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

# GOES-16 EXIS EUVS
# L1b Provisional Maturity

25 September 2019

revised 25 September 2019 17:00

Presenter: Janet Machol - NOAA NCEI and U. Colorado CIRES

Contributors:

| | |
|---|---|
| U. of Colorado LASP: | F. Eparvier, D. Woodraska, T. Eden, S. Mueller, M. Snow, R. Meisner, A. Jones, T. Redick, .... |
| NCEI/CIRES: | S. Codrescu, W. Rowland, and C. Peck |
| Other: | Rodney Viereck, Matt Garhart, ... |

# Outline

# Quick Summary

- Initial testing using L0 data processed by LASP has provided most cal values.
- GOES-17 behavior is similar to GOES-16 using LASP-processed-L0 data and Ground System OE L1b.
  - No surprises.
  - Studies done with L1b, L2, and LASP-L0-processed data.
  - Solar activity low since launch.
- GPA: many ADRs submitted, many resolved, a few remain.
- Instrument: new LUTs, some issues resolved, a few remain.
- All PLPT tests: PASSED
- Provisional Validation Product Maturity Assessment.

Not passed. Need 2 ADRs implemented.
Request data embargo until data is fixed.

ADR = Algorithm Discrepancy Report

LUT = Look Up Table

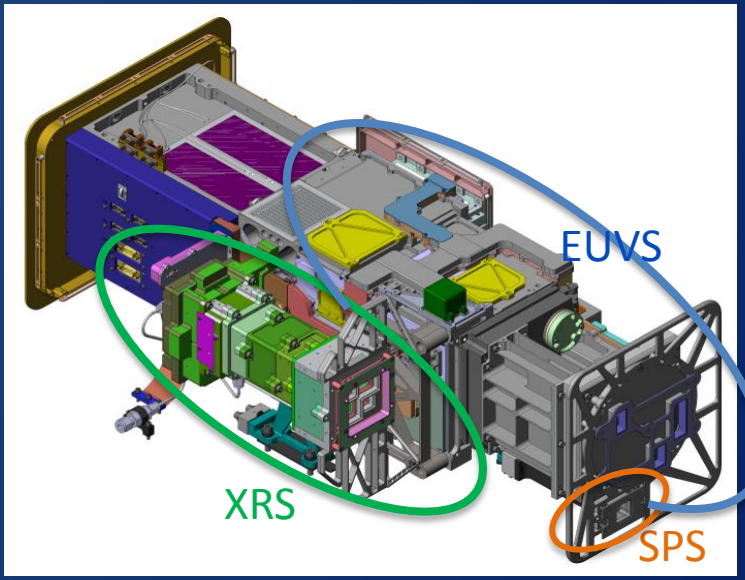
# Top Level Evaluation

| L1b products | Past Performance | Current Status (after DO 08.01) | Future Outlook |
|---|---|---|---|
| EUVS-A, -B | • calibration issues<br>• ADR issues | • improved calibrations<br>• temperature correction ADR needs to be fixed<br>• line irradiance ADR needs to be fixed<br>• other ADRs | • expect remaining issues to be fixed |
| EUVS-C | • calibration issues<br>• ADR issues | • daily data is high quality<br>• investigating high cadence data difference between GOES-16 and -17 | • expect remaining issues to be fixed |
| model | • major ADR issues | • model improvements will occur (via the LUTs)<br>• unclear if model is working in GPA until other ADRs are fixed | • expect remaining issues to be fixed |

# EXIS

# EUV and X-Ray Irradiance Sensors (EXIS)

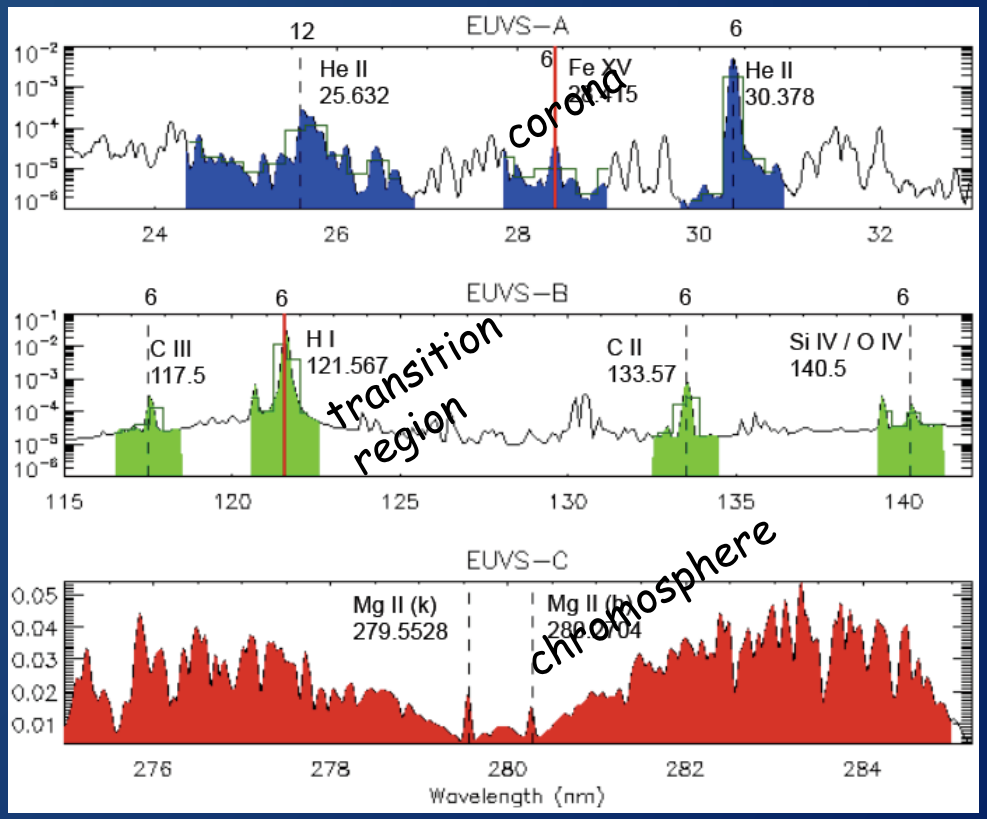
- X-Ray Sensor (XRS)
  - Monitor solar flares
    - Impacts communications and navigation
    - Warning for potential SEP events
- Extreme Ultraviolet Sensor (EUVS)
  - Measures ultraviolet irradiance which impacts upper atmosphere
- Sun Pointing Sensor (SPS)
  - Used for alignment (quad diode, 3.5°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

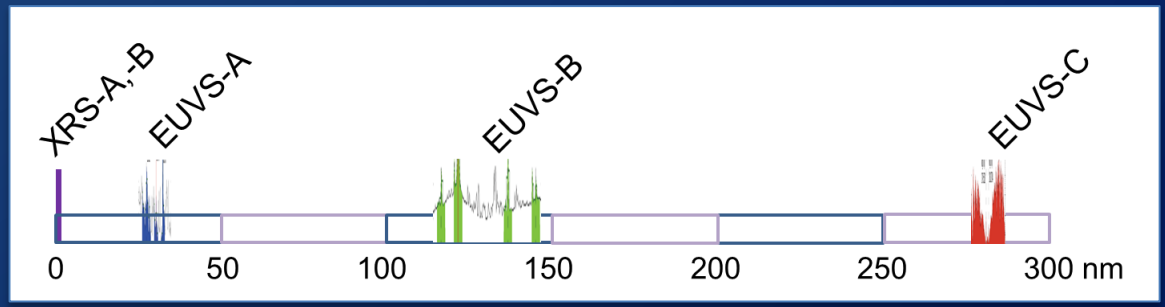



EXIS was designed, built and tested by the Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado.

# Extreme Ultraviolet Sensor (EUVS)

- Requirements
  - ≤30 s cadence
  - ≤20% accuracy
  - Spectral model (5-127 nm)
- 3 Grating Spectrographs
- EUVS-A: 24 diode array, filter wheel
- EUVS-B: 24 diode array
- EUVS-C: 512 diode array
- L1b Products
  - 7 solar lines
  - Mg II index
  - Spectral model (5-127 nm)
  - high res data



# REVIEW OF BETA MATURITY

**BETA REVIEW: 8 MARCH 2017**

**BETA ADDENDUM: 17 MARCH 2017**

# EUVS-related GPA Issues at GOES-16 Beta

| ADR | Issue | Status | Delivery date |
|---|---|---|---|
| 462 | Replace Mg II line peak fitting routine | CLOSED | DO.06.03 |
| 247 | EUVS LUTs not implemented properly | CLOSED | DO.05.00 |
| 204, 355 | Revmove unsigned variable attributes | CLOSED | DO 06.03 |
| 228 | Filename timestamps | CLOSED | DO 07.01 |
| 430 | Eclipse flags set too late | CLOSED | DO 06.00 |
| 282 | Irradiance spectra | CLOSED | PR 06.07 |
| 276, 277 | AU factor LUT issues | CLOSED | DO.06.02 |
| 278 | EUVS long name errors | CLOSED | DO 06.00 |
| 279 | EUVS daily averages are NaN | CLOSED | DO 06.00 |
| 280 | Bad 121 nm bin | CLOSED | PR 06.07 |
| 281 | EUVS files have no UNLIMITED dimension | CLOSED | DO 07.00 |

# GOES-16 Instrument Issues at Beta
# to be resolved prior to Provisional Status

| Title | Description | Status | Mitigation |
|---|---|---|---|
| EUVS-C decline | The EUVS-C signal appears to be declining. | CLOSED | Trend is under investigation. Eventual mitigation may be to switch to C2 which will require calibration. See Slide 50. |
| Changes for future PLTs | A list of requested changes for PLTs for GOES-S and beyond has been created by LASP. | CLOSED | "Lessons Learned and Improvements" presented to MOST. Requests were implemented by Flight. |

# L1B PRODUCT QUALITY ASSESSMENT

# GPA Issues for Provisional Validation

- >70 EUVS-related ADRs have been closed since 2016.
- Analysis with Ground System OE and ITE L1b data and LASP processed L0-data.

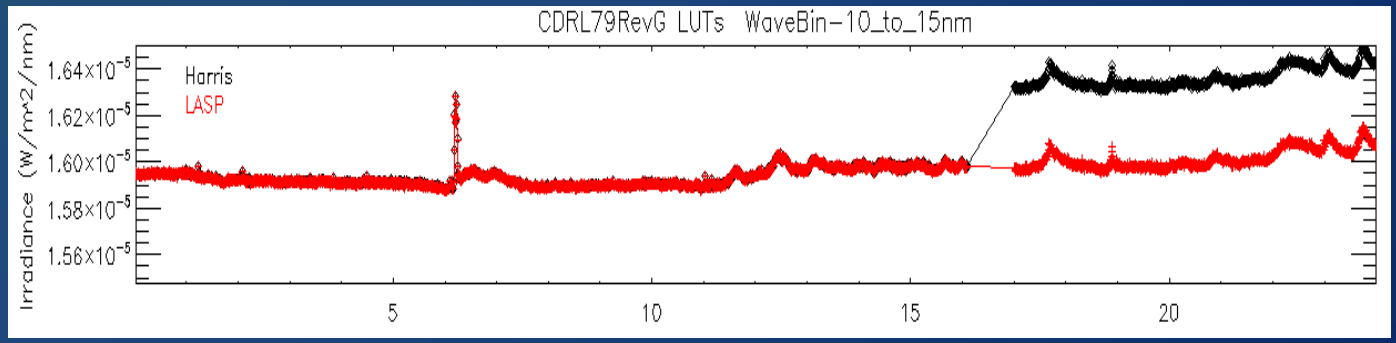
- Two examples of ADRs fixed in DO 08.01
  - ADR 840  EUVS CaseNumbers set incorrectly
  - ADR 857  EUVS Negative Currents

- Two GPA issues that should have been fixed by Provisional Validation
  - ADR 898 temperature correction
  - ADR 471  EUVS-A and -B time dependence of darks

# Fixed ADR Example: ADR 840

ADR 840: EUVS case numbers set incorrectly. (fixed DO 08.01)

- EUVS case number defines which inputs model should use.
- Daily and weekly calibrations were not flagged and ended up in running daily averages in model irradiances.



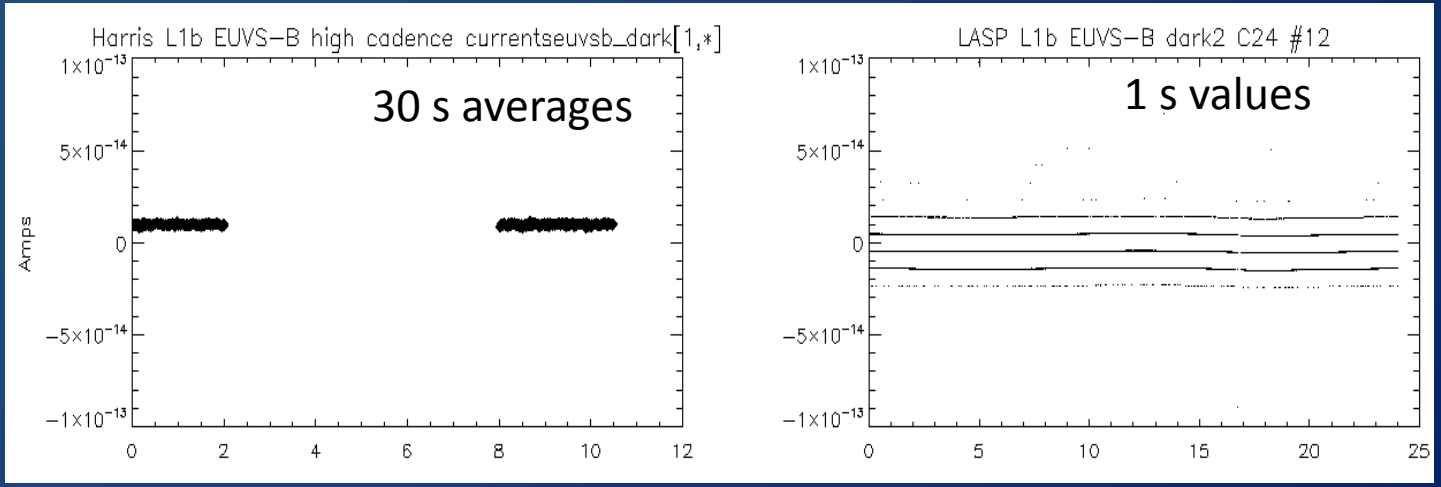

Credit: Don Woodraska

Correction: If euvs_md == CAL or euvs_md == DIAG, then set EUV_CaseNumber = 8 (bad).

# Fixed ADR Example: ADR 857

ADR 857: Include EUVS negative currents. (fixed DO 08.01)

- EUVS currents < 0 were being set to 0.
- Negative currents should be included to avoid biasing data high. (Same issue occurred with XRS.)

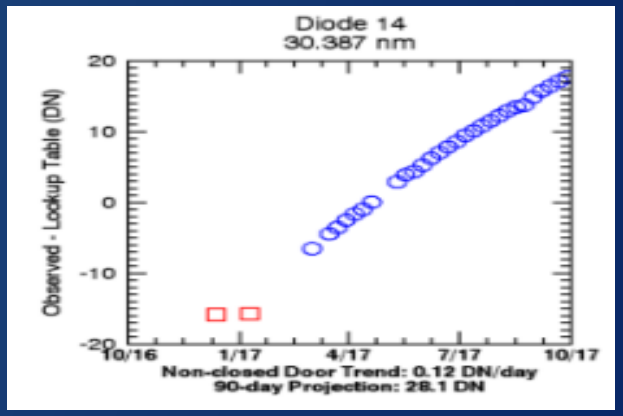



Credit: Don Woodraska

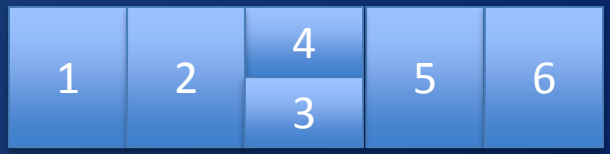
Correction: Do not set negative currents to 0.

# ADR 471: EUVS dark count correction

- Original Request: Add time-dependent correction to dark counts.
- Several iterations.
- DO 08.01 fix
  - Remove double-count 30.4 and 121.6 nm split diodes and use double precision.

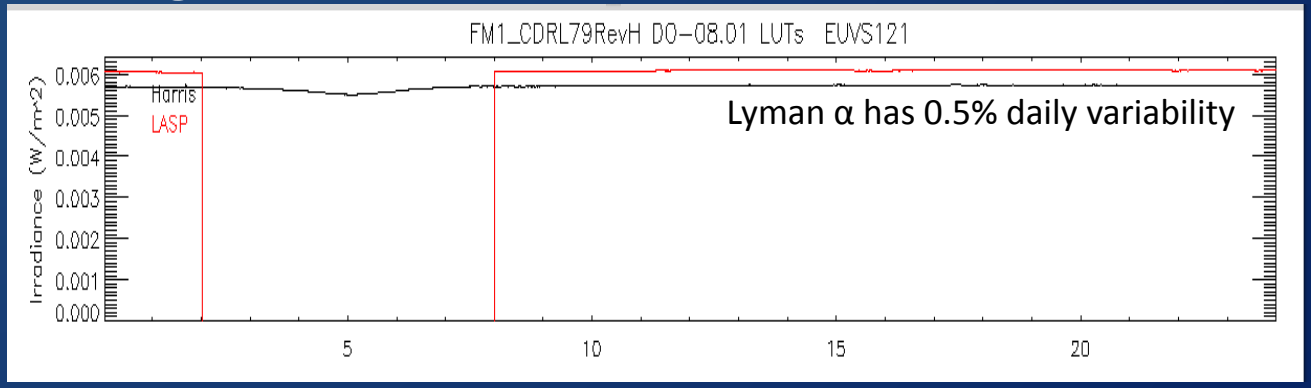



dark count trend over 6 months




diodes for 121.6 nm line

- Remaining issue: 6% offset in 121.6 nm line



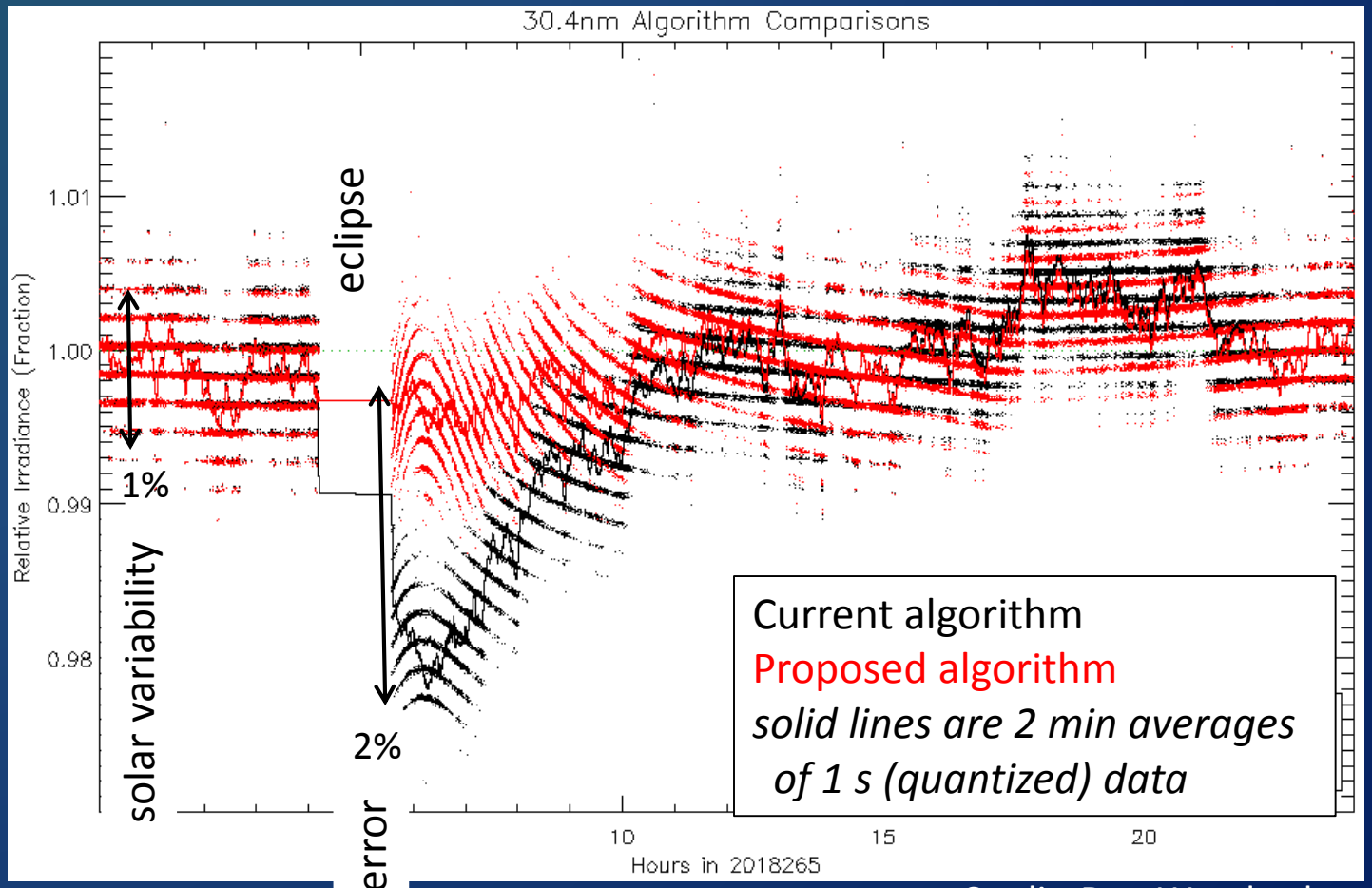
# ADR 898: Dark Counts Temperature Correction (1/9)

- Major offsets to EUVS irradiances require a revised temperature correction to the dark counts.
- Determined from looking at long term trends.

- Software fix
  - an equation change
  - simplification of LUTs from 24 MB table to 2 variables

# Error without temperature correction (2/9)

*Variability from error > solar variability*




Credit: Don Woodraska

# Why measure EUV variability? (3/9)

Variations in solar EUV by up to a factor of 10 increase have major impacts.

More EUV irradiance heats the thermosphere more.

A warmer atmosphere expands.

Satellite drag can increase by a factor of 10.

Satellite operators must correct orbit calculations.

More EUV irradiance modifies the ionosphere.

Impacts radio communications and GPS navigation.



Image Credit: ESA

# EUV variability needed for drag model (4/9)

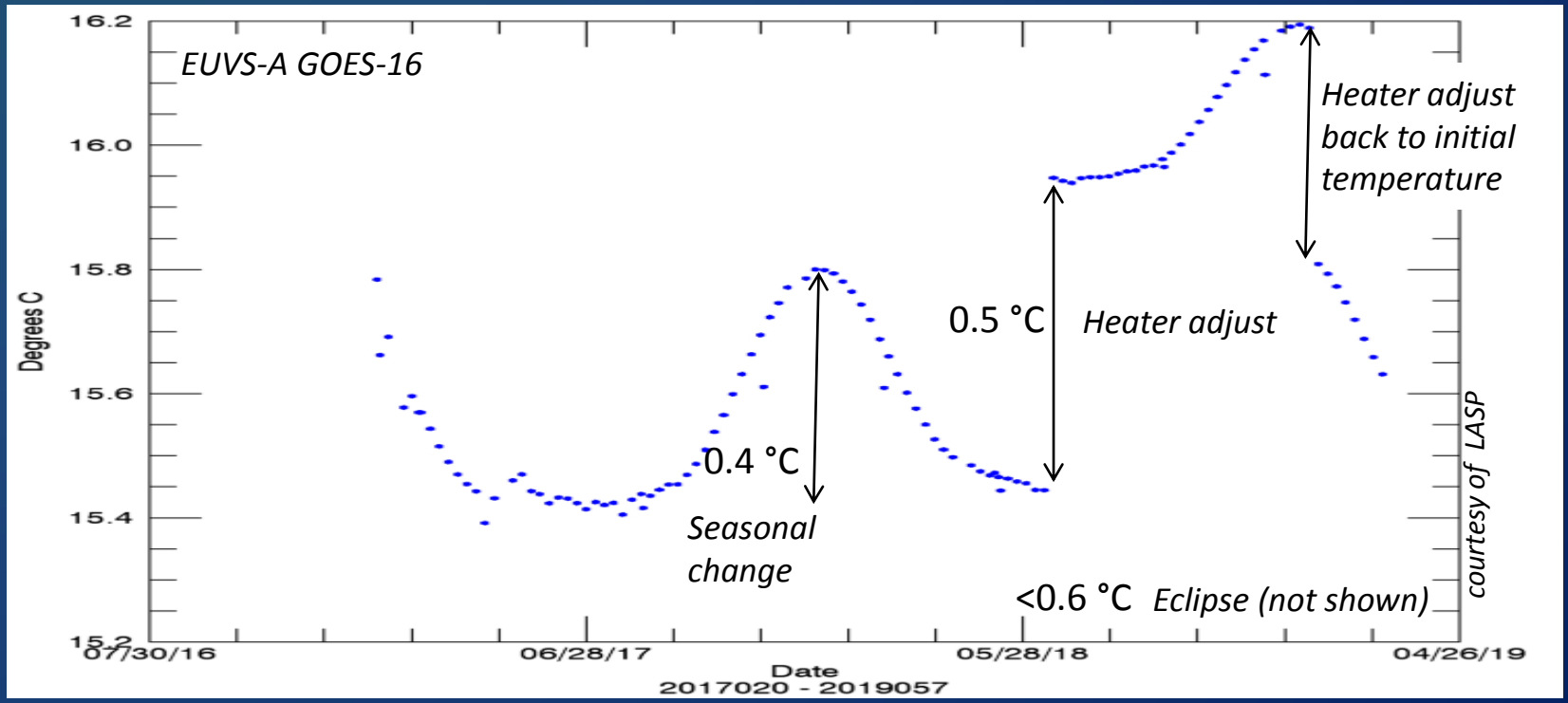
- Space Environment Technologies (SET) uses EUV to form solar indices.
  - Currently uses GOES 14/15 EUV bands.
  - Will switch to GOES-R EUVS lines* and Mg II.

- High Accuracy Satellite Drag Model (HASDM)
  - Uses these indices as inputs.
  - Run by the USAF.
  - The output used to revise NORAD catalogue of satellite 2 line elements every 8 hours.

* 28.4, 30.4 and 121.6 nm

# How big are temperature changes? (5/9)

- Weekly dark observations show temperature changes.
- Use error with heater adjust to estimate seasonal error.




These GOES-16 data are preliminary, non-operational data and are undergoing testing.
Users bear all responsibility for inspecting the data prior to use and for the manner in which the data are utilized.

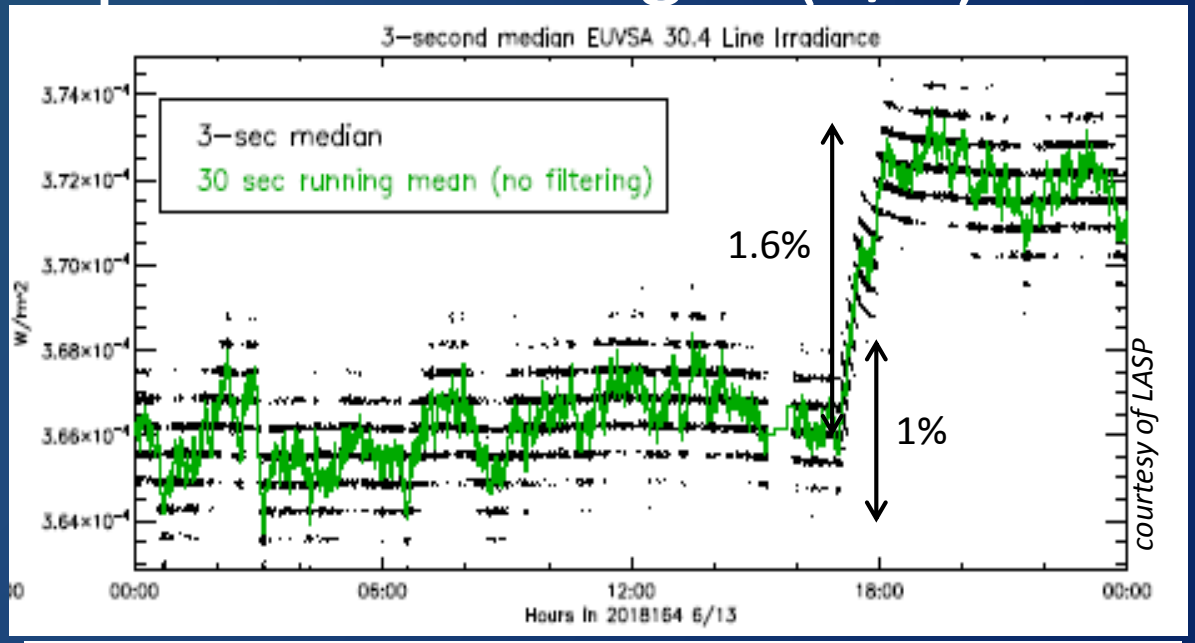
# Impact of temperature changes (6/9)

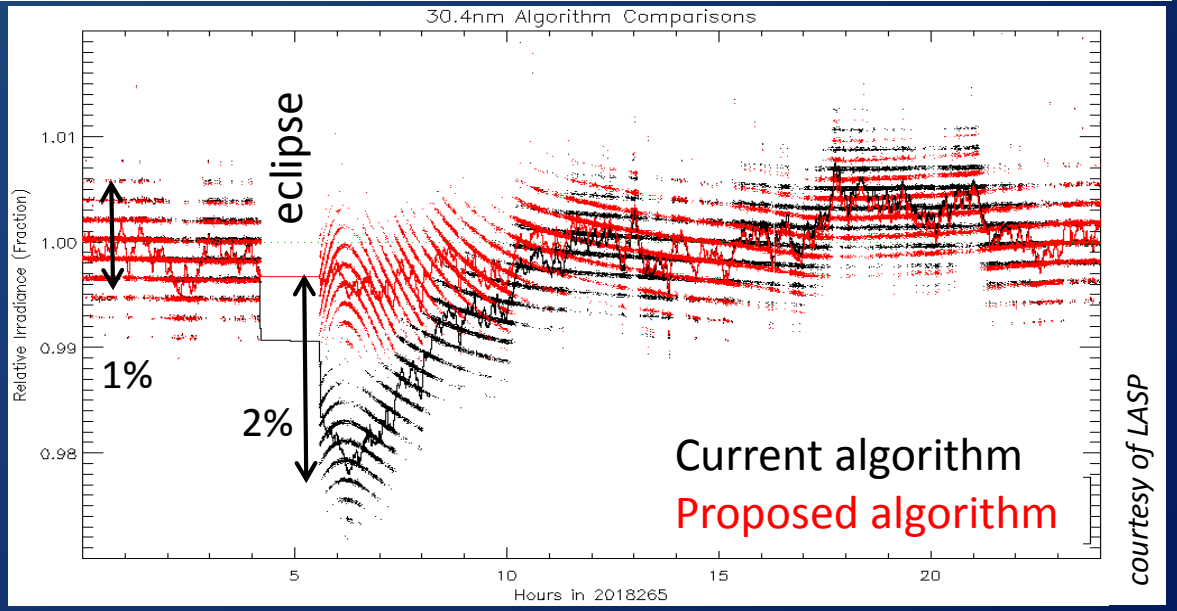
Daily variability at 30.4 nm: 1%

ΔT adjust= 0.5 °C
has a 1.6% irradiance change

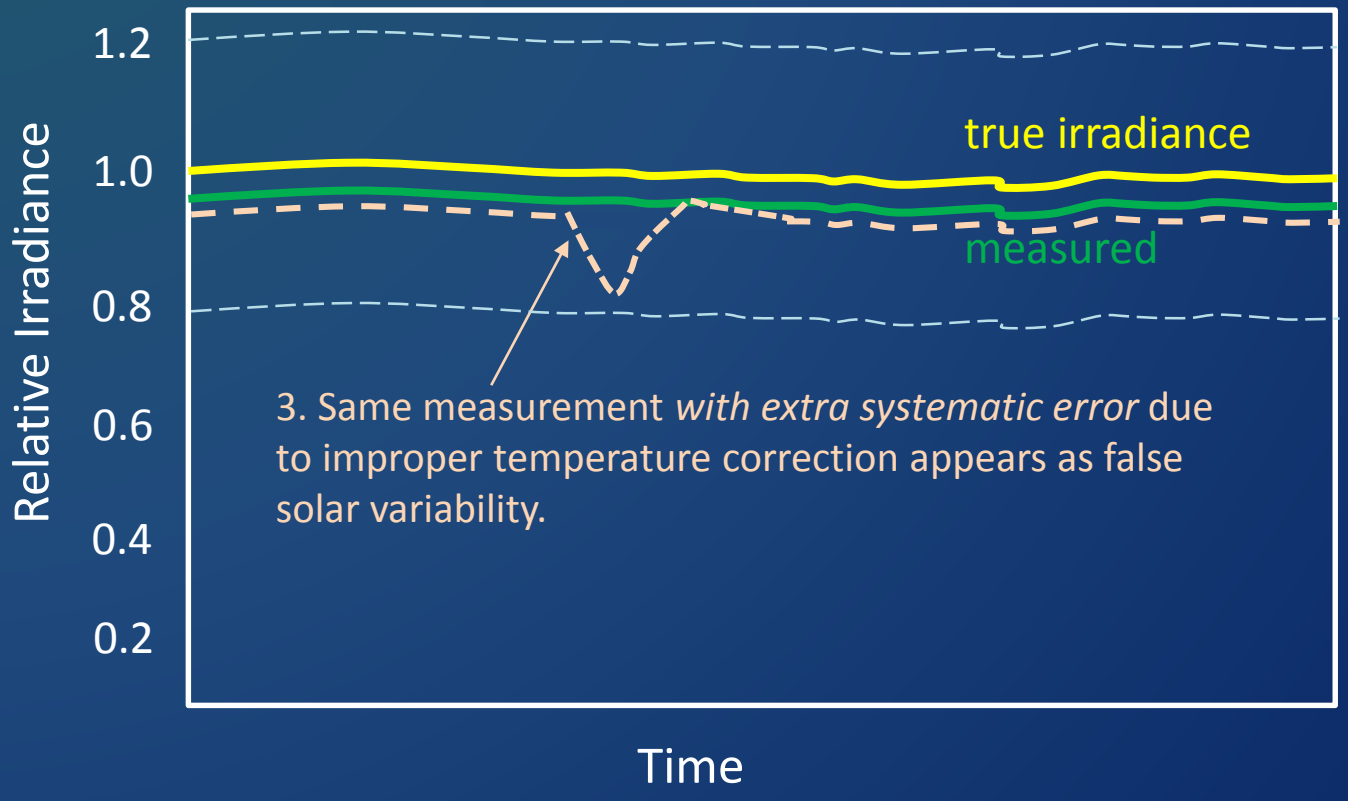
ΔT seasonal = 0.4 °C
→ 1.3% seasonal change
→ *Seasonal temperature error comparable to daily variability*

Eclipse irradiance change = 2%.
→ *Eclipse impact is twice as large as daily variability and lasts >6 hours.*



# EUVS Accuracy Requirements (7/9)




1. PORD ±20% allowed systematic error

2. Measured error which maintains true solar variability.

Bias or Systematic Errors: Offset errors that remains with repeated measurements. Systematic errors can be reduced through calibration.
Random, Stochastic or Precision Errors: Random-like values about the mean value. (not shown in cartoon)

# EUVS Accuracy Requirements (8/9)

- PORD accuracy requirement for EUVS is 20%.
- Intended to refer to the uncertainty (bias) in the absolute long term accuracy of the calibration.
- Not intended to cover other systematic errors that impact variability.
  - Example: if the true daily variability is only 1%, then irradiances with systematic errors that cause 7% variation are meaningless.

| ID | **Requirement** |
|---|---|
| **EXISPORD122**<br>EXISPORD123 | **Irradiance Product Accuracy**<br>The accuracy of the EUV irradiance products, at the spectral resolutions given in EXISPORD107 and the cadence given in EXISPORD130, **shall** be within 20%, 1-sigma, of the actual irradiance. |

# Temperature correction (9/9)

*Without ADR correction, the errors due to eclipse or seasonal variability range from 0.5 to 7 times the daily solar variability.*

*Approximate impacts of corrections*

| wavelength [nm] | post-eclipse error/total irradiance | daily solar variability | post-eclipse error/ daily variability | seasonal error/ daily variability | effectiveness of ADR 898 correction | used for HASDM |
|---|---|---|---|---|---|---|
| 25.6 | 2% | 2% | 1 | 0.6 | very good | |
| 28.4 | 4% | 5% | 0.8 | 0.5 | very good | yes |
| 30.4 | 2% | 1% | 2 | 1.3 | very good | yes |
| 117.5 | 5% | 2% | 2.5 | 1.6 | half of error remains | |
| 121.6 | 0.5%? | 0.5% | 1? | 0.6 | uncertain | yes |
| 133.5 | 7% | 1% | 7 | 4.6 | good | |
| 140.5 | 1% | 1.5% | 0.7 | 0.4 | small improvement | |

*Values in table based on plots for eclipse day of 2018 doy 265 (not shown) courtesy of Don Woodraska (also not shown). Extra credit: M. Snow.*

# Post-Launch Product Tests

Test Plans and Procedures are from the RIMP*.

| PLPT | Test Title | Operator | Status | Criteria |
|---|---|---|---|---|
| 01 | EUVS-C Mg II Scaling | LASP | Pass | [1] |
| 02 | EUVS L1b Model Baseline | LASP | Pass | [1] |
| 03 | EUVS L1b Uncertainties | LASP | Pass | [1] |
| 04 | EUVS Bootstrap Degradation; Mg II -to- 117.5/133.5 | LASP | Pass | [1] |
| 05 | EUVS Bootstrap Degradation; 117.5/133.5 -121.6/140.5 | LASP | Pass | [1] |
| 06 | EUVS Bootstrap Degradation; 121.6/140.5 -to- 25.6/30.4 | LASP | Pass | [1] |
| 07 | EUVS Bootstrap Degradation; 25.6/30.4 -to- 28.4 | LASP | Pass | [1] |
| 14 | XRS/EUVS/Mg II Inter-Satellite Comparisons (L1b) | LASP, NCEI | Pass | none |

[1] RIMP Provisional Success Criteria: "EUVS L1b product data are available and analysis is completed."

- Most PLPT tests use LASP-processed L0 data.
  - PLPTs for calibrations need unprocessed data.
  - Allows use of early data for trending where GPA was incorrect initially or high resolution data was not available.
  - Allows comparisons of current data where GPA is incorrect.
- Ground System OE L1b data used for considerable ADR testing and some PLPT 14 results.

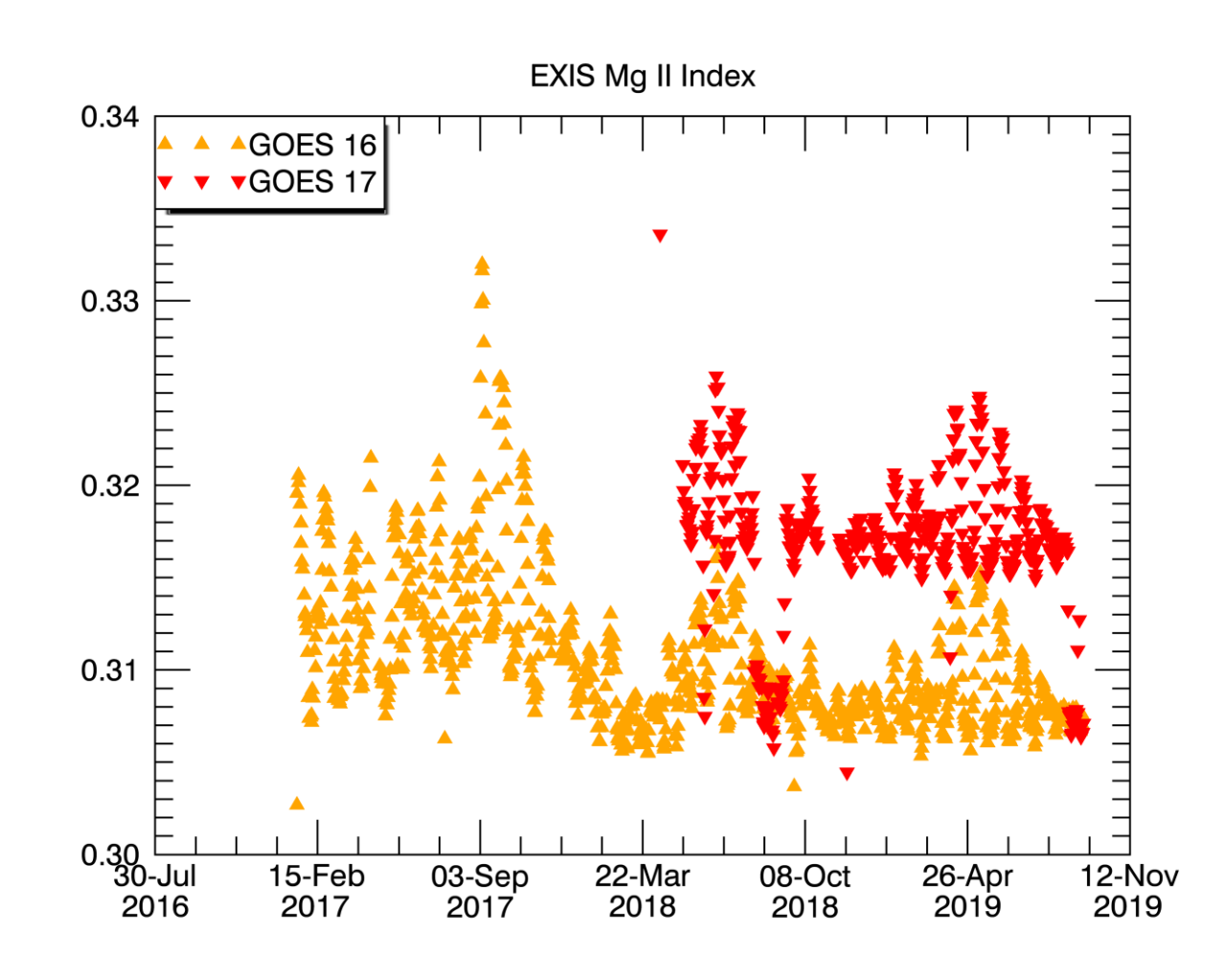
* Appendix A.2 in the EXIS Readiness, Implementation, and Management Plan (RIMP v1.1; 416-R-RIMP-0316)

# #1: EUVS-C Mg II Scaling (1/6)

- **Objective**: Determine the NOAA Mg II scaling factors needed for historical continuity.
- **Provisional Success Criteria**: EUVS L1b product data are available and analysis is completed.

- Scaling is to a standard spectral resolution as described in:
  - A Revised Magnesium II core-to-wing ratio from SORCE SOLSTICE, M. Snow, et al., Earth and Space Sciences, (accepted).
- New factors: $MgII_{standard} = a + b \cdot MgII_{EXIS}$
  - GOES 16: a = 0.19052770 b = 0.23545029
  - GOES-17: a = 0.20745769 b = 0.17505354
- LUT implementation will occur soon.

# #1: EUVS-C Mg II Scaling (2/6)

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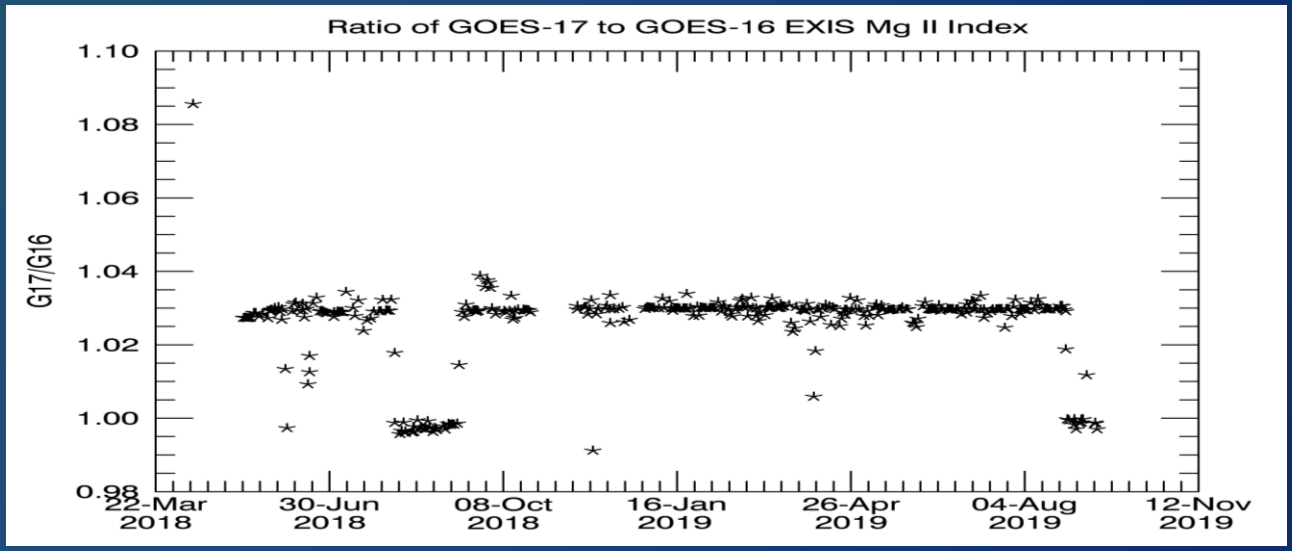
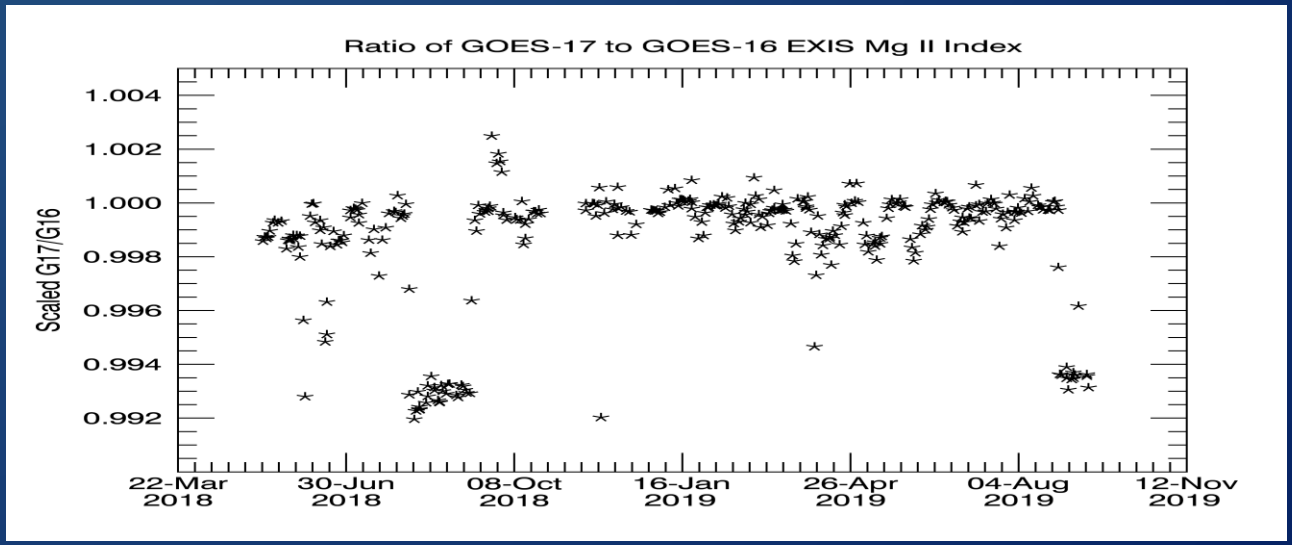
Users bear all responsibility for inspecting the data prior to use and for the manner in which the data are utilized.

# #1: EUVS-C Mg II Scaling (3/6)

ratio of unscaled $MgII_{EXIS}$




ratio of scaled $MgII_{standard}$

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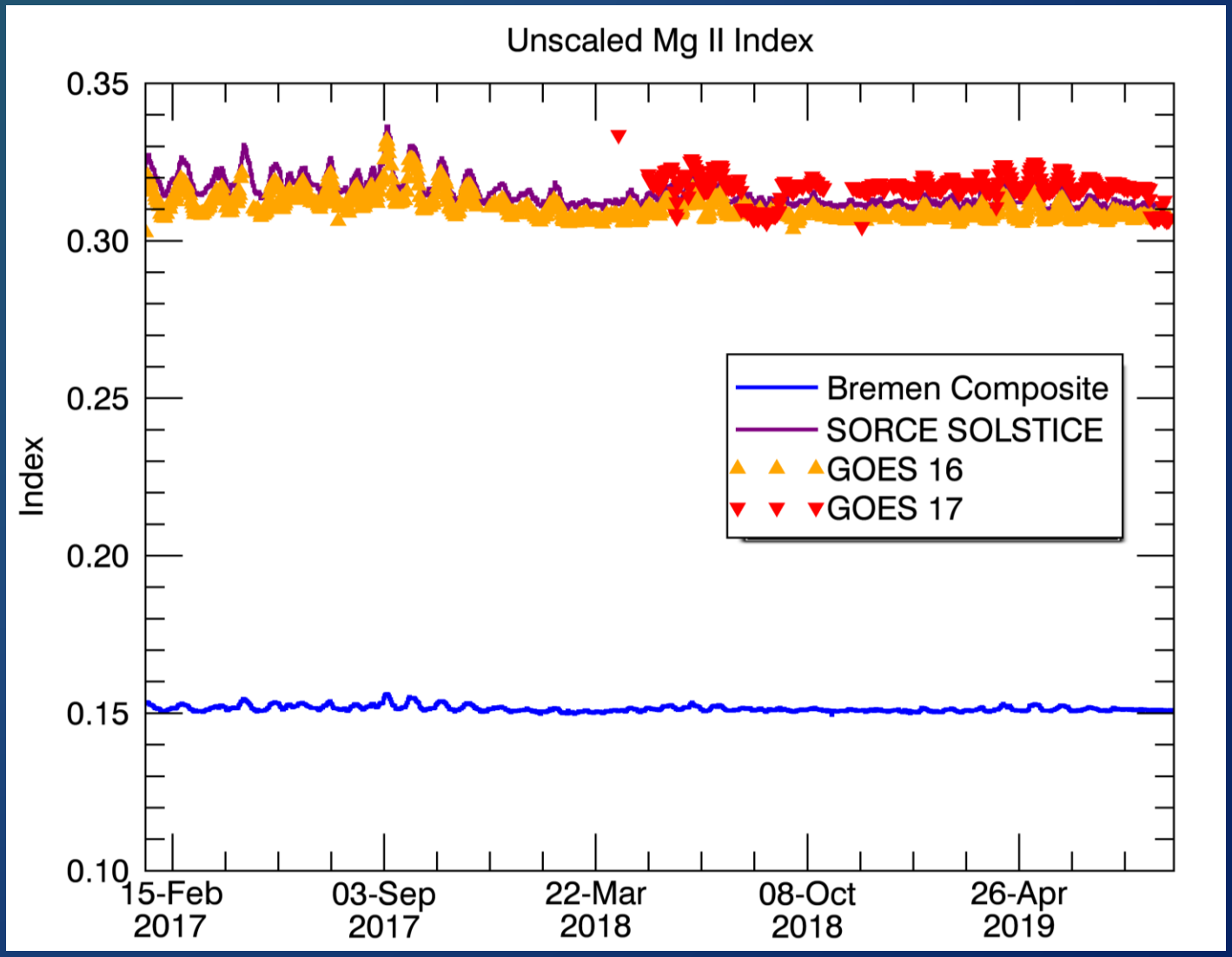
# #1: EUVS-C Mg II Scaling (4/6)

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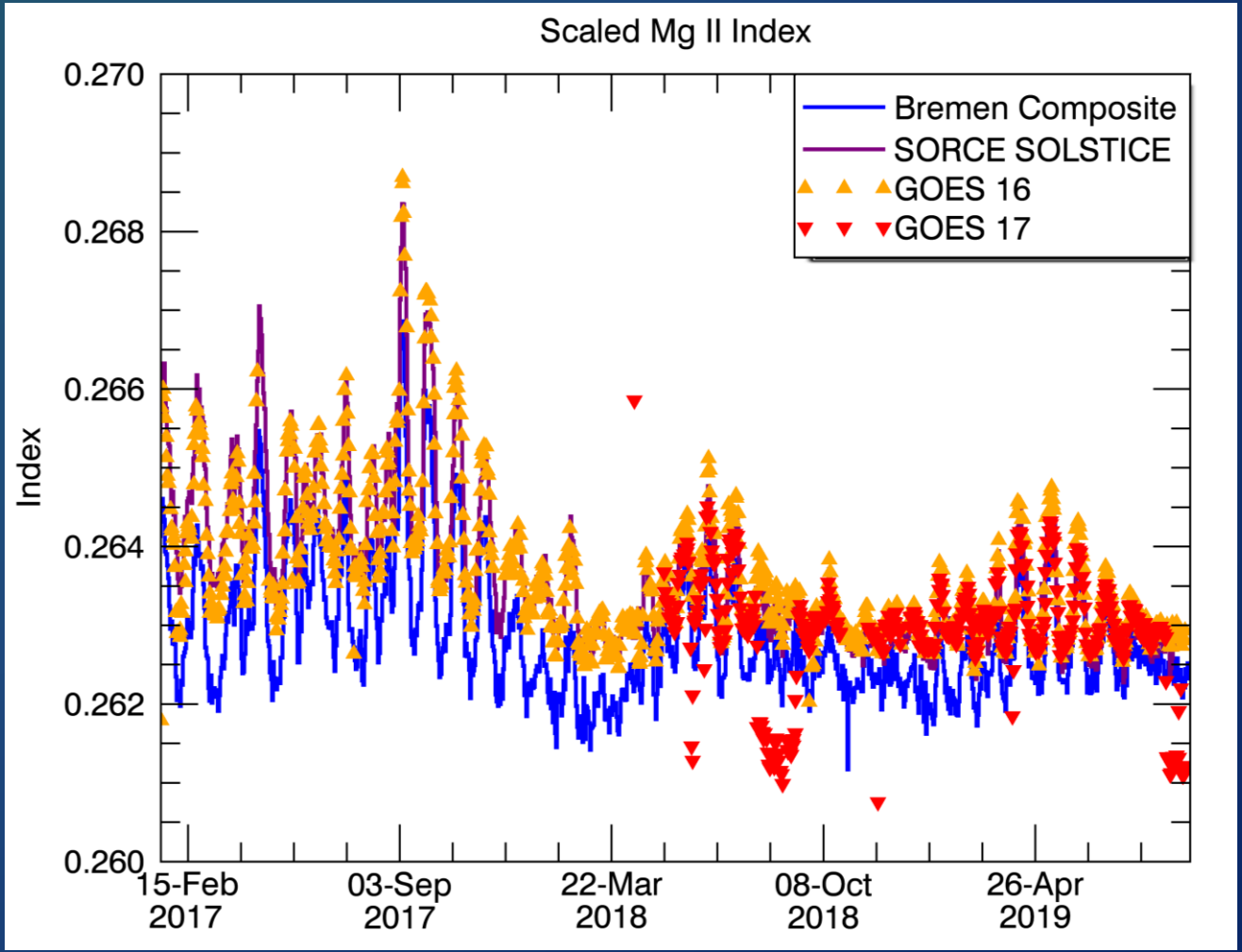
# #1: EUVS-C Mg II Scaling (5/6)

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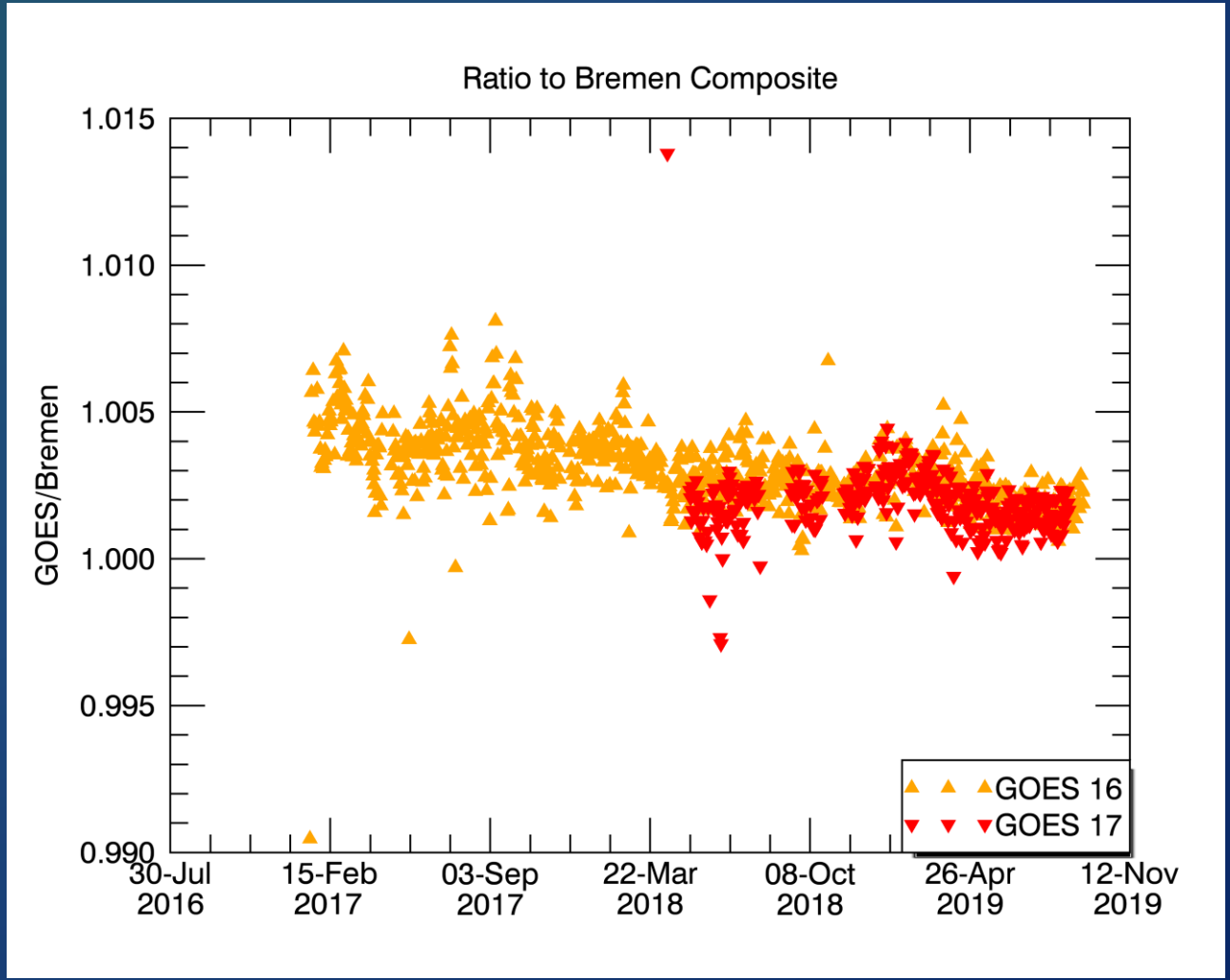
# #1: EUVS-C Mg II Scaling (6/6)

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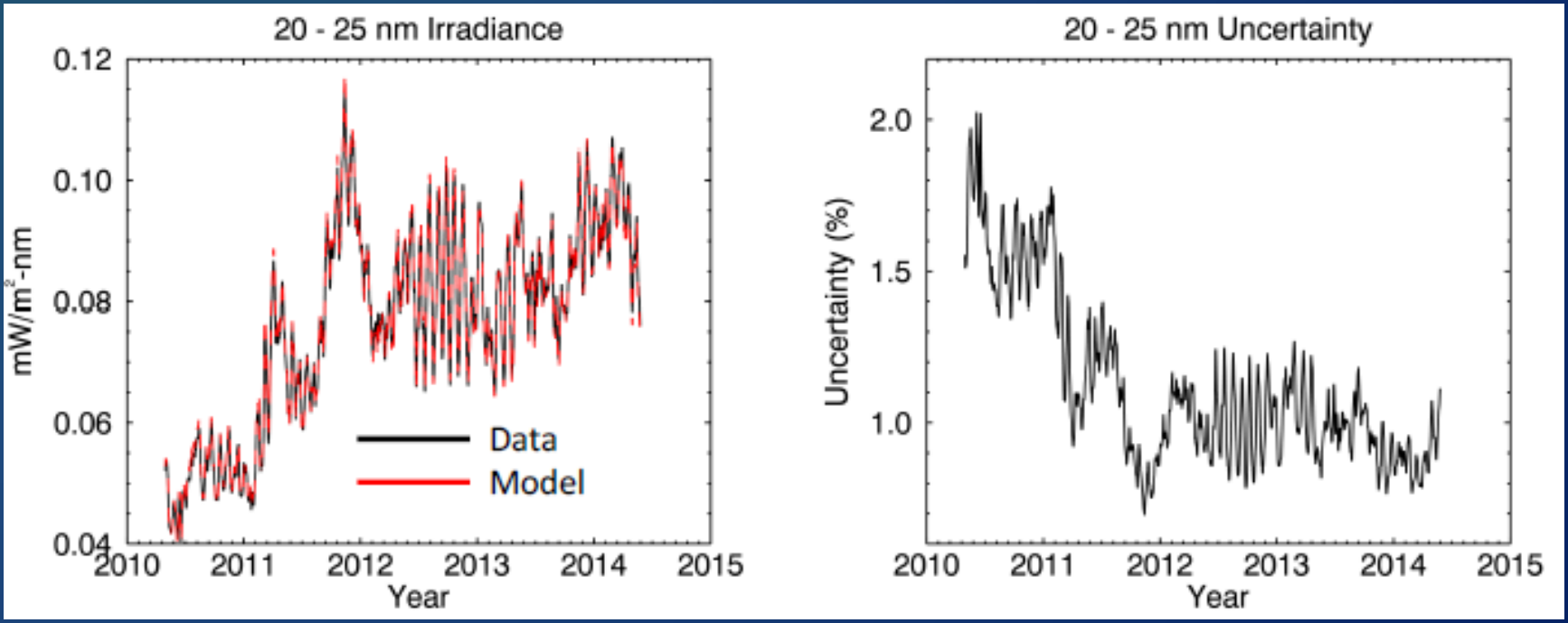
# #2: EUVS L1b Model Baseline (1/2)

- **Objective**: Determine if coefficient parameter updates are needed for the EUVS proxy model.
- **Provisional Success Criteria**: EUVS L1b product data are available and analysis is completed.

- The GOES-R EUVS Model for EUV Irradiance Variability, E.M.B. Thiemann, et al., J. Space Weather and Space Climate (in review).
  - Discusses 7 training data sets, cross-calibration.
  - Paper provides correlation coefficients.
  - Coefficients will be available from NCEI website.
- LUTs not yet updated in order to test ADR 471.

# #2: EUVS L1b Model Baseline (2/2)

Example: Comparison of EUVS model and data. (Figure from paper.)




from Thiemann, et al., (in review)

# #3: EUVS L1b Uncertainties (1/4)

- **Objective**: Determine the uncertainties in the EUVS level 1b irradiances.
- **Provisional Success Criteria**: EUVS L1b product data are available and analysis is completed.

- Uncertainties due to statistical errors were calculated for three different days using L0 data, with varied levels of solar activity.
- No systematic errors were included.
- Errors due to temperature effects will be discussed later.
- Main results for GOES-16 at 1 s cadence:
  - 25.6 nm: 2.2% < $\sigma_E/E$ < 4.5%
  - 28.4 nm: 2.2% < $\sigma_E/E$ < 4.0%
  - 30.4 nm: $\sigma_E/E \approx 3.35\%$
  - 117 nm: 3.2% < $\sigma_E/E$ < 9.8%
  - 121 nm: $\sigma_E/E \approx 2.9\%$
  - 133 nm: 4.1% < $\sigma_E/E$ < 5.0%
  - 140 nm: 2.7% < $\sigma_E/E$ < 5.0%

*Note: For 30-s uncertainties, divide these values by √30 = 5.48.*

# Uncertainty Calculation (2/4)

Diode Current: $C = \frac{g(S - S_0)}{\Delta t}$

$g$ = Diode gain (fC/DN)
$S$ = Diode signal (DN)
$S_0$ = Diode dark signal (DN)
$\Delta t$ = Integration time (sec)

Error Propagation: $\sigma_C{}^2 = \left(\frac{\partial C}{\partial g}\varepsilon_g\right)^2 + \left(\frac{\partial C}{\partial S}\sigma_S\right)^2 + \left(\frac{\partial C}{\partial S_0}\sigma_{S_0}\right)^2 + \left(\frac{\partial C}{\partial \Delta t}\sigma_{\Delta t}\right)^2$

Relative Uncertainty: $\frac{\sigma_C}{C} = \left[\left(\frac{\sigma_g}{g}\right)^2 + \left(\frac{\sigma_S}{S - S_0}\right)^2 + \left(\frac{\sigma_{S_0}}{S - S_0}\right)^2 + \left(\frac{\sigma_{\Delta t}}{\Delta t}\right)^2\right]^{1/2}$

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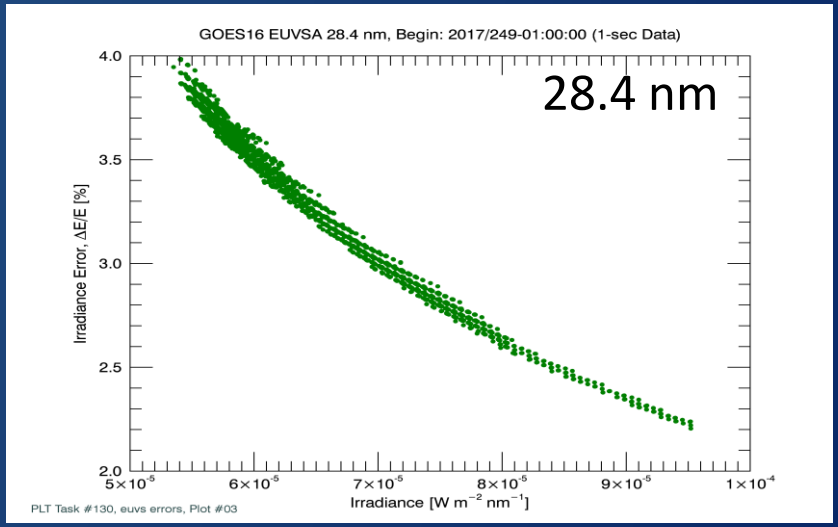
Irradiance: $E = \frac{C}{R}$

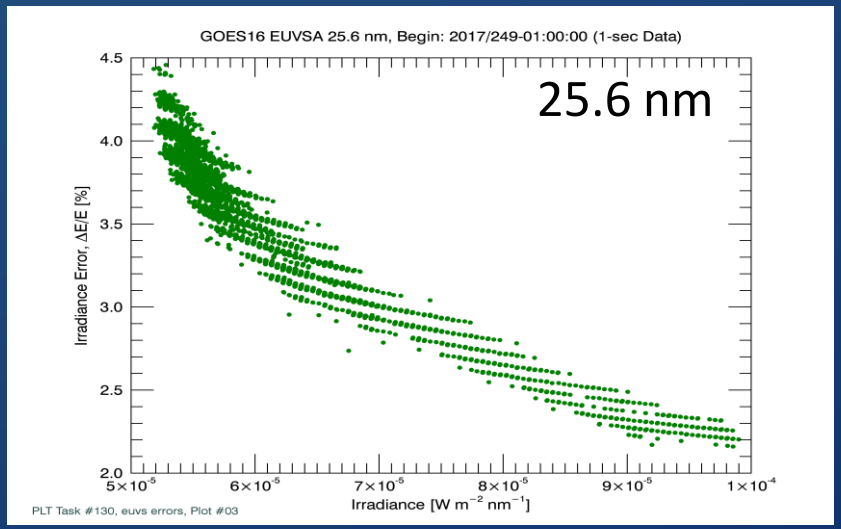
$C$ = Diode Current (Amps)
$R$ = Diode Responsivity (Amps $m^2$ $W^{-1}$)

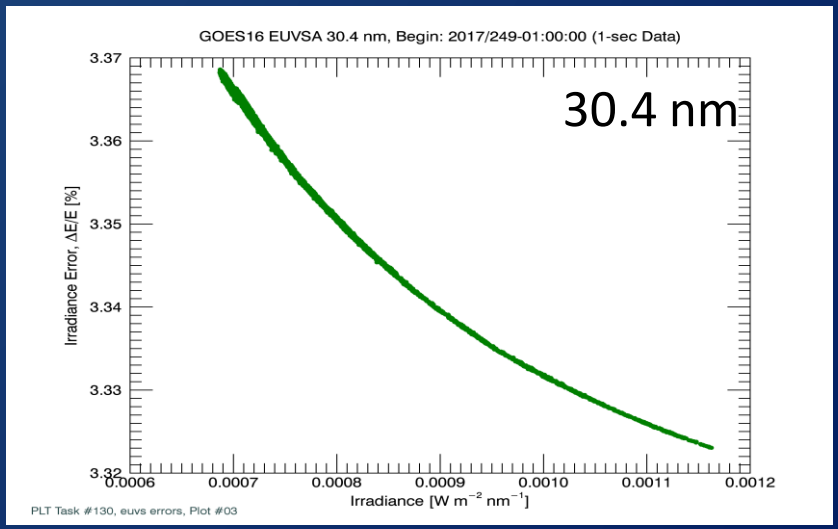
Relative Uncertainty: $\frac{\sigma_E}{E} = \left[\left(\frac{\sigma_C}{C}\right)^2 + \left(\frac{\sigma_R}{R}\right)^2\right]^{1/2}$

Credit: Tom Eden.

# Uncertainty for EUVS-A (3/4)




Credit: Tom Eden.

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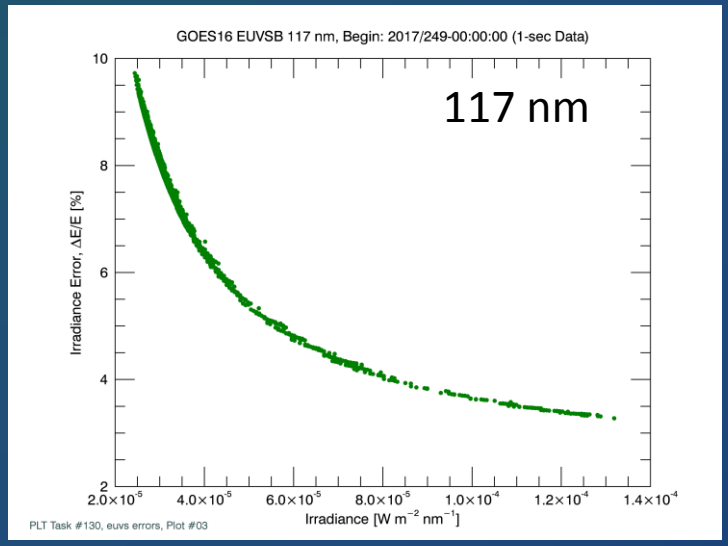
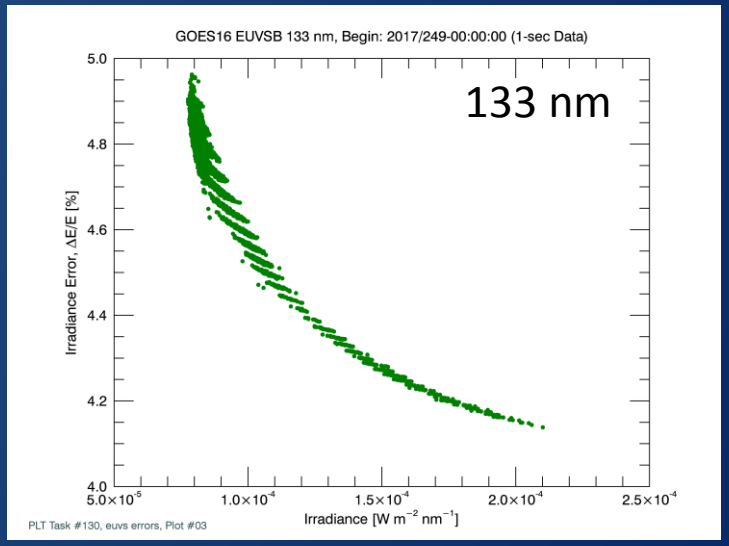
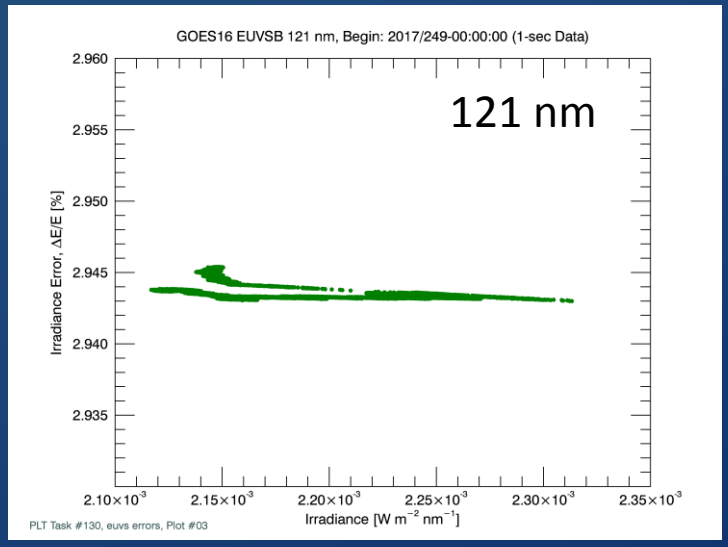
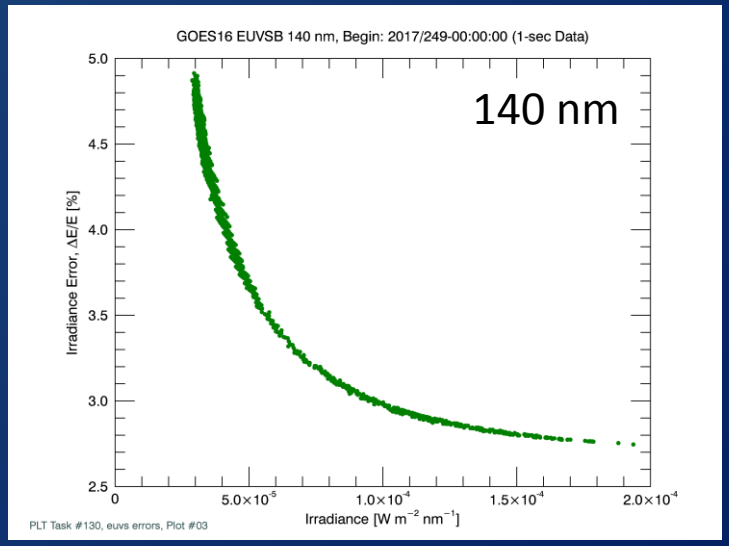
# Uncertainty for EUVS-B (4/4)




Credit: Tom Eden.

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# #4-7: EUVS Degradation

- Original plan was "bootstrap" calibration:

  #4 Mg II -to- 117.5/133.5

  #5 117.5/133.5 -to- 121.6/140.5

  #6 121.6/140.5 -to- 25.6/30.4

  #7 25.6/30.4 -to- 28.4

- *Instead*, on-orbit degradation is calibrated with:
  - EUVS A comparisons to secondary filter (and/or Mg II or SDO ESP)
  - EUVS B comparisons to SORCE SOLSTICE (will switch to Mg II)
- The following slides show the current degradation calibration and early investigation of using Mg II for calibration.

# EUVS-A Degradation Tracking (1/4)

EUVS-A (25.6, 28.4, 30.4 nm)

- Filters were calibrated at SURF.
- On orbit degradation is tracked by daily and weekly calibrations.
  - Daily comparisons are made between primary and secondary filters.
  - Weekly calibrations are with the tertiary plus one other filter.
  - Corrections provided in LUTs of the form:

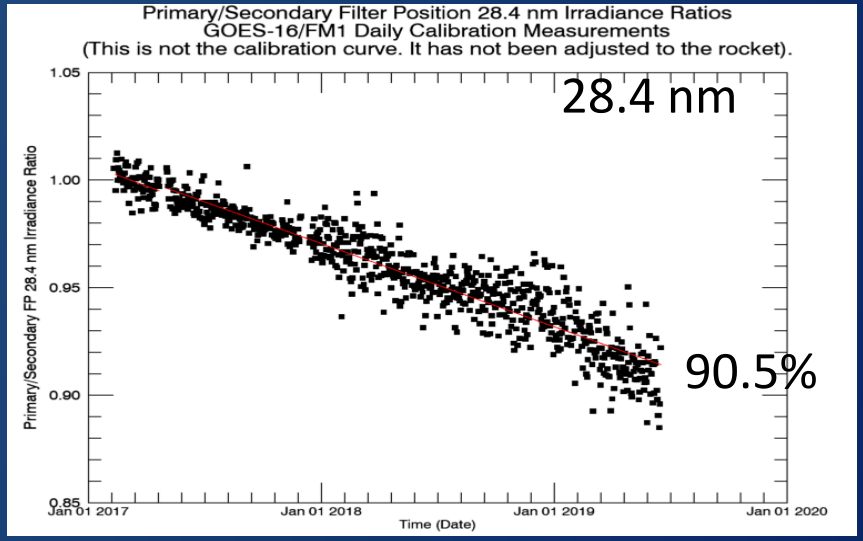
$$f_{FF} = p_0 + p_1 \cdot exp\left(\frac{-t-p_2}{p_3}\right) + (p_4 \cdot t)$$

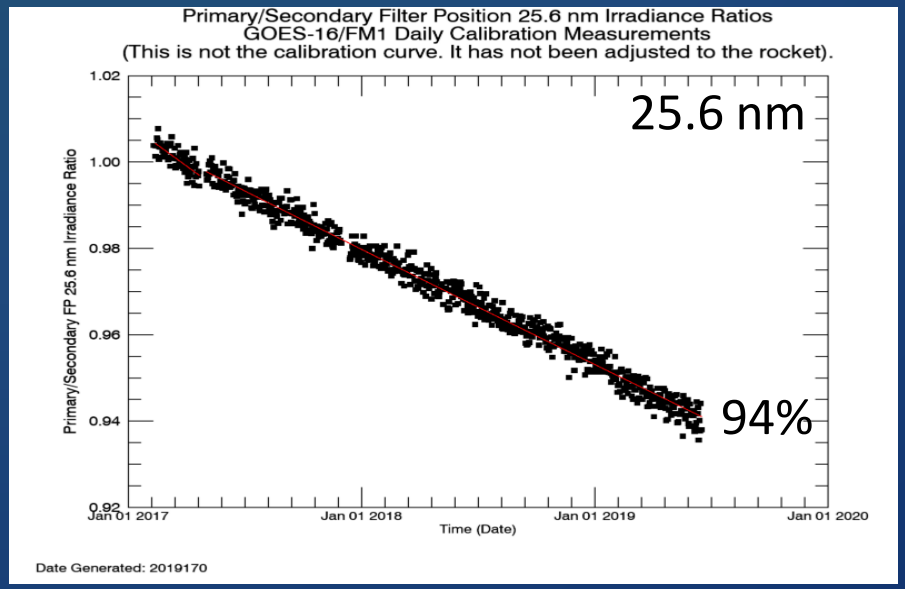
- June 2018 SDO rocket test may provide additional calibration.

# EUVS-A Degradation Tracking (2/3)

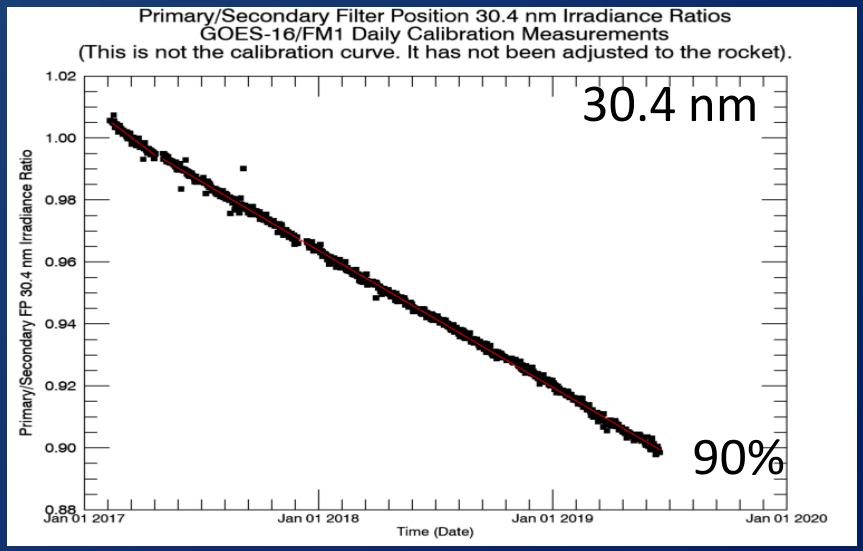
Primary to secondary filter ratios

- Red lines are fits to degradation.
- Fit uncertainties depend on signal strength: approx. ±0.5 to 3%



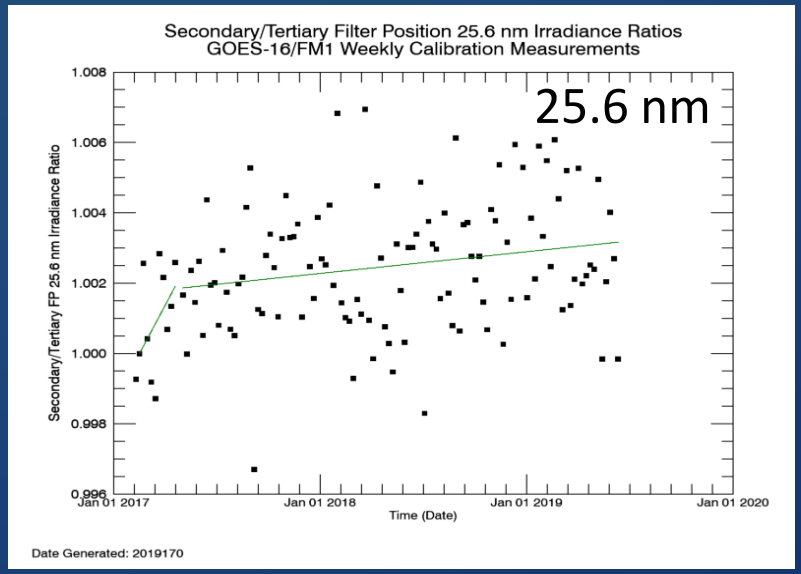

Credit: Don Woodraska.

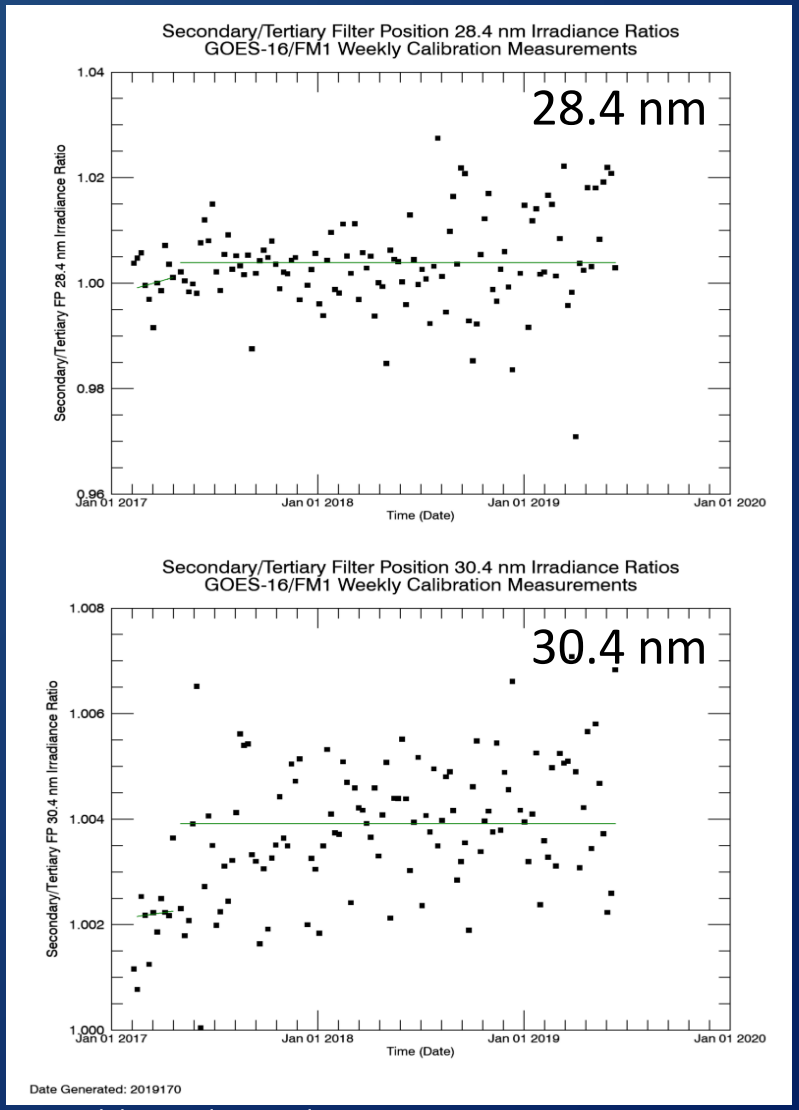


# EUVS-A Degradation Tracking (3/3)

Secondary to tertiary filter ratios

- Green lines are fits
- All filters degrading




Credit: Steve Mueller

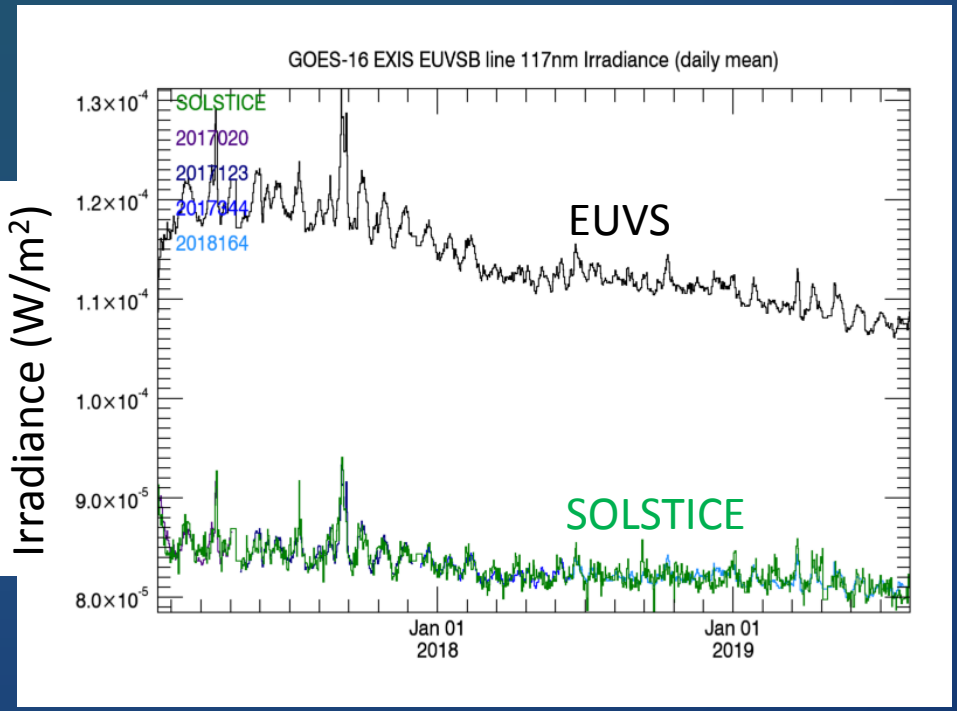
# EUVS-B Degradation Tracking (1/6)

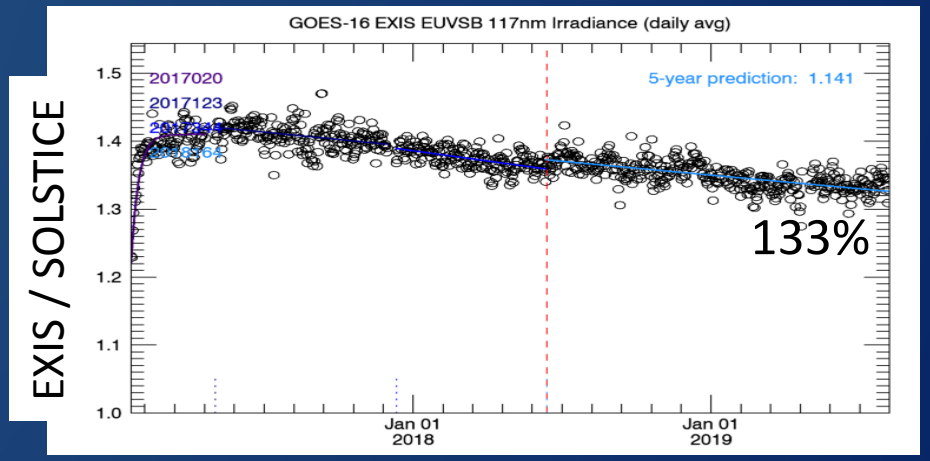
EUVS-B (117.5, 121.6, 133.5, and 140.5 nm)

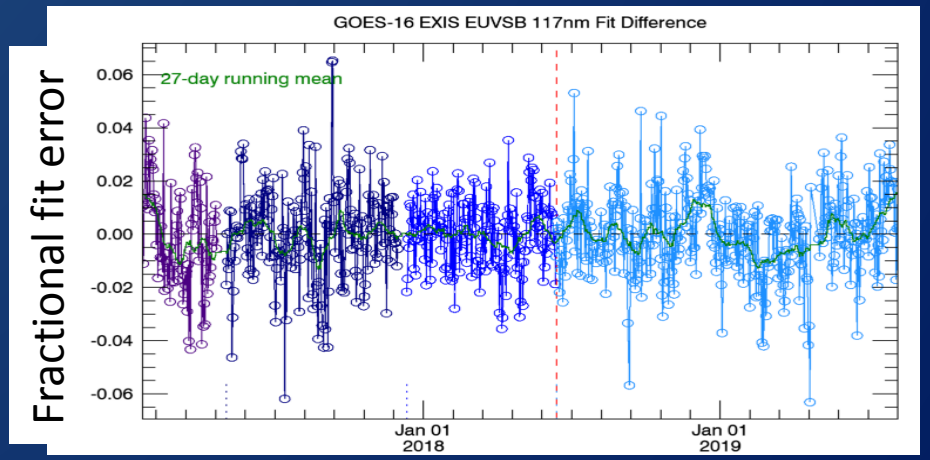
- Calibration codes use L0 data with temperature corrections.
- Degradation determined by ratio with SORCE SOLSTICE.
  - Distinct fits over different time intervals.
  - Fits will use Mg II in 2020+ (after SORCE SOLSTICE end of mission.)
- Contributions to irregular behavior:
  - SOLSTICE calibrations and limited duty cycle
  - Possible degradation rate changes with solar variability and ops changes
  - Most recent fit needs to be updated with new data
- Results
  - Degradations corrected for all lines to a few percent
  - 117 and 133 nm lines show sharp increase (recovery) after launch
  - At current rate, signal level in mid-2024 will be a factor of:
    - 117 nm:  1.14, 121 nm: 0.45, 140 nm: 1.06, 133 nm: 'unknown'

# EUVS-B Degradation Tracking (2/6)

## 117 nm



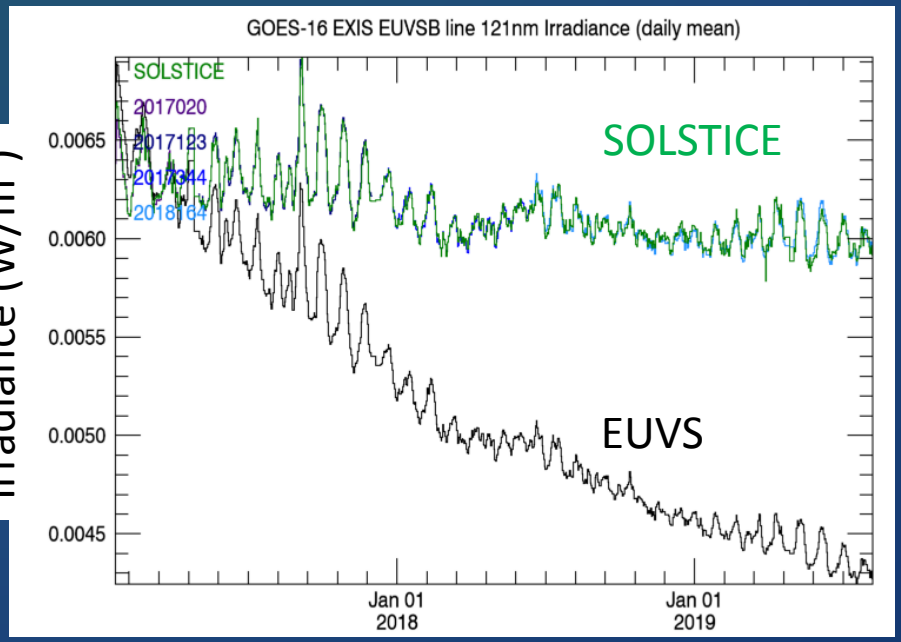



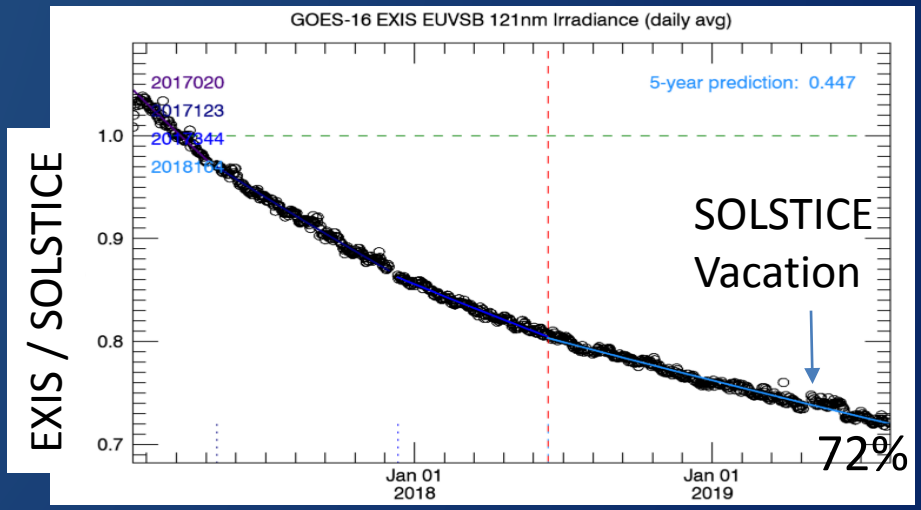



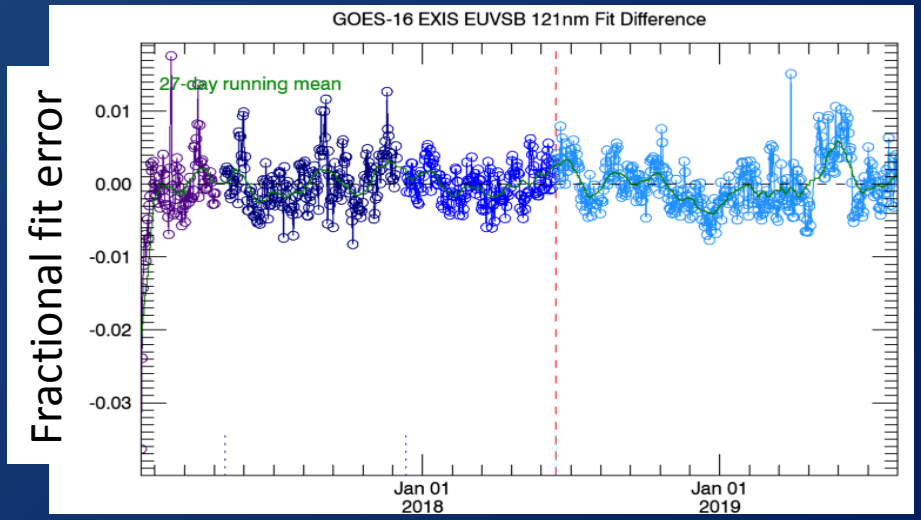

Credit: Don Woodraska

# EUVS-B Degradation Tracking (3/6)

## 121 nm



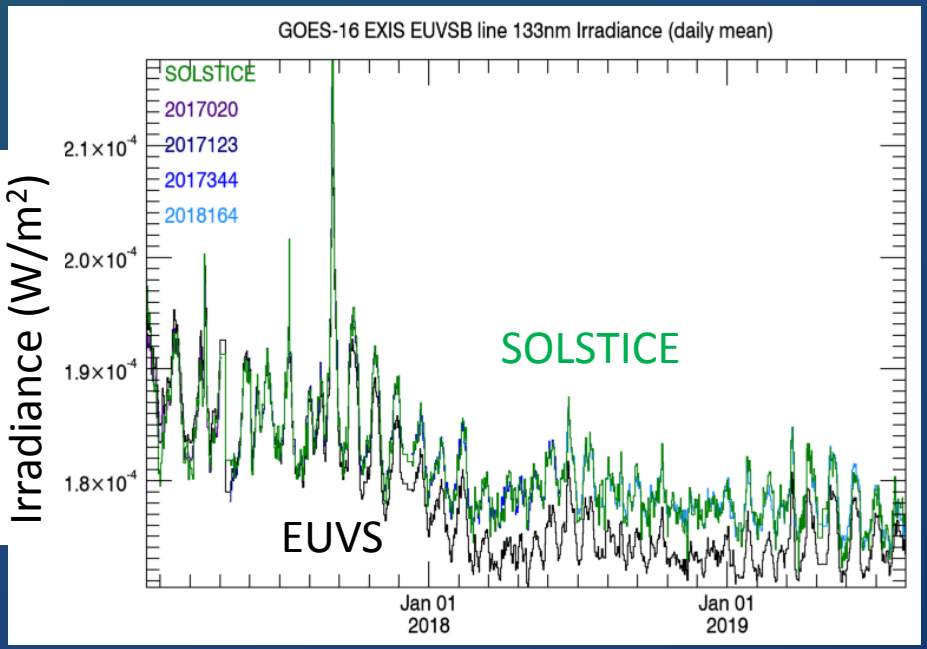



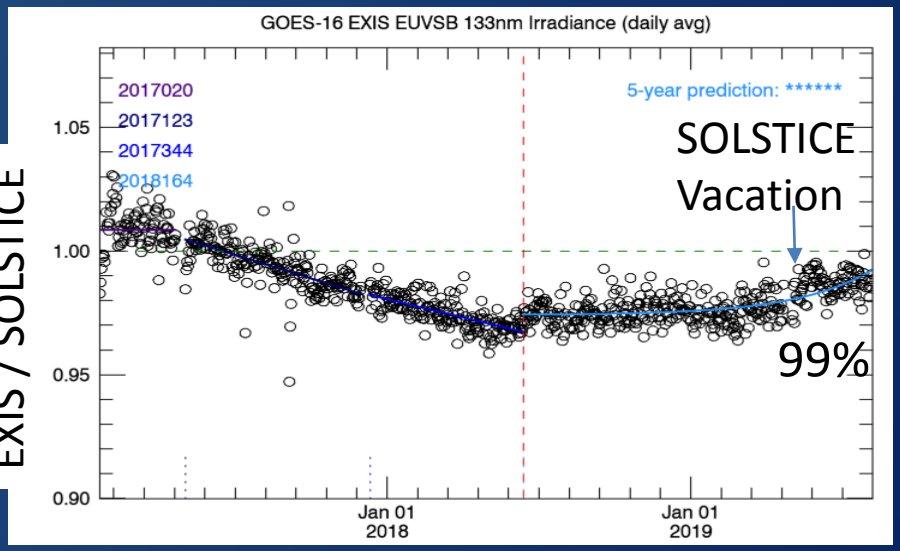



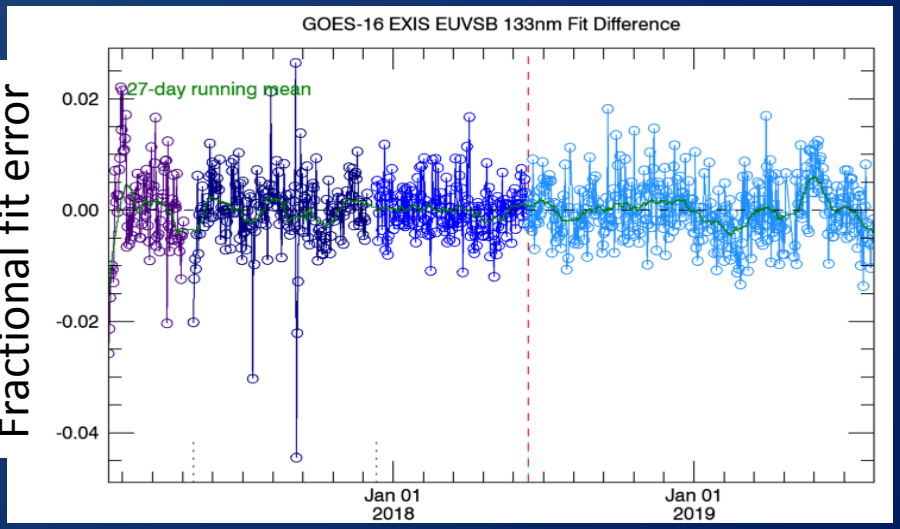

Credit: Don Woodraska

# EUVS-B Degradation Tracking (4/6)

## 133 nm



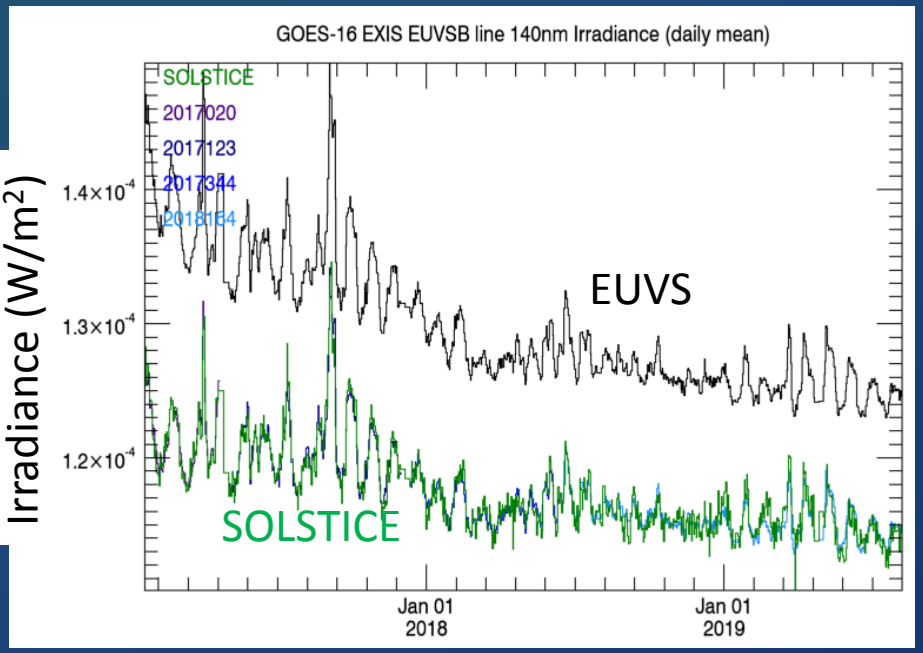



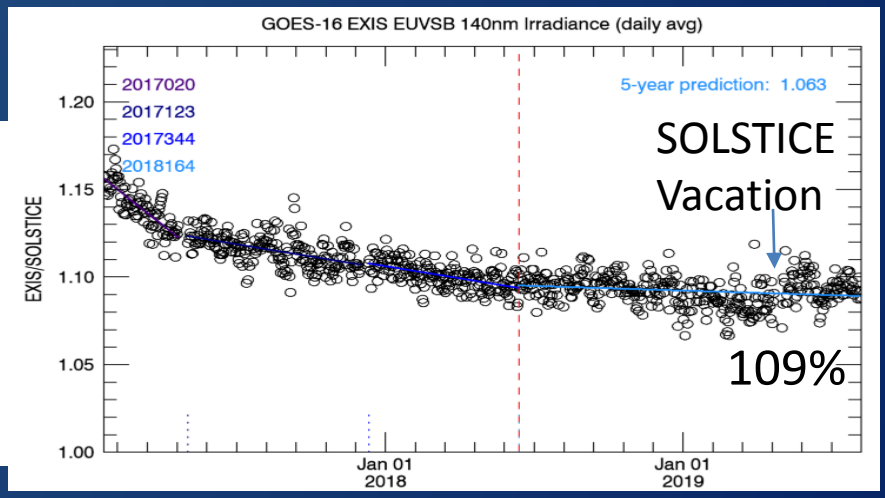



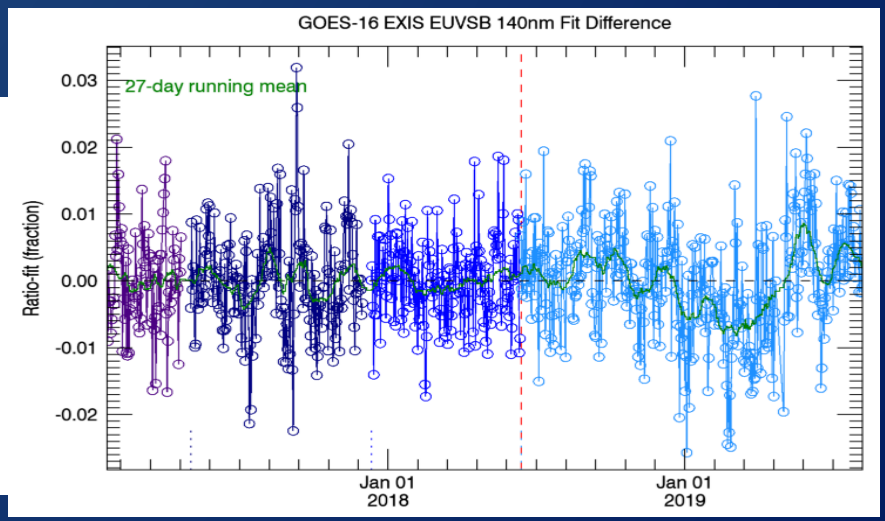

Credit: Don Woodraska

# EUVS-B Degradation Tracking (5/6)

## 140 nm



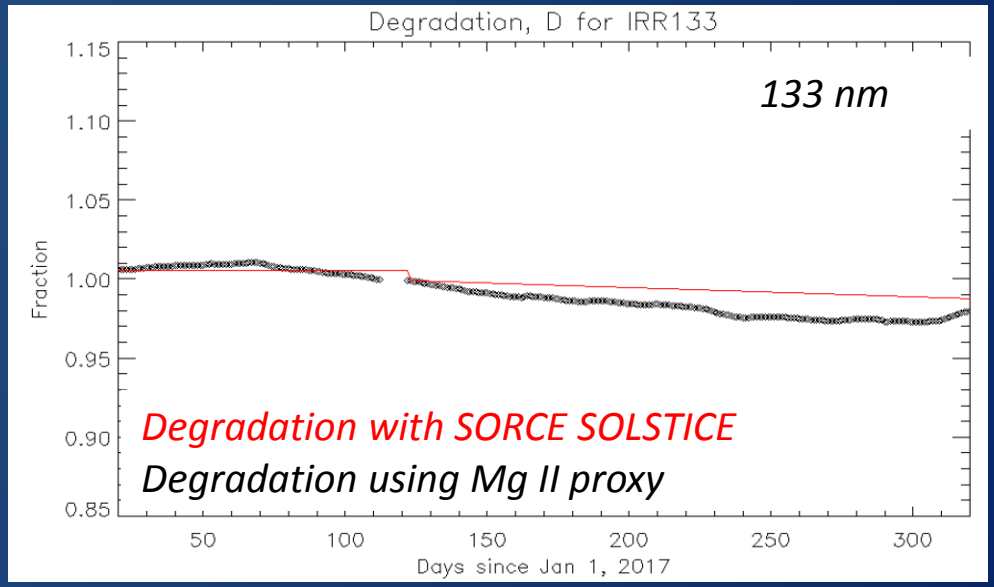




Credit: Don Woodraska

# EUVS-B Degradation Tracking (5/6) Scaling with Mg II

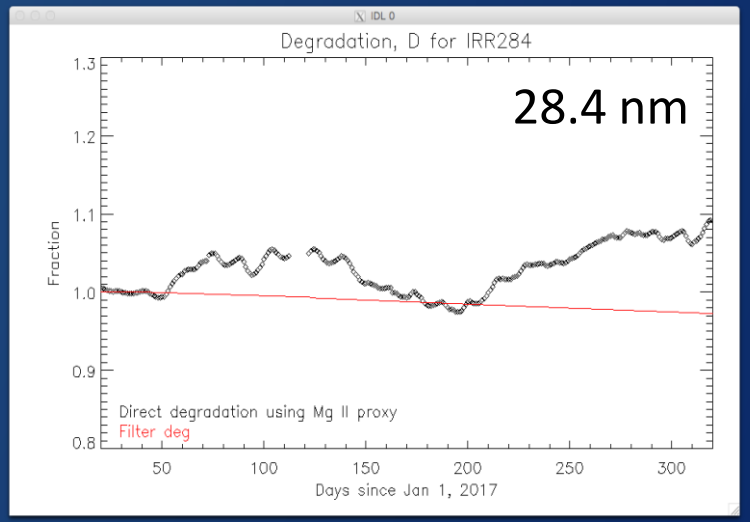
Early tests with GOES-16 data to determine degradation with Mg II proxy

| Wavelength (nm) | Error wrt SORCE |
|---|---|
| 25.6 | ~3% |
| 28.4 | ? |
| 30.4 | ~3% |
| 117 | ? |
| 121 | 3% |
| 133 | 2-3% |
| 140 | 2-3% |

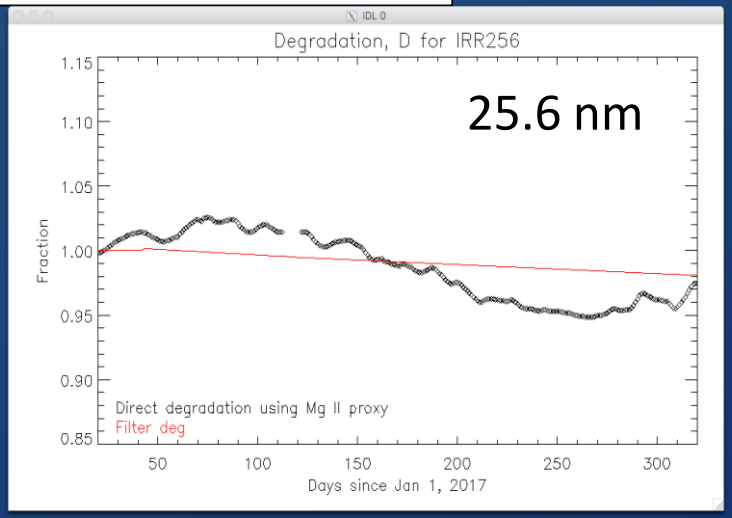


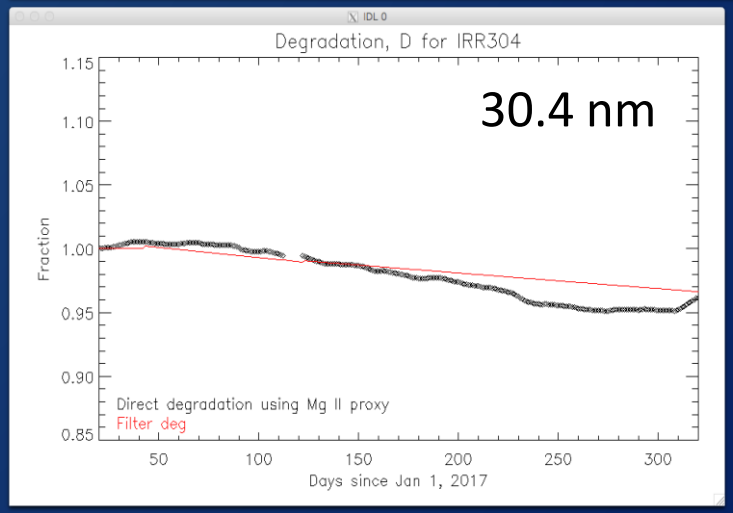
# EUVS-A Degradation Calibration with Mg II

- A Mg II proxy is created for each line for GOES-16.
- The ratio of line to proxy provides the degradation.




degradation from Mg II proxy
degradation from SOLSTICE

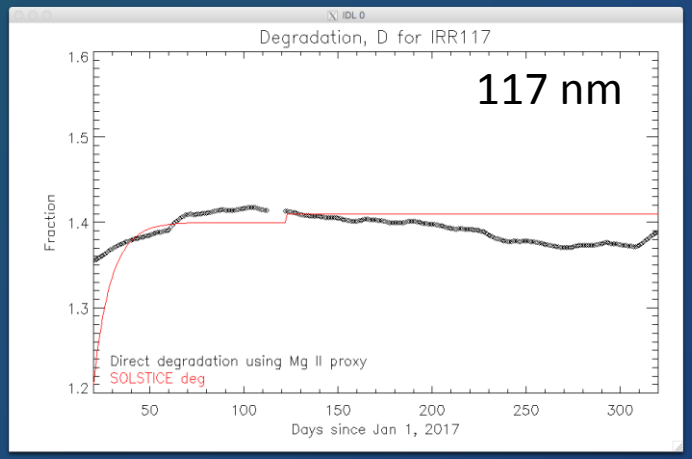


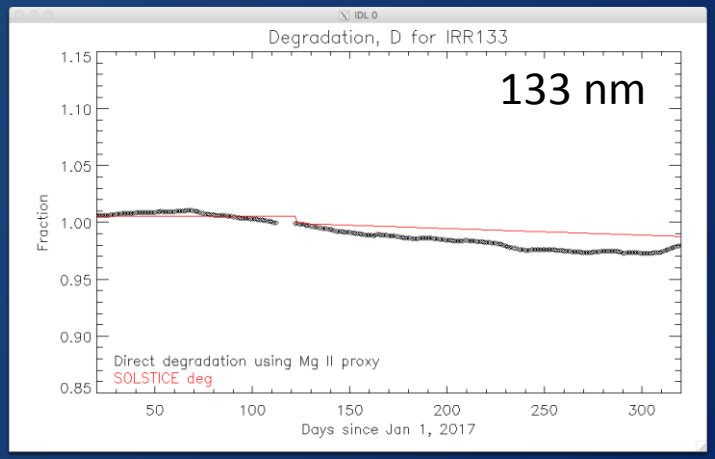



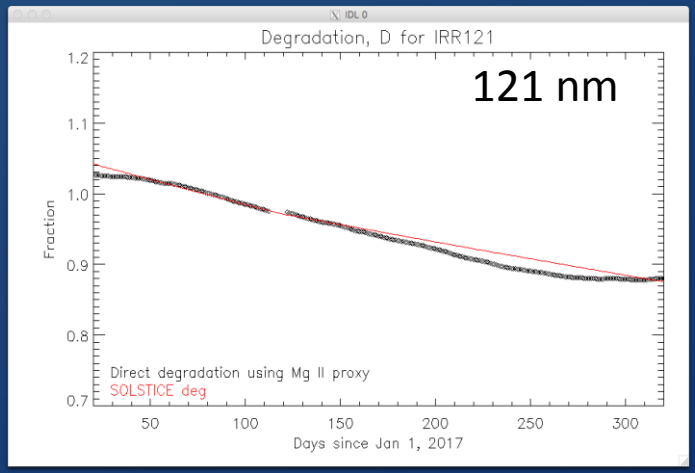

Credit: Don Woodraska

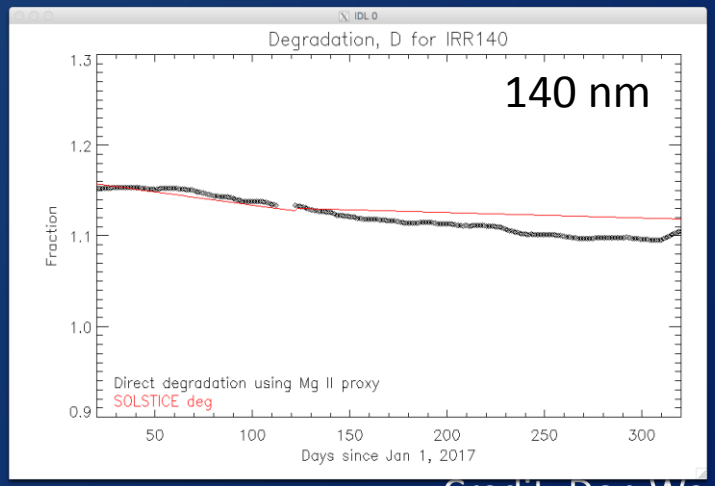
# EUVS-B Degradation Calibration with Mg II

degradation from Mg II proxy
degradation from SOLSTICE




Credit: Don Woodraska

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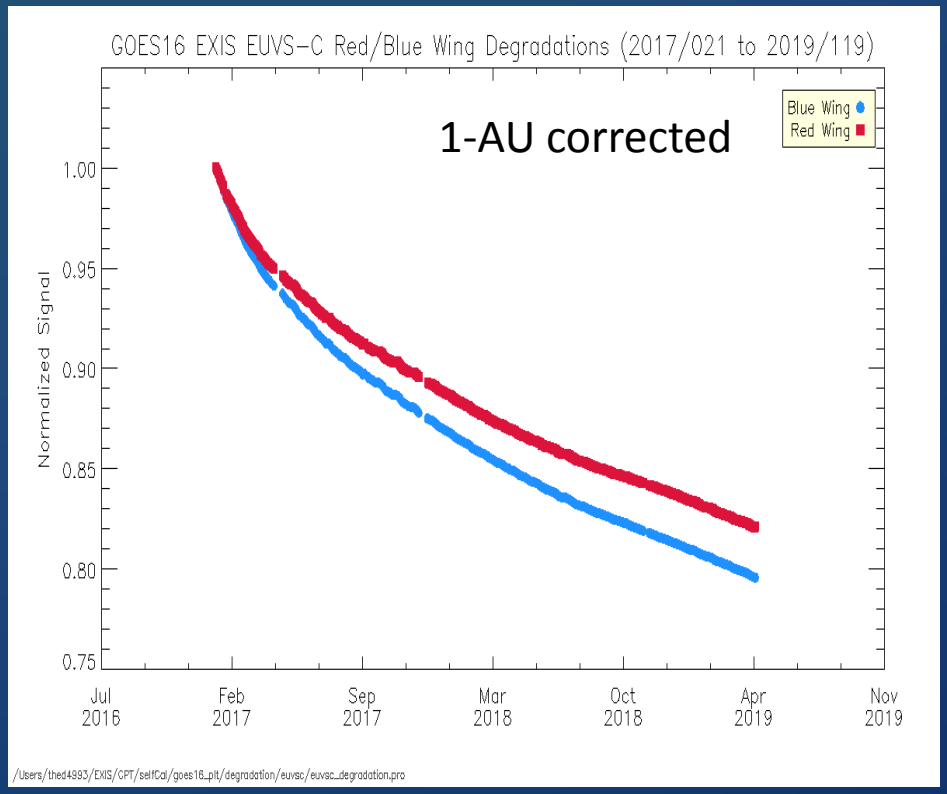
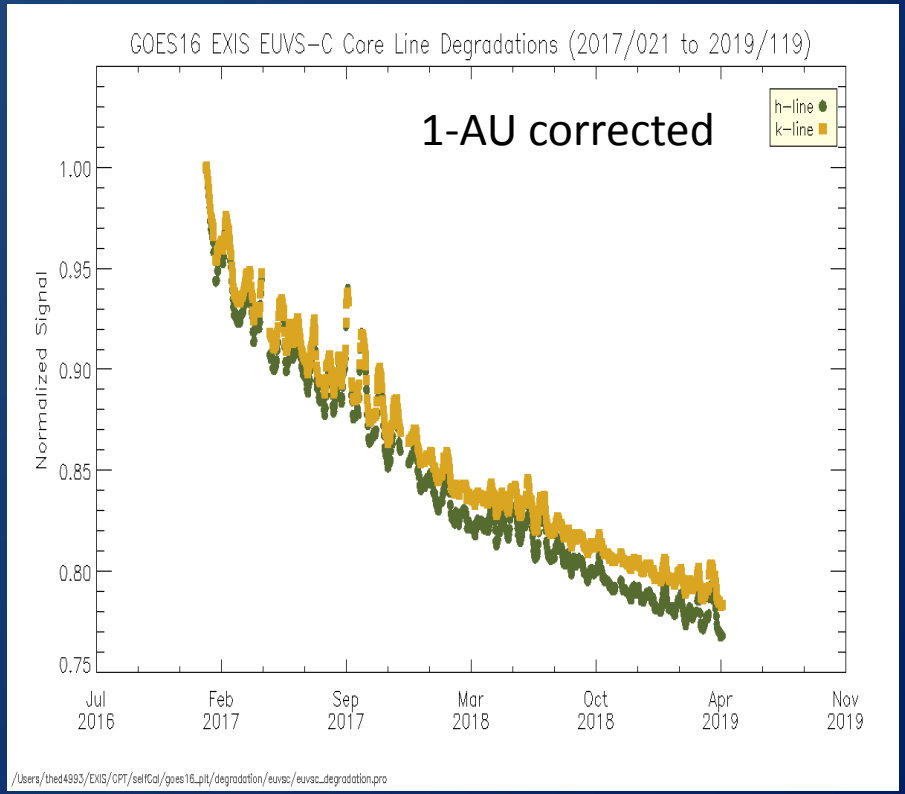
# EUVS-C Degradation Tracking and Mg II Stability

- Red wing and blue wing degradations
- Mg II index is not impacted significantly




Credit: Tom Eden

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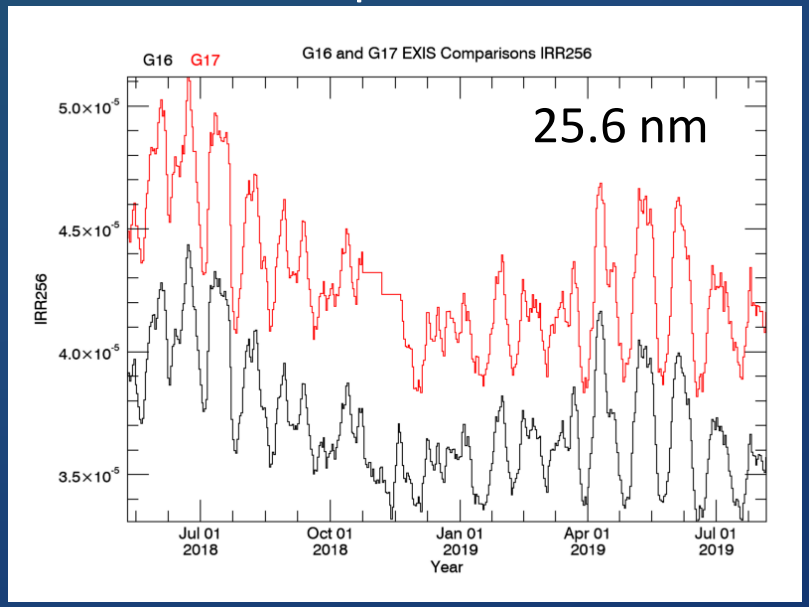
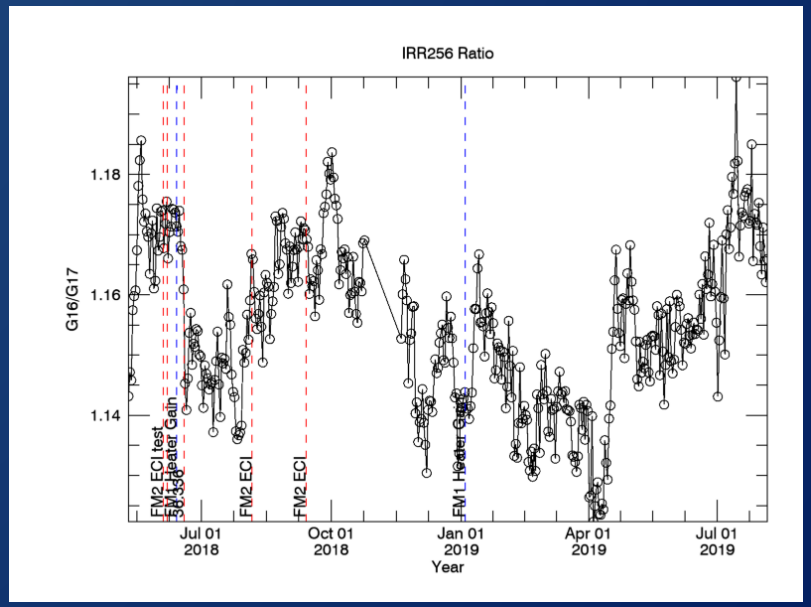
# #14: EUVS/Mg II Inter-Satellite Comparisons

- EUVS-A: GOES-16 compared to GOES-17
  - G17 and G16 have different bandpasses and so do not agree for dim lines.
  - Degradation has not been updated recently.
  - Shows need for frequent calibration tests to determine trends.
  - Shows impacts of ECI.

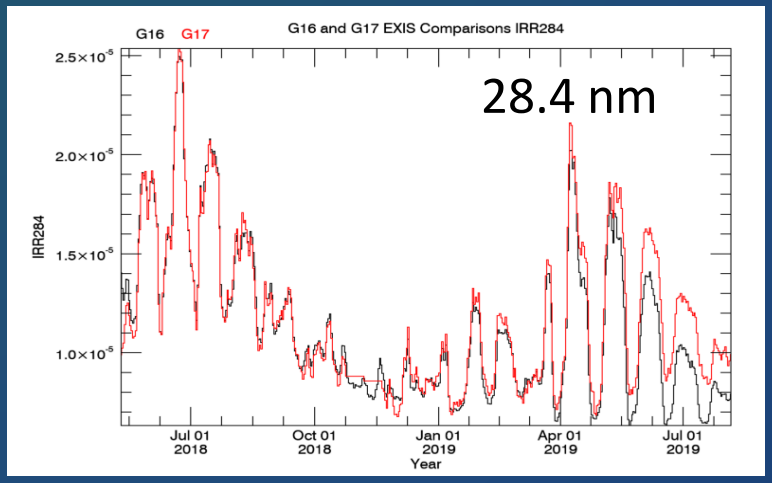


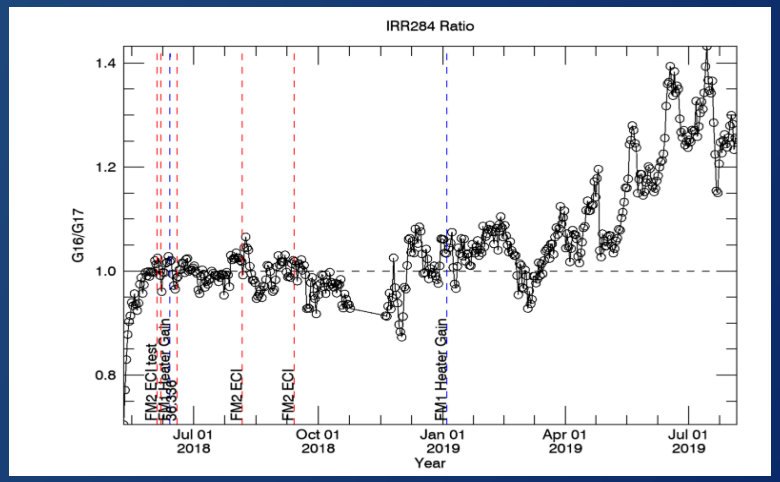



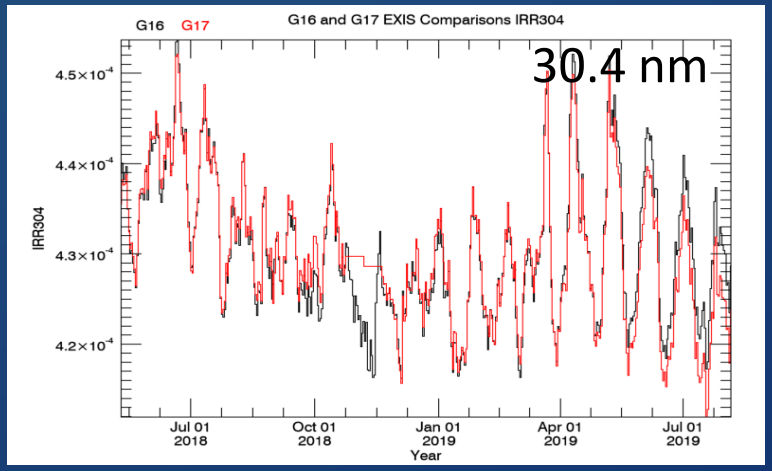

Credit: Don Woodraska

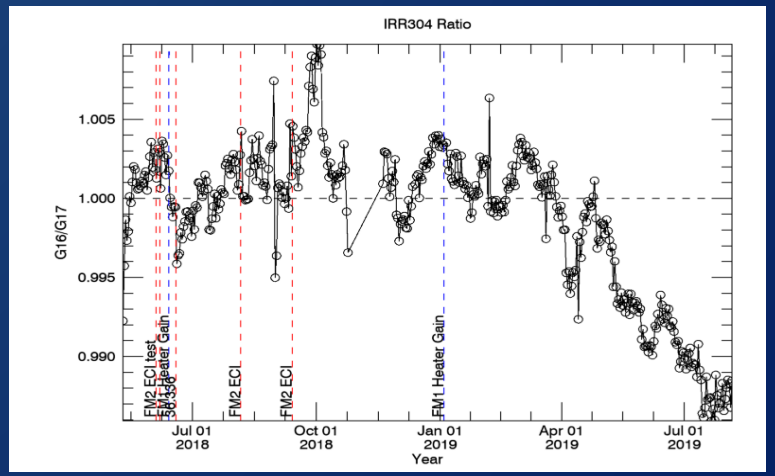
# #14: EUVS/Mg II Inter-Satellite Comparisons

- EUVS-A: GOES-16 compared to GOES-17




Credit: Don Woodraska

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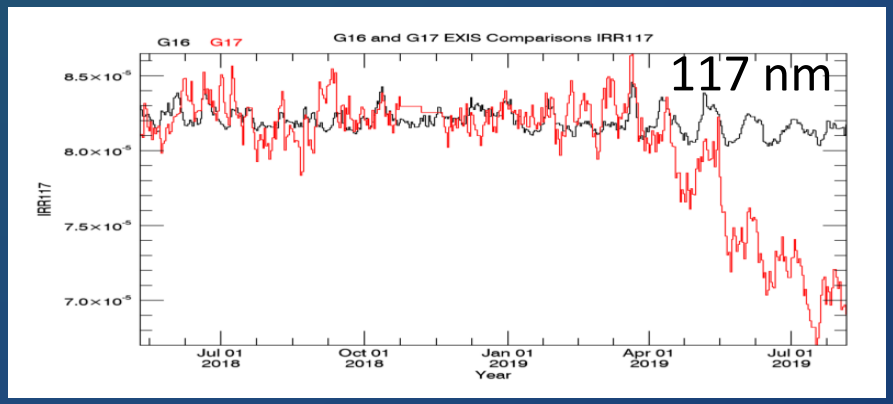
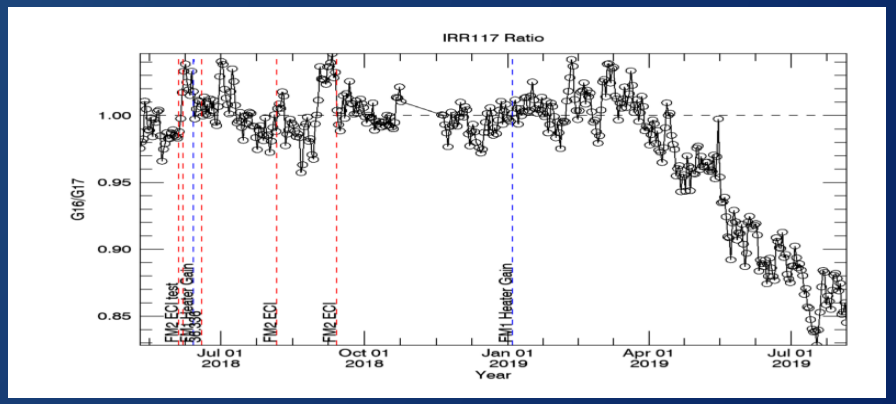
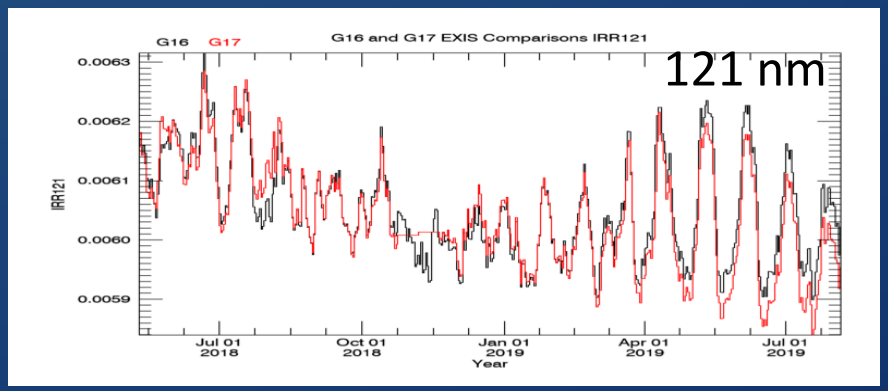
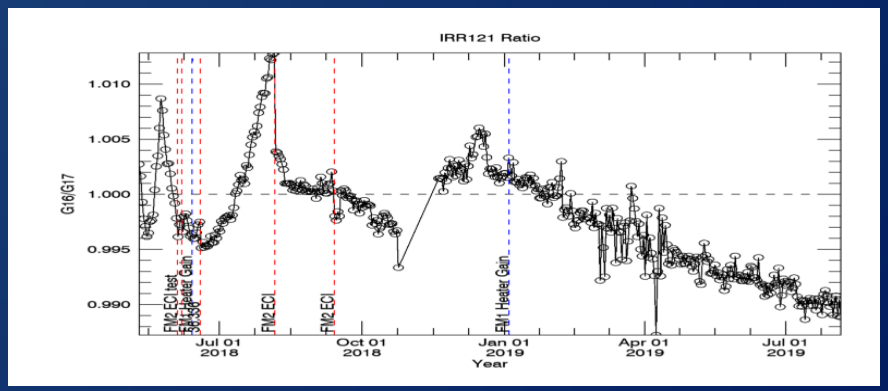
# #14: EUVS/Mg II Inter-Satellite Comparisons

- EUVS- B: GOES-16 compared to GOES-17
  - Latest calibration correction not determined/applied to G17
  - Shows need for constant monitoring, recalibration, reprocessing




Credit: Don Woodraska

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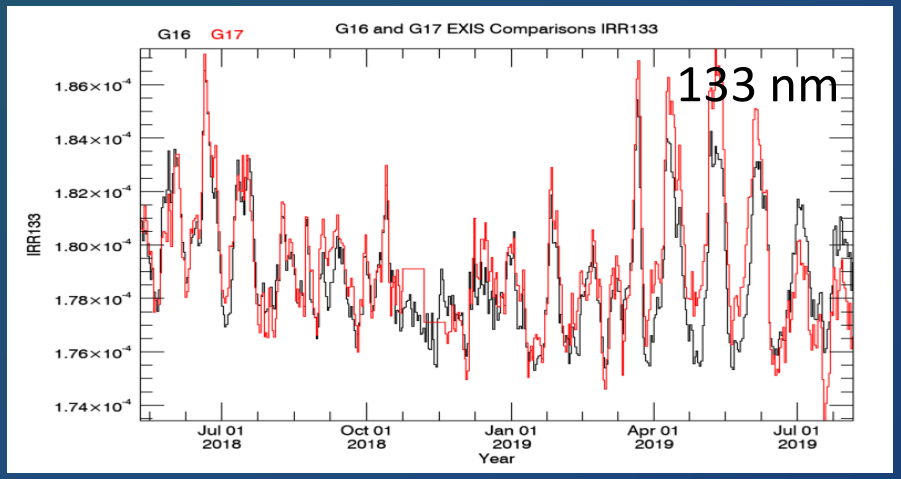
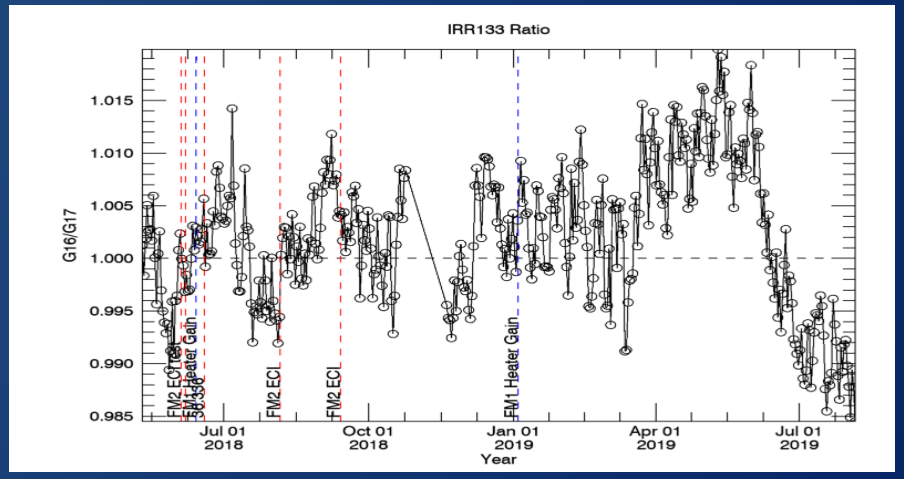
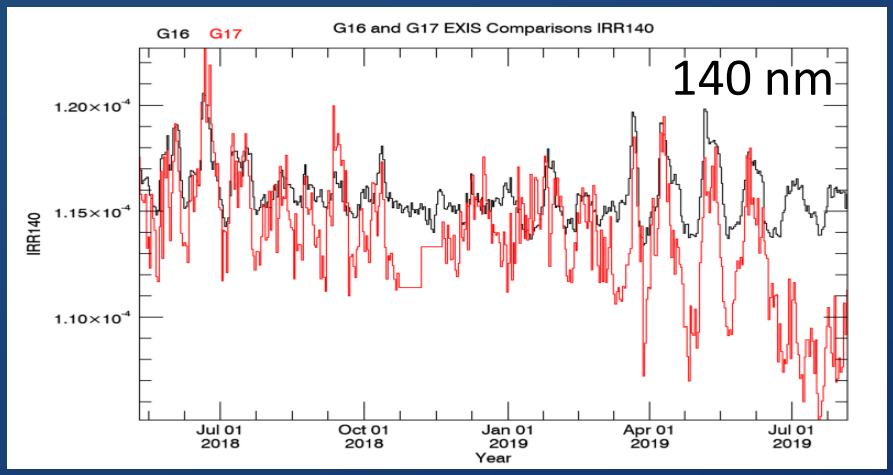
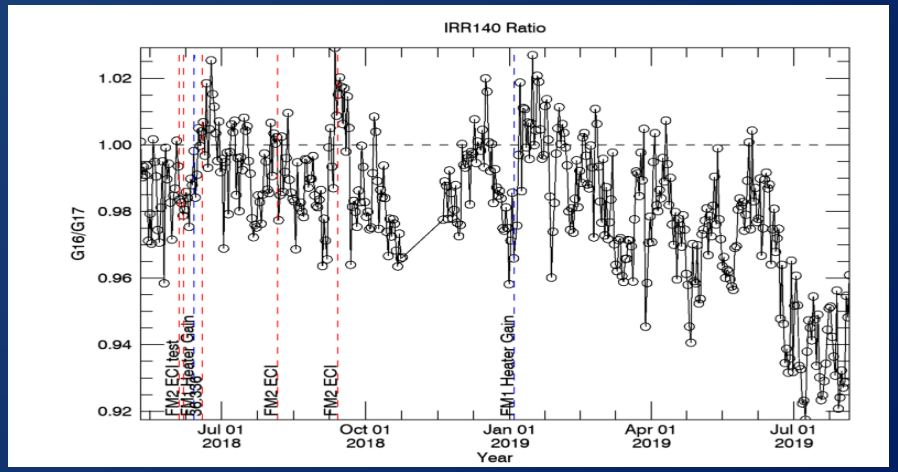
# #14: EUVS/Mg II Inter-Satellite Comparisons

- EUVS- B: GOES-16 compared to GOES-17




Credit: Don Woodraska

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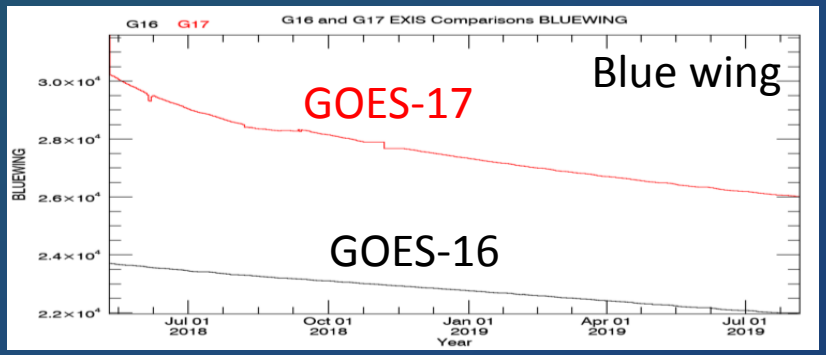
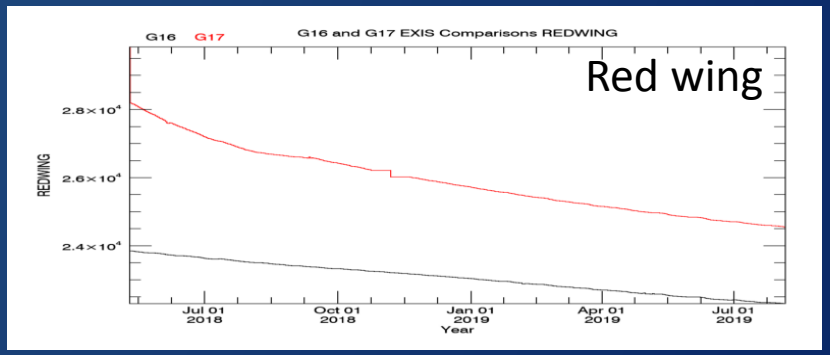
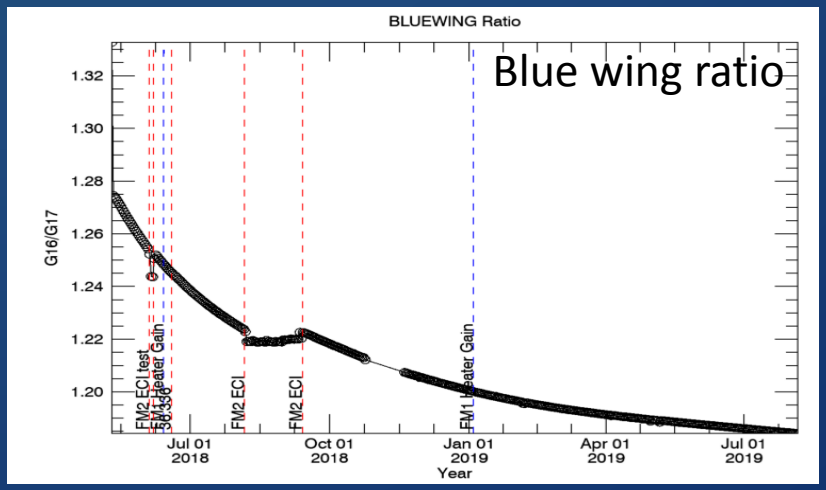
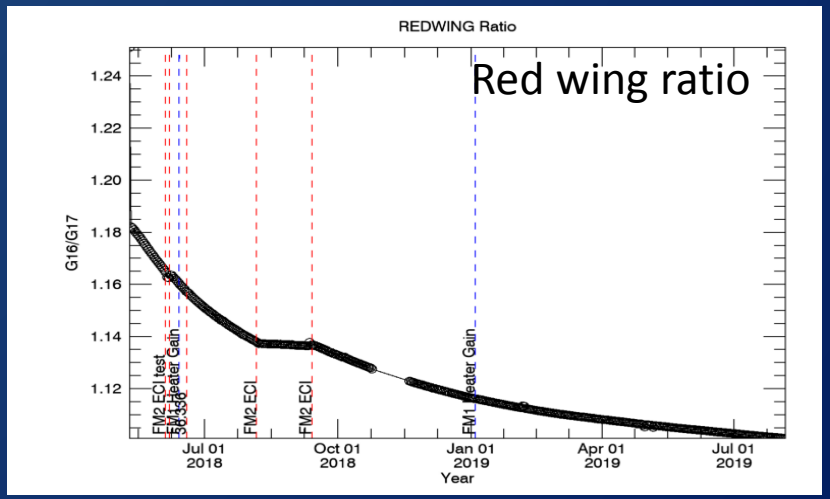
# #14: EUVS/Mg II Inter-Satellite Comparisons

- EUVS-C: Comparison of red and blue wings for GOES-16 and -17
  - ECI periods cause changes in degradation trends

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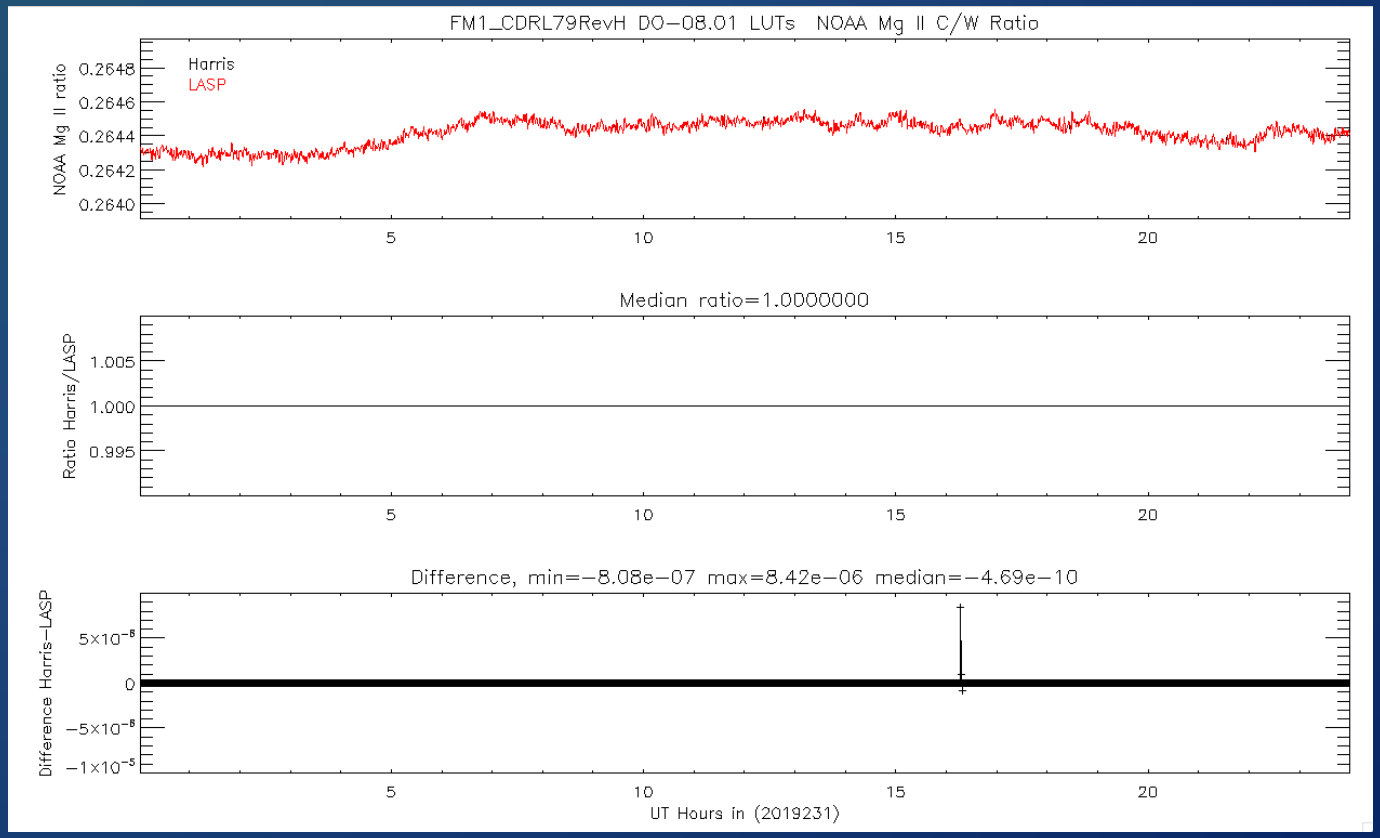
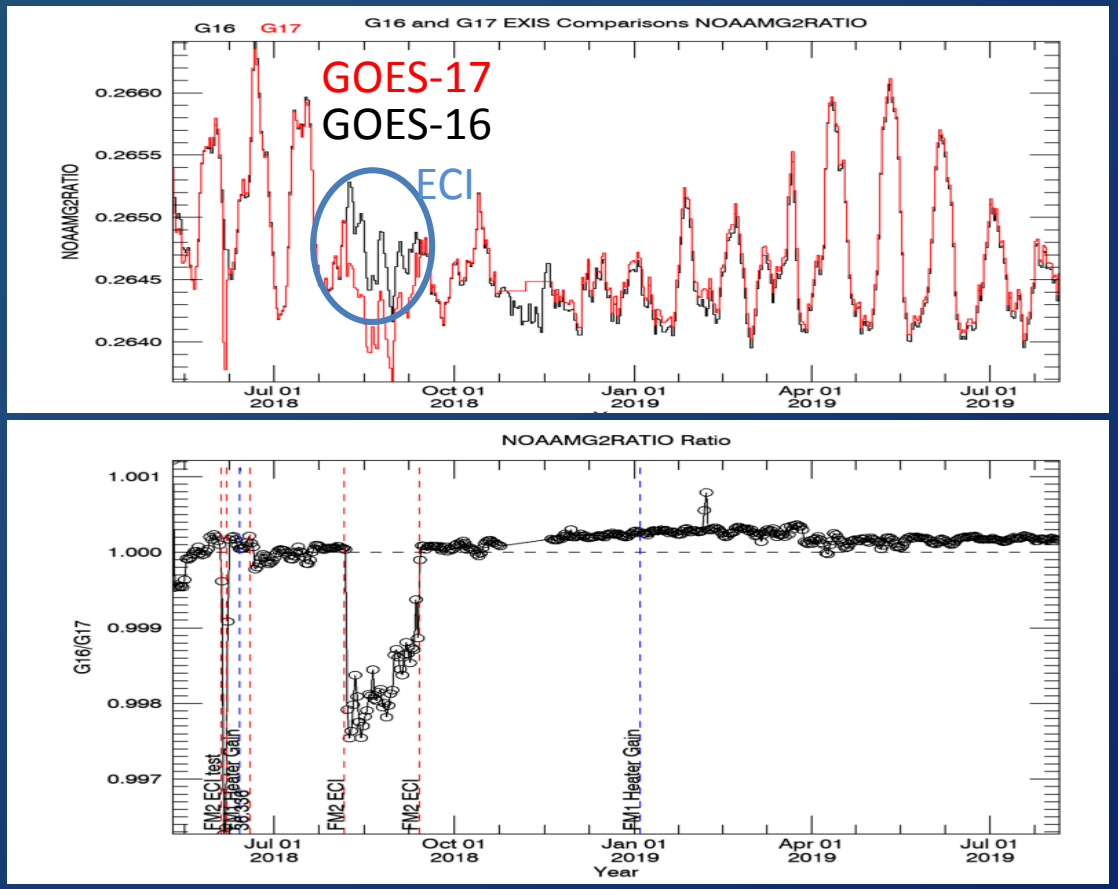
# #14: EUVS/Mg II Inter-Satellite Comparisons

- Mg II: L0-derived values compared with GPA values for GOES-16
  - No difference



# #14: EUVS/Mg II Inter-Satellite Comparisons

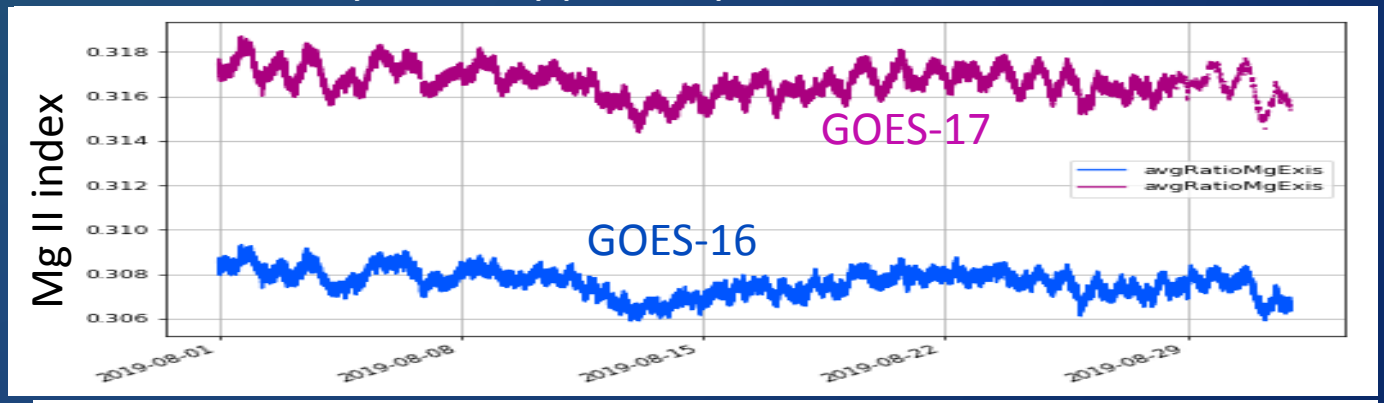
- EUVS-C: Comparison of daily Mg II for GOES-16 and -17
  - ECI periods have incorrect Mg II values with current L1b GPA code

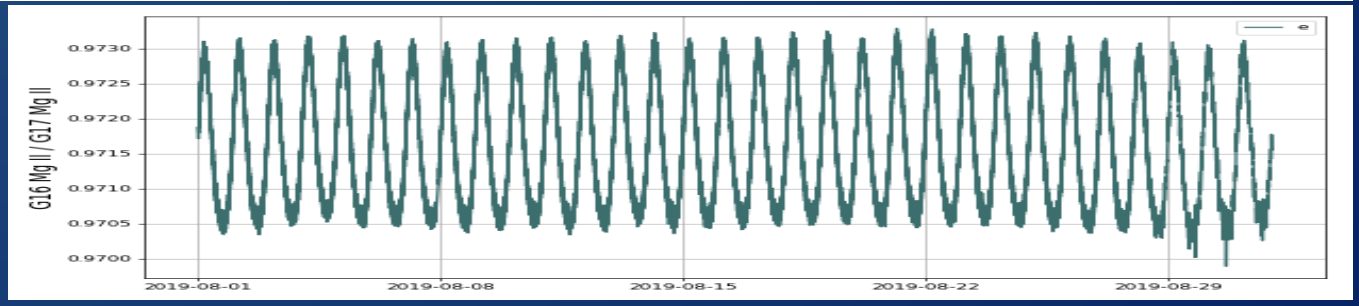



These GOES-16 and -17 data are preliminary, non-operational data and are undergoing testing.
Users bear all responsibility for inspecting the data prior to use and for the manner in which the data are utilized.

# #14: EUVS/Mg II Inter-Satellite Comparisons

- EUVS-C: Mg II comparison of 30-s G-16 and -17 for August 2019
  - Mg II variation over (a quiet) month is 1.3%
  - Daily variation due to Doppler shifts(?), more pronounced on GOES-17.
    - 0.3% on GOES-16, 0.6% on GOES-17
    - GOES-16/GOES-17 Mg II ratio has daily variation of 0.3%.
  - Cause of variability is....Doppler impacts? ..... needs further investigation.

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# COMPARISON TO PERFORMANCE BASELINE

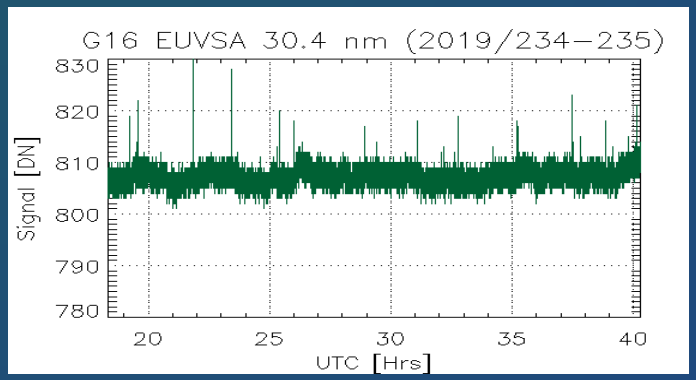
# Performance Baseline

| MRD ID | Quantity | MRD Requirement | MIT/LL Predicted Performance | NCEI Value at Provisional* | Related PLPTs | Status |
|---|---|---|---|---|---|---|
| 577 | EUVS Long-term stability (life of mission) | < ±5% or ability to track | Track Changes | Track Changes | 04, 05, 06, 07 | PASS |
| 2027 | EUVS Product Measurement Range | EUVS-A: 0.5X to 10X solar max $1.4x10^{-5}$ to $5.3x10^{-2}$ W/m$^2$<br>EUVS-B: 0.5X to 10X solar max $1.4x10^{-5}$ to $5.3x10^{-2}$ W/m$^2$ | EUVS-A: $9.5x10^{-6}$ to $5.0x10^{-3}$ W/m$^2$<br>EUVS-B: $2.6x10^{-3}$ to $1.0x10^{-1}$ W/m$^2$ | EUVS-A: 4.7e-7 to 0.93 W/m$^2$<br>EUVS-B: 1.8e-6 to 1.64 W/m$^2$ | See next slides. | PASS |
| 2028 | EUVS Product Measurement Accuracy | < 20% | EUVS-A at 14.27%<br>EUVS-B at 11.62%<br>EUVS-C at 0.10% | EUVS-A: ≤2.7%<br>EUVS-B: ≤7.7% | See next slides. | PASS |
| 2031 | EUVS Product Measurement Precision | < 20% at min flux | EUVS-A: 4.6%<br>EUVS-B: <0.05% | EUVS-A: ≤2.9%<br>EUVS-B: ≤9.4% | See next slides. | PASS |
| 2032 | EUVS Long-term stability | < ±5% or ability to track | Track Changes | Track Changes | 04, 05, 06, 07 | PASS |

* Sources of values on following slides. Values calculated at 30 s cadence.

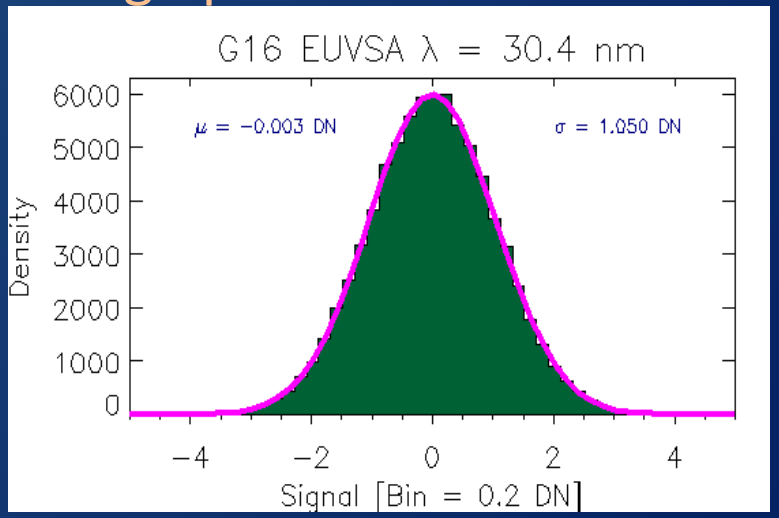
# Statistical Analysis

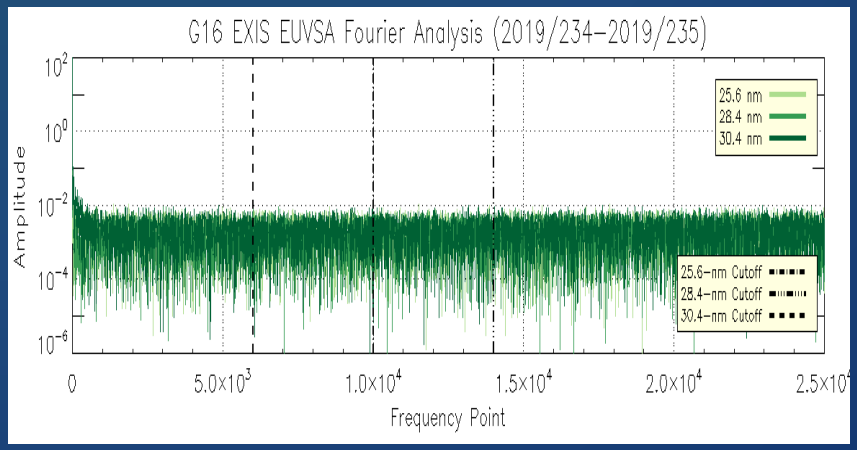
## How the 30-s uncertainty is determined.




1. Here is the raw signal at a 1-s cadence.

3. Find 1-σ from distribution of high pass filtered data.




2. Perform FFT and choose appropriate cut-off frequency for high-pass filtering.

Credit: Tom Eden

# Statistical Analysis
# Precision and 1-sigma Uncertainty (2/2)

| Channel | Wavelength (nm) | Measured at 1 sec: Precision (W/m2) | Measured at 1 sec: 1-sigma Precision 1-sigma (DN) | Measured at 1 sec: 1-sigma (W/m2) | Measured at 1 sec: Max Irrad (W/m2) | PORD 30-s Min Irrad (W/m2) | Precision / PORD (%) | Uncertainty / PORD (%) |
|---|---|---|---|---|---|---|---|---|
| EUVSA | 25.6 | 1.42e-6 | 0.904 | 1.28e-6 | 0.93 | 8.80e-6 | 2.9 | 2.7 |
| | 28.4 | 1.80e-6 | 0.789 | 1.42e-6 | 1.16 | 1.36e-5 | 2.4 | 1.9 |
| | 30.4 | 2.46e-6 | 1.050 | 2.58e-6 | 1.20 | 1.32e-4 | 0.34 | 0.36 |
| EUVSB | 117.5 | 1.24e-5 | 0.815 | 1.01e-5 | 3.98 | 2.40e-5 | 9.4 | 7.7 |
| | 121.6 | 6.56e-6 | 1.191 | 7.81e-6 | 3.13 | 4.00e-3 | 0.30 | 0.36 |
| | 133.5 | 5.01e-6 | 0.781 | 3.91e-6 | 1.64 | <none> | | |
| | 140.5 | 4.21e-6 | 1.025 | 4.32e-6 | 4.17 | <none> | | |

Notes:
1. Precision was calculated at 1 DN in each diode that comprises the line irradiance.
2. Maximum irradiance (989,000 DN) was calculated for two of the brightest diodes for any EUVS-A line in question, i.e., split diodes for 30.4. The calculation was done as a mean for each line on day 2019/235. For EUVS-B, Diodes 8 & 9 (split diodes) were used for 121 nm; for 117 nm, diode 15 is used; for 133 nm, diode 20 is used; and for 140 nm, diodes 2 & 3 are used.
3. Ratios of measured value to the PORD minimum irradiance values were calculated at a 30-s cadence by dividing the 1-s measured values by √30.

Credit: Tom Eden

# SUMMARY OF REMAINING ISSUES

# EUVS GPA Issues to be completed before Full Validation

| ADR | Issue | * | Description / Impacts | Delivery date |
|---|---|---|---|---|
| 471 | EUVS-A, -B dark time dependence | | 7% offsets in 121 nm | ? |
| 523 | Reduce packet size for APID 255. | | reduce from 20 Hz data | ? |
| 894 | Lunar transit flag not set | | | [1] |
| 898 | EUVS dark current temperature correction | | adds false variability | [1] |
| 958 | Change EXIS LUT variables to double precision | | | [1] |
| 1002 | Move "...leap seconds" from units to long name. | | | ? |

[1] targeted patch in Spring 2020

* Impact on status: Minor Impact | Moderate Impact | Major Impact

# Remaining Instrument EUVS Issues

| # | Issue | Description | Comments to Users |
|---|---|---|---|
| 1 | Create Mg II proxies for degradation | Need to create Mg II proxies for EUVS to use for degradation models | This is required for calibration of EUVS after SORCE SOLSTICE is turned off in January 2020 |
| 2 | EUVS-A and -B temperature corrections | See list of remaining ADRs. | Data invalid until temperature corrections are implemented. |
| 3 | EUVS filter degradation | Need to improve understanding of degradations. Under investigation by LASP with Task Order 10. | This is essential to get correct degradation corrections. |
| 4 | rocket calibration | Recently available spectrum should be used to calibrate EUVS data. | This will validate irradiances. |
| 5 | EUVS-C spike removal | Determine if this should be added to L1b code. | Spikes can add noise to data. |
| 6 | EUVS model during flares | small revisions | |
| 7 | EUVS-C systematic behavior | Further detailed investigation of behavior of wings and lines. | Examine impacts of Doppler and seasonal effects and degradation. |

# PROVISIONAL MATURITY ASSESSMENT

# Provisional Maturity Definition

- Validation activities are ongoing and the general research community is now encouraged to participate.
- Severe algorithm anomalies are identified and under analysis. Solutions to anomalies are in development and testing.
- Incremental product improvements may still be occurring.
- Product performance has been demonstrated through analysis of a small number of independent measurements.
- Product analysis is sufficient to establish product performance relative to expectations (Performance Baseline).
- Documentation of product performance exists that includes recommended remediation strategies for all anomalies and weaknesses. Any algorithm changes associated with severe anomalies have been documented, implemented, and tested.
- Testing has been fully documented.
- Product is ready for operational use and for use in comprehensive cal/val activities and product optimization.

# Provisional Validation (1/2)

| Preparation Activities | Assessment |
|---|---|
| Validation activities are ongoing and the general research community is now encouraged to participate. | Validation activities are ongoing. Results have been discussed with SWPC. Eventual release of data by NCEI will enable research community participation. |
| Severe algorithm anomalies are identified and under analysis. Solutions to anomalies are in development and testing. | The temperature issue has been developed and is awaiting GPA installation and testing. |
| Incremental product improvements may still be occurring. | Product improvements will result from the resolution to issues given on the slides titled "GPA Issues for Provisional Validation" and "Remaining Instrument EUVS Issues". |

# Provisional Validation (2/2)

| End State | Assessment |
|---|---|
| Product performance has been demonstrated through analysis of a small number of independent measurements obtained from select locations, periods, and associated ground truth or field campaign efforts. | EUVS flux measurements have been compared with measurements from SORCE SOLSTICE and the Bremen Mg II composite. Instrument was calibrated at NIST. |
| Product analysis is sufficient to communicate product performance to users relative to expectations (Performance Baseline). | Yes, product performance will be communicated to users via the Readme *when* data is released. |
| Documentation of product performance exists that includes recommended remediation strategies for all anomalies and weaknesses. Any algorithm changes associated with severe anomalies have been documented, implemented, tested, and shared with the user community. | The PUG and CDRL80 require some updates. This presentation details major remaining issues and remediation strategies. The Readme will summarize remaining issues and strategies. Strategies have been discussed extensively with SWPC and agreed to by them. |
| Testing has been fully documented. | This presentation, PLT reports, and PLPT reports. |
| Product is ready for operational use and for use in comprehensive cal/val activities and product optimization. | This data is not ready for operational use. This data is ready for further cal/val and product optimization. |

# Summary and Recommendations

- All sensors are performing very well.
- Calibration LUTs have been updated. Further updates will occur.
- Observed issues are similar between GOES-16 and -17.
- Paths toward diagnoses and fixes of issues have been identified.
- Some issues will prevent Full status unless resolved.
- EUVS data should be embargoed until ADRs 898 and 471 are properly implemented.
- NCEI is working to create L0-processed scientific L1b EUVS data which can be released to the public when ready.

NCEI-CO does not recommend that the GOES-16 EUVS data be used for operations or provided to the public in its current state.
NCEI-CO does not recommend that EUVS L1b data be transitioned to Provisional status at this time.

# PATH TO FULL VALIDATION

# Path to Full Validation

- Data analysis with L1b, L2, and LASP-processed L0 data.
- Identify and resolve instrument issues including those listed in the Summary of Remaining Issues slides.
- Analyze daily, weekly and quarterly calibrations.
- Provide updated calibration tables.
- Verify L1b revisions for ADRs on Remaining GPA Issues slides.
- LASP is handing all GOES-16 and -17 calibration work over to NCEI on 1 January 2020.
- Proceed with L0 reprocessing at NCEI to provided scientific data for comparisons.

# Risks for Full Validation Status

| Issue | * | Notes |
|---|---|---|
| New issues found during continued monitoring | Possible | |
| Required ADR fixes need to be completed on slide titled "EUVS GPA Issues to be completed before Full Validation" | Possible | |

# AUXILLIARY INFORMATION

# EUVS LUT Filenames

On 2019-08-30 the following EUVS LUTs were in use:

## GOES-16

EUVSA_Cal_INR(FM1A_CDRL79RevH_PR_08_01_01)-619067700.0.h5
EUVSB_Cal_INR(FM1A_CDRL79RevH_PR_08_01_01)-619067700.0.h5
EUVSC_Cal_INR(FM1A_CDRL79RevH_PR_08_01_01_PROPASS_Mod)-619067700.0.h5
EUVSPEC_Cal_INR(FM1A_CDRL79RevH_PR_08_01_01)-619067700.0.h5
Yearly_1AU_Correction_Table(2019)-599572800.0.h5

## GOES-17

EUVSA_Cal_INR(FM2A_CDRL79RevF_PR_08_01_01)-619068400.0.h5
EUVSB_Cal_INR(FM2A_CDRL79RevF_PR_08_01_01)-619068400.0.h5
EUVSC_Cal_INR(FM2A_CDRL79RevF_PR_08_01_01_PROPASS_MOD)-619068400.0.h5
EUVSPEC_Cal_INR(FM2A_CDRL79RevF_PR_08_01_01)-619068400.0.h5
Yearly_1AU_Correction_Table(2019)-599572800.0.h5

# 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