MODIFICATION OF VIIRS SENSOR DATA RECORD OPERATIONAL CODE FOR CONSISTENCY OF DATA PRODUCT LIMITS

Gabriel Moy[a], Frank De Luccia[a], Chris Moeller[b]

[a]The Aerospace Corporation, 2310 E. El Segundo Blvd. El Segundo, CA 90245
[b]CIMSS, U. Wisconsin, 1225 W. Dayton St. Madison, WI 53706

ABSTRACT

The Visible Infrared Radiometer Suite (VIIRS) sensor data record (SDR) product contains geolocated and calibrated radiances, quality flags, and derived products such as brightness temperature and reflectance. The active fire team reported an inconsistency in the way radiance limits and derived products limits are generated. The quality flags are also independently determined for radiance limits and derived product limits. This paper focuses on operational code modifications to address the inconsistent radiance and derived products and quality flag determination algorithm.

Index Terms— VIIRS, SNPP, radiance, SDR

1. INTRODUCTION

The VIIRS sensor onboard Suomi NPP, which launched on October 28, 2011, contains 22 bands spanning the visible and infrared wavelengths from 0.4 to 12.5 um. The bands consist of 14 reflective solar bands (RSB), 7 thermal emissive bands (TEB), and a day night band [1]. A raw data record (RDR) is processed into a SDR which contains geolocated and calibrated radiances, quality flags, and radiance derived products such as brightness temperature and reflectance. SDR products are used to generate 22 environmental data records (EDR) including active fire, ocean color, and sea surface temperature. The active fire team reported an inconsistency in the way radiance limits and derived products limits are generated. Unfortunately, the values at the radiance and brightness temperature upper limits are inconsistent.

VIIRS TEBs consist of two imaging resolution bands (I4, I5) and five moderate resolution bands (M12 – M16). Current radiance and brightness temperature limits of these bands are shown in Table 1. A radiance vs. brightness temperature, or equivalent blackbody temperature (EBBT), look-up table (LUT) is derived by applying a weighted sum corresponding to the detector-averaged relative spectral response of the TEB to the Plank spectral exitance at various brightness temperatures. When calculated radiance is above the radiance upper limit, the current algorithm returns the brightness temperature limit as the derived product value. For VIIRS RSBs, reflectance values are capped at 1.6 independent of whether the corresponding radiance is of good quality, capped, or poor quality. The quality flags are set by independently checking the radiance against its limits and the derived product against its own limits.

An algorithm change is proposed and implemented such that only the radiance is checked against its upper limit, and if a radiance is valid, its derived product will also be valid. Instead of lowering the brightness temperature limits to make a consistent radiance-brightness temperature pair, the radiance limit is increased to match the brightness temperature. New radiance upper limits are shown in brackets in Table 1.

2. MODIFICATION OF VIIRS SDR CODE

Modifications to the operational code consist of defining new radiance limits, expanding the EBBT LUT, and algorithm changes to checking limits.

2.1. Updating radiance limits

The radiance limits are defined in an xml file called ProCmnProductDictionary_CFG.xml. In that file, 'radiance range' is updated and a new data field named 'radiance2' is added. The 'radiance2 offset' is set to the calculated radiance at the lower brightness temperature limit for TEBs and set to 0 W/m^2-ster-um for RSBs, as a negative radiance is not meaningful. The 'radiance2 range' is set equal to 'radiance range' for each band. In the code, the radiance lower limit is equal to the radiance offset. The radiance upper limit is the radiance offset plus radiance range.

2.2. Expanding the EBBT LUT

As the valid radiance range has expanded, the radiance vs. brightness temperature curves sampled by the EBBT LUT also need to be expanded. Using the relative spectral response curves from pre-launch testing [2][3], a new set of curves are generated. The old and new ranges of brightness temperatures are shown in Table 2.

Table 1. Current radiance and brightness temperature limits. New radiance upper limits consistent with brightness temperature upper limits are in brackets.

Band	Radiance Lower Limit [W/m^2-ster-um]	Radiance Upper Limit [W/m^2-ster-um]	Brightness Temperature Lower Limit [K]	Brightness Temperature Upper Limit [K]
I4	-0.01	3.61 [4.6510]	208	367
I5	-0.08	18.49 [22.897]	150	380
M12	0	3.39 [4.4116]	203	368
M13	-0.01	485.15 [605.76]	192	683
M14	-0.03	21.04 [26.151]	120	365
M15	-0.02	20.5 [25.541]	111	381
M16	-0.02	17.38 [22.170]	103	382

Table 2. Current and new limits of the EBBT LUT.

Band	Current BT Lower Limit [K]	New BT Lower Limit [K]	Current BT Upper Limit [K]	New BT Upper Limit [K]
I4	208	190	367	390
I5	110	100	381	390
M12	140	140	360	390
M13	199	180	634	700
M14	128	110	365	390
M15	111	95	380	390
M16	103	95	380	390

The new brightness temperature ranges have an 8-23 K margin over the largest valid radiance of the TEBs. Plots of the expanded I5 and M15 curves are shown in Figure 1. The new LUT has a maximum radiance sampling interval (Δradiance) of 0.005 W/m^2-ster-um and brightness temperature sampling interval (ΔBT) of 0.0025 K for each band.

2.2. Algorithm changes

With new radiance and radiance derived product limits, algorithm changes are made to ensure consistent products and quality flags when calculated radiance is above or below the limits. The new algorithm is broken down into four cases:

Case 1: Calculated radiance > XML defined radiance upper limit
• Calculated radiance replaced by radiance upper limit
• Calculated reflectance or brightness temperature replaced by value consistent with radiance upper limit
• Set "radiance out-of-range", "reflectance/BT out-of-range", and "pixel quality poor" flags

Case 2: XML defined radiance2 upper limit < Calculated radiance <= XML defined radiance upper limit
• Set "radiance out-of-range", "reflectance/BT out-of-range", and "pixel quality poor" flags

Case 3: XML defined radiance lower limit <= Calculated radiance < XML defined radiance2 lower limit
• Calculated reflectance or brightness temperature replaced by value consistent with radiance2 lower limit
• Set "reflectance/BT out-of-range" flag

Case 4: Calculated radiance < XML defined radiance lower limit
• Calculated radiance replaced by radiance lower limit

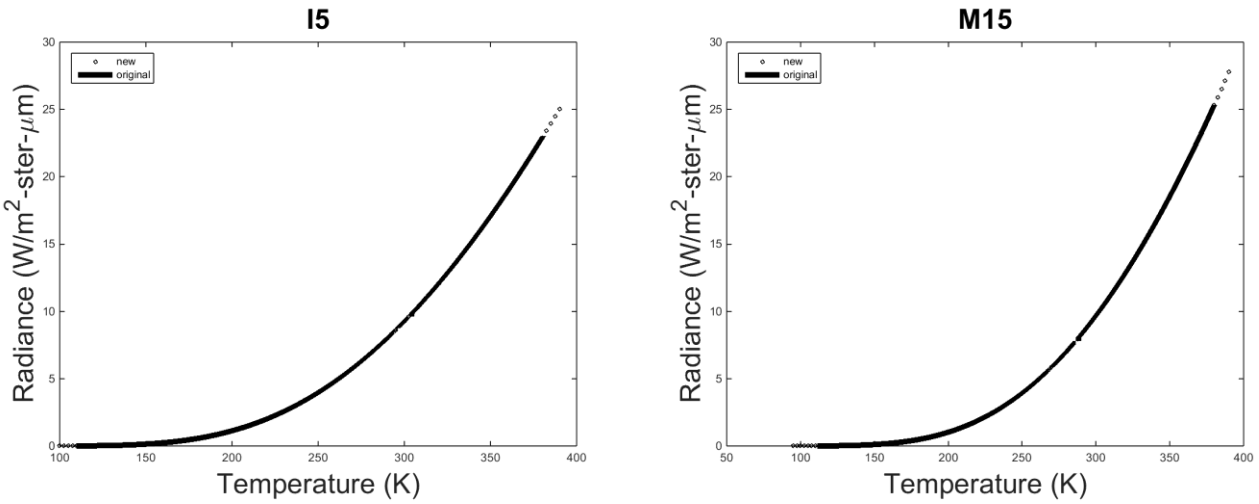

Figure 1. Expanded radiance vs. brightness temperature curves for I5 and M15.

• Calculated reflectance or brightness temperature replaced by value consistent with radiance2 lower limit
• Set "radiance out-of-range", "reflectance/BT out-of-range", and "pixel quality poor" flags

3. RESULTS

After implementing all of the changes to ADL Mx8.8, an RDR with inconsistent products and flagging was reprocessed. In the base Mx8.8 run, the M15 band SDR at September 2, 2014, 12:05Z has 5 pixels with calculated radiance of 20.5. One of the pixels is saturated while the other four pixels have quality flag set to 65, which is equivalent to both "radiance out-of-range" and "pixel quality poor". The brightness temperatures of the four non-saturated pixels range from 361.5 K to 366.8 K. With the updated limits and code, the saturated pixel stays saturated and the other four pixels have radiances corresponding to the brightness temperatures with quality flags set to zero. The higher radiance limits have turned the four poor quality pixels into useable data with consistent radiance/brightness temperature values. In the same base Mx8.8 run, the I3 band has nine pixels with "radiance out-of-range" flag set. After the update, all nine pixels now also have the "reflectance/BT out-of-range" set.

In another case on October 15, 2014 17:04Z, the M12 band shows 17 pixels with quality flags set to 65 or 193 (which is all three flags set). All the radiance values are set to the XML defined radiance upper limit of 3.39 W/m^2-ster-um. The pixels with quality flag set to 65 have brightness temperatures of 359.3 K to 360.0 K while the pixels with quality flag set to 193 have brightness temperatures set to 203 K. In the current code, if the calculated brightness temperature is beyond the lookup table, it is set to the XML defined brightness temperature lower limit even if the brightness temperature is above the upper limit of the lookup table. With the revised limits and expansion of the EBBT LUT, all pixels have quality flag set to 0 and consistent radiance/brightness temperature pairs. There should no longer be cases where there is a valid radiance with a brightness temperature beyond the lookup table.

Looking at the I5 band for this case, there are16 pixels with quality flag set to 65. All radiance values are set to the XML defined radiance upper limit of 18.49 W/m^2-ster-um with brightness temperatures ranging from 359.0 K to 376.2 K. With the revised limits and code, all pixels have quality flag set to 0 and radiance values ranging from 18.6 to 22.1 W/m^2-ster-um with the same brightness temperatures as the baseline run. Figure 2 shows the baseline Mx8.8 radiance values of I5 along with a subset of pixels (radiance values greater than 14) before and after the update.

4. CONCLUSION

The modifications to radiance limits, and radiance derived product limits, EBBT lookup table, and flag determination algorithm will bring consistency to SDR products when implemented in operations. The expansion of radiance limits and the EBBT LUT will decrease the number of poor quality pixels. All changes are approved and implemented into ADL Mx8.9. In the future, the radiance 2 range will be reviewed for possible adjustments to improve data quality flagging in the VIIRS SDR product.

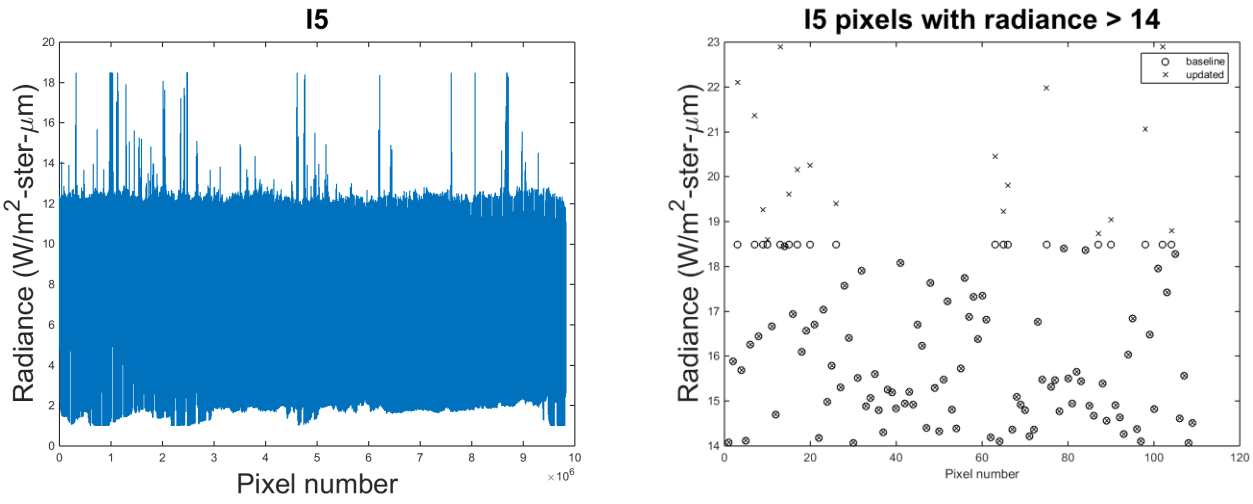

Figure 2. Baseline radiance values for I5 (left). Baseline and updated I5 radiance values pixels with radiance values > 14 W/m^2-ster-um (right). The baseline run has radiance values capped at 18.49 W/m^2-ster-um even though the brightness temperature ranges from 359.0 K to 376.2 K.

5. REFERENCES

[1] F. De Luccia, B. Guenther, C. Moeller, X. Xiong, and R. Wolfe, "NPP VIIRS Pre-Launch Performance and SDR Validation", International Geoscience and Remote Sensing Symposium (IGARSS) Proceedings, 24-29 July 2011.

[2] C. Moeller, J. McIntire, T. Schwarting, D. Moyer, "VIIRS F1 best relative spectral response characterization by the Government Team", SPIE Proceedings Volume 8153: Earth Observing Systems XVI, September 2011.

[3] C. Moeller, J. McIntire, T. Schwarting, D. Moyer, J. Costa, "Suomi NPP VIIRS Spectral Characterization: Understanding Multiple Releases", SPIE Proceedings Volume 8510: Earth Observing Systems XVII, October 2012.