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

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

2016 JPSS Science Teams Annual Meeting
NOAA Center for Weather and Climate Prediction, College Park, MD
August 2016
Table 1 – Draft Scoring Scheme for GSICS Near-Real-Time Correction for 2014 Geostationary Imager IR Channels

<table>
<thead>
<tr>
<th>Unit</th>
<th>Threshold</th>
<th>Goal</th>
<th>Metop-A/AISI</th>
<th>Aqua/AIRS</th>
<th>SNPP/CrlS (in FSR mode)</th>
<th>NOAA-14/HIRS</th>
<th>CLARREO-1A/IR</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Max</td>
<td>Min</td>
<td>Max</td>
<td>Weight</td>
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<td>Score</td>
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<td>Year</td>
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<td>Dynamic Range</td>
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<td>180</td>
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<td>Spectral Range SWIR</td>
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<td>Spectral Range LWIR</td>
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<td>7.85</td>
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<td>Diurnal Coverage</td>
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<td>5</td>
<td></td>
<td>OK</td>
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<td>Radiometric Stability</td>
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<td>Radiometric Noise</td>
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<td>Uncertainty from SBAF</td>
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<td>1</td>
<td></td>
<td>OK</td>
<td>1.0</td>
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<tr>
<td>Spectral Stability</td>
<td>cm-1/yr</td>
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<td>0.01</td>
<td>10</td>
<td></td>
<td>OK</td>
<td>1.0</td>
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<td>Absolute Cal Acc</td>
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<td>0.01</td>
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<td>Documented Traceability</td>
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<td>Total</td>
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<td>100.0</td>
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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.”
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:

\[ R_{\text{scene}} = R e \left\{ \left( C'_\text{scene} - C'_\text{SP} \right) / \left( C'_\text{ICT} - C'_\text{SP} \right) \right\} R_{\text{ICT}} \]

with:

Nonlinearity Correction: \( C' = C \cdot (1 + 2 \alpha_2 V_{DC}) \)

ICT Predicted Radiance: \( R_{\text{ICT}} = \epsilon_{\text{ICT}} B(T_{\text{ICT}}) + (1-\epsilon_{\text{ICT}}) \left[ 0.5 B(T_{\text{ICT, Refl, Measured}}) + 0.5 B(T_{\text{ICT, Refl, Modeled}}) \right] \)

Parameter Uncertainties:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Nominal Values</th>
<th>3-σ Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T_{\text{ICT}} )</td>
<td>280K</td>
<td>112.5 mK*</td>
</tr>
<tr>
<td>( \epsilon_{\text{ICT}} )</td>
<td>0.974-0.996</td>
<td>0.03</td>
</tr>
<tr>
<td>( T_{\text{ICT, Refl, Measured}} )</td>
<td>280K</td>
<td>1.5 K</td>
</tr>
<tr>
<td>( T_{\text{ICT, Refl, Modeled}} )</td>
<td>280K</td>
<td>3 K</td>
</tr>
<tr>
<td>( \alpha_2 ) LW band</td>
<td>0.01 – 0.03 V(^{-1})</td>
<td>0.00403 V(^{-1})</td>
</tr>
<tr>
<td>( \alpha_2 ) MW band</td>
<td>0.001 – 0.12 V(^{-1})</td>
<td>0.00128 – 0.00168 V(^{-1})</td>
</tr>
</tbody>
</table>

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

\[ \sigma_{BT} \text{(K)} \]

\[ \sigma_{RU} \text{(K)} \]

\[ \text{wavenumber (cm}^{-1}) \]

\[ T_{ICT} \]

\[ \epsilon_{ICT} \]

\[ T_{ICT,Refl,Meas} \]

\[ T_{ICT,Refl,Model} \]

\[ T_{ST} \]

\[ \epsilon_{ST} \]

\[ T_{ST,Refl} \]

\[ a_2 \]

Total RU
Suomi-NPP CrIS, example 3-sigma RU estimates

For a cold, high cloud spectrum

Graphs showing 3-sigma RU estimates for different wavenumbers and temperatures.
JPSS-1 Calibration Accuracy is very similar to Suomi-NPP CrIS

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

![Longwave FOV #](image1)

![Midwave FOV #](image2)
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.
- Correction 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 \( \alpha \).
- 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

SW CrIS
MW CrIS (error bar is 1-sigma T uncertainty)*

* 85mK 3-sigma

-70.8 mK

$T_{ECT}$ correction (Predina)

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.
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
CrIS / IASI SNOs @ 680 cm⁻¹

4-day means

IASI-A

IASI-B

Hamming apodization, Conversion to BT at scene radiance, Southern SNOs
CrIS / IASI SNOs @ 900 cm$^{-1}$

4-day means

IASI-CrIS (K)

IASI - CrIS (K)

IASI - A
IASI - B

Hamming apodization, Conversion to BT at scene radiance, Southern SNOs
CrIS / IASI SNOs @ 1585 cm⁻¹

IASI - CrIS (K)

4-day means

IASI - A
IASI - B

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