GOES EUVS Calibration

Pre-Flight Calibrations: Fred Hanser (ATC)
PLT data and modeling:Don McMullin (SSRC)

GOES-NOP XRS/EUV SENSOR Calibration

Assurance Technology Corporation

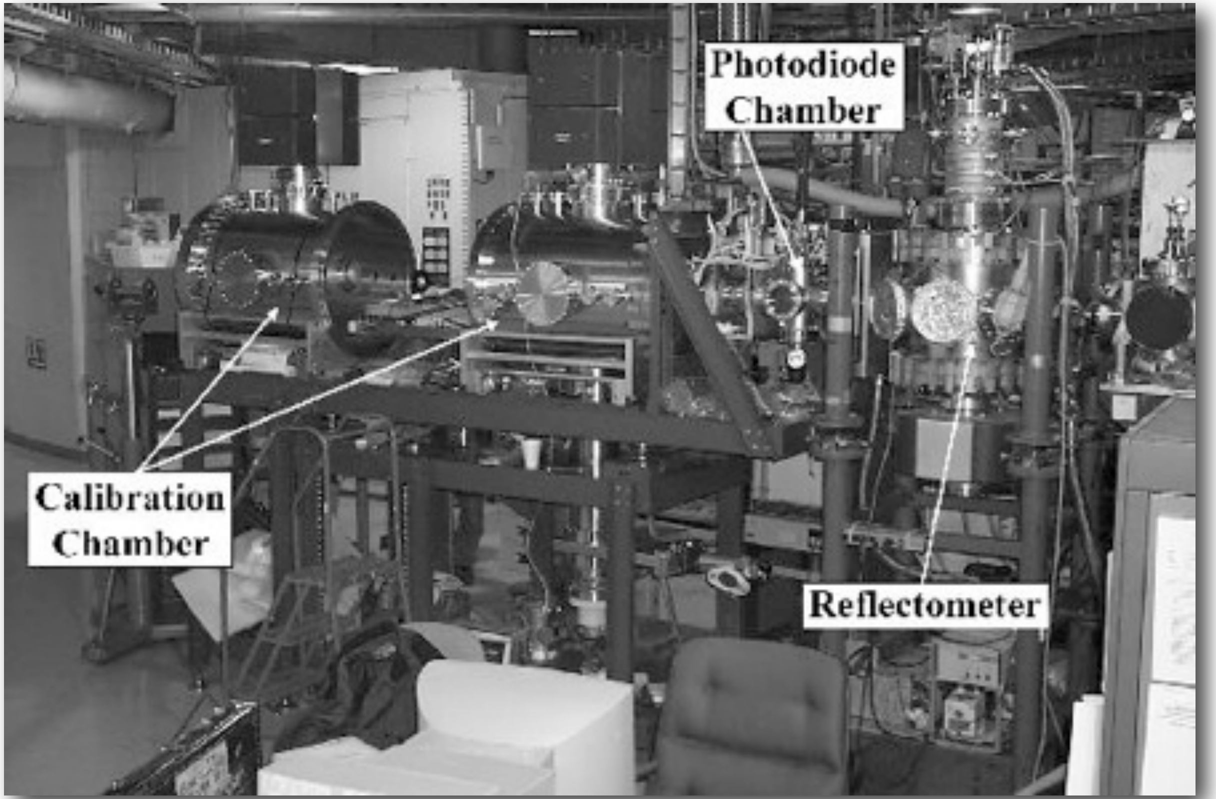
October 19, 2011

Slightly modified by Andrew Jones

GOES-NOP EUV Telescope Channel Calibration at the Naval Research Lab (NRL) X24C beamline at the National Synchrotron Light Source (NSLS)

Calibration chamber used for EUVS has X, Y, ϴ, ϕ motion

Photodiode chamber and Reflectometer used to measure photodiode and grating properties prior to use in the EUV sensor



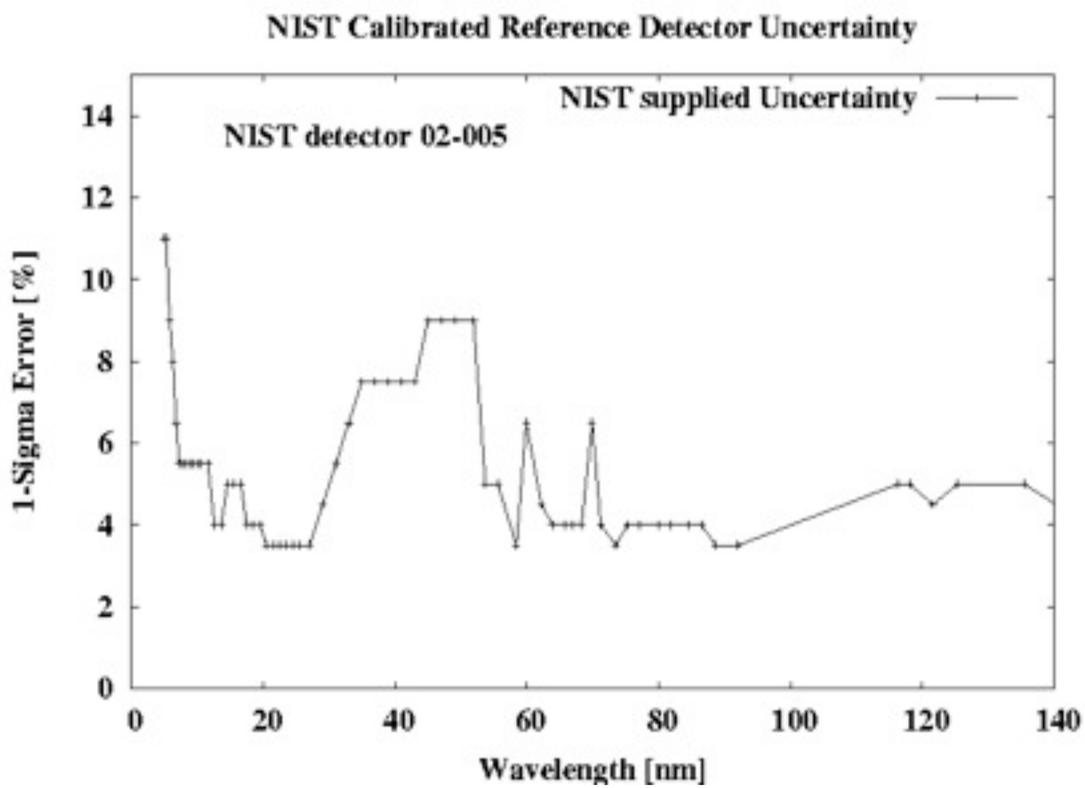
Setup

- Use beamline grating monochrometer to select over the range of 1-130 nm
  - Thin beamline filters used to reduce the intensity of higher harmonics
  - EUV beam intensity measured with a NIST calibrated IRD AXUV 100G photodiode
    - Photodiode calibrated before and after each EUV sensor calibration

GOES-NOP EUV SENSOR CALIBRATION

- Several uncalibrated AXUV photodiodes are cross-calibrated with the calibrated photodiode during each EUV sensor calibration period
  - Cross-calibrated photodiodes are used to measure EUV beam intensity during most of the EUV sensor calibration period
  - Reduces the EUV irradiation of the calibrated photodiode, and possible photodiode degradation from radiation damage
  - Early calibrations showed that excessive use of the calibrated photodiode during calibration of an EUV sensor resulted in a significant decrease of photodiode calibration when recalibrated at NIST
    - » This introduces additional uncertainty in the EUV channel calibrations

GOES-NOP EUV SENSOR CALIBRATION NIST Calibration Uncertainty



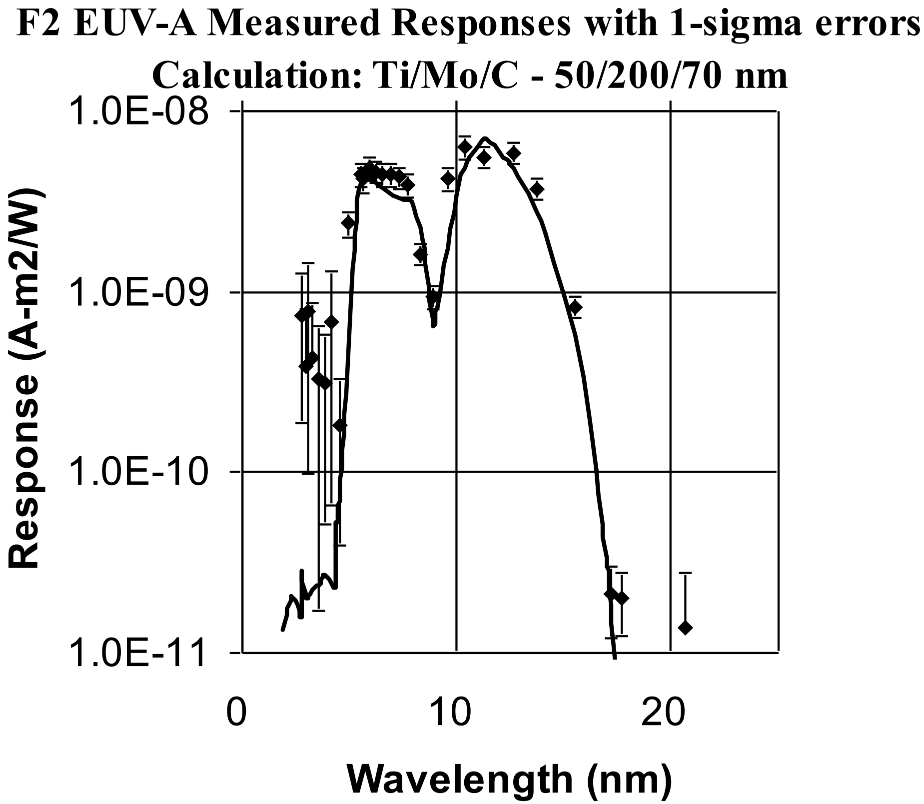
EUV-A SENSOR CALIBRATED RESPONSE

GOES-NOP EUV-A Channel Calibration for the F2 Sensor

- Figure of Calibrated Response shown on following slide(*)
- Absolute integrated calibration factor for the shorted wavelength range of about 5-15 nm is 4.482E-8 (A-m^2-nm)/W
  - Channel telemetry gain is about 1.90E-15 A/count
    - » Requires decompressing the telemetry count and subtracting an offset count of about 25,000

(*)Tables of Calibrated Response shown in backup slides

EUV-A SENSOR CALIBRATED RESPONSE

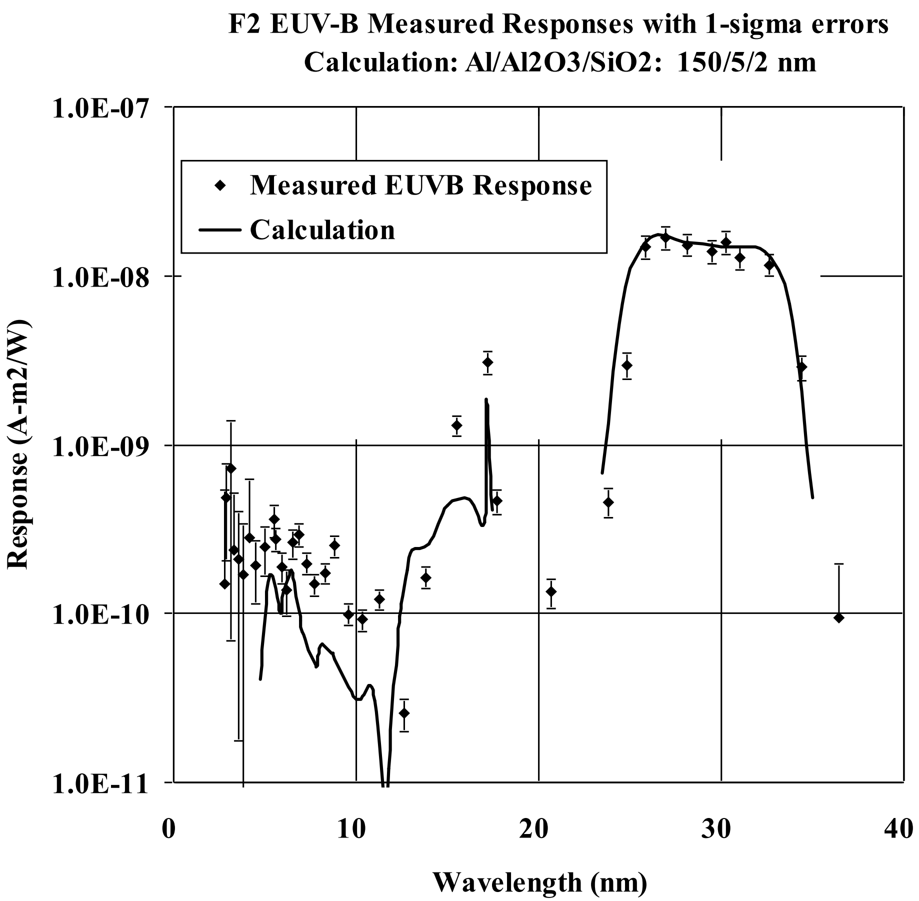


EUV-B SENSOR CALIBRATED RESPONSE

GOES-NOP EUV-B Channel Calibration for the F2 Sensor

- Figure of Calibrated Response shown on following slide
- Absolute integrated calibration factor for the shorted wavelength range of about 25 - 34 nm is 1.333E-7 (A-m^2-nm)/W
  - Channel telemetry gain is about 1.90E-15 A/count
    - » Requires decompressing the telemetry count and subtracting an offset count of about 16,000

EUV-B SENSOR CALIBRATED RESPONSE

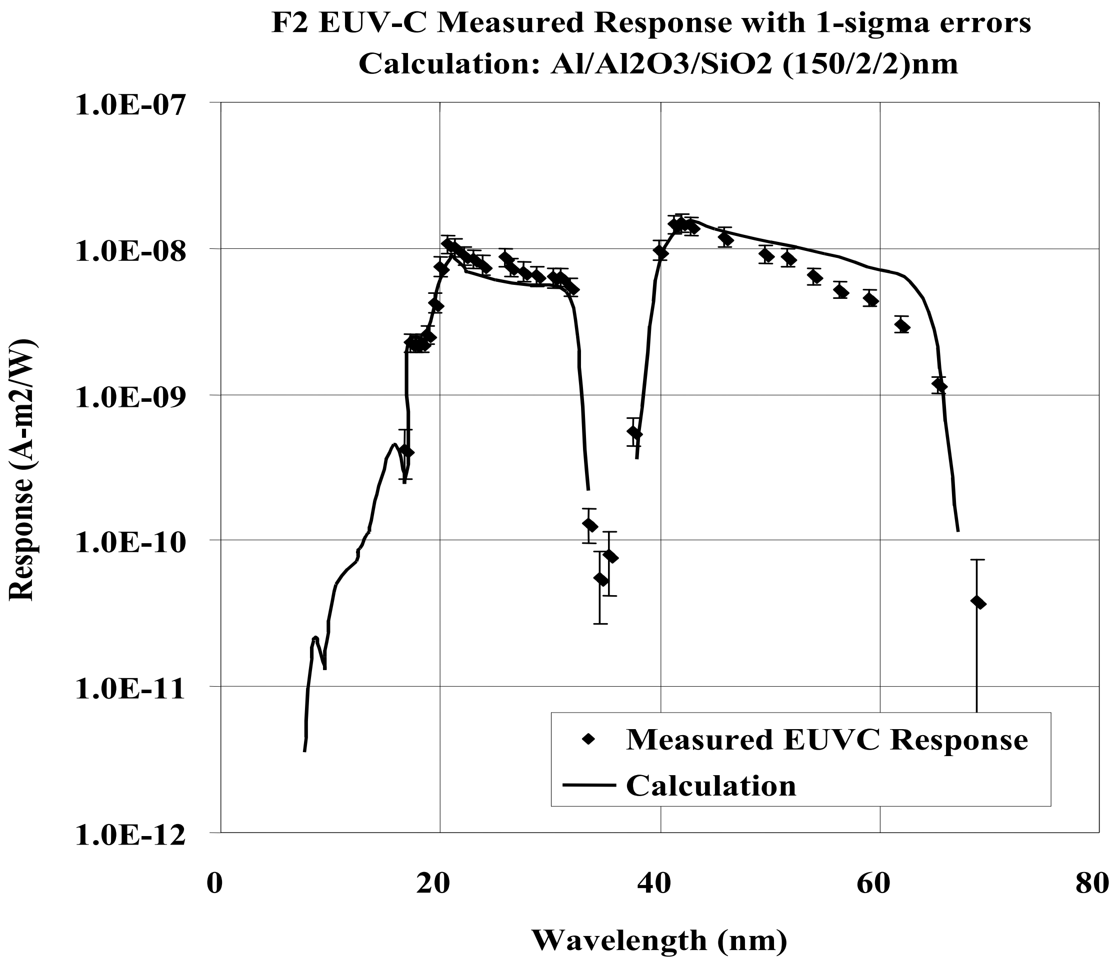


EUV-C SENSOR CALIBRATED RESPONSE

GOES-NOP EUV-C Channel Calibration for the F2 Sensor

- Figure of Calibrated Response shown on following slide
- Absolute integrated calibration factor for the shorted wavelength range of about 16.8 to 35.4 nm is 1.067E-7 (A-m^2-nm)/W
  - Channel telemetry gain is about 1.90E-15 A/count
    - » Requires decompressing the telemetry count and subtracting an offset count of about 16,000

EUV-C SENSOR CALIBRATED RESPONSE

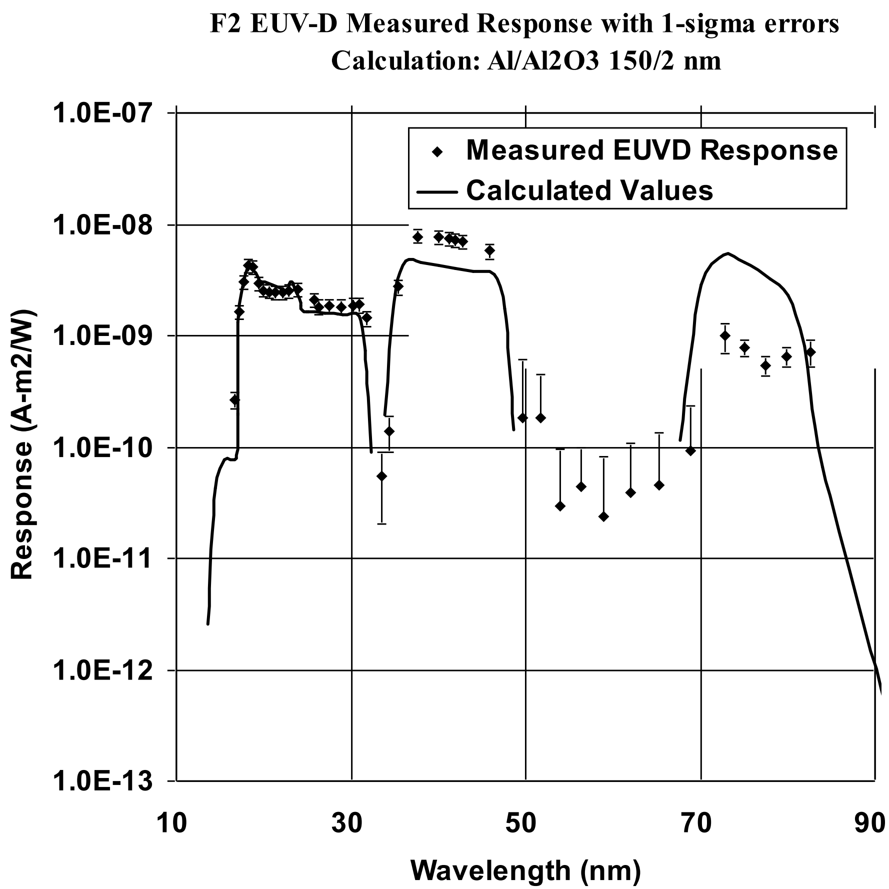


EUV-D SENSOR CALIBRATED RESPONSE

GOES-NOP EUV-D Channel Calibration for the F2 Sensor

- Figure of Calibrated Response shown on following slide, Table of Calibrated Response shown on next slide
- Absolute integrated calibration factor for the total wavelength range of about 16.8 to 82.6 nm is 1.277E-7 (A-m^2-nm)/W
  - Channel telemetry gain is about 1.90E-15 A/count
    - » Requires decompressing the telemetry count and subtracting an offset count of about 24,000

EUV-D SENSOR CALIBRATED RESPONSE

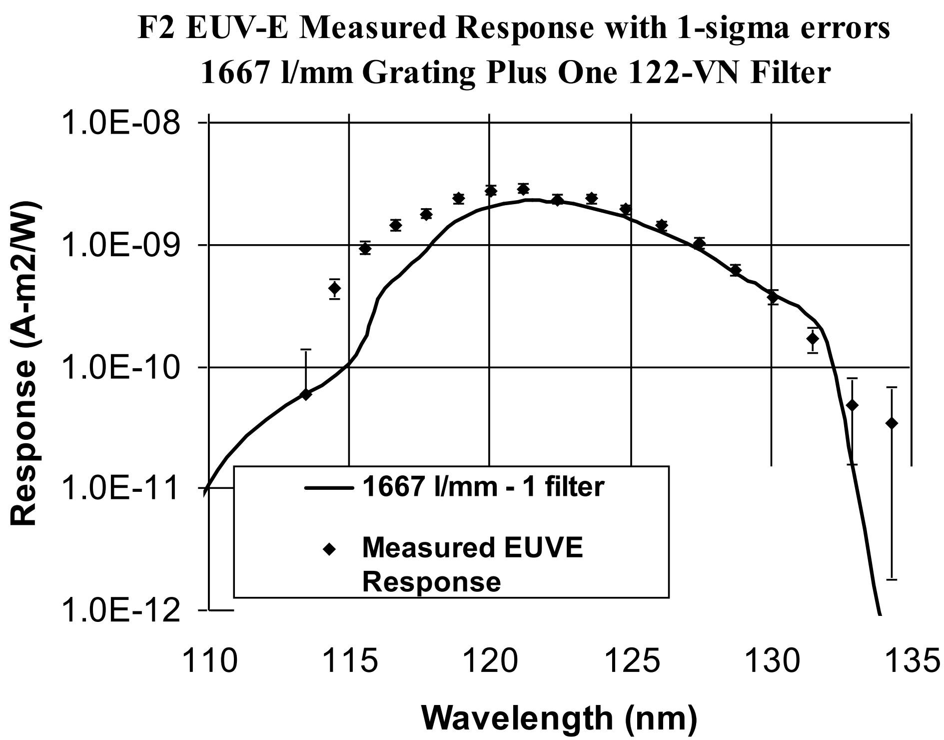


EUV-E SENSOR CALIBRATED RESPONSE

GOES-NOP EUV-E Channel Calibration for the F2 Sensor

- Figure of Calibrated Response shown on following slide
- Absolute integrated calibration factor for the wavelength range of about 113 to 134 nm is 2.756E-8 (nm-A-m^2)/W
  - Channel telemetry gain is about 1.90E-15 A/count
    - » Requires decompressing the telemetry count and subtracting an offset count of about 25,000

EUV-E SENSOR CALIBRATED RESPONSE



GOES EUVS
Post-Launch Data Evaluation

EUV Workshop
October 25-27, 2011
LASP / CU

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Acknowledgements

- This work was motivated from a set of tasks sponsored by NOAA, related to the GOES-R SIS and the GOES-N EUVS considered key to ensuring the effective use of operational space weather data sets in the next decade.
- These tasks were performed using GOES N Post-Launch Test period data sets and as-built EUVS drawings and test data.
- Team Members
  - Space Systems Research Corporation
    - Donald R. McMullin
  - Computational Physics, Inc.
    - Douglas J. Strickland
    - J. Scott Evans
    - Wade K. Woo
  - Naval Research Laboratory
    - Simon P. Plunkett

The Problem

Early GOES N EUVS results indicated irradiance values were as much as several factors of 10 different from what was expected

The Solution

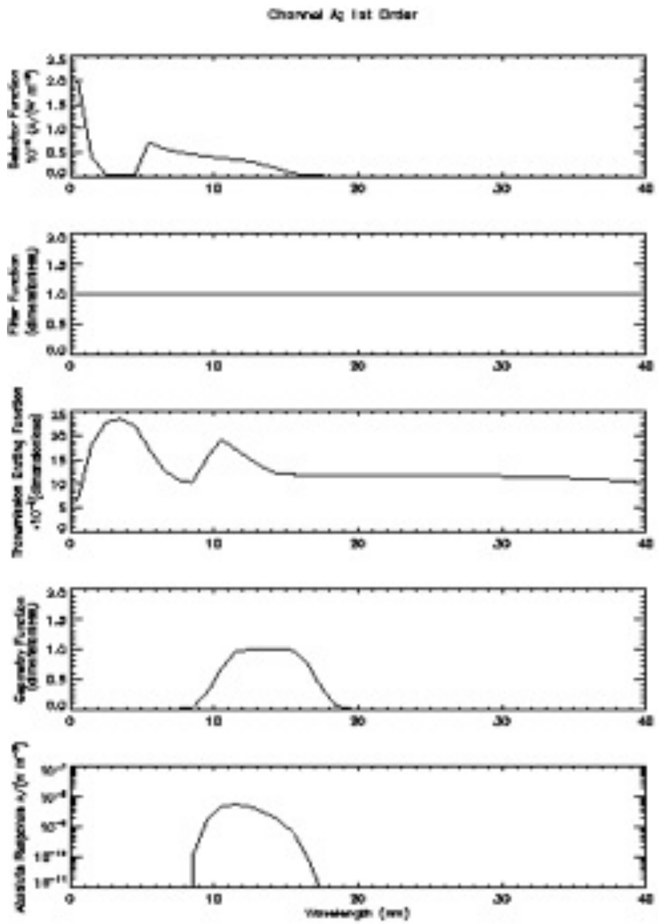
Build a numerical model of the EUVS that can predict the irradiances measured on-orbit, and compare results with other instruments (TIMED-SEE, SOHO-SEM)

Instrument Parameters

Parameters
- Detectors
- Filters
- Gratings
- Geometry
- Electronics (gain)

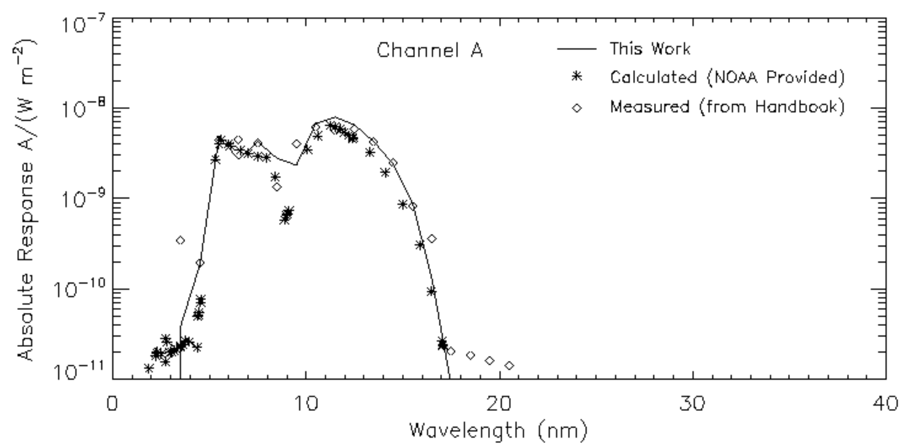
Comments
- Some parameters and values listed in EUVS Handbook (pg 85)
- Others taken from NOAA provided model or as-built drawings and other documents

Channel A Calibration Determination



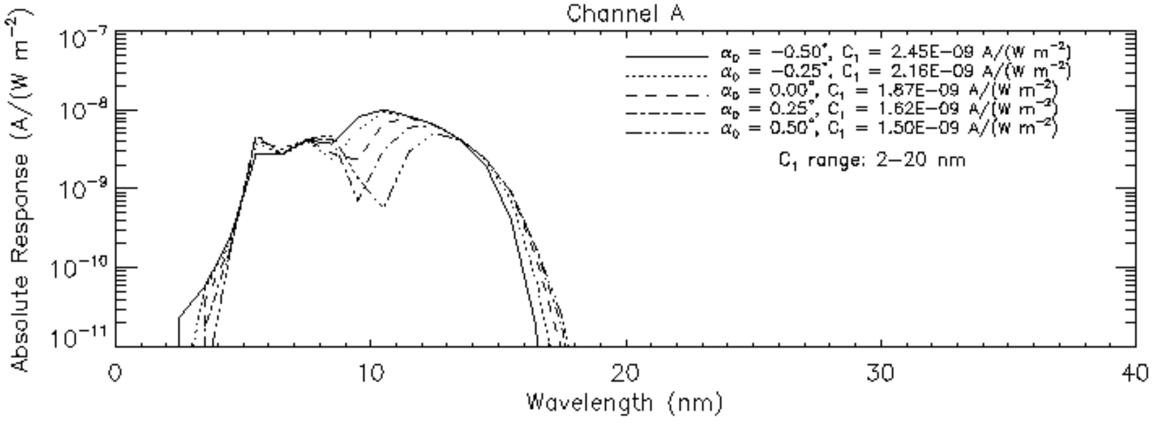
Left: Derived Channel A 1st order response function and its product components.

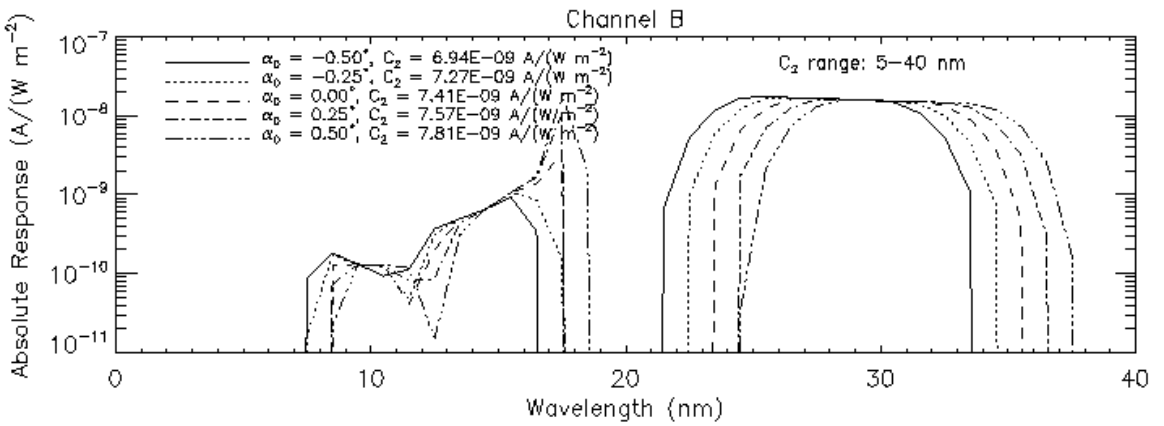
Below: Derived response function for orders 1-3 for comparison with measured (from handbook) and calculated (provided by SEC) values



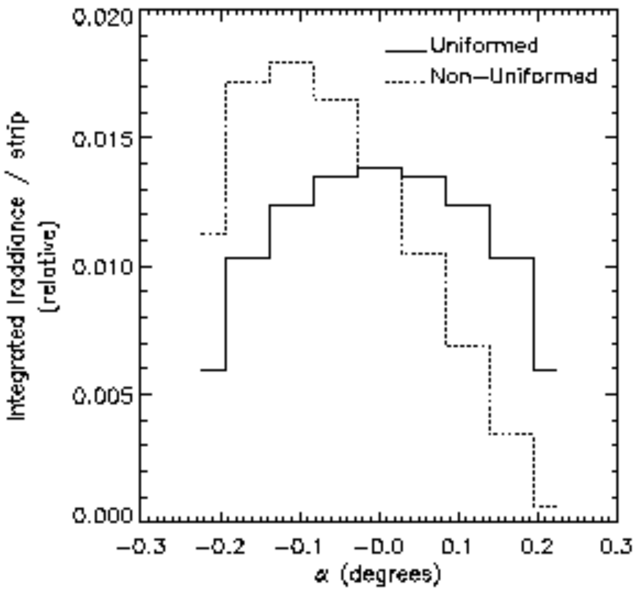
Absolute response functions

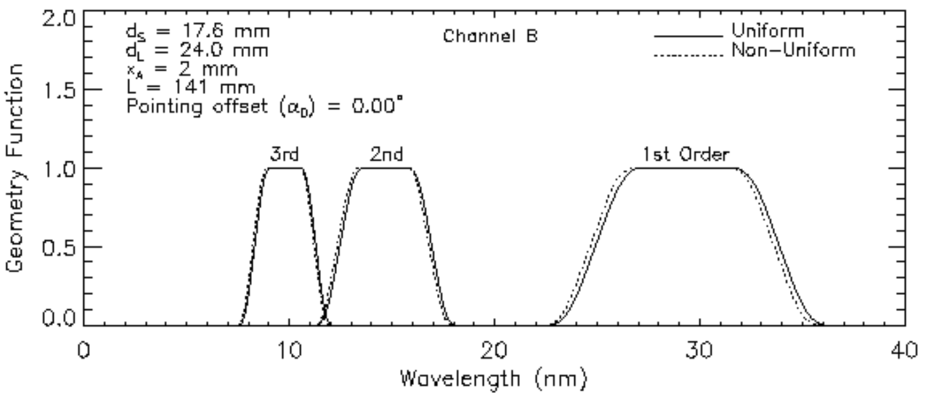
Calculated absolute response functions for channels A and B. Results are shown for five offset angles, a uniform disk luminosity distribution, and orders 1-3. Included are corresponding conversion factors using a SEE quiet-time spectrum



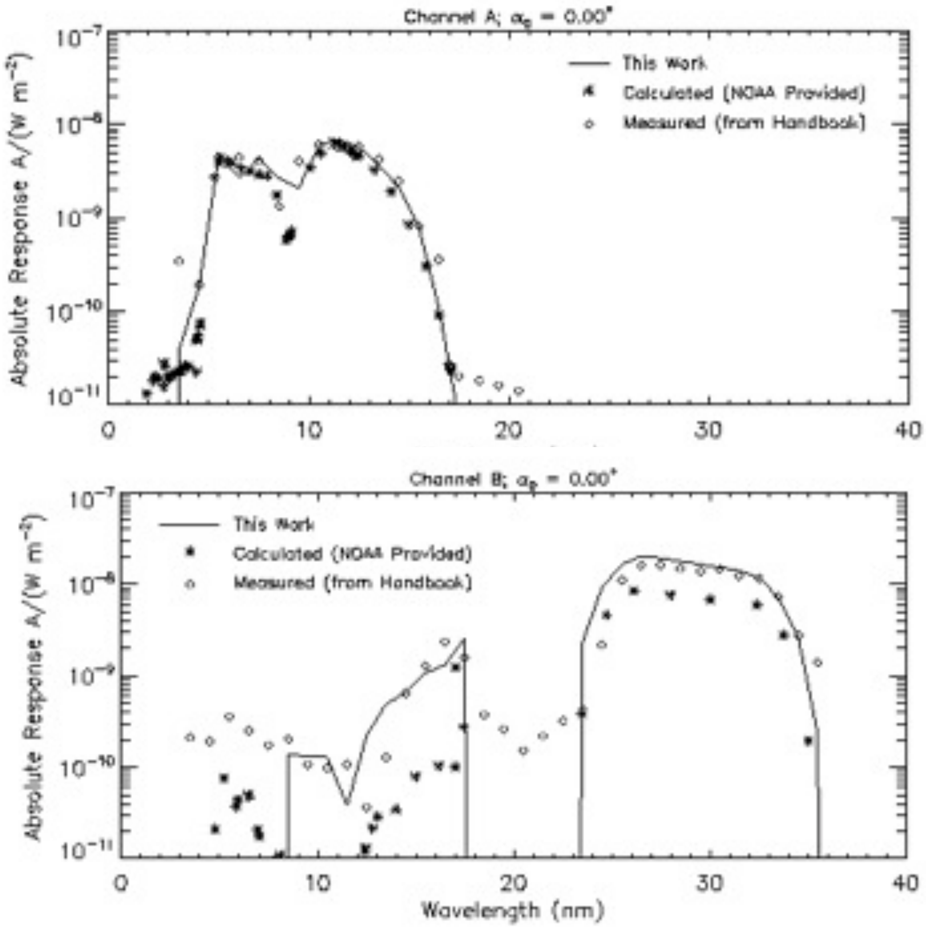


Histograms for uniform and non-uniform luminosity. Corresponding geometry functions for Channel B

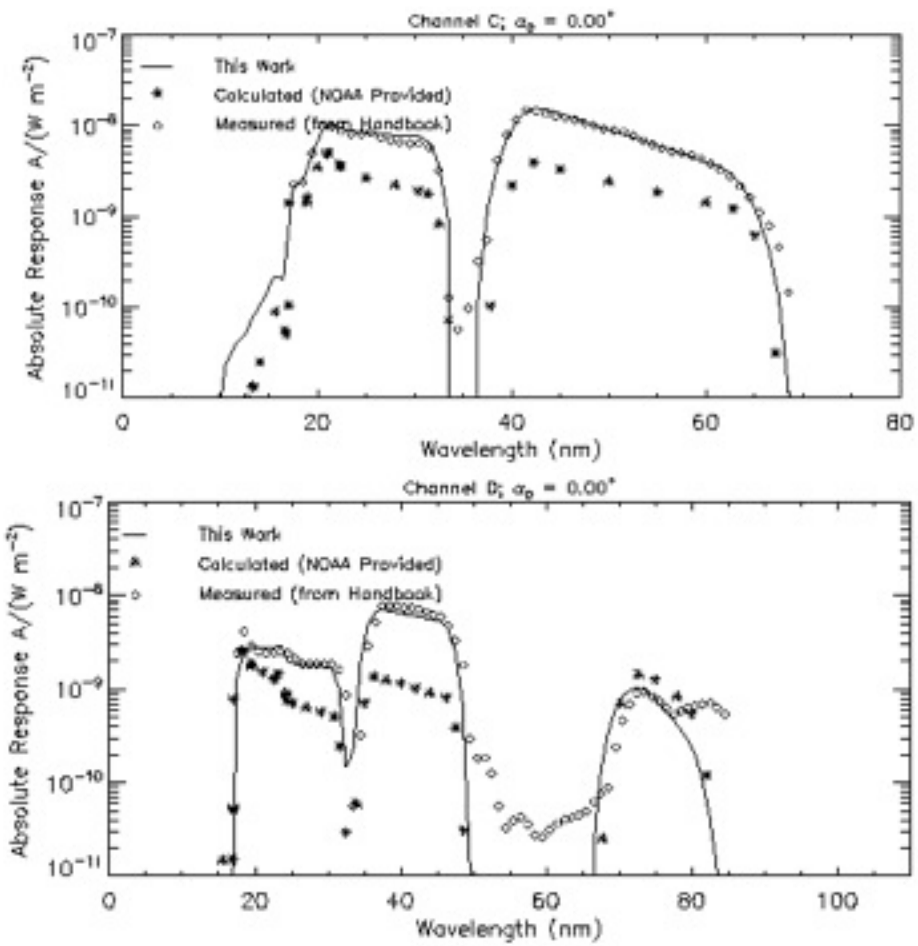




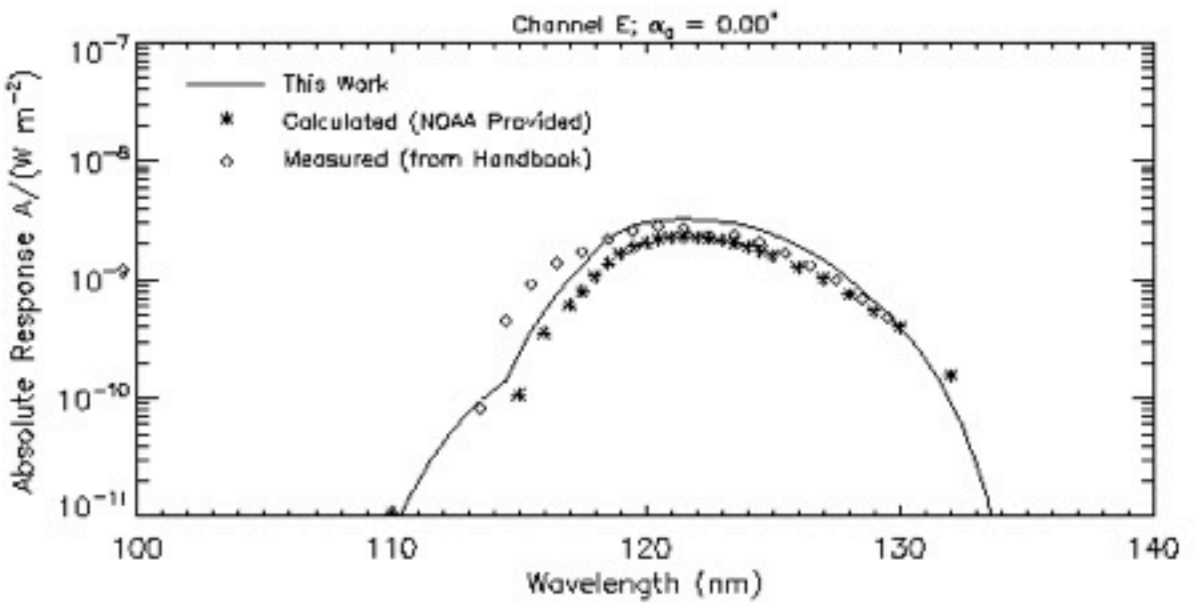
Comparing calculated with measured conversion factors for Channels A and B



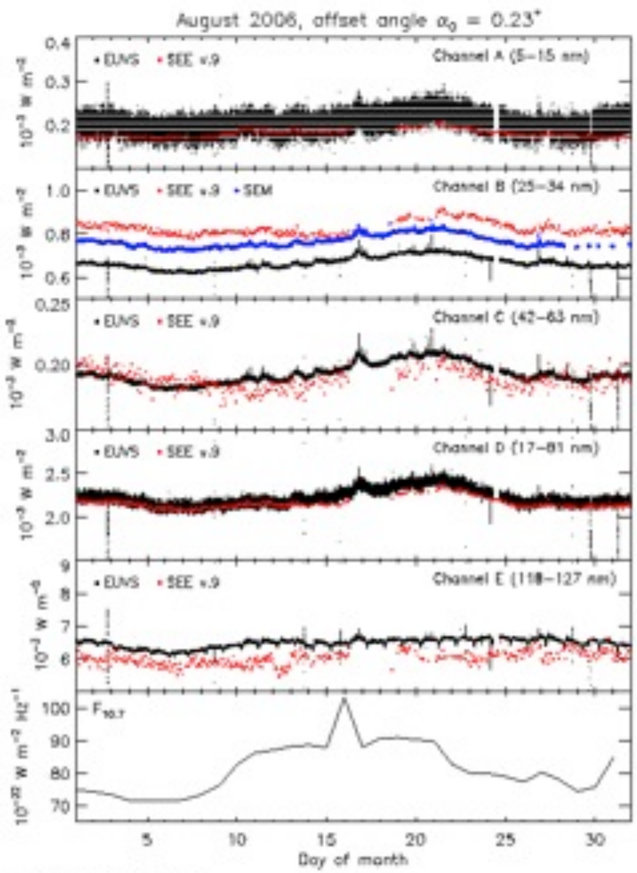
Comparing calculated with measured conversion factors for Channels C and D

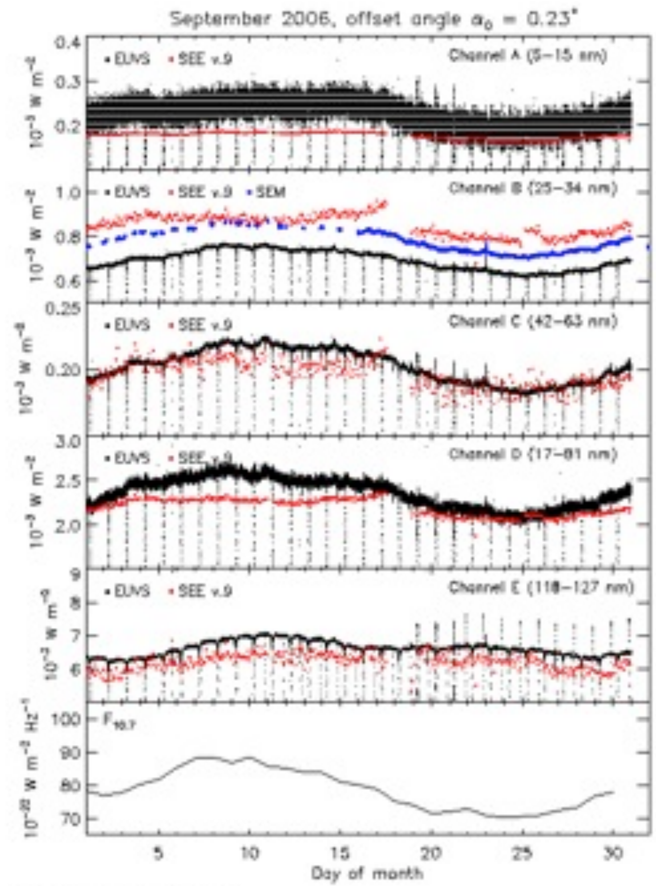


Comparing calculated with measured conversion factors for Channel E



Comparing EUVS with SEE and SEM data for Aug and Sep 2006





Comments on comparisons for Channels A and B

Channel A

EUVS gives larger values than SEE with the difference increasing in time.

SEE's values come from the processing of XPS data that will have greater uncertainties than EGS data used for the remaining channels.

Channel B

The energy flux within the HeII 30.4 nm line is primarily responsible for the behavior seen in this channel.

There is overall agreement within the expected uncertainties among the three measurements.

Comments on comparisons for Channels C and D

<u>Channel C</u>

Good agreement in temporal behavior is observed between EUVS and SEE with less than 10% difference in magnitude at most times after smoothing the noisier SEE values.

However, we found a significant spread in the energy flux (for fixed counts) that is strongly dependent on the spectral shapes used.

<u>Channel D</u>

There is overall excellent agreement between EUVS and SEE for this channel.

Comments on comparisons for Channel E and summary comment for all channels

Channel E

HI Ly α dominates the signal for this channel (more than HeII 30.4 nm in Channel B) and, consequently, the processed data are not sensitive to the underlying spectral behavior.

There is a persistent difference of ~10% between the two data sets.

Conclusion

- Overall, the agreement with SEE and SEM is encouraging and in some cases, EUVS would appear to be providing superior measurements (e.g, temporal behavior in Channels A and D).
- For all channels, the differences are within the expected uncertainties of the three sets of measurements.

Backup Tables (Hanser)

GOES-NOP EUV-C SENSOR CALIBRATED RESPONSE

Wavelength [nm]	Detector Response [Amp-m^2/W]	Response Error [Amp-m^2/W]
16.752331	4.20E-10	1.55E-10
17.217609	2.27E-09	3.14E-10
17.70947	2.23E-09	3.12E-10
18.23026	2.24E-09	3.14E-10
18.782609	2.55E-09	3.61E-10
19.369474	4.28E-09	6.35E-10
19.994194	7.55E-09	1.08E-09
20.660557	1.06E-08	1.51E-09
21.372867	1.02E-08	1.45E-09
22.136047	8.86E-09	1.27E-09
22.955749	8.56E-09	1.24E-09
23.838493	7.73E-09	1.15E-09
25.82462	8.69E-09	1.27E-09
26.373963	7.44E-09	1.10E-09
27.545879	6.94E-09	1.04E-09
28.826784	6.49E-09	9.78E-10
30.232626	6.34E-09	9.63E-10
30.988253	6.39E-09	9.75E-10
31.78262	5.44E-09	7.97E-10
33.500135	1.30E-10	3.56E-11
34.430436	5.55E-11	2.89E-11
35.413882	7.93E-11	3.71E-11
37.559527	5.65E-10	1.17E-10
39.981941	9.80E-09	1.46E-09
41.314229	1.46E-08	2.13E-09
42.014232	1.49E-08	2.19E-09
42.738366	1.42E-08	2.11E-09
45.902999	1.19E-08	1.82E-09
49.57377	9.21E-09	1.35E-09
51.638484	8.66E-09	1.17E-09
53.88266	6.51E-09	8.17E-10
56.330759	5.26E-09	6.62E-10
59.011899	4.59E-09	5.73E-10
61.961019	3.06E-09	3.88E-10
65.220	1.18E-09	1.49E-10
68.842	3.91E-11	3.43E-11

EUV-C calibrated response (35.4-68.8 nm) = 2.141 A-m2-nm/W (+/-14.2%) – use for 40-64 nm response.

EUV-C calibrated response (16.8-35.4 nm) = 1.062E-07 A-m2-nm/W (+/-14.7%) – use for 17-32 nm response

GOES-NOP EUV-E SENSOR CALIBRATED RESPONSE

Wavelength [nm]	Detector Response [Amp-m^2/W]	Response Error [Amp-m^2/W]
113.434584	5.86E-11	8.12E-11
114.481994	4.40E-10	8.07E-11
115.548928	9.37E-10	1.14E-10
116.635936	1.45E-09	1.41E-10
117.74359	1.80E-09	1.73E-10
118.872483	2.39E-09	2.22E-10
120.023233	2.79E-09	2.51E-10
121.196481	2.89E-09	2.60E-10
122.392892	2.34E-09	2.07E-10
123.613161	2.40E-09	2.10E-10
124.858006	1.94E-09	1.71E-10
126.128179	1.43E-09	1.29E-10
127.42446	1.02E-09	1.00E-10
128.747664	6.18E-10	6.51E-11
130.098636	3.74E-10	5.29E-11
131.478261	1.69E-10	4.08E-11
132.88746	4.80E-11	3.22E-11

EUV-E calibrated response (113-134 nm) =
2.756E-08 A-m^2-nm/W (+/-10.0%).

GOES-NOP EUV-A SENSOR CALIBRATED RESPONSE

Wavelength [nm]	Detector Response [Amp-m^2/W]	Response Error [Amp-m^2/W]
2.755	7.33E-10	5.44E-10
2.917	3.84E-10	4.12E-10
3.100	7.73E-10	6.75E-10
3.306	4.33E-10	4.34E-10
3.542	3.28E-10	3.11E-10
3.815	3.13E-10	2.61E-10
4.133	6.83E-10	6.16E-10
4.508	1.84E-10	1.45E-10
4.959	2.38E-09	3.75E-10
5.510	4.47E-09	6.78E-10
5.635	4.18E-09	6.32E-10
5.904	4.83E-09	7.10E-10
6.199	4.63E-09	6.73E-10
6.525	4.47E-09	6.39E-10
6.888	4.46E-09	6.25E-10
7.293	4.30E-09	5.96E-10
7.749	3.87E-09	5.37E-10
8.265	1.62E-09	2.24E-10
8.855	9.30E-10	1.40E-10
9.536	4.18E-09	5.99E-10
10.331	6.29E-09	8.72E-10
11.270	5.59E-09	7.80E-10
12.650	5.86E-09	7.94E-10
13.774	3.73E-09	5.09E-10
15.496	8.27E-10	1.14E-10
17.218	2.10E-11	8.77E-12
17.709	1.99E-11	7.56E-12
20.661	1.38E-11	1.43E-11

EUV-A calibrated response (4.5-20.7 nm) = 4.400E-08 A-m2-nm/W (+/-14.2%).
EUV-A calibrated response (2.8-20.7 nm) = 4.482E-08 A-m2-nm/W (+/-15.6%) – use for 5-15 nm response.

GOES-NOP EUV-D SENSOR CALIBRATED RESPONSE

Wavelength [nm]	Detector Response [Amp-m^2/W]	Response Error [Amp-m^2/W]
16.752331	2.62E-10	4.27E-11
17.217609	1.64E-09	2.18E-10
17.70947	3.00E-09	4.08E-10
18.23026	4.29E-09	5.80E-10
18.782609	4.14E-09	5.61E-10
19.369474	2.93E-09	3.98E-10
19.994194	2.55E-09	3.48E-10
20.660557	2.48E-09	3.42E-10
21.372867	2.46E-09	3.39E-10
22.136047	2.46E-09	3.41E-10
22.955749	2.49E-09	3.48E-10
23.838493	2.57E-09	3.62E-10
25.82462	2.08E-09	2.98E-10
26.373963	1.83E-09	2.60E-10
27.545879	1.85E-09	2.69E-10
28.826784	1.81E-09	2.65E-10
30.232626	1.87E-09	2.75E-10
30.988253	1.89E-09	2.80E-10
31.78262	1.43E-09	2.35E-10
33.500135	5.52E-11	3.50E-11
34.430436	1.40E-10	4.87E-11
35.413882	2.73E-09	4.30E-10
37.559527	7.81E-09	1.10E-09
39.981941	7.62E-09	1.08E-09
41.314229	7.37E-09	1.05E-09
42.014232	7.20E-09	1.03E-09
42.738366	6.95E-09	9.93E-10
45.902999	5.75E-09	8.60E-10
49.57377	1.82E-10	4.35E-10
51.638484	1.84E-10	2.68E-10
53.88266	2.92E-11	6.60E-11
56.330759	4.45E-11	5.29E-11
59.011899	2.36E-11	5.71E-11
61.961019	3.90E-11	6.88E-11
65.22041	4.60E-11	8.89E-11
68.841755	9.36E-11	1.42E-10
72.888889	9.98E-10	2.99E-10
75.096305	7.86E-10	1.35E-10
77.441599	5.36E-10	1.04E-10
79.938104	6.50E-10	1.26E-10
82.600933	7.09E-10	1.93E-10

EUV-D calibrated response (68.8-82.6 nm) = 9.018E-09 A-m2-nm/W (+/-26.2%) – use for 70-80 nm response.
EUV-D calibrated response (33.5-49.6 nm) = 8.269E-08 A-m2-nm/W (+/-15.4%) – use for 35-48 nm response.
EUV-D calibrated response (16.8-33.5 nm) = 3.595E-08 A-m2-nm/W (+/-14.2%) – use for 17-31 nm response.
EUV-D total calibrated response (16.8-82.6 nm) = 1.277E-07 A-m2-nm/W (+/-15.8%).

GOES-NOP EUV-B SENSOR CALIBRATED RESPONSE

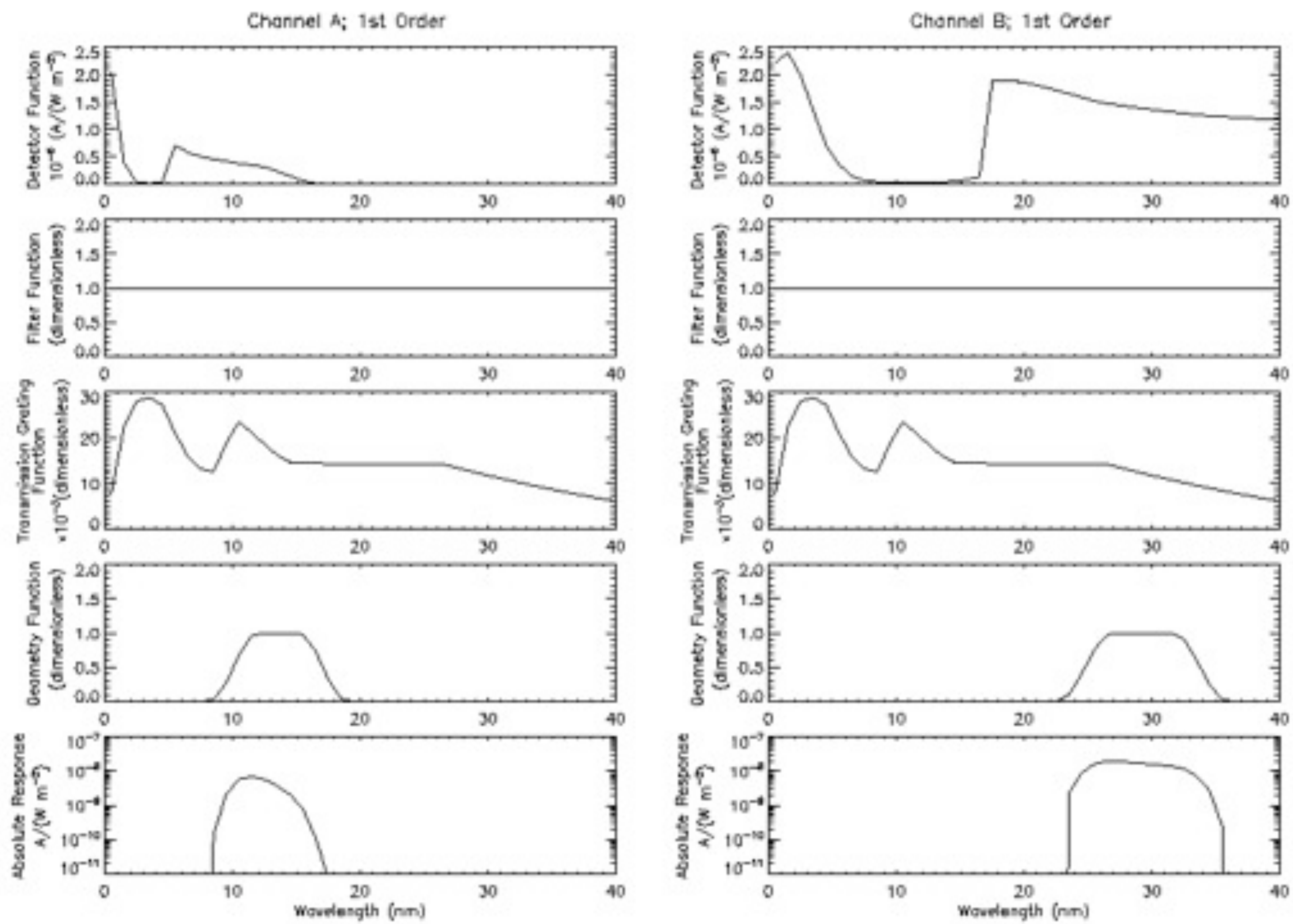
Wavelength [nm]	Detector Response [Amp-m^2/W]	Response Error [Amp-m^2/W]
2.755	1.48E-10	3.95E-10
2.917	4.90E-10	2.83E-10
3.100	7.26E-10	6.57E-10
3.306	2.38E-10	2.79E-10
3.542	2.09E-10	1.91E-10
3.815	1.71E-10	1.68E-10
4.133	2.81E-10	3.39E-10
4.508	1.92E-10	7.81E-11
4.959	2.47E-10	7.91E-11
5.510	3.58E-10	7.60E-11
5.635	2.78E-10	4.32E-11
5.904	1.89E-10	4.00E-11
6.199	1.39E-10	4.19E-11
6.525	2.62E-10	5.28E-11
6.888	2.94E-10	4.62E-11
7.293	1.97E-10	2.86E-11
7.749	1.48E-10	2.12E-11
8.265	1.74E-10	2.46E-11
8.855	2.51E-10	3.53E-11
9.536	9.88E-11	1.42E-11
10.331	9.22E-11	1.36E-11
11.270	1.22E-10	1.75E-11
12.650	2.57E-11	5.54E-12
13.774	1.64E-10	2.32E-11
15.496	1.29E-09	1.82E-10
17.218	3.10E-09	4.83E-10
17.709	4.60E-10	7.55E-11
20.661	1.34E-10	2.63E-11
23.838	4.58E-10	9.22E-11
24.792	2.96E-09	5.14E-10
25.825	1.48E-08	2.27E-09
26.947	1.69E-08	2.58E-09
28.172	1.53E-08	2.35E-09
29.513	1.40E-08	2.17E-09
30.233	1.58E-08	2.45E-09
30.988	1.28E-08	2.03E-09
32.619	1.16E-08	1.72E-09
34.430	2.86E-09	4.68E-10
36.455	9.49E-11	1.01E-10

EUV-B calibrated response (12.7-36.5 nm) = 1.333E-07 A-m2-nm/W (+/-15.5%) – use for 25-34 nm response.

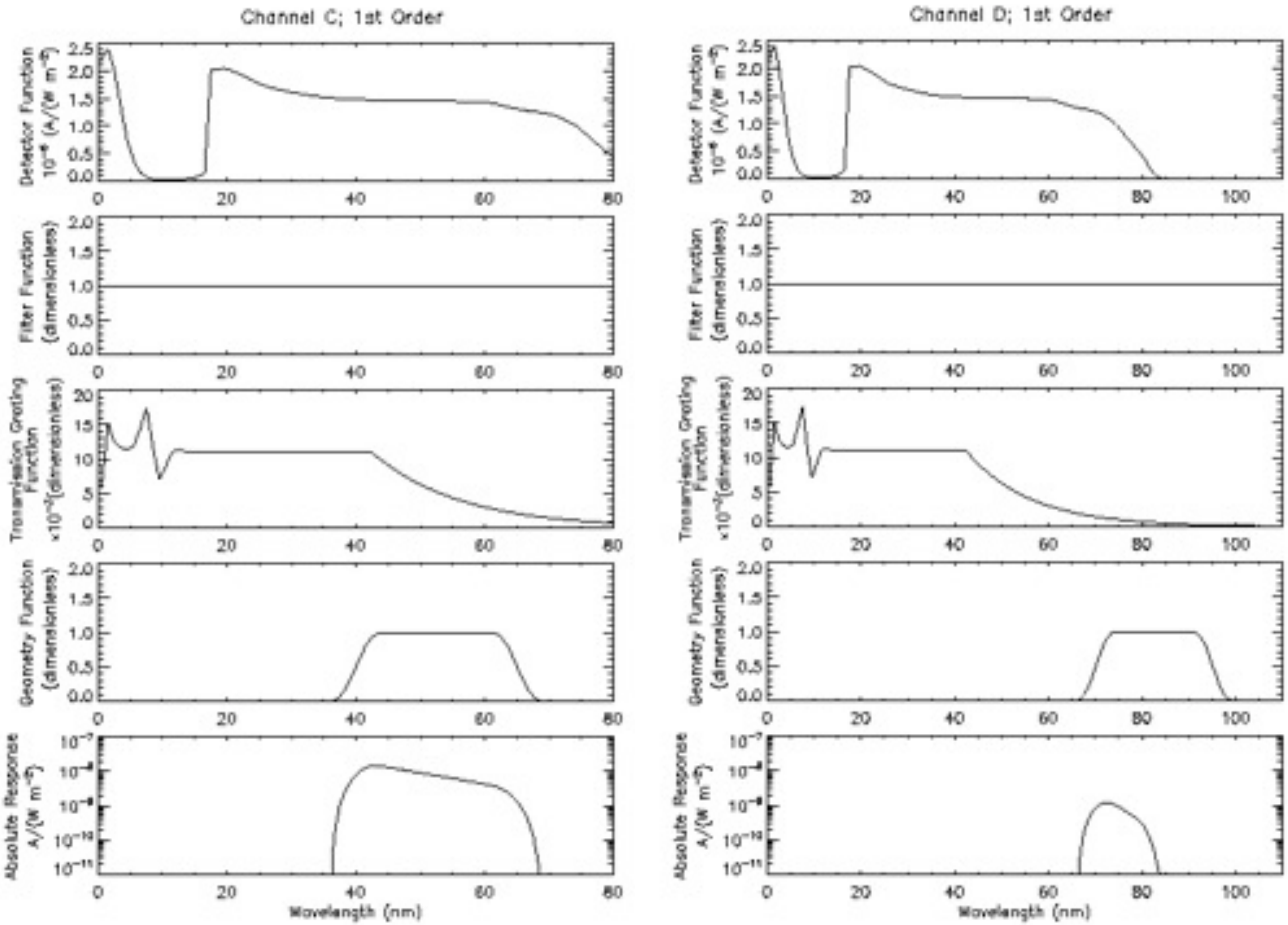
EUV-B calibrated response (20.7-36.5 nm) = 1.264-07 A-m2-nm/W (+/-15.5%)

Backup Slides (McMullin)

1st order absolute response functions for Channels A and B. Offset angle is 0°.

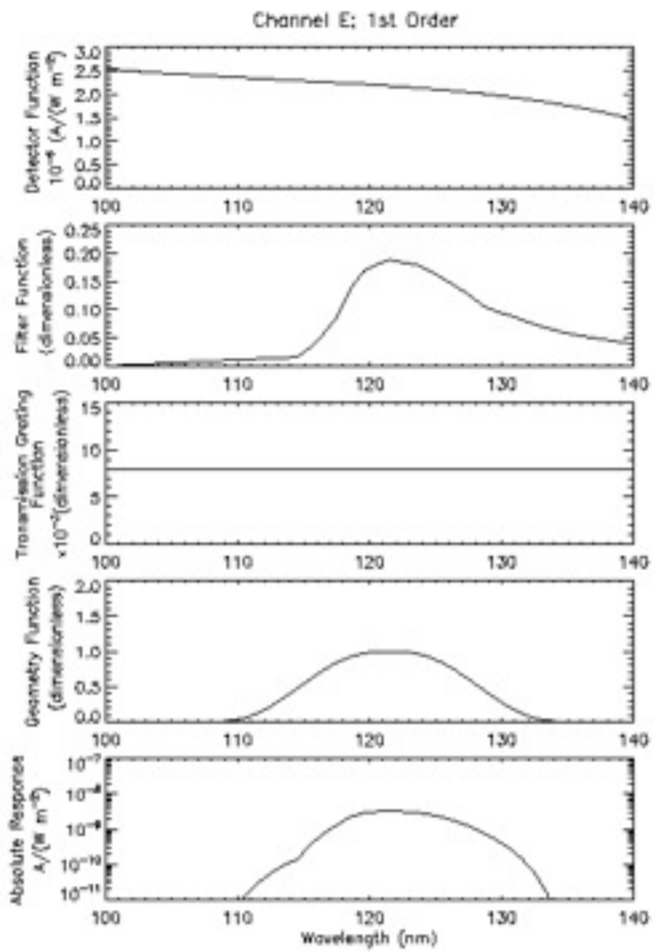


1^{st} order absolute response functions for Channels C and D. Offset angle is 0^o.

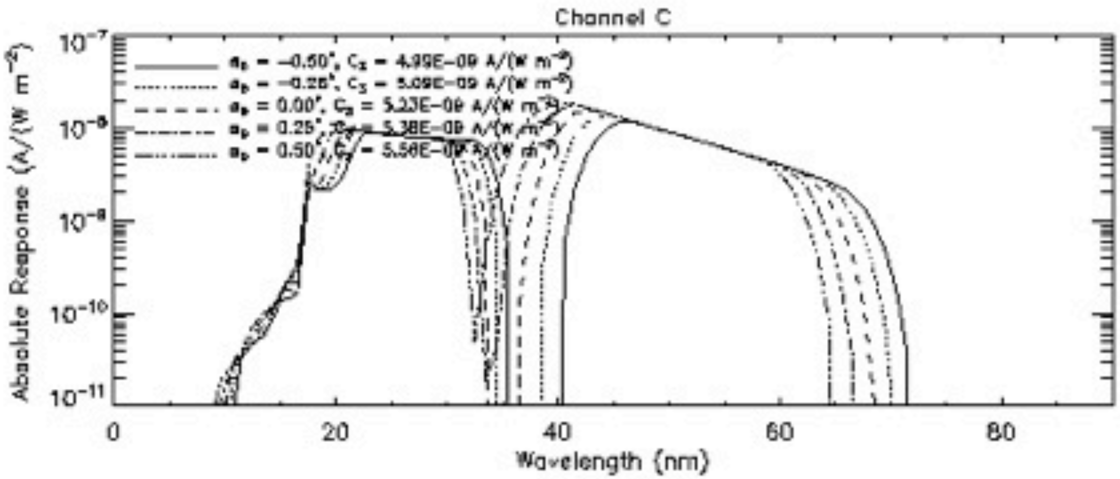


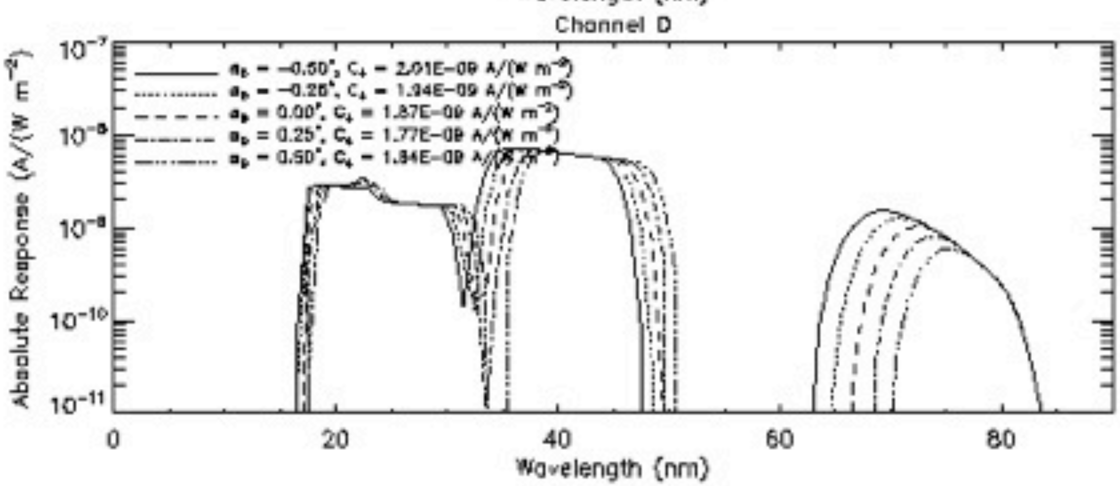
SSRC

1st order absolute response function for Channel E. Offset angle is 0°.

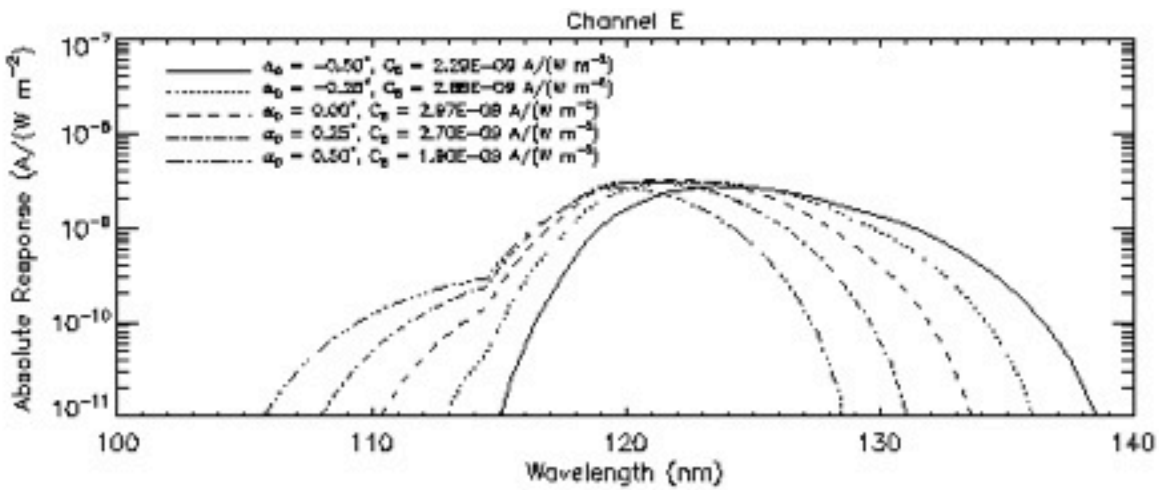


Effect of offsets on absolute response functions for Channels C and D





Effect of offsets on absolute response function for Channel E



Comparing EUVS with SEE and SEM data for Oct and Nov 2006