SUSIM UARS Calibration and Measurements of Solar UV Spectral Irradiance Variation (2003-2005)

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Presentation Focus

Properties and behavior of responsivity degradation in SUSIM

Theory and methods used for SUSIM responsivity calibration

SUSIM measurements 2003-2005 during SORCE overlap

SUSIM UARS Overview

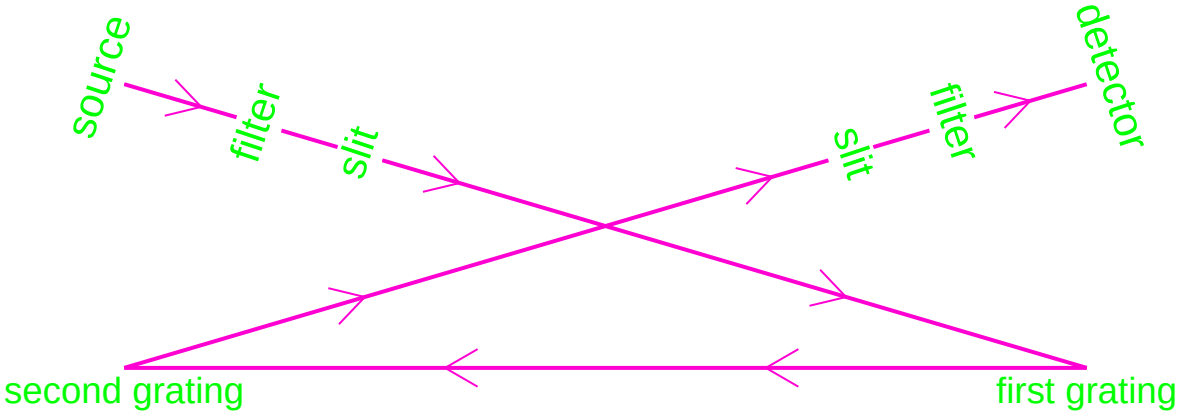
Solar Ultraviolet Spectral Irradiance Monitor (SUSIM):

- Aboard Upper Atmosphere Research Satellite (UARS)
- "Daily" measurements from October 11, 1991 to August 1, 2005 ($\sim$88% of all days)
- Two dual dispersion grating spectrometers
- Four stable Deuterium calibration lamps
- Three resolutions (0.15 nm, 1.1 nm, and 5 nm)
- Multiple optical paths promote redundant measurements
- Flexible optical paths permit instrument diagnosis

SUSIM UARS Instrument

conceptual diagram

SUSIM UARS OPTICAL ELEMENT DIAGRAM



source	entrance filter	entrance slit	first grating	second grating	exit slit	exit filter	detector
D_2 lamp 1	quartz	narrow (.15 nm)	UG1	UG	narrow (.15 nm)	MgF_2	PLE
D_2 lamp 2	MgF_2	mid (1.1 nm)	UG2		mid (1.1 nm)	ND 7%	PSE
D_2 lamp 3	MgF_2	wide (5 nm)	UG3		wide (5 nm)	ND 15%	PCS
D_2 lamp 4	quartz	wide (5 nm)	UG4		wide (5 nm)	glass	SLE
sun	MgF_2		LG1	LG		ND 7%	SSE
	MgF_2		LG2			ND 15%	SRE
	none		LG3			glass	PCL
			LG4			none	

Elements used to obtain SUSIM daily 1.1 nm spectral irradiance.

Previously used elements.

Optical Responsivity Degradation

SUSIM UARS design approach

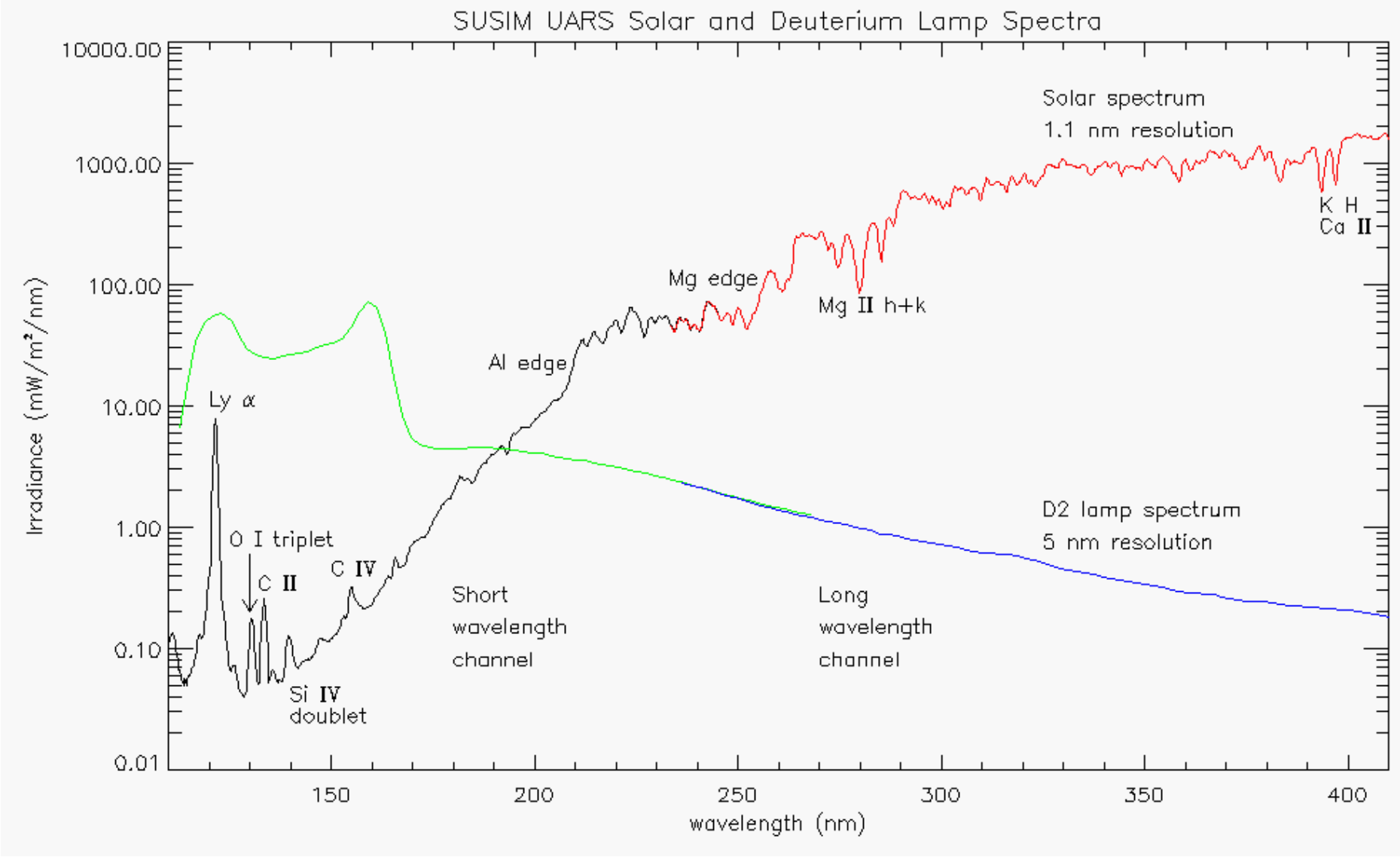
SUSIM was designed specifically to address this difficult problem

Mechanism is understood to be UV induced polymerization of stray hydrocarbon contaminants on optical surfaces.

SUSIM was intended to address this problem through:

- redundant solar measurements by several optical channels having differing exposure rates.
- measurements of the deuterium lamps

SUSIM Solar and Lamp Measurements



SUSIM Calibration Method

a brief summary

The deuterium lamps are stable, but their exit windows degrade.

Transmission (responsivity) of each lamp window is calibrated via simultaneous measurements of different lamps having different exposure rates
One lamp was lighted at each of monthly, quarterly, semi-annual, and annual cadences.

Measurements of the lamps calibrate the infrequently exposed reference channels.

Reference channels calibrate the working channel on days that reference channels measured the sun.

Responsivity on each day is interpolated between calibration days using an empirically determined function.

SUSIM Experience with Responsivity Degradation

empirical findings

Degradation "progresses" as function of UV exposure and not time.

Degradation rate is stronger during earlier exposures becoming weaker for later exposures.

Degradation of filters (pass-through elements) has same general dependence regardless of material (MgF2 or quartz) indicating surface and not a bulk material phenomenon.

Degradation in reflective elements (e.g. gratings) can be negative (!) indicating:

- an underlying interference process
- buildup of a conducting layer
- a surface-based phenomenon

SUSIM Data Reduction Processing

signal measurement effects accounted for

1. dark signal
2. nonlinearity
3. detector gain
4. temperature
5. pointing (FOV)
6. wavelength
7. stray and scattered light
8. optical responsivity

Deuterium Lamp Output Calibration

overview of technical approach

The lamps themselves were stable, but their MgF_2 windows degraded not unlike the spectrometer's filters.

Lamps operated on 4 different schedules, but were measured simultaneously by the same channels.

Consider measurements of just two lamps on two different days by an instrument channel having responsivity, R_c. The measurement equation is (approximately):

$$S_i(d) = L_i(x_i(d)) \times R_c(d)$$

where S_i is the measured signal of lamp i
L_i is the output intensity of lamp i
x_i is the cumulative UV exposure of lamp i
d is the day (time) of the simultaneous measurement

Deuterium Lamp Output Calibration

overview of technical approach (continued)

Consider lamps 2 and 4 are each measured by the same instrument channel on several different days. Taking the ratio of the two equations applied from the above, the ratio of the two lamp outputs is equal to the ratio of the two signals for either one of the days:

$$L_2(x_2(d_n))/L_4(x_4(d_n)) = S_2(d_n)/S_4(d_n)$$

where n can indicate any number of different days. Note that responsivity term has cancelled out.

These equations provide measurements for determining parameter values in a parameterized model for degradation in the lamp window.

In practice, SUSIM's annual and semi-annual lamps were used to determine their degradation and that result was imposed on the other two lamps through coincident intercomparisons with them.

SUSIM Reference Channels

usage and calibration

At the start of the SUSIM experiment, only one Reference Channel was operating on a half yearly cadence

Degradation was quite strong in the working channel (at one point responsivity was down by a factor of 20) demonstrating the need for reference channels

More Reference Channels were added as the experiment progressed.

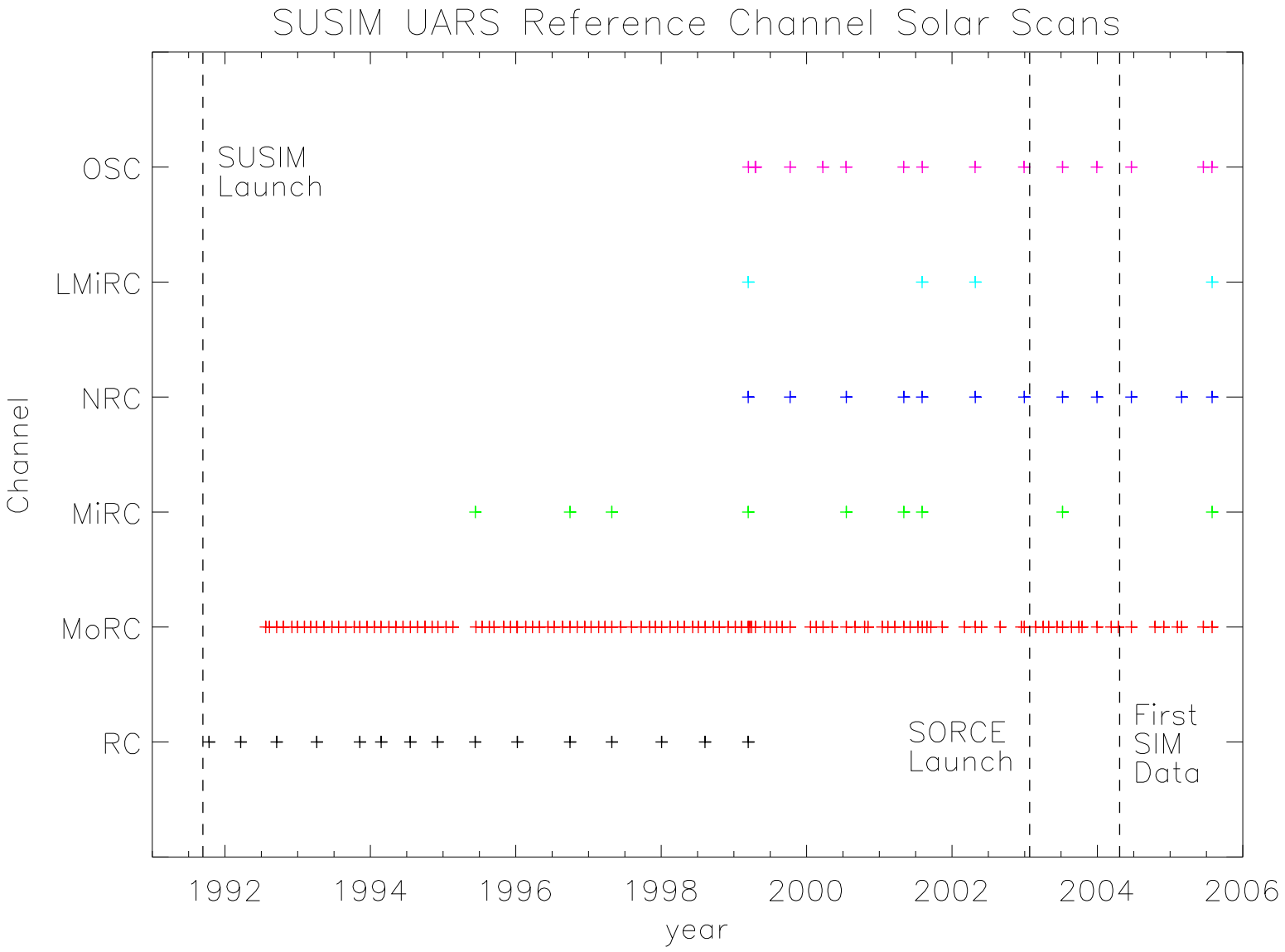
By the final stages of the experiment (2003-2005) the responsivity calibration was probably better than at any other time, in a relative sense.

SUSIM Reference Channel Solar Scans

Scan Name	Optical Path Ent	Xit	Res	Gra	Det	cadence	Wave-lengths
RC	M4	–	WW	UG1	SSE	2/year	110–265
RC	Q2	–	WW	UG1	SLE	2/year	235–410
nRC	M4	–	WW	LG2	SSE	2/year	110–265
nRC	Q2	–	WW	LG2	SLE	2/year	235–410
MoRC	–	–	WW	UG2	PLE	11/year	410–235
MoRC	–	–	WW	UG2	PSE	11/year	265–110
MiRC	–	–	WW	UG3	PLE	∼1/year	410–235
MiRC	–	–	WW	UG3	PSE	∼1/year	265–110
LMiRC	–	–	WW	LG3	PLE	0.7/year	410–235
LMiRC	–	–	WW	LG3	PSE	0.7/year	265–110
oSC	Q1	–	MM	UG4	PLE	2/year	412–233
oSC	M1	–	MM	UG4	PSE	2/year	264–110

SUSIM Reference Channel Solar Scans

channels and dates



SUSIM Reference Channels

usage and calibration, continued

Measurements of the calibrated lamps by the Reference Channels provide the responsivity calibration when viewing the lamps.

Intercomparisons among reference channels with different exposures were used to estimate lamp and sun responsivity differences.

No degradation in the secondary gratings (which define each spectrometer) nor in any of the detectors was observed.

SUSIM Working Channel Responsivity Calibration

transfer from reference channels and interpolation to every day

On days when reference channels measured the sun, the calibration was transferred to the working channel.

For intervening days, the working channel responsivity was interpolated.

The signals corrected for everything except responsivity changes were found to fit the following function extremely well (Floyd, 1999).

$$S(x) = (1 + a_3 M) \times (a_0 + a_1 \log(1 + x/a_2))$$

where S is the wavelength-dependent signal
x is the UV exposure of the channel in time units
M is the MgII index, a solar activity proxy
a_n are fitted parameters for each wavelength range

Note that this equation is merely a parameterized version of the measurement equation in which the measured signal is the product of the irradiance and responsivity.

Working Channel Responsivity Interpolation Function

$S(x) = (1 + a_3 M) \times (a_0 + a_1 \log(1 + x/a_2))$

The factor on the left represents the solar irradiance component.

The factor on the right represents the change in instrument responsivity.

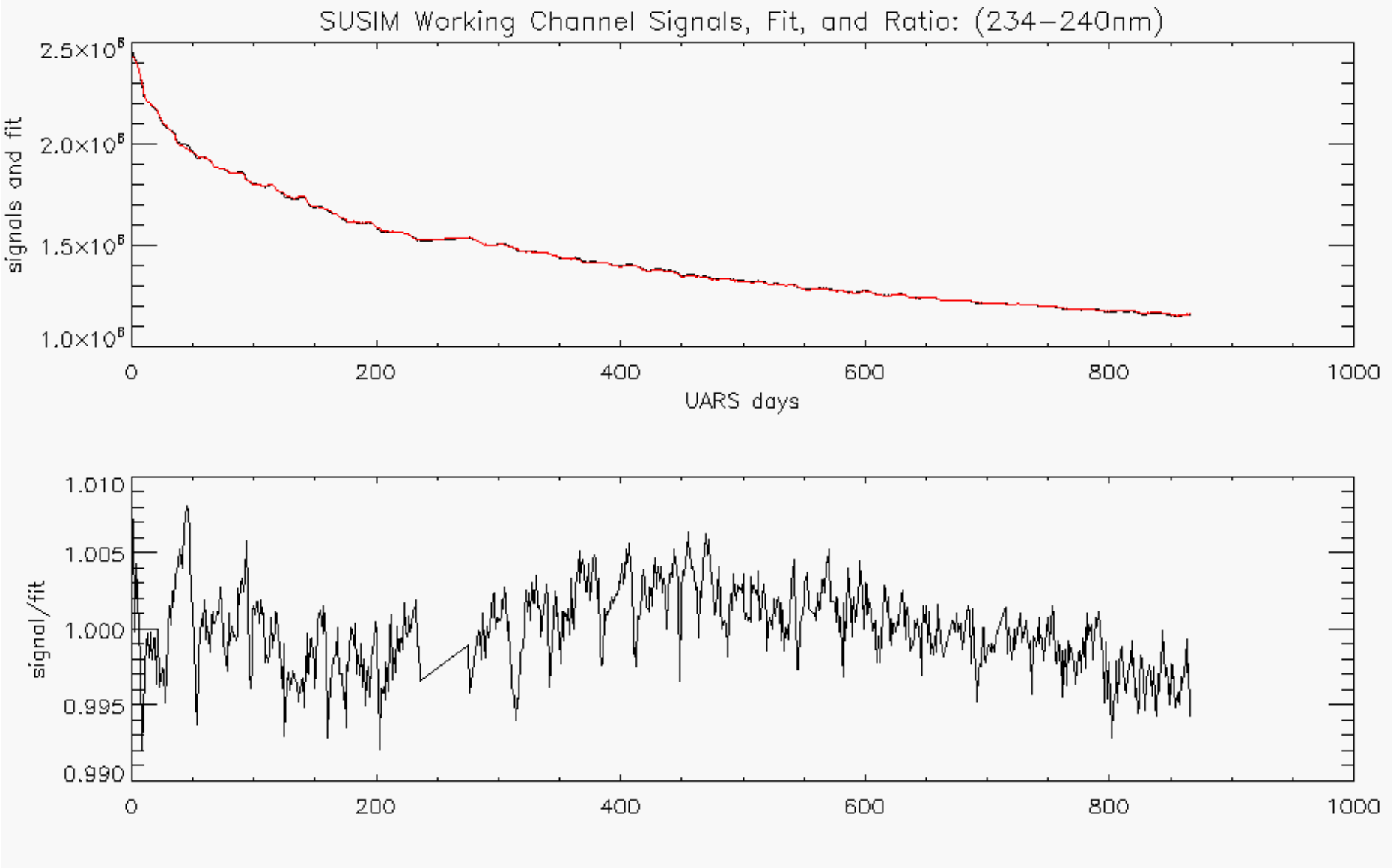
The value of a_2 represents the "curvature" of the function.

To obtain the responsivity between calibration days, the a_2 value of the fit was retained and the values of a_0 and a_1 were adjusted to match the responsivity on bracketing calibration days.

The MgII index was used to make the irradiances, but (as one can now see) it plays an extremely minor role in the interpolation of responsivity between calibrations.

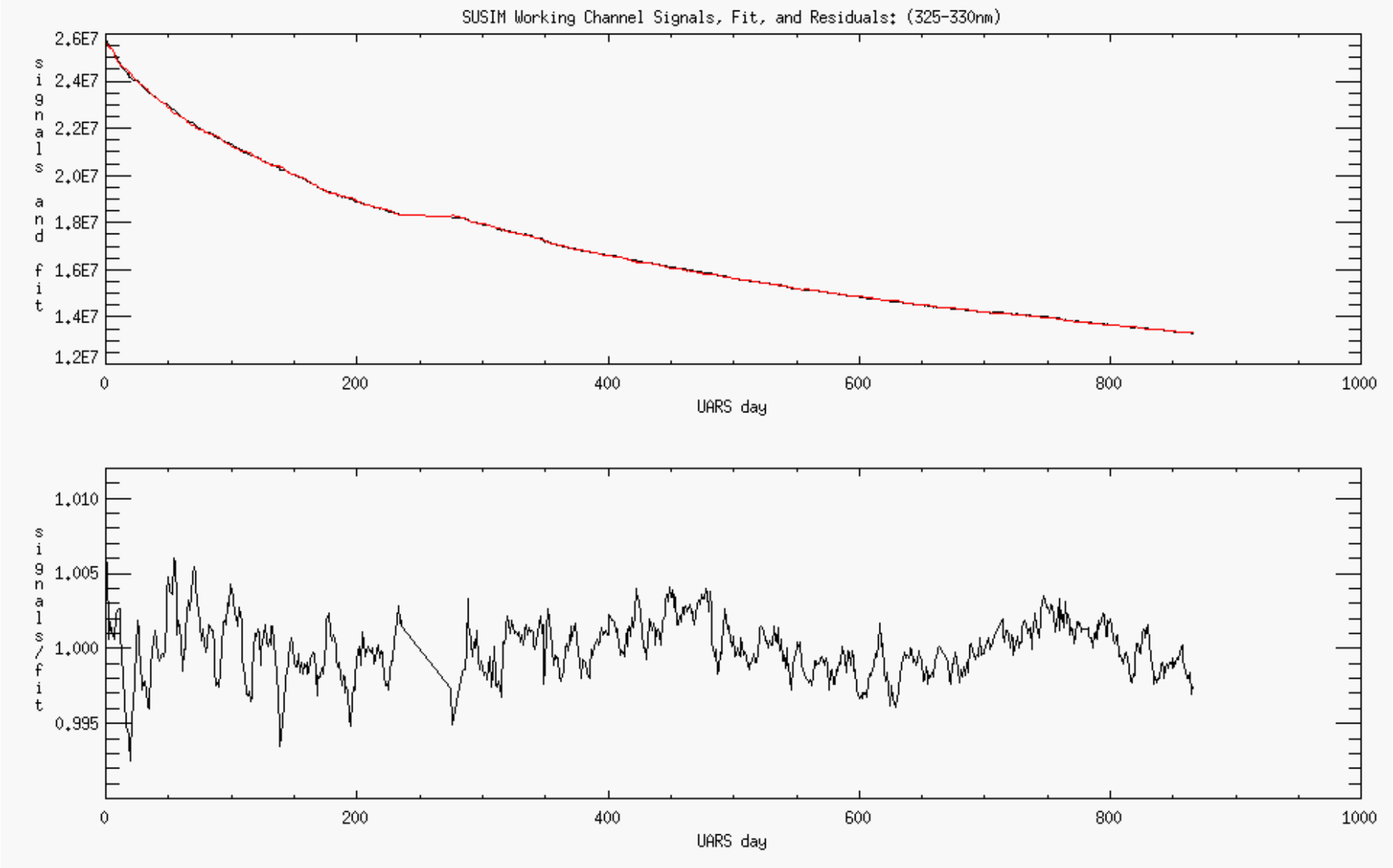
Fits of SUSIM Working Channel Adjusted Signals

short wavelength channel: 234–240 nm



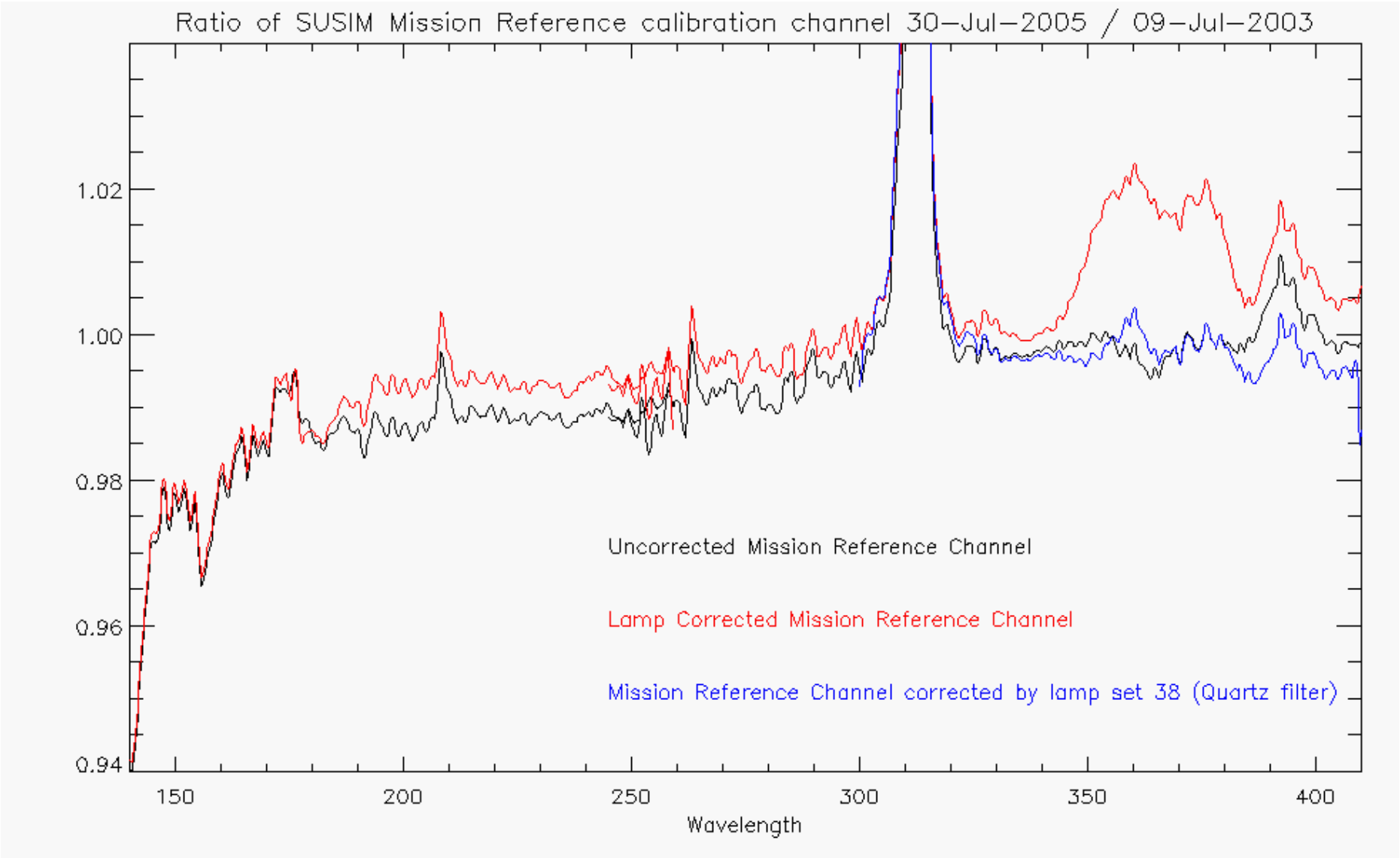
Fits of SUSIM Working Channel Adjusted Signals

long wavelength channel: 325–330 nm



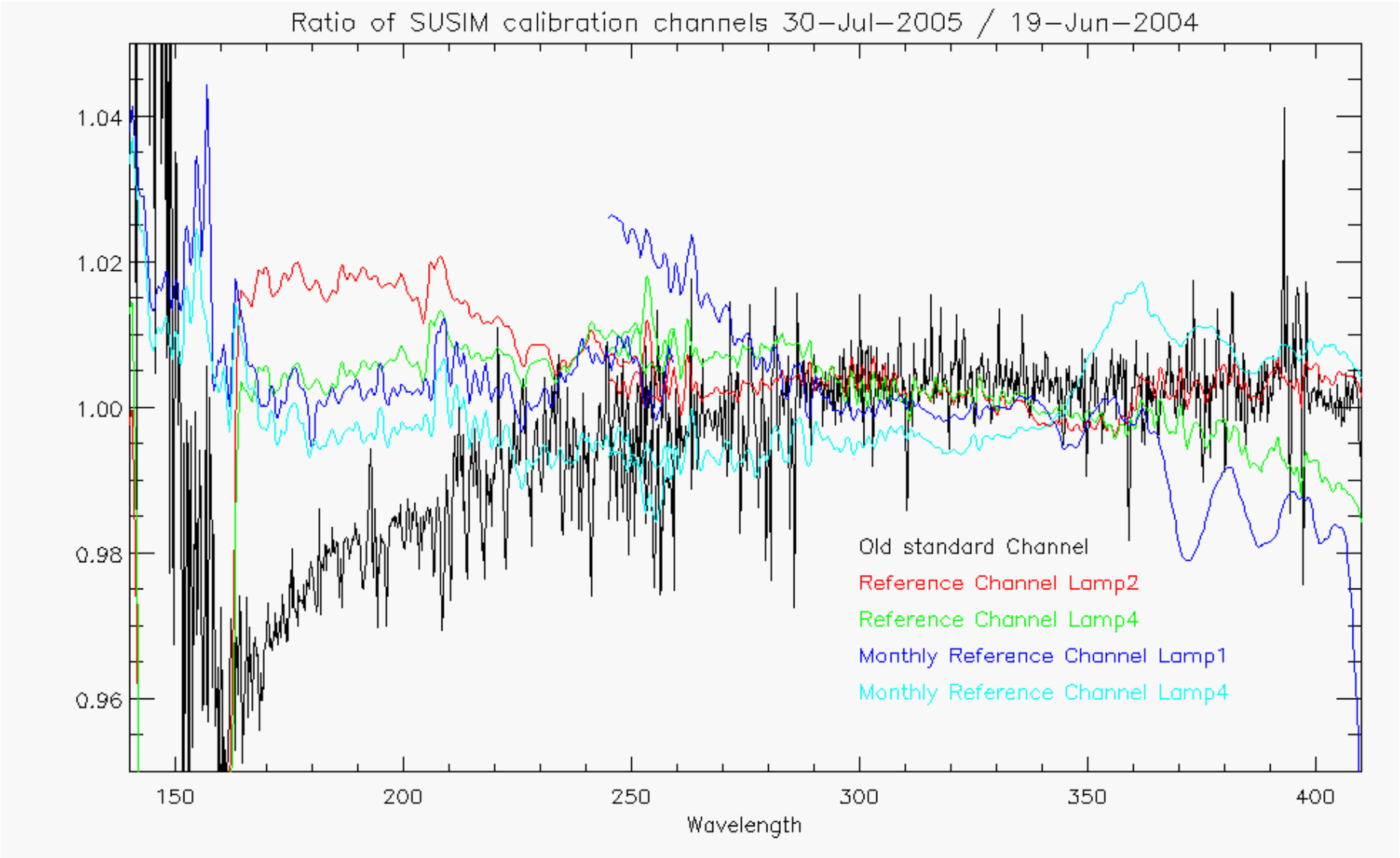
SUSIM Solar Irradiance Ratios

Mission Reference Channel: July 30, 2005 to July 9, 2003



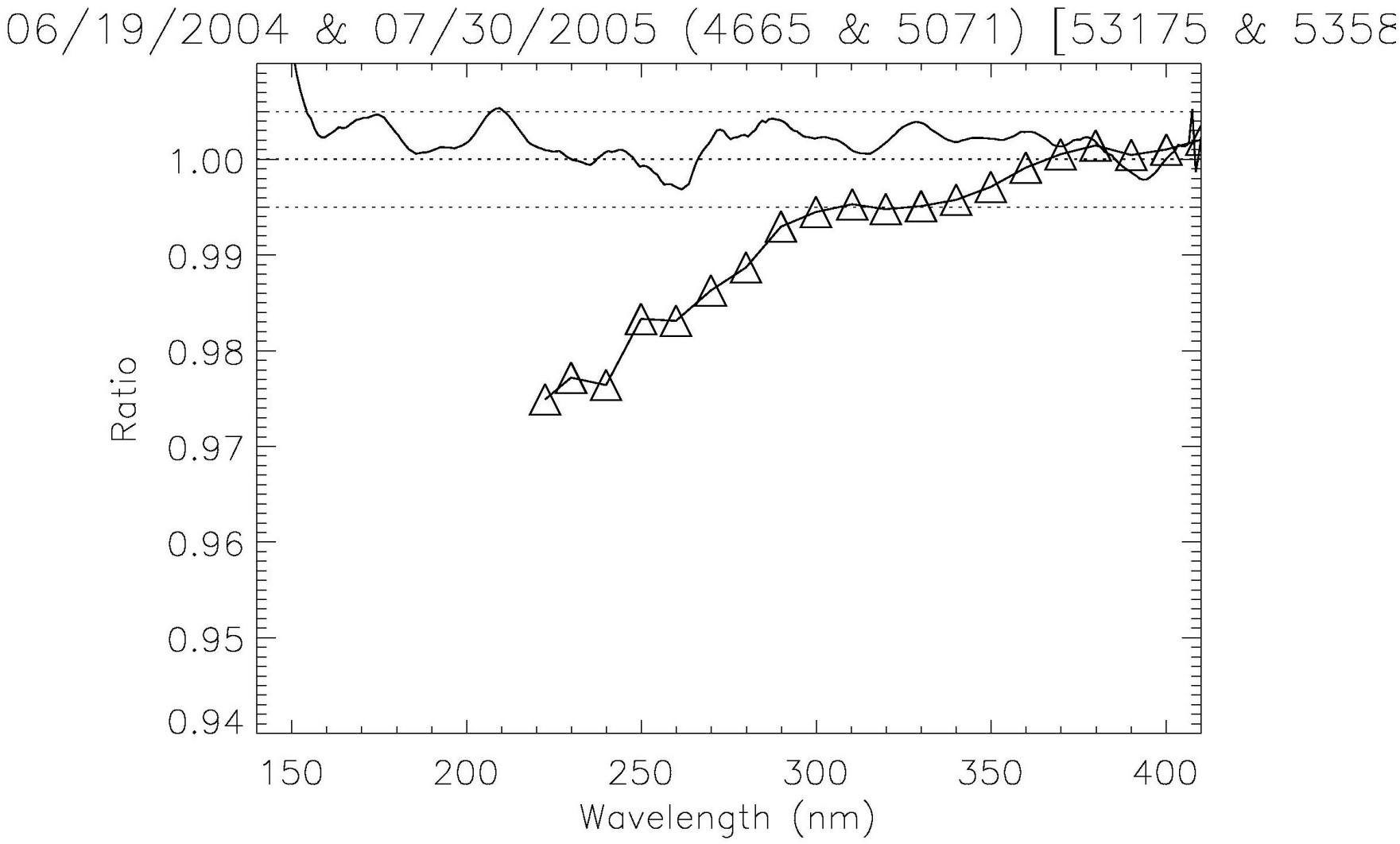
SUSIM Solar Irradiance Ratios

Available Reference Channels: July 30, 2005 versus June 19, 2004



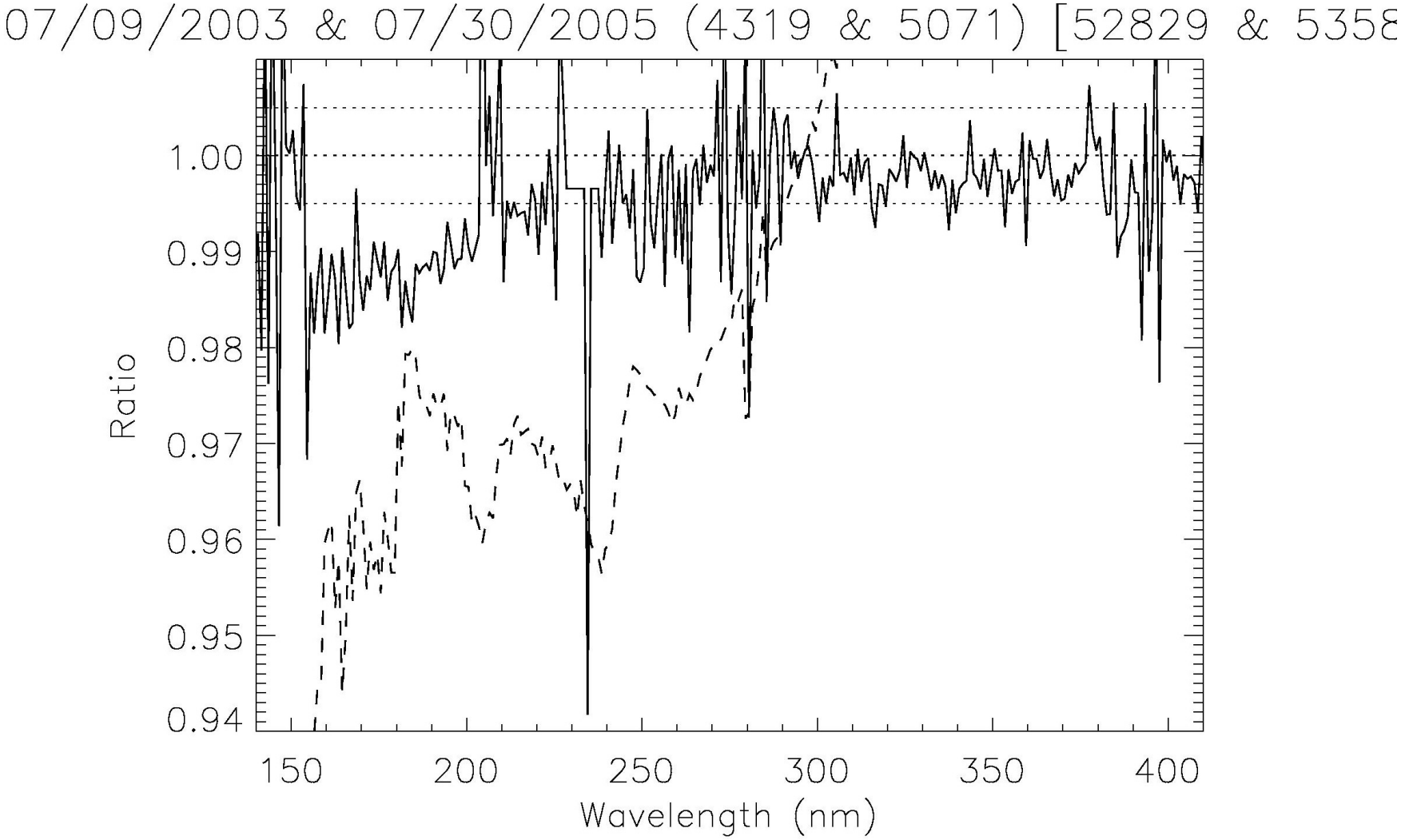
Comparison of SUSIM and SIM

solar change from June 19, 2004 to July 30, 2005



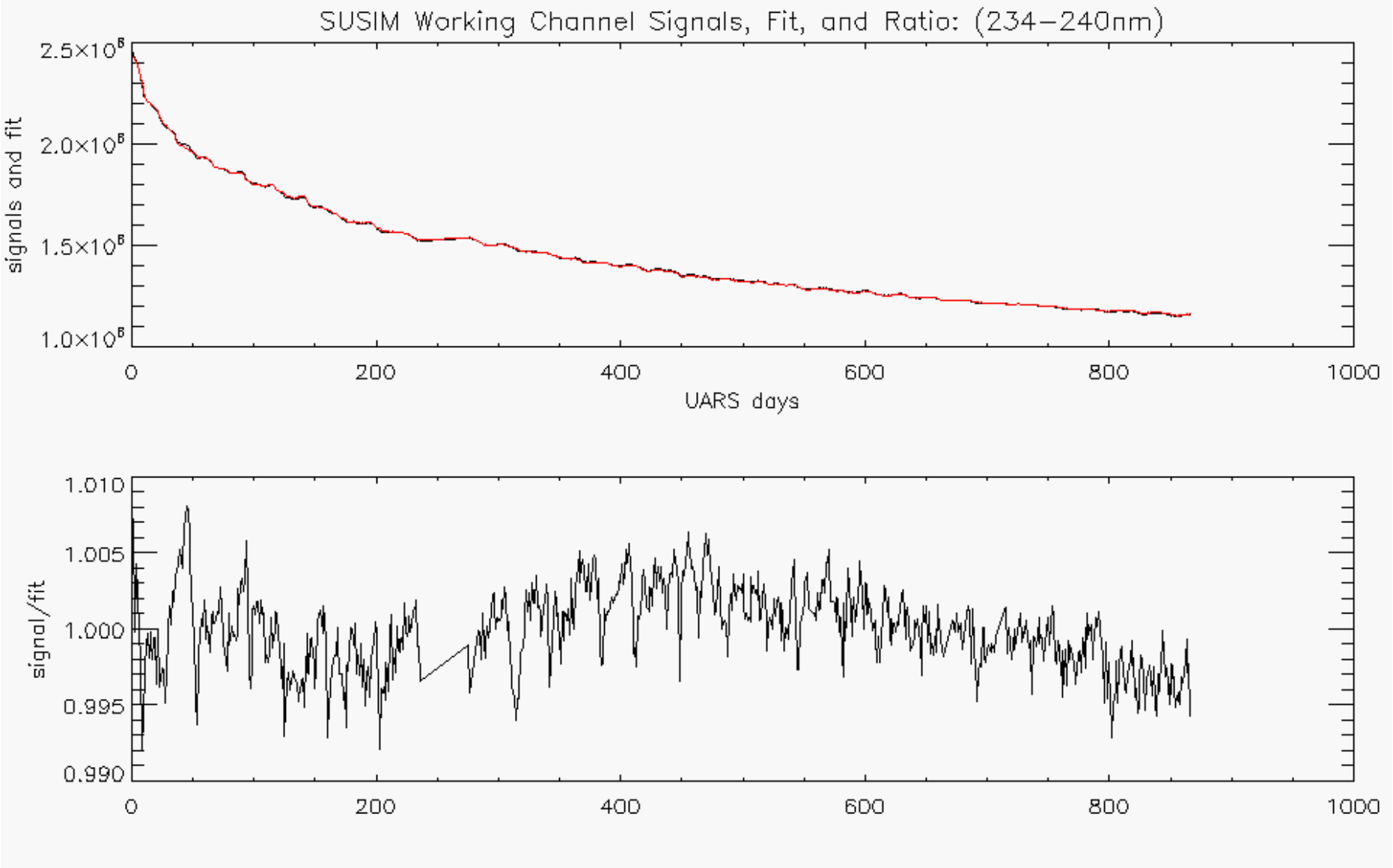
Comparison of SUSIM and SIM

solar change from July 9, 2003 to July 30, 2005



Fits of SUSIM Working Channel Adjusted Signals

short wavelength channel: 234–240 nm



Fits of SUSIM Working Channel Adjusted Signals

long wavelength channel: 325–330 nm