GOES-17 ABI VNIR Bands Radiometric Calibration and Performance

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INTRODUCTION

GOES-17(G17), the second of the new generation geostationary weather satellites, was launched on March 1, 2018, and became GOES-WEST on February 12, 2019. Advanced Baseline Imager (ABI) onboard G17 has six reflective channels (two Visible and four Near-IR bands), which are calibrated using their observations of the space and solar calibration targets. The GOES-R Calibration Working Group (CWG) has developed an Instrument Performance Monitoring (IPM) system to validate the VNIR calibration performance, and has the capability of deriving calibration coefficients for ABI VNIR channels to verify and improve the GS results. This poster reports major results and improvement of G17 ABI VNIR bands calibration and performance since its launch, including: 1) Mitigation of B02 ~8% bias; 2) Discovery of dependence of VNIR gains on Focal Plane Module (FPM) temperature fluctuation; 3) Striping removal with correction of erroneous detectors gains due to the lunar intrusion rejection malfunction in solar calibration at Ground Segments (GS).

METHODS

CWG developed an in-house GOES-16/17 solar calibration processing to partly verify the results of GS and other research purposes. G17 ABI VNIR channel calibration uses observations of the solar calibration target (SCT) and solar calibration space look, following the solar calibration equation to calculate the detector gains (m) of VNIR bands, which depends on the parameters $f_{\text{int,ch}}$, $L_{\text{SCT}}^{\text{eff}}$, $\bar{x}_{\text{SCT}}$,$\bar{x}_{\text{Solar\_Cal\_Space}}$, Q, $(f_{int,ch})$ and p. Where m denotes VNIR band gain, $f_{\text{int,ch}}$as solar calibration integration factor 9, $L_{\text{SCT}}^{\text{eff}}$ as Effective SCT channel average spectral radiance, and Q is quadratic coefficient for each detector in bands. $\bar{X}$ is the average of scene count for SCT and space look view, reprehensively. p is the Integration factor power term (per channel), specified in the algorithm. The computation of $L_{\text{SCT}}^{\text{eff}}$ depends on the distance from Earth to sun, Sun-to-SCT diffuser normal angle of incidence, the effective bidirectional reflectance distribution function (BRDF) and mirror reflectivity.

The solar calibration gain was then applied in the Earth scene calibration following the equation (Eq 1):

$$Rad = \frac{m*DN+Q*DN*DN}{\rho_{EW}^{scene}*\rho_{NS}^{scene}} \qquad (1)$$

Where Rad is for the calibrated Earth radiance. DN is for delta count from the raw Earth count with subtracting the background space look view count, $\rho_{EW}^{scene}$and ρ_{NS}^{scene} are the reflectivity of the NS and EW scan mirror.

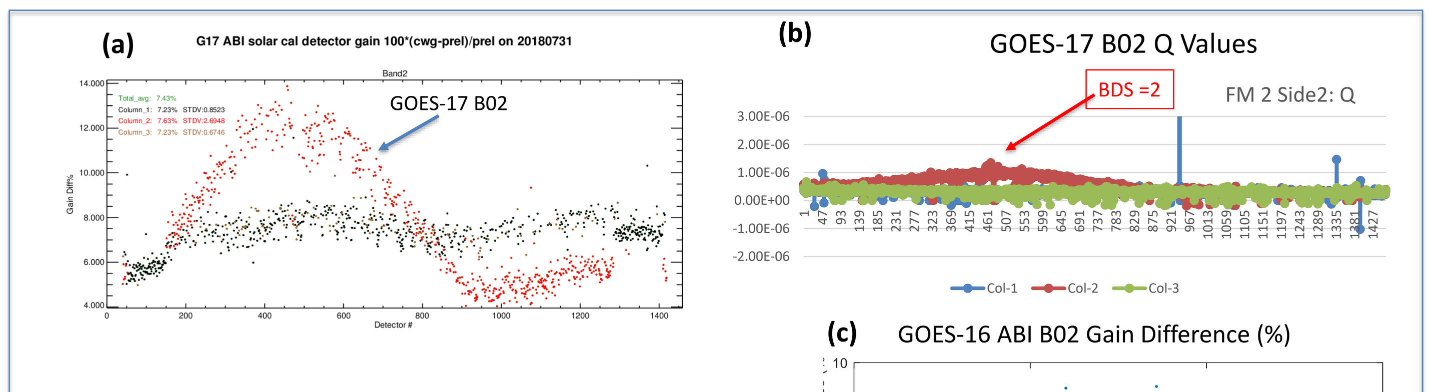
Beside of in-house solar calibration, CWG has developed an Instrument Performance Monitor (IPM) system that includes metrics for G17 ABI striping identification and characterization.

RESULTS

➢ Mitigation of G17 B02 bias

Similarly as G16, G17 ABI B02 was biased ~8.5% high from GEO-LEO monitoring after its launch and the gain difference between post-launch solar calibration vs pre-launch was ~ 7.43%. CWG's analysis (Xi et al. 2019) shows a similar bias can be found in HIMAWARI-8/9 AHI band. The gain/Q from sphere calibration should not be used to for LEF calibration (irradiance) to derive K-LUT at low signal range because of its dynamical range, which in fact results in the bias in K-LUT. Uncertainty or nonlinearity in the prelaunch FEL test in ABI B02 can directly affect K and then the gain from post-launch solar calibration.

Thus, CWG submitted a new G17 solar diffuser K-LUT (scaled down by 7.43%). The new K-LUT was implemented in OE on 05/05/2019 and the B02 bias was mitigated successfully.



GOES-17	BDS = 1	BDS = 2	BDS=3	All BDS
Gain Difference (%)	7.23	7.63	7.23	7.43
STD (%)	0.852	2.695	0.675	

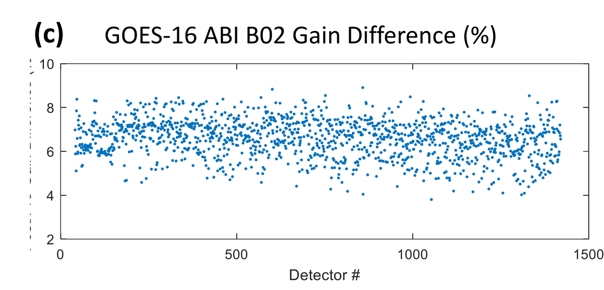


Fig. (a) G17 B02 detector-level post/pre-launch gain on 07/31/2018. (b)Large oscillation in Pre/Post-gain difference vs. detector was related to the larger (out family) Q factor for BDS=2. (c) G16 B02 performance was shown in bottom right.
Tab. the mean ratios of the detector from the different BDS.

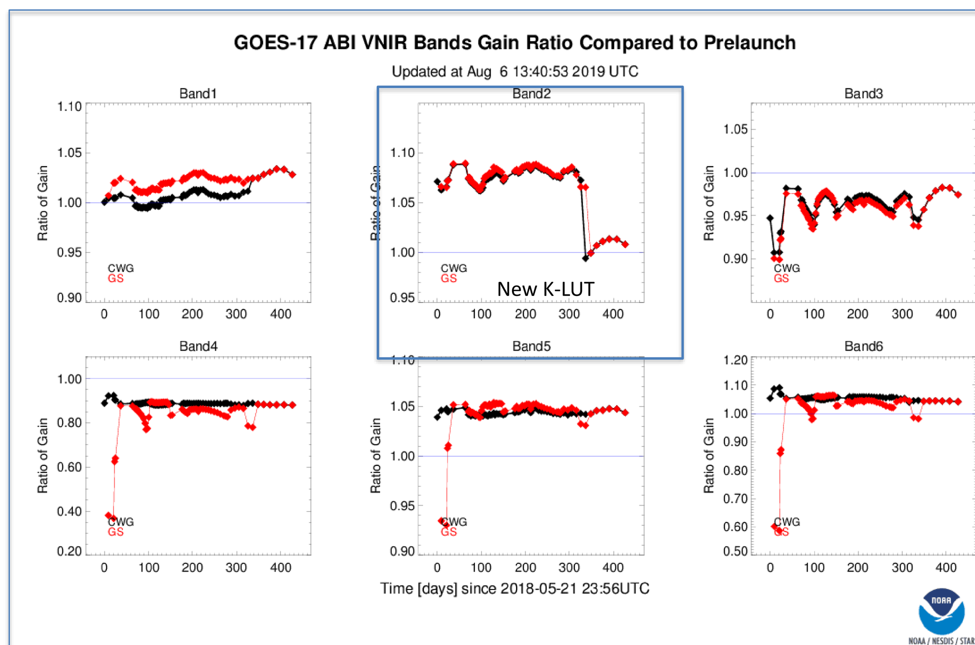


Fig. G17 ABI VNIR bands mean gain ratio to the prelaunch for CWG (black) and GS (red) since 05/21/2017. The new K-LUT was implemented in OE on 05/05/2019, which was originally scheduled on 04/23/2019 as CWG did. The B02 bias was mitigated successfully.

➢ VNIR gains vs FPM temperature fluctuation

Different from G16, G17 Loop Heat Pipe (LHP) was found malfunctioned. It brings up to 20K seasonal variation of VNIR FPM temperature superimposed on the diurnal fluctuation of up to 12K in eclipse season. Through the changes of SCT and space look view accordingly, CWG indicates that such a large VNIR FPM temperature fluctuation affects the solar calibration. Especially in G17 B03, its gain is highly anti-correlated to the VNIR FPM temperature fluctuation, while B04 is positively correlated due to the response of their different photodetector characteristics. VNIR FPM temperature change can bring B03 a gain change of 0.27%/1k and 0.1%/1k in B02/B04. A bias will be expected to be introduced into the Earth scene calibration if the gain is not updated timely in eclipse season. To reduce the impacts of FPM temperature fluctuation, several potential mitigation scheme options thus are proposed and compared.

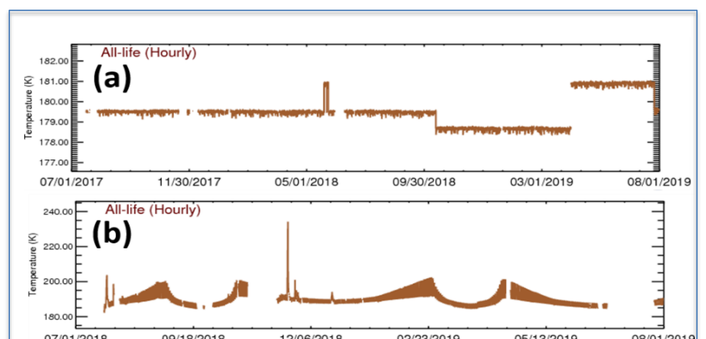


Fig. (a) G16 VNIR FPM temperature. (b) G17

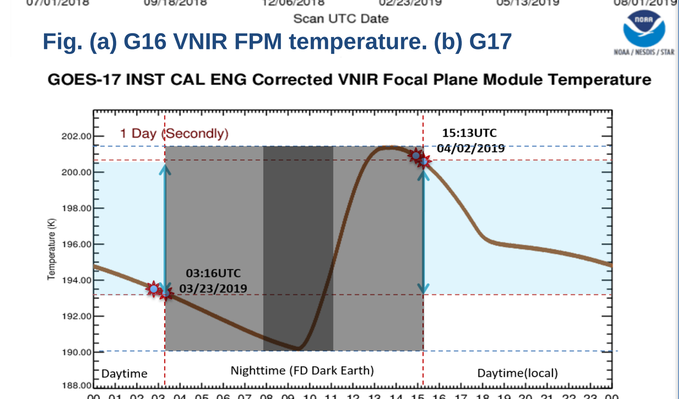


Fig. Timing of solar calibration events at the large diurnal variation of VNIR FPM.

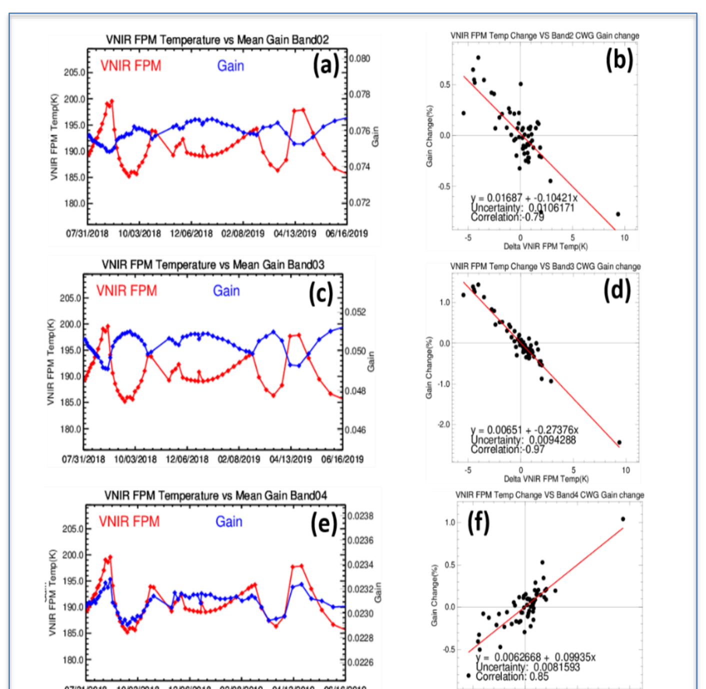


Fig. G17 ABI VNIR B02/0/04 mean gain vs VNIR FPM temperature. (b) Mean gain rate vs VNIR FPM temperature rate with a linear regression fitting

FPM	Band	Wavelength (μm)	Detectors	Detector Type	Resolution (km)
VNIR	1	0.47	676	SiliconPINDiode	1
	2	0.64	1460	SiliconPINDiode	0.5
	3	0.86	676	SiliconPINDiode	1
	4	1.38	372	HgCdTe HDVIP	2
	5	1.61	676	HgCdTe HDVIP	1
	6	2.25	372	HgCdTe HDVIP	2

Bands	B01	B02	B03	B04	B05	B06
Slope	-0.012	-0.104	-0.274	0.099	-0.006	0.055
Uncertainty	0.00983	0.01062	0.00943	0.00816	0.00819	0.00981
Correlation	-0.15	-0.79	-0.97	0.85	-0.1	0.59

Tab. Slopes, uncertainty and correlation from the linear regression.

Mitigation schemes	Advantages	Disadvantages
Frequent solar calibration at the eclipse season	▪ Accurate gain update in time, compared to an increasing cadence of solar calibration originally	▪ Increase the expose of solar diffuser to the Sun and quicken its degradation ▪ Large diurnal variation of FPM temperature
Normal solar calibration with continuous gain adjustment with tracing FPM temperature fluctuation	▪ Accurate gain adjustment in time ▪ No issue of quickening solar diffuser degradation	▪ GS processing capability ▪ FPM temperature anomaly
Normal solar calibration with step gain adjustment at certain position of FPM temperature fluctuation	▪ Feasibility in implementation ▪ No issue of quickening solar diffuser degradation	▪ Less accurate gain adjustment ▪ Partly diurnal correction ▪ GS processing capability ▪ FPM temperature anomaly

Tab. Comparison of mitigation schemes to reduce impacts of FPM temperature on G17 VNIR gains.

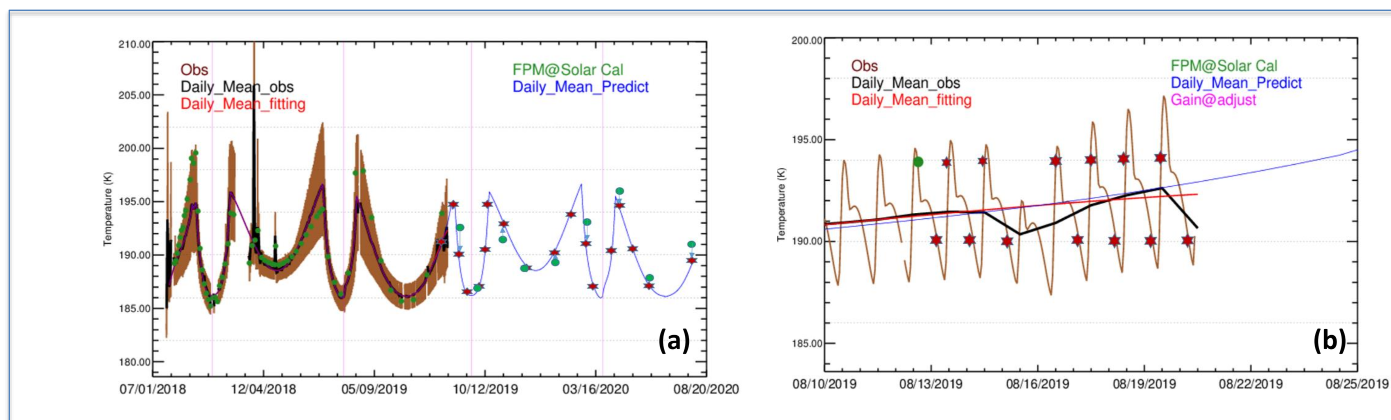


Fig. (a) Diagram illuminating the FPM temperature at solar calibration events and gain adjustment in mitigation scheme in seasonal scale. (b) Adjustment in the diurnal variation of FPM.

➢ VNIR Striping removal

Striping pattern noise, primarily in the horizontal direction, exists in G17 ABI L1b products. For this purpose, the CWG has developed a metrics tool for ABI striping identification, quantification and characterization. The root cause of striping has been found to predominately arise from calibration algorithm deficiencies and artifacts. CWG identified that G17 VNIR B02/05/06 L1b images had suffered with striping in certain periods, which was related to the faulty of GS solar calibration. The root-cause was found to be with the wrong lunar intrusion rejection LUT used, resulting in a latch-up the solar space look and erroneous detector gains. This striping was removed successfully in those bands after the new LUT in OE since 05/05/2019 (Black et al. 2019, Qian et al.2019).

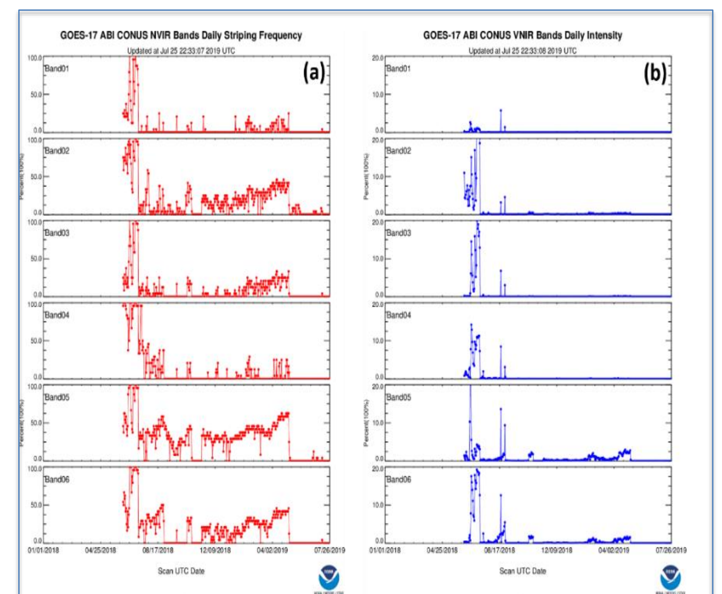


Fig. Statistics of striping occurrence frequency and intensity in percentage for G17 ABI VNIR bands.

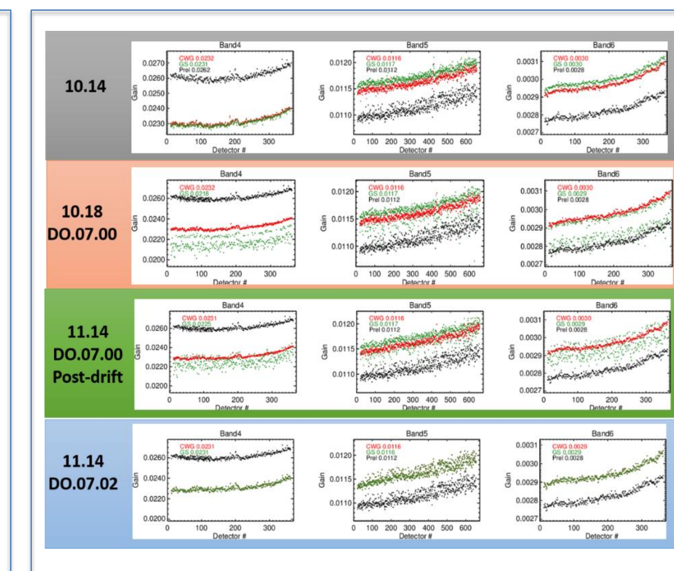


Fig. G17 ABI VNIR bands detector gains from the prelaunch, CWG and GS for the several solar calibration events.

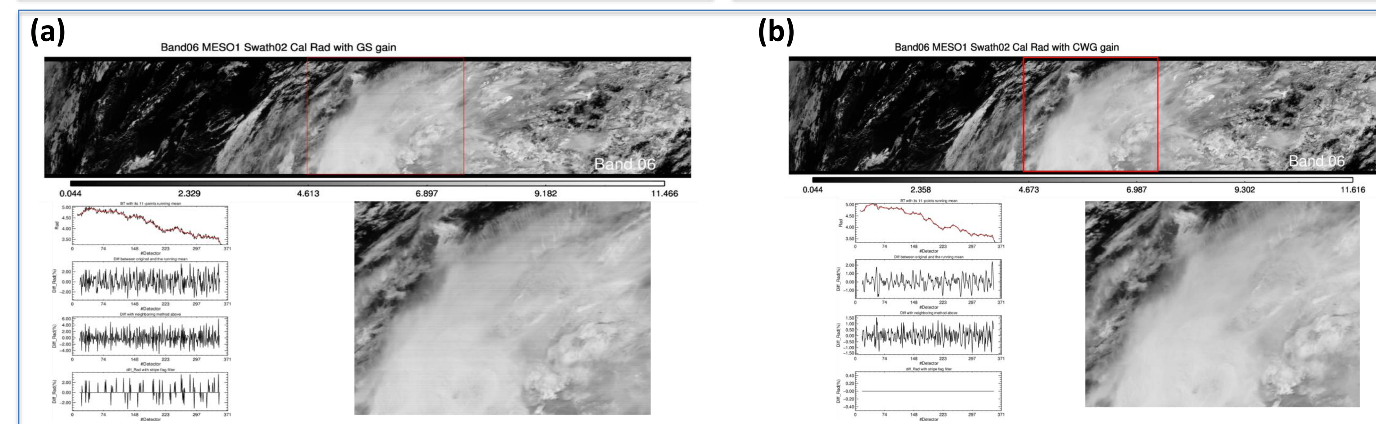


Fig. (a) An example of G17 B06 L1alpha swath radiance with the GS gain (Top), which repeated the striping in the location as OE L1b image. (b) Same as (a), but for B06 L1alpha radiance image with the CWG gain, which shows clear image without striping.

CONCLUSIONS

1) **CWG has developed tools to validate G17 ABI reflective channel radiometric calibration and performance and supports to improve the GS results after its launch.**
2) **G17 B02 ~8% bias was mitigated with a new CWG K-LUT implemented in OE since May 2019.**
3) **CWG identified a dependence of G17 VNIR gains on the FPM temperature fluctuation in seasonal scale and quantified it with the proposal of mitigation schemes to reduce the impacts of FPM temperature fluctuation.**
4) **G17 VNIR bands L1b images quality was significantly improved with striping removal since May 2019. This is due to correction of the erroneous detector gains with the new lunar intrusion rejection LUT.**

REFERENCES

1. Shao X. et al. GOES-17 Calibration Working Group report, College Park, Maryland, April 2019.
2. Kalluriet, S., Alcala, C., Carr, J., Griffith, P., Lebair, W., Lindsey, D., Race, R., Wu, X. Q. and Zierk, S., "From photons to pixels: processing data from the advanced baseline imager," Remote Sens.10, 177 (2018). https://doi.org/10.3390/rs10020177.
3. Van Naarden, J., "Recommended configuration for GOES-17 ABI at the start of post-launch testing", Harris-ABI Tech Memo, (2018).
4. Black B. et al. GOES-17 Calibration Working Group report, College Park, Maryland, April 2019.
5. Qian H. et al. GOES-17 Calibration Working Group report, College Park, Maryland, April 2019.
6. CDRL0079/CDRL0080 ABI_Calibration_Handbooks.

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