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 emmissive 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

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

- Radiance units are W/m^2-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_OUTOFRANGE flag
- Set REFL_EBBT_ OUTOFRANGE flag
- Set PIXEL_SDR_QUALITY_POOR flag

Case 2: radMax2 < Calculated radiance ≤ radMax

- Set RADIANCE_OUTOFRANGE flag
- Set REFL_EBBT_ OUTOFRANGE flag
- Set PIXEL_SDR_QUALITY_POOR flag

Radiance & BT/Reflectance

Case 3**: radMin ≤ Calculated radiance < radMin2

- Calculated reflectance or BT replaced by value consistent with radMin2
- Set REFL_EBBT_ OUTOFRANGE flag

Case 4: Calculated radiance < radMin

- Calculated radiance replaced by radMin
- Calculated reflectance or BT replaced by value consistent with radMin2
- Set RADIANCE_OUTOFRANGE flag
- Set REFL_EBBT_ OUTOFRANGE 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 radiances > 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:
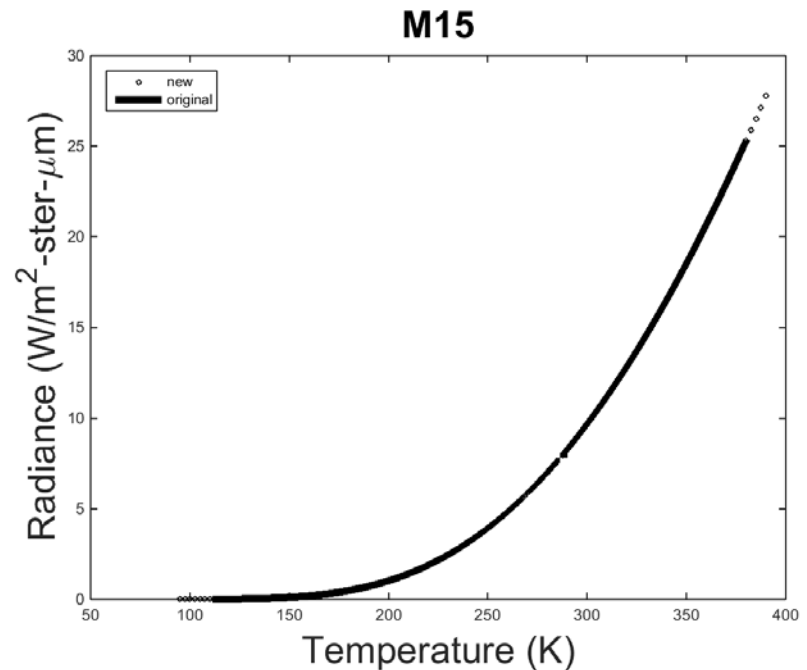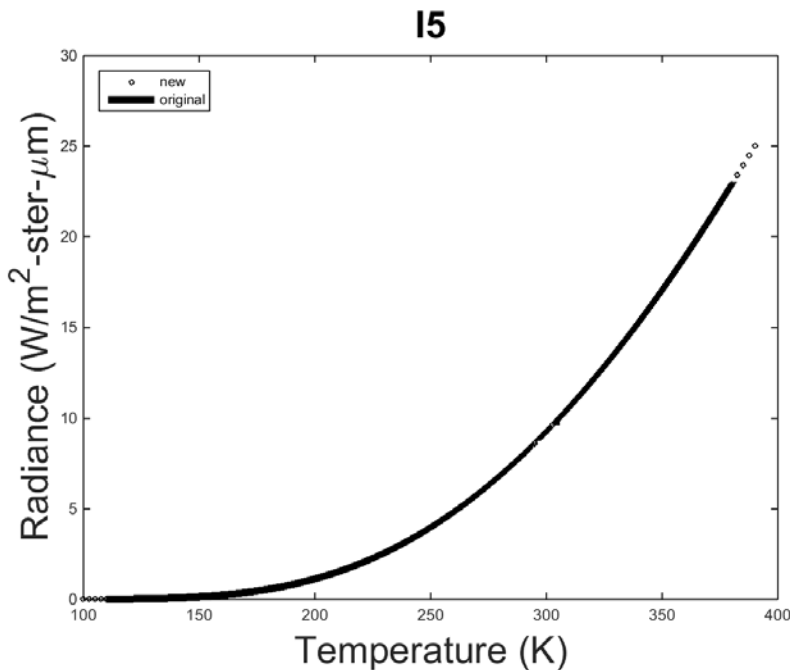
Validation (1 of 2)

- RDR=RNSCA-RVIRS_npp_d20140902_t1205371_e1207024_b14756_c20140902140229030671_noaa_ops.h5
- Band M15
  - *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
  - *Patched run*
    - The four pixels previously flagged as QF1=65 is now set as QF1=0
      - *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)

```
>> indices = find(base.M15.radianceValues == 20.5)

indices =

    1498951
    1540578
    1950059
    2388814
    2388815

>> [single(base.M15.QF1(indices)) base.M15.radianceValues(indices)
base.M15.brightnessTemperatureValues(indices)]

ans =

   65.0000   20.5000   361.8564
   65.0000   20.5000   366.7927
   65.0000   20.5000   361.5062
    9.0000   20.5000   381.0000
   65.0000   20.5000   365.7667

>> [single(ebbt.M15.QF1(indices)) ebbt.M15.radianceValues(indices)
ebbt.M15.brightnessTemperatureValues(indices)]

ans =

        0   21.0863   361.8605
        0   22.1957   366.8010
        0   21.0087   361.5103
   9.0000   25.5411   381.0000
        0   21.9625   365.7750
```

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