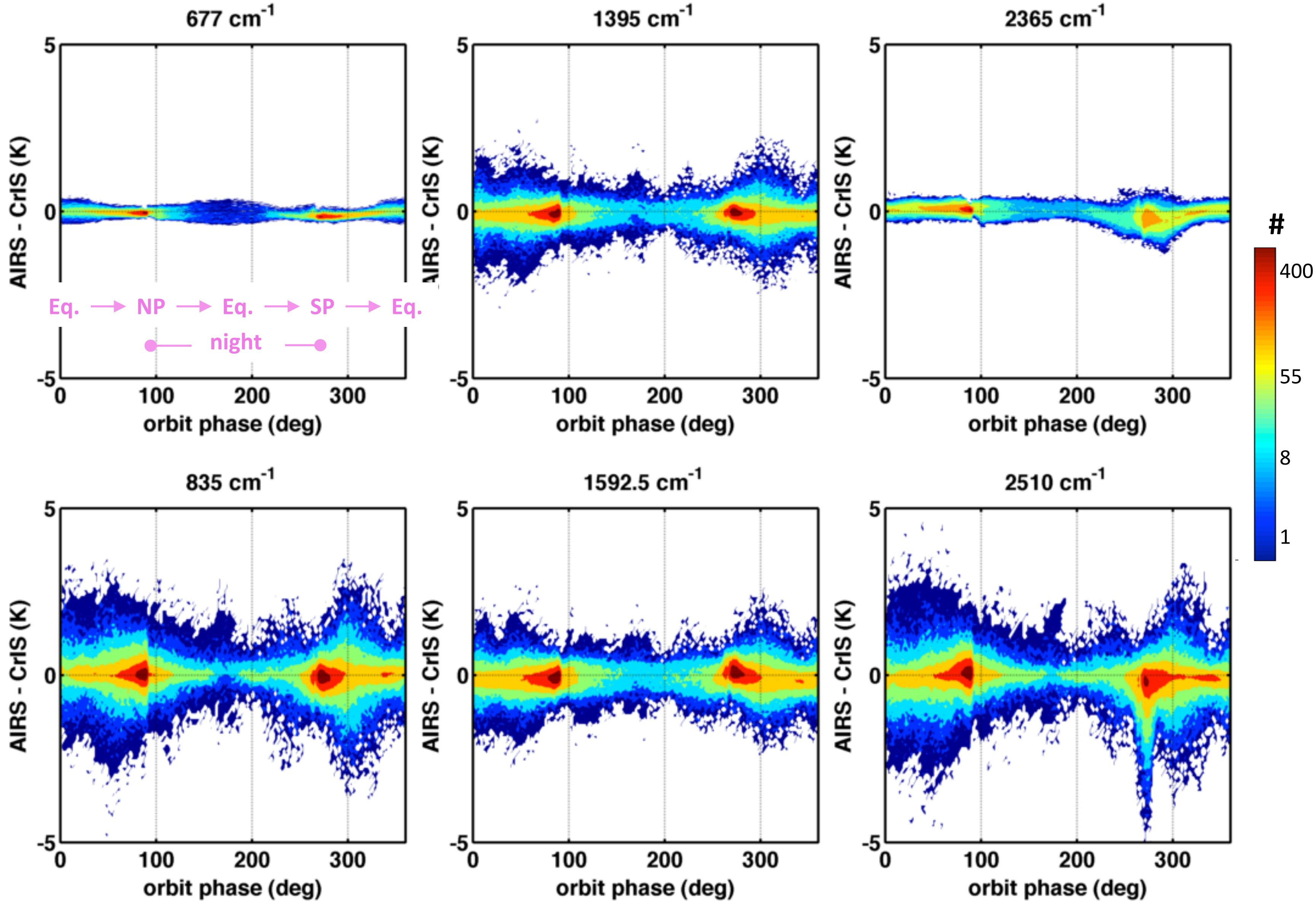
BT Difference Distributions, 19 Apr – 19 Aug



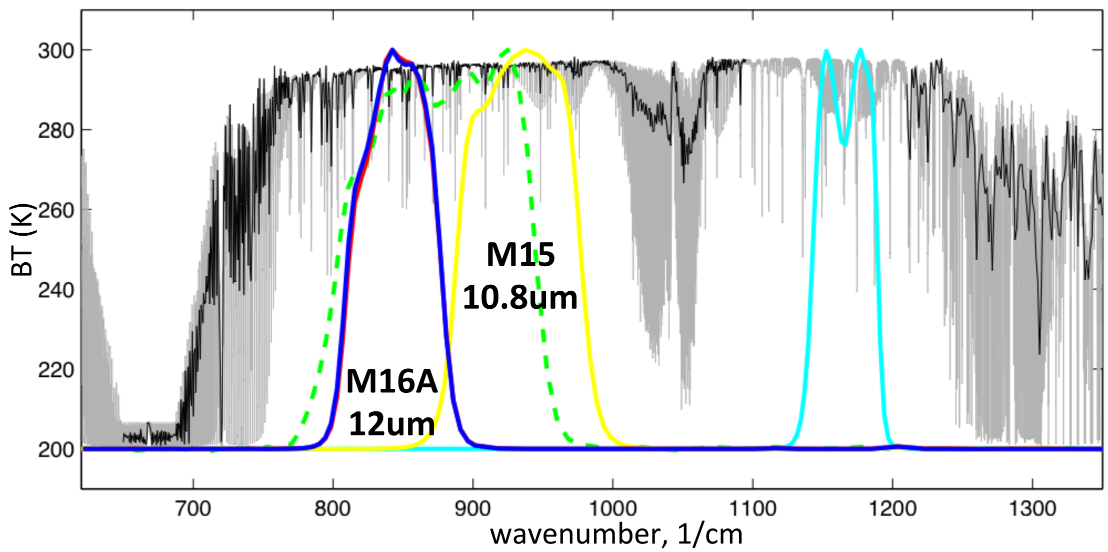
Distributions versus Scene Brightness Temperature

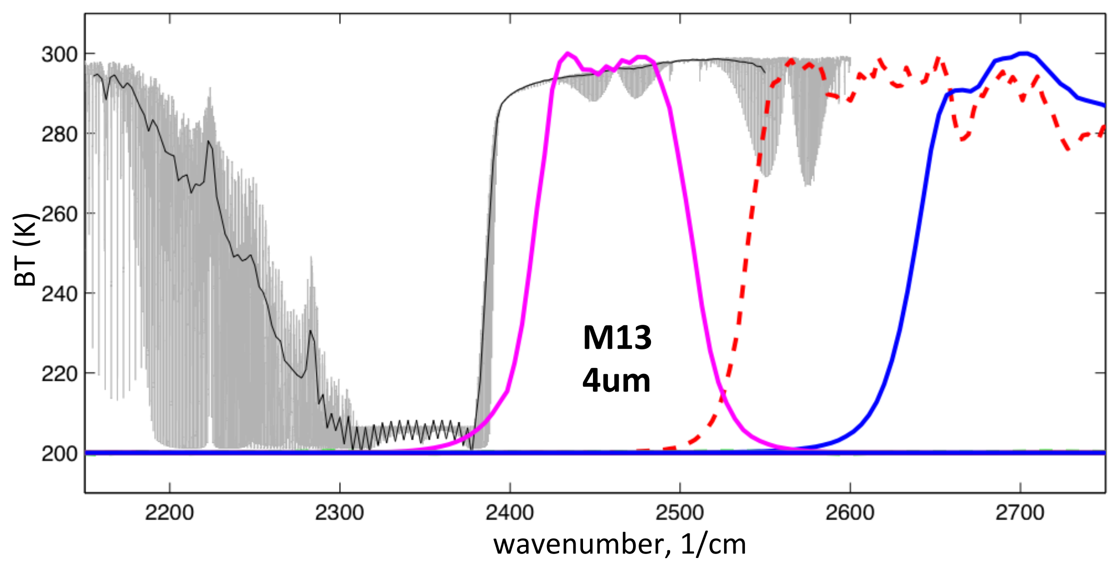


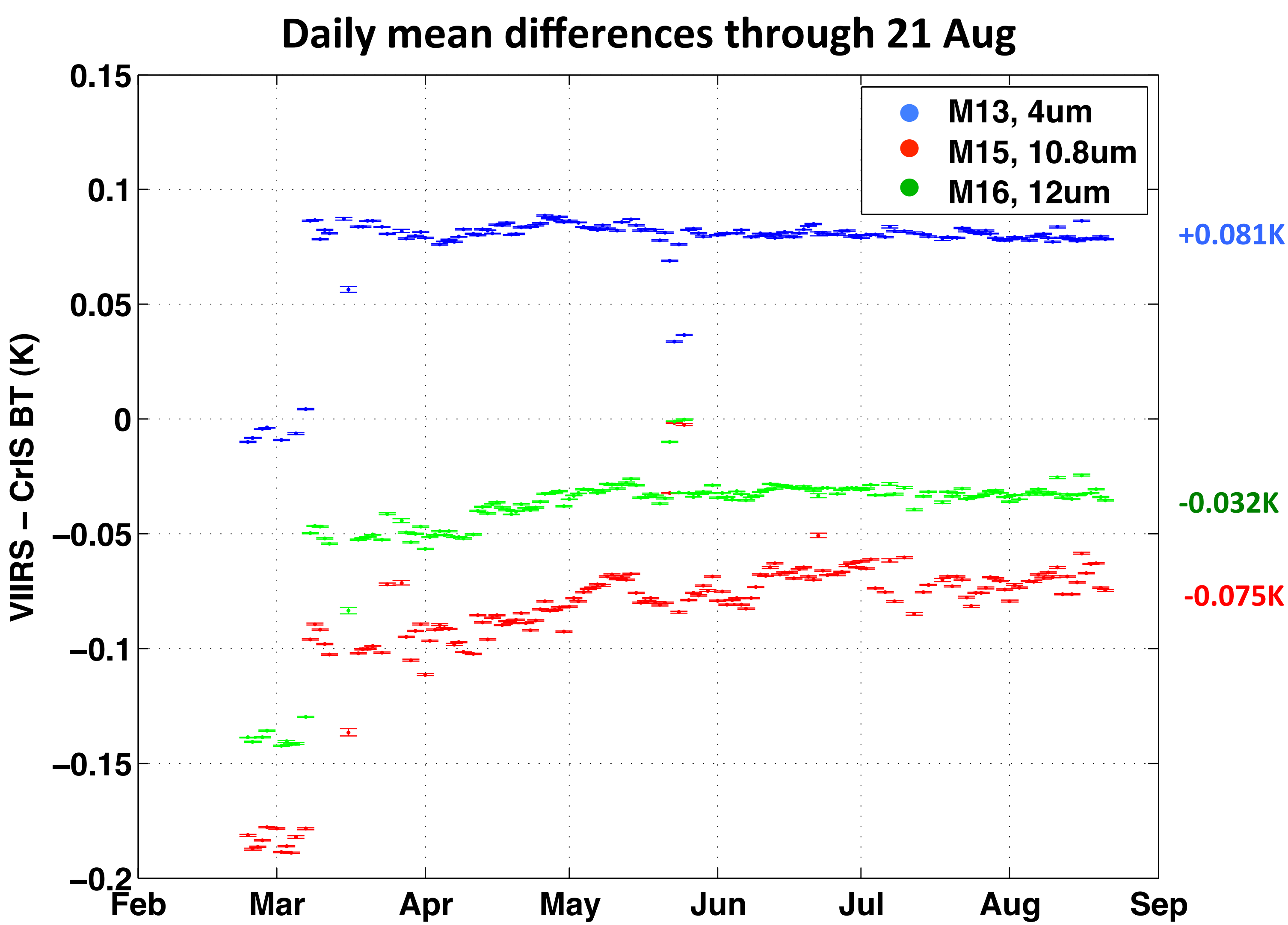
Distributions versus Orbit Phase



Monochromatic spectrum, CrIS spectrum, and VIIRS SRFs

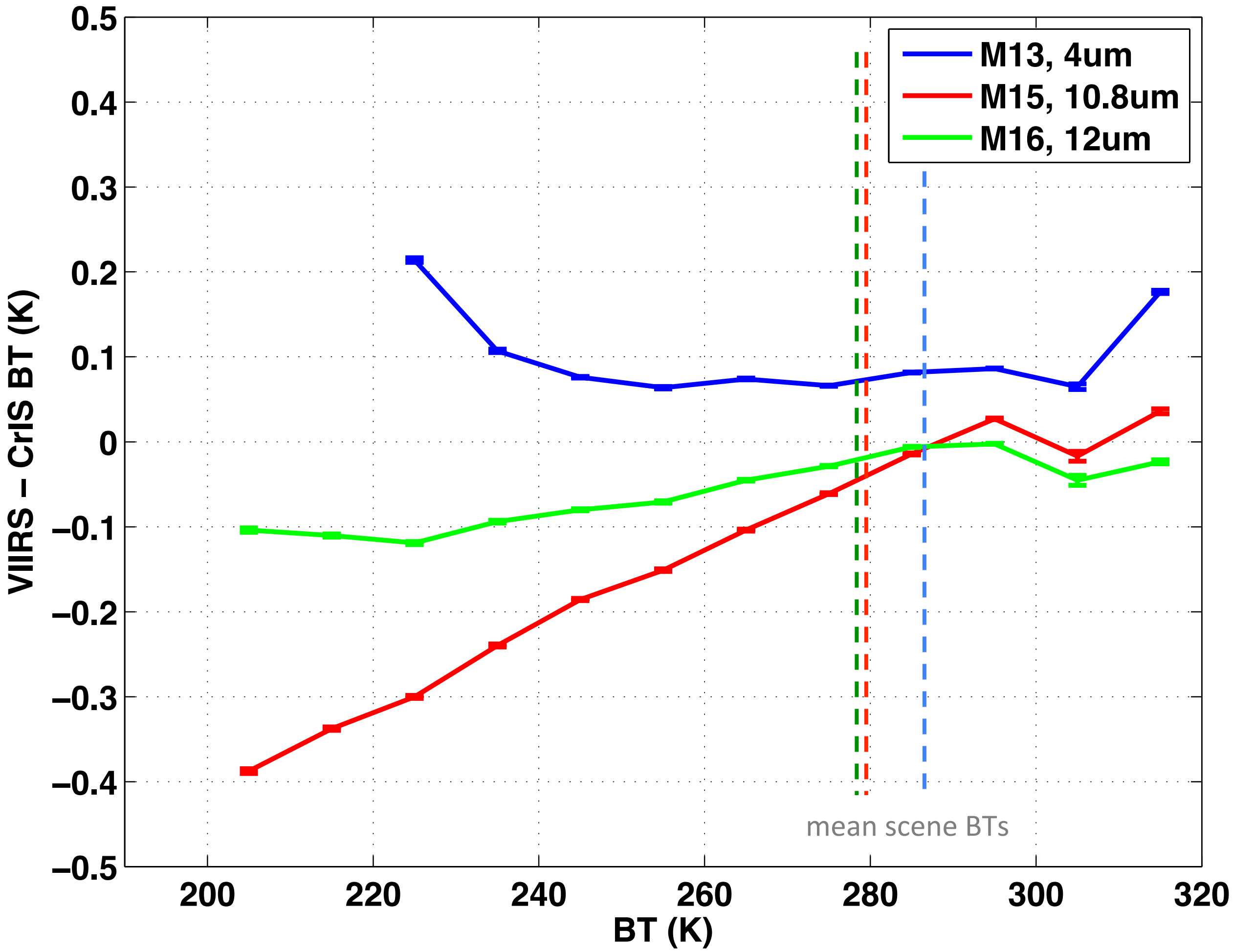




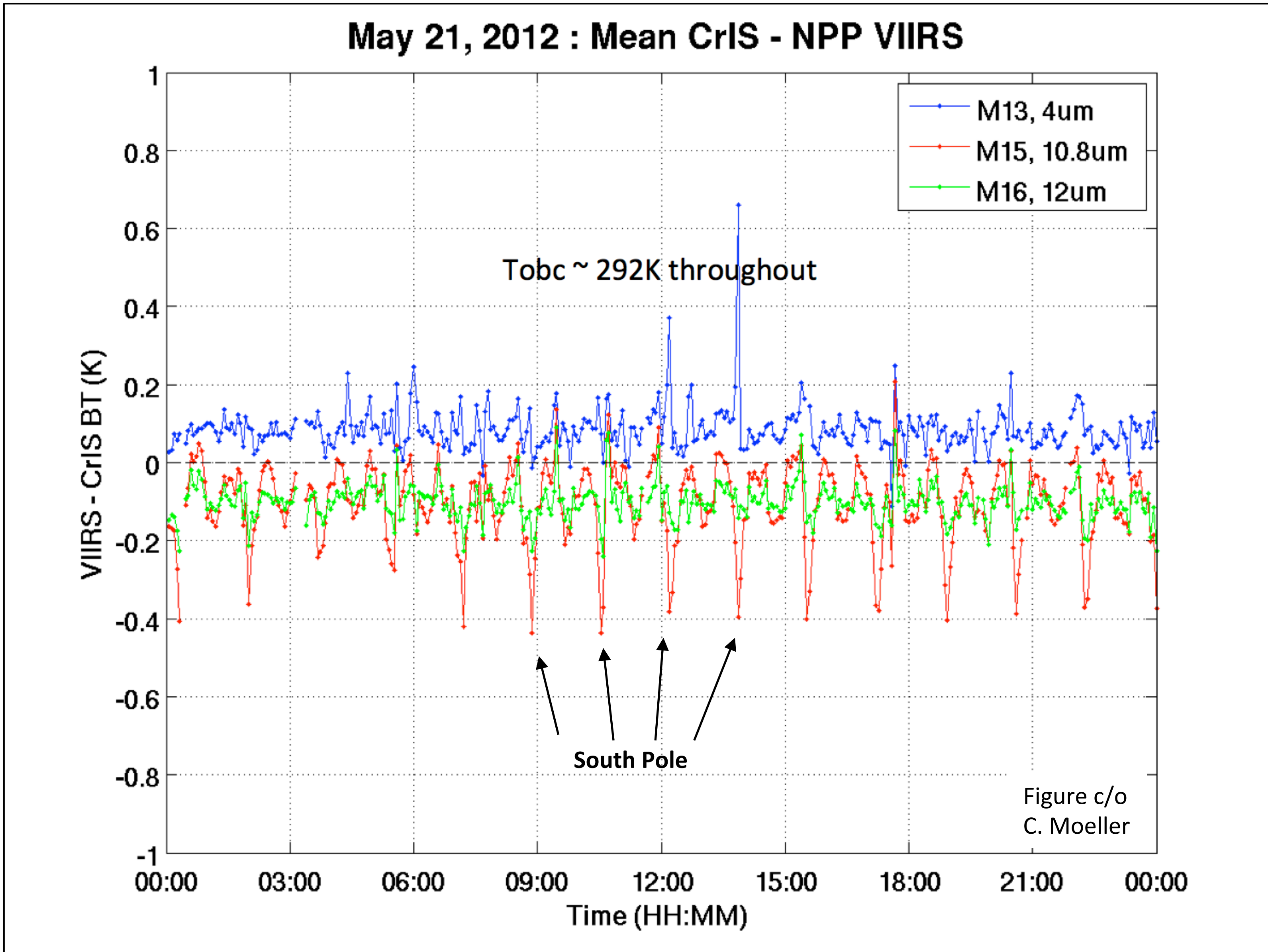


- CrIS processing is CSPP with v33 Eng. Packet; VIIRS is IDPS product
- Major discontinuities are due to known events (e.g. VIIRS OBS LUT change in early March, shutdown/restart on March 24/25, CrIS v33 Eng. Packet on Apr. 11, VIIRS OBC temperature ramp in late May)

Differences versus scene BT (19 Apr – 21 Aug)



- M13 differences show little dependence on scene BT, except for coldest scenes
- M15 and M16 show clear scene BT dependence of differing magnitude



May 21, 2012 : Mean CrIS - NPP VIIRS
M13, 4um
M15, 10.8um
M16, 12um
Tobc ~ 292K throughout
South Pole
Figure c/o
C. Moeller
VIIRS - CrIS BT (K)
Time (HH:MM)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00

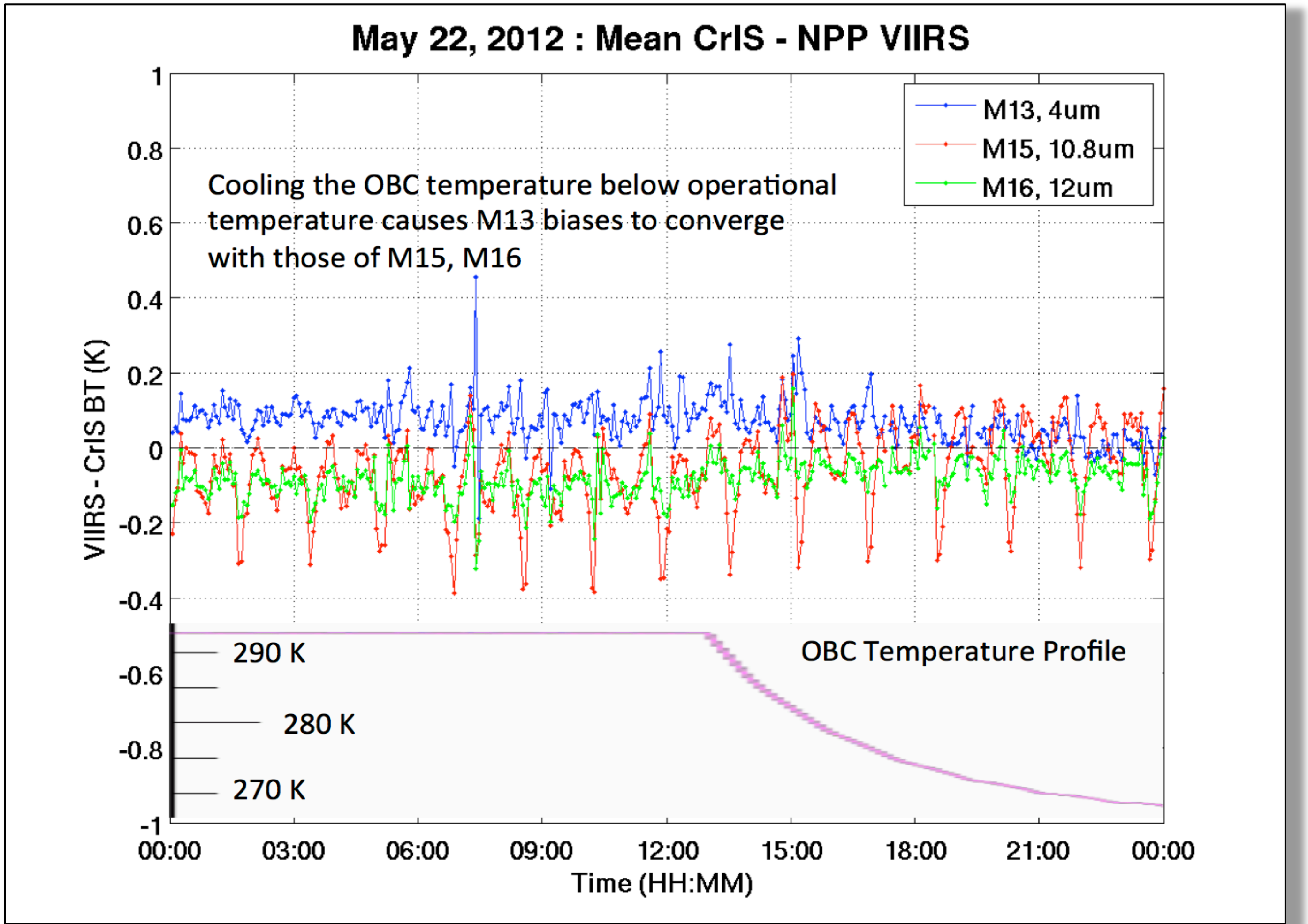


Figure c/o C. Moeller

- As the VIIRS OBC temperature approaches the instrument temperature, the VIIRS calibration becomes less sensitive to knowledge of the OBC emissivity and to knowledge of the instrument temperatures, and also changes the nonlinearity “set point”; Changes to the CrIS/VIIRS comparisons during this test implies that small improvements to the VIIRS calibration parameters are possible.
- For warm scenes, cooling the OBC temperature causes (1) M13 biases to converge with those of M15 and M16, as well as (2) better overall agreement with CrIS.

Summary

- The CrIS pre-launch uncertainty budget predicted 3-sigma RU of 0.1K to 0.3K for all scene temperatures, wavelengths, and FOVs, with leading contributions from the ICT temperature, ICT emissivity and reflected components, and radiometric nonlinearity.

- Post-launch Cal/Val efforts to assess the radiometric and spectral calibration of CrIS are on-going at this point. Evidence from a wide range of analyses is being assembled to determine if refinements to the calibration parameters/algorithm will be required.

- AIRS/CrIS comparisons provide a new look into the performance of both sensors. Regarding CrIS calibration, the comparisons will aid in the assessment of the nonlinearity corrections and the orbital dependence of the ICT environmental model, for example. This analysis will be extended by separating the comparisons by CrIS FOV#, and with use of the AIRS L1C data when it is available.

- CrIS/VIIRS comparisons are useful for diagnosing the calibration of both sensors; present results look very good but also indicate where improvements to the VIIRS calibration could be pursued.

Thank You