SOP for GOES ABI Image Striping

GOES-R CWG

2020-04-xx

Introduction

Each band of the Advanced Baseline Imager (ABI) on Geostationary Operational Environmental Satellite (GOES) has 332 to 1460 rows of detectors for each of its 16 bands that scan the target in swath of about 500 km width (at nadir). Depending on band, there are three or six columns of detectors in each of these rows, all were carefully characterized, and the detector on each row that performs the best was designated as the Best Detector Select (BDS) and used in operation. If any of these selected detectors is not properly calibrated, radiance by this detector will be abnormally different from its neighbors. This often creates a linear artifact in the image along the scan direction, commonly referred to as image striping. This Standard Operation Procedure (SOP) describes how the Calibration Working Group (CWG) responds to such anomaly.

Algorithm Error

Detector can be incorrectly calibrated because of errors in calibration algorithm. For GOES-16, for example, the calibration algorithm used incorrect values of integration factor for the visible and near infrared (VNIR) channels from 03/16/2017 – 04/28/2017, B05 from 11/19-2017 – 12/29/2017, and a brief period for all the 6 VNIR bands of G16 on 04/10/2018;implementation of the unmatched quadratic look-up-table (LUT) with the updated calibration algorithm from 1/17/2018-02/07/2018; incorrect implementation of obsolete solar calibration results from 04/08/2019-04/09/2019; and incorrect nonlinearity coefficients for some detectors of the infrared (IR) channels till 08/18/2018 These led to multiple stripes in the VNIR and IR images, respectively. Typically, these happen during the beginning of life (BOL) of a satellite mission, which are removed once the root cause is found and corrected.

Detector Change

Throughout the mission life, well-characterized detector may change over time in several ways. Sometimes, a detector’s response to signals changes (increases) suddenly (Fig. 1). This is normal, often referred to as “level shift”, and is likely due to change in dark current. Level shift usually does not affect detector performance. For example, the noise in terms of Noise Equivalent differential Temperature (NEdT) remains normal before and after the level shift. However, a flawed algorithm to reject lunar contamination may misidentify the sudden space count increase as lunar intrusion. In response, the Ground Processing Algorithm (GPA) uses the space count just before the level shift. This creates a "latch up" of space count that ignores future change of space count and leads to incorrectly calibrated radiance and stripes in image. Note that the Internal Calibration Target (ICT) count is not subject to lunar intrusion and therefore does not latch up after level shift. Depending on the magnitude and timing, latch up can be self-released by diurnal variation of space counts, or require operator intervention. Before the space count latch up can be eliminated by a more sophisticated lunar contamination rejection algorithm, satellite operator must manually release some of them as soon as it is found.

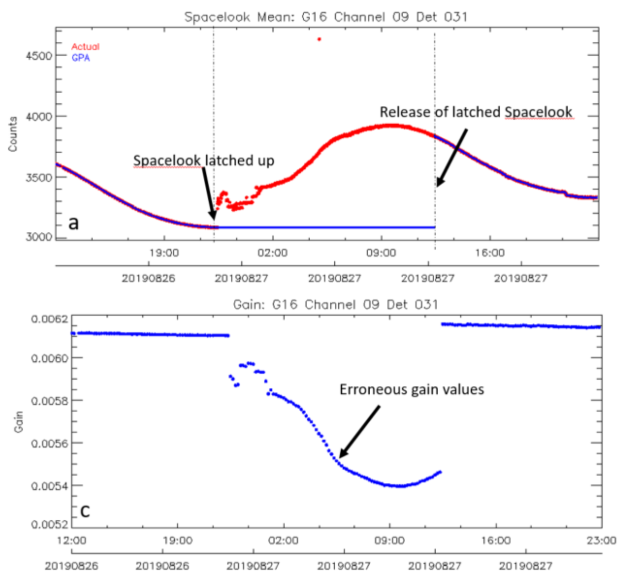

Figure 1: Time-series of space count (a), ICT count (b), gain (c), and NEdT (d) during an episode of space count latch up of GOES-16 Channel 9 Detector #31 on August 26-27, 2019. The red symbols in (a) & (b) are the ABI measurements, which show a level shift for both space and ICT counts at 2230 UTC on August 26. The blue symbols in all panels are values derived and used by GPA, for which the space count in (a) latched (remained constant) after level shift but the ICT count in (b) did not. This resulted in erroneous gain in (c) that caused a relatively colder line in every swath of images (image striping). At 1226 UTC on August 27, the space count was manually reset to its correct value, which released the latch up and resumed normal calibration. Note that the detector noise in (d) had been stable and well within the requirement throughout the scenario.

Over time, detector can also become saturated (Fig. 2, Fig. 3), noisy (Fig. 4), or unstable (Fig.54). These lead to steady or intermittent image striping. In all these cases, the degraded detectors have never performed acceptably again, therefore it should be replaced ("BDS Update") once identified.

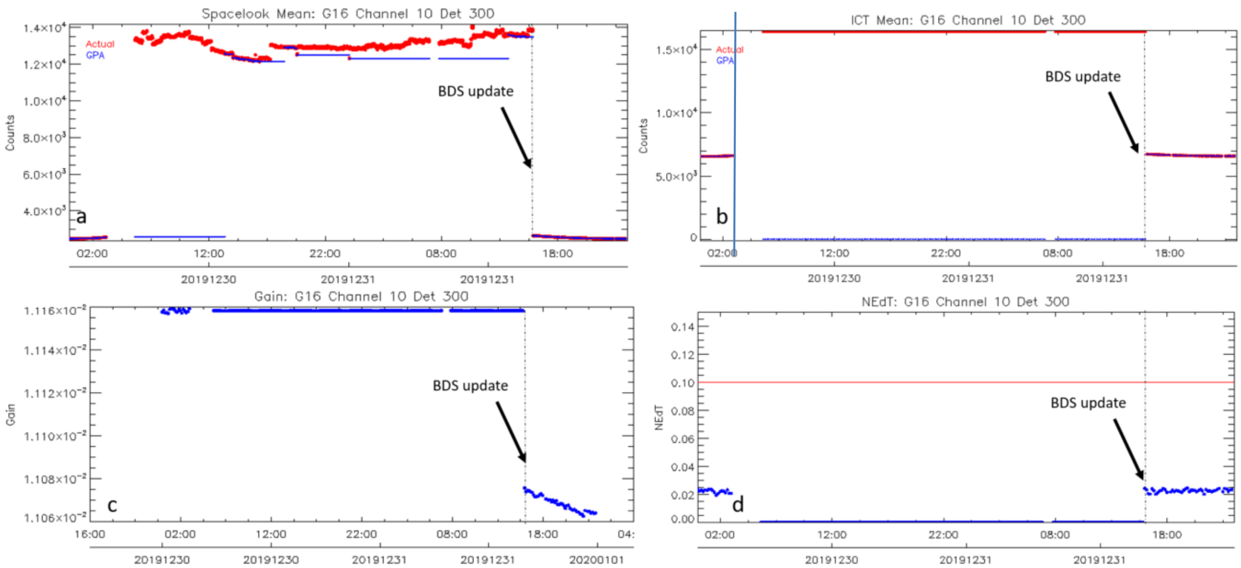

Figure 2: Similar as Figure 1, but during an episode of ICT saturation of GOES-16 Channel 10 Detector 300 on December 30-31, 2019. The SPL count was not saturated, yet experienced several human interventions to release the latched SPL count (a). The ICT count for this detector was saturated between ~0400 UTC on December 30 to ~1600 UTC on December 31, when GPA set the ICT count to zero. (b) Normal calibration resumed after a "BDS update" replaced the degraded detector.

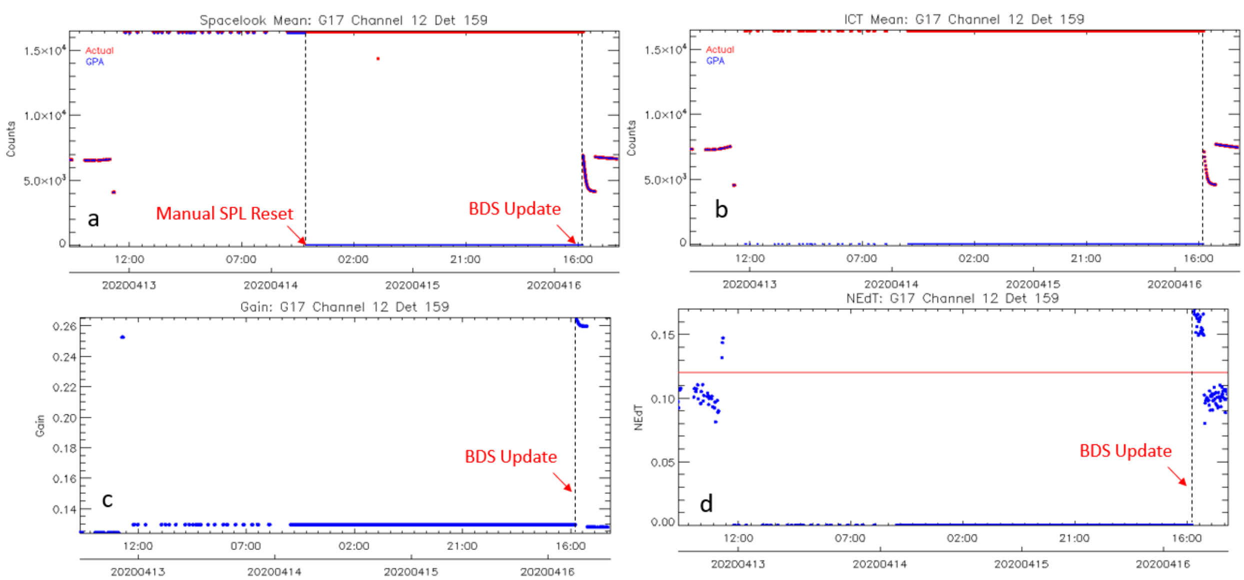

Figure 3. Similar as Figure 2, but during an episode of saturated SPL and ICT counts for G17 B12 Det#159 between 16:25 UTC on 04/13/2020 and 16:56 UTC on 04/16/2020. In the GPA processing, the SPL count was latched-up at a value before the saturation. A manual space-look reset was conducted around 17:54 UTC on 04/14/2020, resulting the GPA SPL set to zero (a). The zero SPL forced the resampling algorithm to skip this detector to mitigate

the strong striping caused by the detector saturation. As the ICT saturated, GPA does not calculate ICT count, gain and NEdT values, resulting in zero value for these parameters in this case (b, c and d). Normal calibration resumed after the "BDS update".

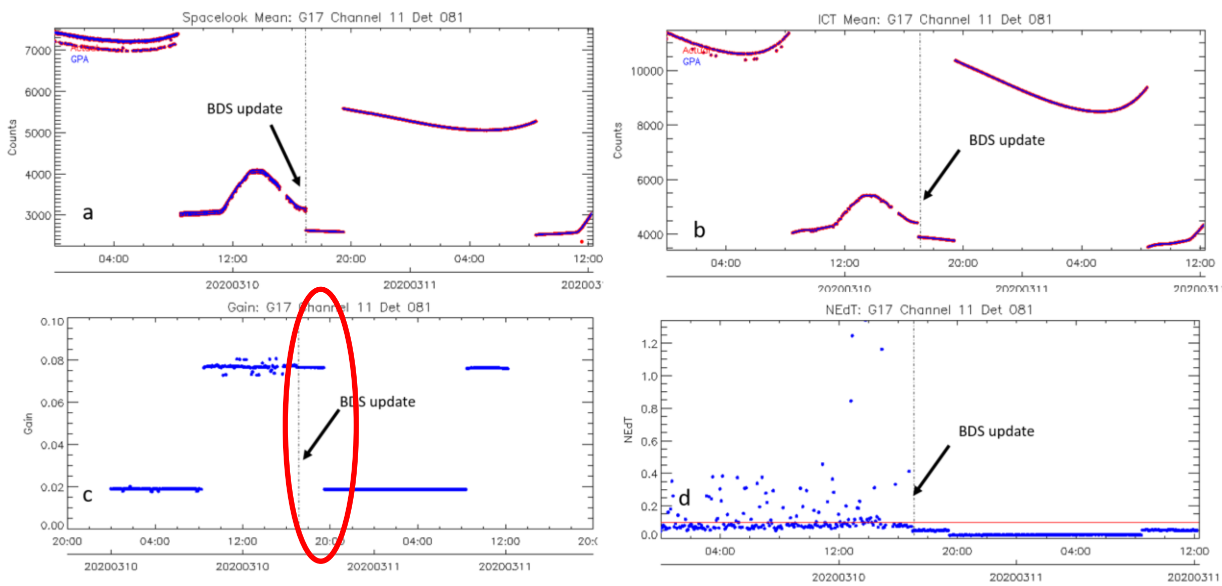

Figure 4: Similar as Figure 2, but during an episode of elevated detector noise and gain instability of GOES-17 Channel 11 Detector 81 that ended on March 10, 2020. The noise often exceeded the requirement marked by a red line in (d); the space count in (a) and ICT count in (b) were nearly bimodal; and the gain in (c) was unstable. This led to intermittent image striping. Normal calibration resumed after a "BDS update" replaced the degraded detector.

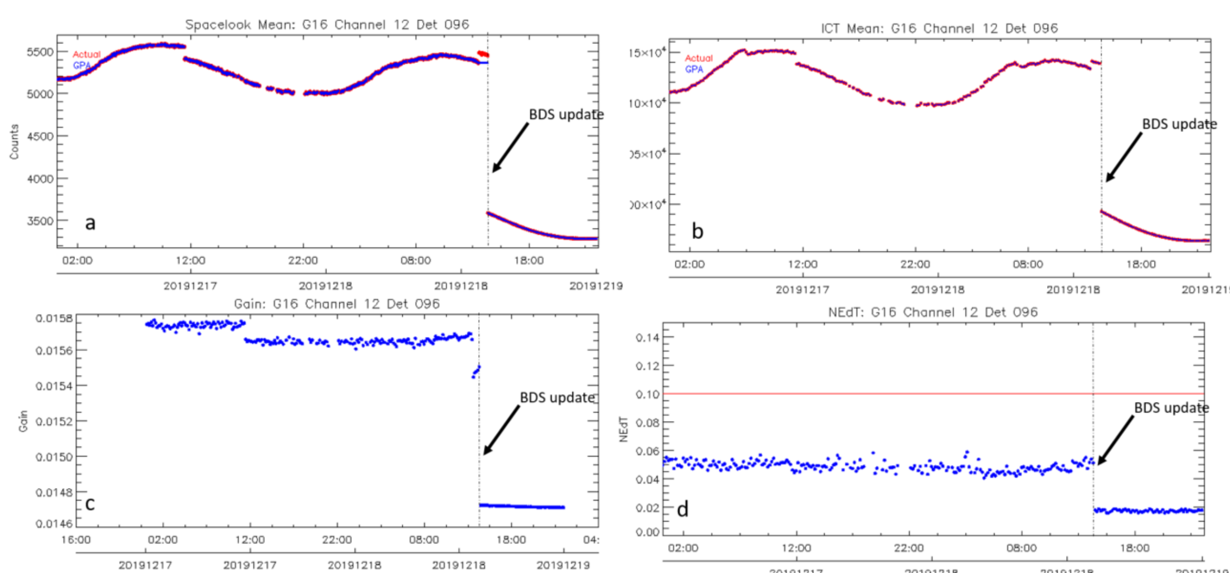

Figure 5: Similar as Figure 3, but during an episode of elevated gain instability of GOES-16 Channel 12 Detector 96 that ended on December 18, 2019. The noise in (d), though meet the requirement, was higher and less stable than usual; and the gain in (c) was unstable. This led to intermittent image striping. **Normal calibration resumed after a "BDS update" replaced the degraded detector.**

Operation Procedure

CWG learns about image striping from email notification from the Radiometric Calibration Engineer at the Office of Satellite Processing and Operation (OSPO), and from the automated notification of CWG's Instrument Performance Monitoring (IPM). Upon receiving the notification, CWG radiometric calibration lead will determine within two working days how to respond, using the following procedure:

1. Identify the offending detector(s).
2. If the offending detector is latched up after a level shift (ref. Fig. 1), recommend a manual release of the latch up.
3. If the gain of the offending detector is unstable, recommend a BDS update. In this context, the gain is unstable if
    a. Its standard deviation is five times larger than its normal value for at least one hour (ref. Fig. 3c & 4c). To compute the standard deviation, remember that gain may have diurnal variation that must be properly accounted for. This also requires computing and archiving the normal value of standard deviation for each detector when it is stable.
    b. The detector noise exceedance is more than 5% of the requirement for at least one hour (ref. 3c). The exceedance is computed as $\frac{1}{n}\sqrt{(x_i - \text{requirement})^2}$, where x_i is the noise (NEdN) exceeding the requirement, and n is the total number of noise measurements during the specified period.
4. If the ICT (or space – for Channels 13-16) count of the offending detector is saturated (ref. Fig. 2), recommend a BDS update. In this context, a detector is saturated if its daily maximum is within three times of the standard deviation of the counts. The standard deviation is computed as in "3a".
    a. If the space-look count of the offending detector is saturated (Fig 3. A), recommendation of manual reset of the space-look while preparing for the BDS update. This manual SPL reset will not be needed once the long-term fix of the lunar-intrusion algorithm is operationally implemented.
5. If none above, initiate a deep dive investigation and inform the community.

Normally, the recommendation is based on the opinions of two Subject Matter Experts (SME) who performed and reviewed the analysis. Exception can be made when only one SME is available.

The radiometric calibration lead will then notify CWG lead of the recommendation, including how many SME participated. With approval of CWG lead, the radiometric calibration lead will notify the following by email:

- OSPO ABI operation team:
  - Jessica Kronewetter: jessica.kronenwetter@noaa.gov
  - Tad Johnson: thaddeus.johnson@noaa.gov
  - Kevin Work: Kevin.Work@noaa.gov
  - John Tsui: John.Tsui@noaa.gov
- OSPO radiometric cal. team:
  - J. Paul Douglas: JPaul.Douglas@noaa.gov
  - Ken Mitchell: Kenneth.J.Mitchell@noaa.gov
- PRO:
  - Jon Fulbright: Jon.Fulbright@noaa.gov
  - Dave Pogo: dave.pogorzala@noaa.gov

Upon receiving the recommendation, OSPO will follow their procedure to implement the action (manually release the latch up or update the BDS). At the completion of the recommended action, OSPO will notify CWG radiometric calibration lead by email, who will

1. Verify the efficacy of the recommended action;
2. Report the results at a CWG meeting;
3. Update the Calibration Event Log (CEL);
4. Update the normal standard deviation for the gain of this detector;
5. Record the new BDS; and
6. Perform any other bookkeeping duties.

END