Technical Memorandum on

Retaining Negative Values as Valid ABI Radiance

2020-06-19 Initial draft by X. Wu
2020-06-28 Incorporated inputs from V. Kondratovich and F. Yu.

Summary

The negative radiances in ABI L1b data should remain as valid measurements. An earlier CWG recommendation and the resulting ADR1072 should be withdrawn. CMI team has the option to set the CMI DQF to desirable values for negative radiances.

Background

On 30 January 2020, user reported negative radiances in Advanced Baseline Imager (ABI) Channel 7 (3.9 μm) Level 1b (L1b) data[1]. At a Calibration Working Group (CWG) meeting on 5 February 2020, Cloud and Moisture Imagery (CMI) team found that these negative radiances were not flagged[2]. Furthermore, all negative radiances were mapped to 197.3 K in CMI product, also not flagged. They suggested setting the CMI Data Quality Flag (DQF) as out_of_range (2) for negative radiance. At the same meeting, CWG suggested setting the L1b DQF to out of range for negative radiance, which would automatically trigger the CMI DQF. An Algorithm Discrepancy Report (ADR1072) was submitted afterward.

Why Is There Negative Radiance for Channel 7 Only?

Radiance is never negative, but measurement of radiance can be negative because of noise. The slope (the factor to convert count to radiance) for Channel 7 is typically 0.00216 mW/m^2-sr-cm^{-1}/count. This means that for an earth scene of 201K that emits radiance of 0.00216 mW/m^2-sr-cm^{-1} at 3.9 μm (Planck function), the average of Channel 7 measurements is one count above its space count, or δ-count = 1. The noise of Channel 7 is 0.0028 mW/m^2-sr-cm^{-1}, or 1.3 count (NEdN / slope). Assuming the noise is normally distributed, 12.5% of these measurements will have δ-count more than 1.15σ or 1.5 count from mean of 1 count on each side, that is, < -0.5 and > 2.5 count, which will be digitized to ≤ -1 and ≥ 3 count, respectively. The negative radiance becomes more prevalent for colder scenes, as shown in Table 1 for a 180 K scene. Table 1 also explains why measurements of other ABI IR channels are immune to noise-induced negative radiance.

[1] Rico Allegrino, "Negative Radiances", email from Peter Keehn forwarded to Fred Wu and Tim Schmit.
[2] Mat Gunshor, Tim Schmit, and Jim Nelson, 4 February 2020 CWG Meeting.

Table 1: Slope, radiance, δ-count, instrument noise (in terms of count), and probability of negative δ-count of a 180 K scene for selected ABI channels.

Band	Wavelength (μm) & Wavenumber (cm^{-1})	Slope (mW/m^2-sr-cm^{-1}/ct)	Rad@180K (mW/m^2-sr-cm^{-1})	δ-count (count)	Noise (count)	Probability of Negative δ-count
7	3.9 / 2564	0.00216	0.0002524	0.12	1.3	32%
8	6.2 / 1613	0.00435	0.1257	28.9	1.7	~0
16	13.3 / 751.9	0.05150	12.45	242	1.2	~0

Why Should These Negative Radiance Be Considered Normal?

Negative radiances is a result of noise, which is intrinsic to all measurements and is assumed normally distributed (random in sign and magnitude). For scene temperature of 201 K, while 12.5% of the measurements will be more than 1.5 count below the mean of δ-count = 1 and digitized as δ-count = -1 (negative radiance), another 12.5% of the measurements will be more than 1.5 count above the mean of δ-count = 1 and digitized as δ-count = 3. If one could not tell which measurement of δ-count = 3 is due to noise and therefore should be flagged, one would be equally unable to single out pixels of δ-count = -1.

There is also a practical concern. The cold scenes in question (especially below 201 K), though rare, appear regularly in natural. It would be difficult to generate the required outlier file (the 16 samples contributing to the pixel radiance) for every one of these pixels.

INR Consideration

The 3.9 μm channel also makes star measurements for geometric calibration or Image Navigation and Registration (INR). The key measurement for that purpose is which detector(s) records peak signal at what time. Radiometric calibration of the measurements, including negative radiance, is not relevant.

END