NICST Internal Memo

Date: June 14, 2010
From: J. McIntire, A. Tolea, and N. Che
To: Bruce Guenther, Jim Butler, and Jack Xiong
Subject: SIS100 Red Leak Investigation for VisNIR Bands

References:

[1] NICST_REPORT_10_008, 'Preliminary Investigation of SIS100 Red Leak,' J. McIntire, A. Tolea, N. Che, April 27, 2010.
[2] 'OOB contribution to SIS100 calibrated radiances,' A. Tolea and J. McIntire, May 18, 2010.
[3] NICST_REPORT_09_002, 'SIS(100) Test Data Analysis for VIIRS FU1,' A. Liu and C. Pan, January 22, 2009.
[4] NICST_MEMO_10_010, 'Summary of F1 Radiometric Calibration Performance for RSB from TV RC-02 Tests,' J. Sun and N. Che, May 3, 2010.
[5] NICST_MEMO_09_012, 'Analysis Results of VIIRS FU1 RC-03 part 2: Detector response as a function of sensor temperature for RSB,' J. Sun and N. Che, October 15, 2009.
[6] VIIRS F1 Spectral Performance ST mtg final, 'VIIRS F1 Spectral Performance,' C. Moeller, J. McIntire, T. Schwarting, and H. Oudrari, January 25, 2010.
[7] 'Performance Specification Sensor Specification,' ps154640-101_c.
[8] W043, 'Request to Modify Dual Gain Transition requirement (SRV0465) in the VIIRS Sensor Specification,' January 15, 2007.
[9] NICST_MEMO_10_012, 'VIIRS F1 RC-01 Part 4 RSB Gain Transition Analysis,' J. McIntire, May 25, 2010.

1. Introduction

The SIS100 is a spherical integrating source with a diameter of 100 cm used as ground support equipment by Raytheon to characterize the VIIRS RSB bands. The SIS100 is known to be "redder" than the solar irradiance profile. As a result, for bluer bands Out Of Band (OOB) filter leaks contribute to the radiance reaching the detector (particularly for M1). In consequence, the gains for these bands are over-reported. Those specifications that rely on the calculated gain to determine compliance or non-compliance must be reevaluated (gain transition, saturation, etc.).

The focus of this memo is to develop a correction factor for the OOB leaks for VIIRS F1 analysis, then apply it to the gain and afore mentioned specifications. Preliminary analysis of the SIS100 red leak was reported in [1,2].

2. SIS100 Red Leak Correction Factor

The SIS100 radiance is tracked in real time by the SIS Radiance Monitor. The data from this monitor is fit to a function described in [3]. For the RC-02 and RC-03 analysis, the resulting SIS100 spectral distribution function was used to determine the SIS100 radiance at the specified center wavelength for each band [4,5]. However, to determine the effect of the OOB filter leaks when using the SIS100, a correction factor must be constructed. The SIS100 radiance weighted by the Relative Spectral Response (RSR) is calculated in relation to the radiance at the specified center wavelength. First, a correction factor is determined using only the In Band (IB) RSR (between the 1% response points), or

$$R_{IB}(B,D,S)=\frac{L_{SIS100}\left(\lambda_{center(B)}\right)\int_{IB} RSR(B,D,S,\lambda)d\lambda}{\int_{IB} RSR(B,D,S,\lambda)L_{SIS100}(\lambda)d\lambda}, \tag{1}$$

where B, D, and S represent band, detector, and subsample, respectively. Next, a correction factor is determined using the full RSR profile (IB + OOB), or

$$R_{IB+OOB}(B,D,S)=\frac{L_{SIS100}\left(\lambda_{center(B)}\right)\int_{IB+OOB} RSR(B,D,S,\lambda)d\lambda}{\int_{IB+OOB} RSR(B,D,S,\lambda)L_{SIS100}(\lambda)d\lambda}. \tag{2}$$

Lastly, to isolate the relative contribution of the OOB RSR (outside the 1% response points), the ratio of the two factors is calculated, or

$$\frac{R_{IB}(B,D,S)}{R_{IB+OOB}(B,D,S)}=\frac{\int_{IB+OOB} RSR(B,D,S,\lambda)L_{SIS100}(\lambda)d\lambda}{\int_{IB} RSR(B,D,S,\lambda)L_{SIS100}(\lambda)d\lambda}\frac{\int_{IB} RSR(B,D,S,\lambda)d\lambda}{\int_{IB+OOB} RSR(B,D,S,\lambda)d\lambda}. \tag{3}$$

Note that NICST version 2 RSRs are used in this work [6]. The detector dependence of the RSR is generally small for the VisNIR; as a result, only the detector averaged correction factors will be provided in this work. For the purposes of this investigation, the SIS100 data from RC-02 Part 1 is used (see Table 1).

3. Effect of Red Leak

Figures 1 – 9 show the SIS100 spectral distribution function (red) versus wavelength for each of the VisNIR bands. In addition, the solar radiance (equal to the solar irradiance divided by π) is shown (black). This is the radiance of the sun reflected off the Earth assuming an Earth albedo of one. The RSR is also plotted, normalized to both the solar and SIS100 profiles (dashed black and red lines, respectively). The SIS100 profile is derived from the lamp level 10-9-18 (note the lamp level refers to the number of 10 W – 45 W – 200 W bulbs). In particular, the OOB region for M1 is more pronounced for the SIS100 relative to the IB peak.

The results for the band averaged correction factors are listed in Table 2 for lamp level 10-9-18 and for each plateau and electronic side. The IB correction factor is roughly 1 – 3% for bands M1 – M4 and I1; the remaining VisNIR bands have a IB correction factor of less than 1%. Note that the IB correction will decrease the radiance for each of these bands. The IB+OOB correction factor for M1 is roughly 40%, the majority of which is due to OOB leaks in the filter. In addition, the IB+OOB correction factor for M3 is 0.4%; in this case the OOB contribution to the radiance nearly cancels out the opposite IB correction of about 2%. For all other bands the IB+OOB correction is nearly equivalent to the IB correction factor. For reference, the ratios of the correction factors for the solar profile are also shown. Again, M1 shows the largest factor, about 2.8%; all other bands are smaller than 1%.

In Table 3, the IB+OOB correction factor is listed for all the lamp levels used in RC-02 limited testing data for Nominal Plateau, electronic side B (lamp levels unique to the comprehensive test are excluded). Note that the factors are generally constant for lamp levels down to 10-2-0. When the radiance of the 10 W lamps become a significant portion of the total radiance, the correction factors change abruptly and then remain constant down to the lowest level 1-0-0. This is also seen in Figure 10. The 200 W and 45 W bulbs have a different color temperature than the 10 W bulbs (roughly 2850 and 2670 K, respectively). The 200 W and 45 W bulbs are crystal while the 10 W bulbs are glass. As a result, the SIS100 profile when the 10 W bulbs dominate is “redder” than when the 45 W or 200 W bulbs dominate. This increases the contribution of the OOB filter leak for M1 in particular, in addition to small effects on the other bands.

The effect on the detector averaged gains for all VisNIR bands are listed in Table 4 for all plateaus and electronics sides. The uncorrected gains were determined from the RC-02 Part 1 data set [4]. Note that the M1 gain is now much lower. This has the effect of increasing the radiance corresponding to saturation and gain transition.

Note that the SIS100 is outside the thermal vacuum chamber, and as such is unaffected by changes in instrument temperature or electronic side. However, these tests were conducted days (sometimes weeks) apart; consequently, comparison of these results indicates stability of the correction over time. Figure 11 compares the correction factor over plateaus and electronic sides for M1 and M3; in general the correction factors are consistent. At low radiance levels (particularly where the 10 W bulbs dominate), there is some variation between the tests.

4. Dual Gain Transition and Saturation

Two specifications in particular are affected by this red leak correction: dual gain transition and saturation. The dynamic range specification SRV0055 states that the sensor shall be calibrated between L_{MIN} and L_{MAX} [7]. For the purposes of this work, the focus will be the upper bound (listed for high gain in Table 5). Compliance with this specification is determined by whether or not the detectors saturate before the required L_{MAX}. Table 5 lists the calculated saturation points (detector averaged) for each VisNIR band at all plateaus and electronics sides. The uncorrected saturation data indicates that M1 and I2 pre-saturate [4]. However, after application of the correction factor, M1 saturates well above L_{MAX} for all plateaus and electronics sides. The compliance of all other bands is unchanged. The correction factor from lamp level 10-9-18 was used.

The dual gain transition for the VisNIR bands is governed by SRV0465, which states that the gain transition shall occur at a scene radiance between L_{MAX} and $1.5L_{MAX}$ for M1 and M2 and between L_{MAX} and $1.2L_{MAX}$ for M3, M4, M5, and M7 [7]. In addition, the wavier W043 has requested that the upper bound in the specification for all dual gain RSB bands be relaxed to $1.5L_{MAX}$ [8]. The gain transition analysis is based on RC-01, which was performed at Cold plateau, electronic side A [9].

Table 6 shows the detector (and HAM side) averaged transition point for both high to low and low to high gain transitions. The transition point determined with the uncorrected gain fails the specification for M1 (about 92% of the specified radiance at transition) [9]. However, the M1 transition calculated using the corrected gains meets the specification (roughly 128% of the specified radiance at transition). All other bands showed minor or negligible changes. Here the correction factor from lamp level 10-9-18 was used.

5. Future Analysis

The analysis of VIIRS F2 and F3 sensors will likely utilize the SIS100 as ground support equipment. If this is the case, the SIS100 radiances must be determined using the full RSR profiles (IB+OOB), or

$$L(B,D,S) = \frac{\int_{IB+OOB} RSR(B,D,S,\lambda) L_{SIS100}(\lambda) d\lambda}{\int_{IB+OOB} RSR(B,D,S,\lambda) d\lambda}. \quad (4)$$

The SIS100 spectral distribution function should be determined as above and described in [3]. Thus, the correction factors described in this memo will be contained in the initial analysis for F2 and F3.

6. Summary

- The evident M1 OOB causes more SIS100 illumination in the red-region to contribute to the detector signal (around 40% more compared to the M1 IB).
- The IB RSR weighted SIS100 radiances for M1 – M4 and I1 are between 1.3% and 3.3% less than the SIS100 radiances at the specified center wavelengths.
- The gain transition for M1 is compliant with the specification for all detectors using the corrected gains (uncorrected gains result in non-compliance).
- The M1 dynamic range requirement is met for all detectors as saturation occurs above L_{MAX} using the corrected gains (uncorrected gains result in non-compliance).
- Future analysis of VIIRS F2 and F3 performance using the SIS100 must take the RSR of the sensor into account.

Acknowledgements

The sensor test data used in this document was provided by the Raytheon El Segundo testing team. Approaches for data acquisition and data reductions, as well as data extraction tools were also provided by the Raytheon El Segundo team. We would like to

thank the Raytheon El Segundo team for their support. The data analysis tools were developed by the NICST team, and we would like to extend our gratitude for their valued assistance.

Table 1: VIIRS F1 RC-02 Part 1 TV data

Test	Part	Plateau	UAIDs	E side
RC-02	1	Cold	U3103366--U3103402	A
RC-02	1	Cold	U3103456--U3103463 U3103465--U3103476 U3103478--U3103493 U3103495	B
RC-02	1	Nominal	U3103779-U3103796 U3103798-U3103816	A
RC-02	1	Nominal	U3103837--U3103857 U3103859--U3103874 U3103876--U3103890 U3103892--U3103902	B
RC-02	1	Hot	U3104426--U3104454 U3104456--U3104463	A
RC-02	1	Hot	U3104332-U3104347 U3104350-U3104352 U3104355-U3104369 U3104371-U3104373	B

Table 2: SIS100 correction factors for VisNIR bands (detector averaged)

		Cold Plateau			Nominal Plateau			Hot Plateau			
Band	E side	R_{IB}	R_{IB+OOB}	R_{IB} / R_{IB+OOB}	R_{IB}	R_{IB+OOB}	R_{IB} / R_{IB+OOB}	R_{IB}	R_{IB+OOB}	R_{IB} / R_{IB+OOB}	Solar R_{IB} / R_{IB+OOB}
M1	A	1.019	0.717	1.422	1.019	0.717	1.421	1.019	0.719	1.418	1.028
M2	A	1.023	1.017	1.006	1.023	1.017	1.006	1.023	1.017	1.006	1.000
M3	A	1.023	0.996	1.027	1.023	0.996	1.027	1.023	0.996	1.027	1.005
M4	A	1.033	1.031	1.001	1.033	1.031	1.001	1.033	1.031	1.001	1.001
M5	A	1.002	1.008	0.994	1.002	1.008	0.994	1.002	1.008	0.994	0.998
M6	A	1.001	1.004	0.997	1.001	1.004	0.997	1.001	1.004	0.997	0.999
M7	A	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
I1	A	1.012	1.013	0.999	1.012	1.013	0.999	1.012	1.013	0.999	0.999
I2	A	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
M1	B	1.019	0.718	1.419	1.019	0.719	1.417	1.019	0.719	1.417	1.028
M2	B	1.023	1.017	1.006	1.023	1.017	1.006	1.023	1.017	1.006	1.000
M3	B	1.023	0.996	1.027	1.023	0.996	1.027	1.023	0.996	1.027	1.005
M4	B	1.033	1.031	1.001	1.033	1.031	1.001	1.033	1.031	1.001	1.001
M5	B	1.002	1.008	0.994	1.002	1.008	0.994	1.002	1.008	0.994	0.998
M6	B	1.001	1.004	0.997	1.001	1.004	0.997	1.001	1.004	0.997	0.999
M7	B	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
I1	B	1.012	1.013	0.999	1.012	1.013	0.999	1.012	1.013	0.999	0.999
I2	B	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 3: SIS100 IB+OOB correction factor versus lamp level (Nominal plateau B side)

SIS100 Level	M1	M2	M3	M4	M5	M6	M7	I1	I2
10--9--18	0.719	1.017	0.996	1.031	1.008	1.004	1.000	1.013	1.000
10--9--17	0.719	1.017	0.996	1.031	1.008	1.004	1.000	1.013	1.000
10--9--16	0.720	1.017	0.996	1.031	1.008	1.004	1.000	1.013	1.000
10--9--15	0.720	1.017	0.996	1.031	1.008	1.004	1.000	1.013	1.000
10--9--14	0.720	1.017	0.996	1.031	1.008	1.004	1.000	1.013	1.000
10--9--13	0.721	1.017	0.996	1.031	1.008	1.004	1.000	1.013	1.000
10--9--12	0.721	1.017	0.996	1.031	1.008	1.004	1.000	1.013	1.000
10--9--11	0.722	1.017	0.996	1.031	1.008	1.004	1.000	1.013	1.000
10--9--10	0.722	1.017	0.996	1.031	1.008	1.004	1.000	1.013	1.000
10--9--9	0.722	1.017	0.996	1.031	1.008	1.004	1.000	1.013	1.000
10--9--8	0.721	1.017	0.996	1.031	1.008	1.004	1.000	1.013	1.000
10--9--7	0.721	1.017	0.996	1.031	1.008	1.004	1.000	1.013	1.000
10--9--6	0.722	1.017	0.996	1.031	1.008	1.004	1.000	1.013	1.000
10--9--5	0.720	1.017	0.996	1.031	1.008	1.004	1.000	1.013	1.000
10--9--4	0.721	1.017	0.996	1.031	1.008	1.004	1.000	1.013	1.000
10--9--3	0.721	1.017	0.996	1.031	1.008	1.004	1.000	1.013	1.000
10--9--2	0.722	1.017	0.996	1.031	1.008	1.004	1.000	1.013	1.000
10--9--1	0.726	1.017	0.996	1.031	1.008	1.004	1.000	1.013	1.000
10--9--0	0.726	1.017	0.996	1.031	1.008	1.004	1.000	1.013	1.000
10--8--0	0.725	1.017	0.996	1.031	1.008	1.004	1.001	1.013	1.000
10--7--0	0.725	1.017	0.996	1.031	1.008	1.004	1.001	1.013	1.001
10--6--0	0.720	1.017	0.996	1.031	1.008	1.004	1.001	1.013	1.001
10--5--0	0.721	1.017	0.996	1.031	1.008	1.004	1.001	1.013	1.001
10--4--0	0.715	1.017	0.995	1.031	1.008	1.004	1.001	1.013	1.001
10--3--0	0.710	1.017	0.995	1.031	1.008	1.004	1.001	1.013	1.001
10--2--0	0.700	1.017	0.994	1.031	1.008	1.004	1.001	1.013	1.001
10--1--0	0.676	1.016	0.992	1.031	1.008	1.004	1.001	1.013	1.001
10--0--0	0.592	1.016	0.984	1.032	1.008	1.005	1.002	1.013	1.002
9--0--0	0.590	1.015	0.984	1.032	1.008	1.005	1.002	1.013	1.002
8--0--0	0.590	1.015	0.984	1.032	1.008	1.005	1.002	1.013	1.002
7--0--0	0.587	1.015	0.983	1.032	1.008	1.005	1.002	1.013	1.002
6--0--0	0.587	1.015	0.983	1.032	1.008	1.005	1.002	1.013	1.002
5--0--0	0.590	1.016	0.984	1.032	1.008	1.005	1.002	1.013	1.002
4--0--0	0.588	1.016	0.984	1.032	1.008	1.005	1.002	1.013	1.002
3--0--0	0.584	1.016	0.983	1.032	1.008	1.005	1.002	1.013	1.002
2--0--0	0.589	1.015	0.984	1.032	1.008	1.005	1.002	1.013	1.002
1--0--0	0.586	1.015	0.983	1.032	1.008	1.005	1.002	1.013	1.003

Table 4: VisNIR detector averaged gains

		Cold Plateau		Nominal Plateau		Hot Plateau	
Band	E side	gain	gain (corrected)	gain	gain (corrected)	gain	gain (corrected)
M1	A	27.28	19.55	27.26	19.55	27.07	19.46
M2	A	23.78	24.18	23.84	24.24	23.80	24.20
M3	A	27.34	27.24	27.35	27.25	27.37	27.27
M4	A	37.45	38.62	37.13	38.28	36.93	38.07
M5	A	51.02	51.42	50.97	51.38	50.93	51.33
M6	A	84.44	84.77	84.19	84.52	83.90	84.23
M7	A	109.90	109.94	109.37	109.41	108.64	108.67
I1	A	4.65	4.71	4.67	4.73	4.68	4.74
I2	A	10.06	10.06	10.09	10.09	10.07	10.07
M1	B	27.28	19.59	27.25	19.60	27.17	19.55
M2	B	23.82	24.23	23.86	24.26	23.86	24.26
M3	B	27.43	27.33	27.46	27.36	27.42	27.32
M4	B	37.53	38.69	37.26	38.41	36.97	38.12
M5	B	51.12	51.52	51.08	51.48	50.95	51.35
M6	B	84.28	84.61	84.00	84.33	83.67	84.00
M7	B	109.89	109.93	109.30	109.34	108.75	108.78
I1	B	4.65	4.72	4.68	4.75	4.68	4.74
I2	B	10.06	10.06	10.11	10.11	10.05	10.05

Table 5: Detector averaged saturation radiance

			Cold Plateau		Nominal Plateau		Hot Plateau	
Band	E side	L_{MAX}	Uncorrected (L_{SAT}/L_{MAX})	Corrected (L_{SAT}/L_{MAX})	Uncorrected (L_{SAT}/L_{MAX})	Corrected (L_{SAT}/L_{MAX})	Uncorrected (L_{SAT}/L_{MAX})	Corrected (L_{SAT}/L_{MAX})
M1	A	135	0.963	1.344	0.961	1.340	0.970	1.348
M2	A	127	1.193	1.173	1.194	1.174	1.189	1.169
M3	A	107	1.255	1.260	1.248	1.253	1.249	1.254
M4	A	78	1.263	1.224	1.268	1.229	1.282	1.243
M5	A	59	1.215	1.206	1.217	1.207	1.218	1.209
M6	A	41	1.115	1.111	1.119	1.115	1.118	1.114
M7	A	29	1.149	1.149	1.156	1.156	1.164	1.163
I1	A	718	1.026	1.012	1.027	1.014	1.025	1.012
I2	A	349	0.978	0.977	0.979	0.978	0.982	0.982
M1	B	135	0.968	1.344	0.968	1.340	0.966	1.348
M2	B	127	1.194	1.173	1.196	1.174	1.196	1.169
M3	B	107	1.251	1.260	1.268	1.253	1.256	1.254
M4	B	78	1.259	1.224	1.264	1.229	1.285	1.243
M5	B	59	1.219	1.206	1.219	1.207	1.223	1.209
M6	B	41	1.121	1.111	1.122	1.115	1.120	1.114
M7	B	29	1.155	1.149	1.163	1.156	1.169	1.163
I1	B	718	1.026	1.012	1.027	1.014	1.030	1.012
I2	B	349	0.978	0.977	0.980	0.978	0.988	0.982

Table 6: Detector averaged gain transition

Band	Uncorrected (L_{TRANS}/L_{MAX})		Corrected (L_{TRANS}/L_{MAX})	
	H to L	L to H	H to L	L to H
M1	0.919	0.919	1.282	1.281
M2	1.120	1.119	1.102	1.100
M3	1.172	1.171	1.177	1.176
M4	1.167	1.166	1.132	1.131
M5	1.129	1.128	1.120	1.119
M7	1.075	1.073	1.075	1.073

Figure 1: SIS100 radiance and M1 RSR

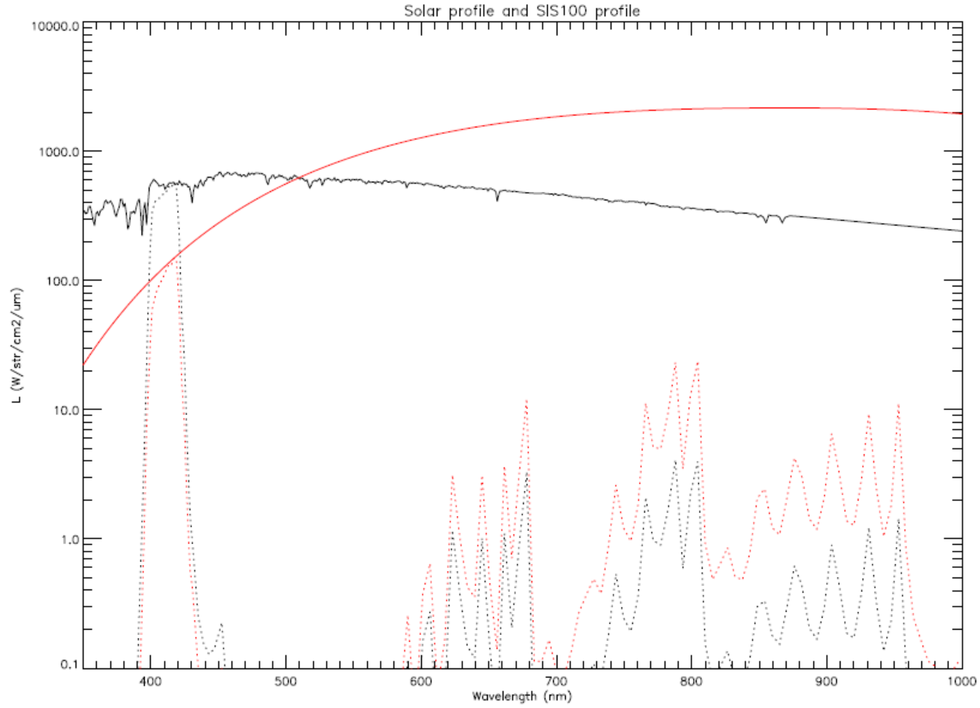

Figure 2: SIS100 radiance and M2 RSR

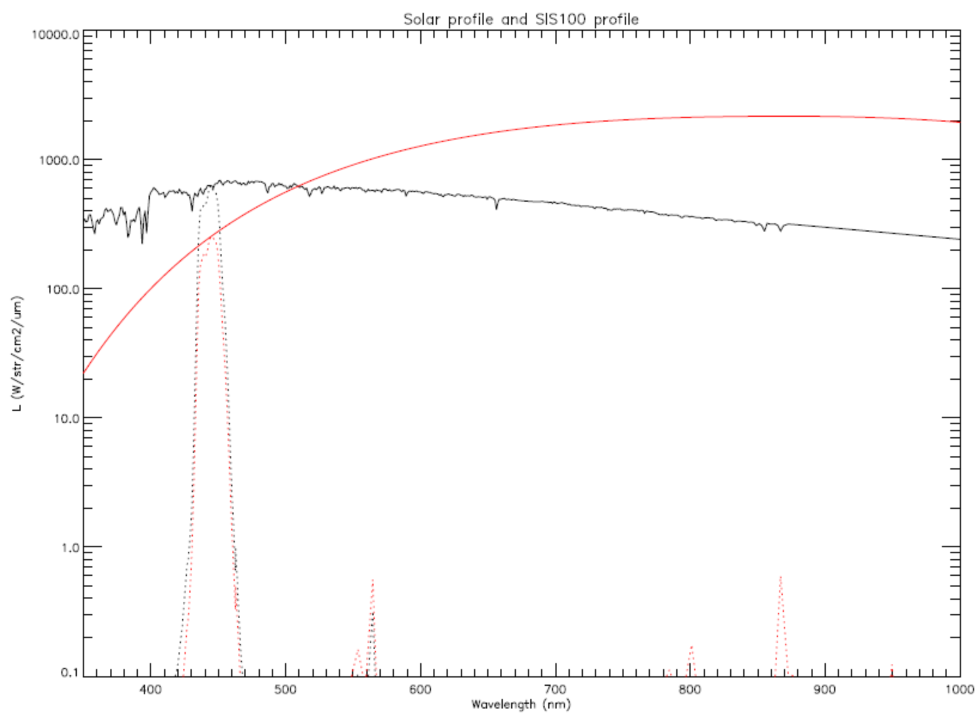

Figure 3: SIS100 radiance and M3 RSR

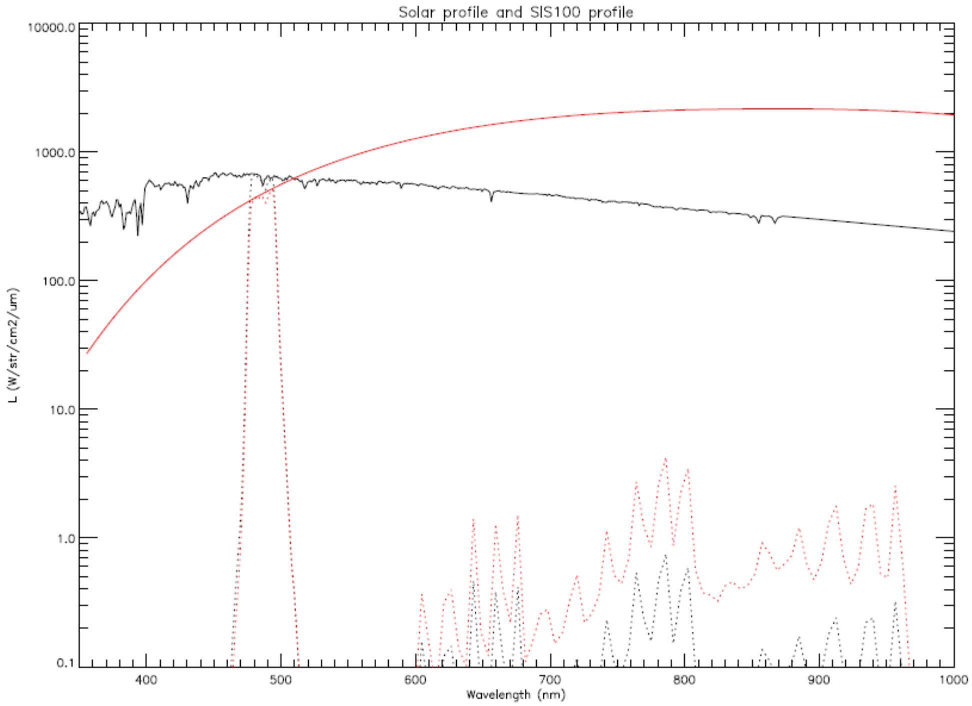

Figure 4: SIS100 radiance and M4 RSR

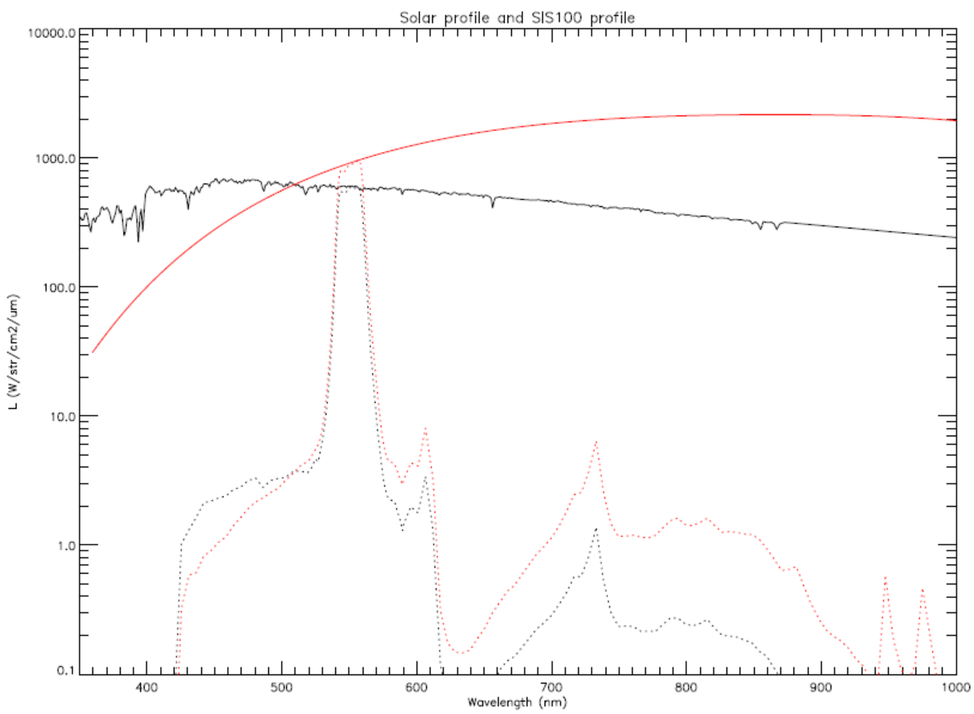

Figure 5: SIS100 radiance and M5 RSR

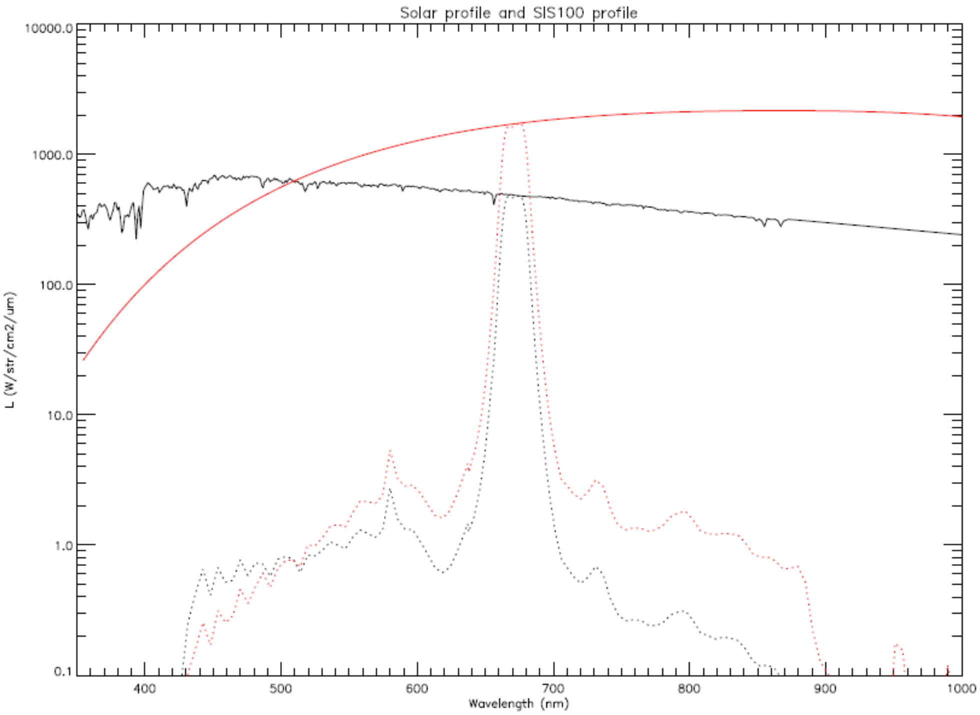

Figure 6: SIS100 radiance and M6 RSR

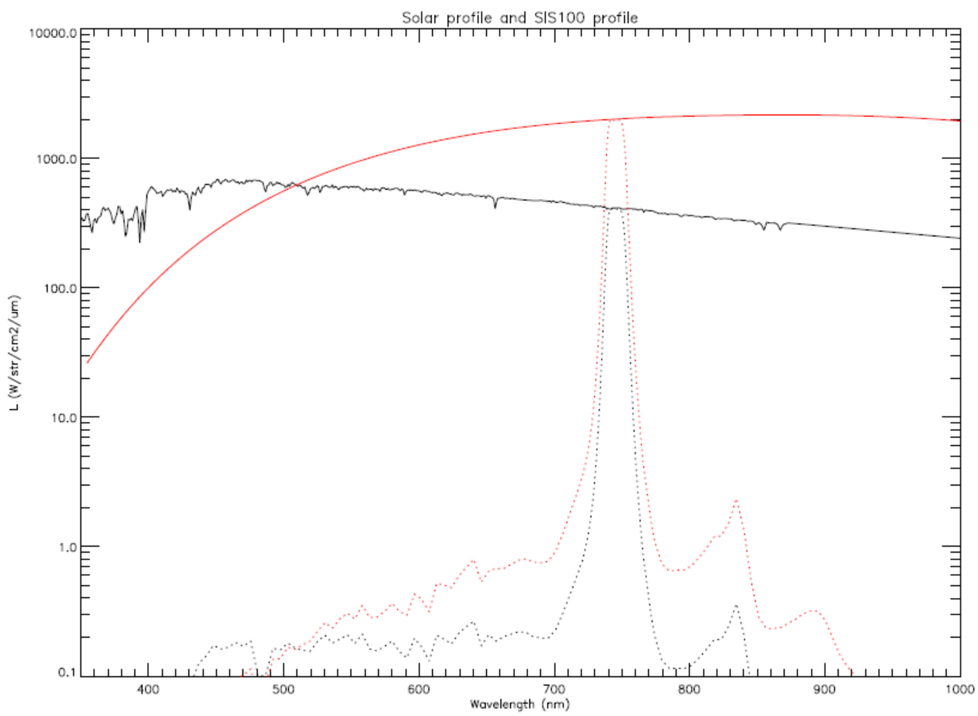

Figure 7: SIS100 radiance and M7 RSR

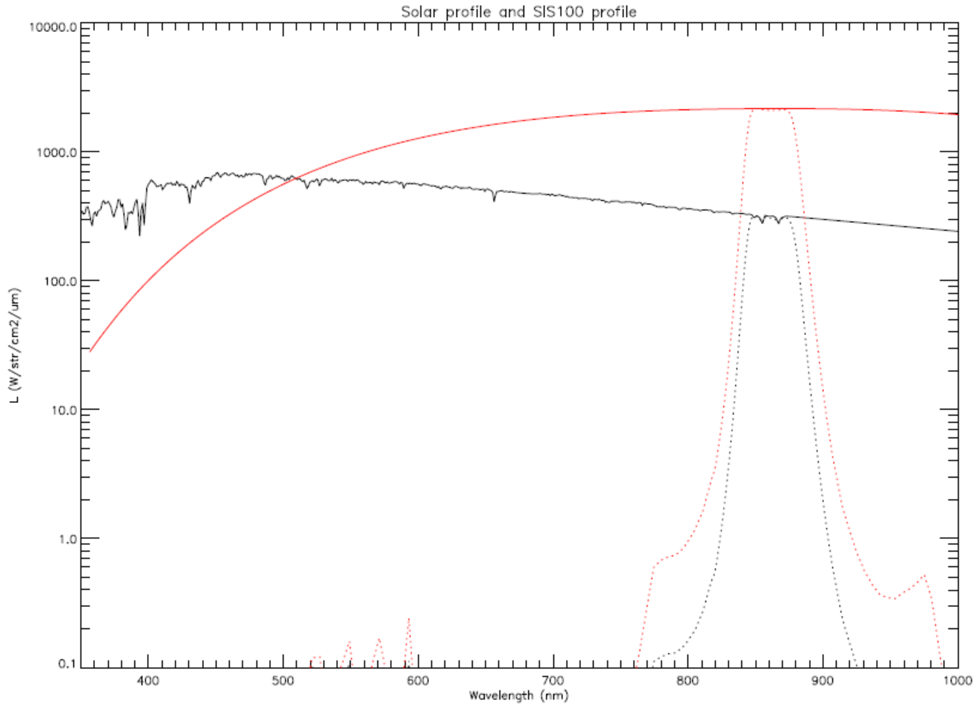

Figure 8: SIS100 radiance and I1 RSR

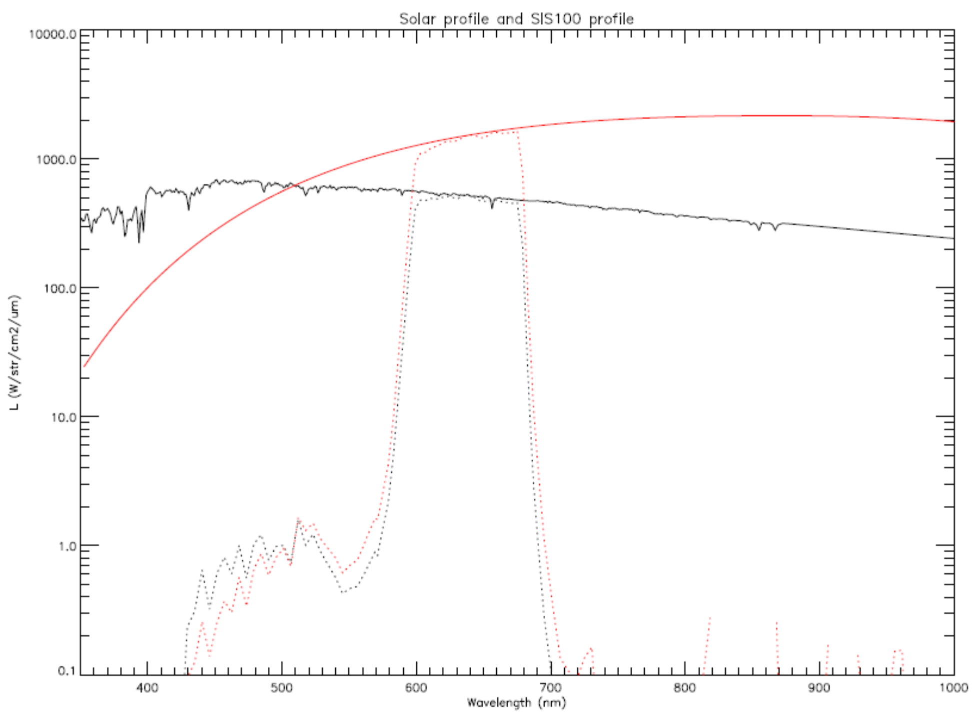

Figure 9: SIS100 radiance and I2 RSR

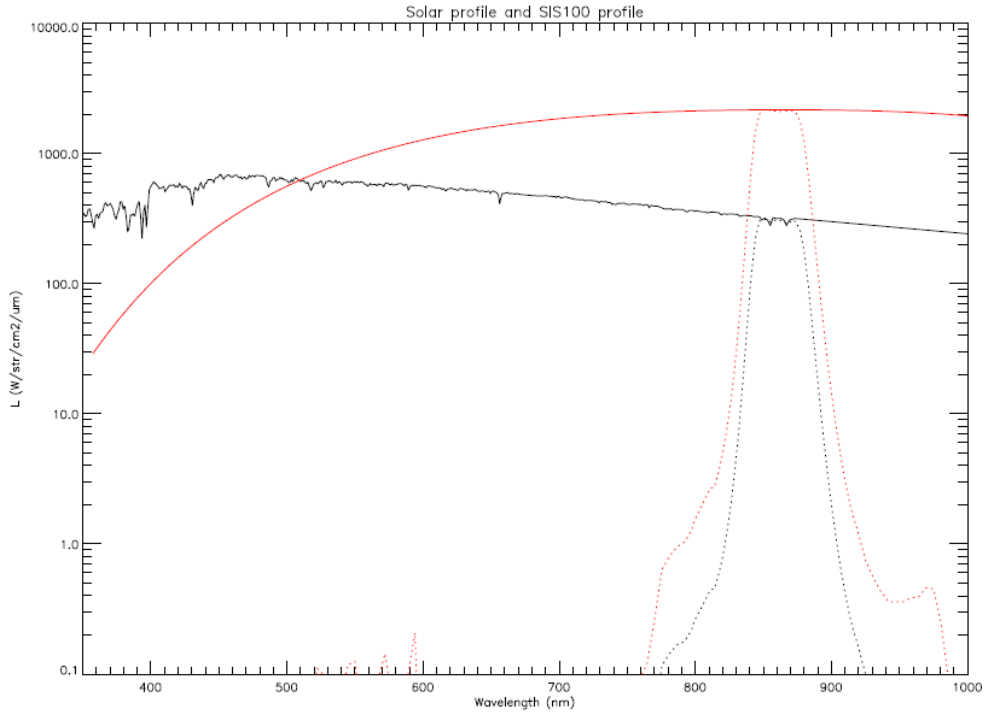

Figure 10: SIS100 correction factor versus lamp level (Nominal plateau B side)

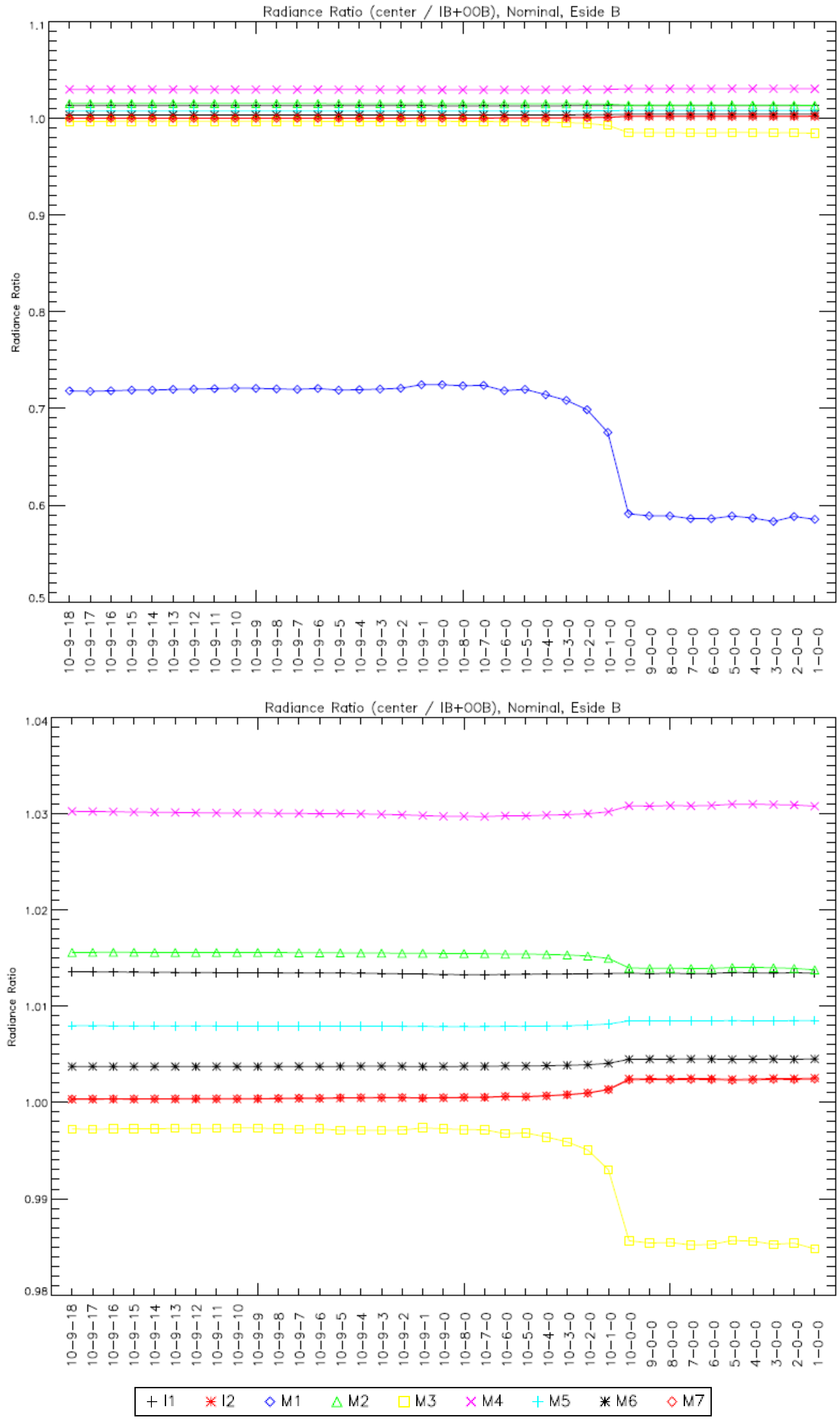

Figure 11: Comparison of SIS100 correction factor over plateau and electronic side