In-Orbit Radiometric Calibration Accuracy of GOES-16/17 Advanced Baseline Imager (ABI)

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GOES-16 launch

Acknowledgements: Previous CWG team members, GOES-R AWG Team, GOES-R Flight Team, GOES-R Program Office, GOES-R MOST Team, GRATDAT Team, MIT/Lincoln Laboratory, and NOAA OSPO Engineers etc.

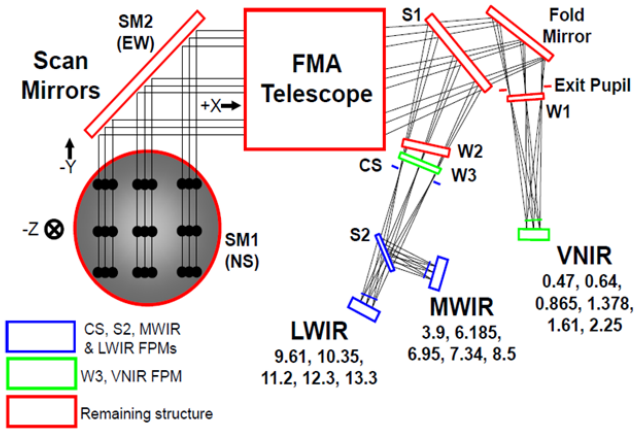
GOES-17 launch

GOES-16/17

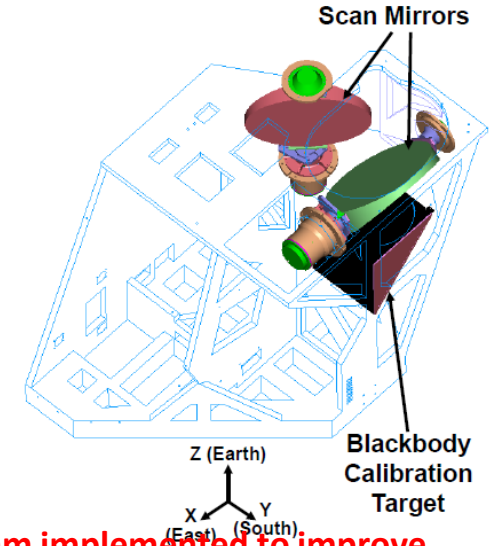
- **NOAA's new generation operational weather satellites at the geostationary orbit**
  - **Advanced Baseline Imager (ABI) is the primary payload**
- **GOES-16: GOES-East at 75.2°W**
  - **Launched on 19 November 2016, became operational as GOES-East on 18 December 2017**
- **GOES-17: GOES-West at 137.2°W**
  - **Launched on 1 March 2018, became operational as GOES-West on 12 Feb 2019.**

Advanced Baseline Imager (ABI)

- **ABI Bands: 16 bands**
  - 6 visible and near-infrared (NVIR) bands
  - 10 infrared (IR) bands
- **Two independent scan mirrors**
  - North-South (NS)
  - East-West (EW)
- **On-orbit calibration for all the bands**
  - On-orbit solar diffuser (SD) for VNIR bands
  - Blackbody for IR bands



ABI Optical Architecture

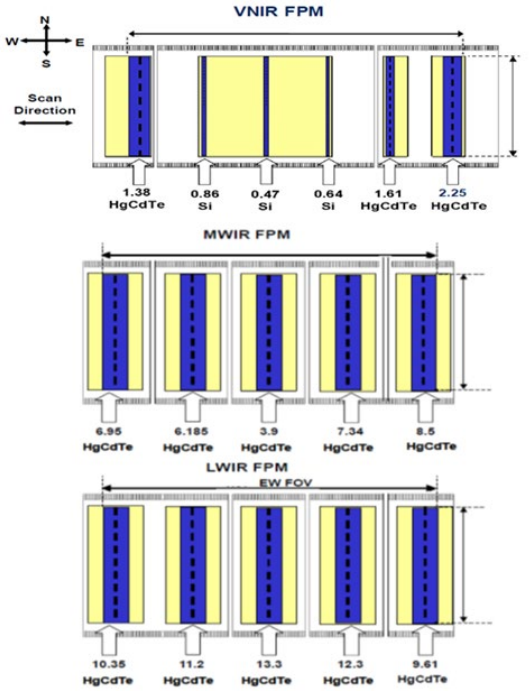


Compared to precedent Imager, many advanced technology and new algorithm implemented to improve the spectral/radiometric/navigation accuracy to higher levels

ABI Bands

- **ABI Bands:**
  - **6 VNIR bands**
  - **10 infrared (IR) bands**

Band	FMP	Central Wvlen (μm)	IFOV EW (urad)	IFOV NS (urad)	Columns	Rows
1	VNIR	0.47	22.9	22.9	3	676
2		0.64	12.4	10.5	3	1460
3		0.87	22.9	22.9	3	676
4		1.38	51.5	42.0	6	372
5		1.61	22.9	22.9	6	676
6		2.25	51.5	42.0	6	372
7	**MWIR**	**3.9**	**51.5**	**47.7**	**6**	**332**
8		**6.2**	**51.5**	**47.7**	**6**	**332**
9		**6.9**	**51.5**	**47.7**	**6**	**332**
10		**7.3**	**51.5**	**47.7**	**6**	**332**
11		**8.5**	**51.5**	**47.7**	**6**	**332**
12	**LWIR**	**9.6**	**51.5**	**47.7**	**6**	**332**
13		**10.4**	**34.3**	**38.1**	**6**	**408**
14		**11.2**	**34.3**	**38.1**	**6**	**408**
15		**12.3**	**34.3**	**38.1**	**6**	**408**
16		**13.3**	**34.3**	**38.1**	**6**	**408**

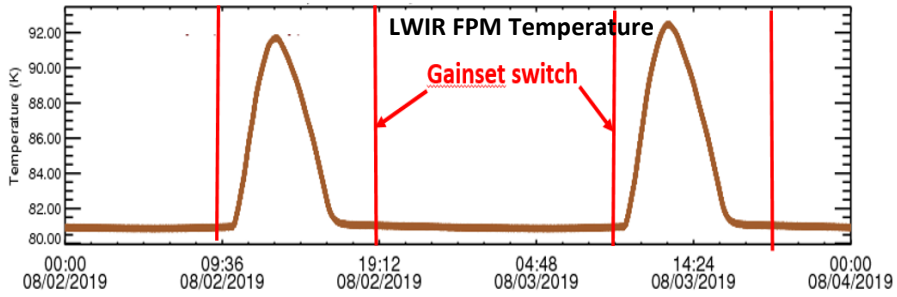


ABI focal plane modules

Hundreds to thousands of detectors from different columns for each band

G17 ABI Loop Heat Pipe (LHP) Anomaly and Mitigation Efforts

- **LHP anomaly detected in late April 2018 causes the malfunction of the cooling system**
  - **Degraded data quality at all IR channels**
- **Great progress to optimize the ABI performance**
  - **Changes of the focal plane module (FPM) operation temperature**
    - Visible and Near-Infrared (VNIR) FPM: floating
    - Infrared (IR) FPMs: controlled at an elevated temperature (~81K) + floating when not controlled
  - **Gain-set switch as needed**
    - Currently set the gain-set switch at fixed time for B08-B16 for the days when the max IR FPM temperature reaches the threshold
  - **Adjustments of operational procedures**
    - Timeline adjustment
    - More frequency of blackbody calibration
  - **Yaw-flip semi-annually**
  - **Algorithm changes**
    - Predictive calibration algorithm (pCal) implementation to improve the cal. accuracy during the unstable FPM period
    - Update RadCal LUTs to reduce striping
    - FPM temperature adjusted solar calibration coefficients for the VNIR bands (ongoing effort)
    - New IR spectral response function (SRF) at 81K (ongoing effort)
    - ….



Objectives

- **To validate and monitor the GOES-16/17 ABI radiometric Calibration Accuracy since in-orbit**
  - **Absolute Calibration Accuracy**
  - **Relative Calibration Variation within Field of Regard (FOR)**
    - Spatial uniformity within FOR
    - Response versus Scan-angle (RVS) for the two scan mirrors
    - Detector-to-detector variation for hundreds to thousands of detector per band

Methodology

- **Absolute Calibration Accuracy**
  - **Global Space-based Inter-Calibration System (GSICS) as the primary tools**
    - Reference instruments for VNIR bands: SNPP VIIRS and NOAA20 VIIRS
    - Reference instruments for IR bands: SNPP CrIS, NOAA20 CrIS, Metop-A/B/C IASI
    - Reference instrument for GOES-17 IR diurnal variation: GOES-16 ABI

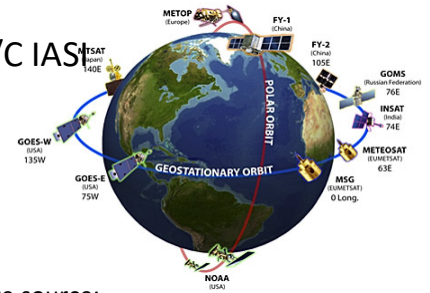
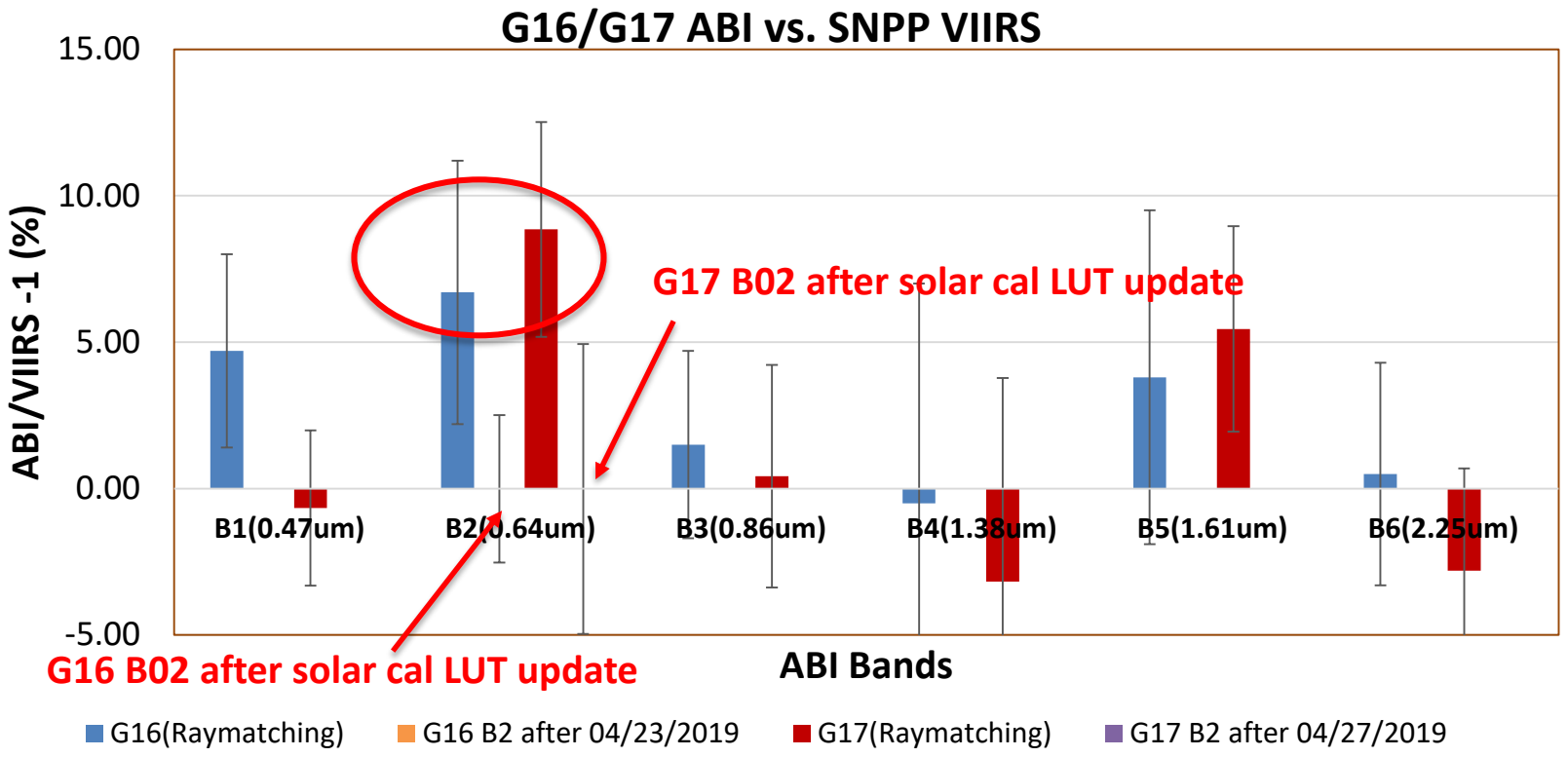


Image source: https://www.star.nesdis.noaa.gov/smcd/GCC/index.php

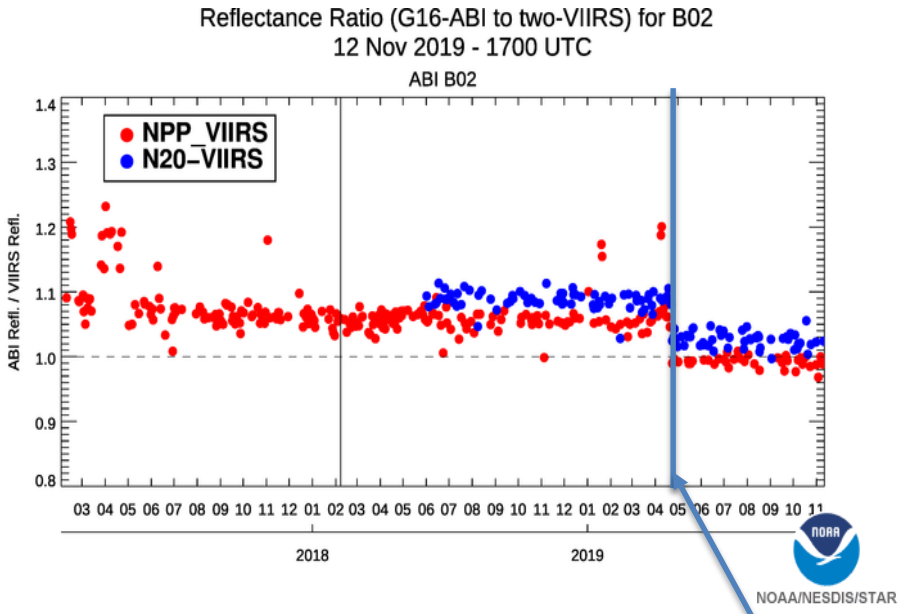
- **Relative Calibration Variation with FOR**
  - **RVS for VNIR bands: lunar irradiance model**
  - **RVS for IR bands: Special space scans**
  - **Detector-to-detector variation: Lunar North-South Scans (NSS)**

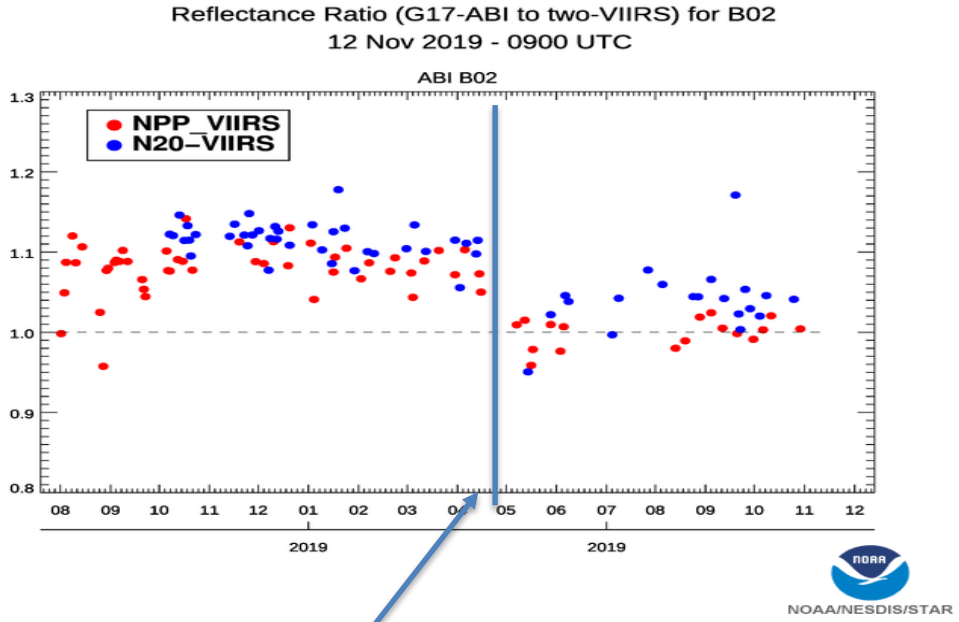
Rad. Calibration Accuracy for VNIR Bands



- **Ray-matching method shows that most of G16/G17 VNIR bands are generally within 5% difference to SNPP/VIIRS, except for B2 (0.64µm) at both G16/G17 satellites.**
- **The updated solar diffuser BRDF look-up table, which was derived based on the prelaunch measurements, was implemented for G16 on 04/23/2019 and G17 on 04/27/2019 to mitigate the large bias for these two bands.**
  - **The new Biases to VIIRS are greatly reduced**

Time-series of ABI vs. VIIRS Calibration Difference



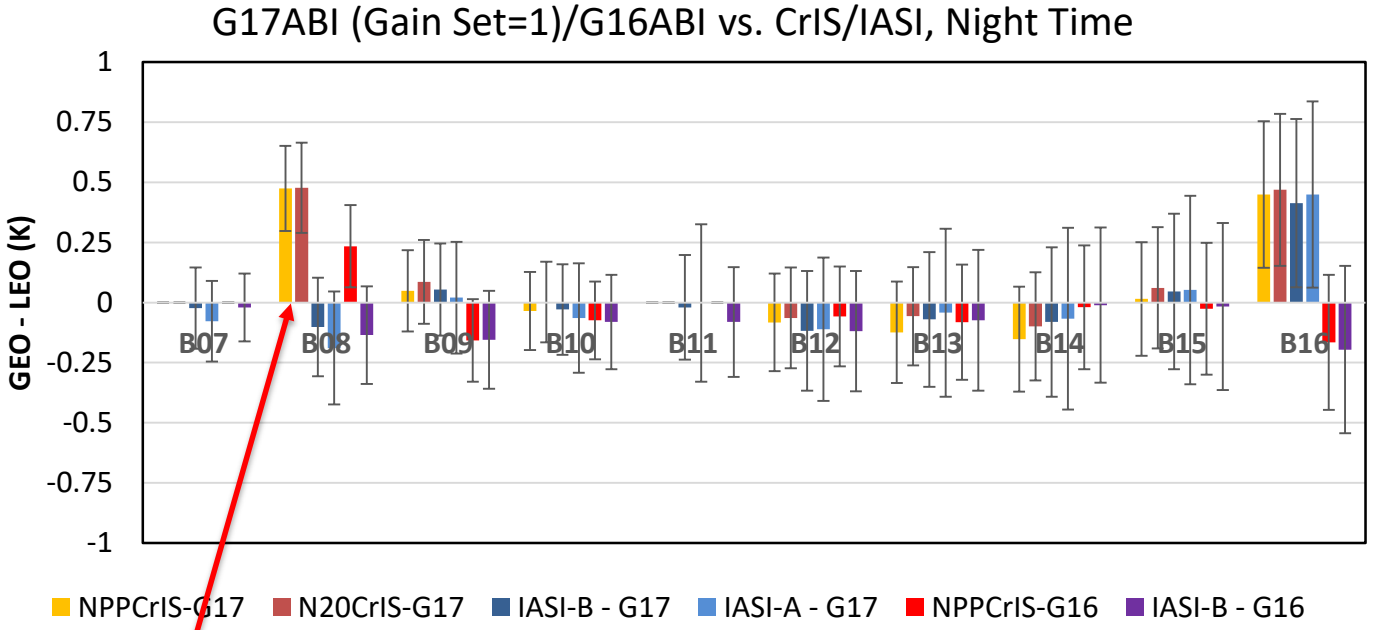


B02 Solar Cal. LUT update

Monitoring for all the VNIR bands are available at:

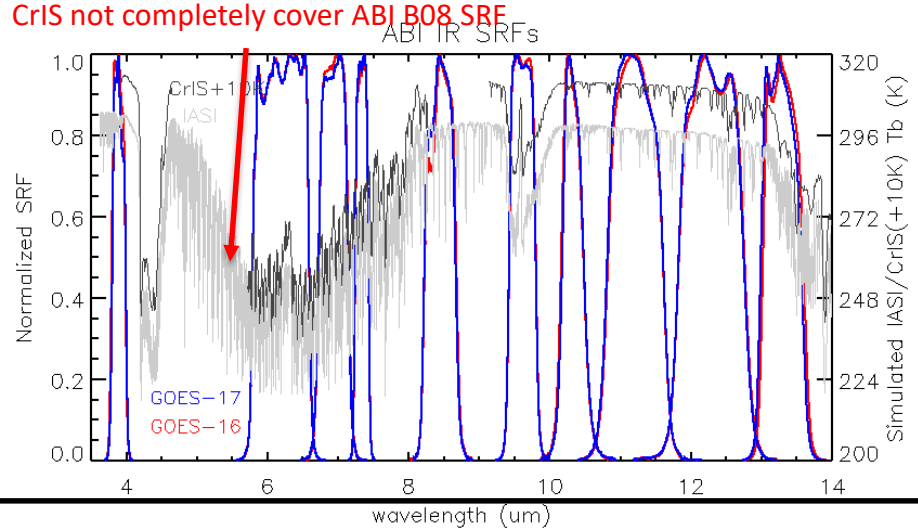
https://www.star.nesdis.noaa.gov/GOESCal/G16_ABI_VNIR_InterCal_static.php
https://www.star.nesdis.noaa.gov/GOESCal/G17_ABI_VNIR_InterCal_static.php

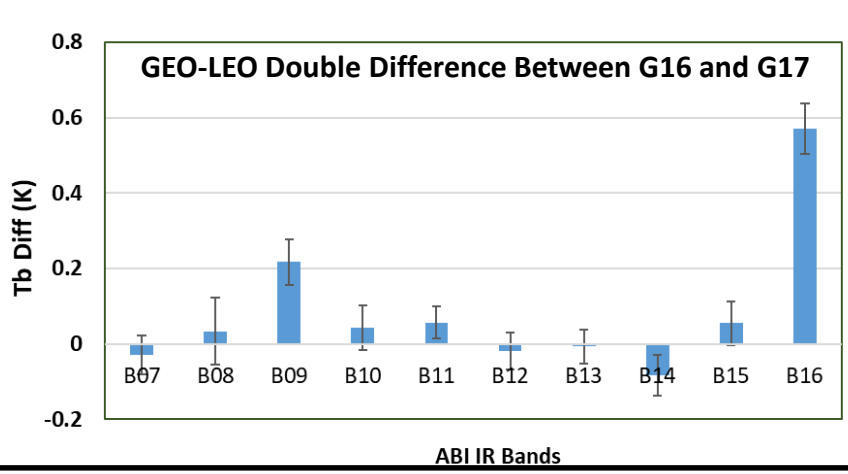
G16/17 IR Calibration Accuracy



GOES-17 ABI data are from Gainset I period

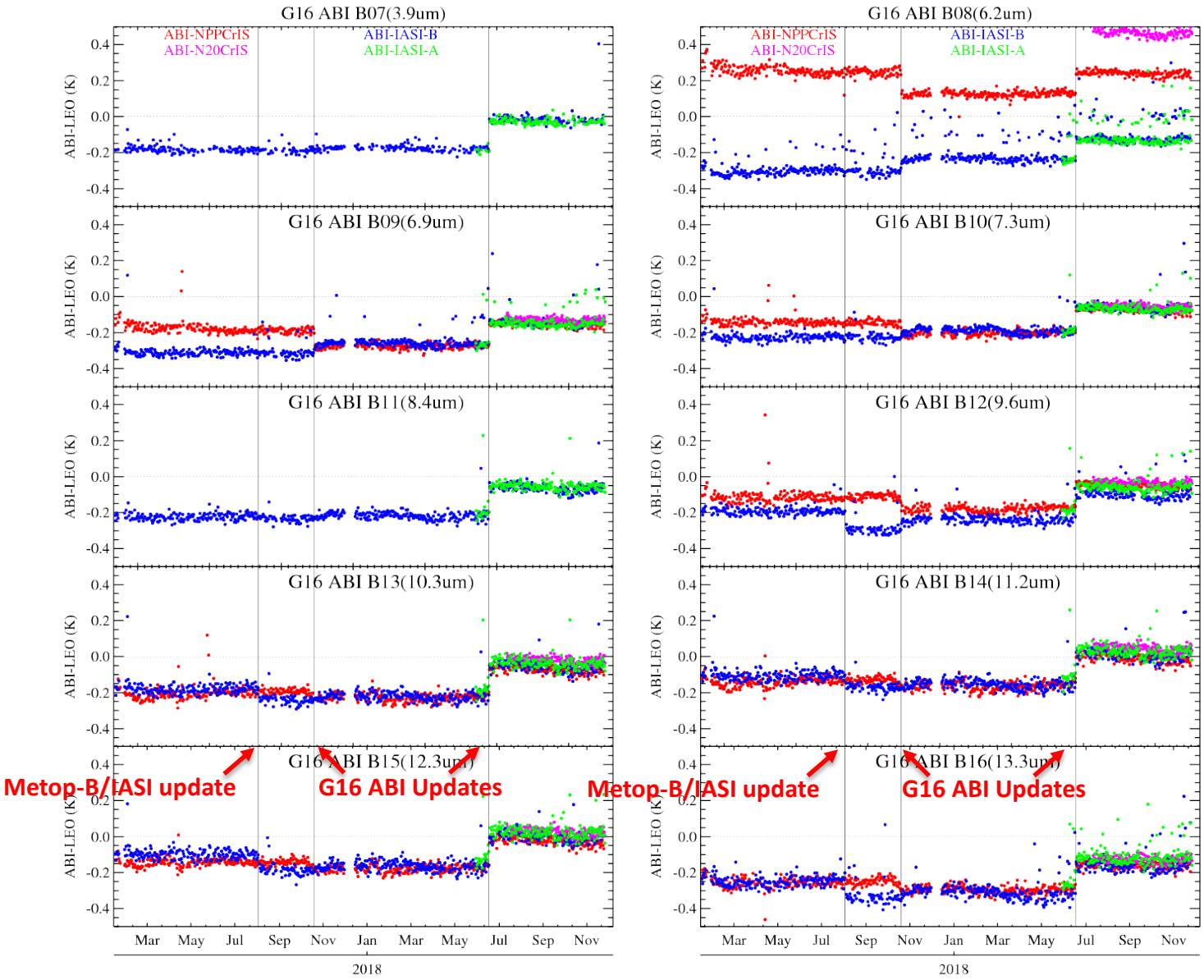
CrIS not completely cover ABI B08 SRF





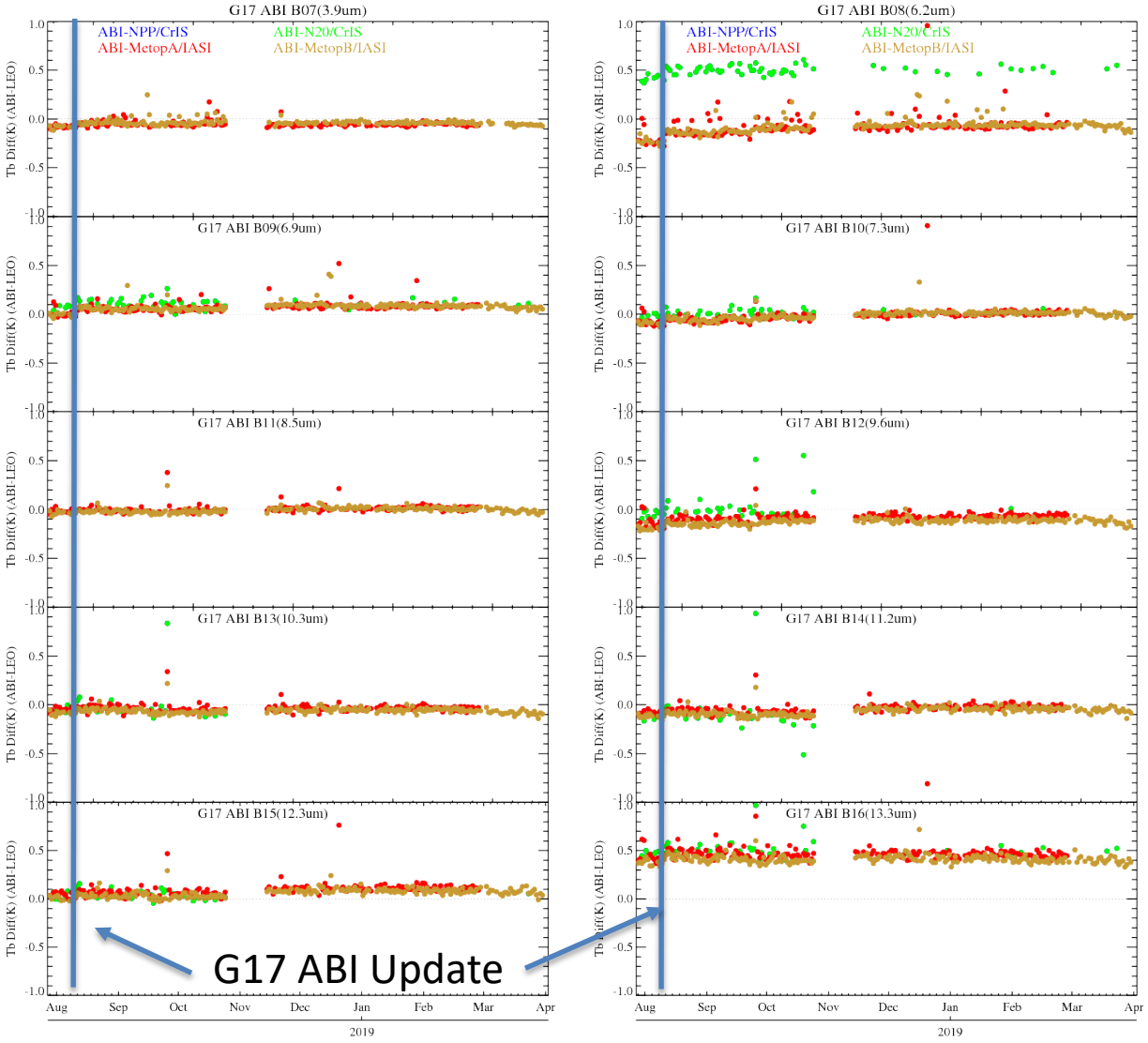
Comparable to G16 with mean difference less than 0.2K , except for B09 (0.22K) and B16 (0.57K)

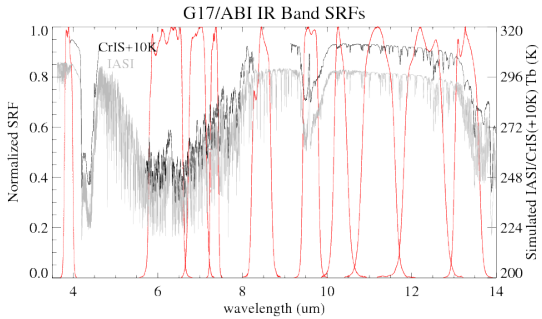
Long-term Monitoring of G16 IR



More detailed daily and long-term monitoring available at: https://www.star.nesdis.noaa.gov/GOESCal/G16_ABI_IR_InterCal_static.php

Long-term Monitoring of G17 IR Calibration Accuracy at Stable FPM Period

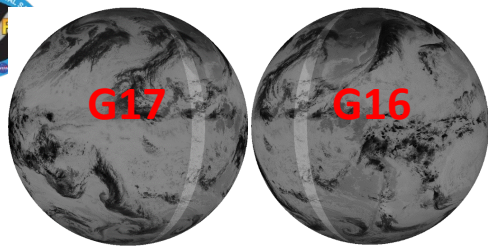


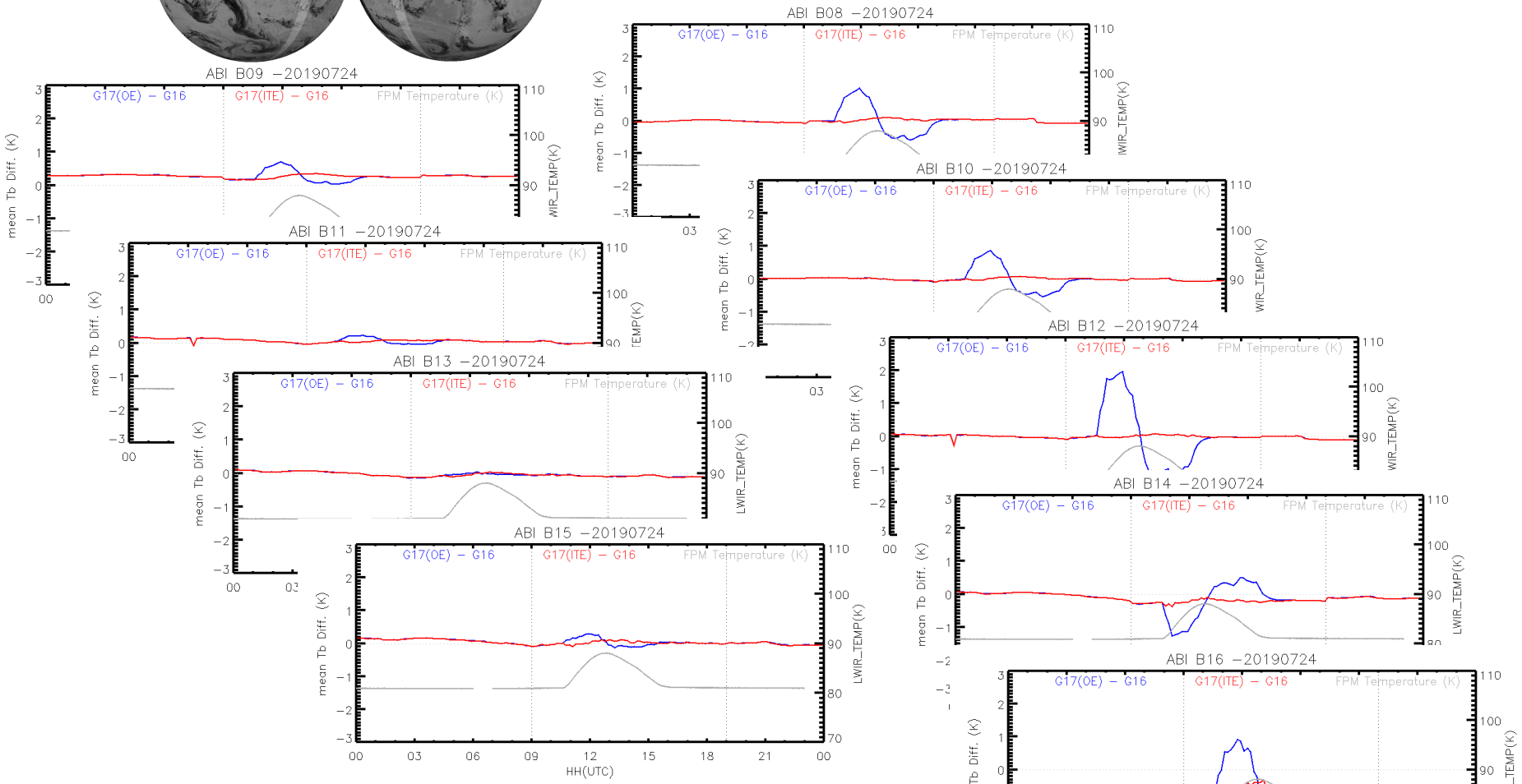


Very stable by monitoring the inter-calibration results with Metop-A/B IASI and NPP/N20 CrIS.

More detailed daily and long-term monitoring available at: https://www.star.nesdis.noaa.gov/GOESCal/G17_ABI_IR_InterCal_static.php

the pCal Performance Validation





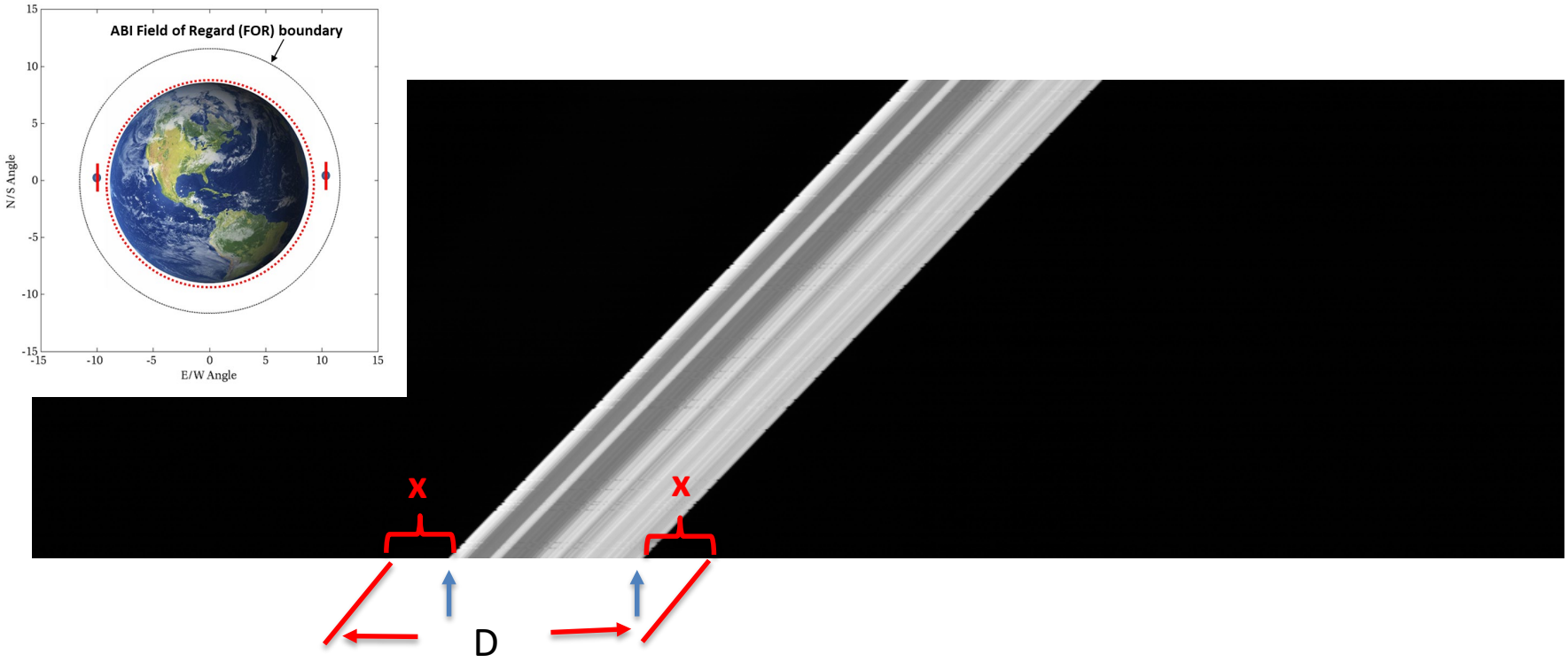
OE: without pCal algorithm

ITE: with pCal algorithm turn-on

FPM temperature

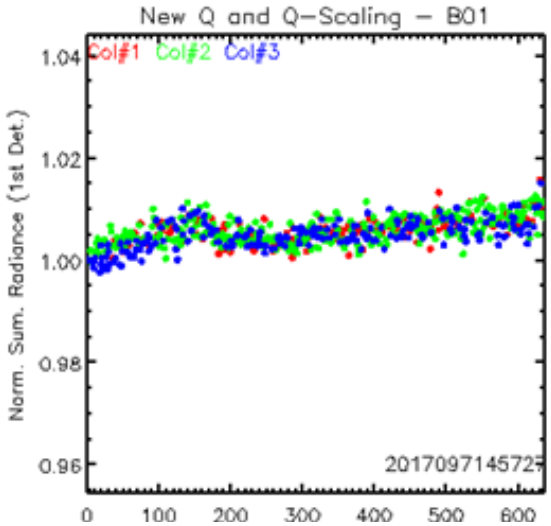
The pCal algorithm significantly improves the G17 IR radiometric Calibration accuracy at the unstable FPM time

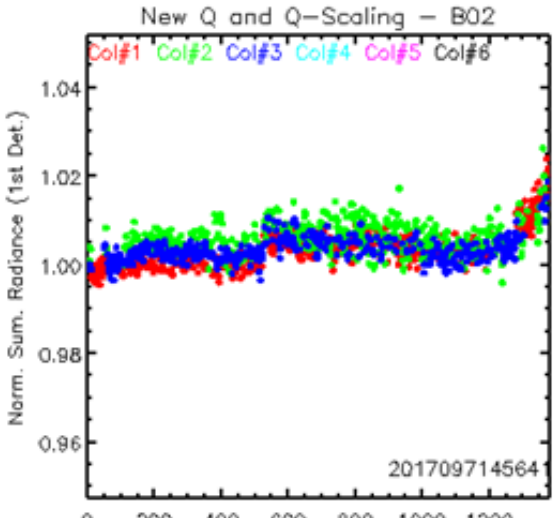
Detector Response Uniformity - method

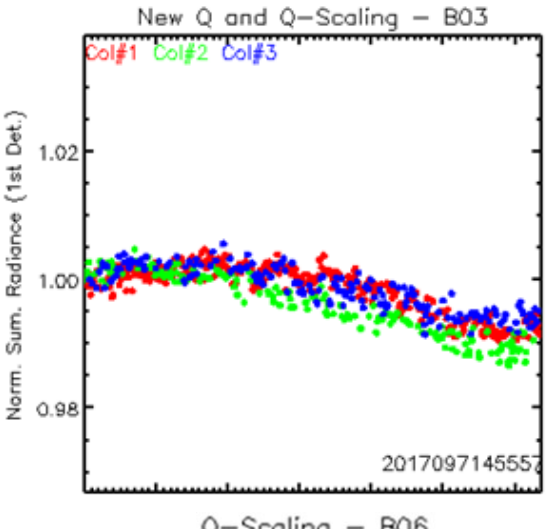


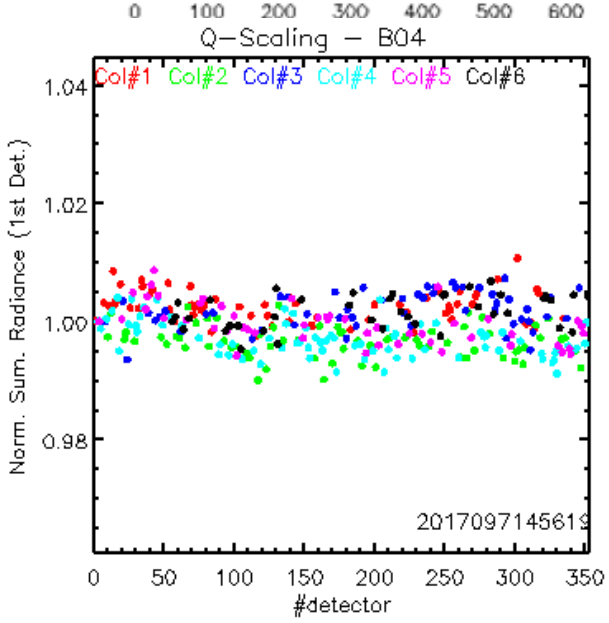
1. Identify the illuminated lunar edge for each detector
2. Vicinity space samples (x) used to compensate for the partial illuminated area, OOF/blooming, and detector noise effects
3. Summarize the radiance of the illuminated lunar surface samples and the vicinity space samples
4. Normalize the summarized radiance to the first column radiance value

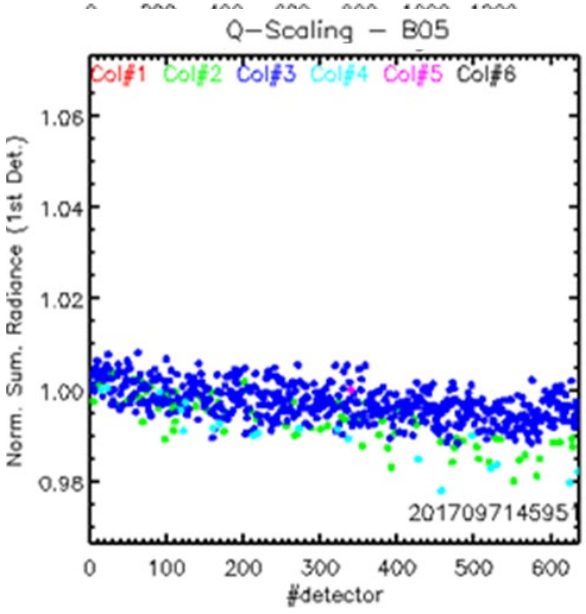
G16 VNIR Detector Uniformity

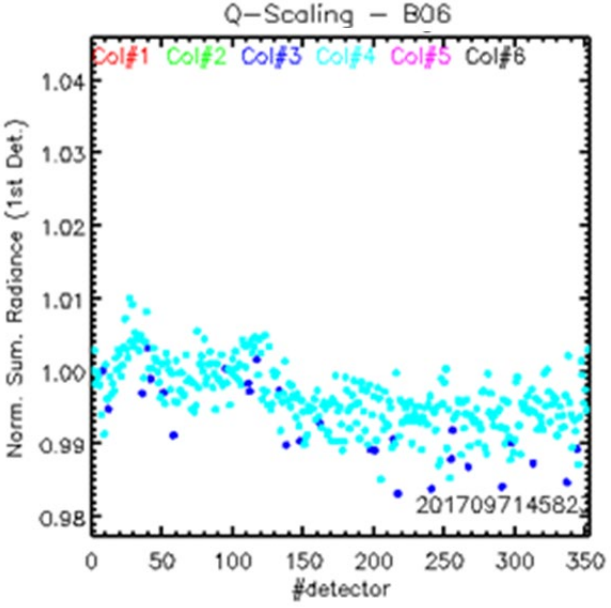






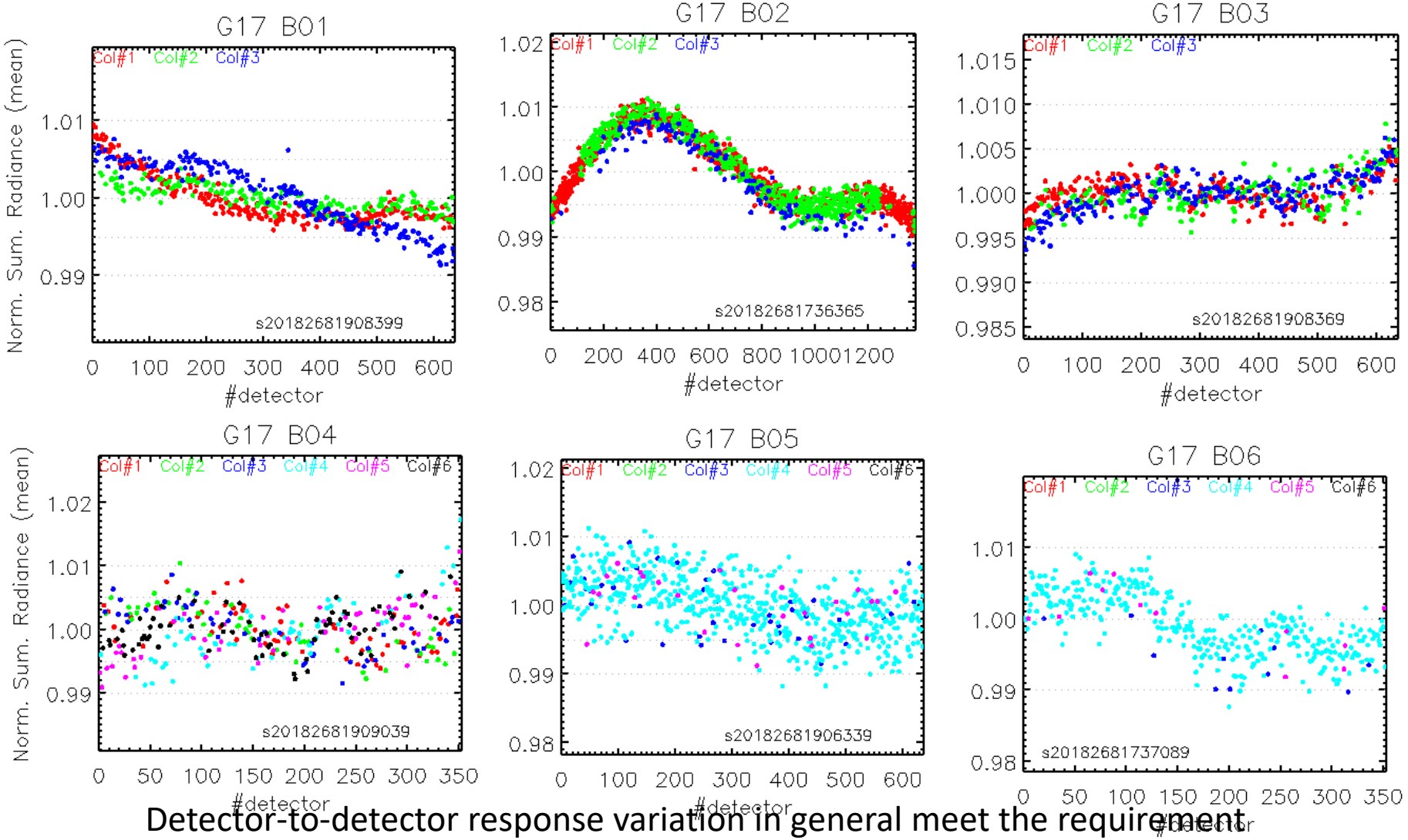






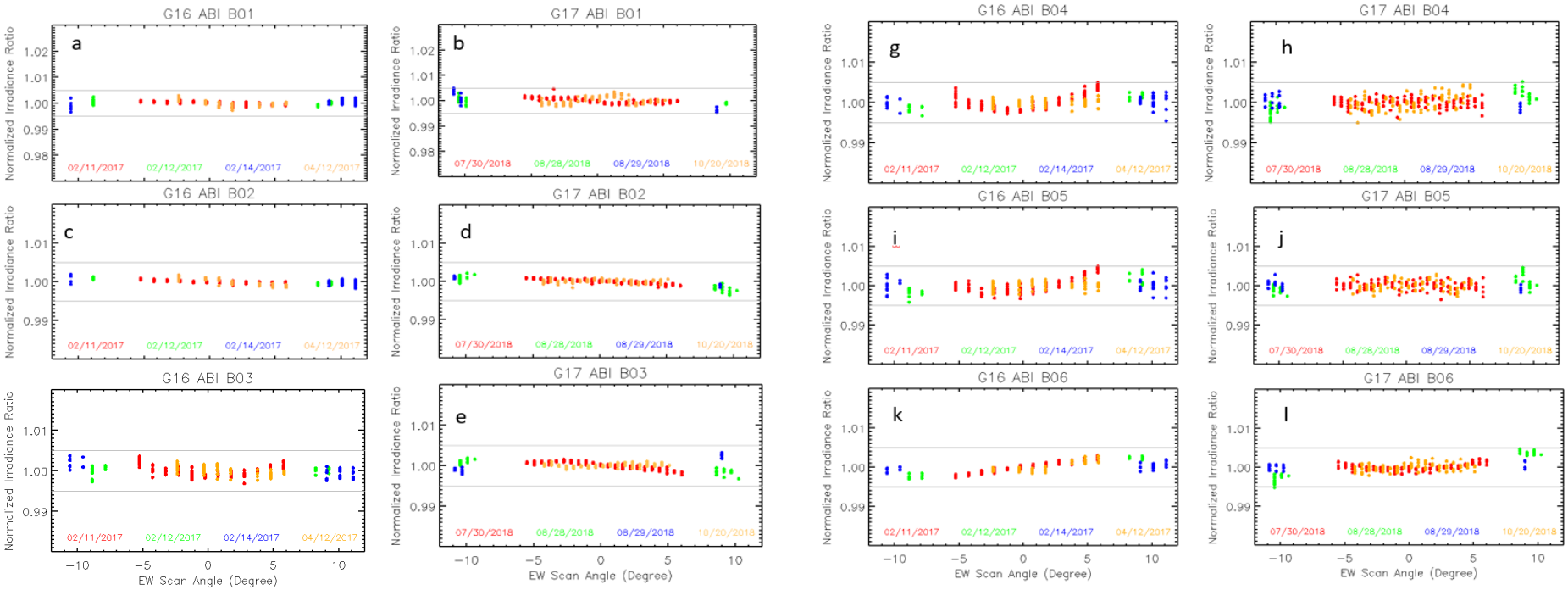
Detector-to-detector response variation in general meet the requirement

G17 VNIR Detector Uniformity



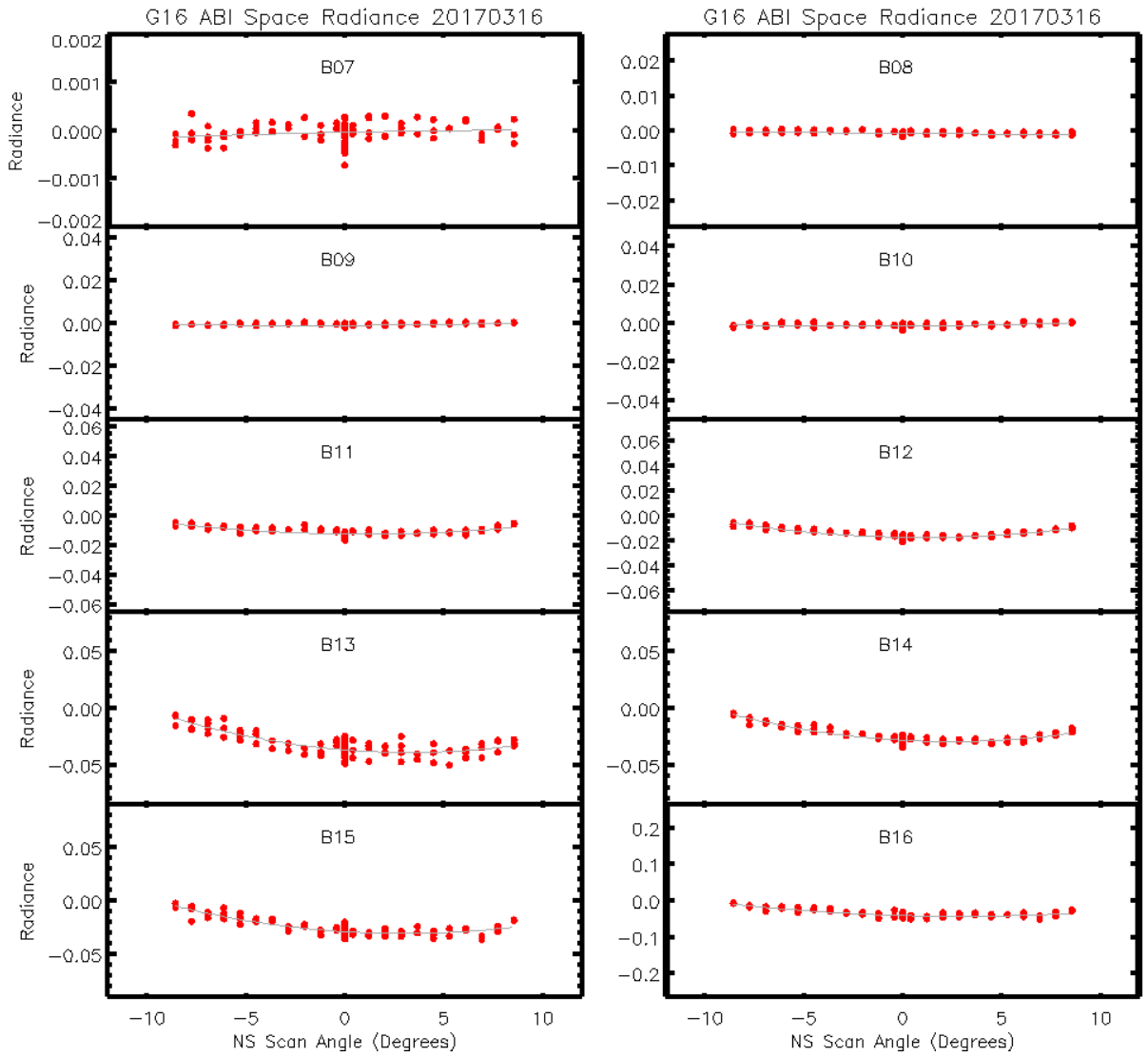
Detector-to-detector response variation in general meet the requirement

RVS for the VNIR Bands



All the G16/G17 ABI VNIR bands meet the RVS requirements

RVS for the IR Bands



- **GOES-16 ABI IR Bands are well within the RVS requirements**
- **GOES-17 ABI IR Bands also meet the waived RVS requirements for the data collected during the gain-set I period**

Summary

- **The overall calibration accuracy for the VNIR bands is less than 5% for most VNIR bands except for G17 B05.**
  - **On April 27, 2019, the solar calibration look-up table was updated for G16/G17 B02, which greatly improves the cal. accuracy and makes the radiance comparable to the reference.**
  - **Uncertainty of G17 B05 is slightly larger than 5%**
- **GOES-16 ABI IR bands are well calibrated and stable**
  - **Bias to CrIS/IASI is less than 0.2K**
- **Despite the LHP anomaly, GOES-17 ABI is optimized to greatly improve its performance.**
  - **Joins GOES-16 to provide the visible and infrared imagery with high spatial, temporal and spectral, radiometric and geometric quality.**
  - **IR radiance is stable and well calibrated when the IR FPM temperature is stable**
  - **The predictive calibration algorithm greatly improve the radiometric calibration accuracy at the unstable FPM temperature period.**
  - **Efforts are still ongoing to further improve the G17 ABI radiance quality.**
- **Spatial Uniformity with ABI FOR also meet the requirements**