

TSIS-1 SIM Version 09 Level 3 Data Product Release Notes (2022/11/15)

NASA’s Total and Spectral Solar Irradiance Sensor -1 (TSIS-1) operates on the International Space Station (ISS). TSIS-1 obtains absolute measurements of the total solar irradiance (TSI) and spectral solar irradiance (SSI). TSI and SSI are essential for scientific models of climate change and solar variability. TSIS-1 has two science instruments, the Total Irradiance Monitor (TIM), and the Spectral Irradiance Monitor (SIM).

This document describes Version 9 (V09) of the TSIS-1 SIM Level 3 (L3) data release. This document summarizes data processing and calibrations changes that affect SIM L3 data and is not a complete list of changes affecting lower-level data products. Details of temporal and spectral coverage can be found in §1.

SIM L3 data is released on 12 and 24-hour cadences. The DOIs for V09 are:

- 12-hour cadence: <http://dx.doi.org/10.5067/TSIS/SIM/DATA317>
- 24-hour cadence: <http://dx.doi.org/10.5067/TSIS/SIM/DATA318>

TSIS-1 SIM V09 L3 data appears in three locations, in the specified formats:

- 1) the LASP LISIRD website (ASCII, CSV, and netCDF)
 - 12-hour: http://lasp.colorado.edu/lisird/data/tsis_ssi_12hr
 - 24-hour: http://lasp.colorado.edu/lisird/data/tsis_ssi_24hr
- 2) the LASP TSIS website (ASCII, IDL SAVfile , and netCDF)
 - <http://lasp.colorado.edu/home/tsis/data/>
- 3) the NASA DAAC (ASCII)
 - <https://disc.gsfc.nasa.gov/datasets?page=1&source=TSIS-1%20SIM>

SIM line spread function (LSF) details are available on the TSIS-1 website:

- <http://lasp.colorado.edu/home/tsis/data/ssi-data/>

An IDL (Interactive Data Language) reader for the ASCII formatted data is available at:

- http://lasp.colorado.edu/data/tsis/file_readers/read_lasp_ascii_file.pro

Changes since the V08 TSIS-1 SIM data release include:

- L3 data product columns are now referenced in ALL_CAPS in the release notes
- Updated irradiance degradation corrections with October 2022 Channel C calibration scans
- New ADDITIONAL_UNCERTAINTY column in all data products
- New L3 Baseline Reference Spectrum Filtering
- Improved FSS-B quad diode degradation model

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1) Temporal and Spectral Coverage

Table 1 gives the available time and spectral range for TSIS-1 SIM L3 data. Nominally, L3 corrected irradiances have a latency of ~25 days to allow for processing and application of instrument degradation corrections. Data latency is driven by the cadence of Channel B observations, which are used in the degradation correction model. This delay may be extended due to delays in receiving telemetry and scheduling constraints such as ISS operations or periods of high beta angles.

Table 1: Time and spectral range of the dataset.

Time Range	Wavelength Range (nm)
2018/03/14 - present	200 – 2400

Temporal gaps are common in the TSIS-1 SIM data record due to factors such as ISS operational activities (e.g., orbit boost), anomalies (e.g., power outages), and obstructions at extreme beta angles. ISS obstructions can result in partial or complete loss of spectra for a given day. Early in the mission, spectral gaps also occurred due to instrument planning and operations errors. Figure 1 shows the V09 L3 TSIS-1 SIM 24-hour data acquisition record. Nominal data are shown in green, data quality flag (QUALITY) = 0, red points show missing data (QUALITY = 1), and blue points show data backfilled from the previous day (QUALITY = 2). Backfilling is never done when temporal gaps exceed 1 day. Pink data were acquired during the HFSS-B(OFF) pointing period (QUALITY = 512, see §5), and purple data are QUALITY = 514 (both back-filled and during the HFSS-B(OFF) period). Data during the HFSS-B(OFF) pointing period have a wavelength-dependent spectral correction applied, maintaining their usability as quality direct irradiance observations, but carry a slightly higher uncertainty as captured in the new ADDITIONAL_UNCERTAINTY column (see §2, §4, & §5).

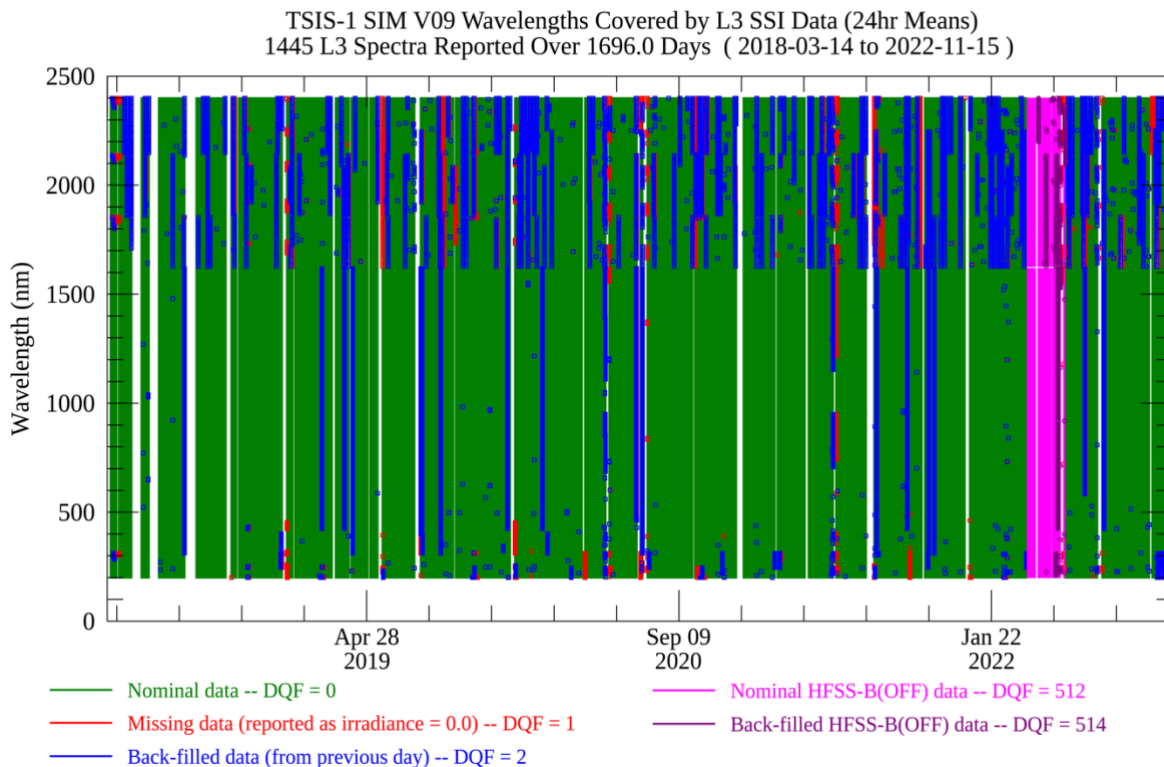


Figure 1: V09 TSIS-1 SIM data acquisition record. As of 15 November 2022, the TSIS-1 SIM data are available on 85.2% of days since the beginning of nominal operations on 14 March 2018.

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2) Spectral Corrections and Uncertainties During HFSS-B(OFF) Pointing

During a two-month period from 19 March – 19 May 2022, TSIS-1 SIM observations were offset in pointing by ~1 arcmin due to surface contamination of the HFSS-B (High-rate Fine Sun Sensor-B). In this document, this is referred to as the HFSS-B(OFF) pointing period. On 19 May 2022, pointing was switched to the redundant sun sensor, HFSS-A, unaffected by surface contamination.

An on-orbit calibration campaign to derive channel and wavelength-dependent spectral correction factors for Channels A & B during the HFSS-B(OFF) pointing period was undertaken in June 2022. To limit solar exposure, especially at off-1AU locations, Channel C calibration scans were not included. This campaign consisted of two sets of calibration observations, taken two weeks apart. In each set of calibration observations, irradiance data were alternately acquired for each detector and channel combination using the contaminated HFSS-B(OFF) and the uncontaminated HFSS-A. To reduce the impact of a changing Sun, every effort was made to minimize the time between identical scans taken with different pointing (sun sensors).

These spectral pointing corrections, applied in V08 and later data releases, bring irradiance data during the HFSS-B(OFF) period in line with nominal measurements, albeit with slightly higher uncertainty. This added uncertainty reflects how well we could determine the off-pointing corrections, given the solar variability in the observed irradiances during the special calibration experiments. These uncertainties are now reported in the ADDITIONAL_UNCERTAINTY column included in all V09 L3 data products, as described in §4 & §5.

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3) Comparison to TSIS-1 TIM TSI

Figure 2 compares the Total Solar Irradiance (TSI) measurements from the V03 data release of TSIS-1 TIM¹ with a TSI estimate (integrated SSI, iSSI) derived from the V09 TSIS-1 SIM L3 data release. The SIM iSSI was generated by integrating the daily L3 spectrum from 200–2400 nm and adding an offset (+52.03 W m⁻²) to account for bandpasses not measured by SIM. Only complete SIM spectra, with no missing or back filled values, were used.

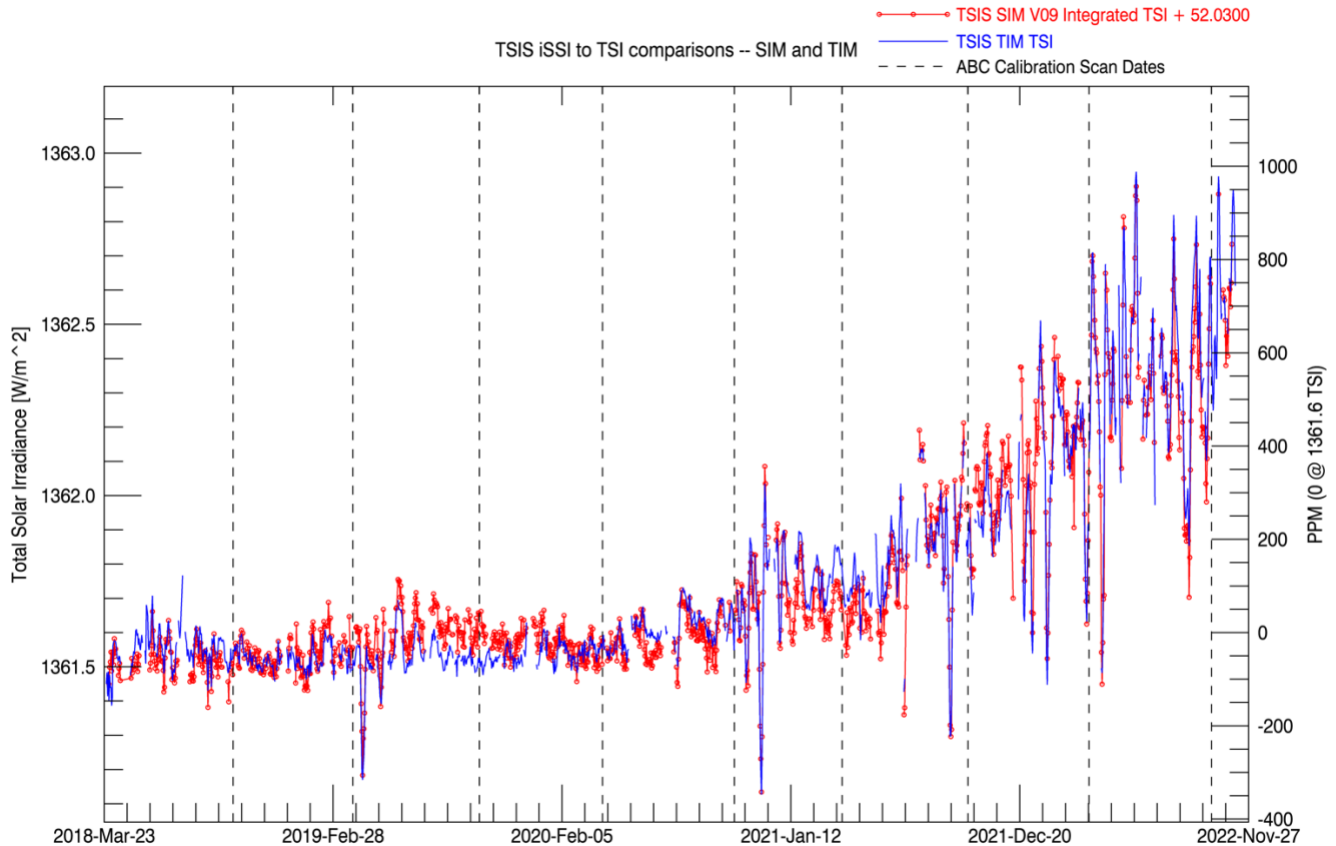


Figure 2: Comparison of V03 data release of TSIS-1 TIM (blue) Total Solar Irradiance (TSI) to the integrated Solar Spectral Irradiance (iSSI) from the V09 data release of TSIS-1 SIM (red). An offset of +52.03 W m⁻² has been added to the iSSI to account for bandpasses not measured by SIM.

Figure 2 highlights the quality of the long-term SIM corrections by comparing the iSSI against the TSIS-1 TIM TSI, which has a reported stability correction uncertainty of ~10 ppm/year. This plot should not be used to evaluate the TSIS-1 SIM absolute calibrations, as the offset (+52.03 W m⁻²) was chosen to match TIM as closely as possible over the mission. However, this value is close to the theoretical expected value of ~4% of the TSI that falls outside of the SIM instrument's spectral range.

¹ See <https://lasp.colorado.edu/home/tsis/data/tsi-data/>

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4) Details of TSIS-1 SIM V09 Changes

1. Updated prism degradation corrections with October 2022 Channel C calibration scans:
 - a. The semi-annual April 2022 Channel C scans cannot be used in degradation calibrations as they were obtained during the HFSS-B(OFF) pointing anomaly.
 - i. Wavelength-dependent spectral corrections were created for Channels A and B by obtaining a series of special calibration scans.
 - ii. We chose not to perform Channel C special calibration scans due to the importance of limiting Channel C solar exposure, and only taking exposures when close to 1AU.
 - iii. We are, therefore, unable to correct the April 2022 Channel C data for the HFSS-B(OFF) pointing and cannot use them in the degradation corrections.
 - b. Channel A and B scans taken during the HFSS-B(OFF) anomaly period have been corrected with a channel and wavelength-dependent calibration and are now included in the degradation correction calculations.
 - c. V09 degradation models were generated using data through October 2022, while the V08 models only included data up until 19 March 2022.
2. New ADDITIONAL_UNCERTAINTY column in all data products:
 - a. As a result of the HFSS-B(OFF) pointing event on 19 March 2022, we have included a new column labeled “ADDITIONAL_UNCERTAINTY” in all TSIS-1 SIM L3 data products.
 - b. In units of $W m^{-2} nm^{-1}$, this column is an irradiance uncertainty measurement independent of the existing irradiance uncertainty columns.
 - c. This column is currently only used for the HFSS-B(OFF) pointing anomaly of 19 March through 19 May 2022, but in future releases it may be used for other anomalies, as indicated by the QUALITY column. For all other time periods this column is zero.
 - d. The HFSS-B(OFF) ADDITIONAL_UNCERTAINTY is based upon the larger of propagated MEASUREMENT_PRECISION irradiance uncertainties and the observed solar variability between HFSS-A and HFSS-B(OFF) calibration scans taken on adjacent orbits in June 2022.
3. New L3 Outlier Filtering:
 - a. Added a filter to the L3 data processing for outliers which deviate by a predetermined amount from a baseline spectrum derived from TSIS-1 SIM observations from 18 March 2021 to 17 March 2022. This period was chosen to cover the beginning of Solar Cycle 25 (SC25).
 - b. The wavelength-dependent tolerances are designed to filter anomalous data not flagged or filtered by our existing processing. The tolerances, which range from 1.5-8%, are based upon SORCE-SIM SC23 and SC24 observations, and the variability measured in our SC25 TSIS-1 SIM baseline reference spectrum.
 - c. The intent of this filter is to catch significant outliers not currently flagged or filtered in our processing.
 - d. Current V09 filtering discards less than ten individual irradiance measurements.
4. Improved FSS-B Quad Diode Filtering:
 - a. The FSS-B quad diode sun position sensor (SPS) degradation model was updated from a single to a double temporal power-law.
 - b. Irradiance measurements obtained with SPS signals that deviate from the model indicate observations affected by ISS obstructions (‘shadows’) or reflections (‘glints’).
 - c. Improves early mission data filtering.
 - d. The new model should supply accurate SPS degradation modelling for the rest of the mission.

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5) Definition of Uncertainties

Four types of uncertainties are reported in the TSIS-1 SIM L3 data release, these are:

INSTRUMENT_UNCERTAINTY ($W m^{-2} nm^{-1}$) is a pre-launch measure of instrument spectral irradiance uncertainty with contributions from component, and unit-level, instrument laboratory characterizations, and calibrations with the final end-to-end full spectrum validation of the measured irradiances against a NIST-traceable cryogenic radiometer performed in LASP's Spectral Radiometer Facility. Reported uncertainties represent an upper limit to the irradiance accuracy for each wavelength.

MEASUREMENT_PRECISION ($W m^{-2} nm^{-1}$) is a wavelength-dependent measure of the on-orbit variance in the scan-to-scan repeatability of the observed spectral irradiances during solar minimum. **MEASUREMENT_PRECISION** is wavelength dependent, but not time dependent.

MEASUREMENT_STABILITY ($W m^{-2} nm^{-1}$) is a relative metric of the on-orbit degradation correction uncertainties. It has contributions from uncertainties due to the post-processing of data (including instrument degradation correction) and differences between the observed irradiances of the three separate SIM channels. Measurement stability is given as 0.0 at wavelengths > 1050 nm, where we do not currently calculate a degradation correction, and for all data that arrives after the last bi-annual Channel C calibration scans. The bi-annual Channel C scans trigger a new data release version, so generally, there will be at least six months of measurement stability values that are 0.0 until they are determined during the creation of the next data release.

ADDITIONAL_UNCERTAINTY ($W m^{-2} nm^{-1}$) is a composite irradiance uncertainty pertaining to anomalous periods and the associated corrections in the data record, indicated by the **QUALITY** data column. This uncertainty is applied to data where, due to atypical circumstances, the data have a higher uncertainty than nominal measurements.

Notes:

- Beginning with the V08 release, **MEASUREMENT_PRECISION** is no longer a term in the **MEASUREMENT_STABILITY** uncertainty.
- As of V09 the only type of **ADDITIONAL_UNCERTAINTY** is related to the HFSS-B(OFF) pointing anomaly in March-May of 2022 (**QUALITY**=512). Channel and wavelength-specific spectral corrections were needed during this period that introduced additional irradiance uncertainty.

For deriving a TSIS-1 SIM absolute irradiance uncertainty, we suggest that the V09 user adds in quadrature all four uncertainty values. For a relative irradiance uncertainty, reflecting the uncertainty in the irradiances between two time periods, use **MEASUREMENT_PRECISION**, **MEASUREMENT_STABILITY**, and **ADDITIONAL_UNCERTAINTY**, added in quadrature.

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6) Data Quality Flags (DQFs)

Each TSIS-1 SIM L3 spectral irradiance measurement includes an associated bit-wise integer data quality flag (DQF) in the QUALITY data product column. A QUALITY value of 0 indicates nominal data that has no associated DQFs. If a spectral irradiance measurement has multiple DQF flags set, the values of each flag are summed to create the final QUALITY value. For example, a QUALITY value of 514 indicates back-filled data that was obtained during the HFSS-B(OFF) pointing anomaly. A table of all TSIS-1 SIM L3 DQFs is shown below (Table 2).

Flag Value	Data Quality Flag Name	Description
1	MISSING_VALUE_FLAG	Indicates missing data items
2	FILL_VALUE_FLAG	Indicates data items which have been backfilled from the previous day's data
512	BAD_HFSSB_POINTING	Indicates irradiance measurements for which a wavelength-dependent correction was applied to account for the HFSS-B(OFF) pointing anomaly that affected data obtained from 19 March to 19 May 2022

Table 2: TSIS-1 SIM L3 data quality flags (DQFs). Note that a QUALITY value of 0 indicates that no DQF is associated with a particular spectral irradiance measurement, and that data should be considered nominal.

7) Additional Notes

To date, TSIS-1 SIM data releases did not require degradation corrections at wavelengths longer than 1050 nm. However, we have recently seen both broad and localized (1620—1850 nm) mild longer-wavelength degradation on Channel A. Degradation corrections are being developed for wavelengths longward of 1050 nm and will be included in the next data release.

8) V09 Release Notes Revision History

1.0: 11/15/2022 – Michael Chambliss, Stéphane Béland, Keira Brooks, Luke Charbonneau, Odele Coddington, Steven Penton, Laura Sandoval, and Erik Richard - *Initial Release*