Peer Stakeholder-Product Validation Review (PS-PVR) for

GOES-18 EXIS XRS L1b Full Maturity

presented: 1 December 2023

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Contributors:

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Outline

Quick Summary

- Calibration values obtained with L0 data.
- GOES-18 behavior is similar to GOES-16 and -17. No surprises.
- Solar activity relatively high since launch.
- GPA: 1 open ADR (not GOES-18 specific)
- All PLPT tests: PASSED
- Full Validation Product Maturity Assessment. PASSED
- XRS versions

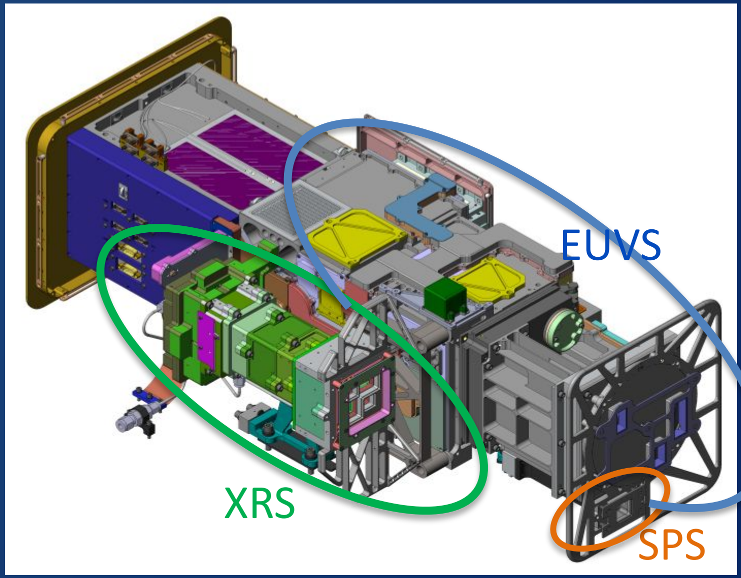
	GOES-16	GOES-17	GOES-18
L1b OE and science LUTs	Rev R	Rev O	Rev G
L1b OE install date	2023-03-31	2023-02-15	2023-11-03
L1b science version (NCEI)	0-0-2	0-0-2	0-0-2
L2 science version (NCEI)	2-2-1	2-2-1	2-2-1

ADR = Algorithm Discrepancy Report
LUT = Look Up Table
OE = Operational Environment

XRS OVERVIEW

EUV and X-Ray Irradiance Sensors (EXIS)

- X-Ray Sensor (XRS)
  - Monitor solar flares
    - Impacts communications and navigation
    - Warns of potential SEP events
- Extreme Ultraviolet Sensor (EUVS)
  - Measures ultraviolet irradiance which impacts upper atmosphere
- Sun Pointing Sensor (SPS)
  - Used for alignment (quad diode, 3.5° FOV)



EXIS was designed, built and tested by the Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado.

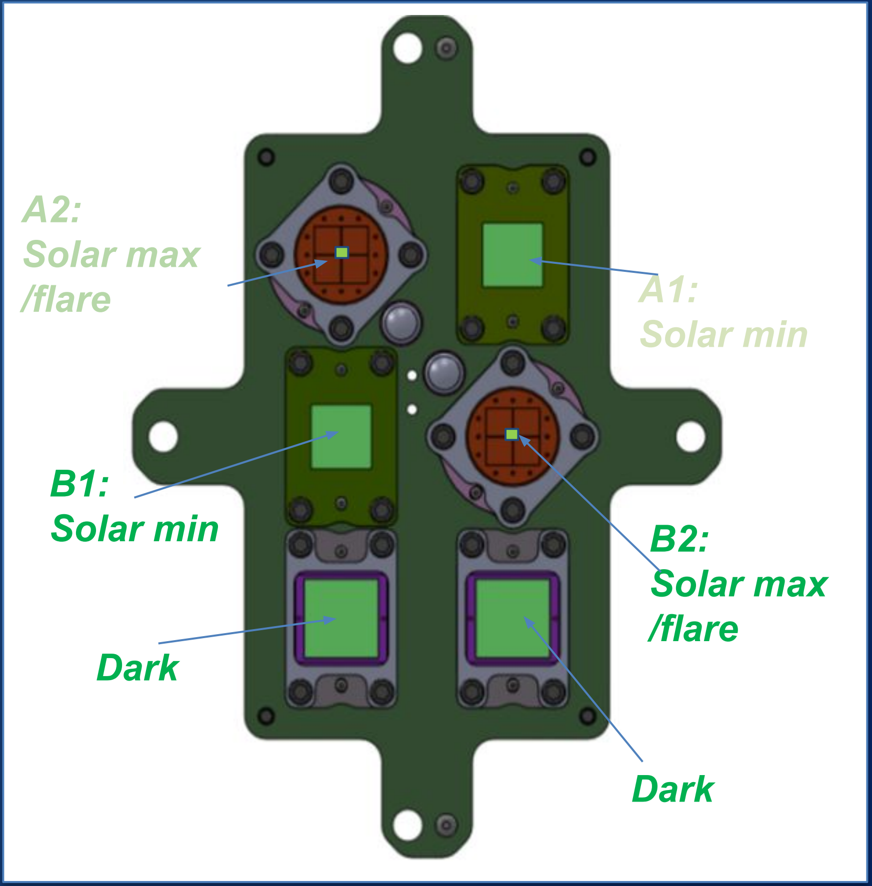
X-Ray Sensor (XRS)

2 soft X-ray wavelength bands

- XRS-A: 0.05-0.4 nm
- XRS-B: 0.1-0.8 nm; used for flare index

12 diodes total

- simultaneous measurements
- XRS-A1, -B1 - low solar activity
- XRS-A2, -B2 - solar flare, quad diodes
- output:
  - XRS-A1, XRS-A2,
  - XRS-A which is primary of -A1, -A2
- 2 dark diodes
- Silicon photodiodes with Be filters



XRS Used for SWPC Radio Blackout Warnings

flare index from 1-minute averaged XRS-B ↓

Scale	Description	Effect	Physical measure	Average Frequency (1 cycle = 11 years)
R 5	Extreme	**HF Radio:** Complete HF (high frequency) radio blackout on the entire sunlit side of the Earth lasting for a number of hours. This results in no HF radio contact with mariners and en route aviators in this sector. **Navigation:** Low-frequency navigation signals used by maritime and general aviation systems experience outages on the sunlit side of the Earth for many hours, causing loss in positioning. Increased satellite navigation errors in positioning for several hours on the sunlit side of Earth, which may spread into the night side.	X20 (2×10^{-3})	Less than 1 per cycle
R 4	Severe	**HF Radio:** HF radio communication blackout on most of the sunlit side of Earth for one to two hours. HF radio contact lost during this time. **Navigation:** Outages of low-frequency navigation signals cause increased error in positioning for one to two hours. Minor disruptions of satellite navigation possible on the sunlit side of Earth.	X10 (10^{-3})	8 per cycle (8 days per cycle)
R 3	Strong	**HF Radio:** Wide area blackout of HF radio communication, loss of radio contact for about an hour on sunlit side of Earth. **Navigation:** Low-frequency navigation signals degraded for about an hour.	X1 (10^{-4})	175 per cycle (140 days per cycle)
R 2	Moderate	**HF Radio:** Limited blackout of HF radio communication on sunlit side, loss of radio contact for tens of minutes. **Navigation:** Degradation of low-frequency navigation signals for tens of minutes.	M5 (5×10^{-5})	350 per cycle (300 days per cycle)
R 1	Minor	**HF Radio:** Weak or minor degradation of HF radio communication on sunlit side, occasional loss of radio contact. **Navigation:** Low-frequency navigation signals degraded for brief intervals.	M1 (10^{-5})	2000 per cycle (950 days per cycle)

GOES-R XRS L2 Products

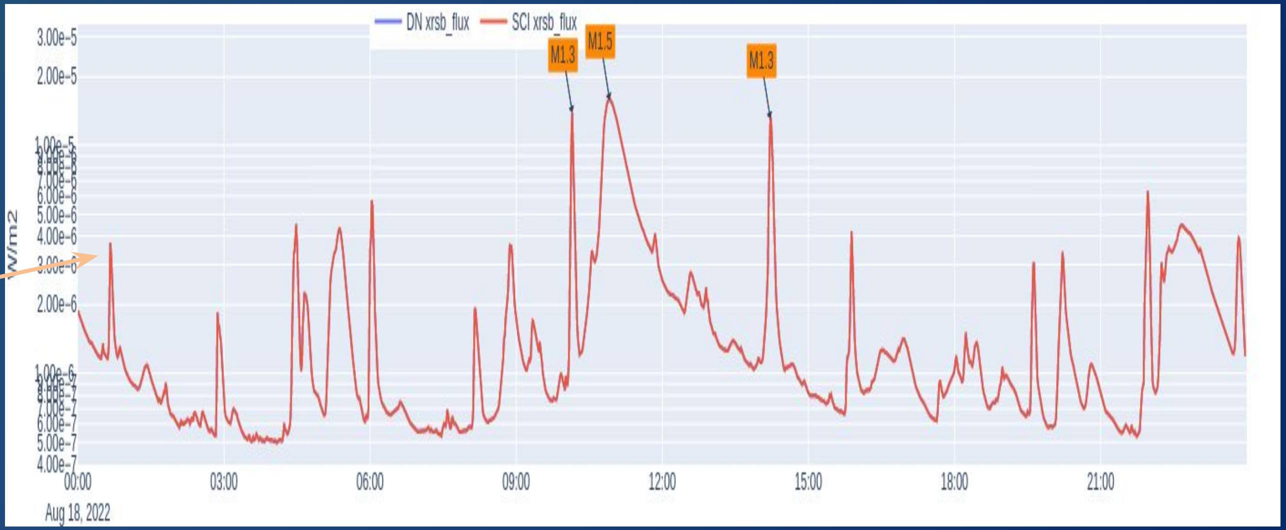
1-sec irradiances

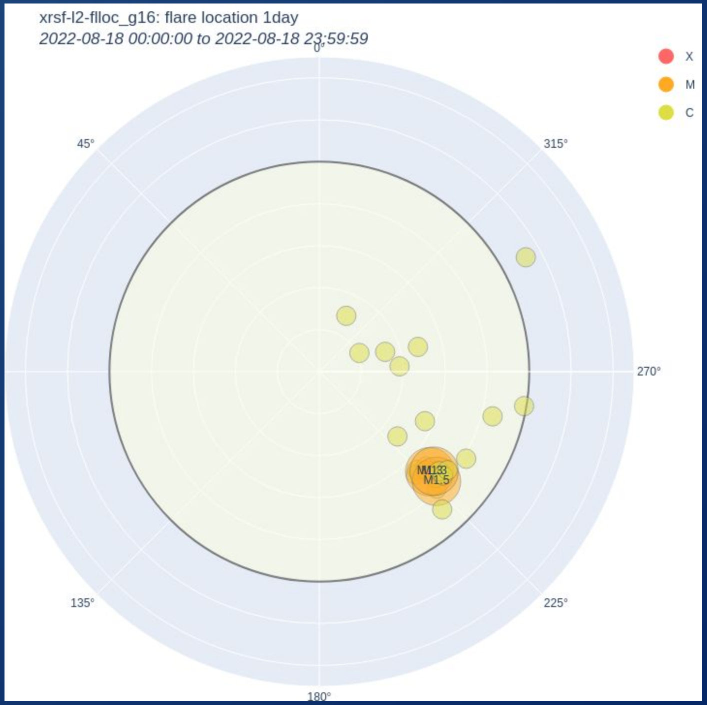
1- min averages

flare detection

daily averages and background

flare location





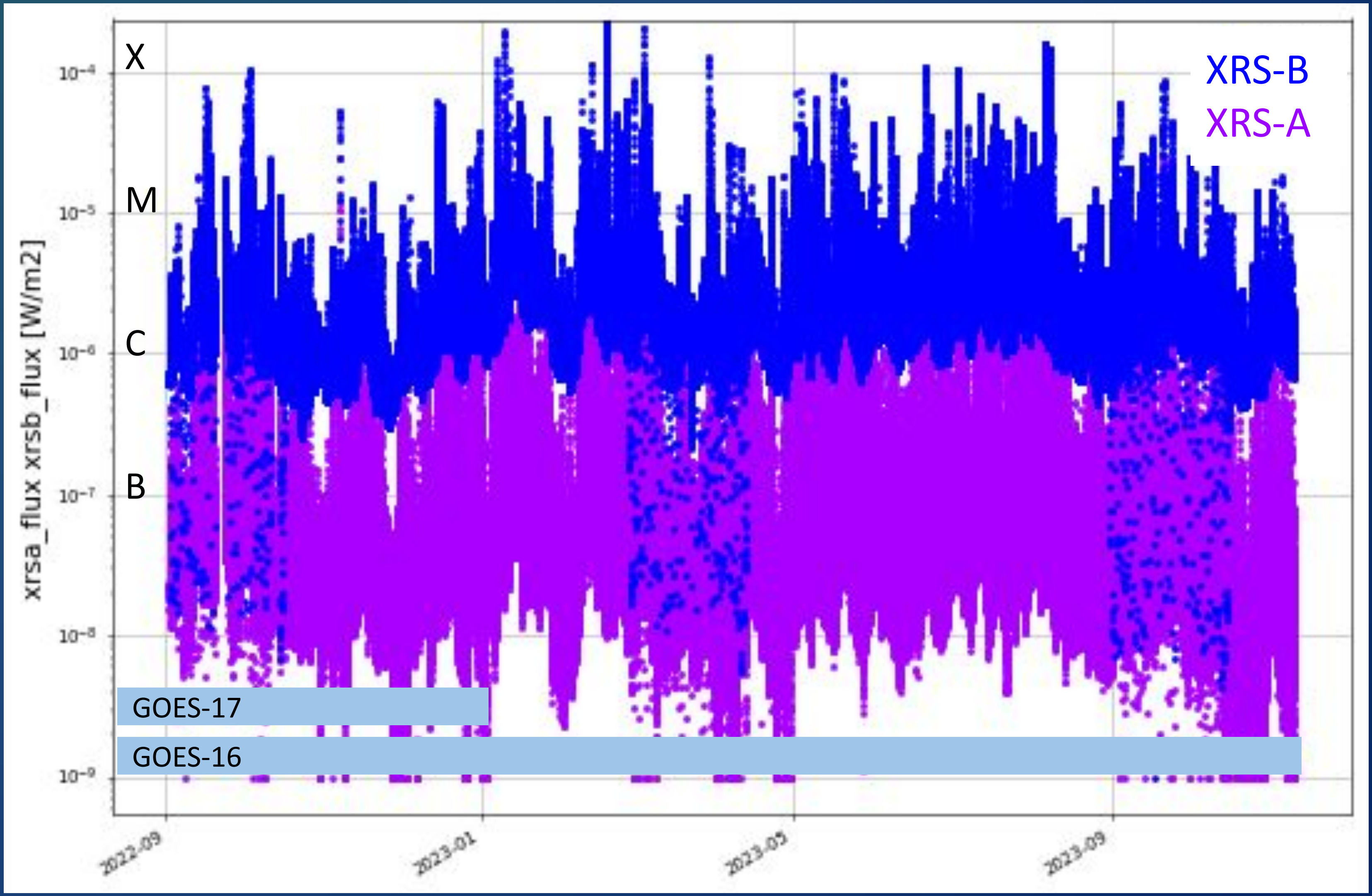
Data Types

Data	L0 → L1b processing	L1b	L2
SWPC	GS	30-s granules	low latency, subset of variables to public
NCEI ops	GS	daily aggregations	daily and mission aggregations
NCEI science-quality	NCEI	reprocessed daily aggregations	reprocessed daily and mission aggregations
LASP	LASP	internal only	n/a

- Presentation uses NCEI science-quality L2 data, unless stated otherwise.
  - Based on mission-length L1b data
  - Averaged aggregations are easier to use for mission-length cross-analysis.
  - L2 data has corrections (e.g., electron contamination for XRS irradiances)
  - Required for analysis of higher level products (e.g., XRS flare location)

ops = operational
GS = Ground System

GOES-18 XRS 1-min (Sep 2022* - Nov 2023)



* final science quality data will start in June 2022

STATUS AT PROVISIONAL MATURITY

XRS GPA Issues at Provisional PS-PVR

- In November 2022, there were 6 open ADRs for Full Validation
- All but one are now closed.

ADR	Issue	Delivery date at Provisional PS-PVR	Status Dec 2023
872	Use correct APID address for G17+ solar array currents	DO.12.01	closed
894 /1087	Output calculated dispersion and cross-dispersion angles during eclipses lunar transits (instead of fill values)	DO.12	closed
1130	SPS_roll_angle revise variable name and change long_name and comment	DO.12	closed
1161	Add EXIS penumbra flag	In analysis by Flight with PRO support. Likely an MM procedural update.	open
1171	Increase ECEF_Z range	DO.12	closed
1272	XRS L1b sc_power_side mismatch between flag value & meaning	TBD	closed

MM = Mission management
DO 12 went into OE on 23 May 2023

XRS Instrument Issues at Provisional PS-PVR

#	Issue	Description	Nov 2022 Status	Dec 2023 Status*
1	XRS-A is larger for GOES-R than for GOES-15.	XRS-A: GOES-17/GOES-15 = 1.32	The source of this discrepancy is unknown. GOES-8 through -15 fluxes agree, and GOES-R fluxes agree. We will use solar X-Ray spectral measurements from other satellites to try to resolve.	Further investigation is planned.
2	Dark radiation coefficients.	Determine coefficient to remove proton contamination during SEP events.	Analysis to determine this term is in progress. Currently not applied (set to 0). Signals will be artificially high during SEP events, especially for XRS-A2 and -B2.	Analysis will start soon, but may require larger SEP events.
3	Dark counts	Improve dark counts with values from periods of lowest electron fluxes.	Until XRS LUT is updated, impact will be to slightly increase fluxes, but this will only be noticeable for the lowest fluxes.	Time-dependent dark counts needed.
4	Determine G18 electron contamination fit coefficients.	L2 electron contamination correction requires coefficients for SEISS MPSHI fluxes.	The L2 coefficients need to be determined for GOES-18. A new machine-learning based method is being tested as well.	GOES-18 coefficients were determined. New methods still under examination and future updates expected.
5	Electron contamination waiver	XRS does not meet PORD requirements when e- fluxes are high and irradiance is low.	LASP Waiver Request 161597revB was submitted which uses GOES-16 waiver values to cover GOES-17 and -18.	LASP Waiver Request 161597revC approved
6	Responsivities	Revise responsivities.	A1/A2 and B1/B2 comparisons showed responsivities needed adjustments.	Revisions made. More revisions needed.

*Status: Completed | In progress

L1B PRODUCT QUALITY ASSESSMENT

Remaining XRS GPA Issues

- 83 XRS-related ADRs have been closed since 2016.
  - Number includes routine LUT updates
- 1 open XRS-related ADRs
  - Issue does not prevent Full Validation.

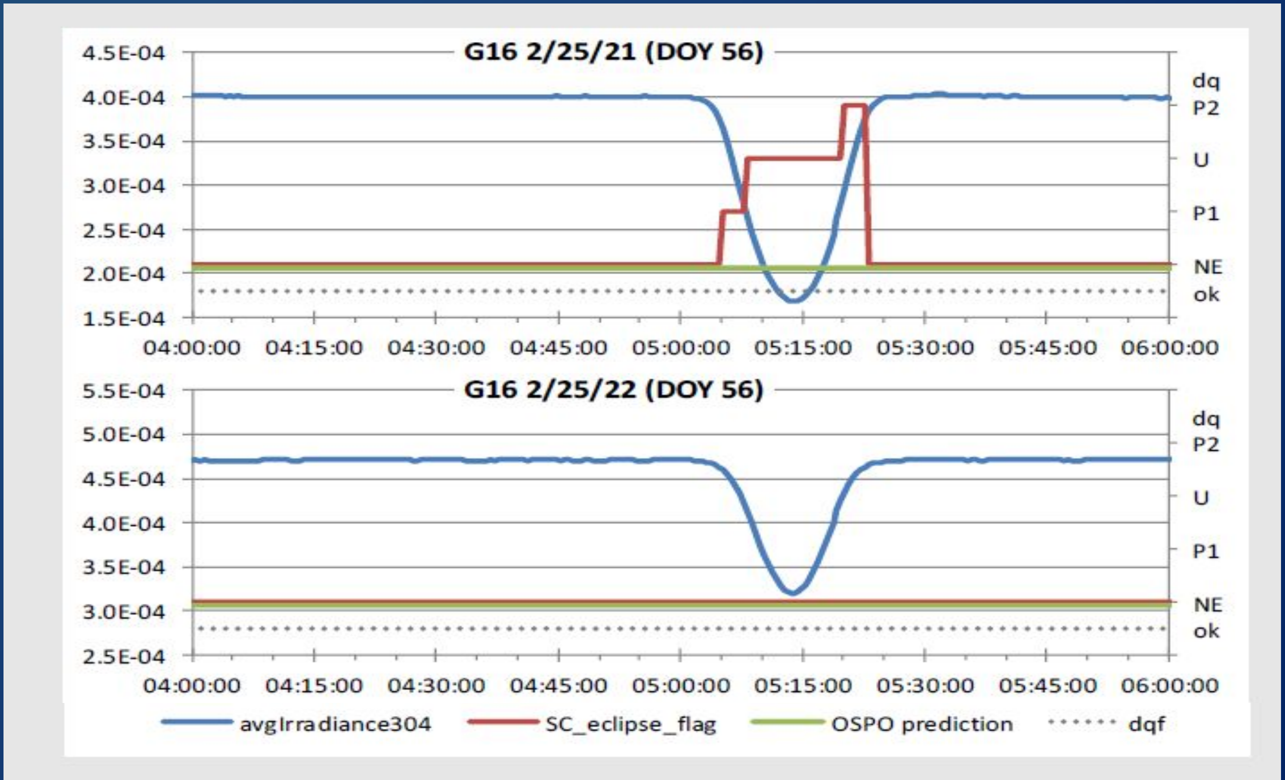
ADR	Issue	Impact	Description / Impacts	Delivery date
1161	Add EXIS penumbra flag	Moderate	XRS flare detection has errors without this flag.	tbd

ADR 1161: Penumbra Flag

ADR for XRS and EUVS:

1. Extend penumbra flagging out from eclipse
2. Create penumbra flags for the penumbra-only days at the beginning and end of the eclipse season.

Operations: increasing irradiances could trigger flare detection.



credit: Randy Race

Post-Launch Product Tests (PLPT)

Full Validation PLPT tests as defined the EXIS RIMP*

Test ID	Test Title	Status	Criteria
13	XRS Flare Location Comparison (L1b)	Pass	[1]
14	XRS/EUVS/Mg II Inter-Satellite Comparisons (L1b)	Pass	[2]

Full Validation Success Criteria:

[1] Derived X-class solar flare location is accurate to within 5 arc minutes.

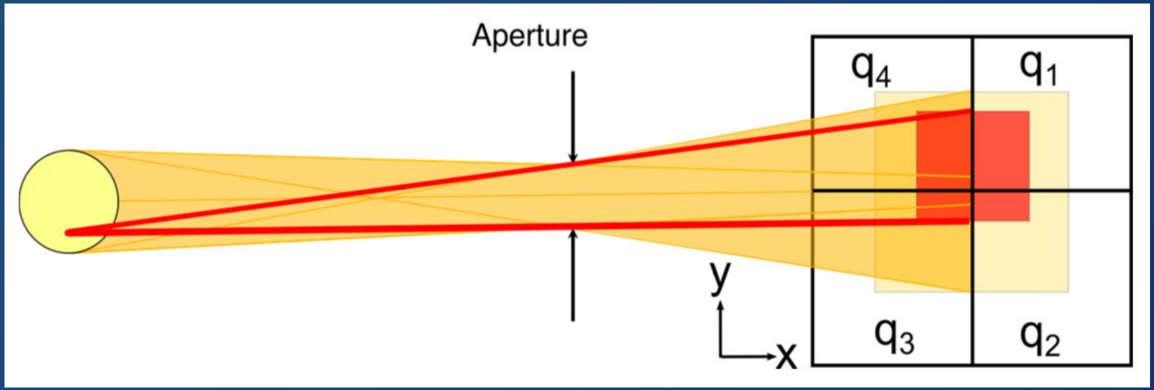
[2] None. There is no pass/fail on the results of these cross-comparison.

*Appendix A.3, p. 29, EXIS Readiness, Implementation, and Management Plan (RIMP v2.0; 410-R-RIMP-0316)

#13: XRS Flare Location Comparison

Flare Location: Method

- Solar Flare Locations (L2 Product)
  - Provides flare locations in four coordinate systems.
  - SWPC Forecasters: 1-min cadence from flare start to peak
  - NCEI: provides at flare peaks
- Determined using XRS-B2 quad diode measurements



Background subtracted signal for each quadrant:

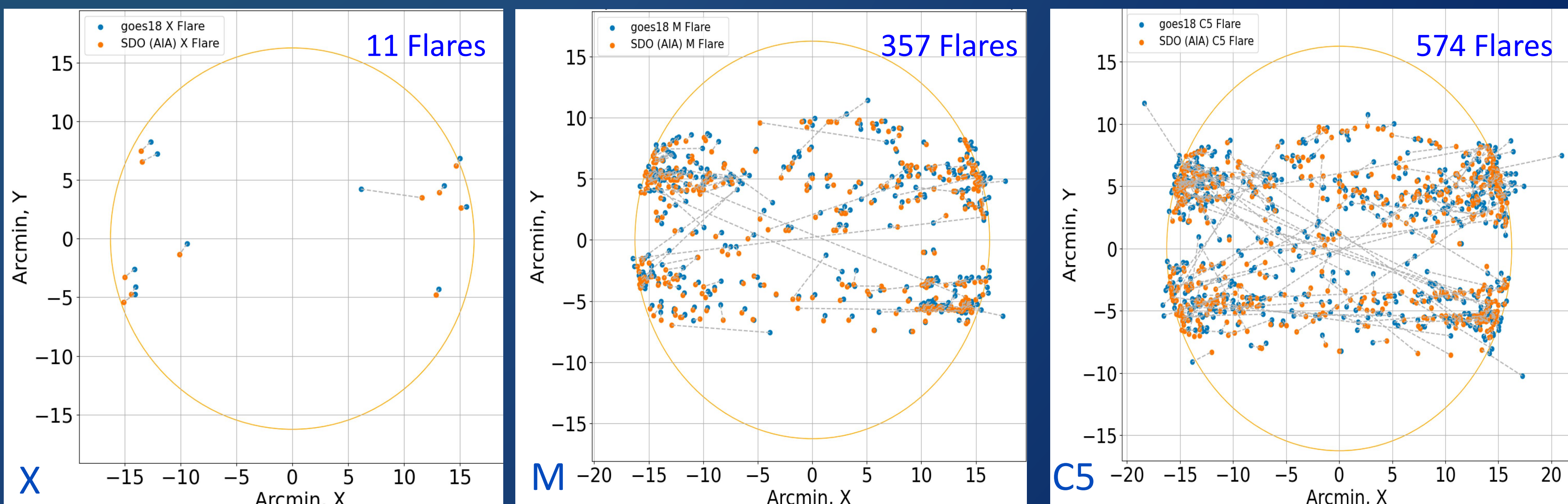
$Q_i = q_i - b_i$ for q_i =quadrant signal, and b_i = background signal

x-position in detector coordinates:

$$x_{det} = \frac{(Q_1 + Q_2) - (Q_3 + Q_4)}{\sum_{i=1}^{4} Q_i}$$

Flare Location: Comparison to AIA

- Success Criteria: X-class flare location error is < 5 arcmin.
  - Solar radius is ~16 arcmin.
- GOES-18 data for 2022-09-08 to 2023-11-09
  - Compared with SDO AIA Flare Locations list*.



Comparison of GOES-18 and AIA flare locations.

*Heliophysics Event Registry (https://www.lmsal.com/sungate/) determined from AIA 131 Å measurements.

Flare Location: Median Errors Updated: 01/17/24

- X-class flare error less than 5 arcmin error requirement

Statistics for Flare Location Algorithm

Flare Class	Number of Flares*			Median Error [arcmin] (primary flares)		
	G16	G17	G18	G16	G17	G18
X	25	10	13	0.71	0.55	1.17
M	495	194	332	0.47	0.45	0.53
C	4776	2191	2931	0.98	0.90	1.06
B	2795	2056	103	3.62	3.50	2.38
All	8091	4451	3379	1.41	1.68	1.01

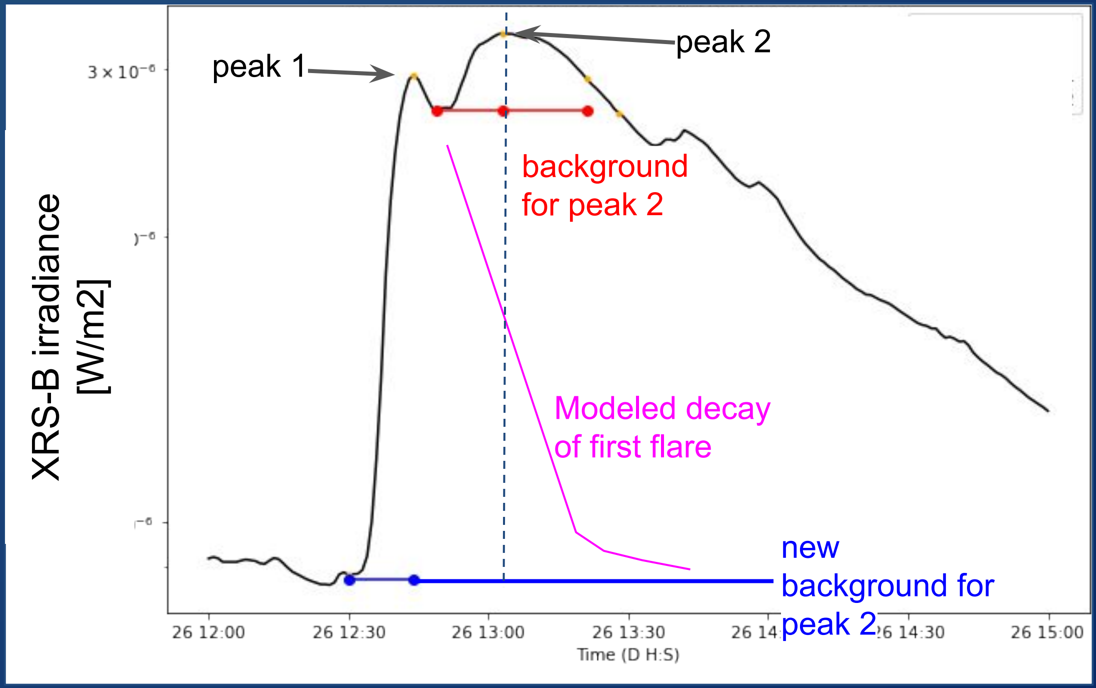
With new background correction

* Date ranges for analysis:

G16	2017-02-09 to 2024-01-24
G17	2018-06-01 to 2023-01-09
G18	2022-09-08 to 2024-01-24

Flare Location: Improvements

- Improved method for sequential flares
  - Overlapping flare events: G16 - 13%; G17 - 12%; G18 - 12%
  - Current method causes large errors for many overlapping flares.
  - Correction uses pre-flare background for successive flares
  - In L2 product soon and further improvements coming.



Flare Location: Multiple Flare Background Correction Updated: 01/17/24

- Tests showed 34% improvement in median errors for non-primary flares

Statistics for Flare Location Algorithm

Flare Class	Median Error [arcmin] Non-Primary Flares: Original Background			Median Error [arcmin] Non-Primary Flares: Corrected Background		
	G16	G17	G18	G16	G17	G18
X	0.11	0.64	-	0.66	1.19	-
M	0.62	0.43	0.81	0.44	0.39	0.67
C	2.50	2.28	2.92	1.57	1.28	2.07
B	6.09	5.87	4.16	3.52	3.23	3.82
All	2.88	3.11	2.11	1.82	1.90	1.60

#14: Intersatellite Comparisons

Satellite Comparisons

PLPT #14: Comparison of satellite data with >2 months measurements overlap

- Single day comparisons of GOES-16, -17 and -18
- Mission-length intrasatellite comparisons
- Mission-length intersatellite comparisons

What are main steps in XRS calibration?

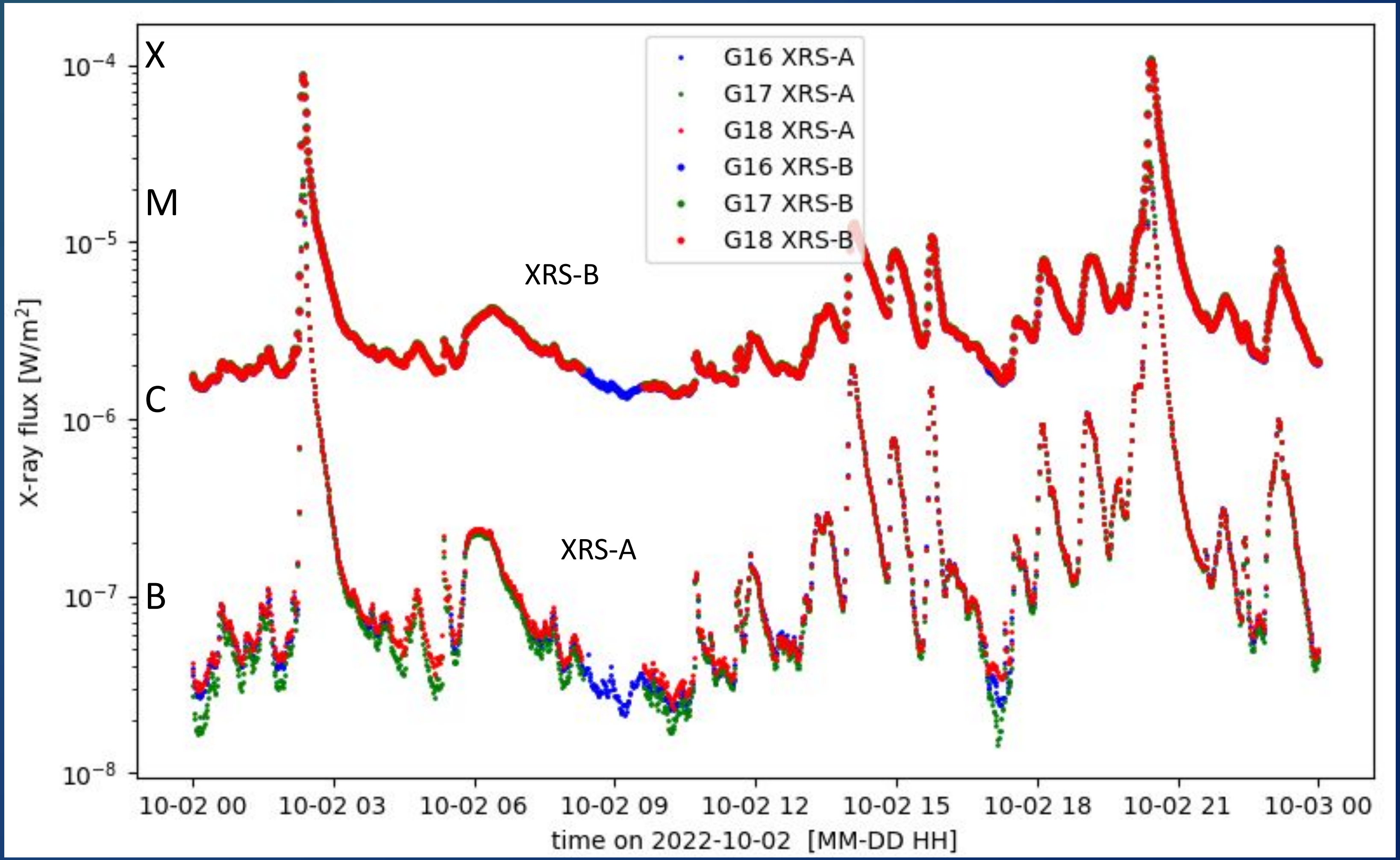
$$\text{Irradiance} = \frac{(\text{Counts} - \text{Dark counts}) \times \text{Gain}}{\text{Responsivity} \times \text{Integration\_Time}}$$

- Dark values revised on orbit from off-points or low e-, low X-ray flux days
- Responsivity calculated pre-launch
  - XRS-A2 responsivity rescaled post launch to match XRS-A1. Same for B.
- Gain determined pre-launch. Monitored on orbit during quarterly offpoints.

1 Day Intersatellite Comparisons

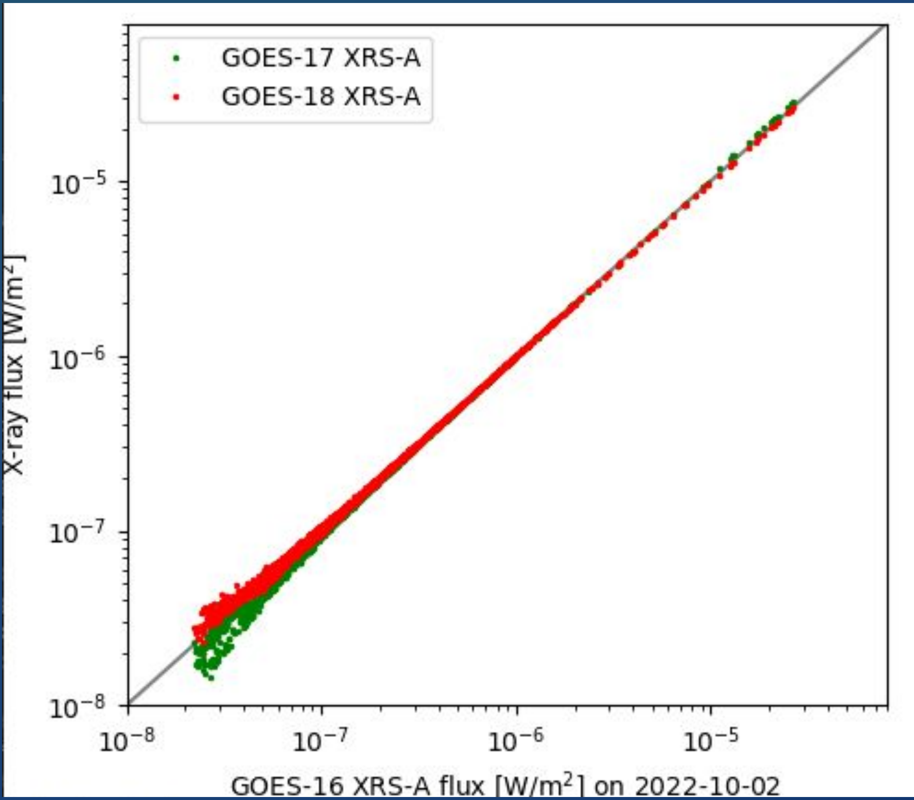
1-Day Comparison: Irradiance Time Series

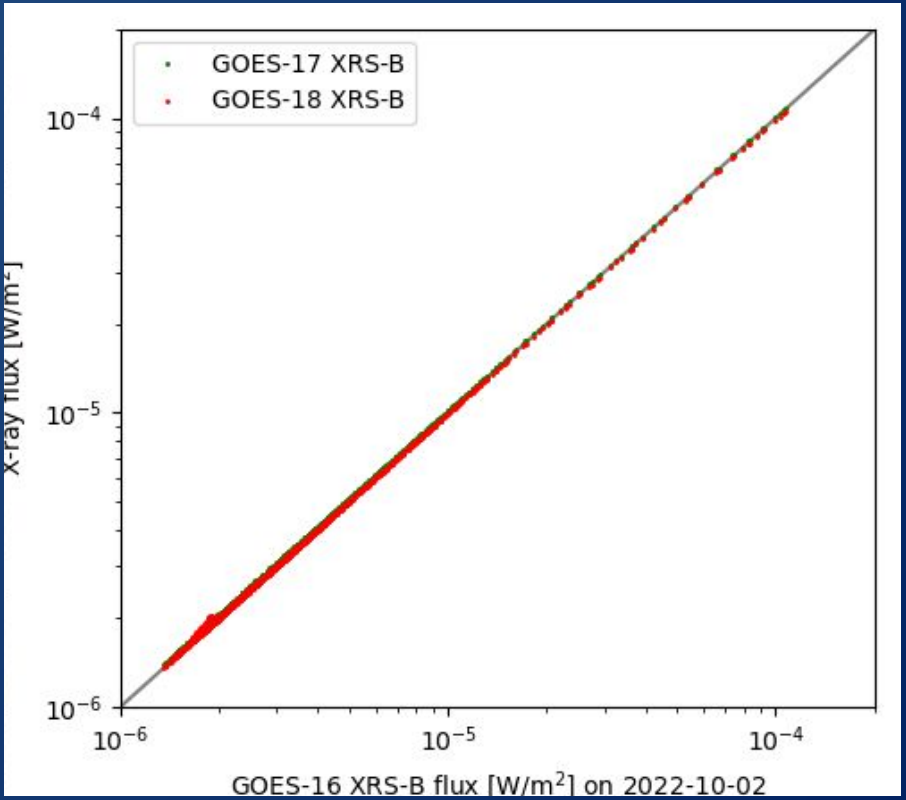
- GOES-16, -17, and -18 comparisons for 1 day (2 Oct 2022)



1-Day Comparison: GOES-17, 18 vs GOES-16

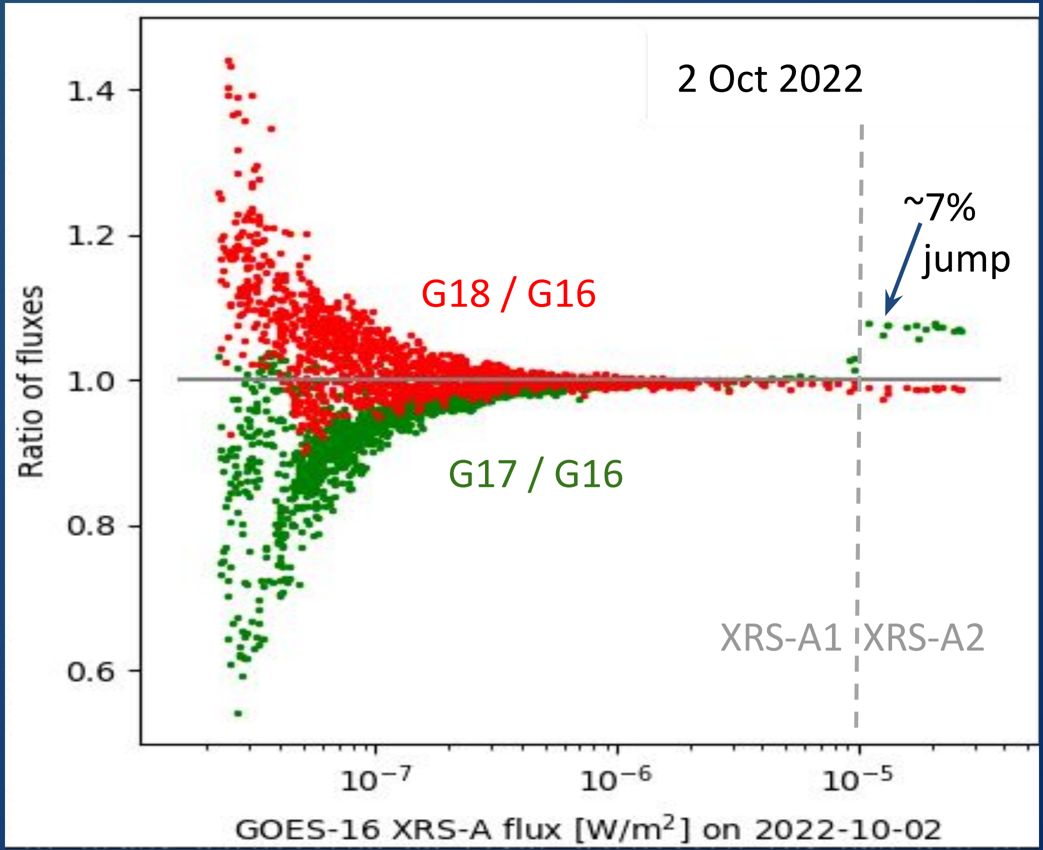
- Comparisons of GOES-17 and -18 to GOES-16 (2 Oct 2022).
- Linear behavior at higher fluxes as expected.





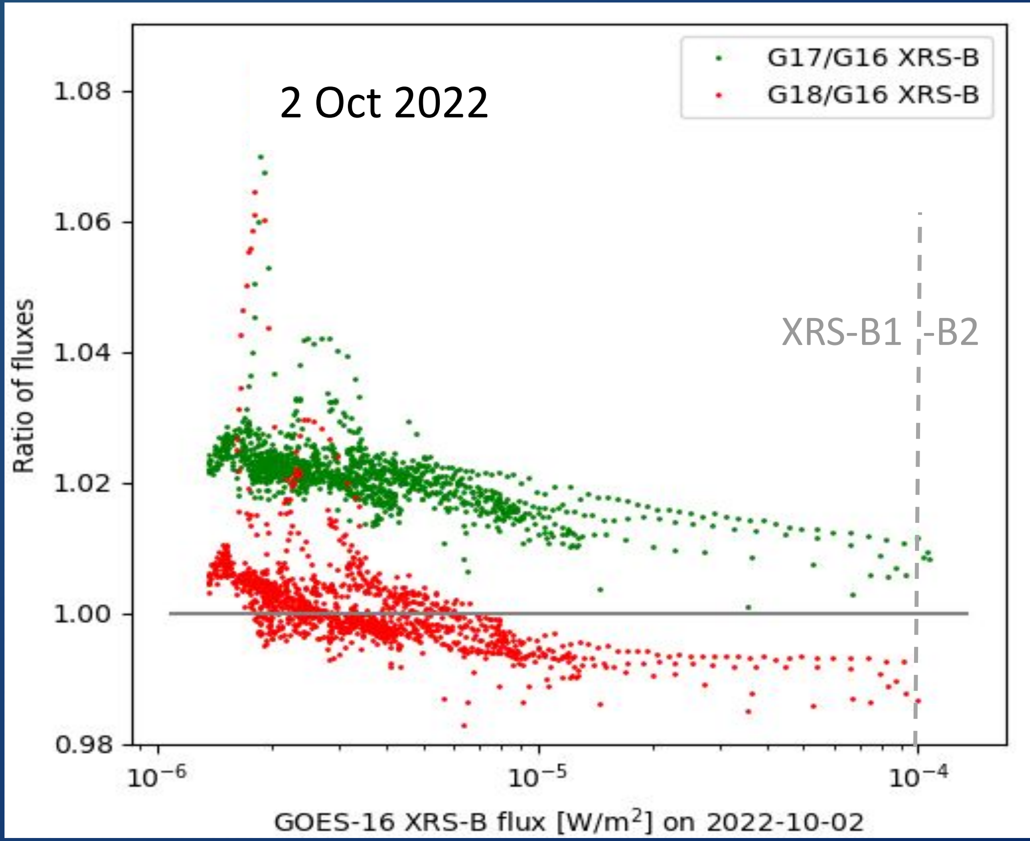
1-Day Comparison: XRS-A Ratios vs Irradiance

- Ratios of XRS-A for GOES-17 and -18 to GOES-16 (2 Oct 2022).
- Approx. 7% jump in GOES-17/-16 ratio at switch from XRS-A1 to -A2
  - Cause: Incorrect scaling of GOES-17 XRS-A2 to -A1.



1-Day Comparison: XRS-B Ratios vs Irradiance

- Ratio of XRS-B for GOES-17 and -18 to GOES-16 (2 Oct 2022).
- Hysteresis for XRS-B1 and -B2 during flares (noted at Provisional PS-PVR)
  - Probable cause: Spectral changes during flare convolved with slight differences in filter transmissions for different satellite instruments.



Mission Length
Intrasatellite Channel Comparisons: Darks

GOES-18 Dark Counts

Analysis and plots (credit: Tom Eden)
Measure signal during quarterly off-point*
before temperature changes drastically.

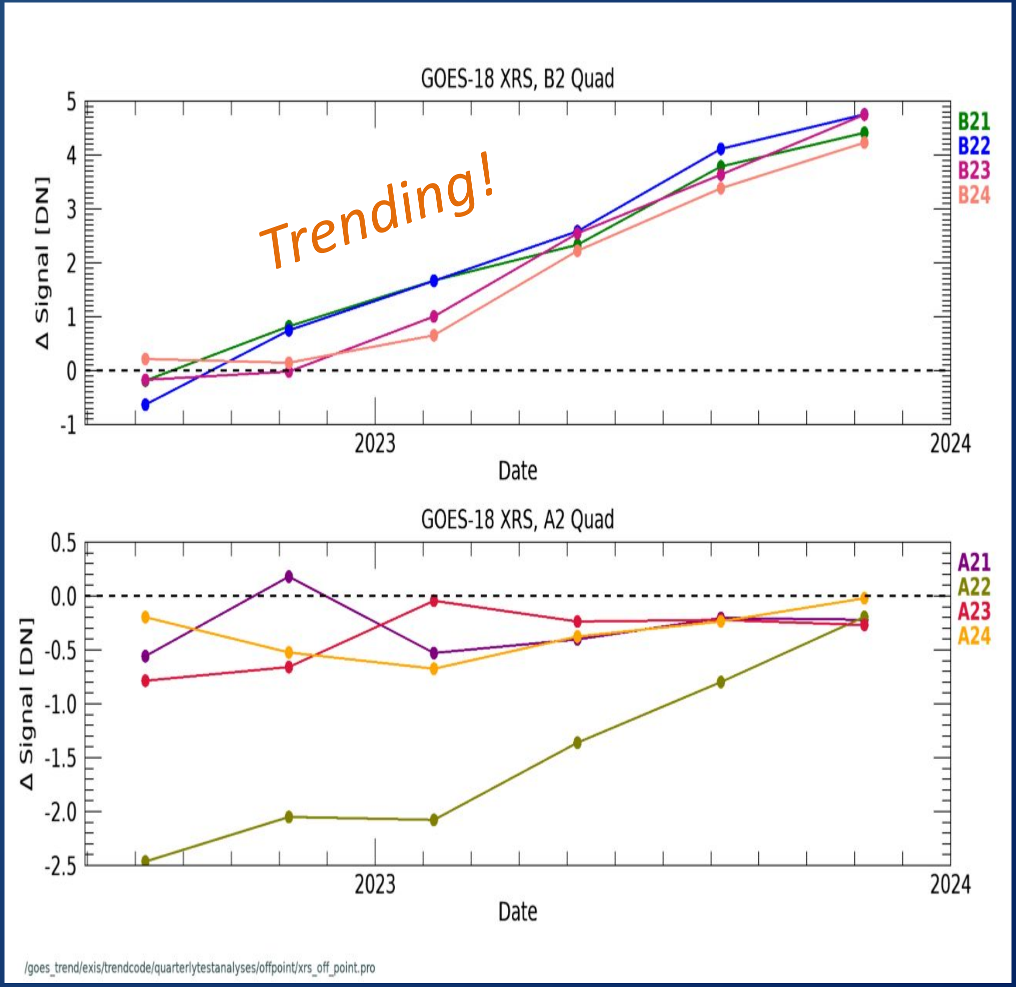
Δ = signal - dark *should be ~0*

XRS-B2: 1 DN = 5.314 x 10^{-8} W/m^2
What is impact of 4 x 5 DN error?
dark error= 20 DN = 10^{-6} W/m^2

Where XRS-B switches from -B1 to -B2,
at 10^{-4} W/m^2 :
impact $\rightarrow$ 1% irradiance error.

Current science processing assumes fixed value for dark counts for each channel.

Action: allow time-dependent darks in science-quality LUTs



* periods with low electron contamination.

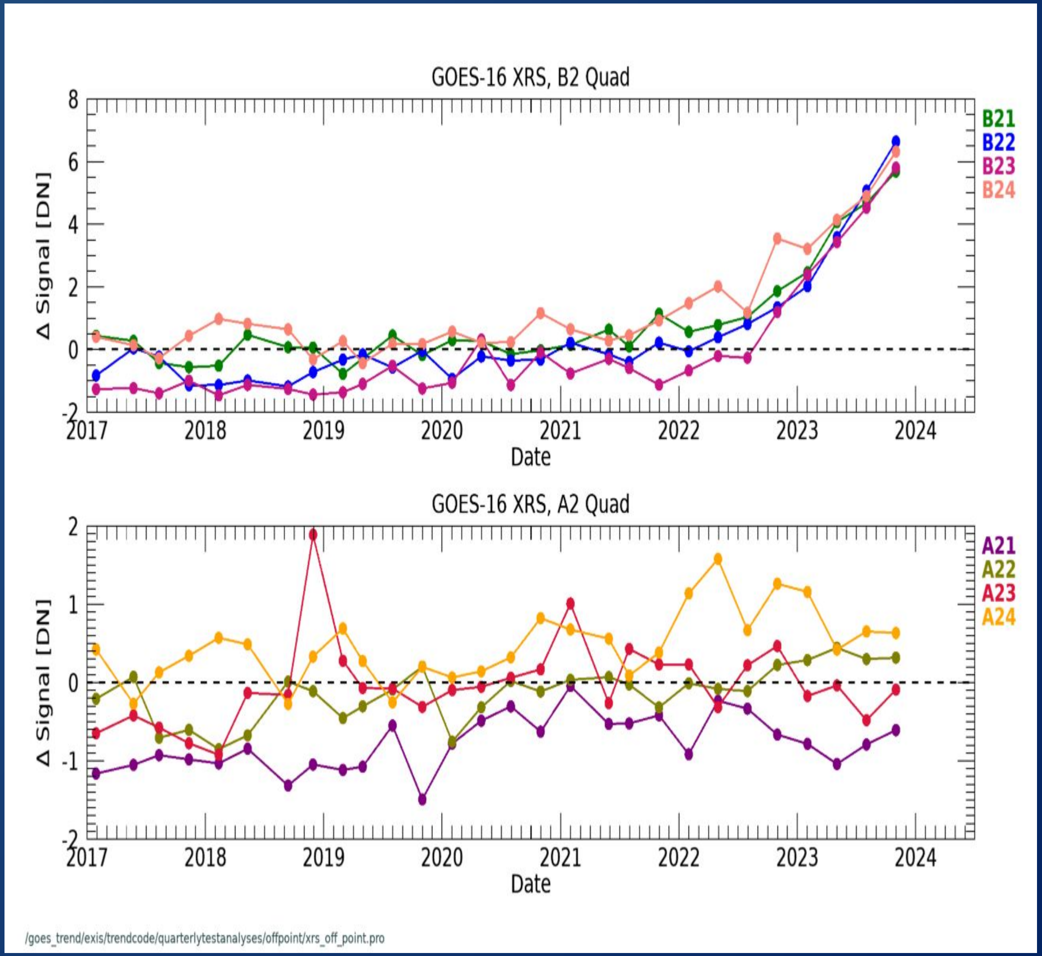
GOES-16 Dark Counts

B2: 1 DN = 4.94×10^{-8} W/m^2
A2: 1 DN = 7.17×10^{-8} W/m^2

<u>GOES-16 XRS-B2</u>
What is impact of 7 DN / dark channel?
28 DN = 1.4×10^{-6} W/m^2

dark error at X1 → 1.4% irradiance error.

<u>GOES-17 XRS-A2</u>
No trend.



GOES-17 Dark Counts

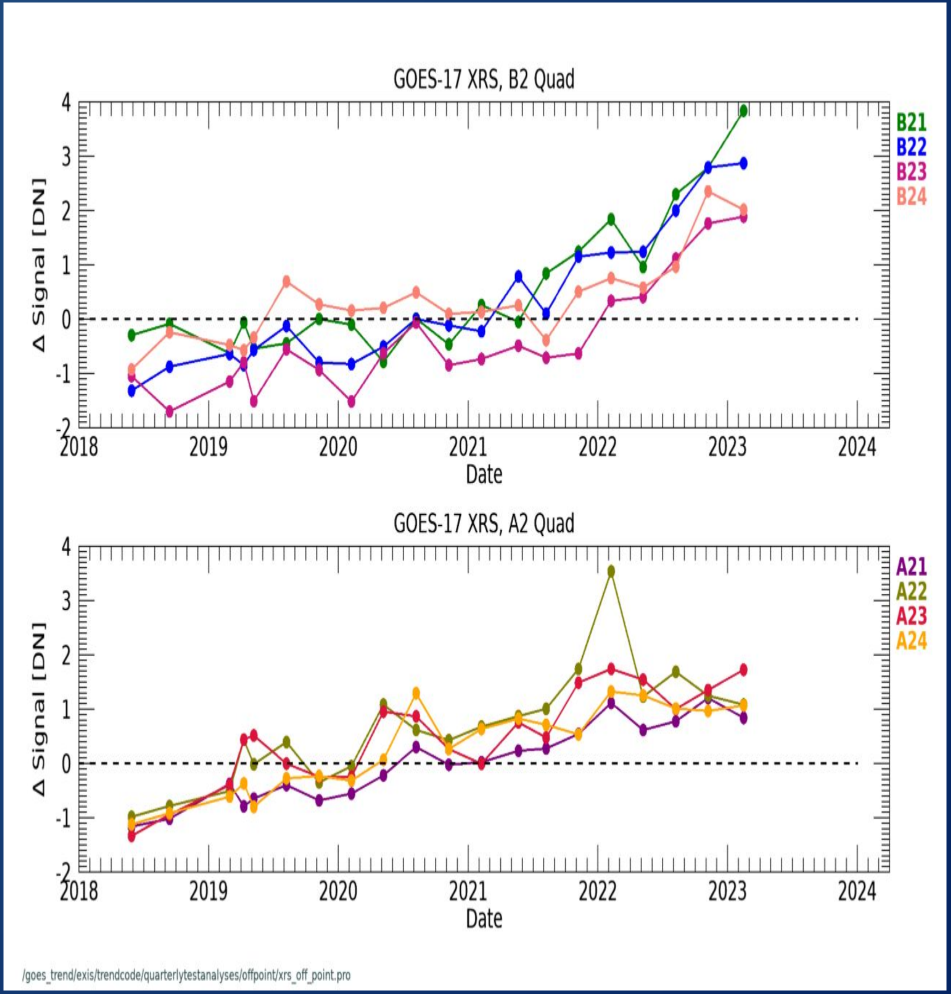
B2: 1 DN = 4.446 x 10^{-8} W/m^2
A2: 1 DN = 7.378 x 10^{-8} W/m^2

<u>GOES-17 XRS-B2</u>
What is impact of 3 DN / dark channel?
12 DN = 5x10^{-6} W/m^2

dark error at X1 → 0.5% irradiance error.

<u>GOES-17 XRS-A2</u>
What is impact of 2DN / dark channel?
8 DN = 6 x 10^{-7} W/m^2

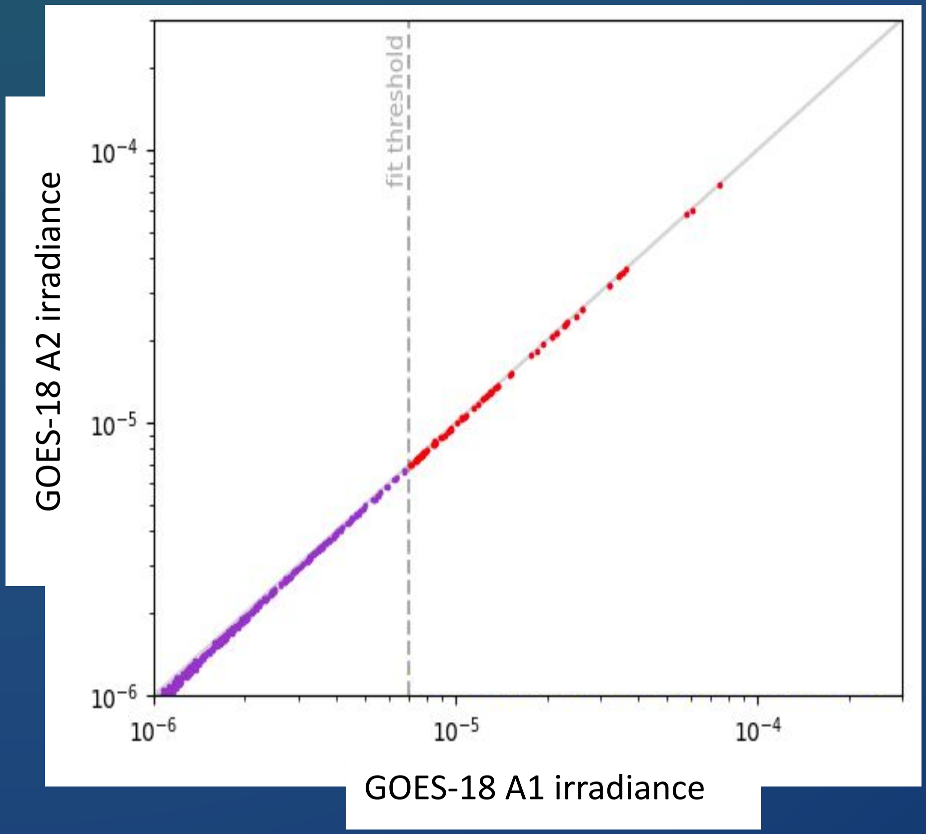
Impact of dark error at switch to A2 (at 1x10^{-5} W/m^2): ~6% irradiance error

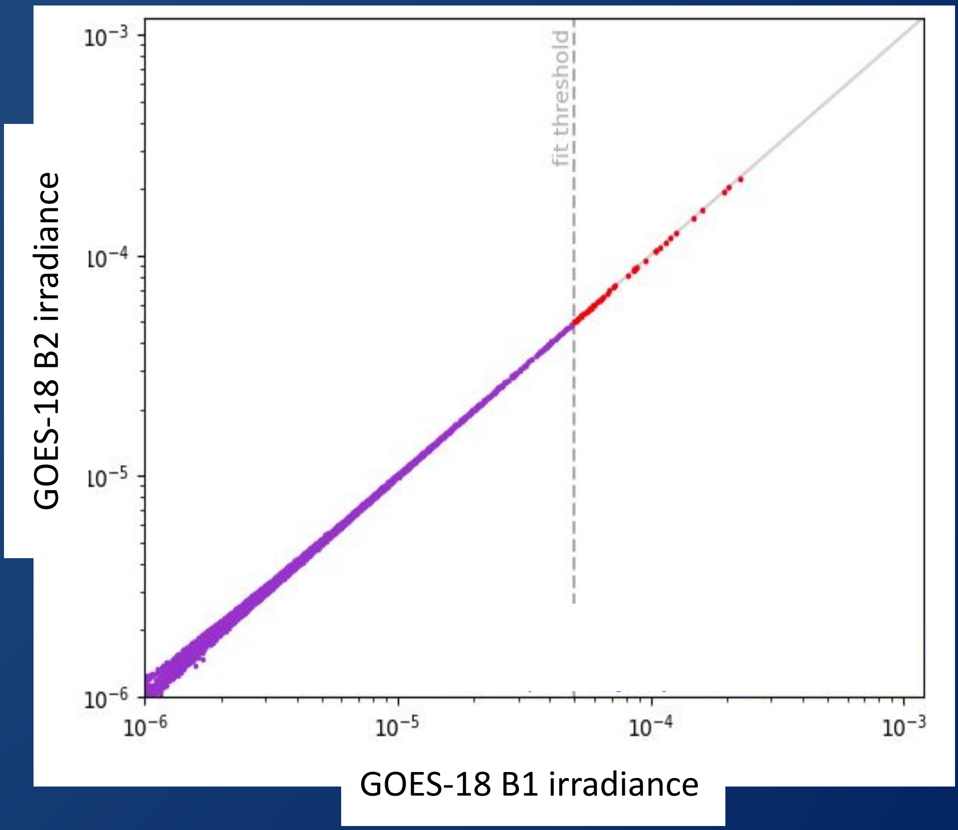


Mission Length Intrasatellite Channel Comparisons: Responsivities

GOES-18 Channel Ratios vs Time

- Full mission: flare peaks only

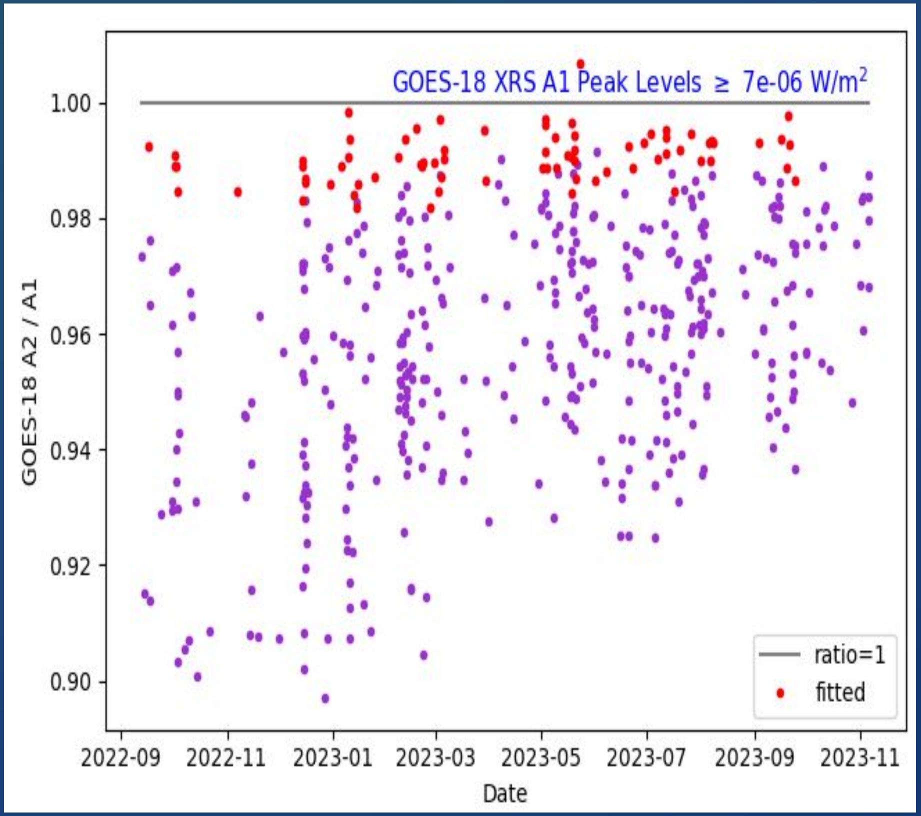




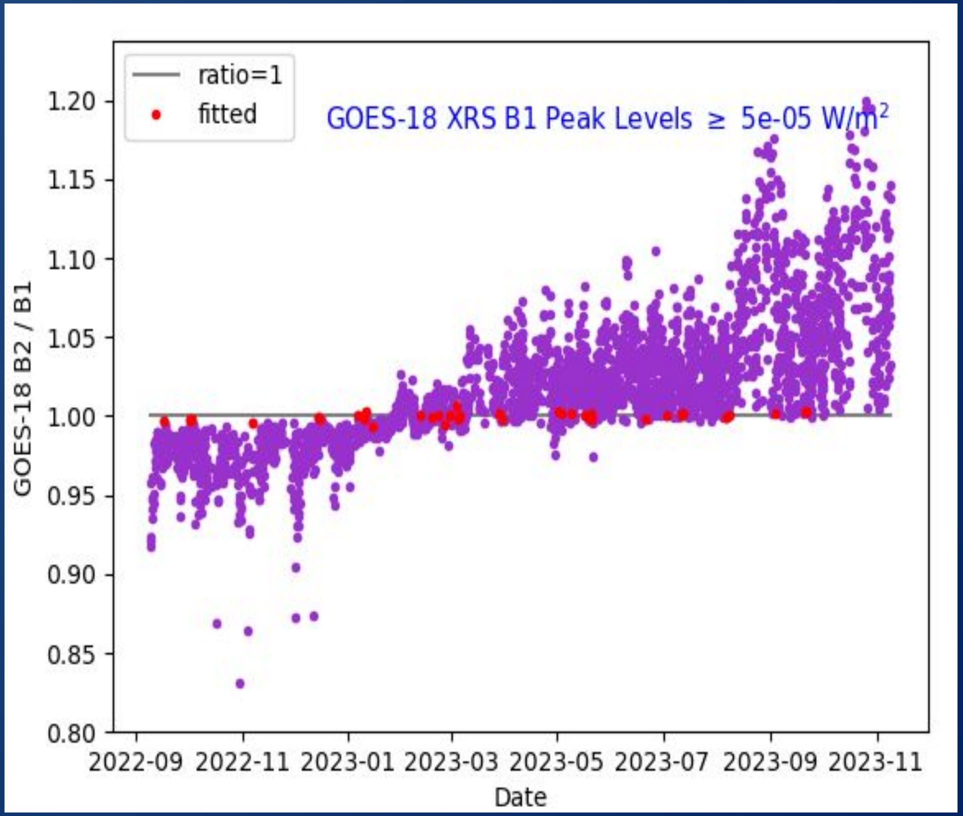
GOES-18 Channel Ratios vs Time

- Time series of ratios A2/A1 and B2/B1

A2/A1



B2/B1



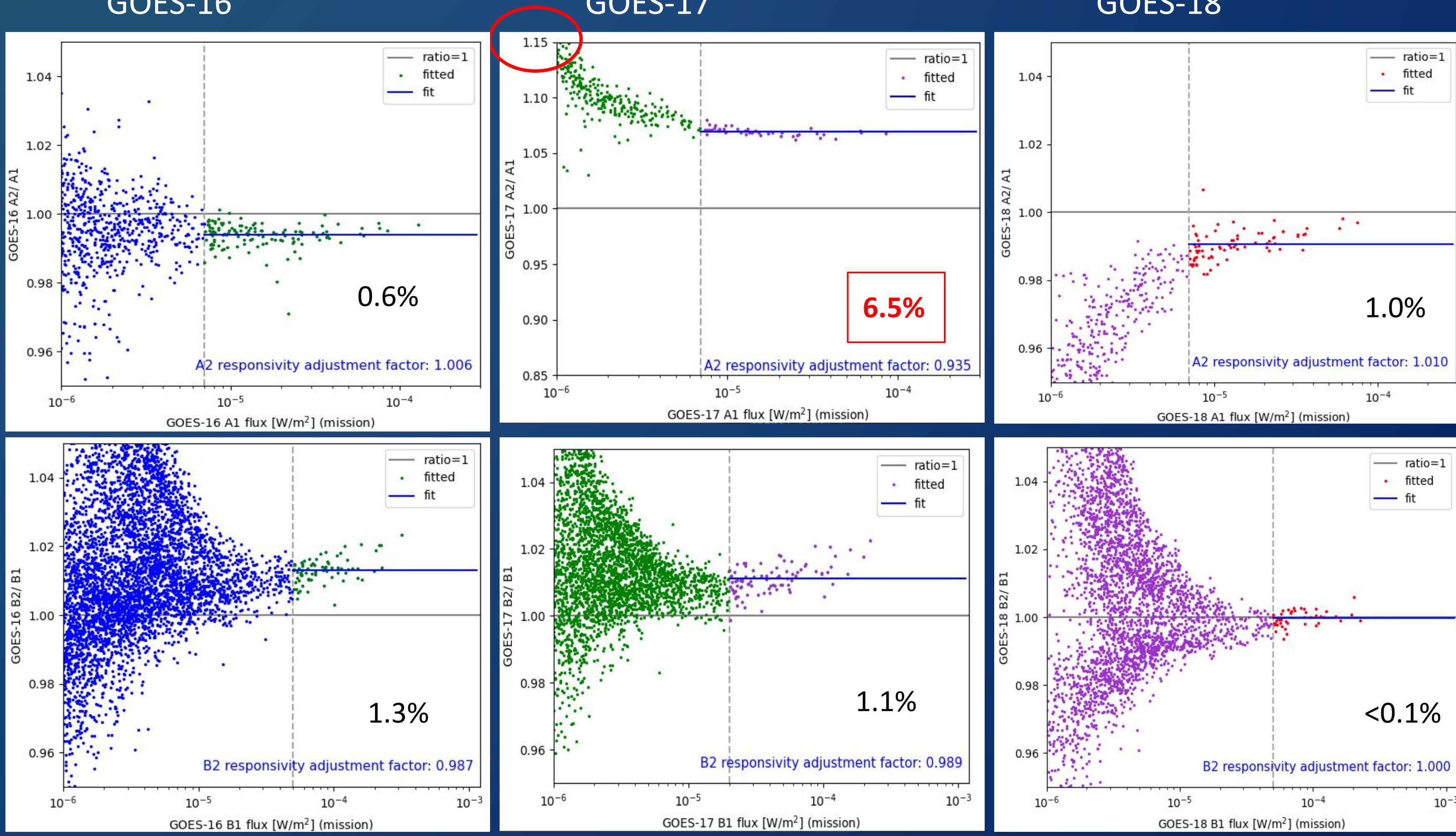
Channel Ratios: Correction

Flare peaks only.
Offsets of A2/A1 and B2/B1 ratios.

GOES-16 GOES-17 GOES-18

A2/A1

B2/B1



XRS Ratios for Responsivity Adjustments

- Offset from 1 of ratios of A2/Al and B2/B1 vs irradiance
  - 7% for G17 XRS-A
  - ≤1.5% all other satellites + channels
- Actions: Revise G17 XRS-A2, B2 responsivity. (ADR 1340)
  Review other channels after time-dependent darks implemented

satellite + channel	fit coefficient A2 = m ·A1 *or* B2 = m ·B1	modify LUT?	current LUT value	revised value for next LUT
G16 A2	0.994		5.06362e-07	
G16 B2	1.013	review	7.68407e-07	
G17 A2	1.070	revise	4.69212e-07	5.02057e-07
G17 B2	1.011	revise	7.70498e-07	7.78973e-07
G18 A2	0.990	review	5.106793e-07	
G18 B2	1.000		7.994771e-07	

Next Steps

Short term

- New GOES-17 LUT with revised XRS-A2 and -B2 responsivities. (ADR 1380)
- New version of GOES-17 science-quality data.

Long term processing

- Create time-dependent XRS LUT.
- XRS science-quality processing at NCEI
  - Add ability to use time-dependent LUT.
  - In Spring 2024 XRS science-quality reprocessing is being recoded.
- GS processing
  - Submit periodic LUT updates or...
  - Submit ADR to revise code to use time-dependent LUTs?

Revise Values

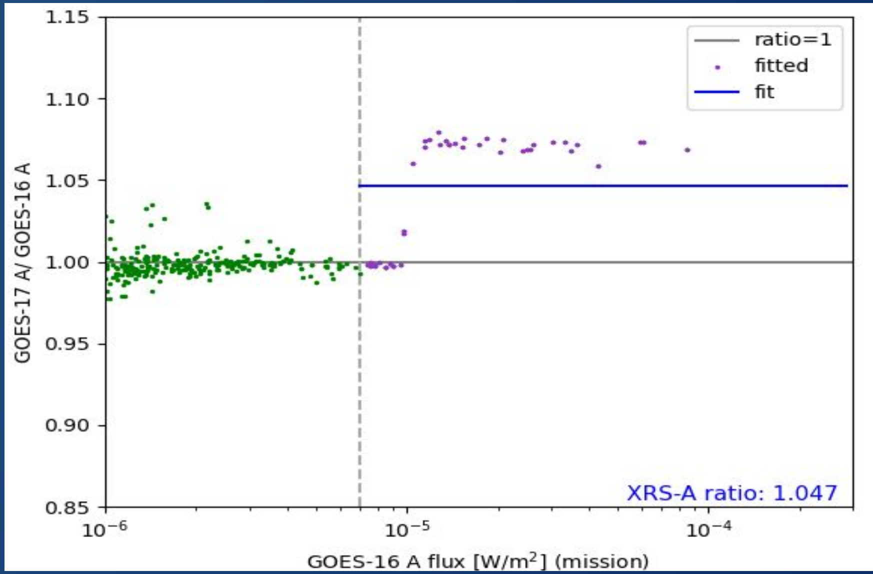
- Reprocess science-quality data with time-dependent darks.
- Determine correct responsivities based on new science-quality data.
- Submit operational XRS LUTs with updated darks (and responsivities).
- Reprocess science-quality data with revised responsivities.

Mission-Length Intersatellite Comparisons

Intersatellite Comparisons: XRS-A

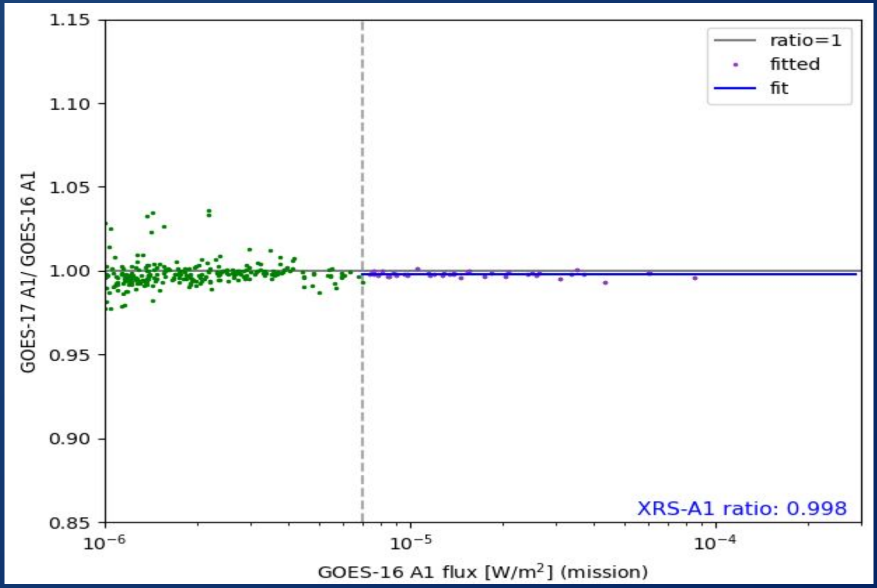
Ratios of flare peak irradiances

G17/16 XRS-A: ~1.07



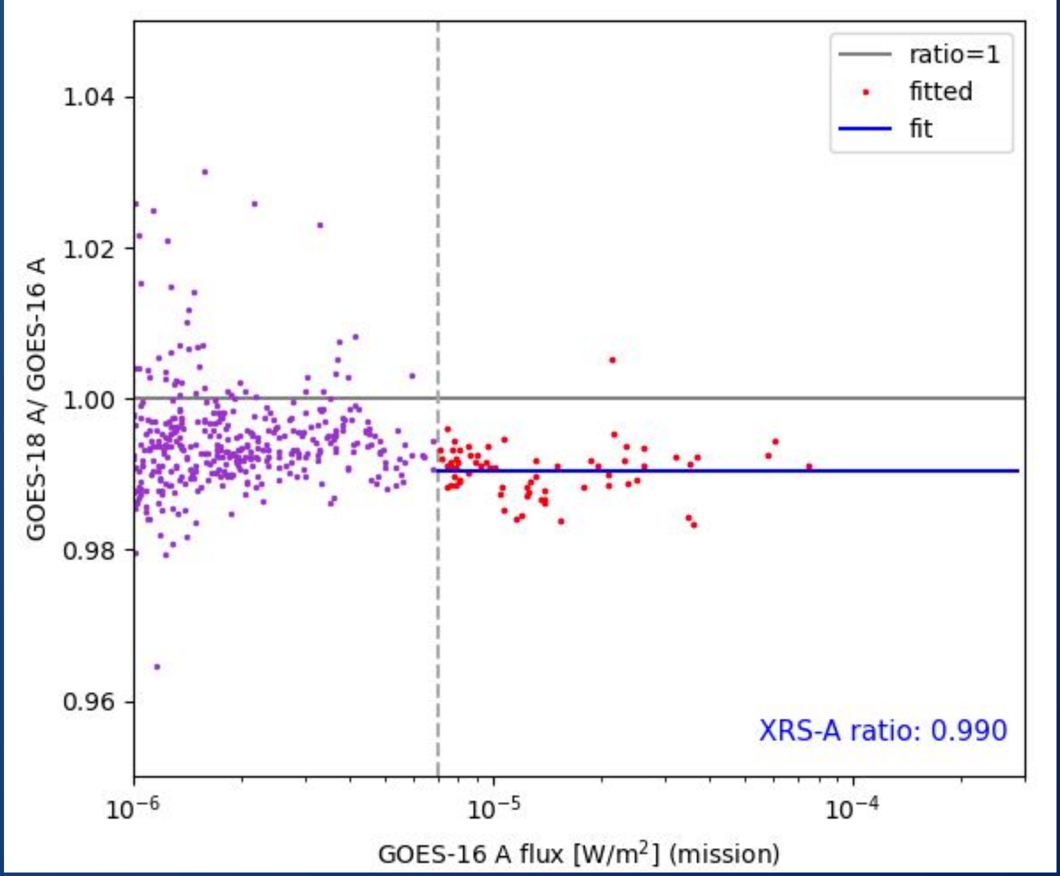
G17/16 XRS-A1: 0.998

Excellent agreement!



Intersatellite Comparisons: XRS-A

G18/16 XRS-A: 0.99

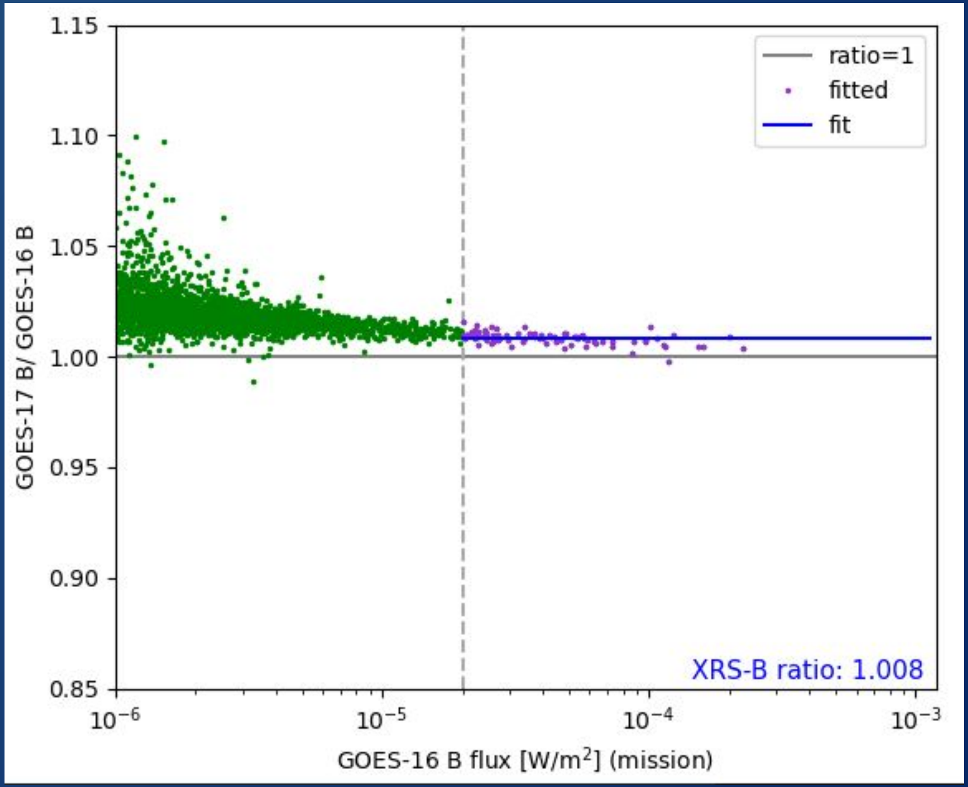


jump due to 2% B2/B1 GOES-16 offset

Intersatellite Comparisons: XRS-B

G17/16 XRS-B: 1.008

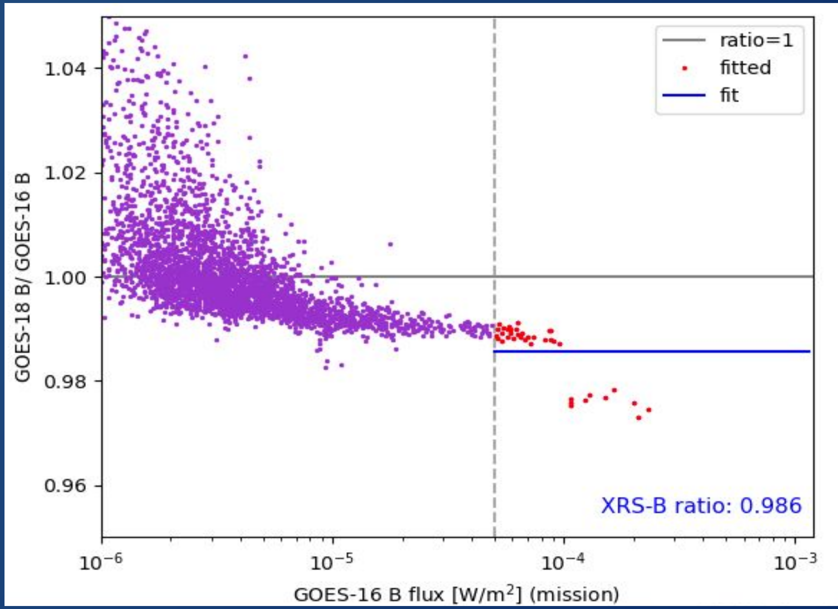
Same size B2/B1 jump for both GOES-16 and -17 cancels out any jump in ratio!



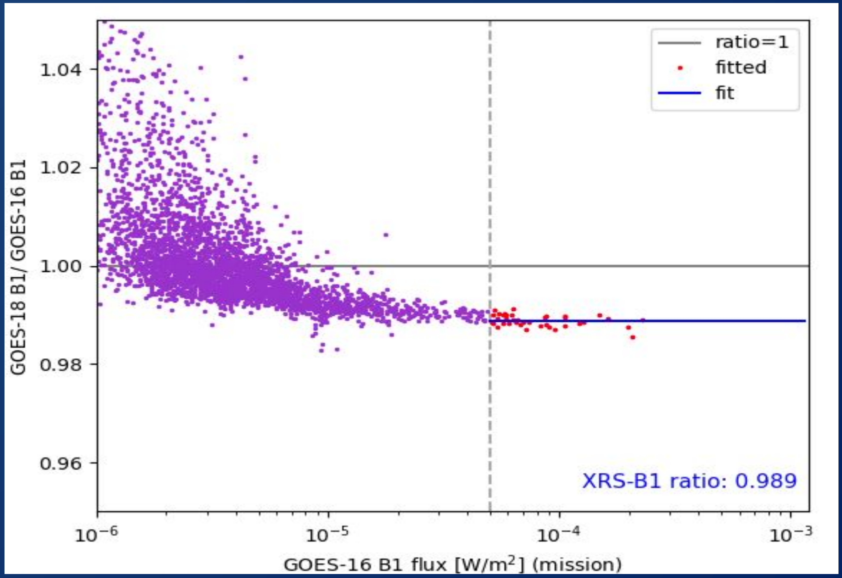
Intersatellite Comparisons: XRS-B

G18/16 XRS-B: ~0.975

Jump due to B2/B1 offset for GOES-16.



G18/16 XRS-B1: 0.989



NOAA XRS Scaling Factors

Approximate ratios between satellites

channel	ratio	G17 PS-PVR (Aug 2020)	G18 PS-PVR (Nov 2022)	G18 PS-PVR (Nov 2023) A or B	G18 PS-PVR (Nov 2023) A1 or B1
A	G16/G15	1.37			
	G17/G15	1.32			
	G17/G16	0.99	1.00	1.07	0.998
	G18/G16		0.99 (XRS-A1)	0.990	0.991
	G17/G18			1.08	1.007
B	G16/G15	1.07			
	G17/G15	1.10			
	G17/G16	1.02	1.01	1.008	1.008
	G18/G16		0.99	0.975	0.989
	G17/G18			1.03	1.019

Performance Baseline Comparison

Performance Baseline

Assessment from Provisional PS-PVR: All requirements are met.
At Full PS-PVR: All requirements continue to be met[1,2].

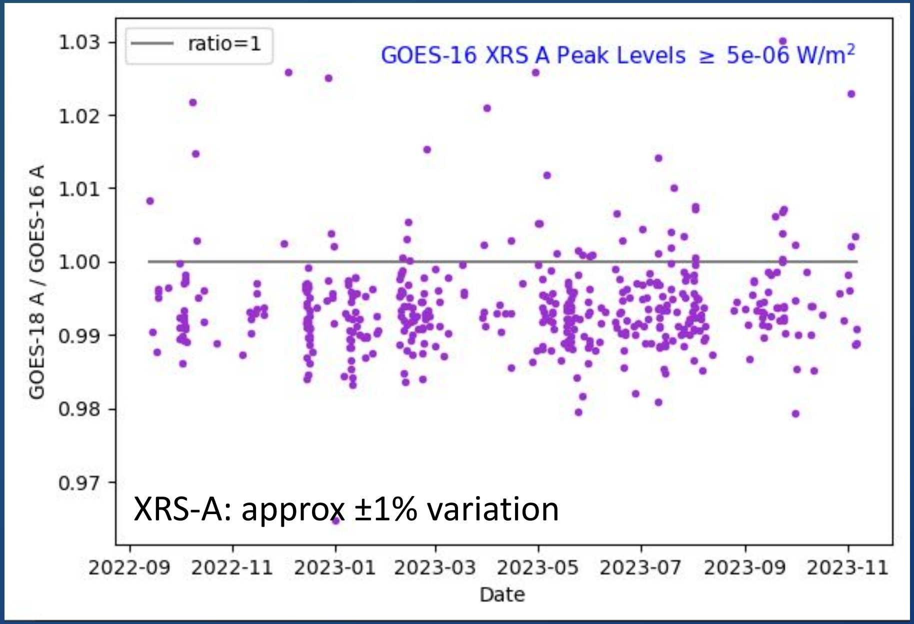
MRD ID	Quantity	MRD Requirement	GOES-16	GOES-17	GOES-18	Related PLPTs	Status
2037	Measurement Range XRS-A	5×10^{-9} to 5×10^{-4} W/m^2	1.20×10^{-10} to 8.12×10^{-3} W/m^2	4.62×10^{-9} to 7.30×10^{-2} W/m^2	**8.37×10^{-9} to 8.42×10^{-2} W/m^2**	#12	PASS
	Measurement Range XRS-B	2×10^{-8} to 2×10^{-3} W/m^2	1.85×10^{-10} to 1.47×10^{-2} W/m^2	6.13×10^{-9} to 4.40×10^{-2} W/m^2	**7.54×10^{-9} to 5.26×10^{-2} W/m^2**		
2038	Measurement Accuracy XRS-A	< 20% at 20X min flux	Not measured on orbit.			None	PASS
	Measurement Accuracy XRS-B	< 20% at 20X min flux	Not measured on orbit.				
2041	Measurement Precision XRS-A	2%	0.87%	0.69%	**0.71%**	#12	PASS
	Measurement Precision XRS-B	2%	1.5%	0.23%	**0.46%**		
2042	Long-term Stability (over mission)	< ±5% or ability to track	Current trend is flat. Ability to track.			#14	PASS

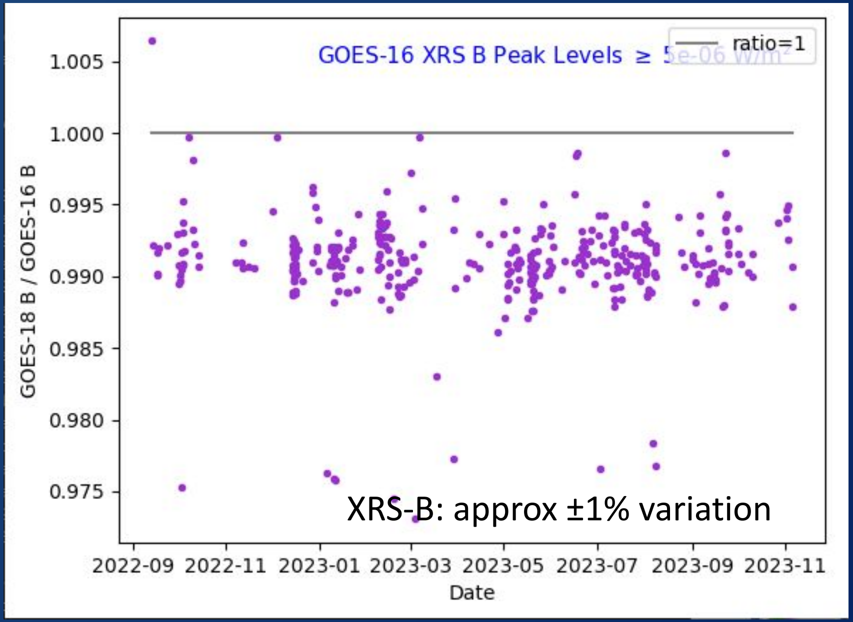
[1] Slides with details for uncertainties, precisions and ranges are unchanged from the Provisional PS-PVR and are included in the Backup Slides.
[2] Updated GOES-18 stability analysis shown on next slide.

Stability of GOES-18 relative to GOES-16

(for MRD 2042)

- Examine ratios of peak irradiances for GOES-18 / GOES-16.
- Irradiances appear stable and we will continue to monitor them.





Instrument Issues

There are no significant new instrument issues.

SUMMARY OF REMAINING ISSUES

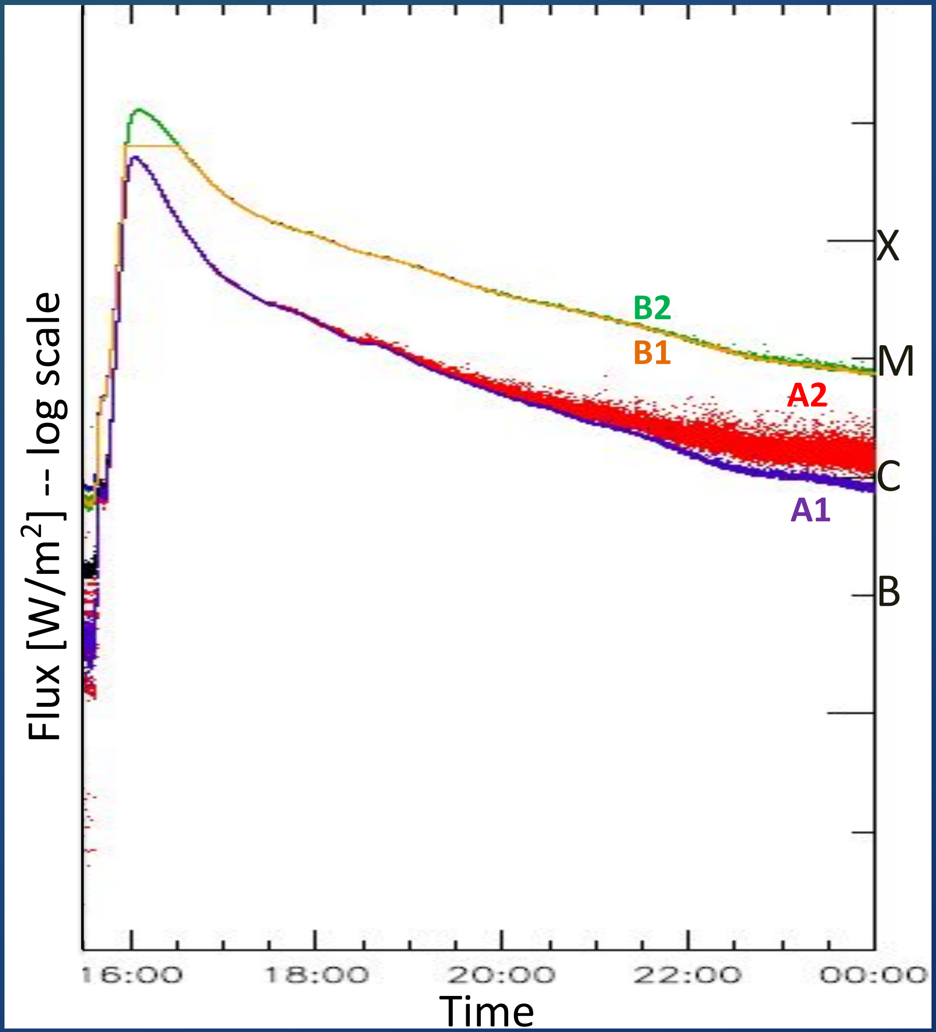
Remaining XRS GPA Issues

ADR	Issue	Impact	Description / Impacts	Delivery date
1161	Add EXIS penumbra flag	Moderate	XRS flare detection has errors without this flag.	tbd

Remaining Instrument XRS Issues

#	Issue	Description	Comments to Users
1	XRS-A is larger GOES-R than on GOES-15.	XRS-A: GOES-17/GOES-15 = 1.32	The source of this discrepancy is unknown and is under investigation. The fluxes from GOES-8 through -15 have all agreed, and the GOES-R satellites all agree with each other. We will use newly available solar X-Ray spectral measurements from other satellites we will try to resolve.
2	Dark radiation coefficients need to be determined.	The dark radiation coefficient is used to correct the signal for proton contamination during SEP events. It is currently not being applied (and set to 0).	(See next Slide.) Analysis to determine this term is in progress. Signals will be artificially high during SEP events, especially in the A2 and B2 channels. May require more SEP events.
3	Dark counts	Need to implement time-dependent LUTs for the science quality data.	Impact until fix will be to slightly increase fluxes, but this will only be noticeable for the lowest fluxes.
4	Electron contamination fit coefficients.	L2 electron contamination correction requires coefficients for SEISS MPSHI telescopes and energy bands.	The L2 algorithm coefficients need to be revised for GOES-18 following dark count and responsivity updates. A new machine-learning based method and a physics-based analysis are being tested as well.
6	Responsivities	Review and revise responsivities for some satellites.	Responsivity for GOES-17 XRS-A2, B2 will be revised. Responsivities for GOES-16 XRS-B2, GOES-17-B2 and GOES-18 XRS-A2 will be reviewed for possible revision after time-dependent dark counts implemented. Requires updated operational LUTs and new versions of science-quality data.

Instrument Issue: Dark Radiation Coefficients



data: G16 operational L1b

Signal is higher in A2 than A1 in SEP event.

CDRL 80 flux equation has a correction terms to account for SEPs; e.g.:

$$C_{rad,\,A1} = k_{A1} \langle C_{Dark,\,rad} \rangle$$

Need to determine k_i

FULL VALIDATION ASSESSMENT

Full Validation Assessment - Preparation

Preparation Activities	Assessment
Validation, quality assessment, and anomaly resolution activities are ongoing.	Validation activities are ongoing. Results have been discussed with SWPC. Release of data by NCEI enables research community participation.
Incremental product improvements may still be occurring.	Product improvements will result from the resolution to issues given on the slides titled "GPA Issues" and "Remaining Instrument Issues".
Users are engaged and user feedback is assessed.	Discussions with SWPC and the science community are ongoing.

Full Validation Assessment - End State

End State	Assessment
Product performance for all products is defined and documented over a wide range of representative conditions via ongoing ground truth and validation efforts.	XRS flux measurements from GOES-15, -16, -17 and -18 have been intercompared. Instrument was calibrated at NIST. Products are documented in Readmes and User Guides.
Products are operationally optimized, as necessary, considering mission parameters of cost, schedule, and technical competence as compared to user expectations.	Except as described on the slide titled "Remaining Instrument Issues“, the products are operationally optimized. Regular monitoring, on-orbit calibrations and LUT updates will maintain this optimization.
All known product *anomalies are documented and shared* with the user community.	Anomalies are listed in the caveats section in the L1b Readmes at the NCEI GOES-R web site.
Product is operational.	Products available real-time for operations at SWPC. Science and operational products available at NCEI.

Summary and Recommendations

- All sensors are performing very well.
- Calibration LUTs have been updated. Further updates will occur.
- Observed issues for GOES-18 are similar to those for GOES-16 and -17.
- Promising paths toward diagnoses and fixes of issues have been identified.
- Fixes for remaining ADRs need to be implemented to provide good data at all times.
- Continued data monitoring and updates to on-orbit LUTs are required. One new LUT will be implemented in the coming weeks.
- Further algorithm review will be required after large SEP events.

NCEI-CO recommends that FM3 XRS L1b data be transitioned to Full Validation status at this time.

Next Steps for XRS

- Utilize new MPSHI science data when available.
  - Generate new L2 electron contamination correction.
  - Correct science quality data.
- Analyze daily, weekly and quarterly calibrations.
  - Occasionally submit revised LUTs (mostly for revised dark counts).
- Identify and resolve instrument issues including those on the Summary of Remaining Issues slide.
- Create a revised NCEI pipeline for XRS data.
- Verify L1b revisions for ADR fixes.
- Continue to develop regular monitoring of data
- Continue to work with SWPC
  - L2 implementation
  - Users request -- expanded / lower-latency EXIS real-time data to the public.
- Continue work on related products.
  - Flare summary composite
  - XRS science-quality data for GOES 1-15

BACKUP SLIDES

EXIS Calibrations

- Nominal Weekly - 90 s comparison with secondary
  - EUVS - A, -B Measure and trend darks and gain.
  - EUVS-A Measure and trend primary filter changes.
  - EUVS - A, -B, -C Measure and trend flatfield.
  - EUVS -C Measure and trend primary channel offset.
- Quarterly cruciform
  - XRS, EUVS-A, -B, -C Measure and trend FOV map
  - XRS, SPS Measure and trend internal gain, dark
- Quarterly other
  - XRS, EUVS-A, -B Measure radiation k factors
  - SPS Check for radiation sensitivity
  - EUVS-C Check radiation filtering, Mg II scaling.
  - XRS Find cross-over thresholds for A1-A2 and B1-B2. Check impact on ratios.
  - XRS Determine NOAA scaling, L1b uncertainties.
  - EUVS L1b model baseline and uncertainties.
  - EUVS Check for bootstrap relationships and degradations.
- Longterm comparisons
  - XRS compare flare locations from XRS and SUVI
  - XRS, EUVS compare measurements with other satellites

XRS LUTs

FM3 LUTs in OE as of 2023-11-01:

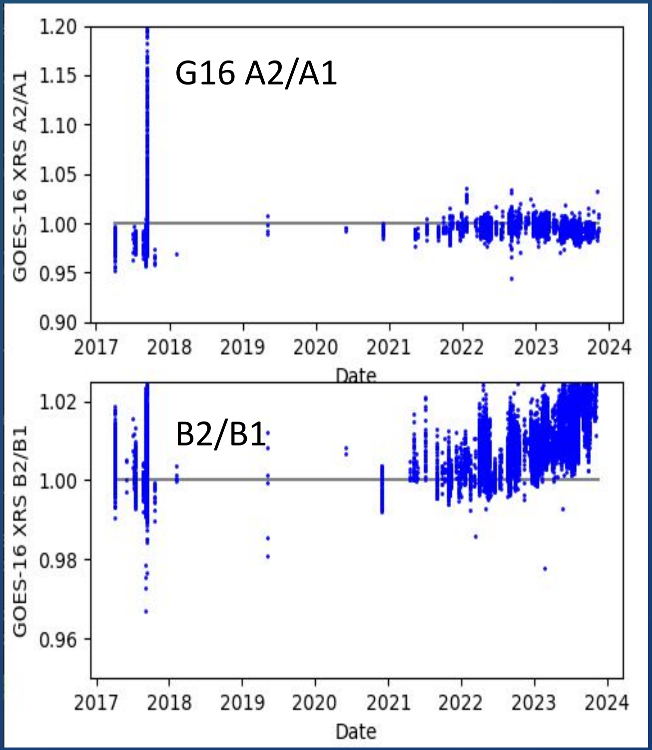
SPS_Cal_INR(fm3_CDRL79revE).h5 *installed* 2023-04-27

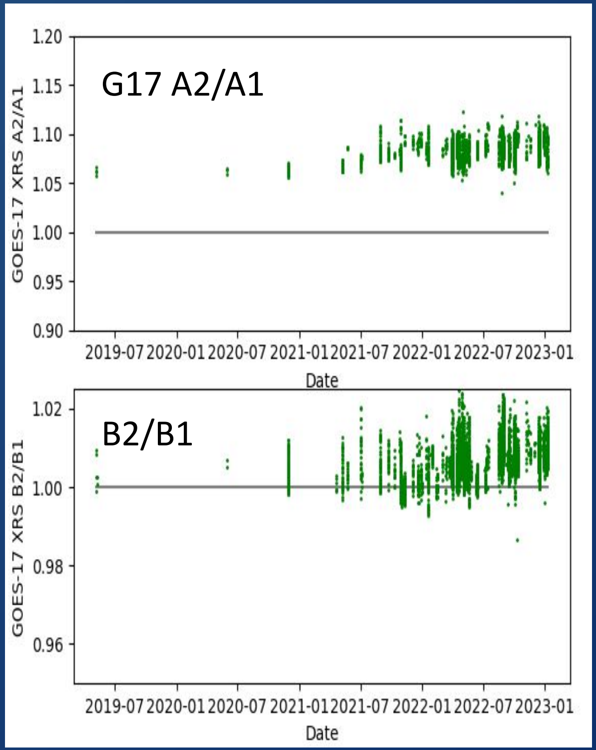
XRS_Cal_INR(fm3_CDRL79revC).h5 *installed 2022-07-15; Rev B, labeled Rev C*

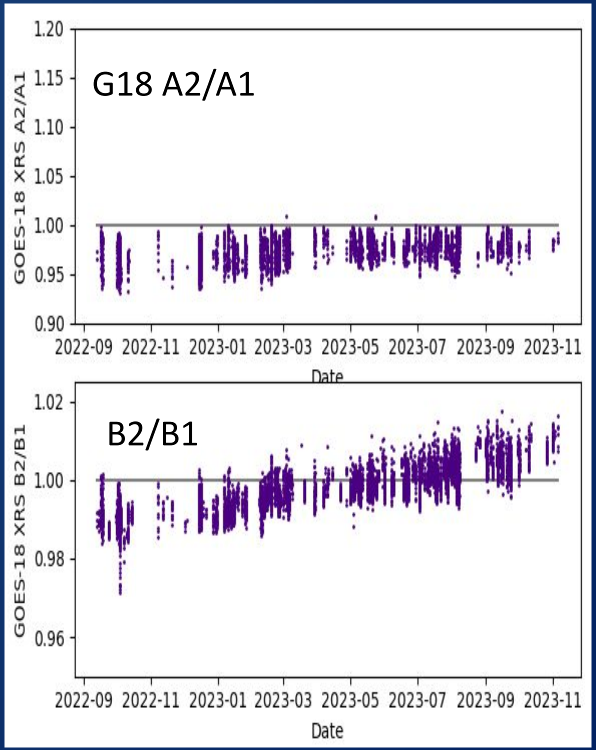
Yearly_1AU_Correction_Table(2023).h5

Channel Ratios vs Time

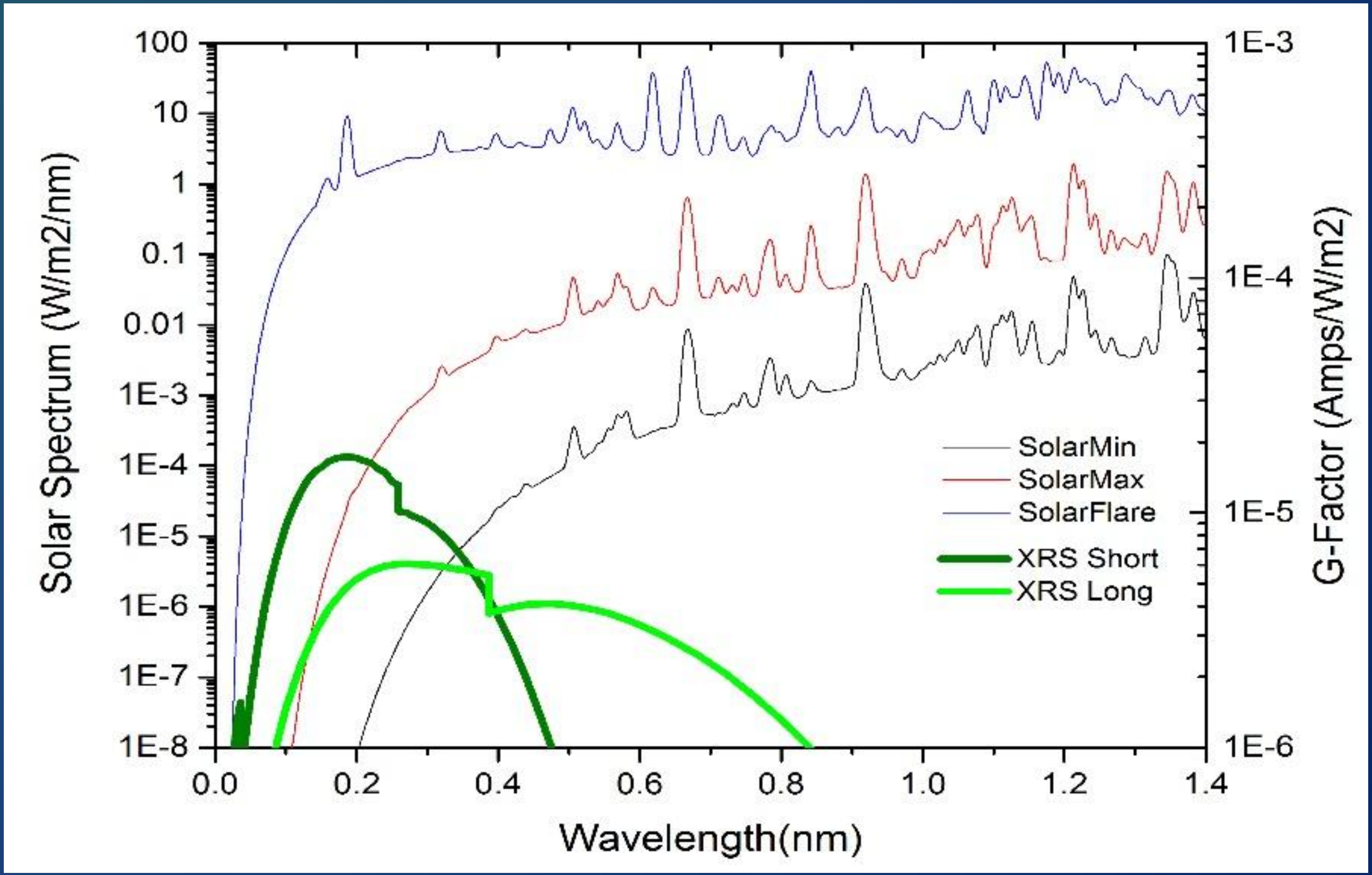
- Explore scaling of high to low channel irradiance. Ideally should be 1.
  - A2/A1 and B2/B1 time series for full mission
  - Included irradiance: XRS-A >2e-6 W/m^2, XRS-B: >1e-5 W/m^2
  - Plots: Different y-axes for XRS-A and -B
  - Highest irradiances are near ratio=1; we will fit peaks





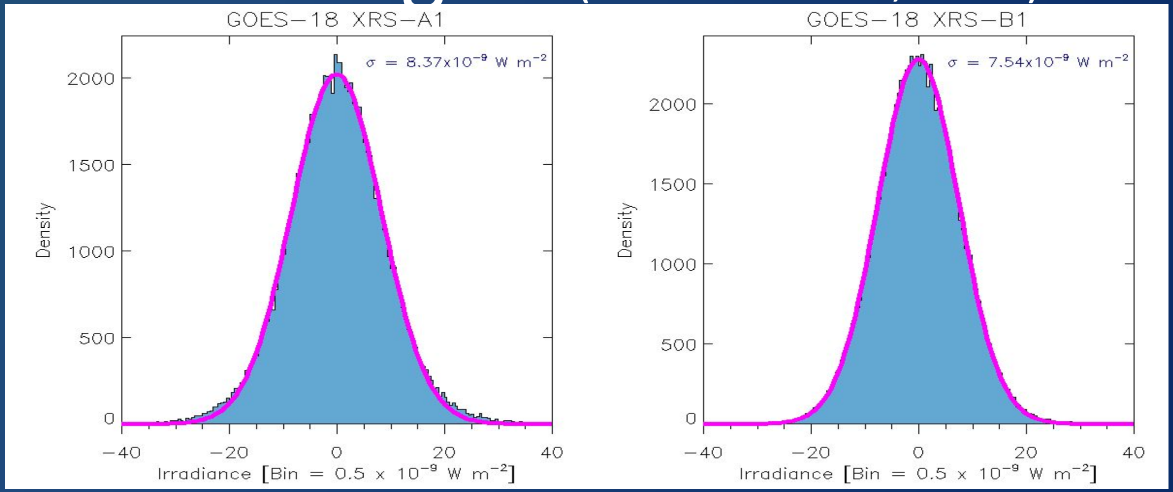


XRS Responsivity and Solar Spectra



Uncertainties and Ranges (for MRD 2037, 2041)

Plots show noise distributions (with 1σ standard deviations) obtained by using high pass filter on **m**easurements for GOES-18.



Precision defined by equivalent irradiances for 1 DN at a typical temperature (14.139° C) on 2022/290.

A1: 1 DN = 1.188×10^{-9} W/m^2 B1: 1 DN = 7.001×10^{-10} W/m^2

A2: 1 DN = 8.516×10^{-8} W/m^2 B2: 1 DN = 5.314×10^{-8} W/m^2

Uncertainties for XRS-A1 and -B1 (from plot above)

σ_{A1} at 1 DN = 8.37×10^{-9} W/m^2 σ_{B1} at 1 DN = 7.54×10^{-9} W/m^2

Minimum irradiances are the larger of the 1-DN equivalent irradiances and uncertainties for A1 and B1.

A1 min: 8.37×10^{-9} W/m^2 B1 min: 7.54×10^{-9} W/m^2

Maximum irradiances are flux equivalents of 989,000 DN (ASIC counter saturation) for A2 and B2.

A1 max: 0.001175 W/m^2 B1 max: 6.924×10^{-4} W/m^2

A2 max: 0.08423 W/m^2 B2 max: 0.0526 W/m^2

credit: Tom Eden

data: LASP-processed L1b

Performance Baseline

MRD ID	Description	Source of Values in Validation Table[1,2]
2037	XRS Product Measurement Range	Essentially no new values measured on orbit. Range minima are uncertainties due to noise for A1 and B1 Range maxima are: flux equivalent of 989,000 DN (ASIC counter saturation) for A2 and B2
2038	XRS Product Measurement Accuracy	Not measured on orbit. Validated pre-launch.
2041	XRS Product Measurement Precision	Essentially no new values measured on orbit. Percent precision = P/(20 x M)*100 P = Precision, M = MRD minimum measurable flux
2042	XRS Long-term Stability	Relative to GOES-16, XRS is currently stable. Future monitoring includes: (1) GOES-18 vs. other GOES satellites, (2) ASIC gain calibrations, (3) FOV mappings, and (4) cruciform scans.

[1] GOES-18 XRS Provisional PS-PVR

[2] Revised stability analysis shown on next slide.

Percent Precision for XRS-A1 and -B1

(for MRD 2041)

Calculate percent precision at a very low MRD-defined irradiance level.

Percent precision at MRD-defined flux = P/(20 x M)*100 (Factor of 20 from MRD 2038).

P = Precision = 1 DN equivalent irradiances

A1: 1.19 x 10^{-9} W/m^2 B1: 7.00 x 10^{-10} W/m^2 (from previous slide)

M = MRD minimum measurable flux (from MRD2037)

A1: 8.37 x 10^{-9} W/m^2 B1: 7.54 x 10^{-9} W/m^2

Measurement precision [%] = P/(20 x M)*100 (Factor of 20 from MRD 2038).

A1: 1.19 x 10^{-9} W/m^2 / (20 x 8.37 x 10^{-9} W/m^2) x 100

B1: 7.00 x 10^{-10} W/m^2 / (20 x 7.54 x 10^{-9} W/m^2) x 100

Percent precision: A1: 0.71%, B1: 0.46%

Data Product Variables (xrsf-l2-flloc)

key:
used by SWPC

coordinates

Var Name	*Data Type*	*dimension(s)*	*long_name*	*comments*	*units*
flloc_hg	float	time, coordinate	Flare location in Stonyhurst/heliographic coordinates (lon, lat).	Values provided for on-disk flares only.	degrees, degrees
flloc_car	float	time, coordinate	Flare location in Carrington coordinates (lon, lat).	Values provided for on-disk flares only.	degrees, degrees
flloc_rtheta	float	time, coordinate	Flare location in heliocentric-radial (R, theta) coordinates. Degrees counterclockwise from solar north.		r_sun, degrees
flloc_xy	float	time, coordinate	Flare location in (x, y) helioprojective Cartesian coordinates.		arcsec, arcsec
time	double	time	Record start time. Neglects leap seconds since 2000-01-01.	Time[UTC] =1 Jan 2000 12:00:00[UTC] + time[secs] + n[secs] where n = {0/number of leap secs since 1 Jan 2000} for a conversion function that {ignores/includes} leap secs.	seconds since 2000-01-01 12:00:00 UTC
solar_p_a			Solar position angle between the celestial north pole and the solar rotational north pole, counterclockwise from celestial		

References
https://github.com/CIRES-STP/goesr_l2_exis_algs/blob/main/xrs10_loc/src/python/xrs10_loc.py
https://www.aanda.org/articles/aa/pdf/2006/14/aa4262-05.pdf Thompson, Coordinate systems for solar image data