CrIS Radiometric Uncertainty (RU) Estimates

Dave Tobin, Hank Revercomb, Joe Taylor, Bob Knuteson, Dan DeSlover, Lori Borg, Graeme Martin
Space Science and Engineering Center, University of Wisconsin-Madison

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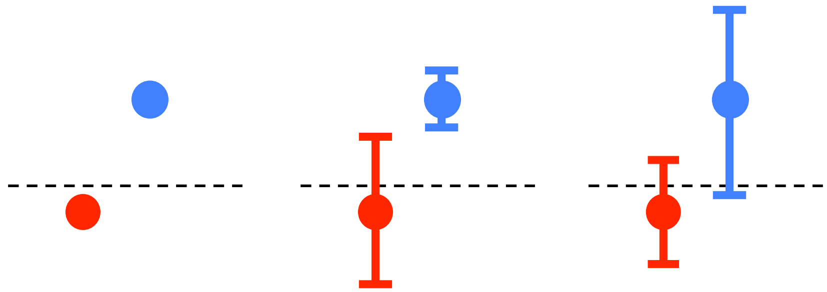
RU estimates are useful for understanding the size and dependencies of the primary contributors to the CrIS SDR uncertainties, for calibration improvements, and for weather, process, trend, and inter-calibration applications.

1. Perturbation of Calibration Equation and Parameter uncertainties
2. On-orbit RU estimates for Suomi-NPP CrIS
3. Changes for JPSS-1 (2017 launch), JPSS-2 (2022 launch) and CrIS-NG (TBD ~2027)

RU estimates for AIRS, IASI, and CrIS

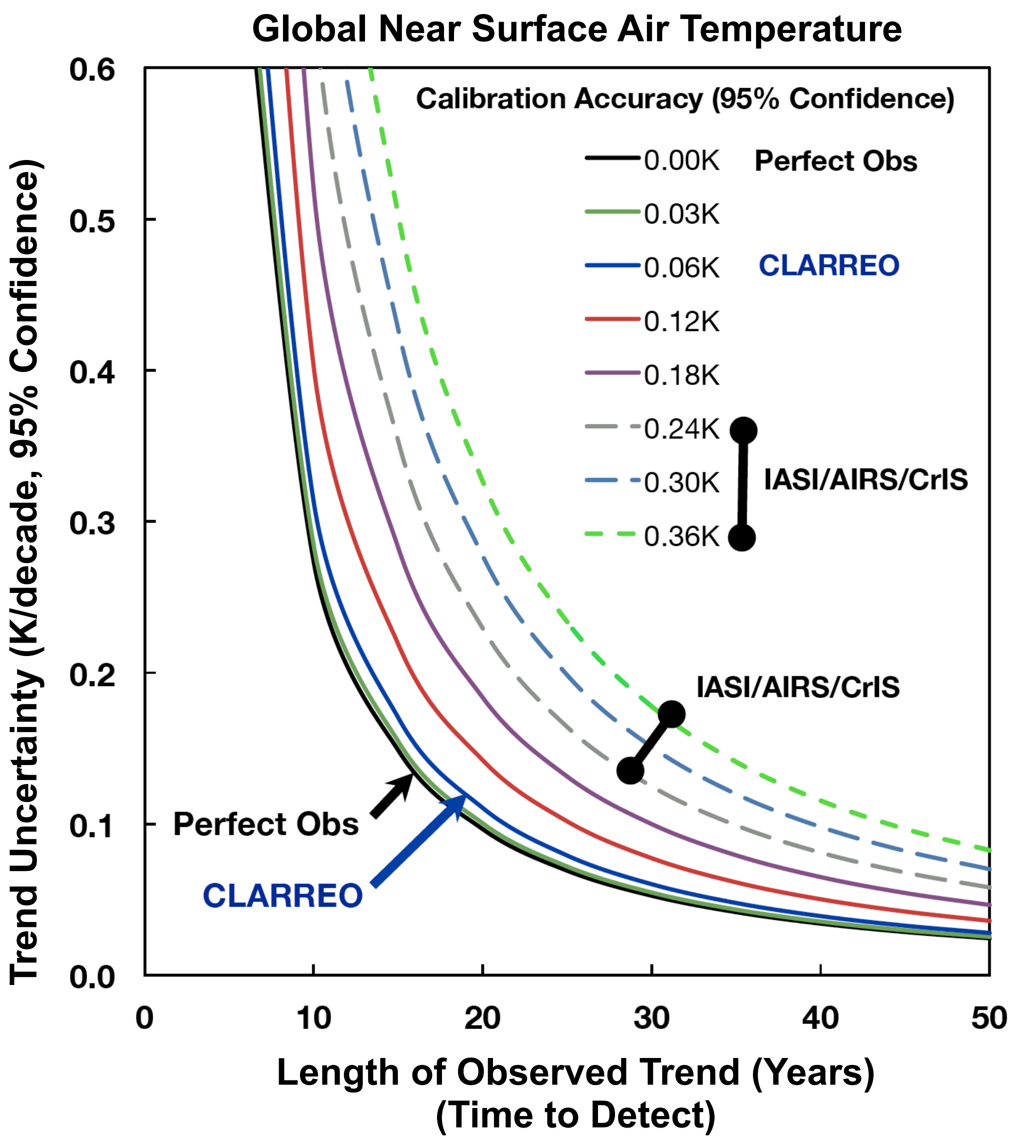
- A) Observation intercomparisons and other Cal/Val approaches versus B) RU estimation via calibration equation perturbation. Synergy between these two.



- RU estimates for AIRS, IASI, and CrIS:
  - Standard RU methodology and terminology needed
  - AIRS: *Pagano et al., Lessons learned from the AIRS pre-flight radiometric calibration. Proc. SPIE 8866, Earth Observing Systems XVIII, 88660U (September 23, 2013); doi: 10.1117/12.2023810.*
  - CrIS: *Tobin et al., (2013), Suomi-NPP CrIS radiometric calibration uncertainty, J. Geophys. Res. Atmos., 118, 10,589–10,600, doi:10.1002/jgrd.50809.*
  - IASI: CNES team is currently working to produce RU estimates for IASI-A and IASI-B.

Achieving Climate Change Absolute Accuracy in Orbit

Wielicki et al., BAMS, 2013



- CLARREO prototypes developed and performance recently demonstrated, but mission TBD.
- Emphasizes the benefit of characterizing AIRS/IASI/CrIS as well as possible, and improving if possible.

Suomi-NPP CrIS Radiometric Uncertainty Estimates

Simplified On-Orbit Radiometric Calibration Equation:

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

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

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

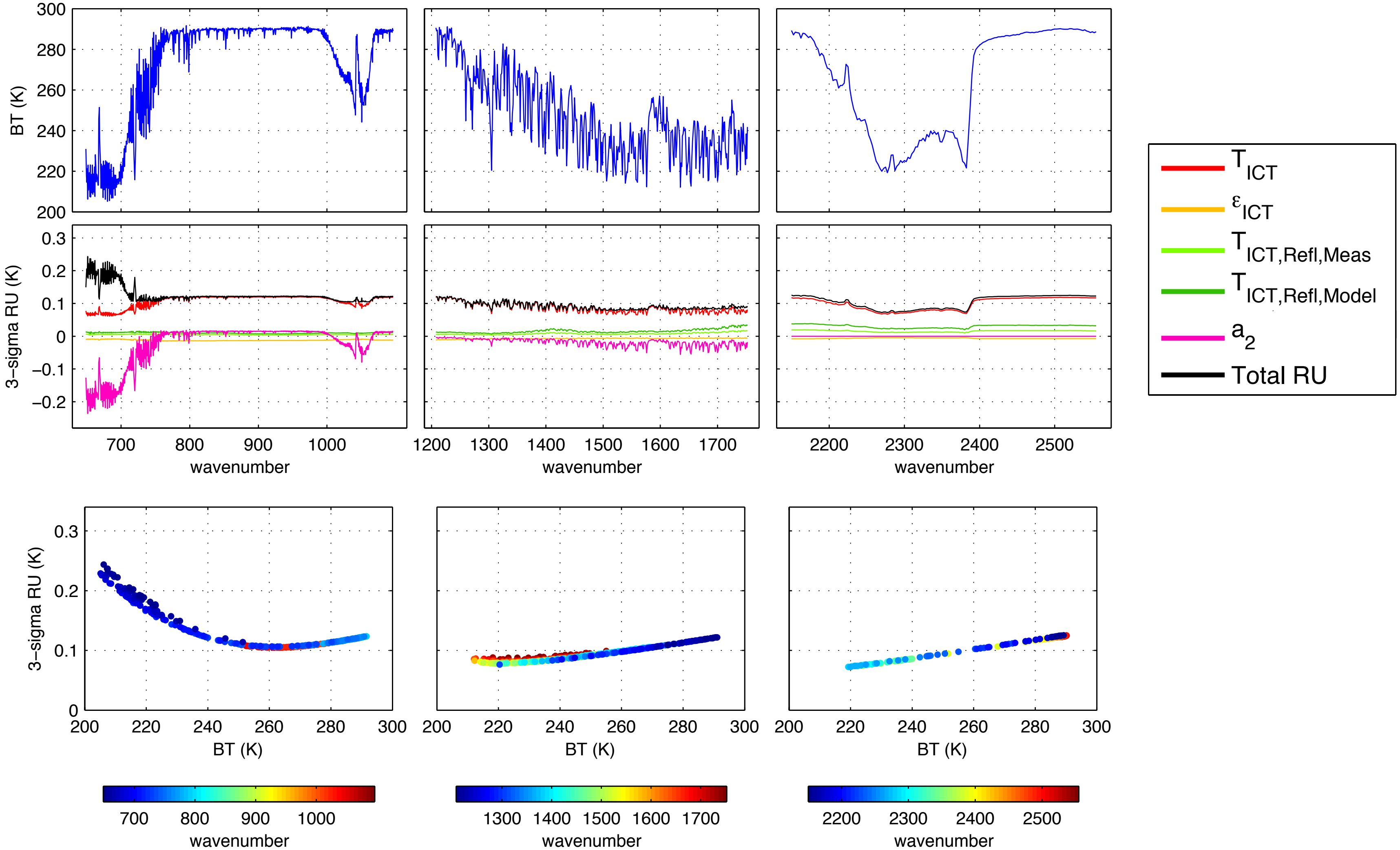
Parameter Uncertainties:

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}

**Exelis at-launch estimate*

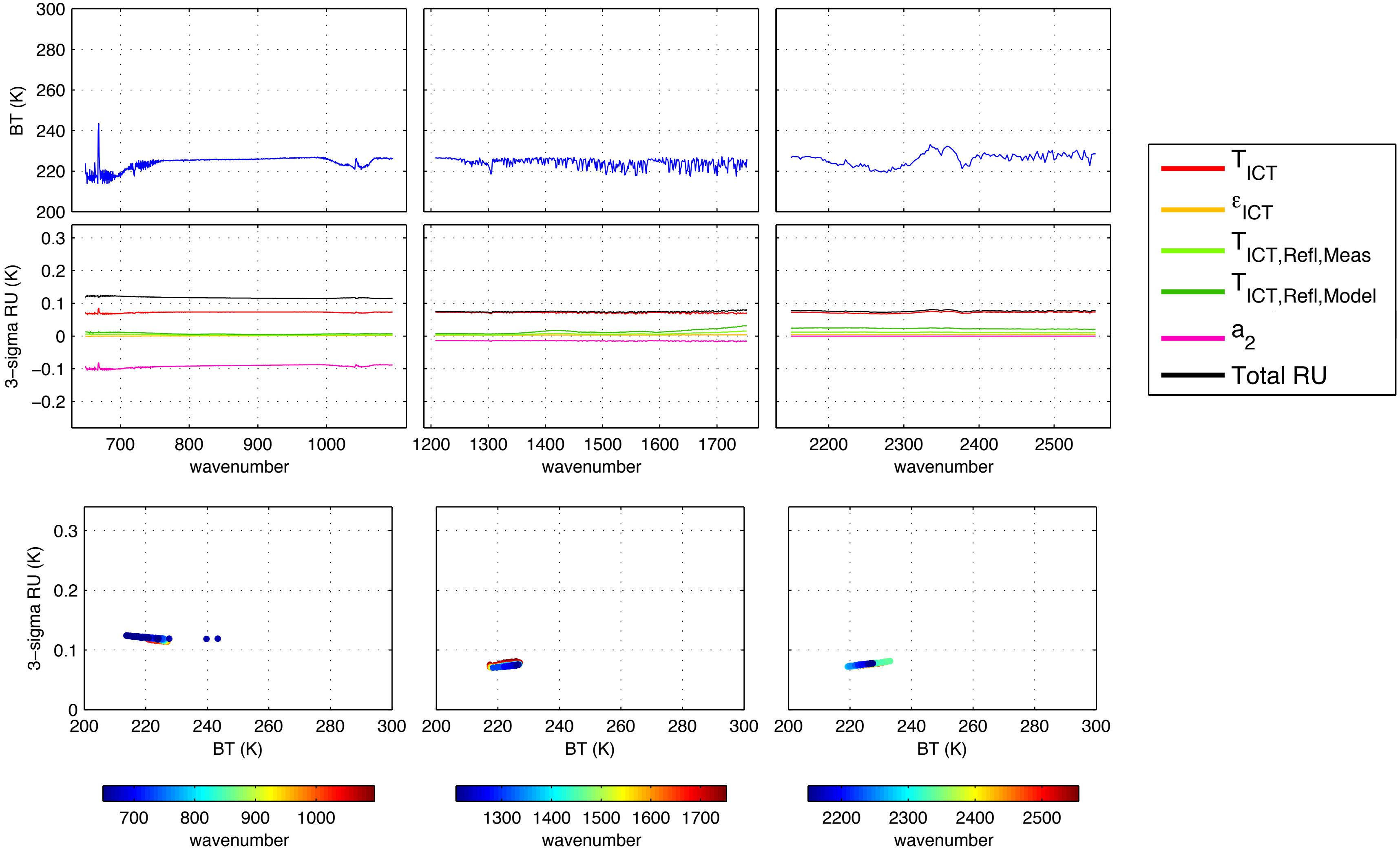
Suomi-NPP CrIS, example 3-sigma RU estimates

For a typical warm, ~clear sky spectrum



Suomi-NPP CrIS, example 3-sigma RU estimates

For a cold, high cloud spectrum



ICT Emissivity and Reflected terms

- Despite relatively low ICT emissivity and greater sensitivity to the reflected terms, cal/val has not shown radiometric artifacts related to these contributions. This is not unexpected due to the ambient temperature design of CrIS and the relative size of these RU contributions compared to other terms.

- The redesigned ICT for J1 and J2 CrIS has emissivity requirements of >0.995 emissivity and uncertainty <0.0015 1-sigma. Modeling and testing to date shows the expected performance meets these requirements and the corresponding RU contributions should be much smaller (~negligible) compared to those for Suomi-NPP.

ICT Temperature

- **Suomi-NPP CrIS has BOL uncertainty of 112 mK 3-sigma, and significant BOL to EOL contributions.**

- **J1 CrIS has BOL uncertainties similar to Suomi-NPP CrIS but reduced BOL to EOL contributions.**

- **Phase change cells on the ICT are being considered for J2 CrIS which would further reduce BOL to EOL contributions and allow performance to be verified on-orbit.**

Nonlinearity

- **On-orbit Nonlinearity RU contributions for J1 CrIS should be similar to those for Suomi-NPP.**
  - Preliminary DM results for J1 are qualitatively similar to FM1 (SW is linear, some linear MW FOVs, all LW FOVs are nonlinear) and the same type of NL correction and TVAC and on-orbit a_2 analysis techniques will be needed for J1.
  - Compared to S-NPP, the J1 LW FOVs are more linear (except FOV5), and 8 of the J1 MW FOVs are very linear.

- **LW and MW detectors are being selected for J2 CrIS. An accurate measure of nonlinearity should be assessed as part of this selection, with an FTS for example.**

Other RU Terms

Smaller contributors not currently accounted for in the calibration algorithm or included in current RU estimates:

- Spectral Ringing
- Polarization
- Possible SW Nonlinearity
- Other smaller/negligible terms:
  - Detector temperature changes, Changes in DA Bias tilt over 4 minutes, Changes in optical flatness, OPD sample rate drift over 4 minutes, Electronic gain drift over 4 minutes, Electronic delay drift over 4 minutes, FOV to FOV crosstalk in same band, FOV to FOV crosstalk between bands, Stray light, Optics temperature change during cal, Changes in channel spectra

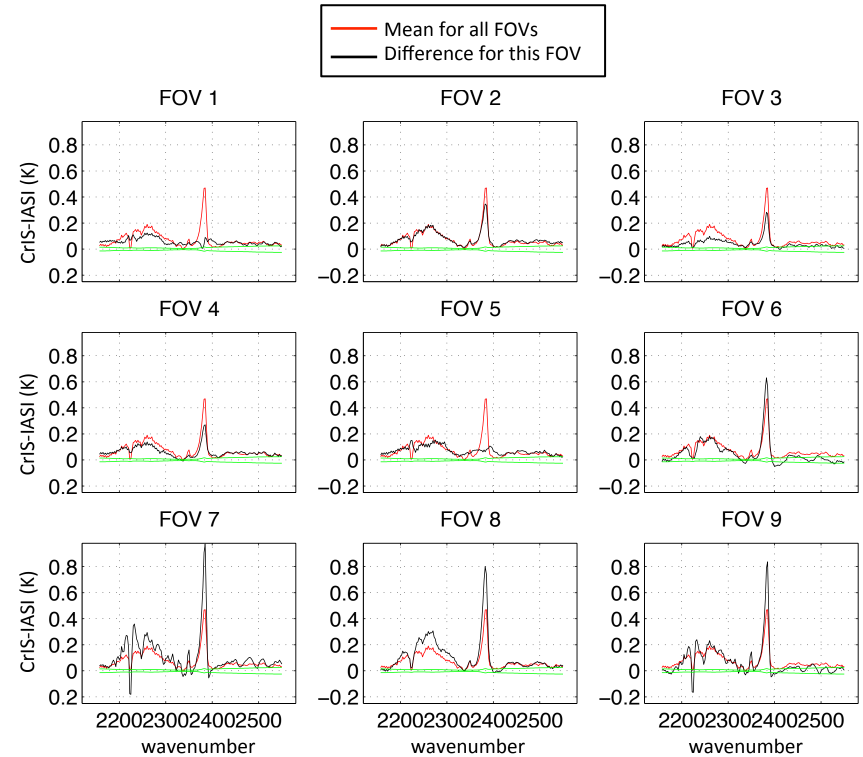
Error from Scene Mirror Induced Polarization

- CrIS uses a 45° gold scene mirror that provides low sensitivity to polarization; no correction is included in the SDR algorithm/processing.
- However, it seems almost certain that CrIS should have polarization effects of ~50 mK for especially warm and cold brightness temperatures in some spectral regions.
- Radiance error dependence $\sim 2p_r p_t\ (N - B_{ICT})$
- A correction should be developed based on CrIS characterization tests yet to be conducted (measurements of scene mirror degree of polarization, p_r, and interferometer polarization sensitivity, p_t)

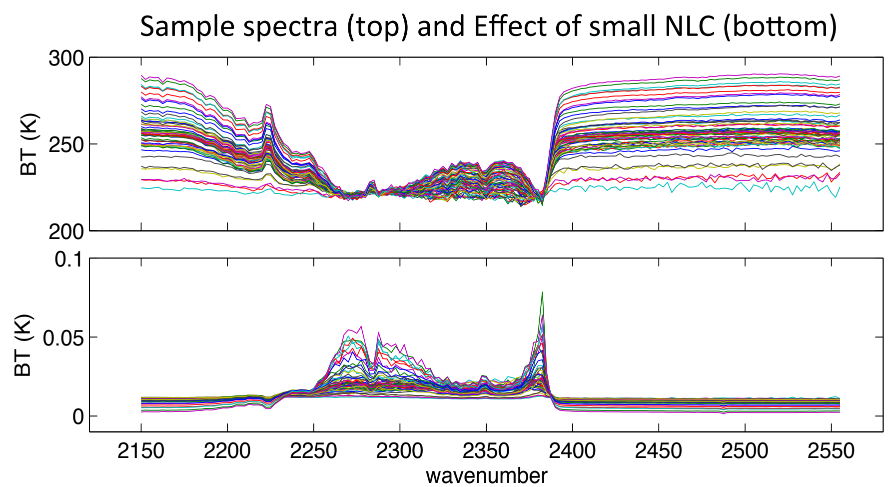
SW Band Biases

- FOV-2-FOV analyses and differences with respect to other sensors suggest small artifacts in the SW band, both in Mean biases and FOV-2-FOV differences.

  E.g. Differences with respect to IASI



- Mechanisms investigated:
  - Spectral shift
  - Thermal SP view contamination
  - Solar SP view contamination
  - Polarization
  - ➢ Low level Nonlinearity
    - Displays FOV dependent behavior
    - Has plausible spectral and scene level dependencies
  - ➢ Low SNR Radiometric Calibration



Other Potential Changes for CrIS

1. **Remove spectral gaps**
   - **J2 baseline design does not remove gaps, but a cost study is underway and if successful will be proposed to NOAA as a design mod.**
2. **Smaller and more numerous footprints**
   - **Not included in J1 or J2 design**

- **There are compelling scientific reasons for both, and feasible concepts presented for implementing both.**
- **Both require efforts/funding to perform further design/costing studies, and both likely require higher data rate for DB downlink.**

Summary

J1: RU should be similar to S-NPP CrIS

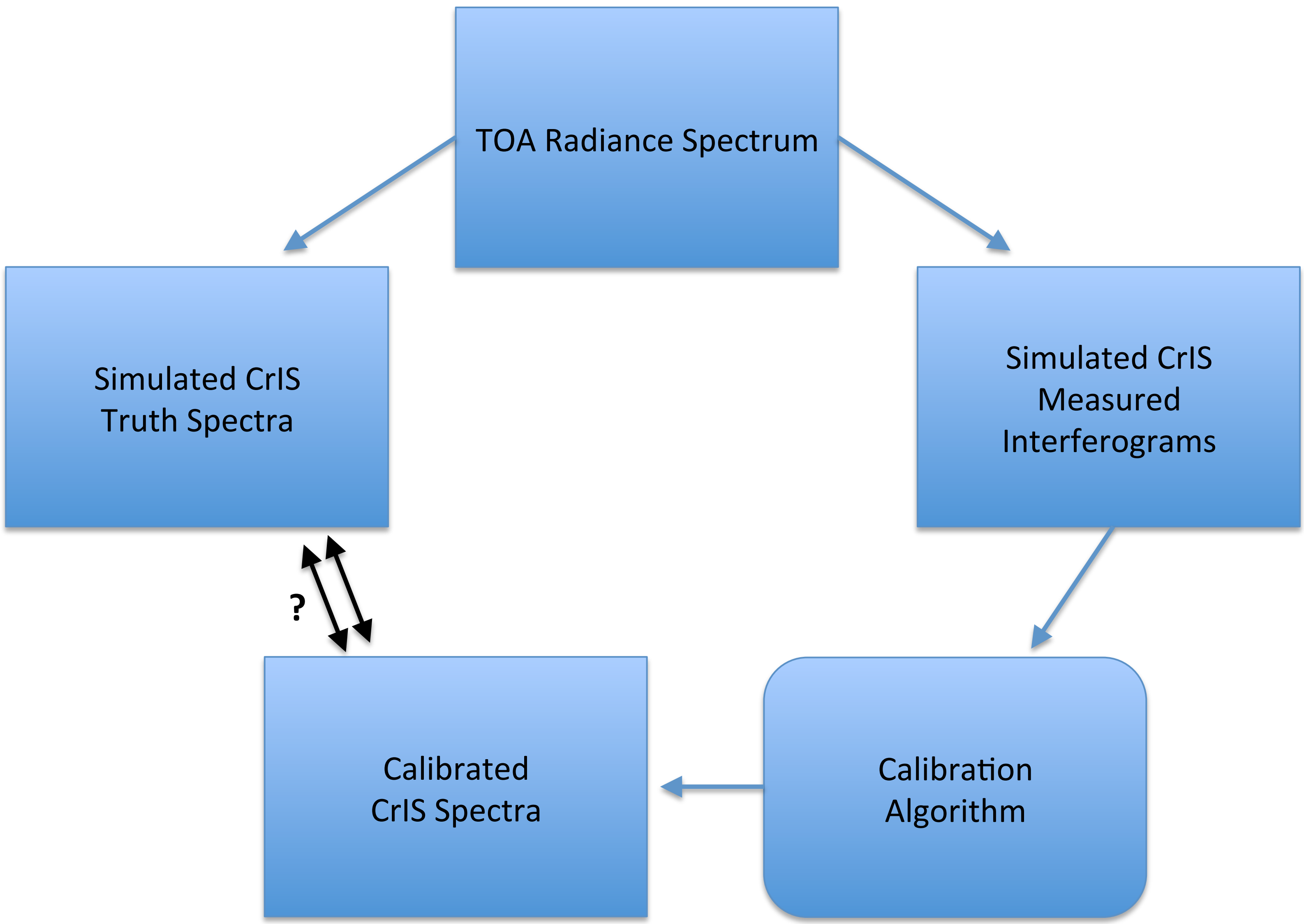
J2: Possibly reduced RU pending detector selection and associated nonlinearity behavior, and addition of ICT phase change cells.

Polarization measurements

Additional changes (remove spectral gaps, smaller footprints) require efforts/funding to perform further design/costing studies, and both likely require higher data rate for DB downlink.

- **Need clear and efficient communication between users, Flight and JPSS project offices, and DB users in order to make progress.**

SDR algorithm testing



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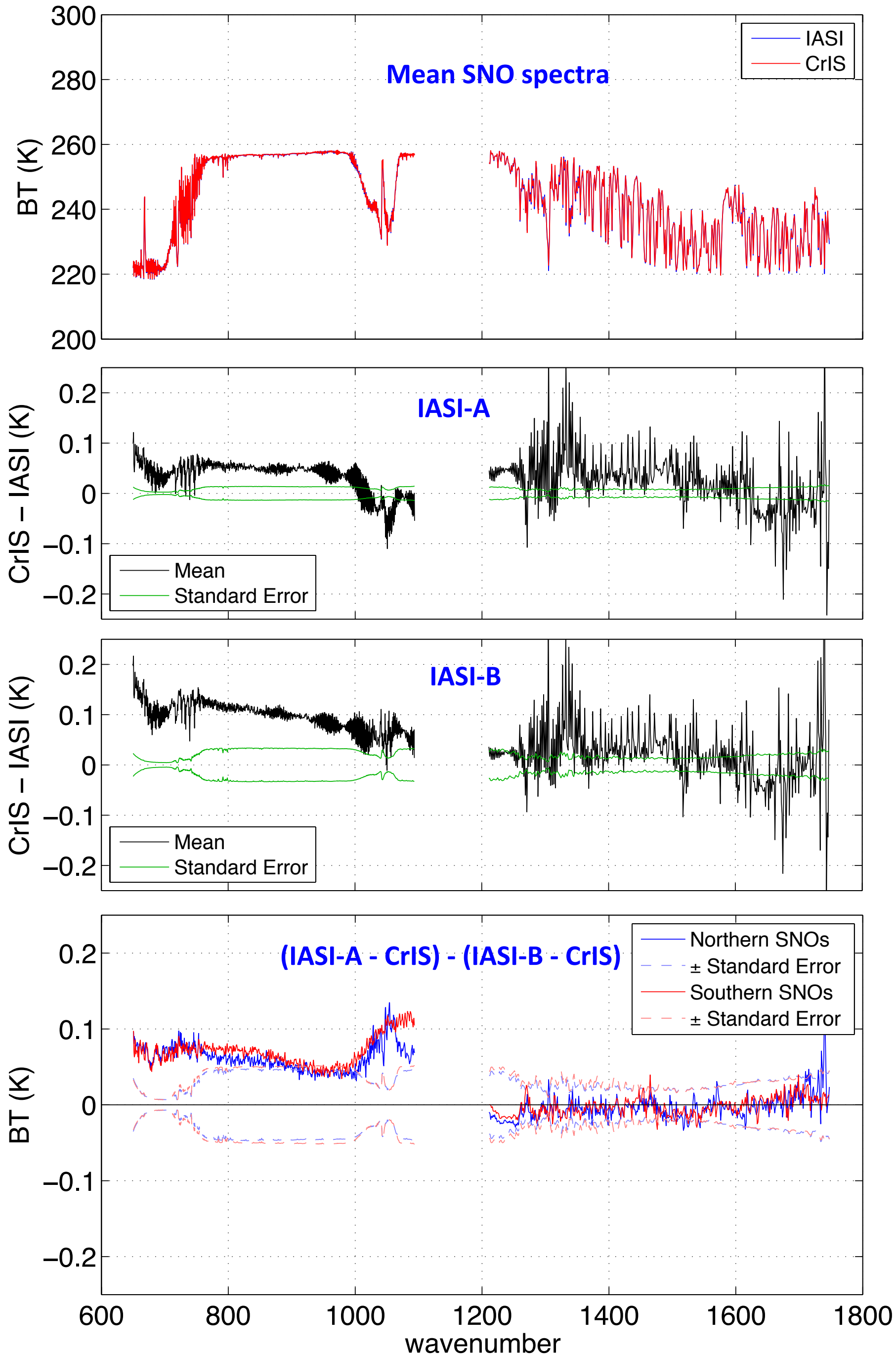
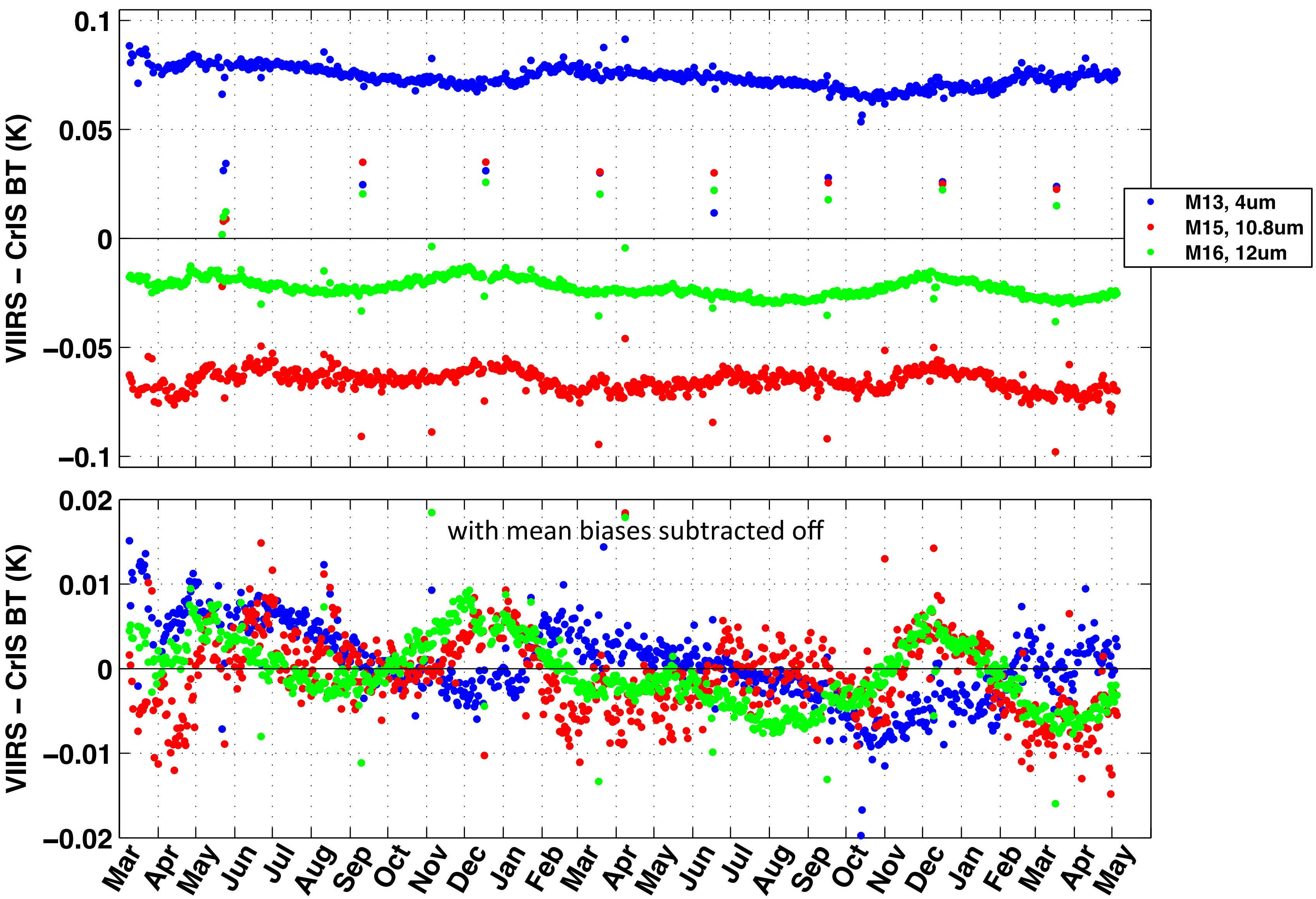
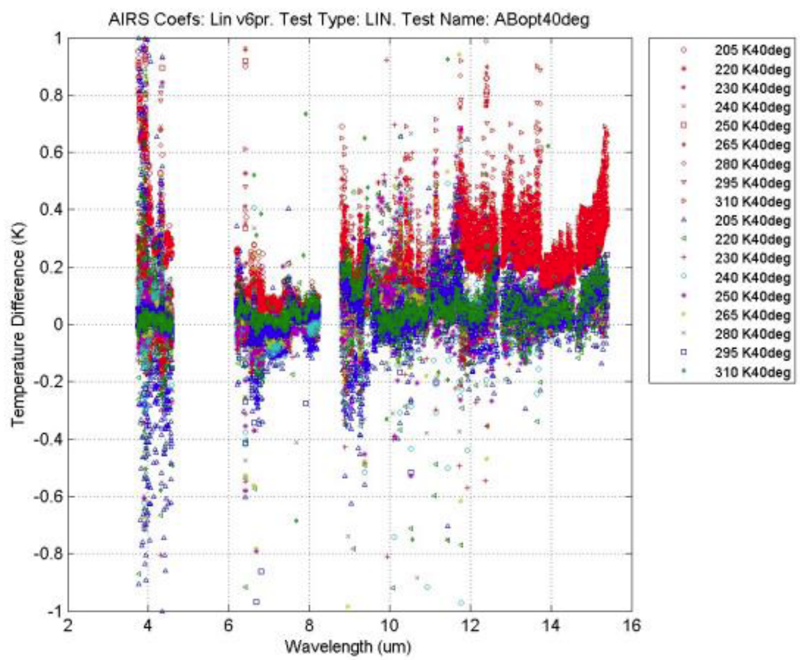
Intercomparison of IASI-A, IASI-B, and CrIS



Intercomparison of CrIS and VIIRS; Daily Mean Differences





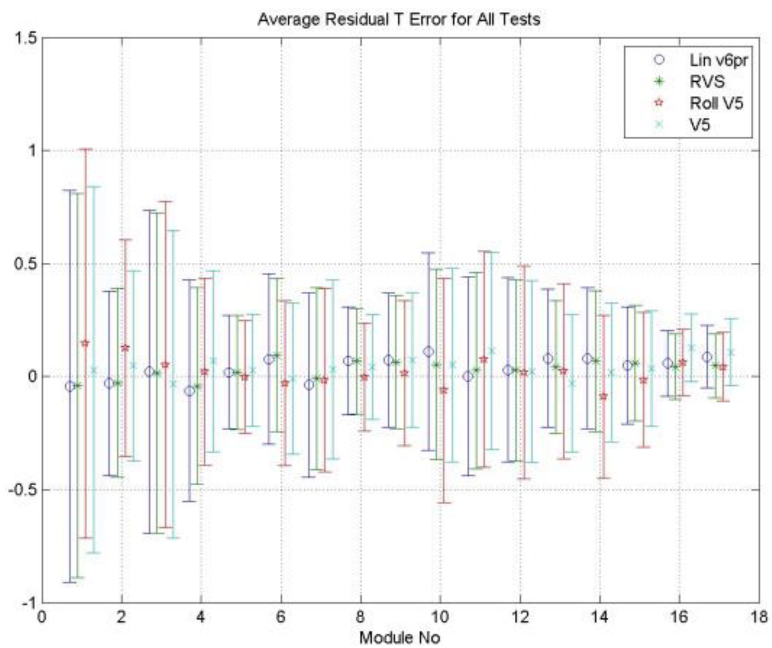
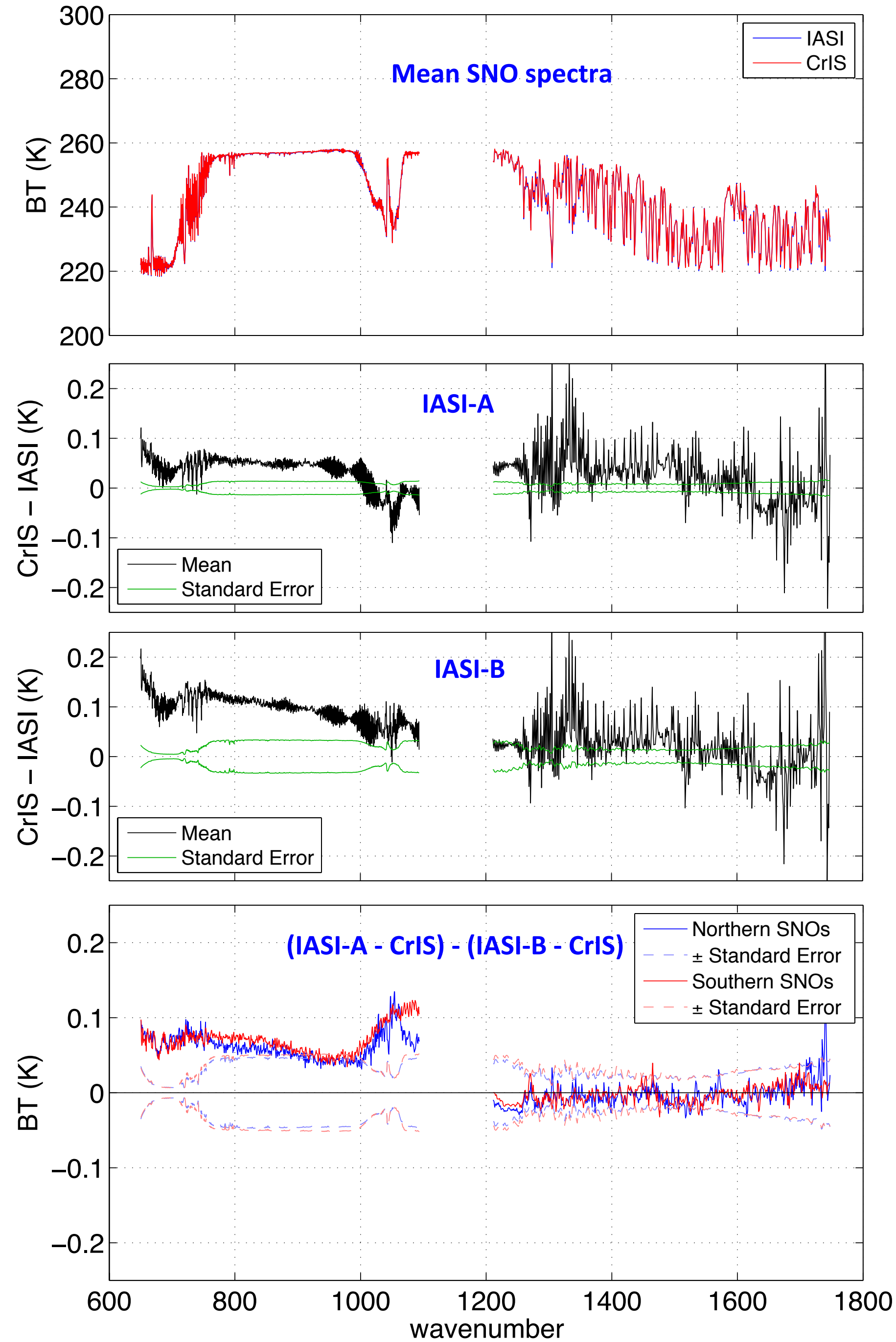
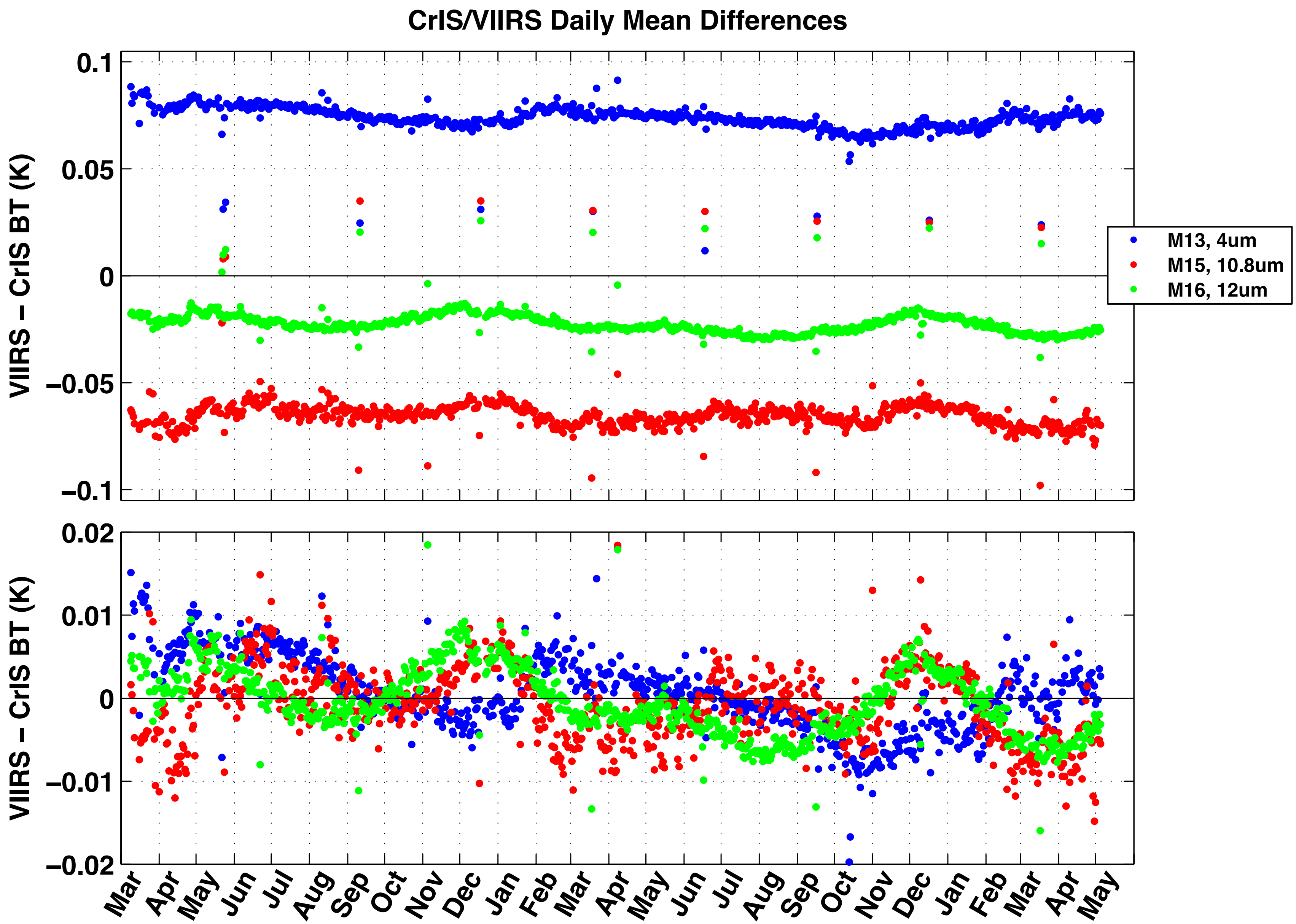


Figure 9a (left). Residual Differences (retrieved vs LABB measured) for ABopt Linearity test at 40 degree scan angle. Red curves are predicted temperature error from the radiometric uncertainty model for each LABB temperature. Figure 9b (right) Average residual error over all tests by module for each of the different polarization coefficient types (legend). Residual errors are similar for most coefficient types.

Pagano, T. S., H. H. Aumann, M. Weiler; Lessons learned from the AIRS pre-flight radiometric calibration. Proc. SPIE 8866, Earth Observing Systems XVIII, 88660U (September 23, 2013); doi:10.1117/12.2023810.



Mean SNO spectra
IASI
CrIS
BT (K)
300
280
260
240
220
200
IASI-A
CrIS – IASI (K)
Mean
Standard Error
0.2
0.1
0
−0.1
−0.2
IASI-B
CrIS – IASI (K)
Mean
Standard Error
(IASI-A - CrIS) - (IASI-B - CrIS)
Northern SNOs
± Standard Error
Southern SNOs
± Standard Error
BT (K)
600
800
1000
1200
1400
1600
1800
wavenumber


CrIS/VIIRS Daily Mean Differences
VIIRS – CrIS BT (K)
0.1
0.05
0
−0.05
−0.1
M13, 4um
M15, 10.8um
M16, 12um
0.02
0.01
0
−0.01
−0.02
Mar
Apr
May
Jun
Jul
Aug
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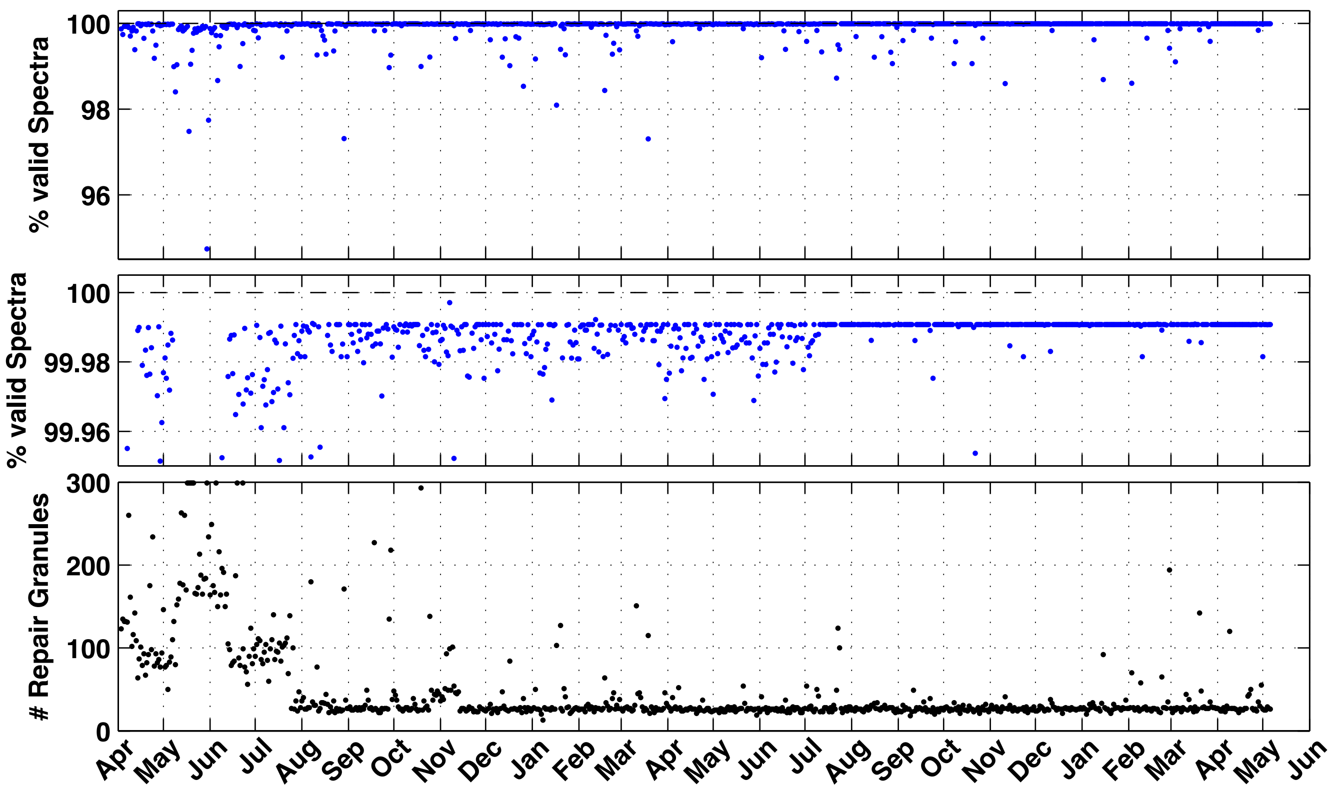
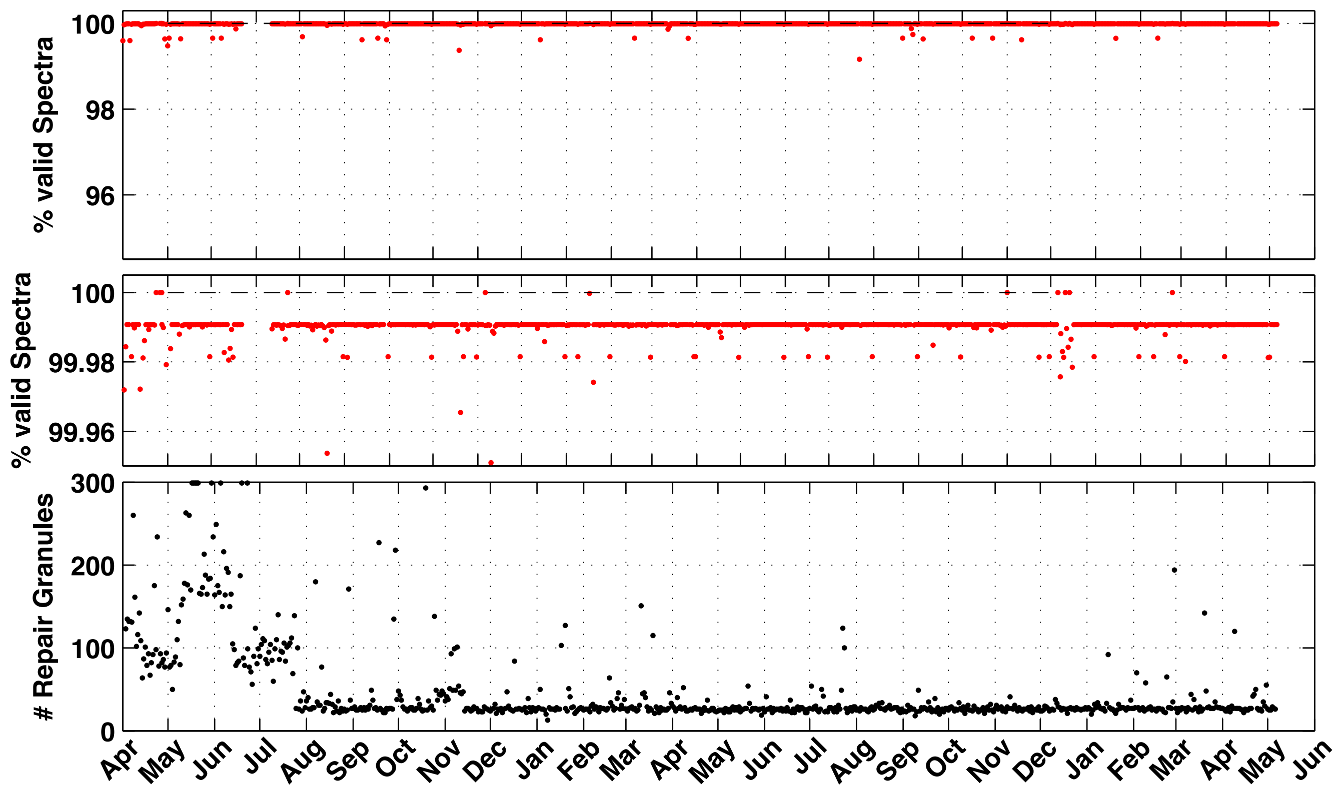
QA & Latency Trending, IDPS



QA & Latency Trending, CSPP



Low SNR Radiometric Calibration

- Rowe et al., 2011: A responsivity-based criterion for accurate calibration of FTIR emission spectra: Theoretical development and bandwidth estimation, *Optics Express*, **19**(7), 5930-5941.
- Rowe et al., 2011: A responsivity-based criterion for accurate calibration of FTIR emission spectra: Identification of in-band low-responsivity wavenumbers, *Optics Express*, **19**(6), 5451-5463.
- Sromovsky, 2003: Radiometric Errors in Complex Fourier Transform Spectrometry," Appl. Opt. **42**, 1779-1787.