SNPP CrIS Side 2 Radiometric Calibration and Radiometric Uncertainty

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SNPP CrIS Side2 Beta/Provisional Maturity Review
25 July 2019

Summary/Conclusion

- Based on what changed, and didn't change, in switching from Side1 to Side2 electronics, along with our current results from cal/val analyses of the Side2 radiometric calibration, we find no reason to change the radiometric calibration coefficients or their estimated uncertainties, and therefore the Radiometric Uncertainty and Radiometric Stability estimates for Side2 remain unchanged from Side1.
- We plan to continue to monitor the cal/val results and have final conclusions at the Validated Review.

CrIS Simplified On-Orbit Radiometric Calibration Equation:

$$L_S = Re\{(C'_{ES} - C'_{DS}) / (C'_{ICT} - C'_{DS})\} R_{ICT}$$

for observed complex spectra, C, of the Earth scene (**ES**), Internal Calibration Target (**ICT**), and Deep Space (**DS**) views.

with:

1. ICT Predicted Radiance: $R_{ICT} = \varepsilon_{ICT} B(T_{ICT}) + (1-\varepsilon_{ICT}) R_{REFL}$

2. Quadratic Nonlinearity Correction: $C' = C \cdot (1 + 2\, a_2\, V_{DC})$

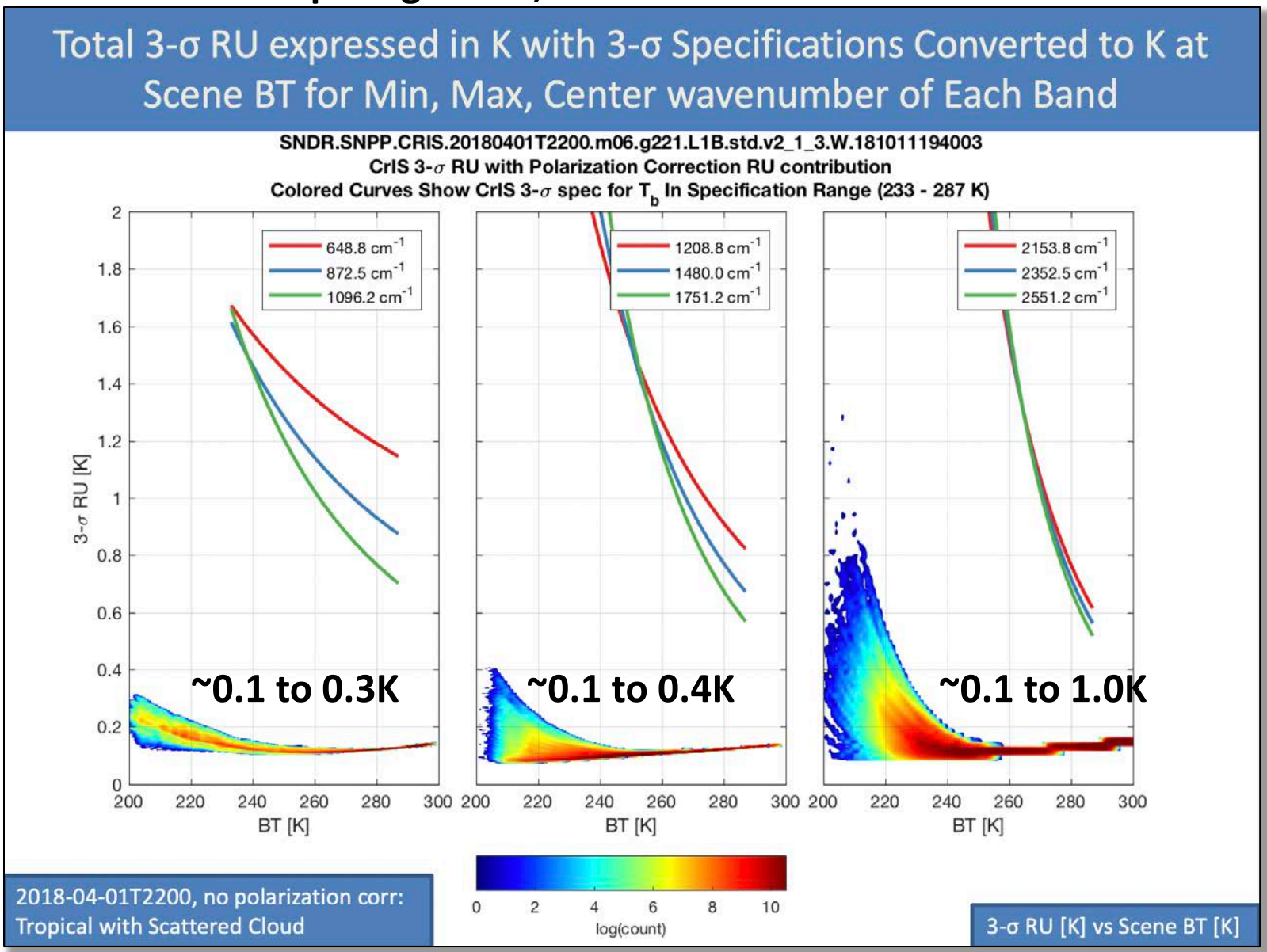
3. Polarization Error (aka Correction): (to be implemented)

$$E_p \cong p_r p_t \left\{ \begin{array}{l} L_S \cos 2(\delta_S - \alpha) - L_H \dfrac{L_S - L_C}{L_H - L_C} \cos 2(\delta_H - \alpha) - L_C \dfrac{L_H - L_S}{L_H - L_C} \cos 2(\delta_C - \alpha) \\ -B_{SSM} \left[\cos 2(\delta_S - \alpha) - \dfrac{L_S - L_C}{L_H - L_C} \cos 2(\delta_H - \alpha) - \dfrac{L_H - L_S}{L_H - L_C} \cos 2(\delta_C - \alpha) \right] \end{array} \right\}$$

for polarization coefficients $p_r p_t$, scene selection mirror polarization angle δ, sensor polarizer angle α, and emission from the scene mirror B_{SSM}. *(H==ICT, C==DS).*

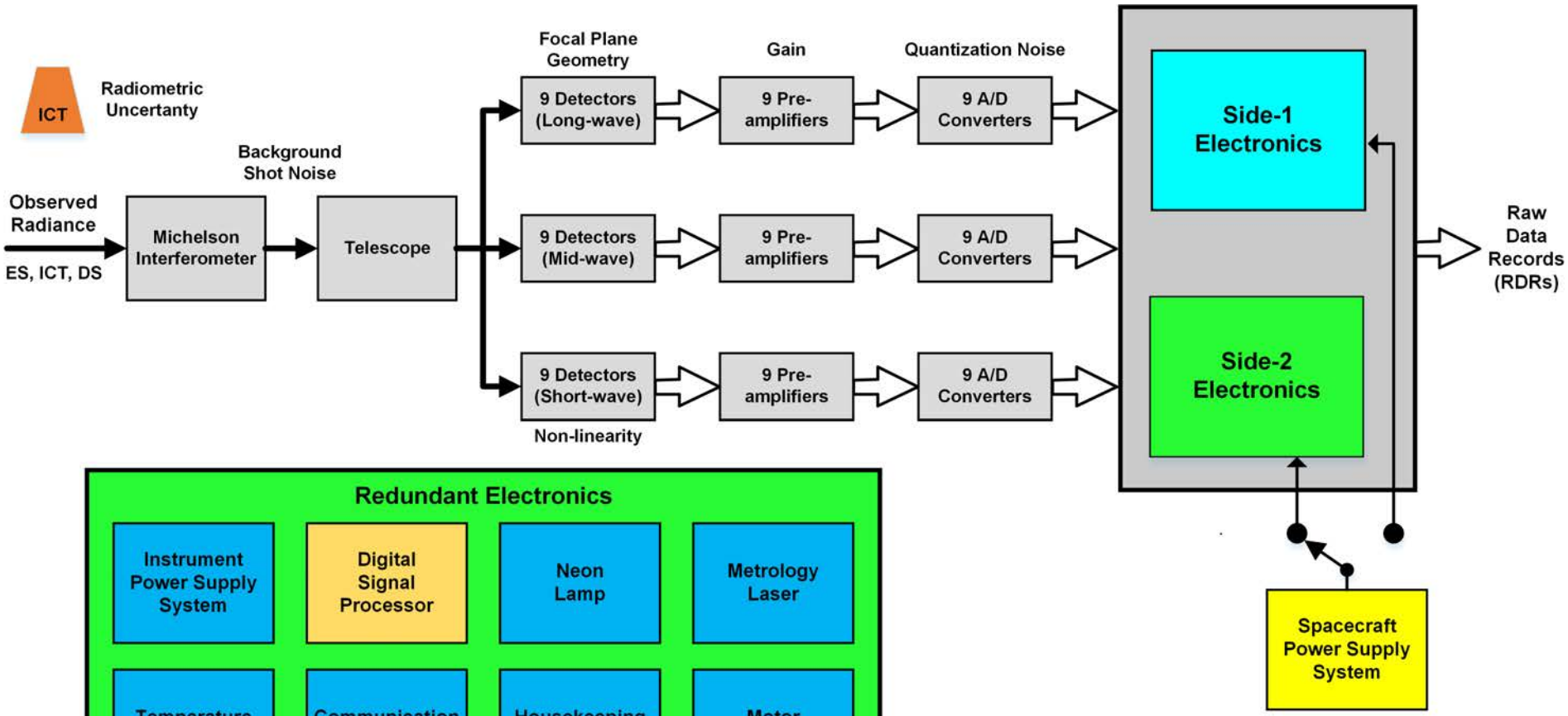
Radiometric Uncertainty Example

Tropical granule, no Polarization Correction



(No PolCorr → full size of correction is included in the RU rollup)

Expect negligible impact of side switch on Radiometric Calibration



- ICT Temperature (side1 vs side2 PRTs)
- ICT environmental model
- Detector Nonlinearity
- Polarization

(graphic c/o Flavio)

Side 2 versus Side 1 Radiometric Calibration Evaluations

- **CrIS/VIIRS Comparisons**
  - primarily ICT Temperature
- **Radiometric FOV-2-FOV comparisons**
  - primarily Nonlinearity
- **CrIS/IASI SNOs and CrIS/AIRS SNOs**
  - End-to-End (ICT Temperature, Nonlinearity, Polarization, and any other effects)
  - Relatively small number of comparisons so far

Suomi-NPP CrIS Radiometric Uncertainty

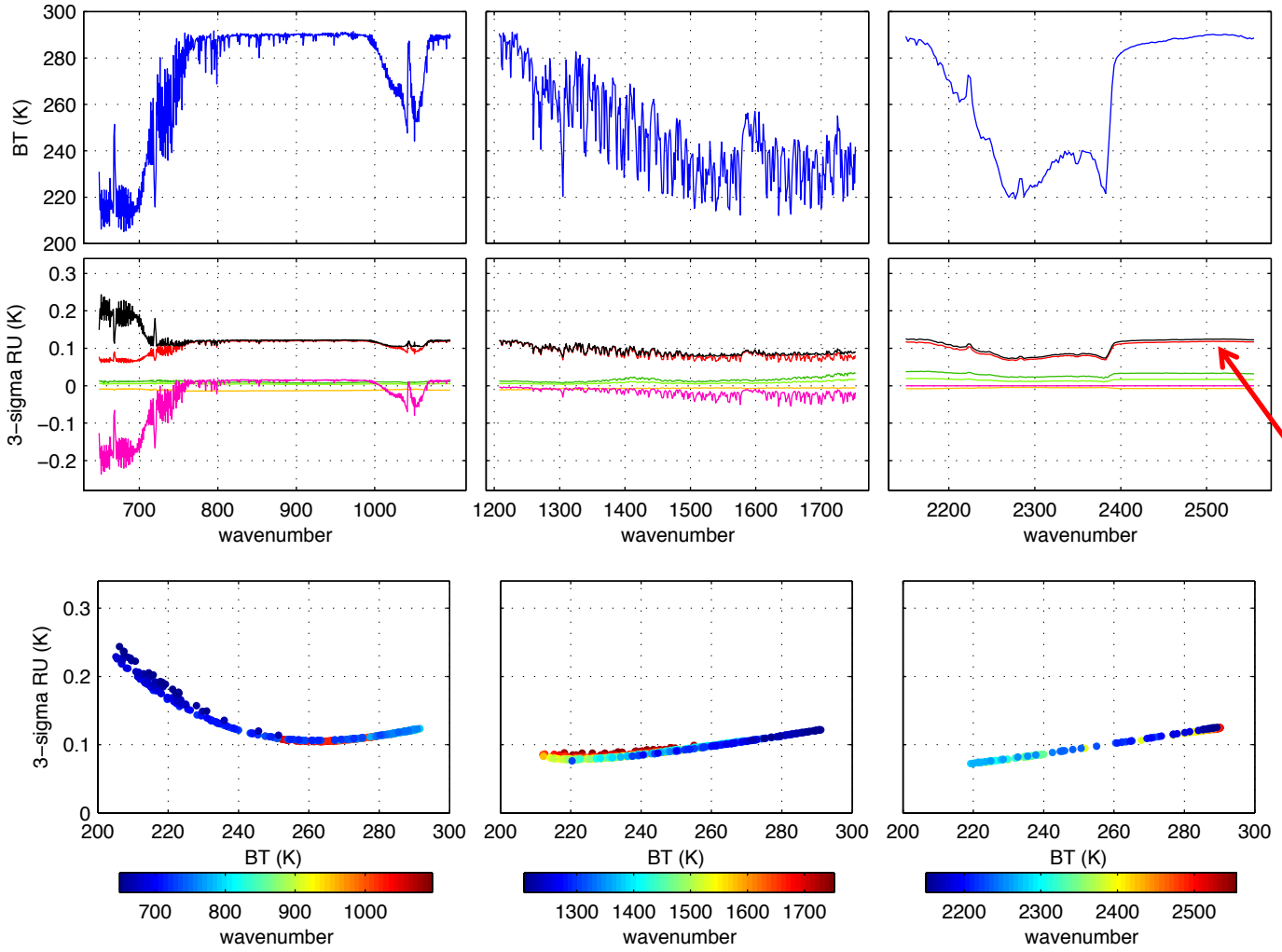
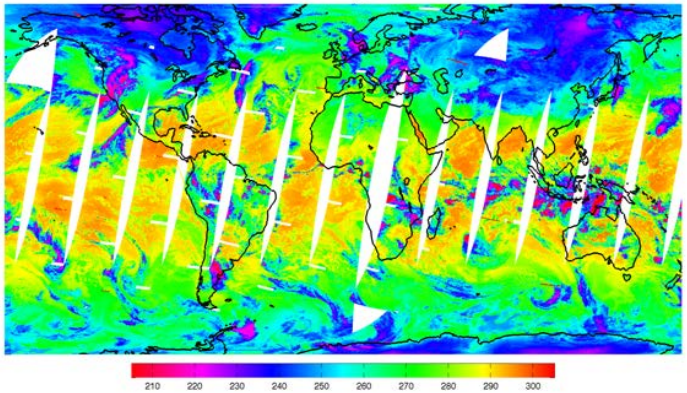


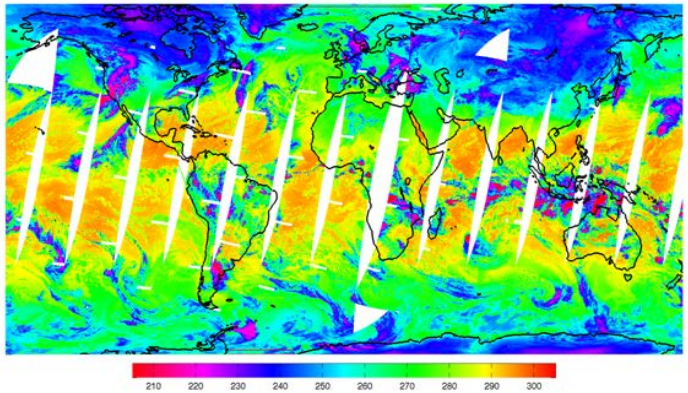
Figure 8. On-orbit RU estimates for a typical warm Earth view spectrum collected on 24 February 2013. Top panels show the observed spectra in the longwave, midwave, and shortwave bands. Middle panels show the various contributions to and the total RU for each band. Bottom panels show the scene brightness temperature dependence of the RU color coded by wavenumber. The legend for the middle panel is the same as that for Figure 3.

CrIS/VIIRS Comparisons

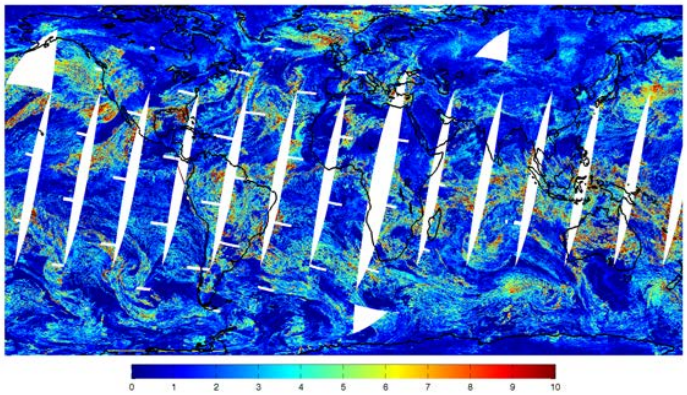
1) CrIS convolved with VIIRS SRF



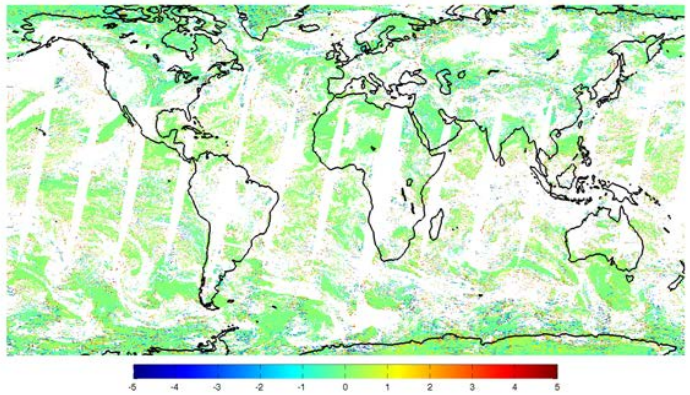
2) VIIRS mean within CrIS footprint



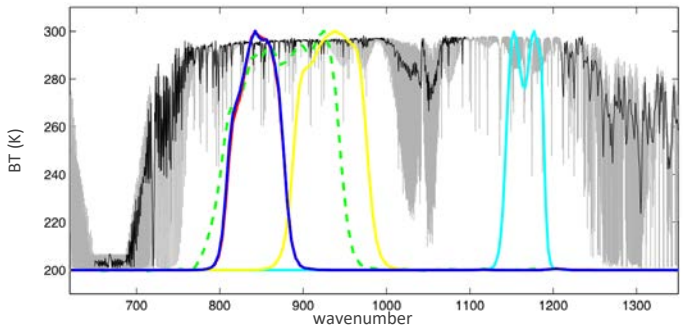
3) VIIRS StdDev within CrIS footprint



4) VIIRS-CrIS differences for homogeneous footprints



M16 I5 M15



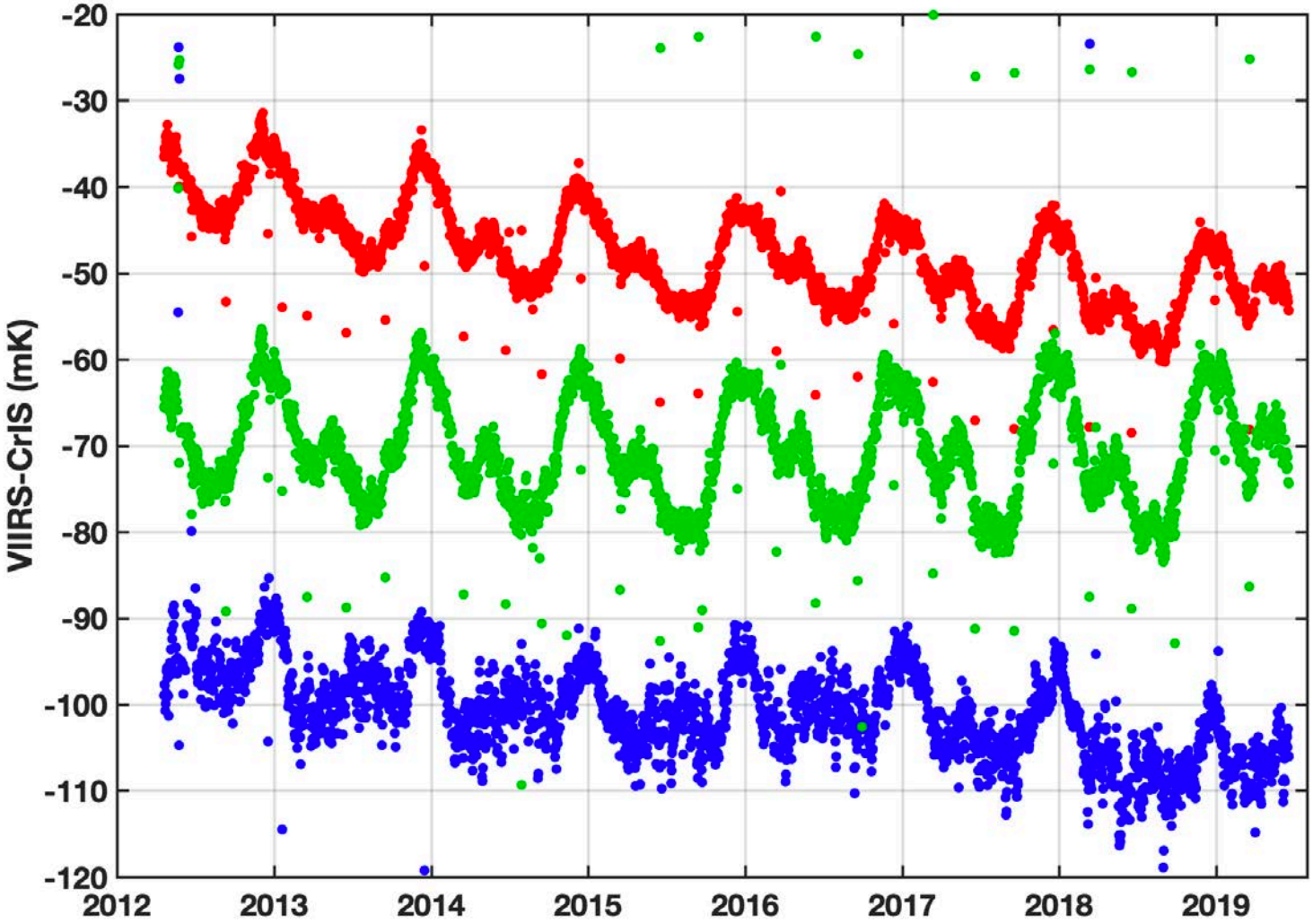
SNPP daily mean differences

(All FOV mean, all scene BTs)

M15 (12.01μm):
All FOV bias = -99.9 ± 5.3 mK
All FOV trend = -1.25 ± 0.06 mK/yr

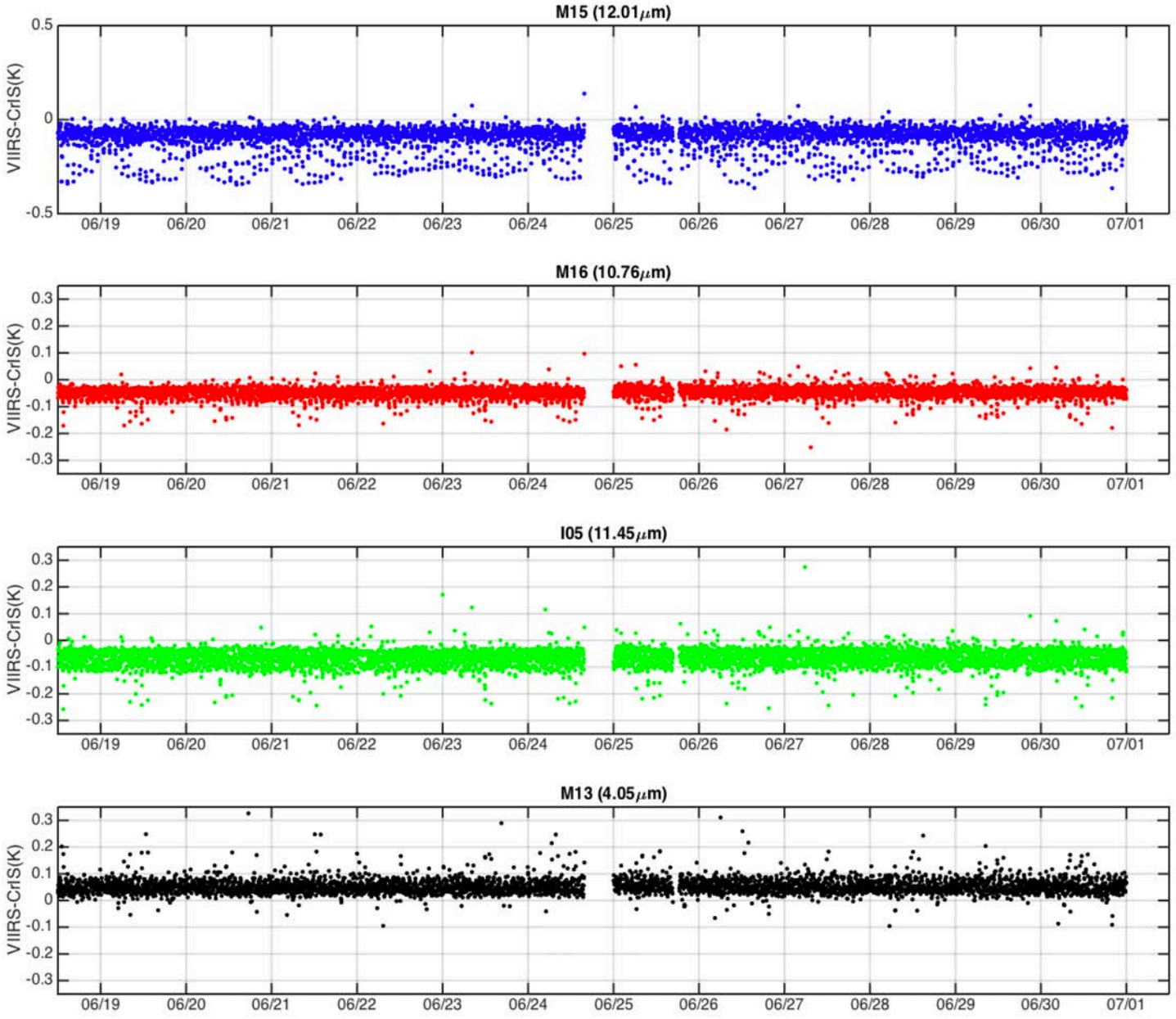
M16 (10.76μm):
All FOV bias = -46.9 ± 5.5 mK
All FOV trend = -2.02 ± 0.06 mK/yr

I05 (11.45μm):
All FOV bias = -70.9 ± 6.2 mK
All FOV trend = -0.29 ± 0.09 mK/yr



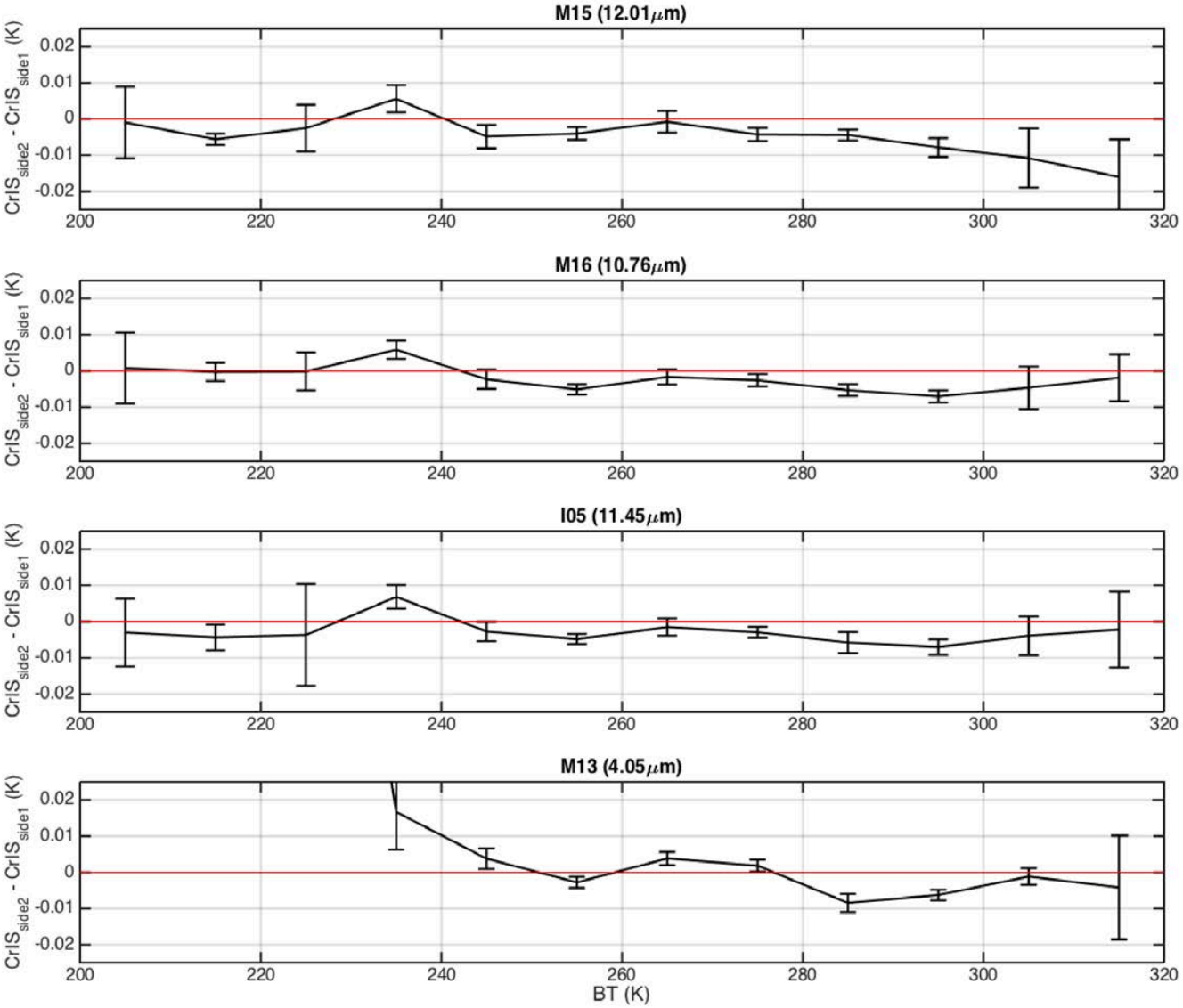
Time-series of differences before and after side switch on 6/24

(average difference for every 4 minutes, all uniform scenes, all FOVs)



CrIS Side 2 minus CrIS Side 1 as a function of scene BT using CrIS/VIIRS 5 days prior to and 5 days after the side switch

(all uniform scenes, all FOVs) k=2 error-bars



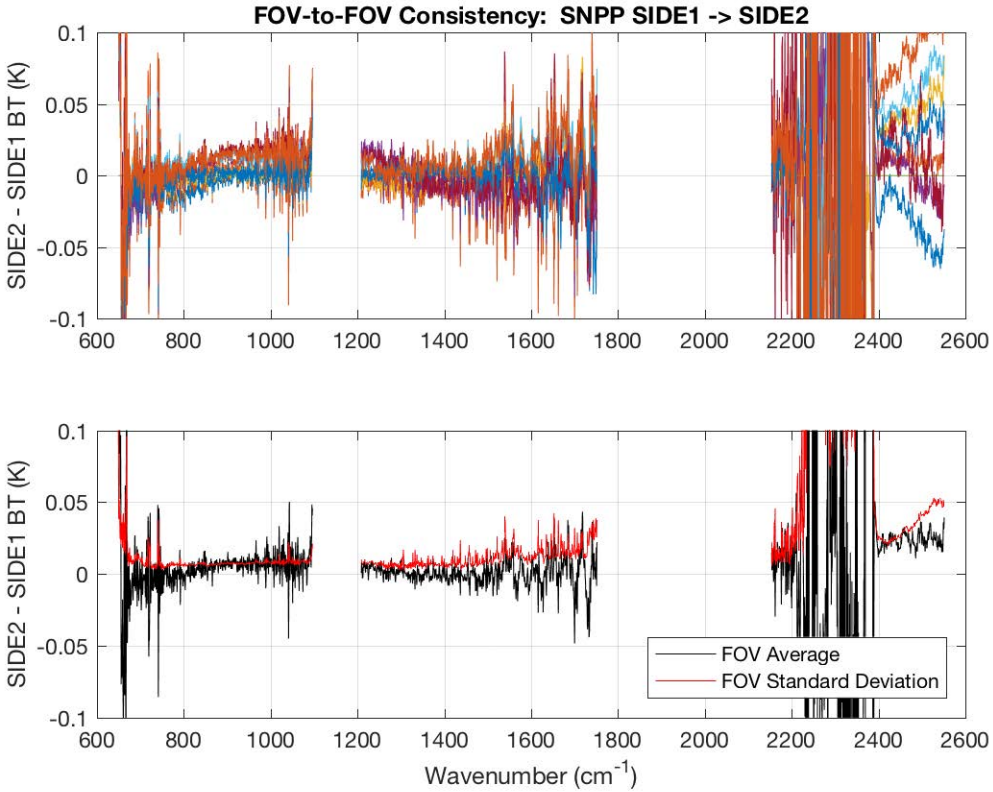
- **Changes at the ICT temperature (~280K) are consistent and suggest changes in the ICT temperature calibration from side1 to side2 of ~5 to 7mK (compared to 37mK 1σ estimated total uncertainty in ICT T, with PRT contribution of 19mK)**

FOV-to-FOV Differences before and after the side switch

SIDE #1 **IDPS SDR Data: 22-March-2019 to 23-March-2019** **SNPP EP37**

SIDE #2 **ADL GOLDEN DAYS: 29-June-2019 to 01-July-2019** **SNPP EP40**

Hamming Apodized



Difference Side2 mean from Side1 for each FOV. Then subtract off FOV5 to compute relative FOV-to-FOV radiometric reproducibility.

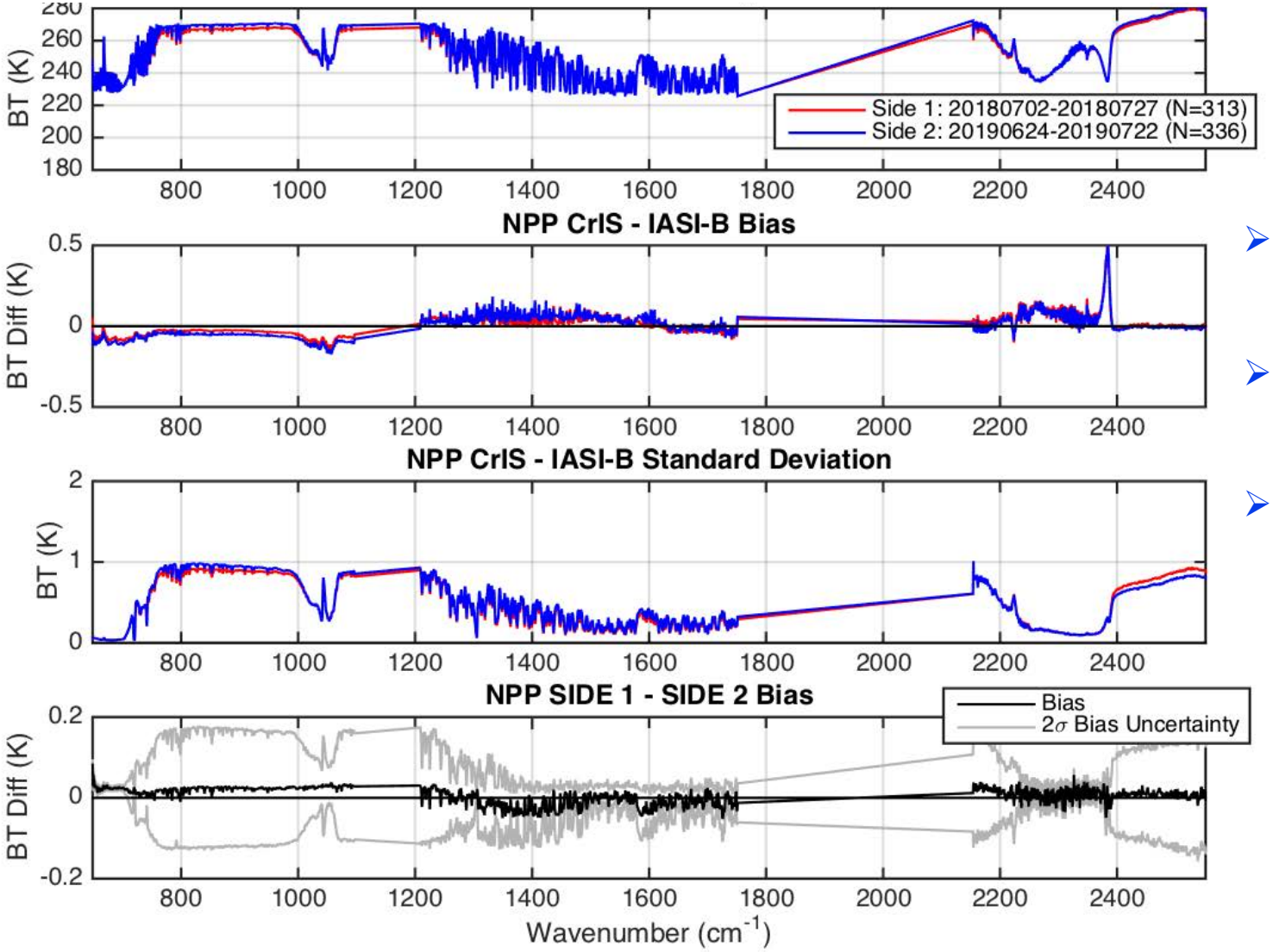
Reproducibility of LW and MW bands < 0.02 K

SW band slightly larger due to higher variability of surface solar reflection in daytime.

- **Changes in the FOV-to-FOV differences are very small (negligible) and suggest no changes to the nonlinearity coefficients**

CrIS/IASI-B SNOs

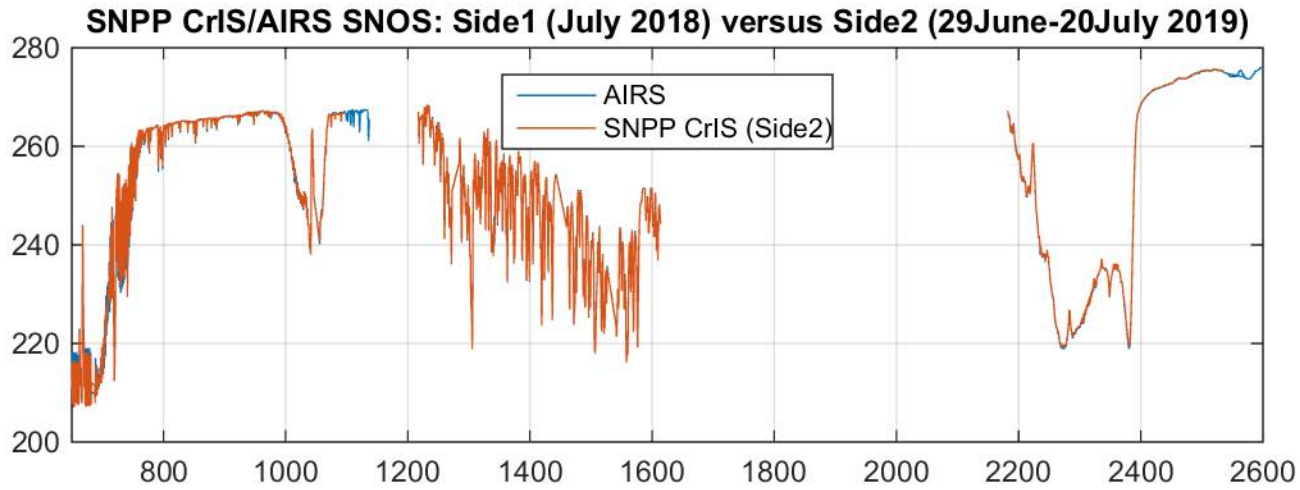
Northern Hemisphere, All FOV mean, Side1=7/2-7/27 2018, Side2=6/24-7/22 2019

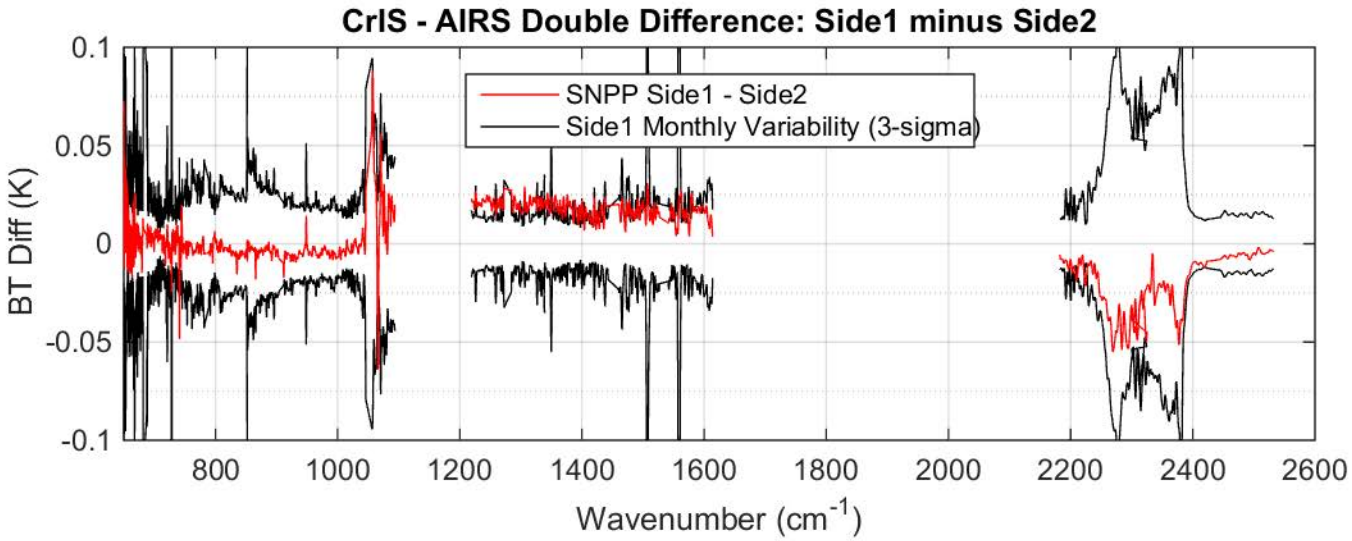


- MW and SW and most of LW region shows no change
- LW CO2 region shows change of +0.025 +/- 0.005K
- Will continue to build up statistics

CrIS/AIRS Comparisons

All FOV mean, Side1=July 2018, Side2=6/29-7/20 2019





- Changes are very small and statistically not significant
- MW band is borderline significant
- Will continue to build up statistics

Summary/Conclusion

- Based on what changed, and didn't change, in switching from Side1 to Side2 electronics, along with our current results from cal/val analyses of the Side2 radiometric calibration, we find no reason to change the radiometric calibration coefficients or their estimated uncertainties, and therefore the Radiometric Uncertainty and Radiometric Stability estimates for Side2 remain unchanged from Side1.
- We plan to continue to monitor the cal/val results and have final conclusions at the Validated Review.

Backup Slides

Radiometric Uncertainty and Stability estimates are unchanged from Side 1

RU Estimate Summary, Current Operational Processing expressed as %B(287K), 1-σ

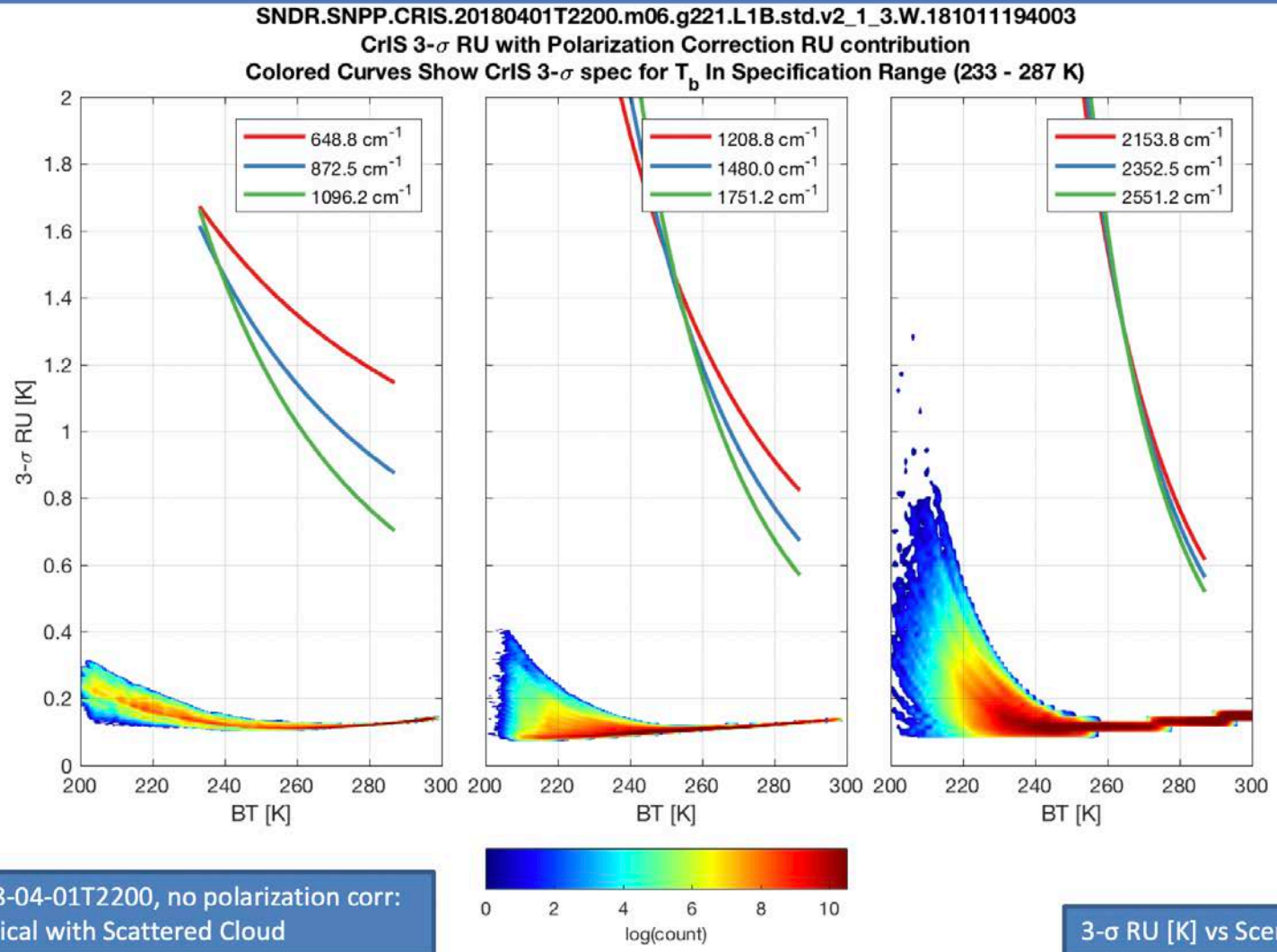
	LW (1-σ)	MW (1-σ)	SW (1-σ)
Specification	0.45%	0.58%	0.77%
Case 1: Typical Tropical ocean with scattered cloud scene	0.0800%	0.0967%	0.2000%
Case 2: Typical Antarctic cold scene	0.0600%	0.0633%	0.0867%
RU estimate*	0.16%	0.19%	0.40%

- The current operational processing does not include polarization correction
- Thus, the calibration bias due to polarization is uncorrected and the associated RU contributor is assumed to be 100% of the uncorrected bias

* Typical tropical ocean with scattered cloud scene case with x2 margin

Radiometric Uncertainty and Stability estimates are unchanged from Side 1. E.g.:

Total 3-σ RU expressed in K with 3-σ Specifications Converted to K at Scene BT for Min, Max, Center wavenumber of Each Band

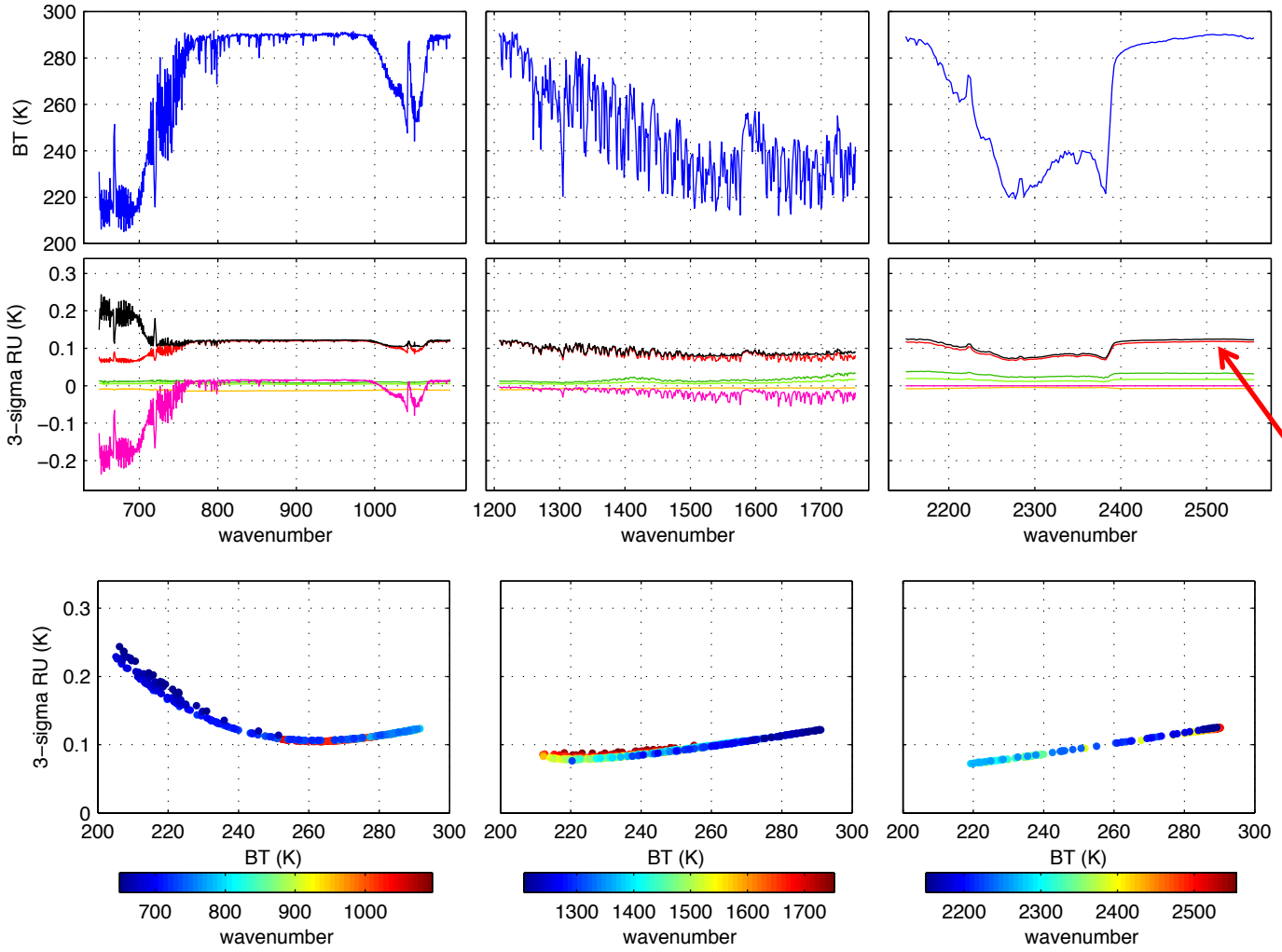


CrIS/VIIRS Comparisons before and after the Side switch

CrIS/VIIRS comparisons

- Comparisons generated routinely and daily match files created
  - VIIRS bands M15 (12.01μm), M16 (10.45μm), I05 (11.45μm), and M13 (4.05μm)
  - Differences characterized versus time, scene BT, FOR, FOV, and orbit phase
- The following slides show results for 5 days prior to the 6/24 side switch to 5 days after
- ➢ Focusing on characterizing the CrIS calibration change due to use of the new side 2 versus side 1 ICT PRTs

Suomi-NPP CrIS Radiometric Uncertainty



Red = contribution from ICT temperature uncertainty (37mK 1σ)

Figure 8. On-orbit RU estimates for a typical warm Earth view spectrum collected on 24 February 2013. Top panels show the observed spectra in the longwave, midwave, and shortwave bands. Middle panels show the various contributions to and the total RU for each band. Bottom panels show the scene brightness temperature dependence of the RU color coded by wavenumber. The legend for the middle panel is the same as that for Figure 3.

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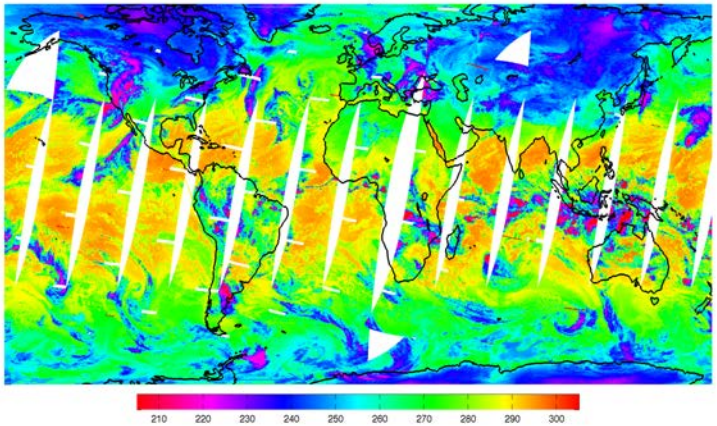
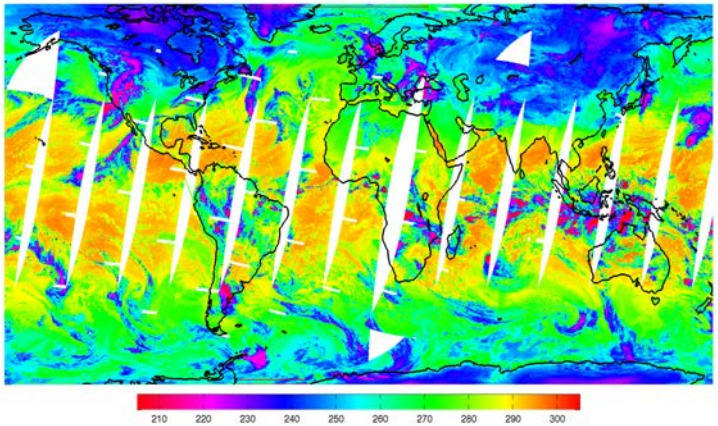


2) VIIRS mean within CrIS footprint



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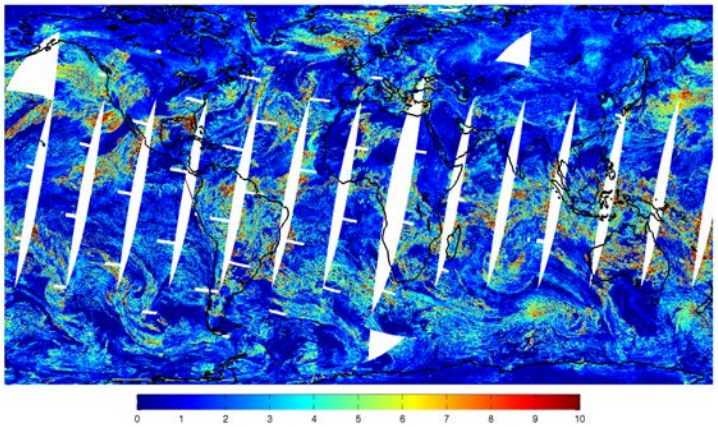
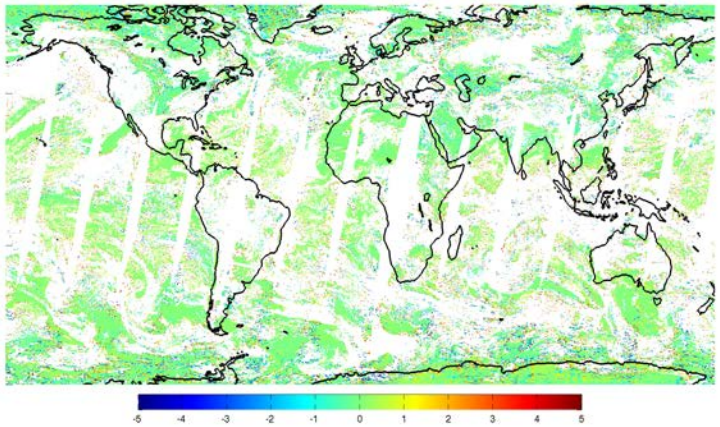
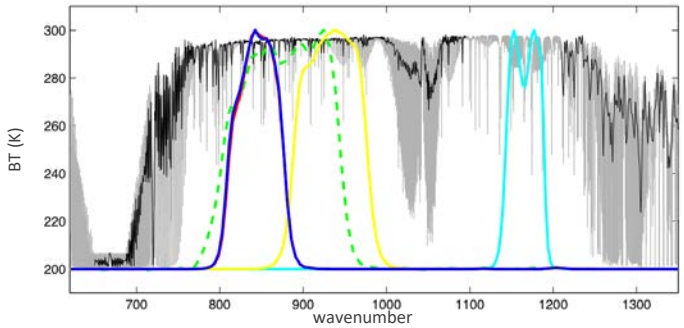


4) VIIRS-CrIS differences for homogeneous footprints



M16 I5 M15



SNPP daily mean differences

(All FOV mean, all scene BTs)

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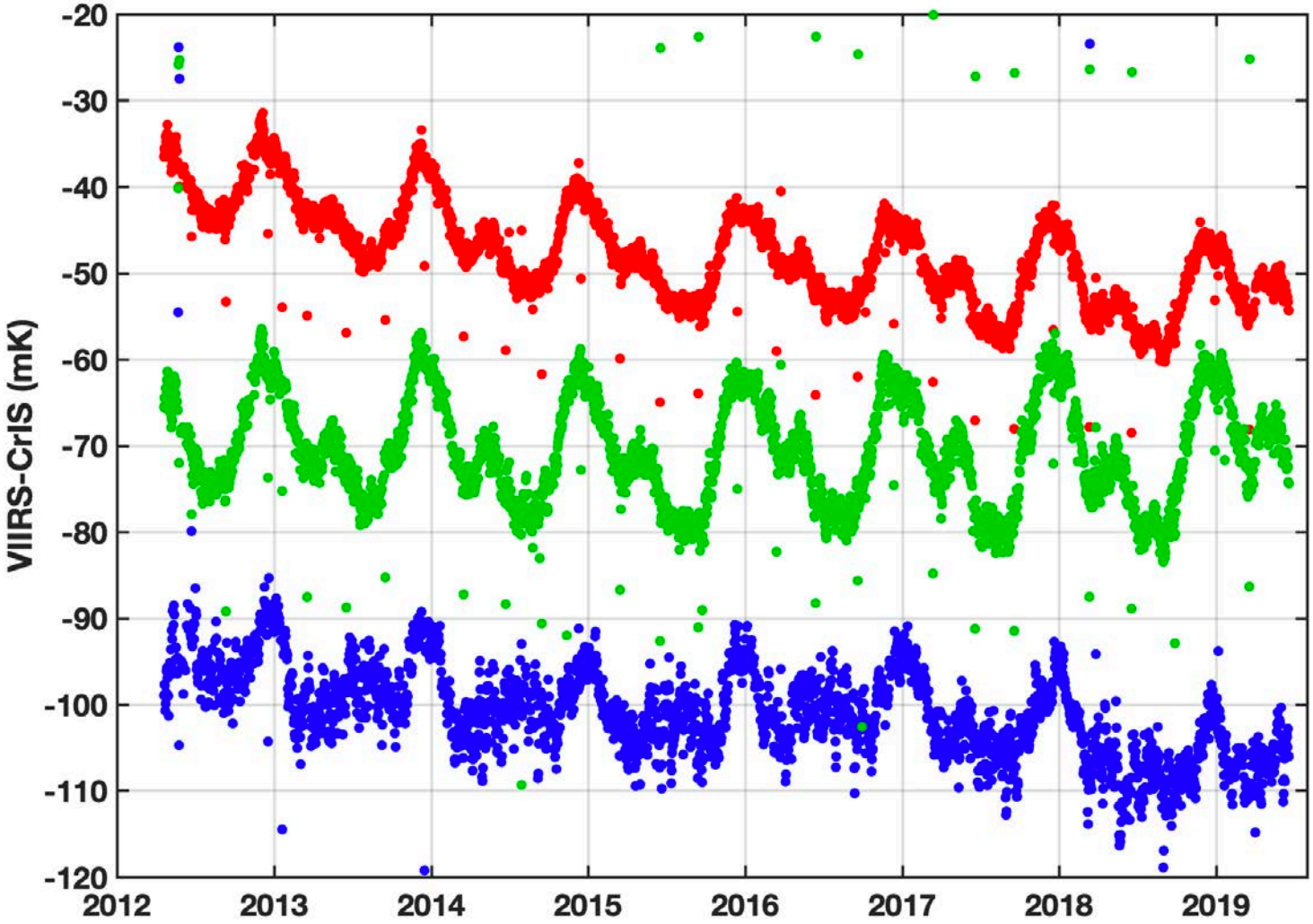
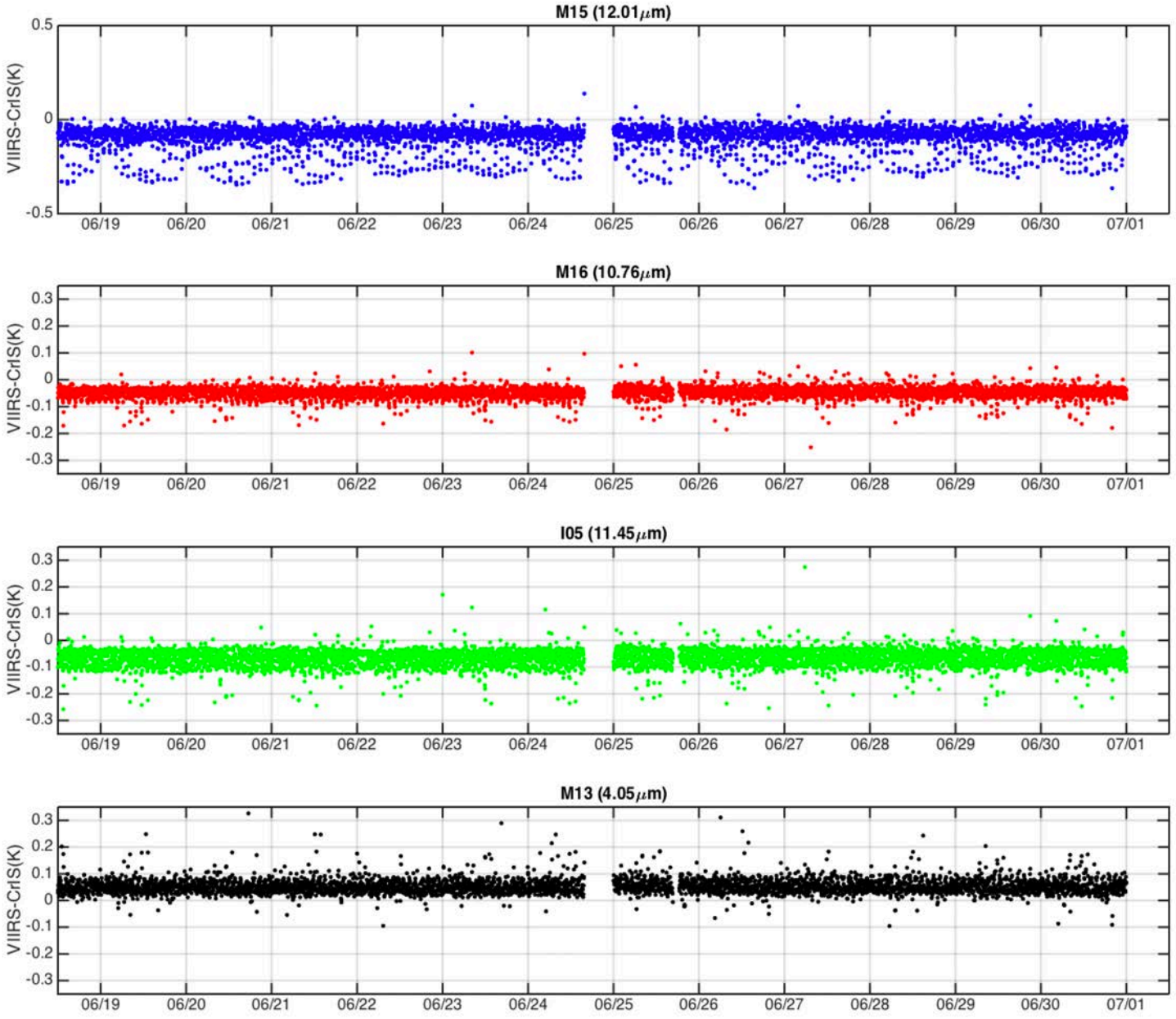


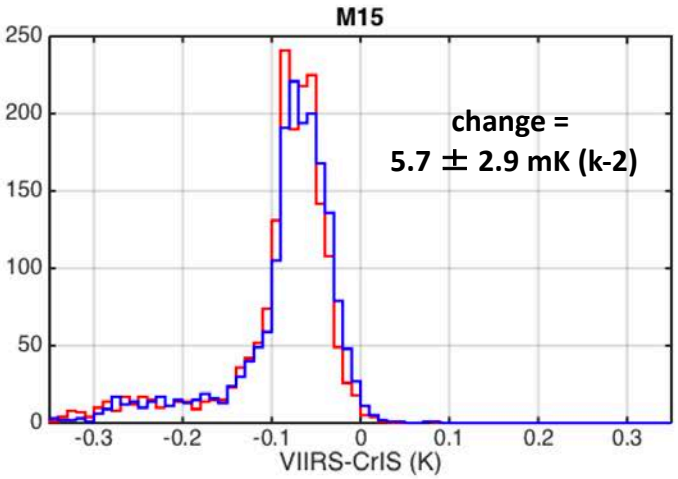
Time-series of differences before and after side switch on 6/24

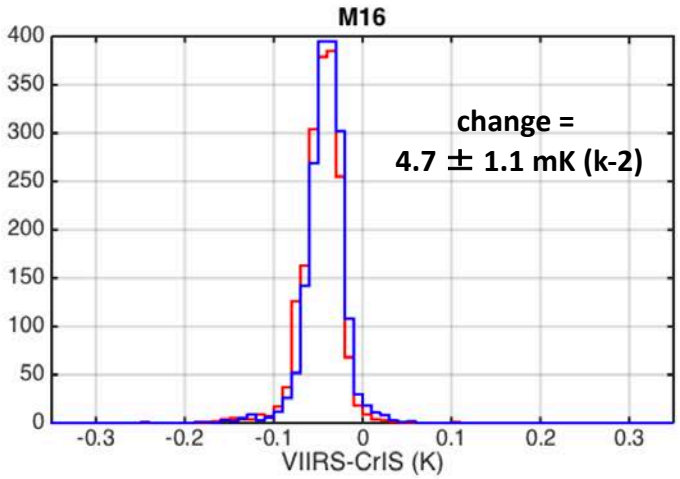
(average difference for every 4 minutes, all uniform scenes, all FOVs)

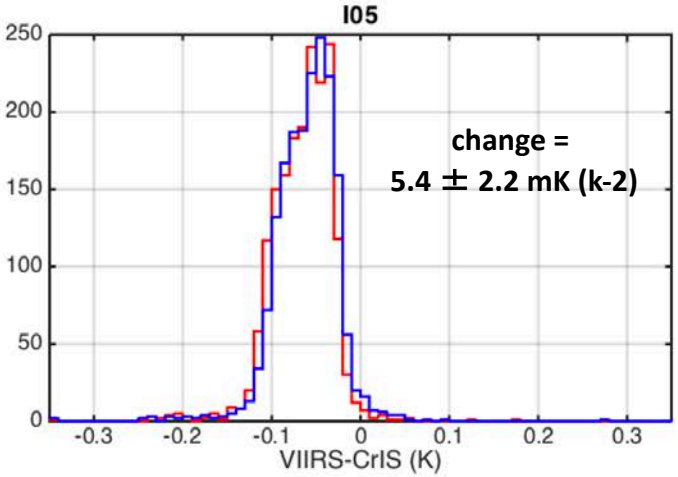


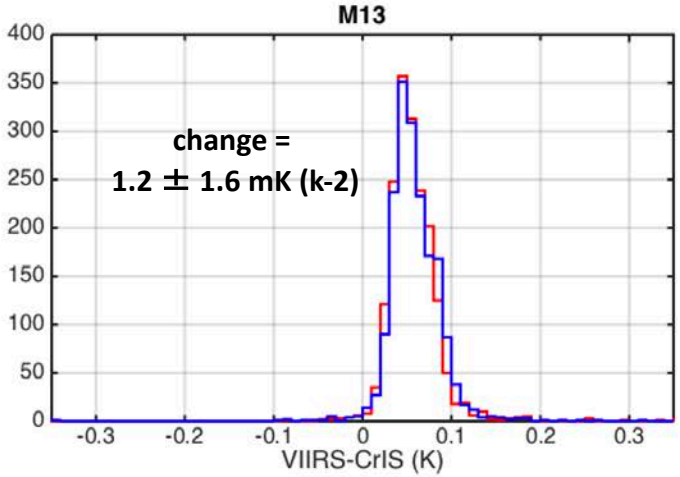
Histogram of differences before and after side switch on 6/24

(all uniform scenes, all FOVs)





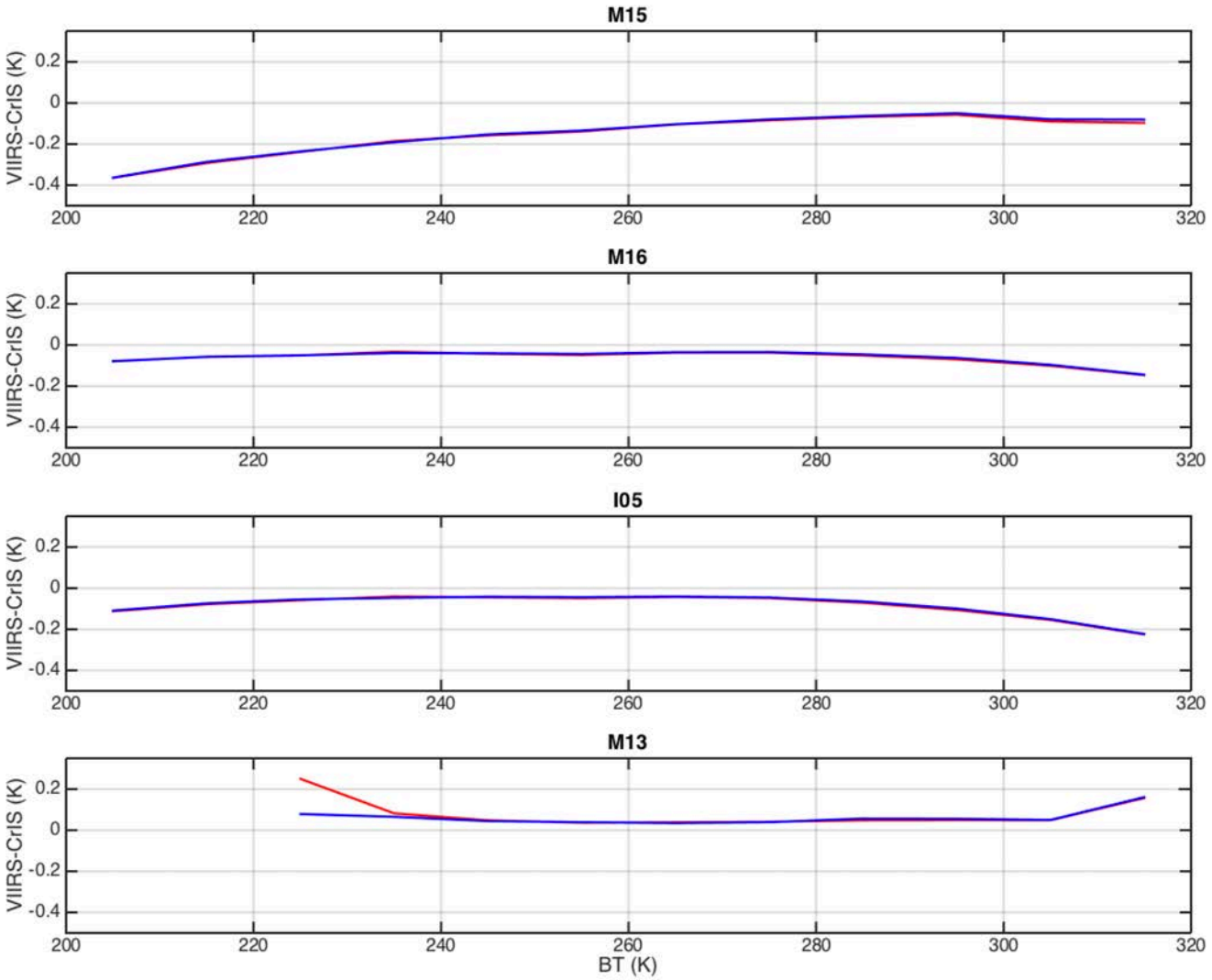




Red = June 19 to 23 **Blue** = June 26 to 30

Mean Differences as a function of scene BT

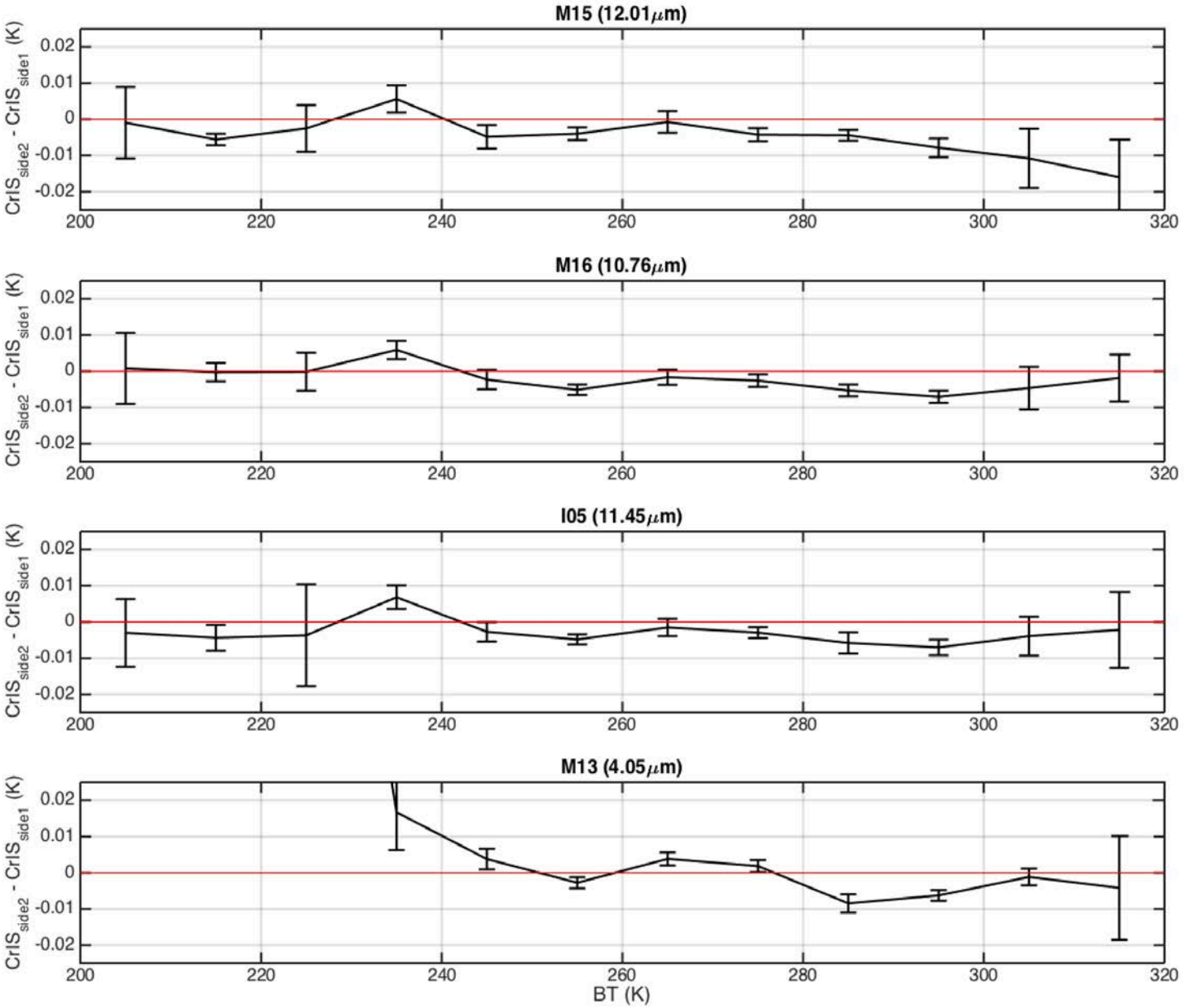
(all uniform scenes, all FOVs)



Red = June 19 to 23 **Blue** = June 26 to 30

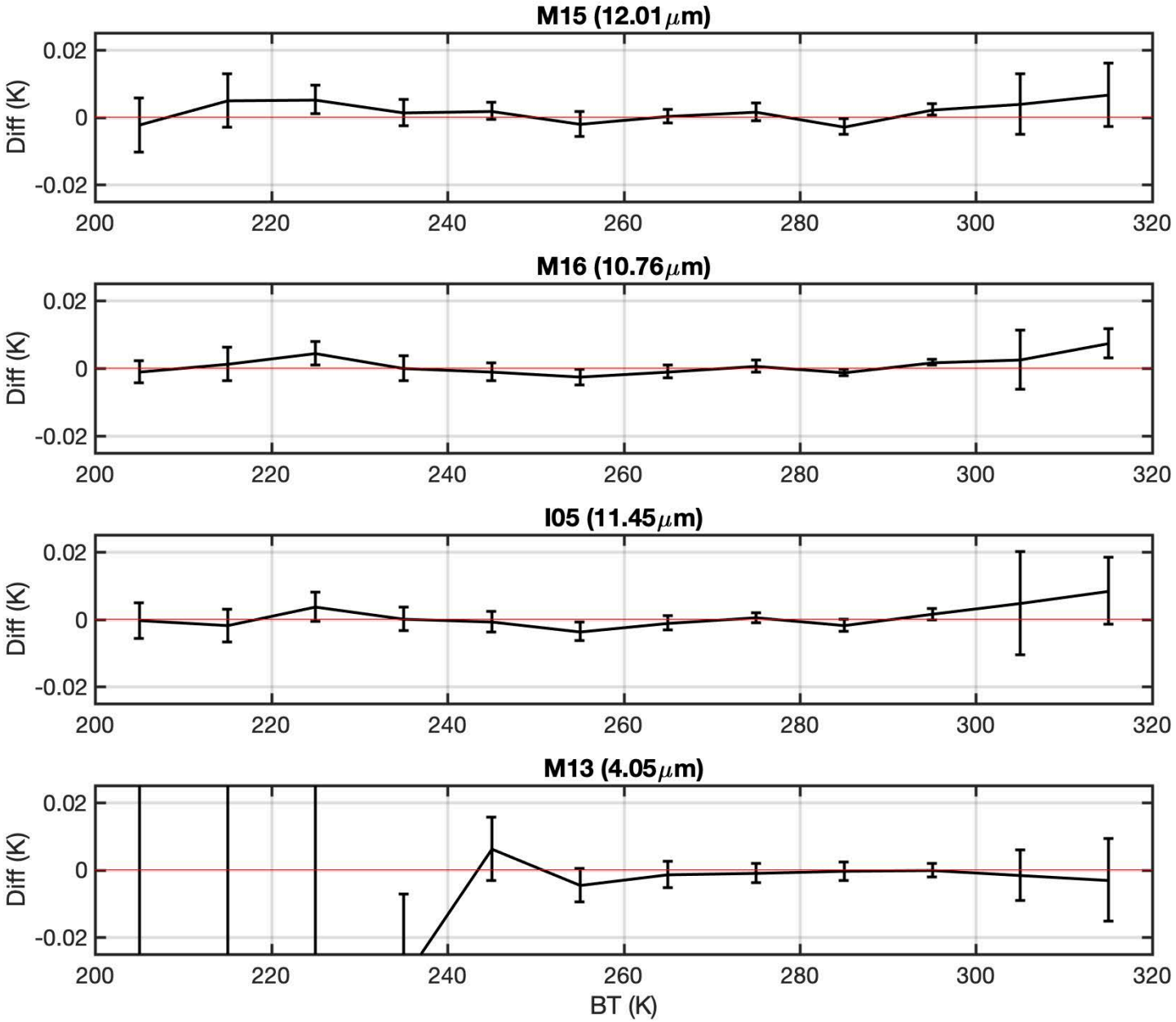
CrIS Side 2 minus CrIS Side 1 as a function of scene BT

(all uniform scenes, all FOVs) k=2 error-bars



Same differences, but in 2015

<19 to 23 June 2015> minus <26 to 30 June 2015>



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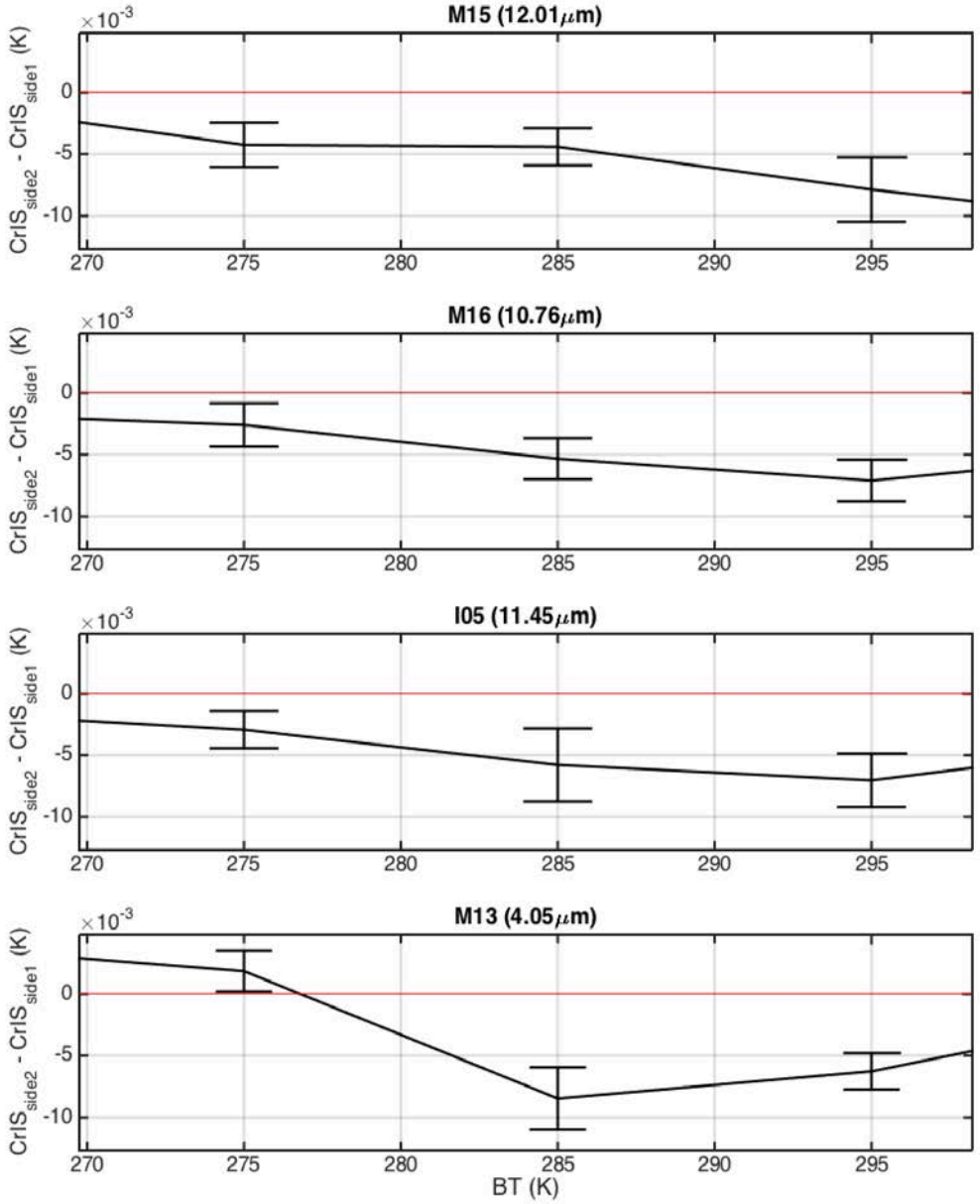


- Changes at the ICT temperature (~280K) are consistent and suggest changes in the ICT temperature calibration from side1 to side2 of ~5 to 7mK (compared to 37mK 1σ estimated total uncertainty in ICT T)

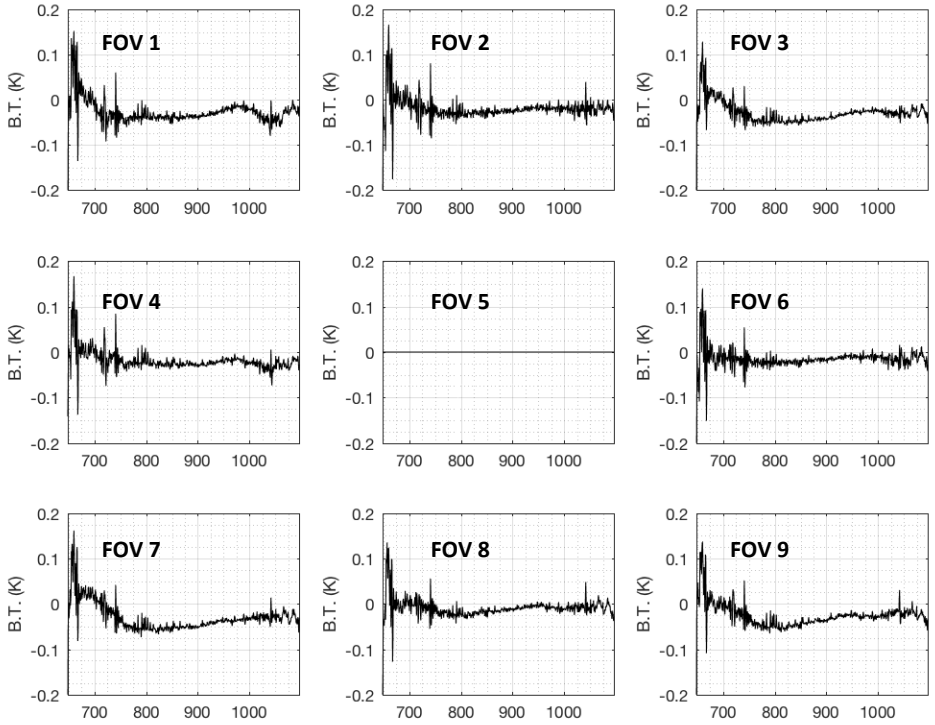
CrIS/VIIRS Preliminary conclusions

- Long term changes in the SNPP CrIS/VIIRS biases over 7 years, with CrIS on side 1, have been very small (~9mK M15, ~14mK M16, ~2mK I05, ~5mK M13)
- Changes in the CrIS calibration from side 1 to side 2 based on CrIS/VIIRS comparisons are very small, with side2 calibration 5 to 7 mK colder than the side1 calibration at the ICT temperature of ~280K.
- These changes are very likely due to the change from the side1 ICT PRTs to the side2 ICT PRTs, and well within the uncertainty in the ICT temperature uncertainty (37mK 1σ).

SNPP Side Switch: FOV-to-FOV Radiometric Continuity

SIDE #1 **IDPS SDR Data: 22-March-2019 to 23-March-2019** **SNPP EP37**

SNPP
LW

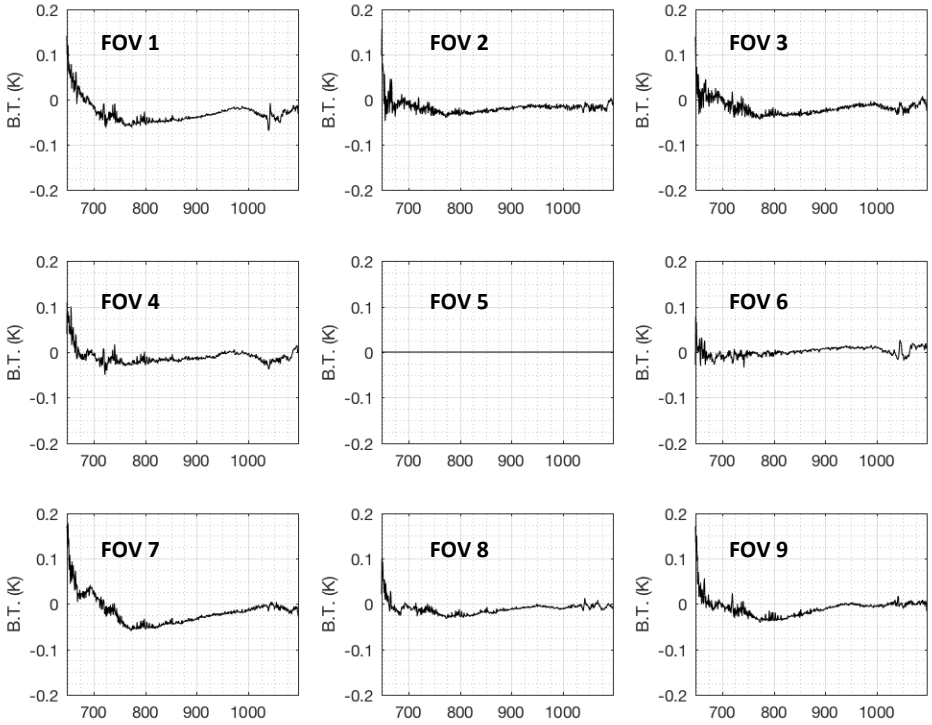


Hamming Apodized

- Radiometric FOV-to-FOV less than 0.2 K.

SIDE #2 **ADL GOLDEN DAYS: 29-June-2019 to 01-July-2019** **SNPP EP40**

SNPP
LW

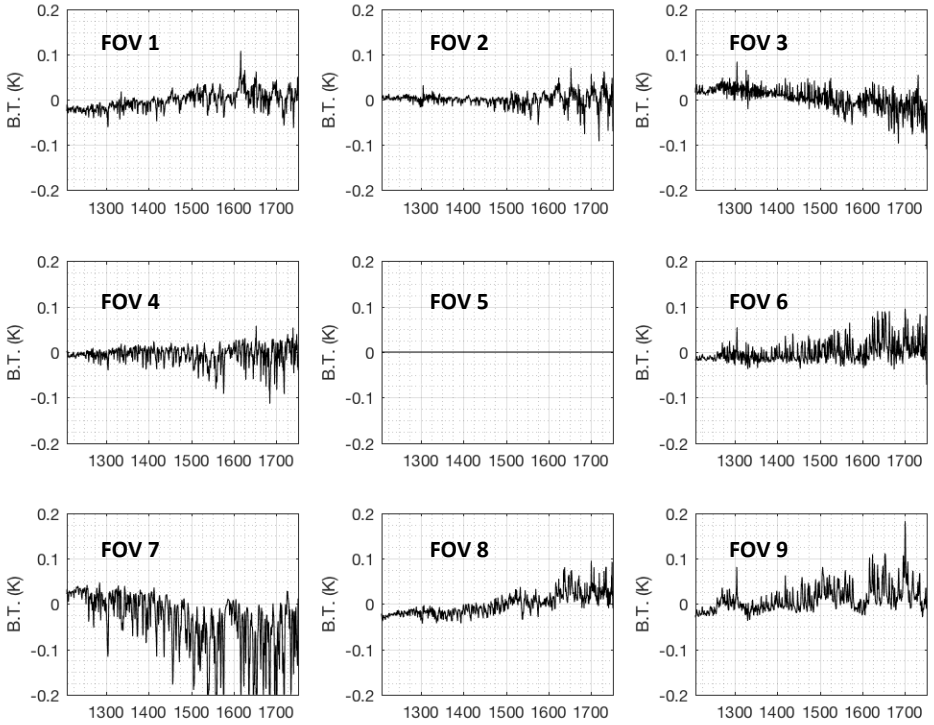


Hamming Apodized

- EP40 preserves the good Radiometric FOV-to-FOV agreement.
- Slight reduction in spectral ringing.

SIDE #1 **IDPS SDR Data: 22-March-2019 to 23-March-2019** **SNPP EP37**

SNPP
MW



Hamming Apodized

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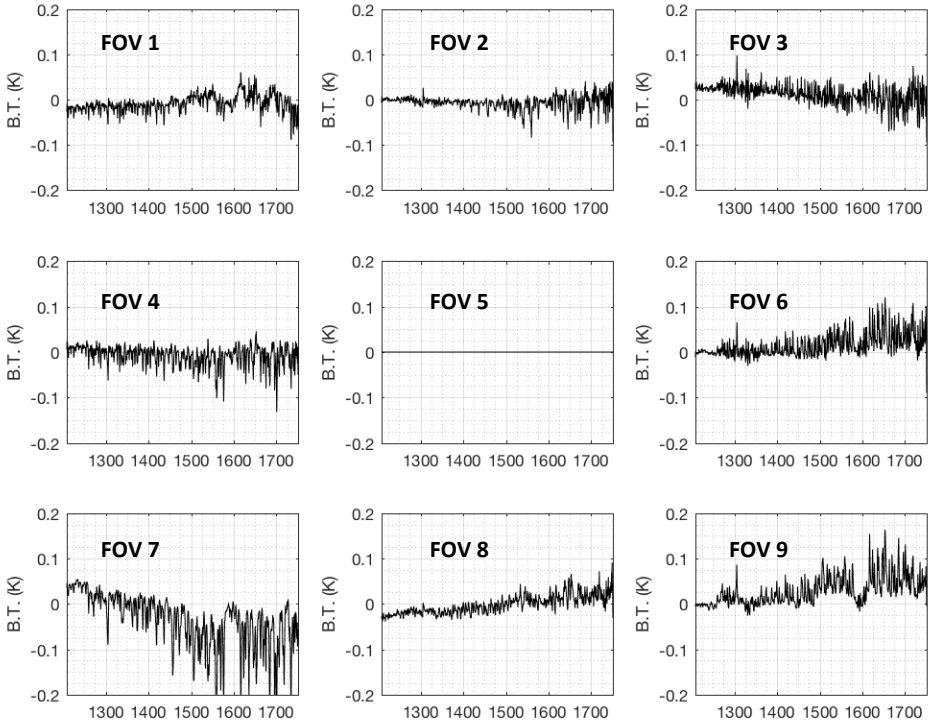
SIDE #2 **GOLDEN DAYS: 29-June-2019 to 01-July-2019** **ADL with EP40**

SNPP MW



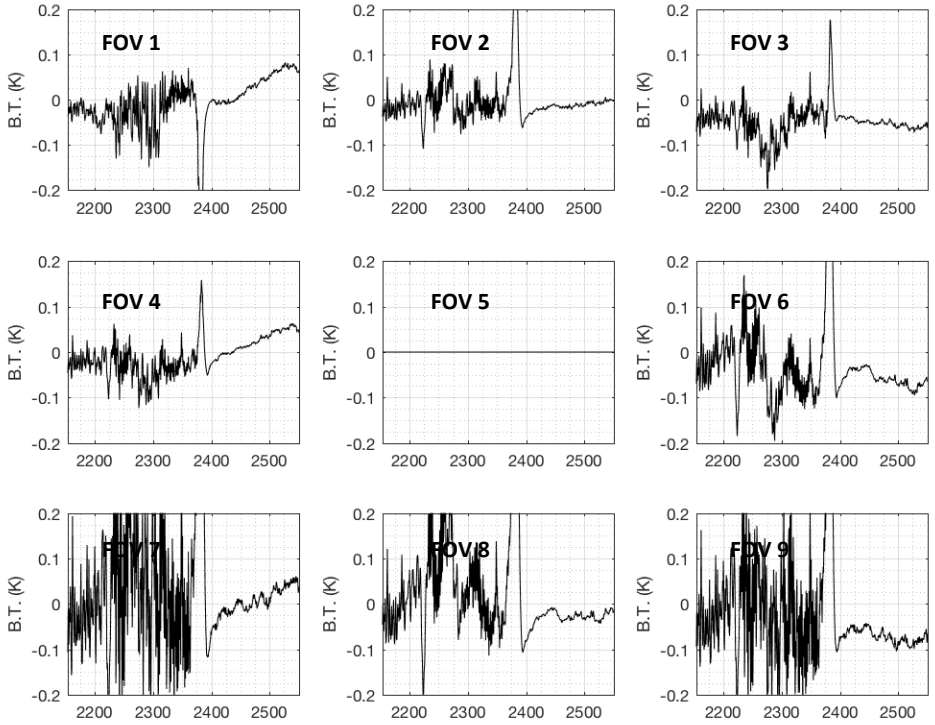
Hamming Apodized

FOV 7 has largest nonlinearity correction in SNPP MW Band

- EP40 preserves the good Radiometric FOV-to-FOV agreement from SIDE1. [Note: MW FOV7 remains slightly out of family due to sub-optimal a2 value.]

SIDE #1 **IDPS SDR Data: 22-March-2019 to 23-March-2019** **SNPP EP37**

SNPP
SW

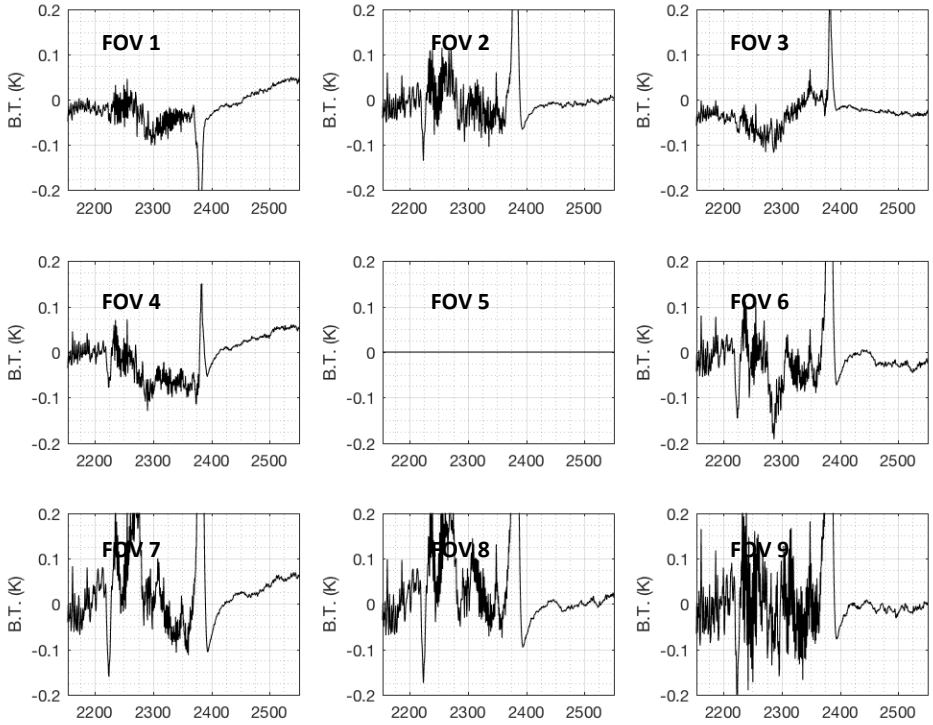


Hamming Apodized

- Radiometric FOV-to-FOV less than 0.2 K.

SIDE #2 **GOLDEN DAYS: 29-June-2019 to 01-July-2019** **ADL with EP40**

SNPP
SW



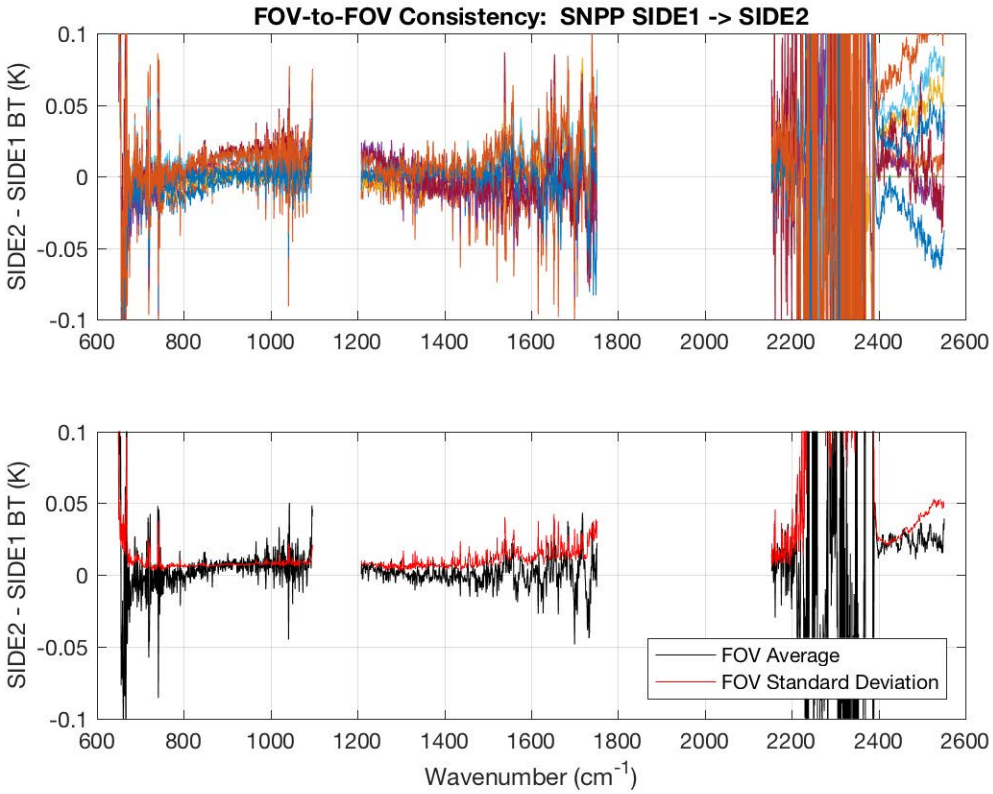
Hamming Apodized

- Some slight improvements in EP40 due to optimized ILS parameters.

SIDE #1 **IDPS SDR Data: 22-March-2019 to 23-March-2019** **SNPP EP37**

SIDE #2 **ADL GOLDEN DAYS: 29-June-2019 to 01-July-2019** **SNPP EP40**

Hamming Apodized



Difference Side2 mean from Side1 for each FOV. Then subtract off FOV5 to compute relative FOV-to-FOV radiometric reproducibility.

Reproducibility of LW and MW bands < 0.02 K

SW band slightly larger due to higher variability of surface solar reflection in daytime.

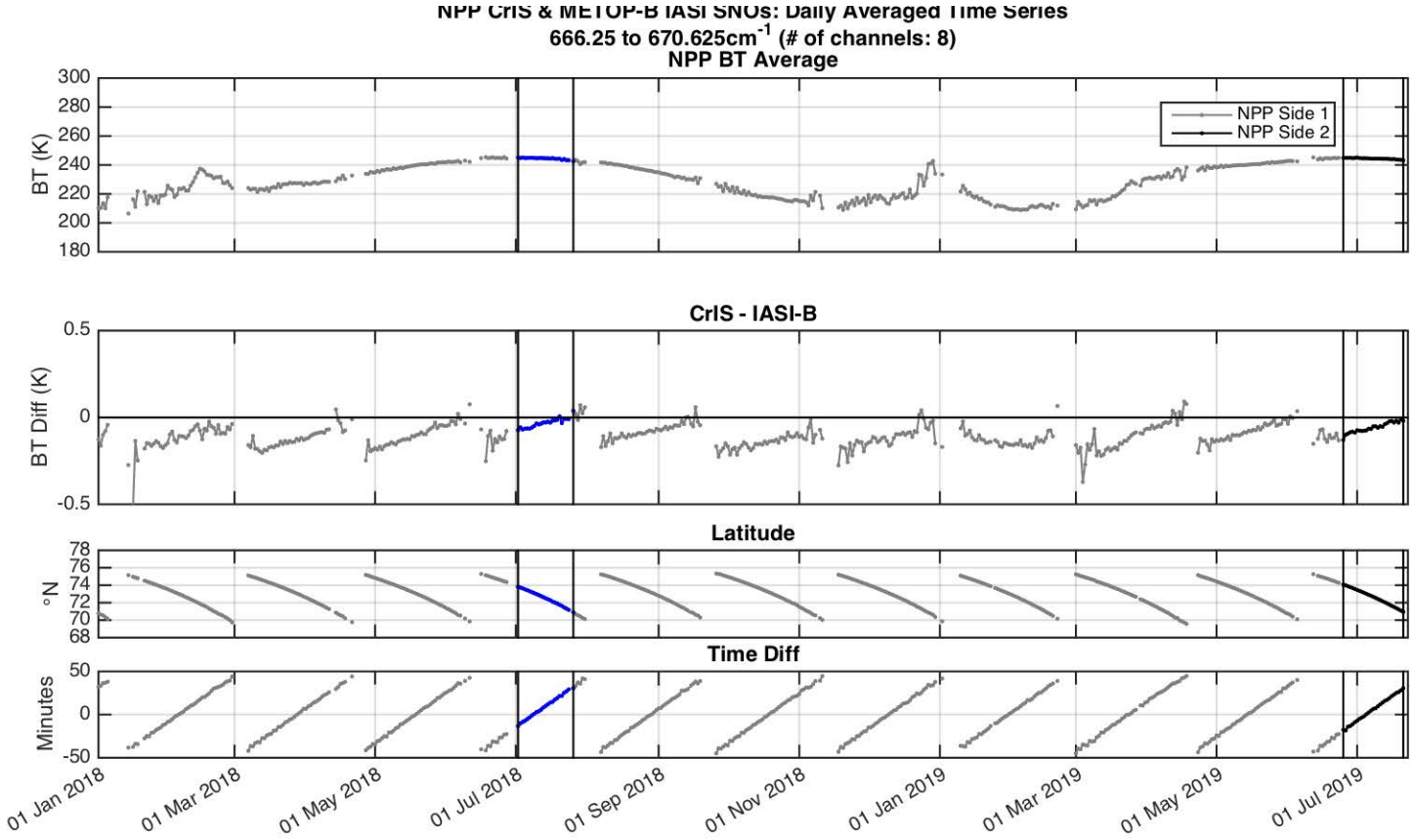
CrIS/IASI-B SNOs

Following slides show **BT differences for Side1 – Side 2** using the time periods highlighted by the previous plots:

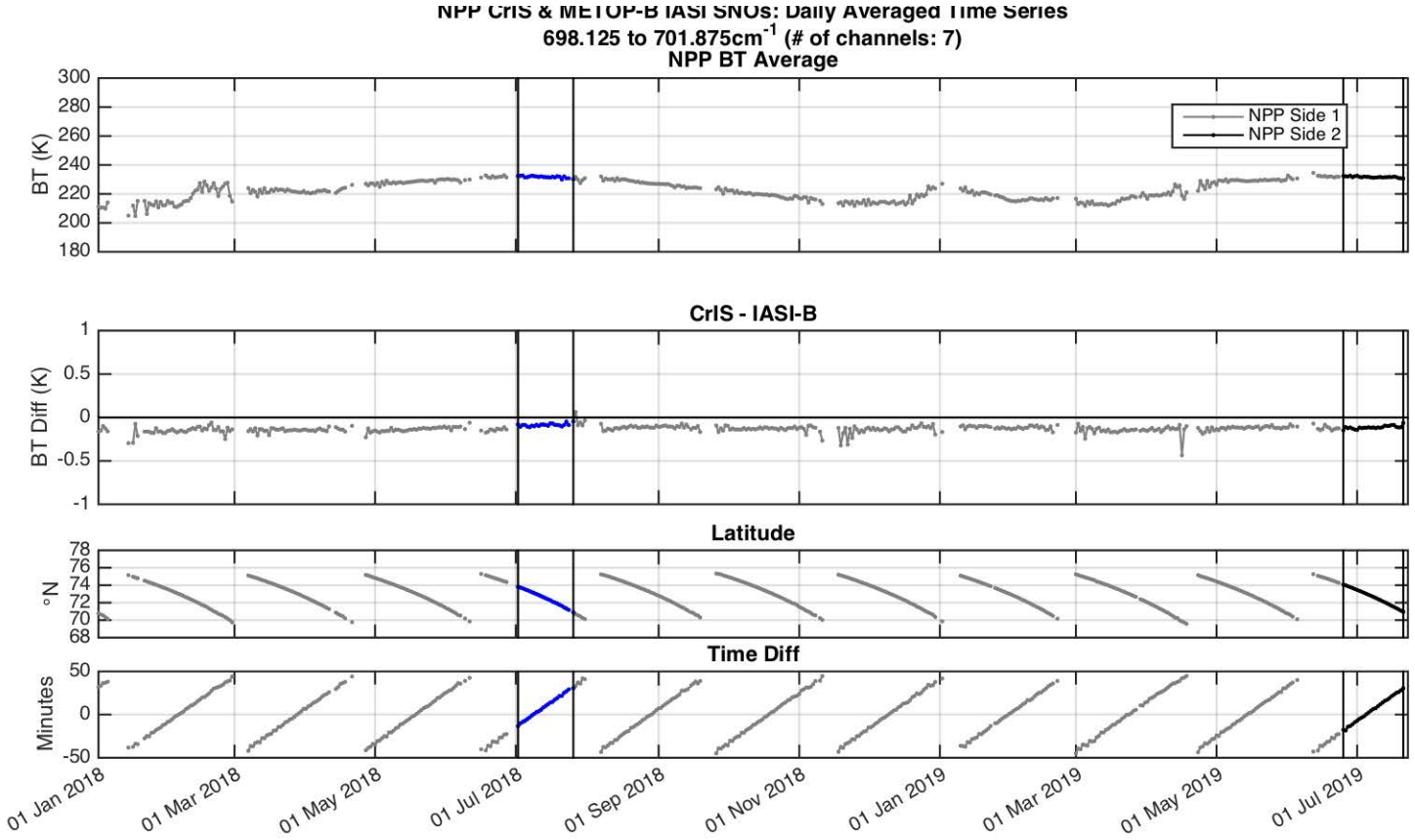
Side 1: July 2nd through July 26th 2019

Side 2: June 25th through July 21st 2019

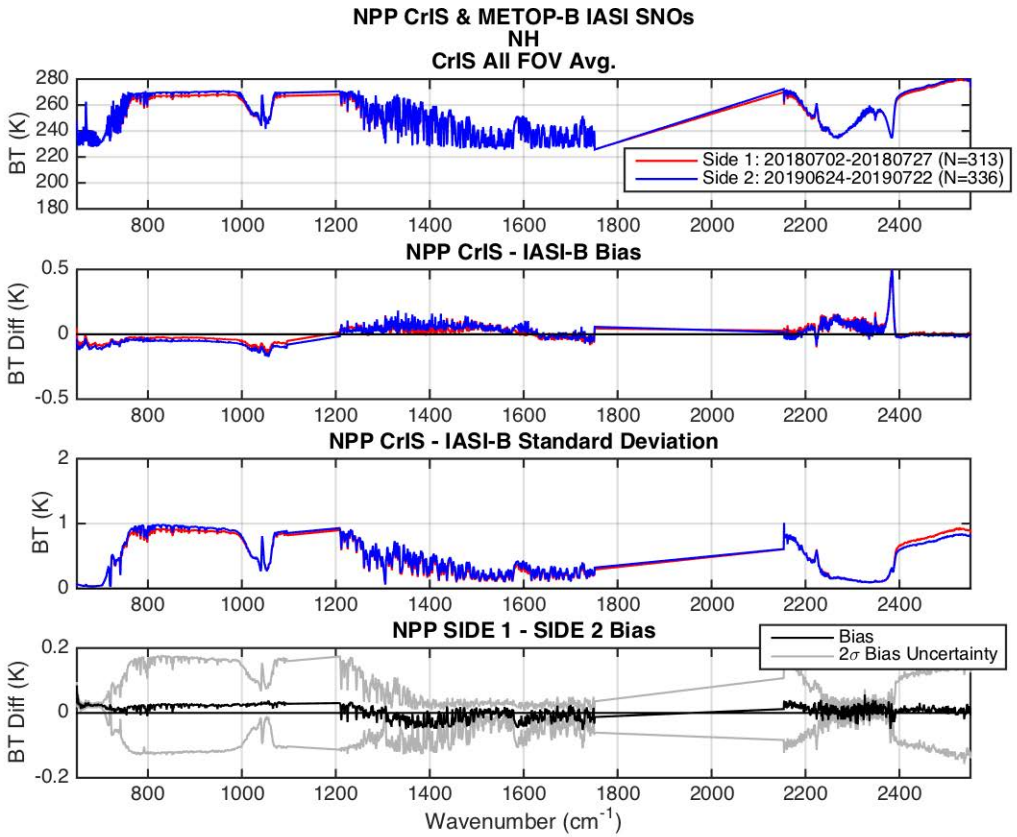
NH


NPP CrIS & METOP-B IASI SNOs: Daily Averaged Time Series
666.25 to 670.625cm-1 (# of channels: 8)
NPP BT Average
BT (K)
NPP Side 1
NPP Side 2
CrIS - IASI-B
BT Diff (K)
Latitude
°N
Time Diff
Minutes
01 Jan 2018
01 Mar 2018
01 May 2018
01 Jul 2018
01 Sep 2018
01 Nov 2018
01 Jan 2019
01 Mar 2019
01 May 2019
01 Jul 2019

NH


NPP CrIS & METOP-B IASI SNOs: Daily Averaged Time Series
698.125 to 701.875cm-1 (# of channels: 7)
NPP BT Average
BT (K)
NPP Side 1
NPP Side 2
CrIS - IASI-B
BT Diff (K)
Latitude
°N
Time Diff
Minutes
01 Jan 2018
01 Mar 2018
01 May 2018
01 Jul 2018
01 Sep 2018
01 Nov 2018
01 Jan 2019
01 Mar 2019
01 May 2019
01 Jul 2019

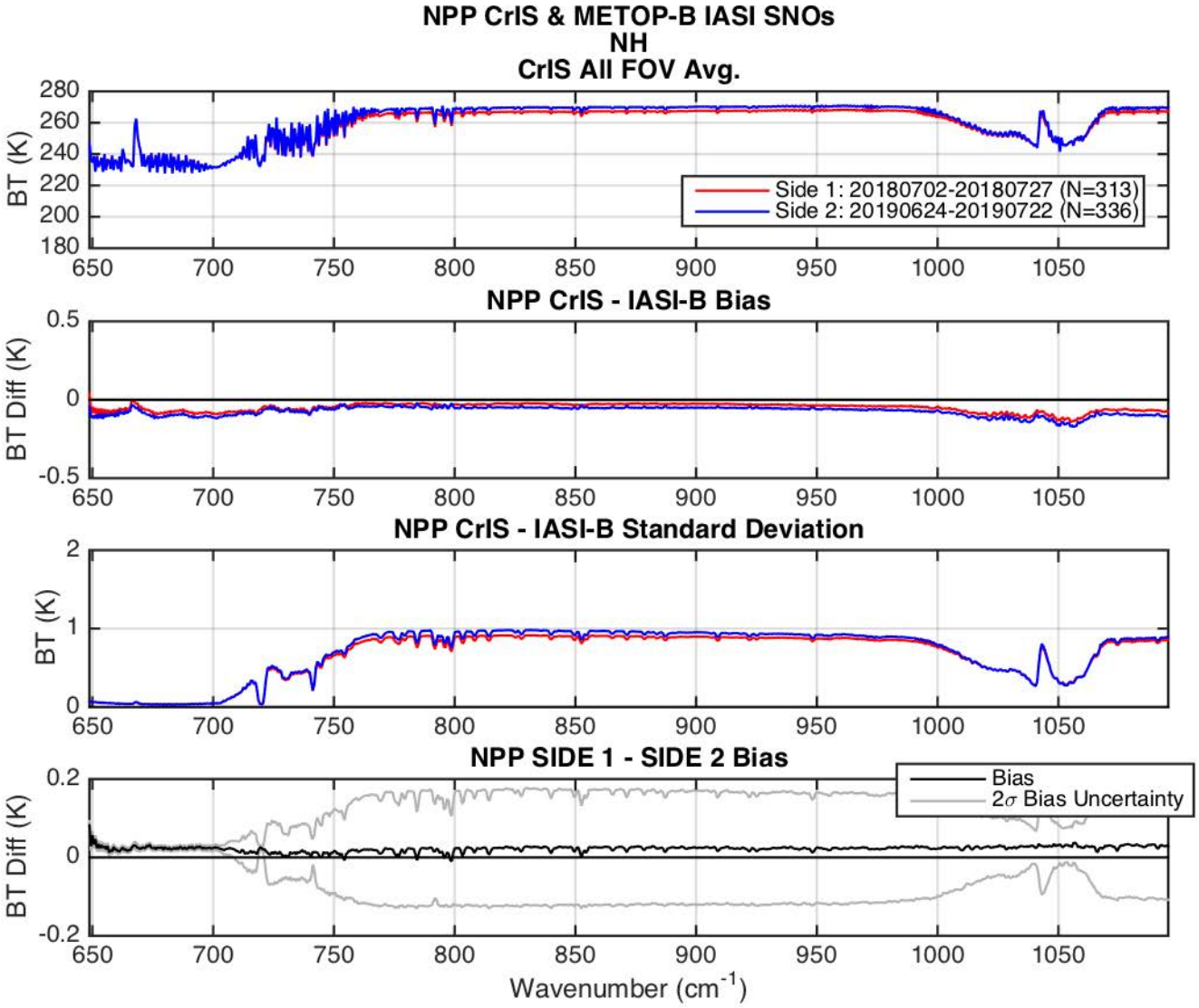
NH



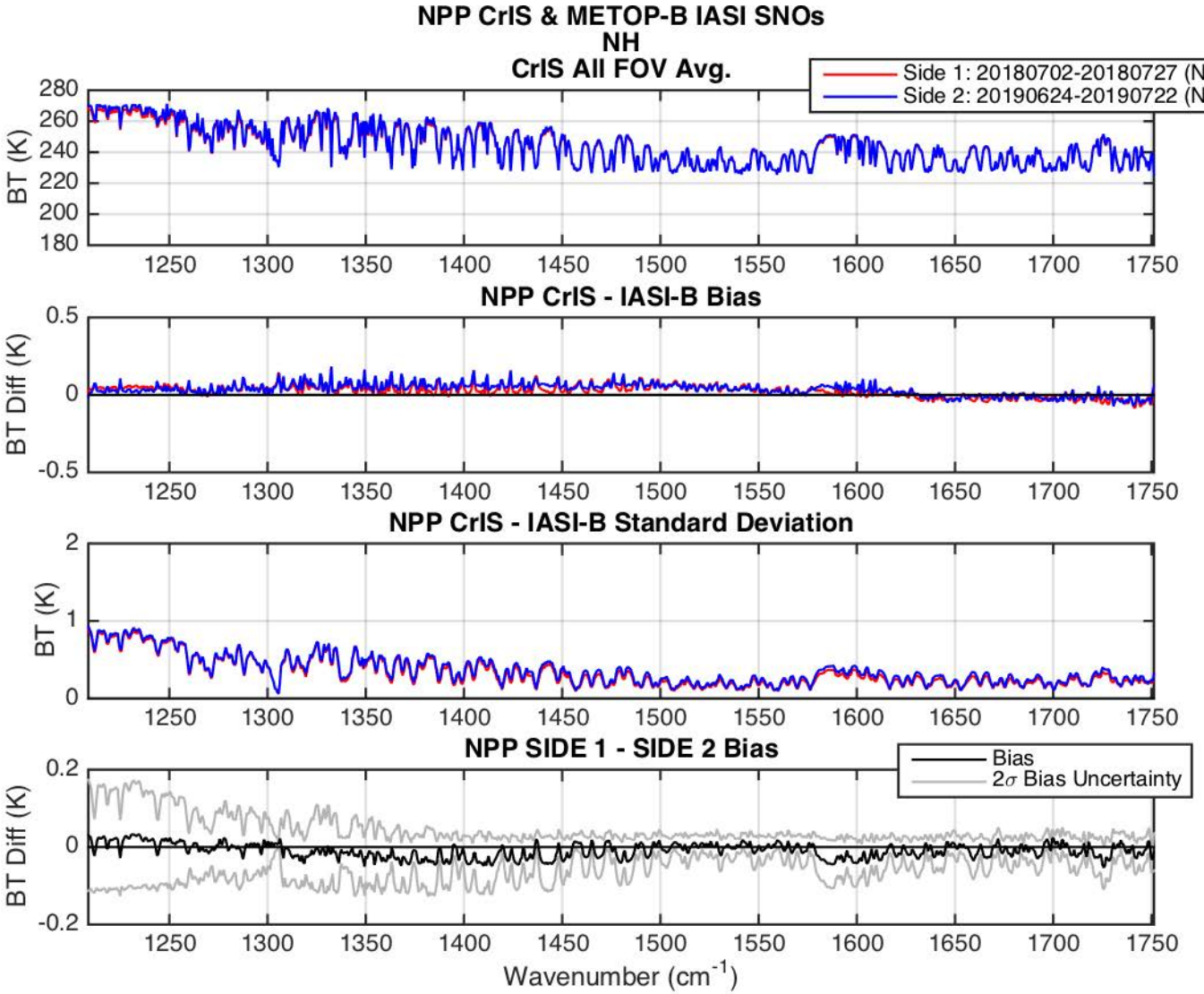
The bias uncertainty shown in grey is the combined 'uncertainty of the means' for the side 1 and side 2 CrIS-IASIB bias.

I.E.: bias_uncertainty_side1 = standard_deviation_side1 / sqrt(#_samples_side1)
bias_uncertainty_side2 = standard_deviation_side2 / sqrt(#_samples_side2)
side1_minus_side2_bias_uncertainty = sqrt(bias_uncertainty_side1^2 + bias_uncertainty_side2^2)

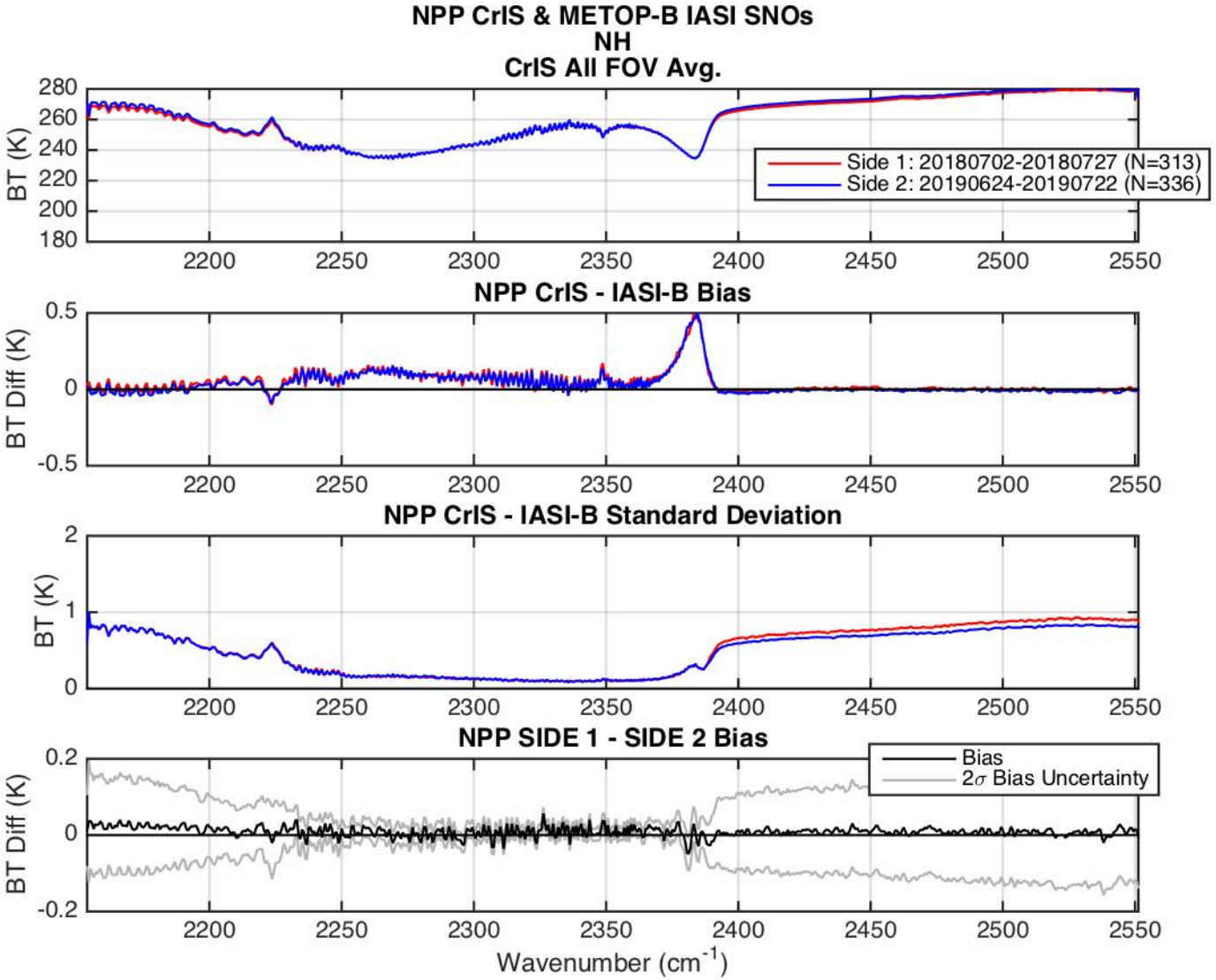
esults


NPP CrIS & METOP-B IASI SNOs
NH
CrIS All FOV Avg.
BT (K)
Side 1: 20180702-20180727 (N=313)
Side 2: 20190624-20190722 (N=336)
NPP CrIS - IASI-B Bias
BT Diff (K)
NPP CrIS - IASI-B Standard Deviation
BT (K)
NPP SIDE 1 - SIDE 2 Bias
BT Diff (K)
Bias
2σ Bias Uncertainty
Wavenumber (cm-1)

esults


NPP CrIS & METOP-B IASI SNOs
NH
CrIS All FOV Avg.
Side 1: 20180702-20180727 (N=313)
Side 2: 20190624-20190722 (N=336)
BT (K)
NPP CrIS - IASI-B Bias
BT Diff (K)
NPP CrIS - IASI-B Standard Deviation
BT (K)
NPP SIDE 1 - SIDE 2 Bias
Bias
2σ Bias Uncertainty
BT Diff (K)
Wavenumber (cm-1)

esults

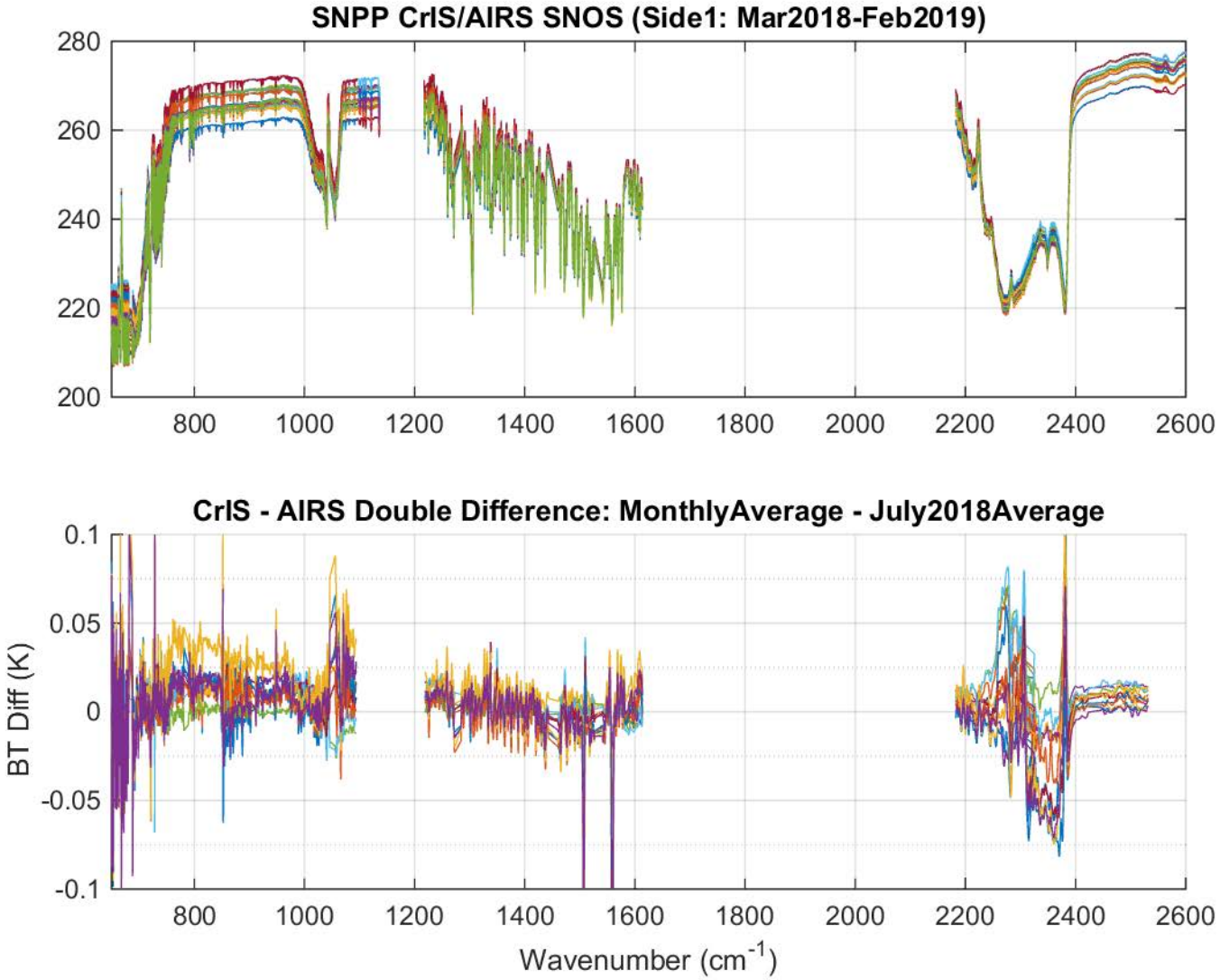

NPP CrIS & METOP-B IASI SNOs
NH
CrIS All FOV Avg.
BT (K)
Side 1: 20180702-20180727 (N=313)
Side 2: 20190624-20190722 (N=336)
NPP CrIS - IASI-B Bias
BT Diff (K)
NPP CrIS - IASI-B Standard Deviation
BT (K)
NPP SIDE 1 - SIDE 2 Bias
BT Diff (K)
Bias
2σ Bias Uncertainty
Wavenumber (cm-1)

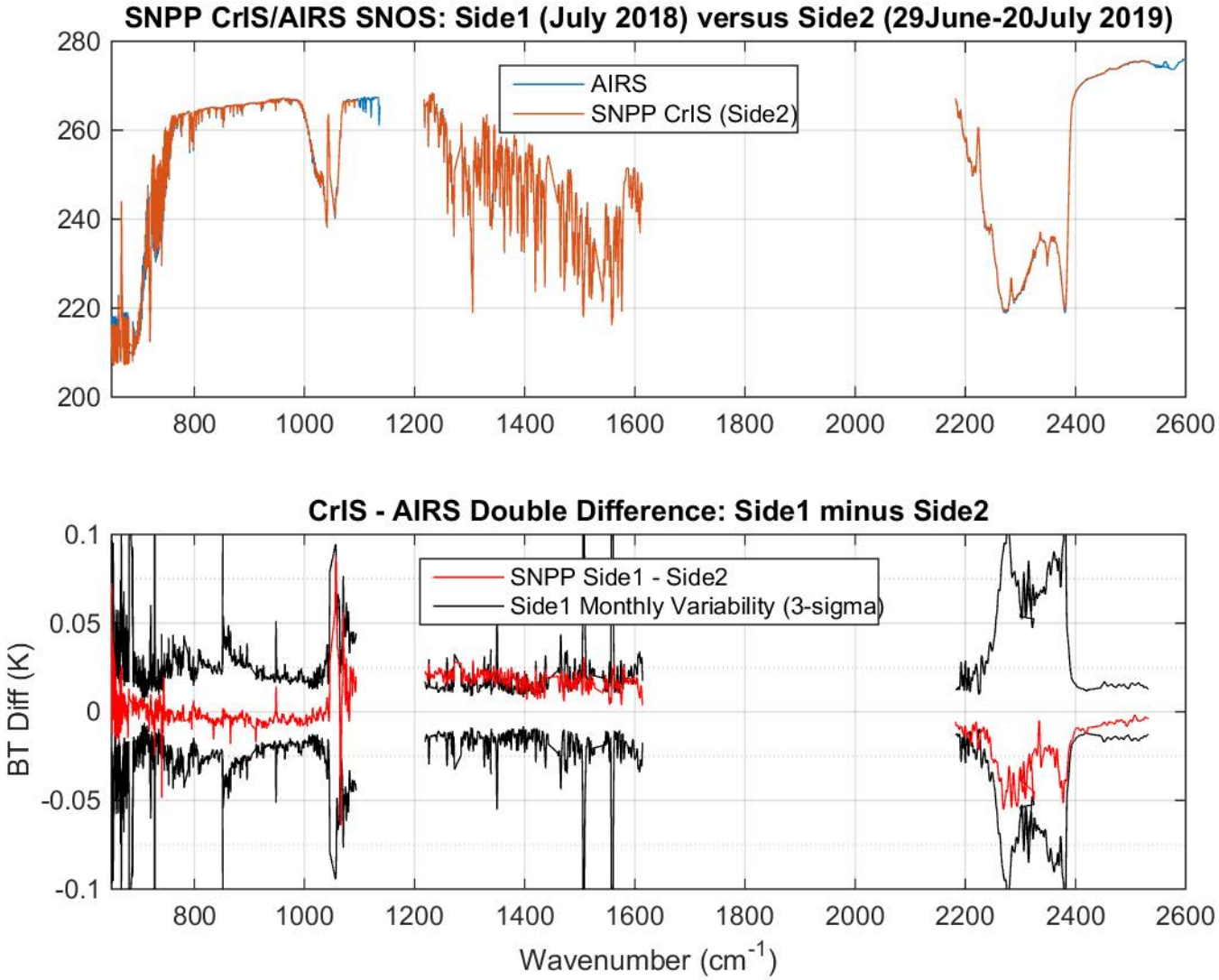
CrIS/AIRS SNOs

Following slides show **BT differences for Side1 – Side 2** using the time periods highlighted by the previous plots:

Side 1: July 2nd through July 26th 2019

Side 2: June 25th through July 21st 2019


SNPP CrIS/AIRS SNOS (Side1: Mar2018-Feb2019)
280
260
240
220
200
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
CrIS - AIRS Double Difference: MonthlyAverage - July2018Average
0.1
0.05
0
-0.05
-0.1
BT Diff (K)
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
Wavenumber (cm-1)


SNPP CrIS/AIRS SNOS: Side1 (July 2018) versus Side2 (29June-20July 2019)
AIRS
SNPP CrIS (Side2)
280
260
240
220
200
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
CrIS - AIRS Double Difference: Side1 minus Side2
SNPP Side1 - Side2
Side1 Monthly Variability (3-sigma)
BT Diff (K)
0.1
0.05
0
-0.05
-0.1
Wavenumber (cm-1)