Modification of VIIRS Sensor Data Record Operational Code for Consistency of Data Product Limits

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Outline

• Suomi NPP VIIRS background
• Inconsistencies of radiance and radiance products
• Changes
  – *Algorithm*
  – *Radiance limits*
  – *Look up table*
• Validation
• Summary
Suomi NPP VIIRS background

• Suomi National Polar-orbiting Partnership (NPP) satellite launched on October 28, 2011 and operates at an altitude of 838 km.
• Visible Infrared Imaging Radiometer Suite (VIIRS) has 22 spectral bands ranging from 0.4 to 12.5 µm.
  – Fourteen reflective solar bands (RSB)
  – Seven thermal emissive bands (TEB)
  – One day night band
• Starting with the Raw Data Record (RDR), the Level 1b product produced post geolocation and calibration are called the Sensor Data Record (SDR).
• The active fire team filed a deficiency report noting inconsistencies of radiance, radiance derived products, and associated quality flags at very high and very low radiances in some SDRs.
Inconsistencies of radiance and radiance products

*Issues raised by the active fire team*

- **Pixel level quality flagging (QF1) inconsistencies**
  - *Radiance limits and brightness temperature limits were checked independently*
  - *Radiance limits and brightness temperature limits were not consistent*
  - *Led to valid radiances having invalid brightness temperatures*

- **Data product inconsistencies**
  - *If measured radiance > upper radiance limit, then upper radiance limit is reported*
  - *Brightness temperature associated with measured radiance is reported*
  - *Led to multiple brightness temperatures at the upper radiance limit*
Radiance limits, quality flag determination algorithm, and look up table changes

• Increase valid radiance range to match brightness temperature limits

• QF1 are now solely based on radiance limits
  – *If there is a valid radiance, there is a valid radiance product (brightness temperature or reflectance)*
  – *Special case of a negative reported radiance due to noise*
    • Radiance flag is still valid and radiance product flag is marked out of range

• Brightness temperature vs. radiance look up table is expanded to accommodate larger radiance range
New radiance limits

<table>
<thead>
<tr>
<th>Band</th>
<th>radMin</th>
<th>radMin2</th>
<th>radMax2</th>
<th>radMax</th>
</tr>
</thead>
<tbody>
<tr>
<td>I1</td>
<td>-0.41</td>
<td>0</td>
<td>862.01</td>
<td>861.6</td>
</tr>
<tr>
<td>I2</td>
<td>-0.24</td>
<td>0</td>
<td>419.04</td>
<td>418.8</td>
</tr>
<tr>
<td>I3</td>
<td>-0.21</td>
<td>0</td>
<td>87.21</td>
<td>87</td>
</tr>
<tr>
<td>I4</td>
<td>-0.01</td>
<td>CalcRad(208 K)</td>
<td>Max(3.61, CalcRad(367 K)) + 0.01</td>
<td>Max(3.61, CalcRad(367 K))</td>
</tr>
<tr>
<td>I5</td>
<td>-0.08</td>
<td>CalcRad(150 K)</td>
<td>Max(18.49, CalcRad(380 K)) + 0.08</td>
<td>Max(18.49, CalcRad(380 K))</td>
</tr>
<tr>
<td>M1</td>
<td>-0.21</td>
<td>0</td>
<td>738.21</td>
<td>738</td>
</tr>
<tr>
<td>M2</td>
<td>-0.2</td>
<td>0</td>
<td>824.6</td>
<td>824.4</td>
</tr>
<tr>
<td>M3</td>
<td>-0.12</td>
<td>0</td>
<td>842.52</td>
<td>842.4</td>
</tr>
<tr>
<td>M4</td>
<td>-0.1</td>
<td>0</td>
<td>800.5</td>
<td>800.4</td>
</tr>
<tr>
<td>M5</td>
<td>-0.08</td>
<td>0</td>
<td>781.28</td>
<td>781.2</td>
</tr>
<tr>
<td>M6</td>
<td>-0.09</td>
<td>0</td>
<td>41.09</td>
<td>60</td>
</tr>
<tr>
<td>M7</td>
<td>-0.04</td>
<td>0</td>
<td>418.84</td>
<td>418.8</td>
</tr>
<tr>
<td>M8</td>
<td>-0.14</td>
<td>0</td>
<td>198.02</td>
<td>197.88</td>
</tr>
<tr>
<td>M9</td>
<td>-0.09</td>
<td>0</td>
<td>92.61</td>
<td>92.52</td>
</tr>
<tr>
<td>M10</td>
<td>-0.04</td>
<td>0</td>
<td>85.48</td>
<td>85.44</td>
</tr>
<tr>
<td>M11</td>
<td>-0.02</td>
<td>0</td>
<td>38.18</td>
<td>38.16</td>
</tr>
<tr>
<td>M12</td>
<td>0</td>
<td>CalcRad(203 K)</td>
<td>Max(3.39, CalcRad(368 K))</td>
<td>Max(3.39, CalcRad(368 K))</td>
</tr>
<tr>
<td>M13</td>
<td>-0.01</td>
<td>CalcRad(192 K)</td>
<td>Max(485.15, CalcRad(683 K)) + 0.01</td>
<td>Max(485.15, CalcRad(683 K))</td>
</tr>
<tr>
<td>M14</td>
<td>-0.03</td>
<td>CalcRad(120 K)</td>
<td>Max(21.04, CalcRad(365 K)) + 0.03</td>
<td>Max(21.04, CalcRad(365 K))</td>
</tr>
<tr>
<td>M15</td>
<td>-0.02</td>
<td>CalcRad(111 K)</td>
<td>Max(20.5, CalcRad(381 K)) + 0.02</td>
<td>Max(20.5, CalcRad(381 K))</td>
</tr>
<tr>
<td>M16</td>
<td>-0.02</td>
<td>CalcRad(103 K)</td>
<td>Max(17.38, CalcRad(382 K)) + 0.02</td>
<td>Max(17.38, CalcRad(382 K))</td>
</tr>
</tbody>
</table>

- Radiance units are W/m²-ster-μm. BT units are K.
- CalcRad(T) is band average radiance calculated for temperature T
- Temperatures in radMin2 column are current minimum BTs
- Temperatures in radMax2 and radMax columns are current maximum BTs
Comments on new radiance limits

• All current radMin values have been retained
• radMin2 values for RSB chosen to be zero, since this is smallest radiance for which a consistent minimum of reflectance of zero can be assigned
• radMin2 values for TEB are chosen to be consistent with current minimum values of brightness temperature
• All current radMax values for RSB have been retained
• All radMax values for TEB are the larger of current radMax and the radiance consistent with maximum BT
• All radMax2 values set slightly higher than radMax so that they have no impact on data product values or flagging
  – *Exception: radMax2 for M6 is lower than radMax so that rollover region is flagged*
Quality flag determination

Radiance & BT/Reflectance

Case 1: Calculated radiance > radMax
- Calculated radiance replaced by radMax
- Calculated reflectance or BT replaced by value consistent with radMax
- Set RADIANCE_OUTOF RANGE flag
- Set REFL_EBBT_OUTOF RANGE flag
- Set PIXEL_SDR_QUALITY_POOR flag

Case 2: radMax2 < Calculated radiance ≤ radMax
- Set RADIANCE_OUTOF RANGE flag
- Set REFL_EBBT_OUTOF RANGE flag
- Set PIXEL_SDR_QUALITY_POOR flag

Case 3**: radMin ≤ Calculated radiance < radMin2
- Calculated reflectance or BT replaced by value consistent with radMin2
- Set REFL_EBBT_OUTOF RANGE flag

Case 4: Calculated radiance < radMin
- Calculated radiance replaced by radMin
- Calculated reflectance or BT replaced by value consistent with radMin2
- Set RADIANCE_OUTOF RANGE flag
- Set REFL_EBBT_OUTOF RANGE flag
- Set PIXEL_SDR_QUALITY_POOR flag

** Case 3 created to allow handling of negative values of radMin, for which it is impossible to calculate consistent values of brightness temperature or reflectance. Negative radeances > radMin are considered in-range since zero scene radiance produces zero retrieved radiance +/- 3×NEdL
Look up table changes

• Brightness temperature vs. radiance curves are recalculated for the increased radiance range
• Bands I5 and M15:
Validation (1 of 2)

- RDR=RNSCA-RVIRS_npp_d20140902_t1205371_e1207024_b14756_c20140902140229030671_noaa_ops.h5
- Band M15
  - \textit{Mx8.5 run}
    - 5 pixels with radiance at maximum value of 20.5
    - Four of those pixels flagged as Radiance out of range (64) and Poor(1), so QF1=65
    - Fifth point is flagged as All Saturated (8) and Poor(1), so QF1 = 9
  - \textit{Patched run}
    - The four pixels previously flagged as QF1=65 is now set as QF1=0
      - \textit{Correct radiance/BT pair}
    - Fifth point is still flagged as All Saturated
Validation (2 of 2)

- Base case (Mx8.5) has radiance capped at 20.5, but has different brightness temperatures
- Modified case has radiance limit increased to 25.5411, which corresponds to BT of 381, as shown in the saturated case
- With higher radiance limit, the radiances corresponding to the different brightness temperatures are now valid (QF1 = 0)

Consistent radiance/brightness temperature pairs and no flagging of valid data
Summary

- Inconsistent radiance/brightness temperature pairs were occurring regularly
  - Processed 41 days of SDRs from 20140904 to 20141015,
  - Bad data in the TEBs, possibly with multiple pixels:
    - I4(5 SDRs), I5(513), M12(504), M14(11), M15(95), M16(105)
- Code and LUT changes bring radiance and radiance derived products to consistent values
- Quality flagging is now exclusively radiance based
- The radiance and brightness temperature ranges of TEBs are slightly increased with additional margin available in the look up tables
- All changes are implemented in next software release