CrIS Calibration Accuracy and its role as an Inter-calibration Reference

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Table 1 – Draft Scoring Scheme for GSICS Near-Real-Time Correction for 2014 Geostationary Imager IR Channels

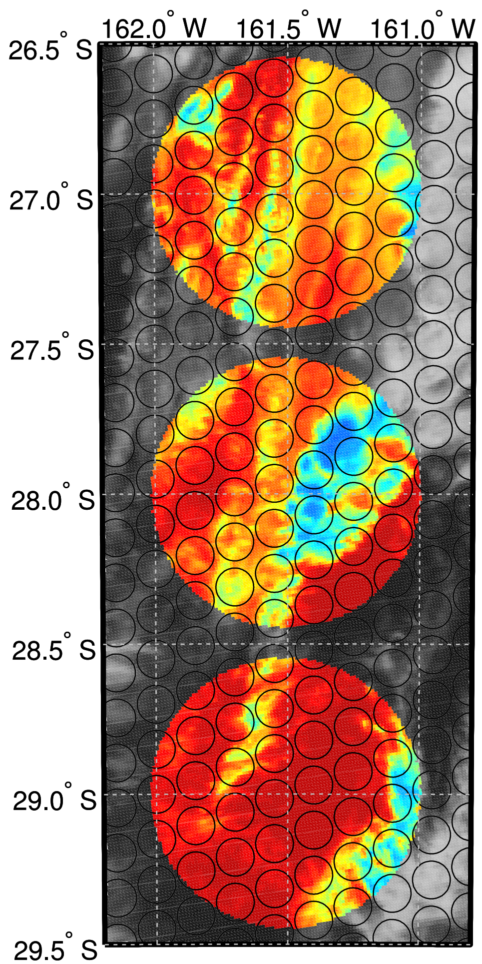
		Threshold		Goal			Metop-A/IASI		Aqua/AIRS		SNPP/CrIS (in FSR mode)		NOAA-14/HIRS		CLARREO-1A/IR	
	Unit	Min	Max	Min	Max	Weight	OK?	Score	OK?	Score	OK?	Score	OK?	Score	OK?	Score
Date Range	Year	2014	2014	2006	2030	10	OK	7.5	OK	4.2	OK	5.8	NOK	0.4	NOK	0.0
Spatial Coverage: Lat	deg	-10	10	-90	90	1	OK	1.0	OK	1.0	OK	1.0	OK	1.0	OK	1.0
Spatial Coverage: Lon	deg	-10	10	-180	180	1	OK	1.0	OK	1.0	OK	1.0	OK	1.0	OK	1.0
Dynamic Range	K	270	300	180	330	2	OK	1.7	OK	1.7	OK	1.7	OK	1.7	OK	1.7
Spectral Range SWIR	µm	3.75	3.92	3.48	4.36	2.2	OK	1.6	OK	1.2	NOK	1.1	OK	1.4	OK	1.8
Spectral Range MWIR	µm	6.25	7.35	5.35	7.85	2.6	OK	2.6	OK	1.4	OK	2.1	NOK	0.2	OK	2.6
Spectral Range LWIR	µm	8.70	13.40	8.30	14.40	5.2	OK	5.2	NOK	2.6	NOK	2.6	NOK	2.6	OK	5.2
Geometric Range: VZA	deg			0	60	1	OK	0.9	OK	0.9	OK	0.9	OK	0.9	OK	0.0
Diurnal Coverage	hr			0	12	5	OK	1.4	OK	1.4	OK	1.4	OK	1.4	OK	5.0
# Collocations	/d	1		10000		4	OK	4.0	OK	4.0	OK	4.0	OK	4.0	OK	4.0
Spatial resolution	km		100		10	1	OK	0.8	OK	0.7	OK	0.7	OK	0.5	OK	0.2
Spatial sampling	km		1000		10	1	OK	0.4	OK	0.7	OK	0.6	OK	0.4	OK	0.1
Geolocation accuracy	km		10		0.1	5	OK	0.2	OK	0.2	OK	0.2	OK	0.2	OK	0.2
Radiometric Stability	K/yr		1		0.001	10	OK	0.2	OK	0.2	OK	0.2	OK	0.2	OK	10.0
Radiometric Noise	K		10		0.1	1	OK	0.7	OK	0.5	OK	0.5	OK	0.5	OK	0.2
Uncertainty from SBAF	K		1		0.01	10	OK	10.0	OK	1.0	OK	1.0	OK	0.3	OK	10.0
Spectral Resolution	cm-1		100		0.5	1	OK	1.0	OK	0.5	OK	0.8	NOK	0.0	OK	1.0
Spectral Stability	cm-1/yr		2		0.01	1	OK	1.0	OK	1.0	OK	1.0	OK	1.0	OK	1.0
Absolute Cal Acc	K		1		0.01	10	OK	2.0	OK	2.0	OK	2.0	OK	0.2	OK	3.0
Documented Traceability	Score 0-6	1		6		6	OK	2.0	OK	2.0	OK	3.0	OK	1.0	OK	6.0
Total						**100.0**	**100%**	**55%**	**93%**	**38%**	**90%**	**42%**	**87%**	**29%**	**97%**	**62%**

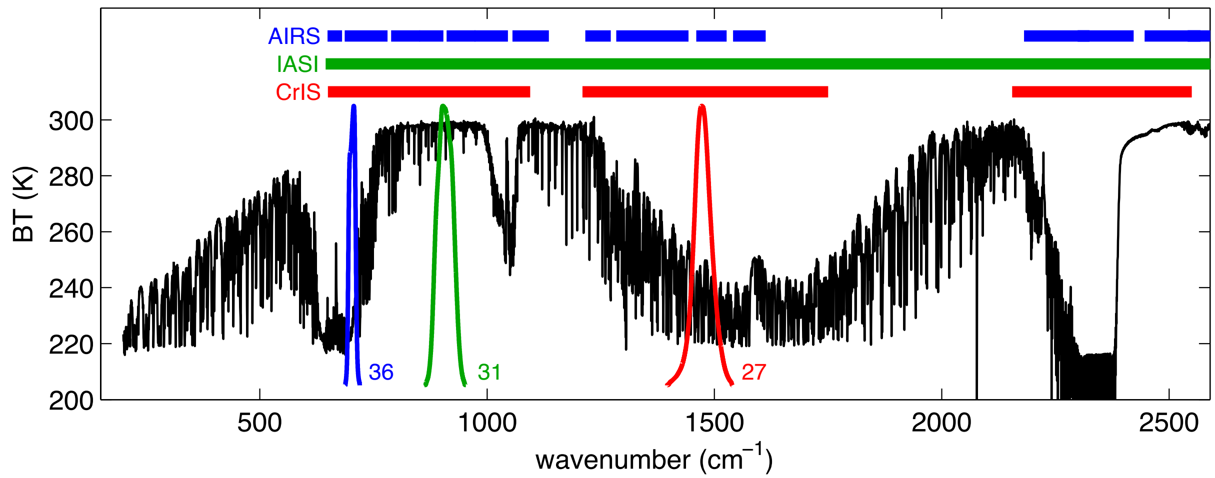
Characterization of the ability of the Climate Absolute Radiance and Refractivity Observatory (CLARREO) to serve as an infrared satellite intercalibration reference

by Tobin, Holz, Nagle, Revercomb, in press in JGR-Atmos

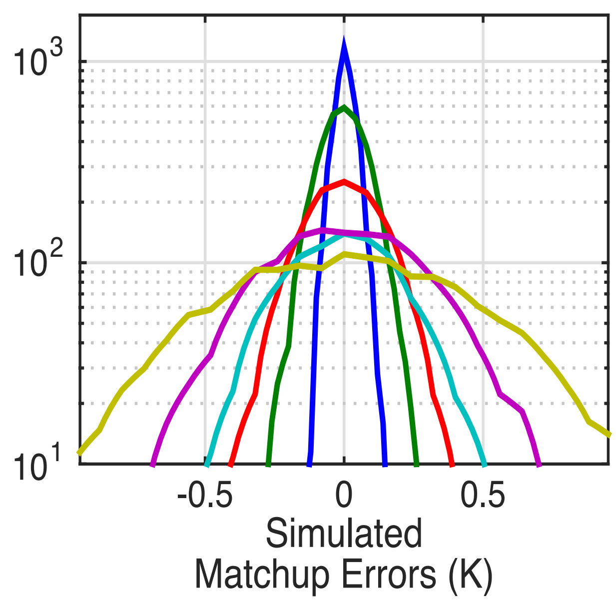
"… presents a new infrared intercalibration methodology that minimizes intercalibration uncertainties and provides uncertainty estimates resulting from the scene spatial variability and instrument noise. … The results are encouraging and suggest that biases between CLARREO and sounder observations can be determined with low uncertainty and with high time frequency during a CLARREO mission."

CLARREO/Sounder SNOs simulated with MODIS data

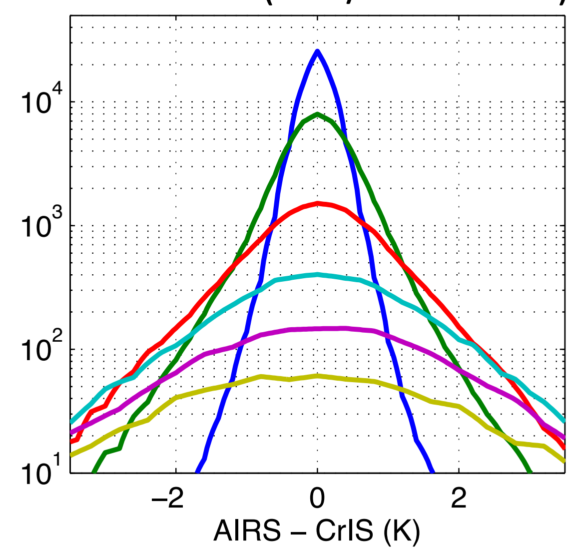




Simulation results



Observed (CrIS/AIRS SNOs)



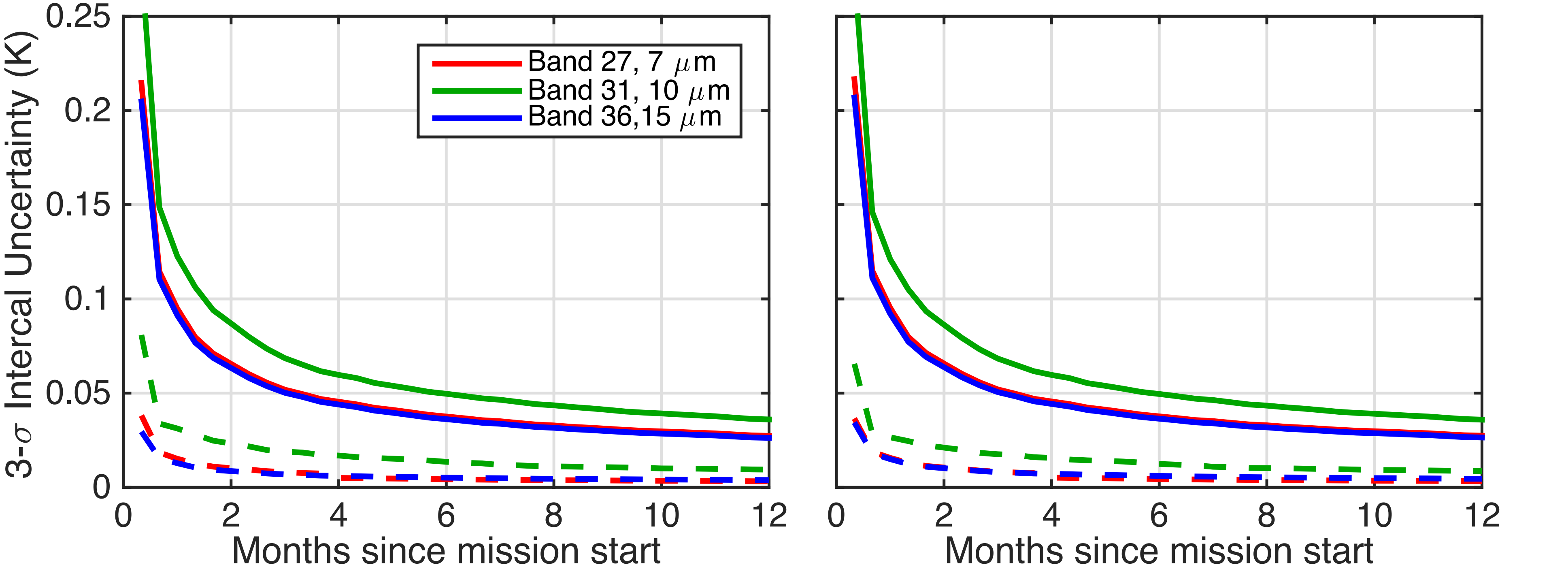


Figure 9. CLARREO Intercalibration (3-sigma) uncertainty as a function of mission length for single spectral channels in the 7, 10, and 15 mm regions for CLARREO/CrIS SNOs (left panel) and CLARREO/IASI SNOs (right panel). Solid curves include spatial and temporal colocation errors and CLARREO and sounder detector noise; dashed curves do not include CLARREO or sounder detector noise. Simulations include CLARREO in 90 degree polar orbit, CLARREO FOV diameter of 50 km, and 20 seconds between adjacent CLARREO FOVs.

Suomi-NPP CrIS Radiometric Uncertainty Estimates

Simplified On-Orbit Radiometric Calibration Equation:

$$R_{scene} = \mathcal{Re}\{(C'_{scene} - C'_{SP}) / (C'_{ICT} - C'_{SP})\} R_{ICT} \quad \text{with:}$$

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

ICT Predicted Radiance: $R_{ICT} = \varepsilon_{ICT}\, B(T_{ICT}) + (1-\varepsilon_{ICT})\, [\, 0.5\, B(T_{ICT,\ Refl,\ Measured}) + 0.5\, B(T_{ICT,\ Refl,\ Modeled})]$

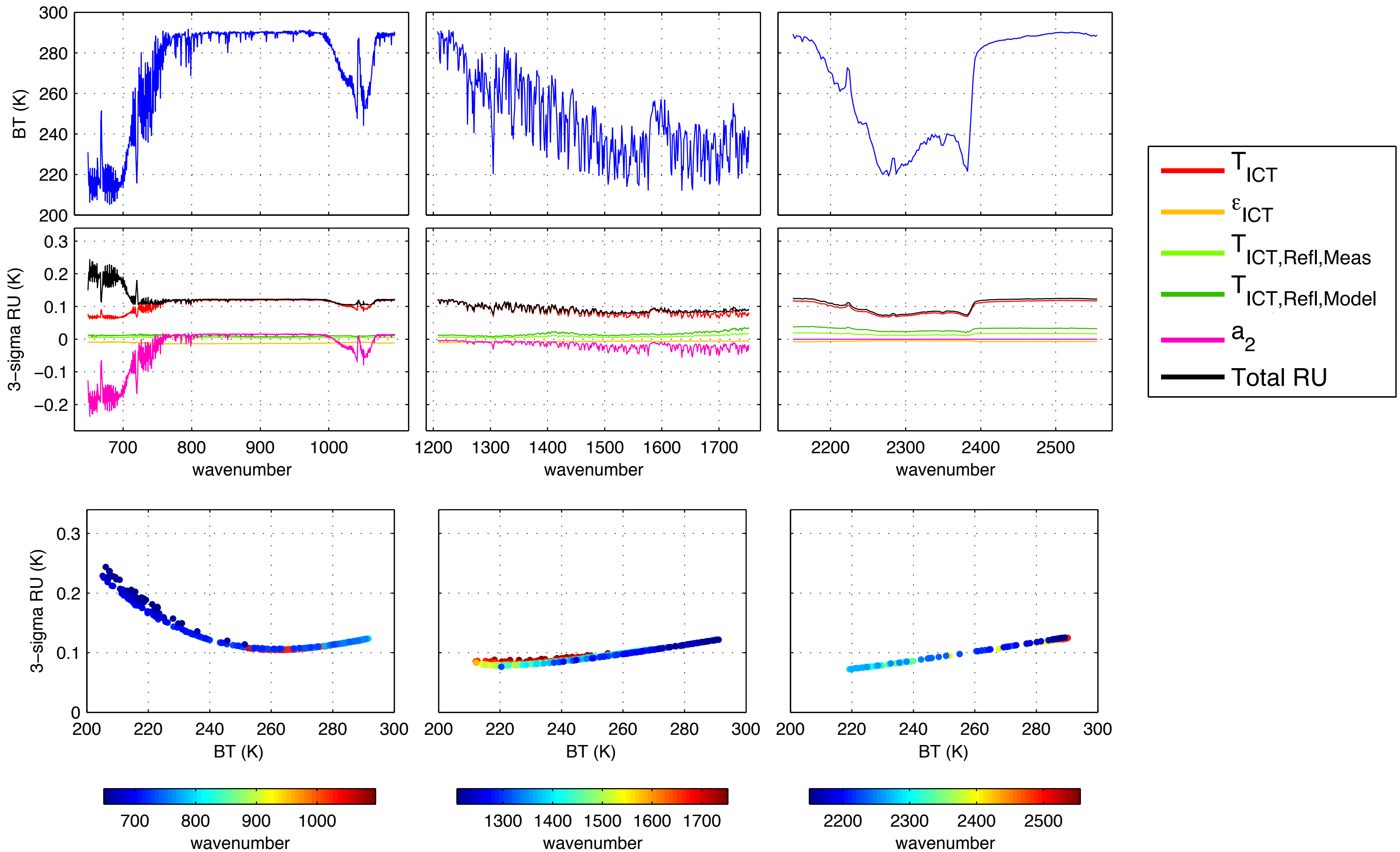
Parameter Uncertainties:

Parameter	Nominal Values	3-σ Uncertainty
T_{ICT}	280K	112.5 mK*
ε_{ICT}	0.974-0.996	0.03
$T_{ICT,\ Refl,\ Measured}$	280K	1.5 K
$T_{ICT,\ Refl,\ Modeled}$	280K	3 K
a_2 LW band	0.01 – 0.03 V^{-1}	0.00403 V^{-1}
a_2 MW band	0.001 – 0.12 V^{-1}	0.00128 – 0.00168 V^{-1}

- **Results provide estimates of the absolute calibration accuracy of the CrIS observations and, combined with the accuracy/precision of inter-calibration techniques, the level to which CrIS can be used as an inter-calibration reference.**

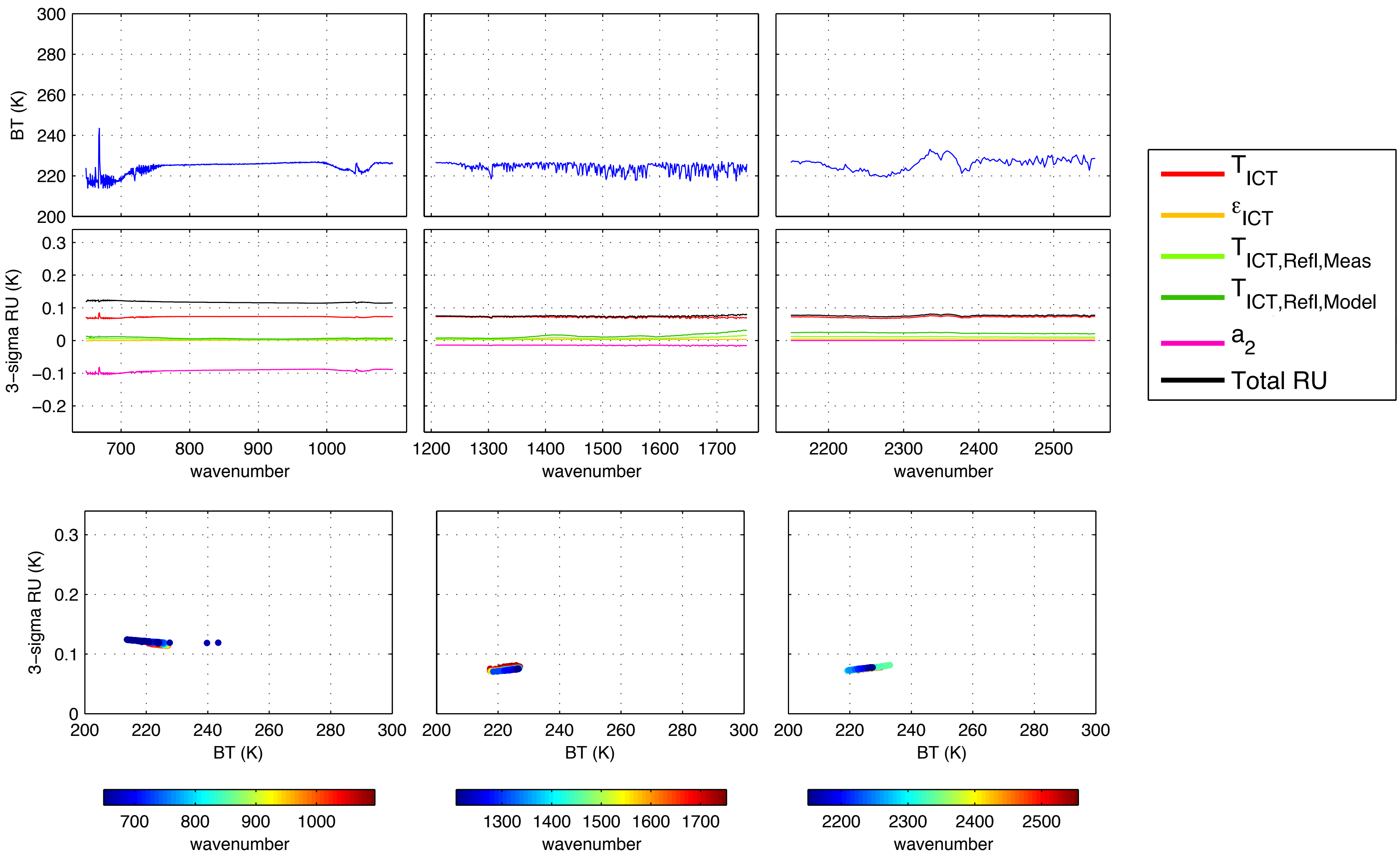
Suomi-NPP CrIS, example 3-sigma RU estimates

For a typical warm, ~clear sky spectrum



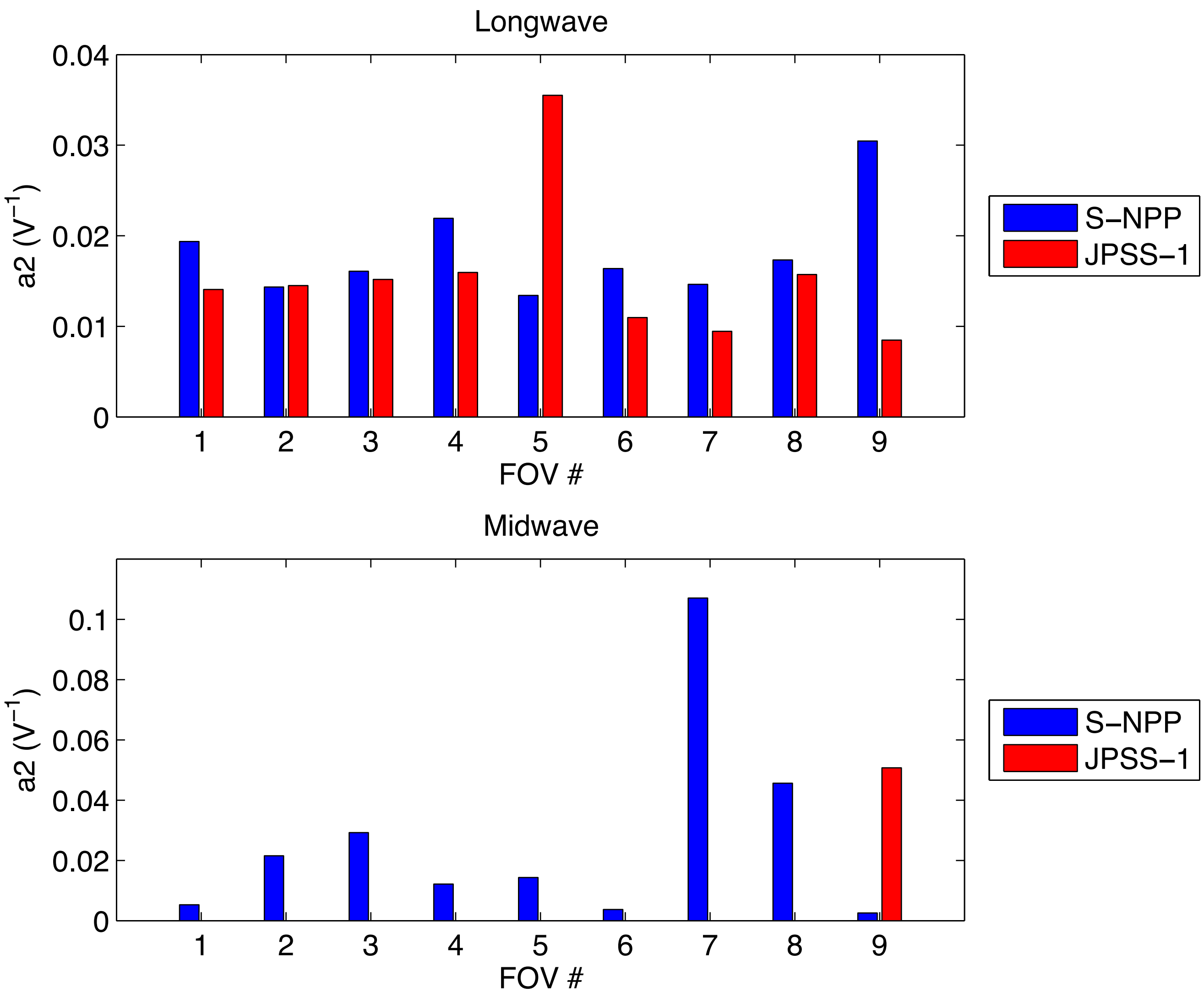
Suomi-NPP CrIS, example 3-sigma RU estimates

For a cold, high cloud spectrum



JPSS-1 Calibration Accuracy is very similar to Suomi-NPP CrIS

Main differences are: 1) Improved ICT emissivity, and 2) Different Nonlinearity magnitudes:



On-going Radiometric Calibration Refinements

- **Suomi-NPP Nonlinearity coefficients**
  - Primarily, reduce MW FOV7 a2 value by ~12%

- **T_{ICT} uncertainty**
  - Current values are too large because axial gradients are overestimated in current analyses. Results in change from 112 mK to ~88 mK 3-sigma.

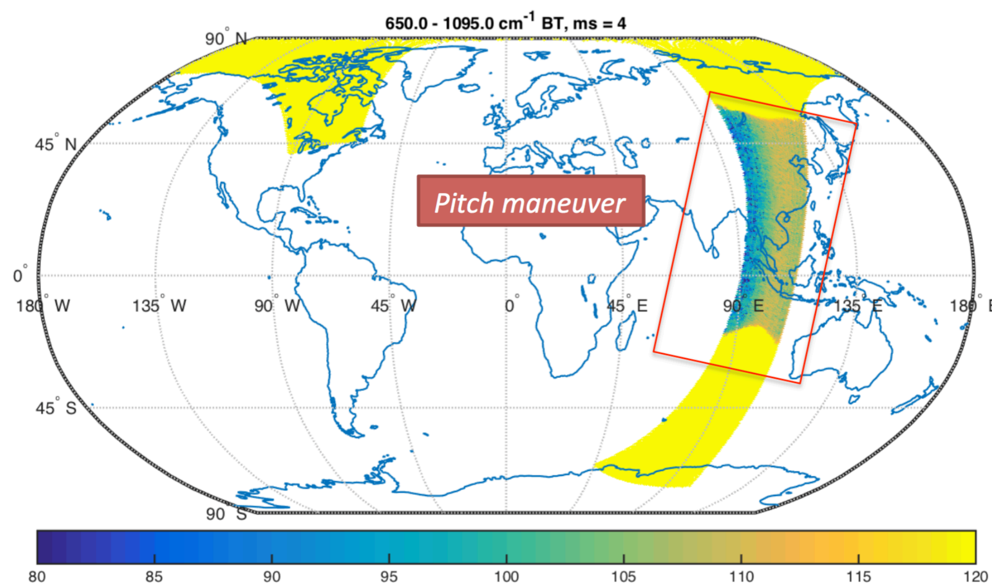
- **Polarization**
  - Calibrations do not include polarization corrections although recent analyses suggests corrections should be included. Currently working to finalize polarization characterization and include in future processing.

Polarization

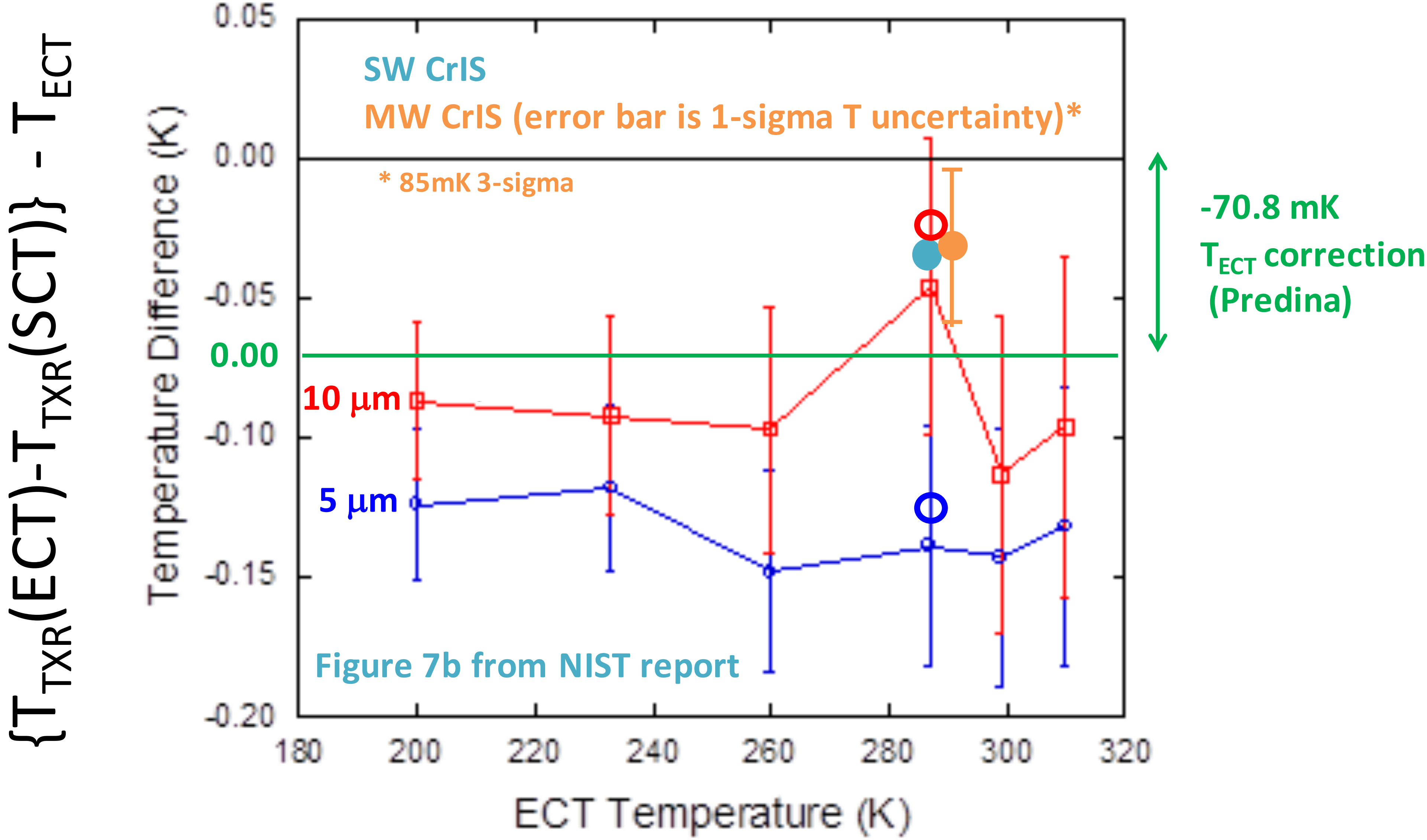
- Incident radiance is partially polarized by reflection from the scene select mirror (SSM); small degree of polarization in the IR for uncoated gold mirrors. The orientation of the polarization axis of the scene select mirror changes with scene mirror rotation. When coupled with the polarization sensitivity of the sensor, this produces a radiometric modulation of the detected signal that is dependent on the rotation angle of the scene select mirror and creates a calibration error
- In summary: SSM and sensor act as a polarizer and analyzer pair
- Corrention formalism following Pagano et al., 2000 ("Scan Angle Dependent Radiometric Modulation due to Polarization for the Atmospheric Infrared Sounder (AIRS)")

➢ 2012 Pitch maneuver data is being used to estimate polarization parameters $p_r p_t$ and α

➢ Earth view calibration effects are expected to be generally small but potentially larger for cold scene SW band radiances.



JPSS-1 Pre-launch calibration Traceability; Comparison to CrIS near ICT temperature



Demonstrates reasonable agreement with TXR 10 micron channel

(5 micron channel seems to have a small negative bias of 40-50 mK)

JPSS-1 Pre-launch calibration Traceability, Basic Summary

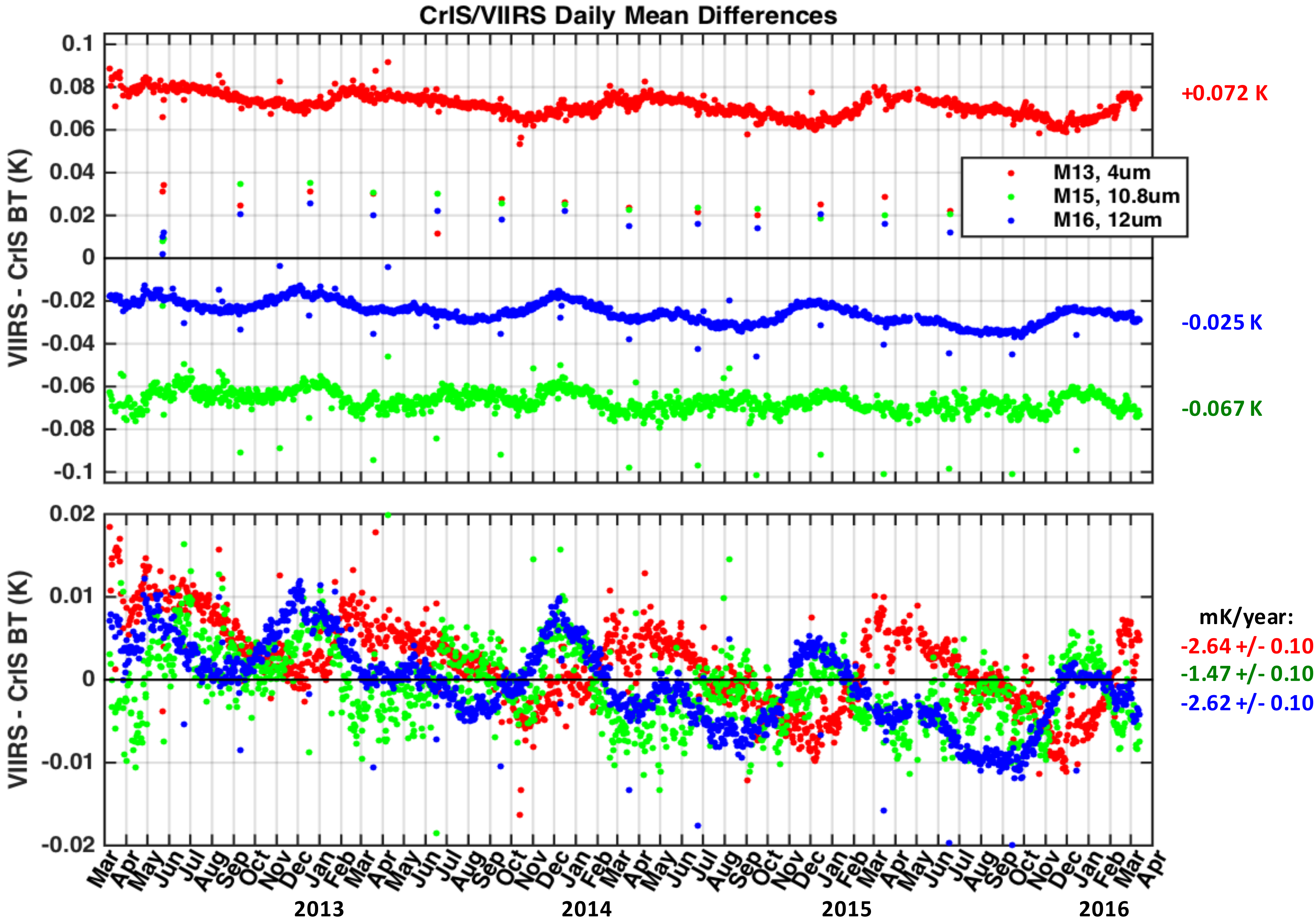
- These NIST TXR results provide valuable validation of ECT and CrIS absolute calibration
- The results do not suggest any adjustment to the CrIS calibration is necessary
- The results also validate the expected emissivity of the ECT and SCT and the ECT gradients characterized by CrIS (not shown here)

➢ Other post-launch traceability chains involve various intercomparisons, including high altitude aircraft underflights, with uncertainties typically on the same order or larger than the CrIS RU.

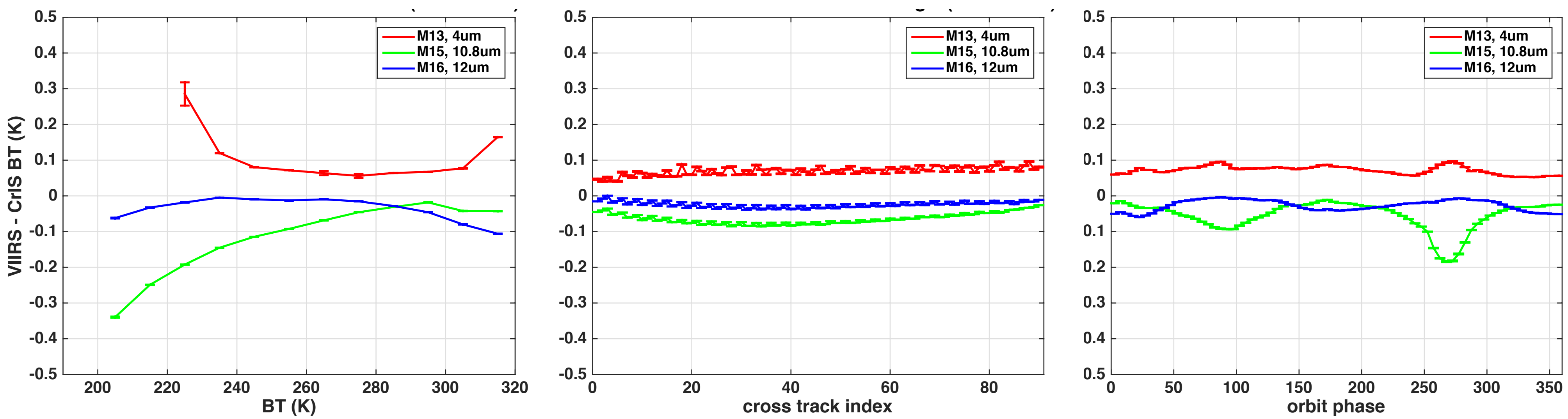
Four years of CrIS/VIIRS inter-comparisons

Results show:

- **Overall very small biases which are very stable with time**
- **Relatively small dependencies on signal level, scan angle, and orbit phase.**
- **Small biases become even smaller on the days when VIIRS performs its quarterly nonlinearity tests.**

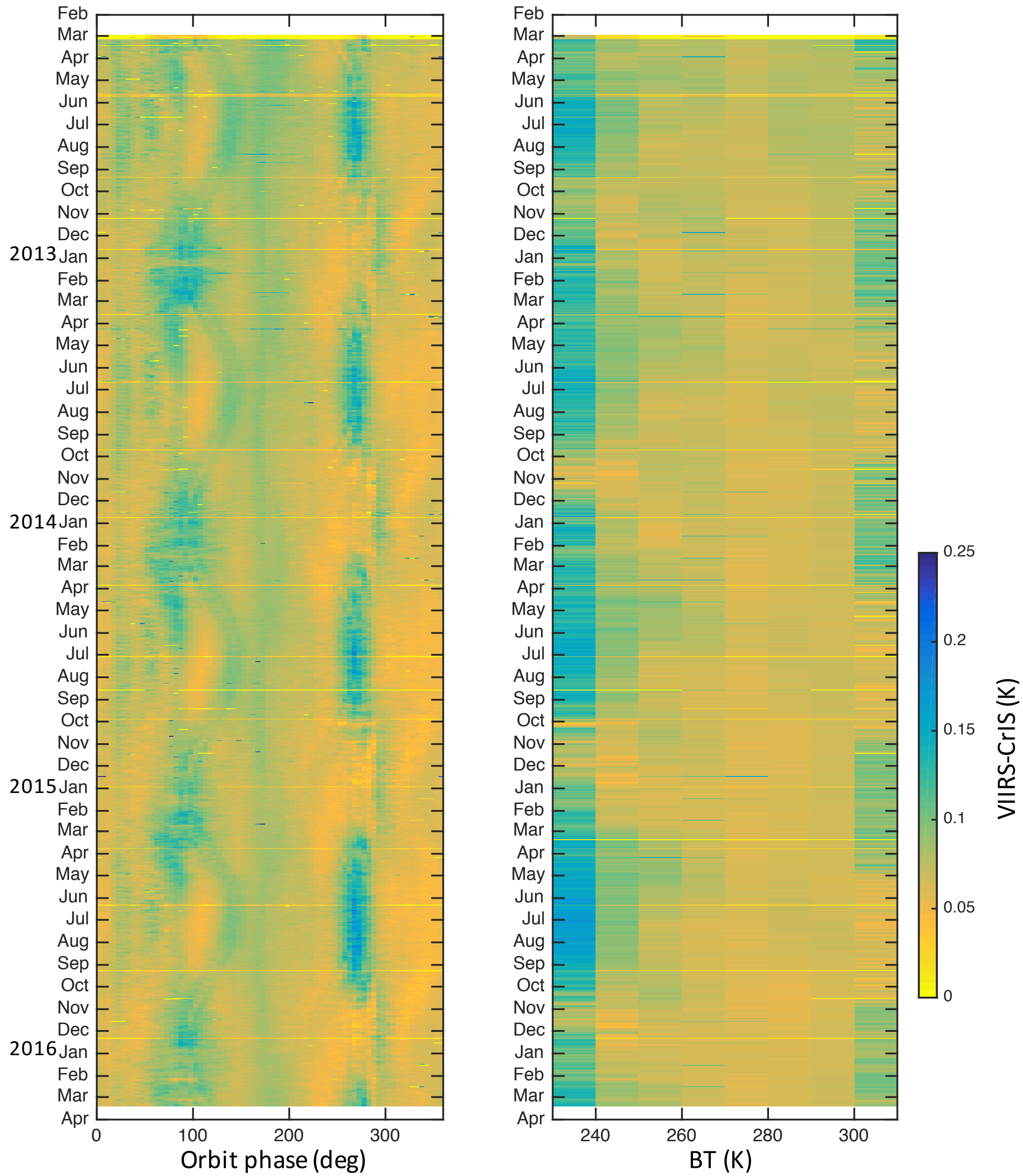


CrIS/VIIRS Daily Mean Differences
VIIRS - CrIS BT (K)
+0.072 K
-0.025 K
-0.067 K
M13, 4um
M15, 10.8um
M16, 12um
mK/year:
-2.64 +/- 0.10
-1.47 +/- 0.10
-2.62 +/- 0.10
2013
2014
2015
2016



VIIRS - CrIS BT (K)
BT (K)
cross track index
orbit phase
M13, 4um
M15, 10.8um
M16, 12um

Time dependence of M12 band biases



Four years of CrIS/IASI inter-comparisons

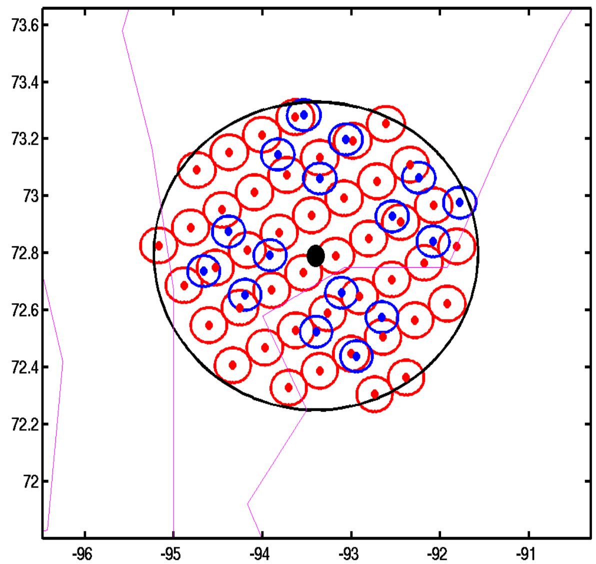
Results show:

- **Overall very small biases which are very stable with time**
- **Small but noticeable dependencies on signal level for some LW and some SW band channels.**
- **IASI-A / IASI-B differences which are generally consistent with potential changes to the IASI LW band nonlinearity corrections.**

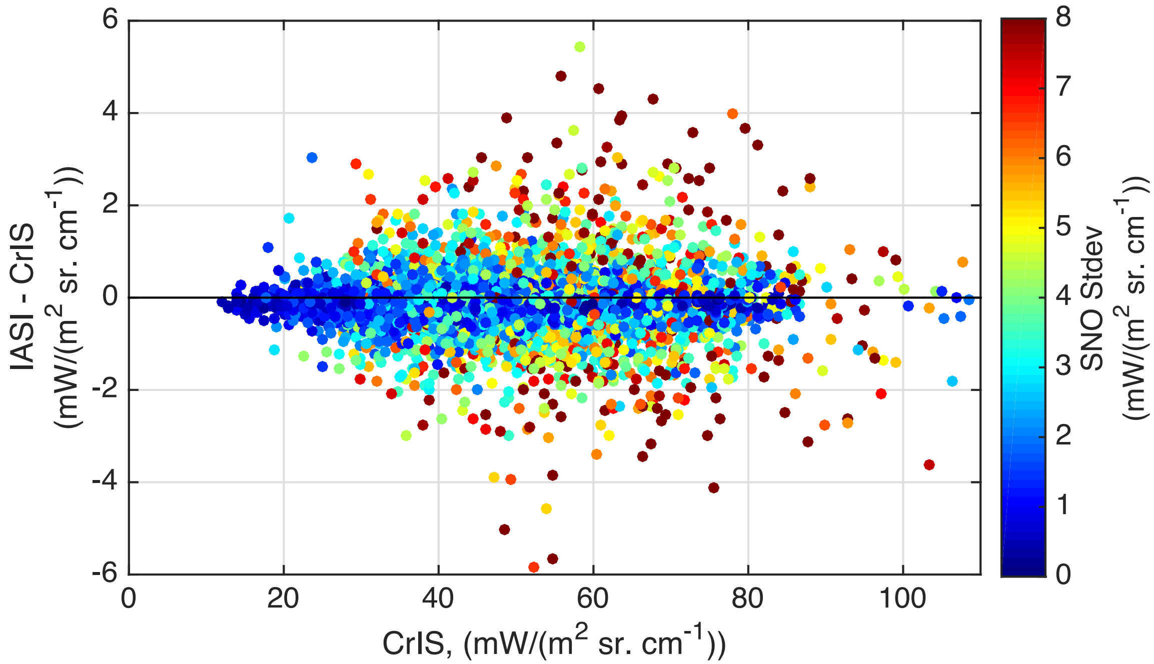
"Big circle" SNOs with matchup criteria: +/- 20 min, 50 km radius

IASI-A/CrIS: 15,553 SNOs from 11-May-2012 to 30-June-2016
IASI-B/CrIS: 10,788 SNOs from 01-Aug-2013 to 08-June-2016

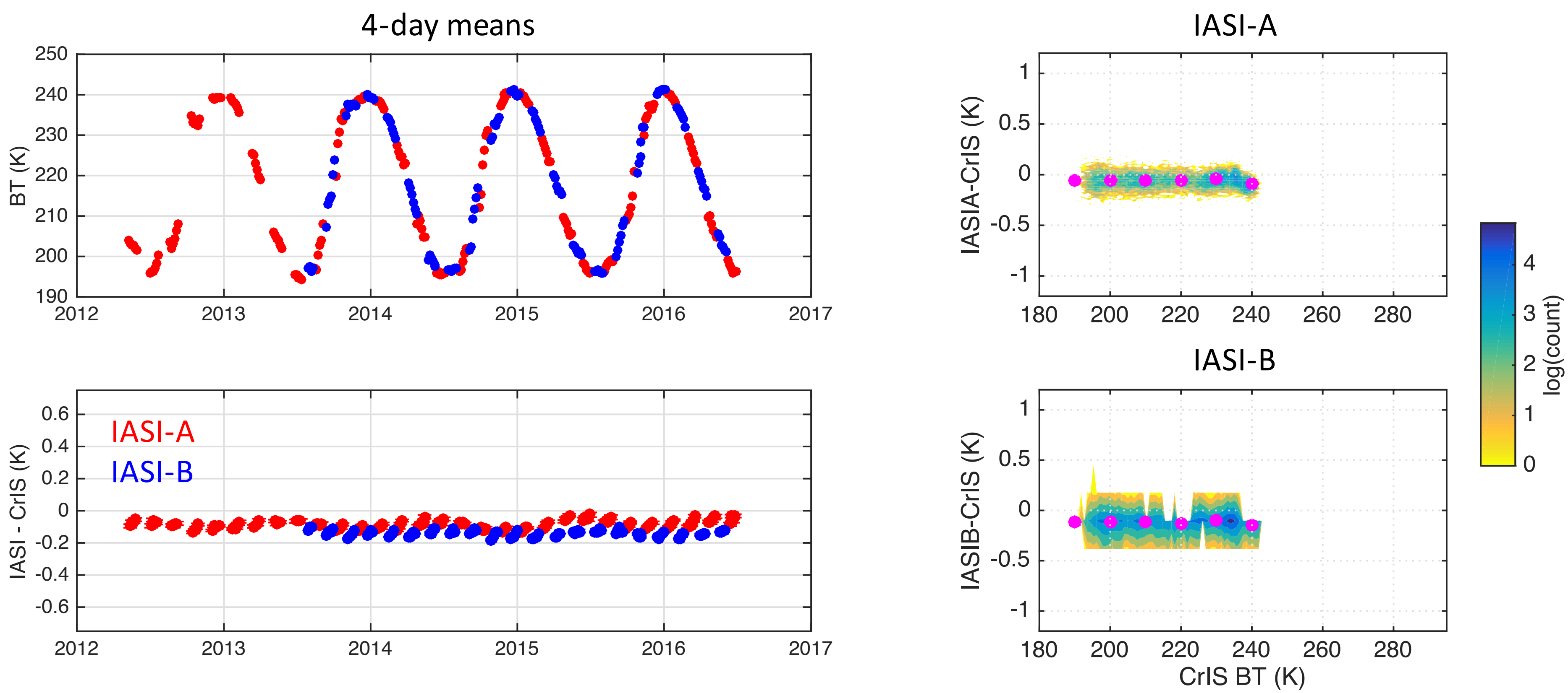
Sample SNO



CrIS / IASI-B SNOs @ 900 cm^{-1}

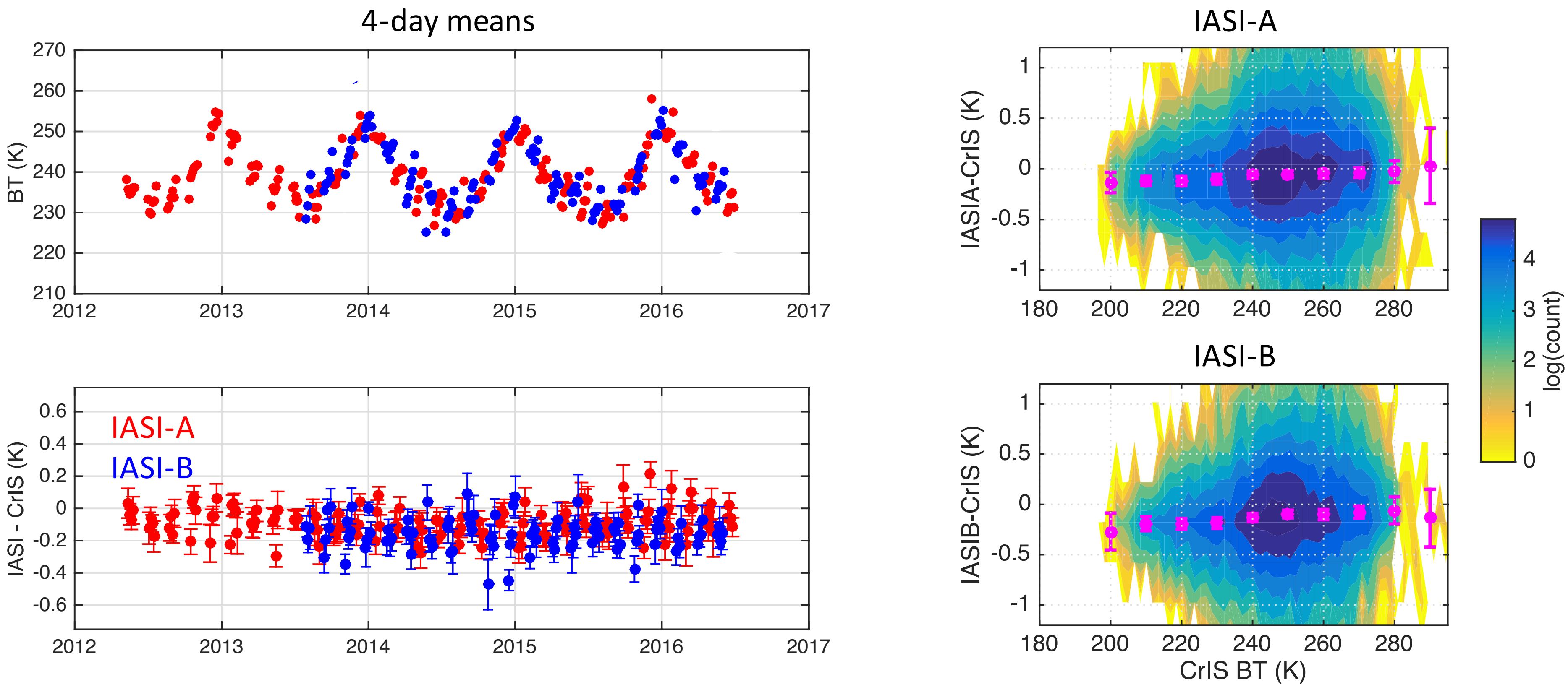


CrIS / IASI SNOs @ 680 cm^{-1}



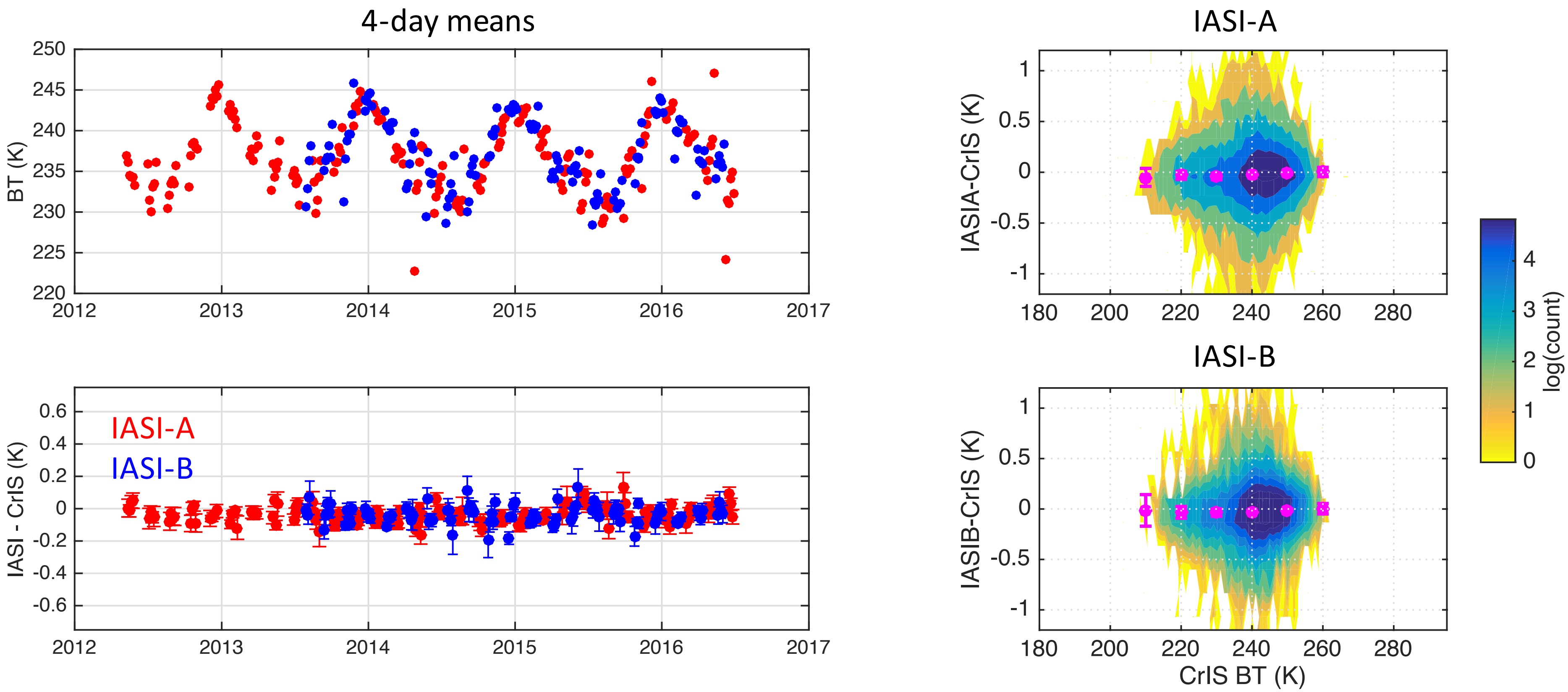
Hamming apodization, Conversion to BT at scene radiance, Southern SNOs

CrIS / IASI SNOs @ 900 cm^{-1}



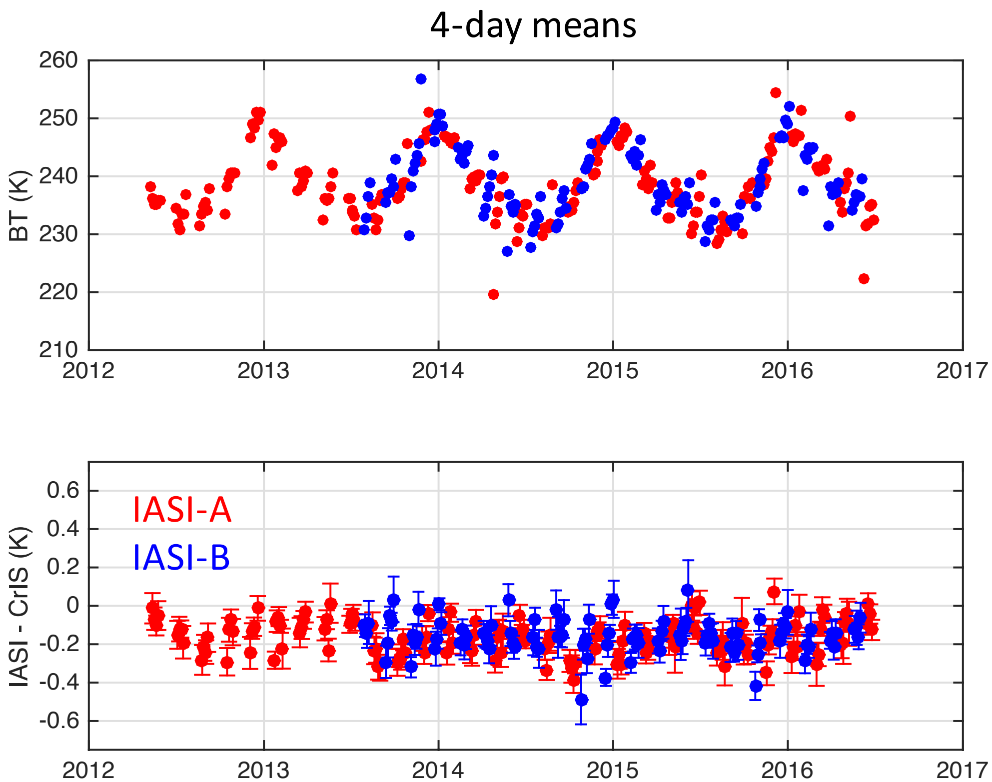
Hamming apodization, Conversion to BT at scene radiance, Southern SNOs

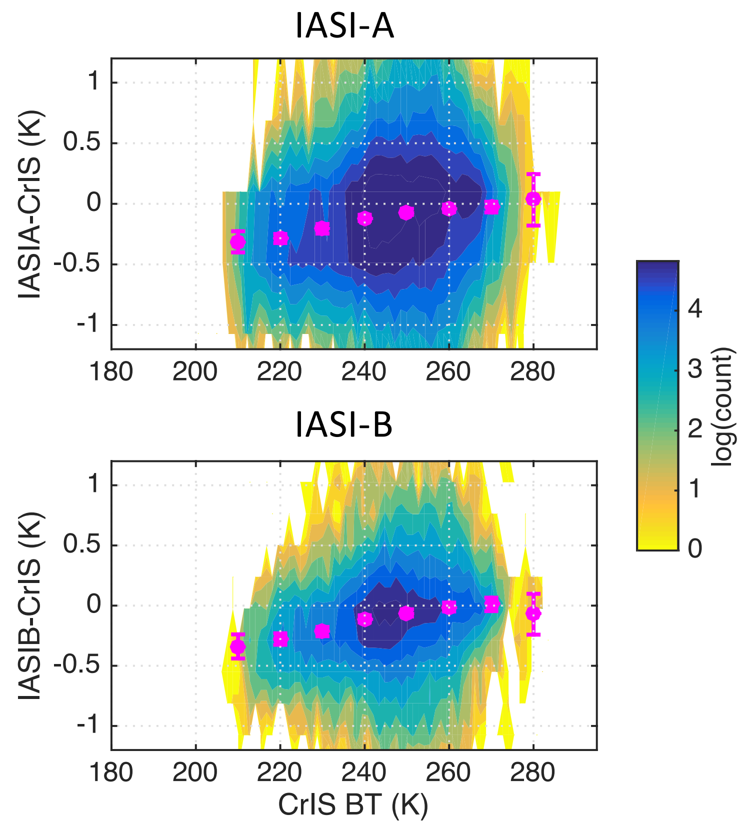
CrIS / IASI SNOs @ 1585 cm^{-1}



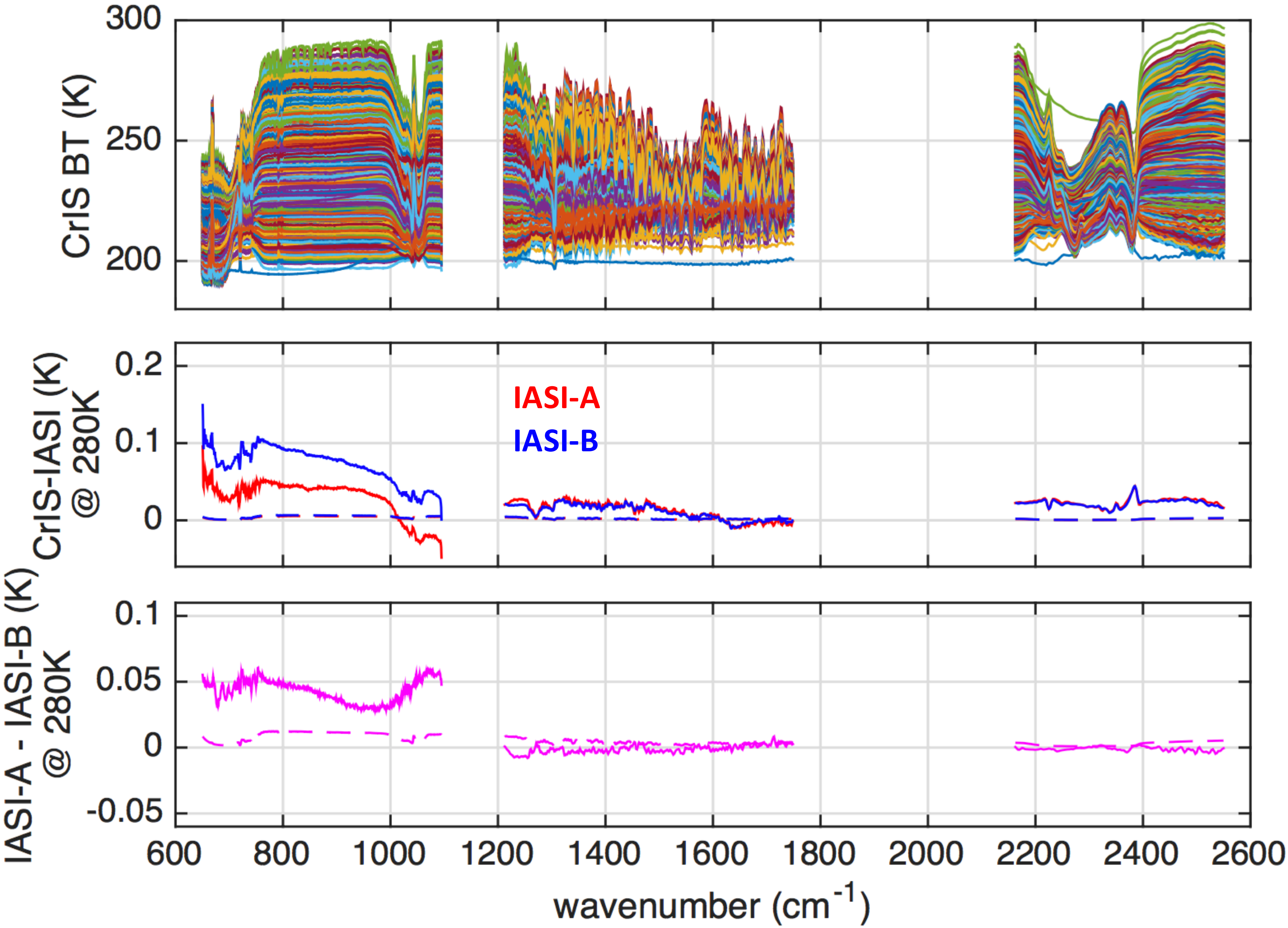
Hamming apodization, Conversion to BT at scene radiance, Southern SNOs

CrIS / IASI SNOs @ 2185 cm^{-1}





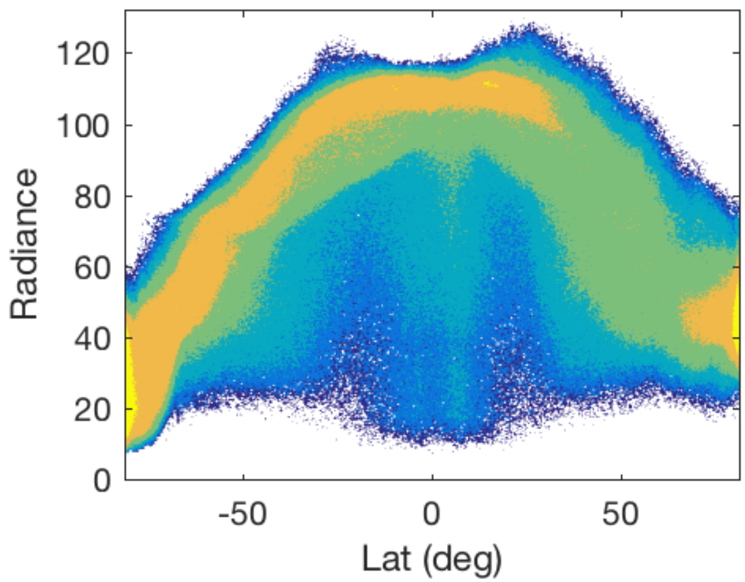
Hamming apodization, Conversion to BT at scene radiance, Southern SNOs

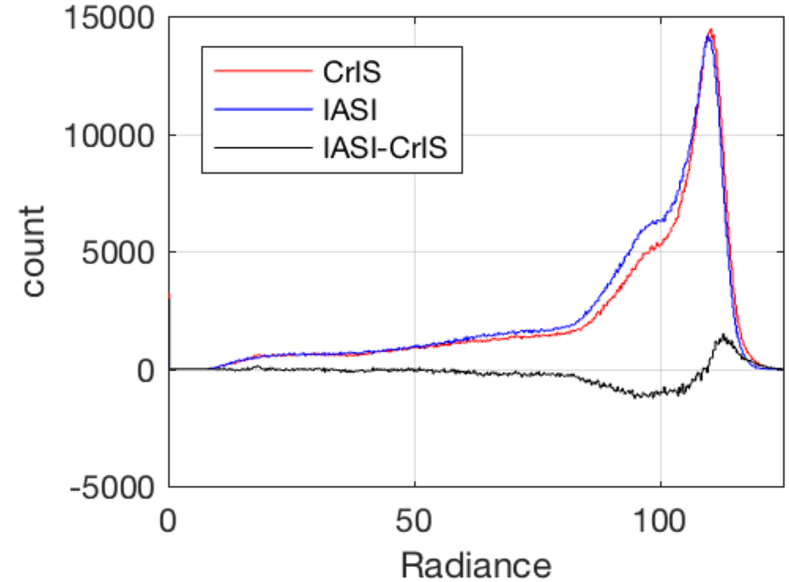


Hamming apodization, Conversion to BT at 280K, all SNOs

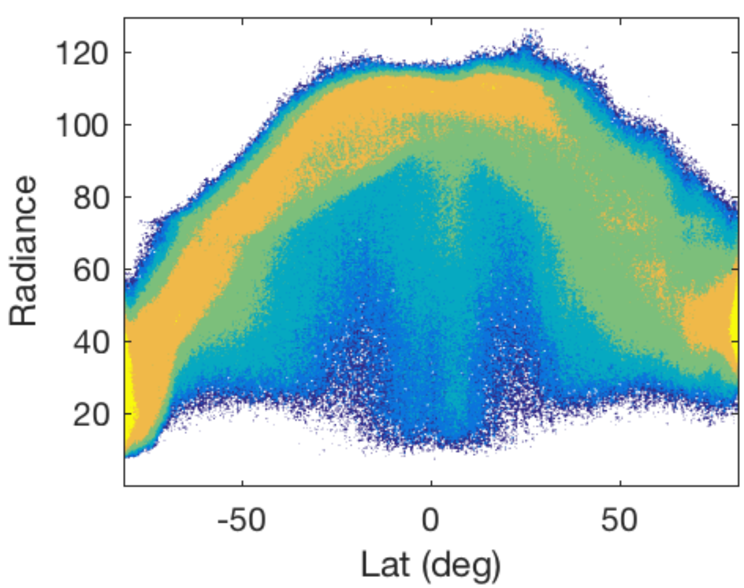
900 cm^{-1} Radiance Distributions, Nadir FORs 2012-2016

IASI, log(counts)

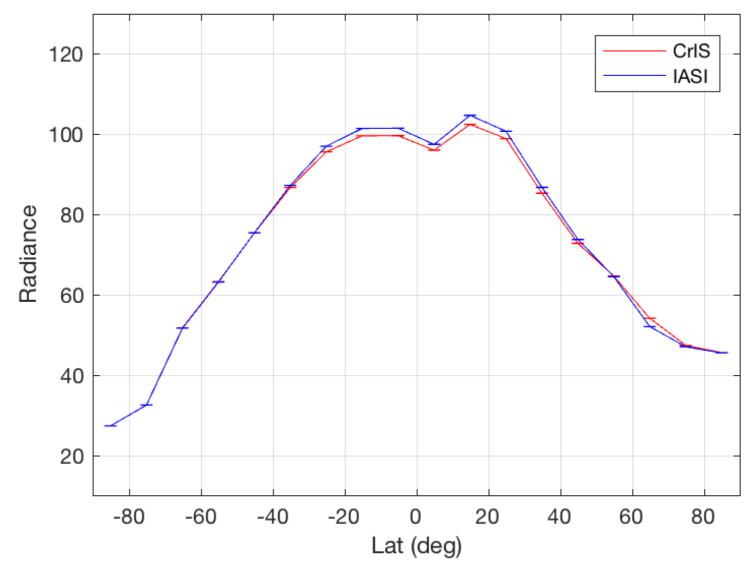




CrIS, log(counts)



Mean Radiance vs. latitude



Overall Summary

- **CrIS is well suited to serve as an intercalibration reference**
  - **Radiometric calibration accuracy is generally small and well understood and documented**
  - **Pre-launch traceability via NIST testing of the ECT and various on-going efforts to establish post-launch traceability as well**
  - **Several calibration refinements underway (e.g. MW nonlinearity, polarization, ICT temperature)**
  - **Full spectral coverage would provide intercalibration of other sensors/bands**