TSIS-1 SIM Version 08 Level 3 Data Product Release Notes (2022/08/11)

NASA's Total and Spectral Solar Irradiance Sensor -1 (TSIS-1) operates on the International Space Station. TSIS-1 provides absolute measurements of the total solar irradiance (TSI) and spectral solar irradiance (SSI), important for accurate scientific models of climate change and solar variability. TSIS-1 is comprised of two instruments, the Total Irradiance Monitor (TIM), and the Spectral Irradiance Monitor (SIM).

This document describes Version 8 (V08) 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. Temporal and spectral coverage details are given in section 1.

SIM L3 data is released on 12 and 24-hour cadences. The DOIs for V08 are:

- 12-hour cadence: http://dx.doi.org/10.5067/TSIS/SIM/DATA315
- 24-hour cadence: http://dx.doi.org/10.5067/TSIS/SIM/DATA316

TSIS-1 SIM V08 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 TSIS-1 SIM Data Release V08 include:

- L3 Data Quality Flags (DQF)
- Spectral Correction for Data Acquired During HFSS-B Anomaly, HFSS-B(OFF)
- Improved L2 Data Flagging
- Smoothed Prism Temperatures
- Improved Dark Correction
- Updated Measurement Stabilities
- Updated Measurement Precisions

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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 the 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 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 V08 L3 TSIS-1 SIM 24-hour data acquisition record. Nominal data are shown in green, data quality flag (DQF) = 0, red points indicate missing data (DQF =1), and blue points indicate data backfilled from the previous day (DQF=2). Backfilling is never done when temporal gaps exceed 1 day. Pink data were acquired during the HFSS-B(OFF) pointing period (DQF=512, see section 5), and purple data are DQF=514 (both missing and during the HFSS-B(OFF) period).

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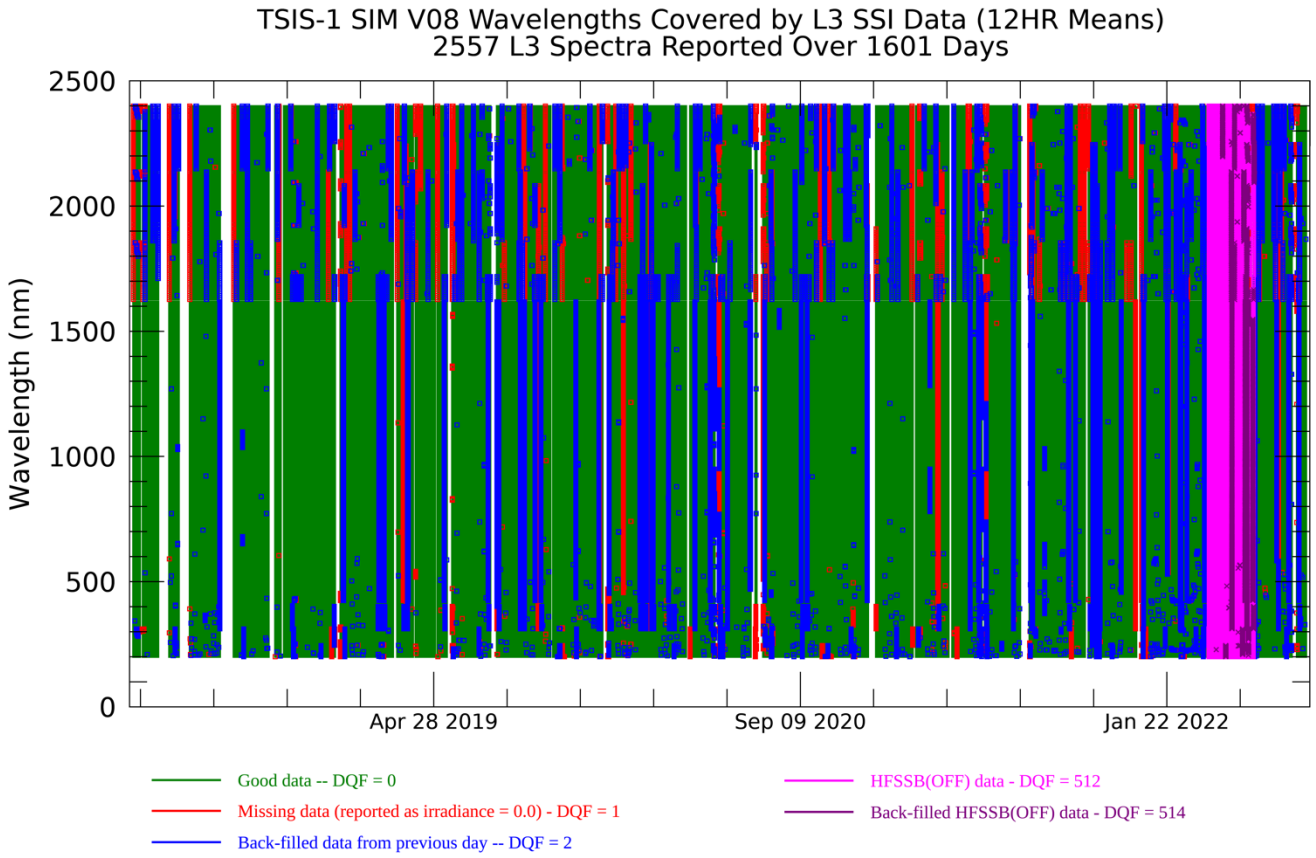

Figure 1: V08 TSIS-1 SIM data acquisition record. As of 23 July 2022, the TSIS-1 SIM data are available on 84.8% of days since the beginning of nominal operations on 14 March 2018.

2) Comparison to TSIS-1 TIM TSI

Figure 2 compares the Total Solar Irradiance (TSI) measurements from the V03 data release of TSIS-1 TIM[1] with a TSI estimate (integrated SSI, iSSI) derived from the V08 TSIS-1 SIM L3 data release. The SIM iSSI estimate was generated by integrating the reported daily L3 spectrum from 200–2400 nm and adding an offset (+51.99 W m^{-2}) to account for bandpasses not measured by SIM. Only complete SIM spectra, with no missing or back filled values, were used.

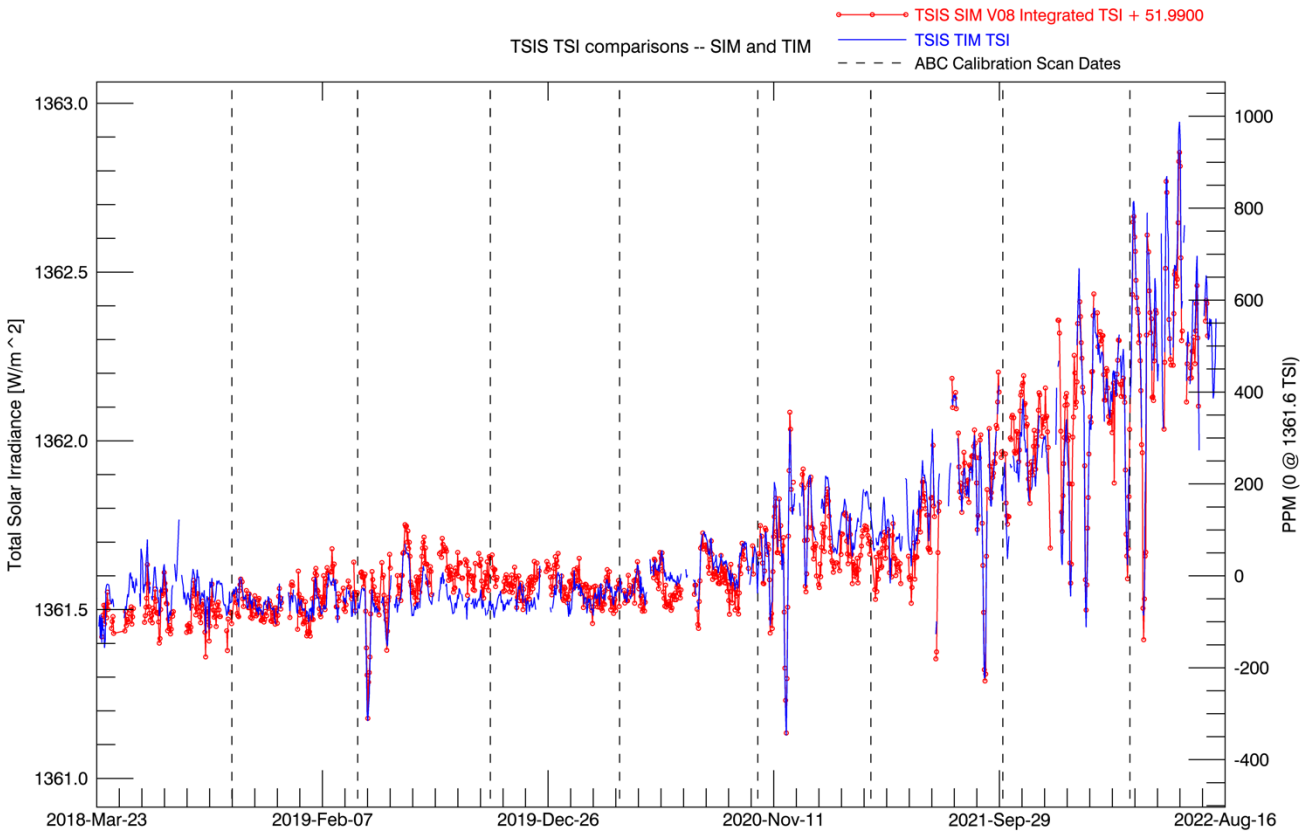

Figure 2: Comparison of V03 data release of TSIS-1 TIM (blue) Total Solar Irradiance (TSI) to the integrated Solar Spectral Irradiance (iSSI) from the V08 data release of TSIS-1 SIM (red). An offset of +51.99 W m^{-2} has been added to the iSSI to account for bandpasses not measured by SIM.

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 (+51.99 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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3) Details of TSIS-1 SIM V08 Changes

Due to the HFSS-B off-pointing anomaly (HFSS-B(OFF), See 5), the April 2022 Channel C calibration scans were not included in the degradation correction model for V08. We will re-evaluate these scans after the October 2022 Channel C scans and determine if the April scans can be used for future data releases.

1. Spectral Correction for Data Acquired During HFSS-B(OFF): Data acquired between 19 March 2022 and 19 May 2022 have had additional wavelength-dependent corrections applied to address an anomalous pointing event on the sun sensor used for pointing during that time.

2. L3 Data Quality Flags: A new L3 data quality flag (DQF) has been added to indicate L3 spectral data for which a wavelength-dependent correction was applied to account for a pointing anomaly that occurred from 19 March 2022 to 19 May 2022.
    - This new HFSS-B pointing anomaly flag (BAD_HFSSB_POINTING) is indicated in the L3 spectral dataset by the presence of a quality value of 512 (zero-based bit 9).
    - Note that it is possible that an L3 data item contains both a quality value of 2 (indicating that the data has been backfilled from the previous day) **and** a quality value of 512 (indicating that the data has been corrected by the wavelength-dependent pointing anomaly correction), resulting in a total quality value of 514.

3. Improved L2 Data Flagging: V08 introduces new L2 data quality flags (DQFs) that indicate:
    - Irradiance measurements acquired during the HFSS-B(OFF) pointing anomaly.
    - Irradiance measurements acquired with the redundant sun sensor (HFSS-A) used for pointing.

4. Improved Dark Correction
    - Fixed a minor bug with filtering the data used for the dark diode correction. This would rarely lead to erroneous irradiance values, primarily in the shortest UV wavelengths where the solar irradiance is small.

5. Smoothed Prism Temperatures
    - Applied a simple boxcar smoothing over a 30 second window to prism temperature readings.
    - The prism temperature varies very slowly over periods of minutes, but we see point-to-point noise in the 1Hz readings.
    - Smoothing reduces noise in the wavelength assignments.

6. Updated Measurement Stabilities
    - The new stability uncertainty is based on the uncertainties of the exponential fits and the Channel C degradation correction. These two uncertainties are calculated separately and added in quadrature.
    - The uncertainty of the exponential fits is estimated by taking the root mean square error (RMSE) of the degradation fits. An RMSE is generated for both the Channel B-C fit and the Channel A-B fits. These are then added in quadrature.
    - The uncertainty of the Channel C degradation correction is estimated by using the Kappa method which compares the degradation rates of Channel B and C to generate a functional degradation rate based on solar exposure time. The uncertainty is generated by looking at the rate of change of the degradation rate over two-year periods. This new method leads to significantly lower uncertainties for this term than the previous stability uncertainty method, which used the entire correction applied to Channel C for this term.
    - Before V08, the measurement precision was added 3 times in quadrature to the measurement stability uncertainty to account for the uncertainty of the ratios used for the old linear degradation correction model. Measurement precision is no longer added to the measurement stability, as this effect is captured by the exponential fit uncertainties.

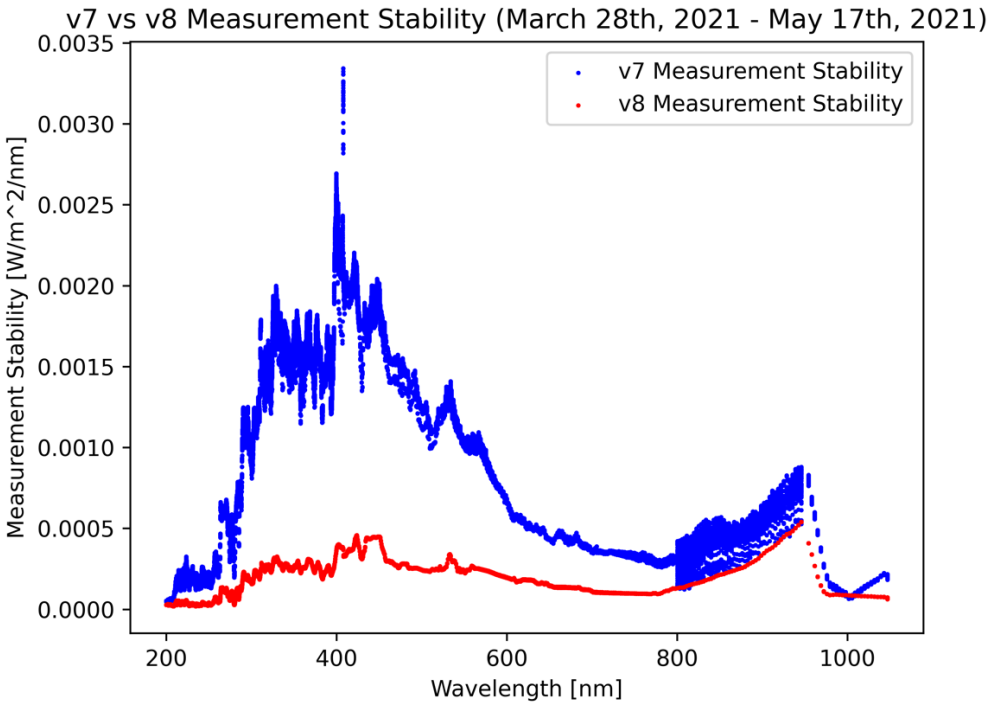

Figure 3: Comparison of TSIS-1 SIM V07 and V08 measurement stability uncertainties for 28 March 2021 – 17 May 2021.

7. Updated Measurement Precisions
    - Re-calculated measurement precision by looking at the scan-to-scan variability of scans close in time taken over a 6-month period centered at solar minimum. Prior releases used an approximately one-year period at the beginning of the mission to derive this uncertainty. This calculation was done using integrated wavelength bands which smooths the uncertainty and lessens the effects of solar variability over short time scales.
    - Resulted in slightly lower and significantly smoother measurement precision values.

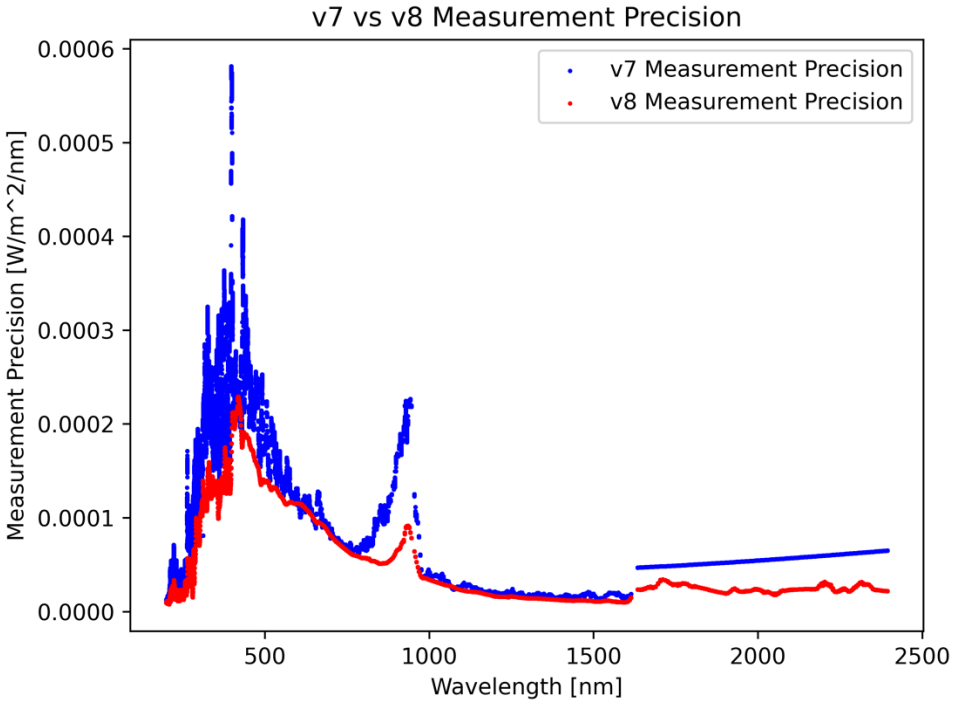

Figure 4: Comparison of TSIS-1 SIM V07 and V08 measurement precision uncertainties.

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4) Definition of Uncertainties

Three types of uncertainties are reported in the TSIS-1 SIM L3 Data Release, these are:

Instrument Uncertainty (in Watts 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 calibration accuracy for each spectral band pending the resolution of an additional correction in the polarization dependence of the entrance slit transmission discovered after launch.

Measurement Precision (in Watts m^{-2} nm^{-1}) is derived from a measure of the on-orbit variance in the scan-to-scan repeatability of the observed spectral irradiances.

Measurement Stability (in Watts m^{-2} nm^{-1}) is a relative metric of the overall 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 3 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.

Note: Beginning with the V08 release, the measurement precision is no longer a term in the measurement stability uncertainty.

For deriving a TSIS-1 SIM irradiance absolute uncertainty, we suggest that the user adds in quadrature all three uncertainty values. For a relative temporal irradiance uncertainty, use the measurement stability uncertainty.

5) Spectral corrections for data acquired during HFSS-B(OFF) pointing

During a two-month period from 19 March 2022 – 19 May 2022, TSIS-1 SIM acquired data with a pointing offset due to an anomaly on the HFSS-B (High-rate Fine Sun Sensor). In this document, this is referred to as the HFSS-B(OFF) pointing. This offset is due to an obscuration on one of the HFSS-B quadrants that results in an ~1 arcmin pointing offset. On 19 May 2022, pointing was switched to the redundant sun sensor, HFSS-A. In June, we completed two calibration series, taken two weeks apart, alternating data acquisition for each detector with HFSS-B(OFF) and HFSS-A, minimizing the time between identical scans taken with the different sun sensors. The data collected during these two sets of calibration scans were then used to create wavelength-dependent spectral correction factors to apply to all data acquired with off-nominal HFSS-B(OFF) pointing.

6) Release Notes Revision History

1.0: 08/12/2022 – Michael Chambliss, Stéphane Béland, Keira Brooks, Luke Charbonneau, Steven Penton, Laura Sandoval, and Erik Richard - *Initial Release*