NOAA-20 CrIS SDR Beta Maturity Status Report

January 25, 2018

CrIS SDR Team

With contributions from NOAA/STAR, NASA/GSFC, Harris, UW/SSEC, UMBC, UMD/CICS, SDL/USU, MIT/LL, Logistikos, Raytheon
Outline

• Algorithm Cal/Val Team Members
• NOAA-20 CrIS Cal/Val Time Line
• NOAA-20 CrIS First Global Coverage Image
• CrIS Instrument Performance
  – On-orbit NEdN
  – DA Bias Tilt
  – Metrology Laser Set Optimization
  – Gain Setting
  – Bit Trim/Impulse Noise Mask Check
  – On-Orbit Torque Null Position Update for In-Track Angles
• CrIS SDR Performance
  – Radiometric Calibration Accuracy
  – Spectral Calibration Accuracy
  – Geolocation Accuracy
• Summary and Path Forward
<table>
<thead>
<tr>
<th>PI</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changyong Cao (acting)</td>
<td>NOAA/STAR</td>
</tr>
<tr>
<td>Dave Tobin</td>
<td>U. of Wisconsin (UW)</td>
</tr>
<tr>
<td>Larrabee Strow</td>
<td>U. of Maryland Baltimore County (UMBC)</td>
</tr>
<tr>
<td>Deron Scott</td>
<td>Space Dynamic Lab (SDL)</td>
</tr>
<tr>
<td>Dan Mooney</td>
<td>MIT/LL</td>
</tr>
<tr>
<td>Dave Johnson</td>
<td>NASA Langley</td>
</tr>
<tr>
<td>Lawrence Suwinski</td>
<td>Harris</td>
</tr>
<tr>
<td>Joe Predina</td>
<td>Logistikos</td>
</tr>
<tr>
<td>Deirdre Bolen</td>
<td>JPSS/JAM</td>
</tr>
<tr>
<td>Wael Ibrahim</td>
<td>Raytheon</td>
</tr>
</tbody>
</table>

- Big thanks for the dedicated and hard work of each of the contributing organizations
- Team work has been and continues to be exceptional
1. Beta
   - Product is minimally validated, and may still contain significant identified and unidentified errors.
   - Information/data from validation efforts can be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose.
   - Documentation of product performance and identified product performance anomalies, including recommended remediation strategies, exists.

2. Provisional
   - Product performance has been demonstrated through analysis of a large, but still limited (i.e., not necessarily globally or seasonally representative) number of independent measurements obtained from selected locations, time periods, or field campaign efforts.
   - Product analyses are sufficient for qualitative, and limited quantitative, determination of product fitness-for-purpose.
   - Documentation of product performance, testing involving product fixes, identified product performance anomalies, including recommended remediation strategies, exists.
   - Product is recommended for potential operational use (user decision) and in scientific publications after consulting product status documents.

3. Validated
   - Product performance has been demonstrated over a large and wide range of representative conditions (i.e., global, seasonal).
   - Comprehensive documentation of product performance exists that includes all known product anomalies and their recommended remediation strategies for a full range of retrieval conditions and severity level.
   - Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose.
   - Product is ready for operational use based on documented validation findings and user feedback.
   - Product validation, quality assurance, and algorithm stewardship continue through the lifetime of the instrument.
### Normal Spectral Resolution

<table>
<thead>
<tr>
<th>Band</th>
<th>Spectral range (cm(^{-1}))</th>
<th>N. of chan.</th>
<th>Resolution (cm(^{-1}))</th>
<th>FORs per Scan</th>
<th>FOVs per FOR</th>
<th>NEdN @287K BB mW/m(^2)/sr/cm(^{-1})</th>
<th>Radiometric Uncertainty @287K BB (%)</th>
<th>Spectral (chan center) uncertainty ppm</th>
<th>Geolocation uncertainty Km (Nadir)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LW</td>
<td>650-1095</td>
<td>713</td>
<td>0.625</td>
<td>30</td>
<td>9</td>
<td>0.14</td>
<td>0.45</td>
<td>10</td>
<td>1.5</td>
</tr>
<tr>
<td>MW</td>
<td>1210-1750</td>
<td>433</td>
<td>1.25</td>
<td>30</td>
<td>9</td>
<td>0.06</td>
<td>0.58</td>
<td>10</td>
<td>1.5</td>
</tr>
<tr>
<td>SW</td>
<td>2155-2550</td>
<td>159</td>
<td>2.5</td>
<td>30</td>
<td>9</td>
<td>0.007</td>
<td>0.77</td>
<td>10</td>
<td>1.5</td>
</tr>
</tbody>
</table>

**Radiometric uncertainty specification converted to Brightness Temperature (BT)**

### Full Spectral Resolution

<table>
<thead>
<tr>
<th>Band</th>
<th>Spectral range (cm(^{-1}))</th>
<th>N. of chan.</th>
<th>Resolution (cm(^{-1}))</th>
<th>FORs per Scan</th>
<th>FOVs per FOR</th>
<th>NEdN @287K BB mW/m(^2)/sr/cm(^{-1})</th>
<th>Radiometric Uncertainty @287K BB (%)</th>
<th>Spectral (chan center) uncertainty ppm</th>
<th>Geolocation uncertainty Km (Nadir)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LW</td>
<td>650-1095</td>
<td>713</td>
<td>0.625</td>
<td>30</td>
<td>9</td>
<td>0.14</td>
<td>0.45</td>
<td>10</td>
<td>1.5</td>
</tr>
<tr>
<td>MW</td>
<td>1210-1750</td>
<td>865</td>
<td>0.625</td>
<td>30</td>
<td>9</td>
<td>0.084</td>
<td>0.58</td>
<td>10</td>
<td>1.5</td>
</tr>
<tr>
<td>SW</td>
<td>2155-2550</td>
<td>633</td>
<td>0.625</td>
<td>30</td>
<td>9</td>
<td>0.014</td>
<td>0.77</td>
<td>10</td>
<td>1.5</td>
</tr>
</tbody>
</table>
• On Jan 5, 2018, forty-eight days after NOAA-20 was launched into Earth orbit, it sent back its first Cross-track Infrared Sounder (CrIS) science data.
• All three bands are working nominally, IDPS successfully generated both Normal Spectral Resolution (NSR) and Full Spectral Resolution (FSR) SDR data.
NEdN compares well to 287K ECT TVAC NEdN – Full Spectral Resolution

Earth view data on 01/21/2018, from 23:40:16 to 23:59:28

- MW9 NEdN elevated as expected from prelaunch TVAC measurements but within specification
- LW7 NEdN elevated (high noise had been seen once before during EMI test phase)
- NEdN calculated on 1-8 is very similar to prelaunch TVAC test results
- NOAA-20 NEdN are comparable to S-NPP

ECT TVAC
(Specification using NSR, need to times 1.4 and 2.0 for FSR data for MWIR and SWIR, respectively)
ICT NEdN Become Better after Instrument Temperature Stable

ICT NEdN on 01/05/2018

ICT NEdN on 01/21/2018
DA Tilt Time History
Total Tilt Value Better than S-NPP

S-NPP Example Total Tilt
0.234 urad

J1 Example Total Tilt
0.123 urad
Optimal Laser Set Point  
FSR Extended Length Interferogram

Current Laser Wavelength is Well Outside keep-out Zones

Stem Lines are at Fold Index Change Wavelength Points

-5 ppm Change in Wavelength after ILS tuning 1547.6395 nm

Base Laser Wavelength 1547.64725 nm

-78 ppm

145 ppm
Gains Verified with Hottest Scene & Trended Over Several Days for Additional Confirmation

Earth Scene ZPD Amplitude trending confirmed gain setting is final

- Gain setting on 1/9 (during 21:00 GMT) provides margin for bands/FOVs
- ES ZPD amplitudes trended from 1/9 (post gain set) through 1/14
- Hottest scene observed from South Africa pass on 1/11 (12:00-13:00 GMT)
  - Actual pass is 12:35:45 – 12:39:15 (~ 32°42’S & 18°42’E to 22°41’S & 14°32’E)
  - Corresponds to apparent brightness temperature of about 336.7K
  - Max absolute ES ZPD Amplitudes for the pass shown below

<table>
<thead>
<tr>
<th>Band</th>
<th>LW</th>
<th>MW</th>
<th>SW</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOV1</td>
<td>7120</td>
<td>3168</td>
<td>4752</td>
</tr>
<tr>
<td>FOV2</td>
<td>6496</td>
<td>3040</td>
<td>4528</td>
</tr>
<tr>
<td>FOV3</td>
<td>7088</td>
<td>3120</td>
<td>5152</td>
</tr>
<tr>
<td>FOV4</td>
<td>6704</td>
<td>3232</td>
<td>4704</td>
</tr>
<tr>
<td>FOV5</td>
<td>5728</td>
<td>2912</td>
<td>4544</td>
</tr>
<tr>
<td>FOV6</td>
<td>6272</td>
<td>2928</td>
<td>4800</td>
</tr>
<tr>
<td>FOV7</td>
<td>6752</td>
<td>3264</td>
<td>5200</td>
</tr>
<tr>
<td>FOV8</td>
<td>6576</td>
<td>3280</td>
<td>4976</td>
</tr>
<tr>
<td>FOV9</td>
<td>6864</td>
<td>3008</td>
<td>4592</td>
</tr>
<tr>
<td>Max</td>
<td>7120</td>
<td>3280</td>
<td>5200</td>
</tr>
</tbody>
</table>
ES ZPD Trending

- ES ZPD trending show gain set provides margin against max 8192 counts
- Occasional high or saturated single sample in SW FOVs from sun glint are not considered for gain or bit trim setting.
- Need future investigation why the MW ES ZPD gain so low
Bit Trim Mask and Impulse Mask assessed with the hot scene data

1. Full Spectral Resolution Bit Trim Mask launched with instrument is sufficient
   - Includes the extended samples for LW and SW
   - No change to data rate

2. NOAA-20 impulse now at same levels as S-NPP
   - Open at ZPD and 1 bit down elsewhere

<table>
<thead>
<tr>
<th>J1 FSR LWIR Bit Trim Table</th>
<th>J1 FSR MWIR Bit Trim Table</th>
<th>J1 FSR SWIR Bit Trim Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start Sample</td>
<td>End Sample</td>
<td>Bits Remaining</td>
</tr>
<tr>
<td>Index*</td>
<td>Index*</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>55</td>
<td>11</td>
</tr>
<tr>
<td>56</td>
<td>96</td>
<td>13</td>
</tr>
<tr>
<td>97</td>
<td>380</td>
<td>12</td>
</tr>
<tr>
<td>381</td>
<td>426</td>
<td>13</td>
</tr>
<tr>
<td>427</td>
<td>450</td>
<td>18</td>
</tr>
<tr>
<td>451</td>
<td>496</td>
<td>13</td>
</tr>
<tr>
<td>497</td>
<td>780</td>
<td>12</td>
</tr>
<tr>
<td>781</td>
<td>821</td>
<td>13</td>
</tr>
<tr>
<td>822</td>
<td>876</td>
<td>11</td>
</tr>
<tr>
<td>822</td>
<td>876</td>
<td>11</td>
</tr>
<tr>
<td>566</td>
<td>659</td>
<td>8</td>
</tr>
<tr>
<td>660</td>
<td>714</td>
<td>9</td>
</tr>
<tr>
<td>715</td>
<td>808</td>
<td>8</td>
</tr>
</tbody>
</table>

* After Decimation.
Bit Trim Mask for NOAA-20

- Real component for hottest scene: South Africa Pass 1/11/18 12:00-13:00 GMT
- Imaginary component also within the mask – 1 bit (for sign) levels
SSM Geolocation ROP performed on 1/12 during 23:00 hr GMT

- SSM Velocity and Motion Compensation disabled
- SSM Commanded In-Track Position set to zero

**Null Torque value is the In-Track offset position**

- Some cross-coupling seen in IT from movement of the CT going from ES10 to Space to ICT during test (48 sec collects)

<table>
<thead>
<tr>
<th>Position</th>
<th>Collection Start</th>
</tr>
</thead>
<tbody>
<tr>
<td>ES 10</td>
<td>23:00:26</td>
</tr>
<tr>
<td>DS</td>
<td>23:02:00</td>
</tr>
<tr>
<td>ICT</td>
<td>23:03:34</td>
</tr>
</tbody>
</table>

- Zoom in of flat portion shows an average value of ~1542.4 urad vs. 1666 urad ground test value
- In-Track angles decrease by ~0.062 mrad in v113 eng pkt (uploaded 1/17) relative to v112 (uploaded 1/3)
- ~1 mrad offset remains between CrIS and VIIRS
- Mapping angles in the engineering packet can be updated to resolve CrIS and VIIRS offset, though CrIS already meets its geolocation specification.
Relative Radiometric Calibration (FOVX – FOV5)

S-NPP LW agreement < 0.15 K

- S-NPP nonlinearity parameters were set during the S-NPP checkout phase in January 2012 but still remain valid six years later.

NOAA-20 LW bias wrt FOV5 ~ 0.2K

- Initial NOAA-20 flight data suggests a small post-launch adjustment to the NOAA-20 LW FOV5 a2 parameter and perhaps some minor refinements of the other FOVs.
Relative Radiometric Calibration (FOVX – FOV5)

S-NPP MW FOV7 has highest nonlinearity
- S-NPP MW nonlinearity was adjusted to remove the line structure in FOV7 however a small systematic bias of 0.1K remains.

NOAA-20 MW FOV9 has highest nonlinearity
- NOAA-20 MW nonlinearity needs to be adjusted to remove the line structure in FOV9, however a small offset may remain similar to that seen in SNPP FOV7.
Relative Radiometric Calibration (FOVX – FOV5)

S-NPP SW FOV7 & 9 are out-of-family
• S-NPP SW has some issues on spectral lines for FOVs 7 & 9. This is more apparent in unapodized spectra. (Apodized shown here)

NOAA-20 SW looks better
• NOAA-20 SW band looks very good
FOV-2-FOV Radiometric Consistency

NOAA-20 on 01/05/2018

MWIR FOV 9 out of family

Non-linearity need to be adjusted
S-NPP on 01/05/2018

Bias (K) vs. Wavenumber (cm⁻¹) for FOVs 1 to 9.
Radiometric Accuracy Compared to Simulation

NOAA-20
On 01/05/2018

S-NPP
Radiometric Accuracy
Double Difference

Data on 01/05/2018

\[(BT - BT_{crtm})_{n20} - (BT - BT_{crtm})_{npp}\]

All channels (except one) are within ±0.2 K with S-NPP
Radiometric Accuracy

Scan Pattern

Data on 01/05/2018

S-NPP
Northern Hemisphere SNOs, Hamming Apodized CrIS – IASI Bias (CrIS using EP v112)

- Variation of results among FOVs in LW CO2 regions
- MW FOV9 out-of-family among FOVs
- Mean differences generally less than ~0.5K
Use AIRS as a transfer standard between S-NPP (CrIS-1) and NOAA-20 (CrIS-2)

- Convert AIRS L1c to CrIS ILS (AIRS2CrIS)
- Find CrIS-1 and AIRS2CrIS SNOs and difference: C1-ARIS
- Find CrIS-2 and AIRS2CrIS SNOs and difference: C2-AIRS
- \((C1-\text{AIRS}) - (C2-\text{AIRS})\) radiometric differences

\((C1-\text{AIRS}) - (C2-\text{AIRS}) = (C1- C2)\)
M16 (~11.8 micron) time series. 4 minute time averages

S-NPP

NOAA-20
Preliminary CrIS/VIIRS Comparisons

M16 (~11.8 micron) on January 7th

S-NPP

NOAA-20
Spectral Accuracy at LWIR
Relative and Absolute (Meet Specification)

Data on 01/05/2018

• Absolute spectral shift
  FOV 5: -5 ppm
  FOV 7: +2 ppm
  FOV 9: +4 ppm
  Other FOVs: within ± 1 ppm
• Need to adjust FOVs 5, 7 and 9 ILS parameters
Data on 01/05/2018
- Absolute spectral shift
  FOV 5: -5 ppm
  FOV 9: +1 ppm
  Other FOVs: negative 2 to 3 ppm
- All FOVs ILS parameters need to be adjusted to within 1 ppm
Data on 01/05/2018

- Absolute spectral shift
  FOV 5: -5 ppm
  FOVs 4, 7, and 8: -4 to -5 ppm
  Other FOVs: negative 2 to 3 ppm
- All FOVs ILS parameters need to be adjusted to within 1 ppm

All on axis FOV 5 in three bands have about 5 ppm shift, which indicate that the true Neon Wavelength is lower than the value current used in the spectral calibration system. Recommended to adjust the Neon Wavelength in the EngPkt v113
1) For the ADL FSR SDRs generated by STAR for the case study of 08 Jan 2018, the UW analysis of relative FOV2FOV agrees well with the STAR FOV2FOV analysis, with the notable exceptions of SW FOVs 1, 2, and 3.

2) For radiances generated using the UW matlab cal code (which uses FOVangles generated from the prescribed v113 EP ILS parameters), the relative FOV2FOV behavior is improved over the ADL SDRs.
Future Improvement:
FOV-2-FOV Spectral Calibration Analysis

UW L1B Radiance w/ UMBC FOVangles

UW Spectral Cal (rel. FOV5): 2018
Geolocation Accuracy

Collocated CrIS and VIIRS images
Results indicate some sub-pixel level difference, relative to VIIRS
Geolocation Accuracy (Meet Specification)

InTrack Direction

CrossTrack Direction

Data after EngPkt v113
Geolocation Accuracy (Meet Specification)

Overall performance for CrIS geolocation for all FOV positions:
- it already meets the specifications (1.5 km at nadir - 11% of FOV size for all scan positions)
- In-track geolocation having up to about 6% FOV size error, which can be resolved by updating the mapping angles using VIIRS geolocation as reference
• NOAA-20 CrIS SDR data well meet and exceed the beta maturity: NOAA-20 CrIS SDR data can be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose

• Major NOAA-20 CrIS SDR data Performance:
  – NEdN: all FOVs and bands within the specification, comparable well to S-NPP
  – Radiometric uncertainty: within the specification, all channels (except one) are with ±0.2 K with S-NPP (global averaged), showing very good agreement with VIIRS, AIRS, and IASI (less than 0.5 K)
  – Spectral uncertainty: within the specification, FOV 5 absolute spectral shift within 1 ppm, relative shift within 3 ppm for all bands after EngPkt v113
  – Geolocation uncertainty: within the specification, in-track geolocation having up to about 6% FOV size error

• NOAA-20 CrIS SDR data are available from 01/04/2018. The data gaps are due to CrIS PLTs or spacecraft maneuvers. Other than that, IDPS ground process can successfully generate the CrIS SDR data
Path Forward

• The CrIS SDR team will continue performing the cal/val with NOAA-20 CrIS towards Provisional status milestone by mid February, 2018
  – Radiometric uncertainty: Non-linearity coefficients adjustment, especially for LWIR and MWIR FOV 9
  – Spectral uncertainty: Fine tuning the ILS Parameters in focal plane to reduce the relative spectral shift among FOVs
  – Geolocation uncertainty: updating the mapping angles using VIIRS geolocation as reference to reduce in-track uncertainty

• Initial feedback from EDR team are very positive. Look forward to further collaborations