SORCE SIM Release Notes for Version 19, Level 3 data product

SIM data in LISIRD (see: http://lasp.colorado.edu/lisird/sorce/) covers the wavelength range 310.25 to 2412.34 over the extended time span of 2003/4/14 to 2011/05/10. This now includes the first year of the mission and up to the time when full time power cycling of the instrument began.

SIM data on the SORCE website (see: http://lasp.colorado.edu/home/sorce/data/) will now include the wavelength range extended in the ultraviolet to 240.02 to partially overlap with the SOLSTICE data product and give the user the option to use either of these data sets. An IDL reader for the ASCII format is available at: http://lasp.colorado.edu/data/sorce/file_readers/read_lasp_ascii_file.pro

Section 1

Version 19 of the SIM data product includes many changes from Version 17, which was the previous official release (Version 18 was an internal release only).

- Developed completely new processing software, allowing much better maintainability, changeability, and increased processing speed.
- Calibrated and corrected the issue with the prism rotation encoder before April 18, 2004, allowing the processing of the data starting on April 10, 2003.
- Re-evaluated the effect in changes of diode responsivity with temperature. Much improved temperature corrections are now applied during processing.
- Improved the accuracy of the solar exposure data records by determining the state of the instrument when the telemetry information is missing due to lost data packets or lockup conditions when telemetry packets are not being generated.
- Re-evaluated the wavelength dependent prism degradation function (Kappa).
- Re-evaluated our time dependent prism degradation function.
- New prism transmission degradation models were determined for both spectrographs (A & B). Different models were calculated and optimized for the various time periods between safehold events. During most of these safehold events, the instrument got very cold after being turned off for many days. Changes in the position of the steering mirror relative to the prism angle are clearly seen after these events, probably due to hysteresis in the mounting assembly mechanism. The model for each of these time periods was established by choosing the best value of our raypath factor, at each wavelength, such as to optimize the agreement between the detected irradiance from both SimA and SimB.
- Abrupt changes in the value of the degradation trends after each safehold event were clearly present. These are attributed to slight changes in the position of the prism along the optical axis, affecting the value of the raypath correction factor. Corrections are now applied to adjust the values of the calibrated irradiance after each safehold event to re-align the data with pre-safehold values.
- **Table 1** lists the occurrences of these safehold events in the time regime reported in Version 19 data.

Section 2

Estimated long-term uncertainty of the irradiance trends in the V19 release:

- The occurrence of the spacecraft/instrument events affect the trends in the different detectors and time regimes differently. The estimated long-term trends are deduced from the scatter of degradation corrected (see steps outlined in **Section 1**) SIMA and SIMB time series at common measurement times

and within the boundaries between spacecraft events. **Table 1** lists these events. Discussion on the absolute irradiance scale of the instrument is found in Harder et al., *Solar Physics*, 263, 3-24, 2010.

- Examples of the uncertainty analysis are shown below for the ultraviolet, visible, and infrared detectors (**Figure 1**). Each graph contains the standard deviation of the SIM A&B fractional differences in irradiance (i.e. (SIMA-SIMB)/SIMA) shown as red symbols. The plot also shows as a purple solid trace the 1σ fractional noise equivalent irradiance (NEI) plotted as NEI/irradiance; the dashed purple line is the 2σ value. This noise estimate can be interpreted as the expected root-mean-square fractional difference between two SIM spectra without influence from long-term degradation or solar variability. The other traces are representative of uncertainty in the trend separated by long periods of time – but within the quoted time window identified in the plot. For the UV (panel a), the fractional difference for the April 2003 to April 2004 time period is shown with blue symbols. The uncertainties in this period are considerably larger than the April 2004 to May 2007 time due to the difficulties of correcting the wavelength scale in this time period. The uncertainties in the April 2004 – May 2007 are commensurate with the uncertainties reported in Harder et al. 2009 (*GRL*, 36, 2009). Extending the record back to April 2003 will allow better comparison with other UARS era sensors and provide an estimate of the trend uncertainty for this time period. In the visible part of the spectrum (**Figure 1b**) the ability to perform long-term corrections typically falls within the 2σ-noise limit, but tends to flatten out at about 2.5×10^{-4} at wavelengths longer than about 540 nm. Increases in uncertainty at wavelengths longer than 760 nm are mostly due to residual uncertainties associated with the temperature coefficient of radiant sensitivity of the photodiodes. In the April 2003 – April 2004 time period, uncertainties in the visible are about 5x larger than shown in **Figure 1b**. For the infrared, long-term trend uncertainties are based on comparisons with the ESR. Three long-term comparisons are shown: comparisons with the SIM A and B ESR's and with the SIM A photodiode. The ESR data in these plots are from the lower noise ESR table experiments. The SIM B photodiode detector does not produce radiometric quality data so is not included in the analysis. Wavelengths longer than 1600 nm reported in Version 19 data are from ESR A operating with a shorter integration time, so its noise level is about 10x larger than the NEI reported in this plot. For time periods after May 2007, comparisons of SIM A&B are similar to the April 2004 – May 2007 time period, but maintenance of the wavelength scale and determination of the raypath through the prism are more difficult to determine owing to the shortened stable time periods between safehold events as evidenced by subtle changes in slope before and after some of the safehold events. See discussion of Version 20 processing for information about processing/analysis steps that will be taken to help improve data quality.

- A 2-intrument comparison, like SIM, cannot rule out a common-mode error in the long-term trend. The only means available to assess this is through integration of the spectrum, and to compare it against the total solar irradiance (TSI). **Figure 2a** shows the SIM Version 19 measurement, integrated between 240 and 2400 nm, compared to the SORCE TIM instrument. Note that the February 2009 – May 2009 solar minimum average irradiance is subtracted to each dataset so the data spans the zero line. Also shown on this plot are the occurrences of the safehold events shown as vertical dashed lines. Over the 240-2400 nm operating range of SIM, the integrated spectrum produces 1318.6 Wm^{-2} missing 3.1% of the TSI. Wavelengths less that 240 nm contribute ~1.1 Wm^{-2} with the remaining deficit due to the unmeasured portion of the infrared spectrum beyond 2400 nm. **Figure 2b** shows the difference in irradiance with the TSI. Again, the plot is centered about the zero line with the solar minimum deficit of -41.939 Wm^{-2} subtracted. The 1σ standard deviation over the whole SORCE

mission is 0.555 Wm^{-2}; this corresponds to a one standard deviation in the fractional difference from TSI of 400 ppm (parts per million) distributed over 1226 spectral bins. This value needs to be put in a context of the accumulated errors in integration associated with the errors on each individual spectral measurement. Estimating the accumulated errors in a trapezoidal integration procedure suggest that very minor errors in both photometry and wavelength shift produce errors commensurate with the uncertainty in **Figure 2b**. For example, using errors of 1σ noise equivalent irradiance and an error of 0.6% of a prism drive step (an angular uncertainty in prism rotation angle of <0.2 arc-seconds) produces an error in the integrated irradiance of 0.53 Wm^{-2}. Thus the systematic trends in the integrated irradiance apparent in FIGURE 2b are more than likely due to a combination of both wavelength and degradation correction, but do not exceed 400 ppm over the full spectrum. Corrective procedures to refine both the wavelength and degradation correction are been investigated and will be implemented in Version 20 processing.

Section 3

Plan for SIM Version 20:

- Version 19 stops on Mission day 3028 (2011/05/10). After this time period, every-orbit power cycling occurs. Version 20 will implement a dynamical wavelength shifter to continuously account for the thermal/mechanical stresses induced by power cycling. This dynamical shifter will be particularly important for the visible and infrared channels and will improve wavelength registration after September 2011.
- Additional refinements in the temperature coefficient of radiant sensitivity are needed for the photodiodes where the temperature swings are larger.
- These steps are projected to improve:
    - the ability to perform AB comparisons,
    - the determination of the raypath through the prism,
    - the determination of the photodiodes degradation (not well represented in V19 processing), and
    - the agreement between the ESR and photodiodes throughout the entire mission.
- Release of Version 20 processing is planned for spring of 2014.

TABLE 1

Date (UT)	Spacecraft/instrument event
2003/04/19.1	OBC reset
2003/08/13.5	Overheat anomaly
2003/10/28.6	Cold soak experiment
2004/04/18.0	Prism rotation encoder corrected
2007/05/14.9	OBC reset
2009/01/05.0	OBC reset
2009/10/14.5	Safehold, Battery under-voltage
2010/09/27.0	OBC reset
2010/11/01.0	OBC reset
2010/12/27.0	OBC reset
2011/01/29.0	OBC reset
2011/05/16.0	CPV 10 failure (battery failure)
2011/05/10.0	Termination of V19 data, V20 will update the record to at least 2013/7/30

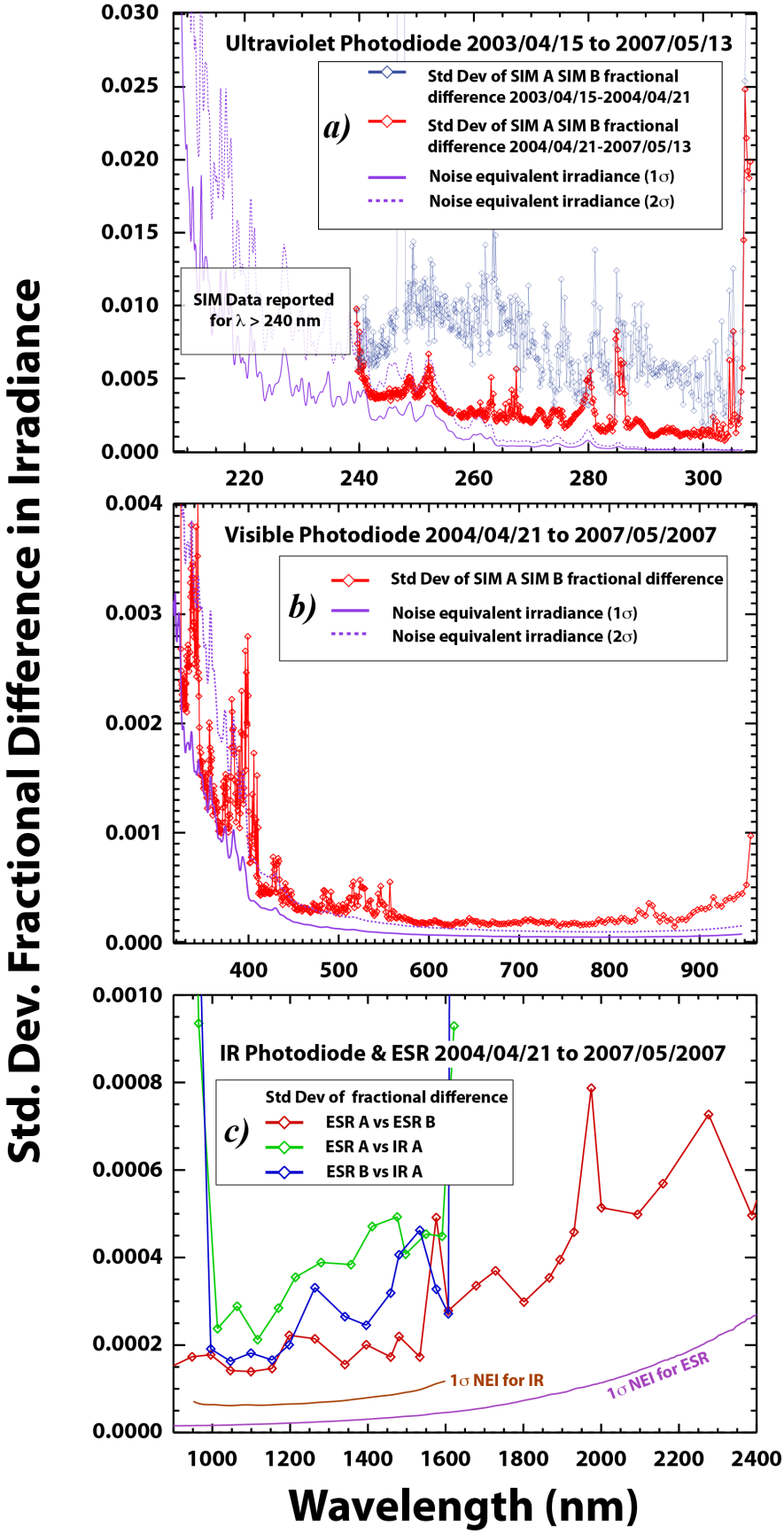

Figure 1a:
The standard deviation of the fractional difference between SIM A and B as a function of wavelength. The red and blue symbols are for two different time periods, the purple traces show the equivalent 1- and 2-σ noise level of the detectors. Additional structure seen in the red and blue traces arises mostly from errors associated with wavelength scale, particularly where the slope of the irradiance curve is steep.

Figure 1b:
Same as Figure 1a except for the visible detector and for the 2004 – 2007 time period. In the visible, the trend uncertainty is typically less that the 2-σ noise limit until about 540 nm where it flattens out at about 2.5x10-4. Longward of about 760 nm additional uncertainty appears due to difficulty of performing temperature corrections. In the 2003 – 2004 time period, the long-term uncertainties are about 5x larger than what appears in this plot.

Figure 1c:
Same as previous panels, but now shows the uncertainties associated with ESR table measurements along the SIM A IR photodiode. Version 19 data longward of 1600 is acquired with the ESR at a shorter integration period, so the noise is about a 10x higher than shown in this plot.

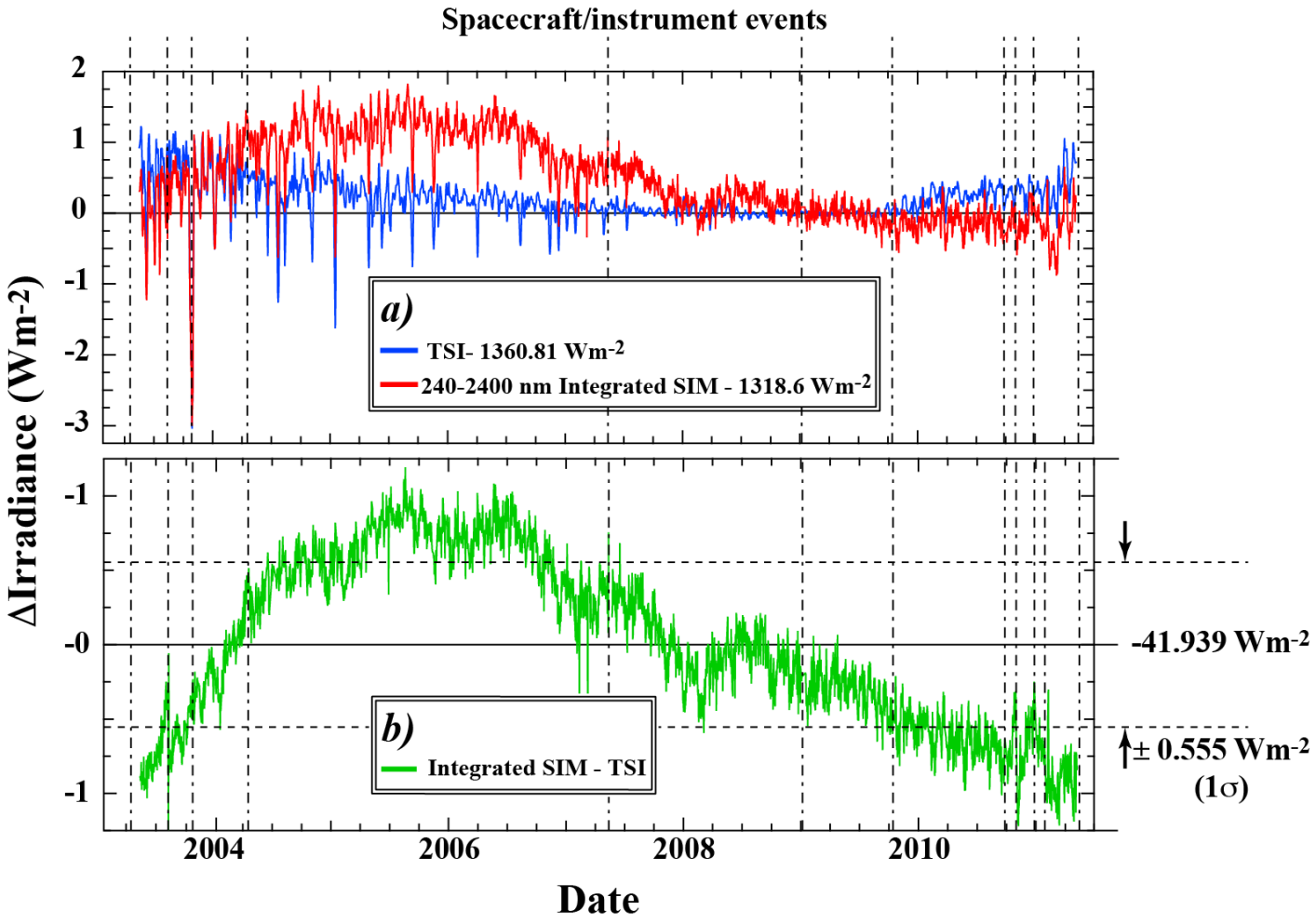

Figure 2a compares the SIM spectrum integrated from 240 to 2400 nm and compared to the SORCE TSI. Both traces have a solar minimum irradiance value (February 2009) subtracted so the plots fit on the same scale. **Figure 2b** shows the difference between integrated SIM and the TSI. The irradiance shortfall on the integrated SIM is -41.939 Wm^{-2}, predominantly in the infrared longward of 2400 nm. The 1-σ difference is ±0.555 Wm^{-2} after accounting for the irradiance shortfall. This difference amounts to about 400 ppm integrated uncertainty distributed over 1226 measurement channels.