TSIS-1 SIM Version 07 Level 3 Data Product Release Notes (2021/12/13)

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 7 (V07) 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-lower 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 V07 are:

- 12-hour cadence: http://dx.doi.org/10.5067/TSIS/SIM/DATA313
- 24-hour cadence: http://dx.doi.org/10.5067/TSIS/SIM/DATA314

TSIS-1 SIM V07 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 V06 include:

- Improved Prism Degradation Corrections
- Updated Measurement Stability Uncertainties
- Improved Data Flagging
- Improved Quad-Diode Filtering
- Improved Doppler and 1AU corrections
- NetCDF L3 Data Product

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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 V07 L3 TSIS-1 SIM 24-hour data acquisition record. Colored points indicate portions of a spectrum that are missing (indicated in the data record with a quality flag value of 1) or that have been backfilled from the previous day (quality flag value of 2). Backfilling is never done when temporal gaps exceed 1 day.

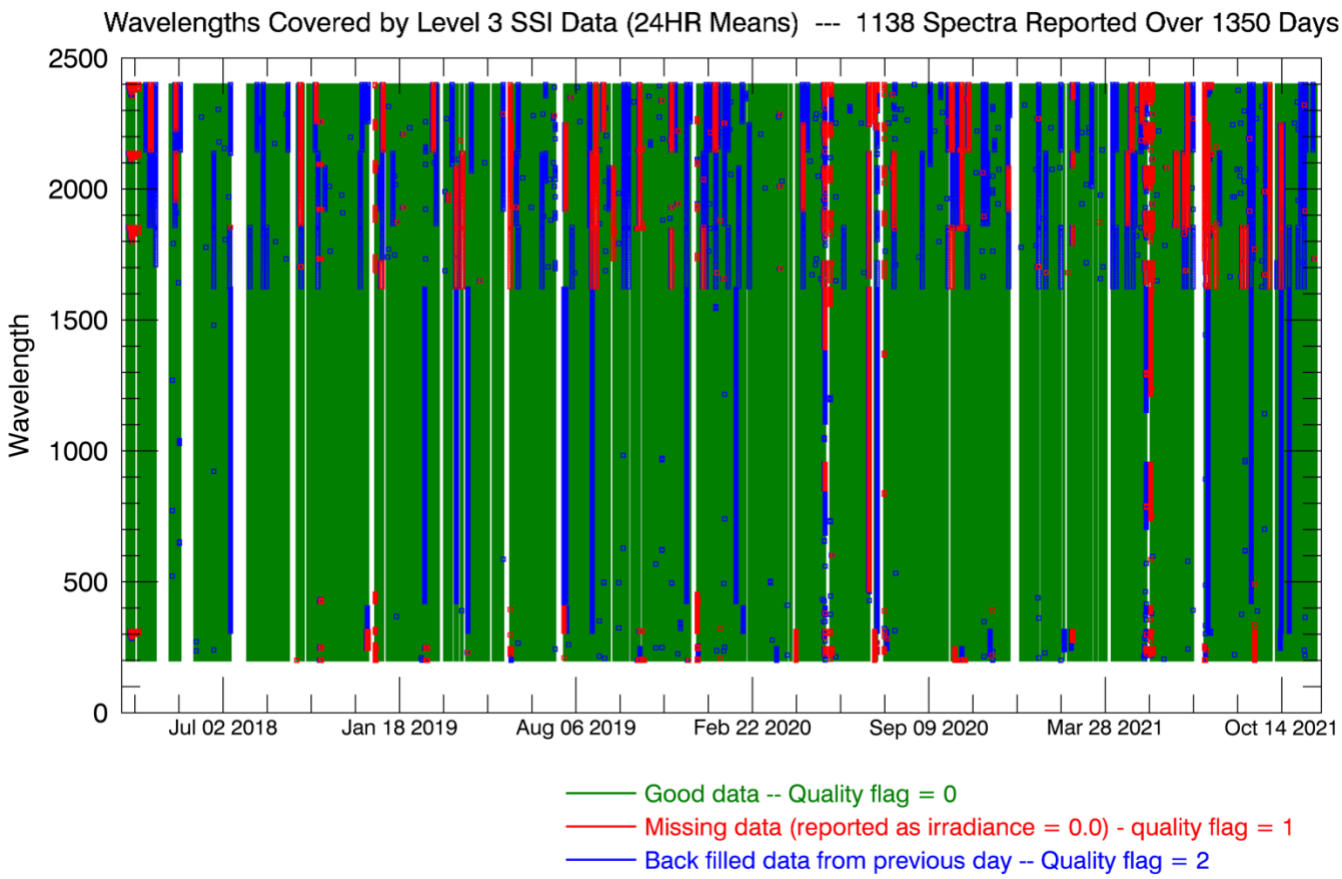

Figure 1: V07 TSIS-1 SIM data acquisition record. As of Dec. 12, 2021, the TSIS-1 SIM data are available on 84.3% of days since the beginning of nominal operations on March 14, 2018.

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 derived from the V07 TSIS-1 SIM L3 data release. The SIM TSI estimate was generated by integrating the reported daily L3 spectrum from 200–2400 nm and adding an offset (+52.20 W m^{-2}) to account for bandpasses not measured by SIM. Only complete SIM spectra, with no missing or back filled values, were used.

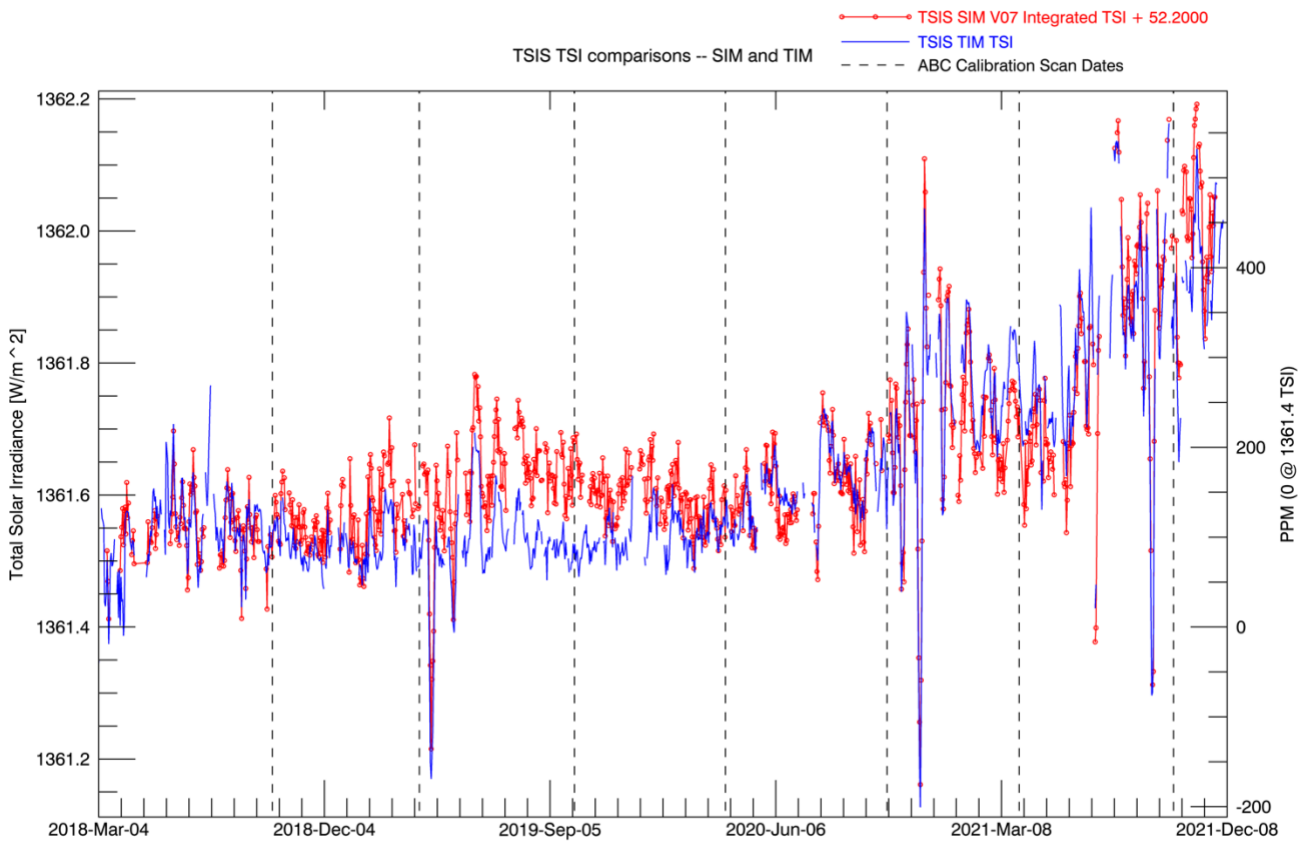

Figure 2: Comparison of V03 data release of TSIS-1 TIM (blue) Total Solar Irradiance (TSI) to the integrated Solar Spectral Irradiance (SSI) from the V07 data release of TSIS-1 SIM (red). An offset of +52.20 W m^{-2} has been added to the integrated SSI to account for bandpasses not measured by SIM.

Figure 2 highlights the quality of the long-term SIM corrections by comparing the integrated SSI 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 (+52.20 W m^{-2}) was chosen to match TIM as closely as possible at the beginning of 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/

3) Details of Changes Since TSIS-1 SIM V06

1. Improved Prism Degradation Corrections
   - October 2021 Channel C observations have been incorporated into the degradation corrections.
   - Improved prism degradation correction algorithm:
     - Updated Channel C correction algorithm to use Channel B & C measurements instead of A & B. An improvement made possible by the increased length of the Channel C data record.
     - Improved the Channel A correction algorithm by replacing linear interpolation with two-term exponential fits for correcting Channel A to C at most wavelengths after mission day 296.
     - Results in a smoother correction, less sensitive to individual Channel C measurements and periods of high solar activity (e.g., the Apr 2021 Channel C measurements which caused V06 problems).
     - Fits are used at all wavelengths except 800–950 nm, piecewise linear corrections are preferred due to higher diode temperature sensitivity in this wavelength range.
   - We are again using all Channel C measurements. The V06 release excluded the April 2021 measurements due to the piece-wise linear correction being very sensitive to any single Channel C measurement with the V06 algorithm.

2. Updated Measurement Stability Uncertainties
   - Changes to the prism degradation corrections also affect the measurement stability calculations. In general, these uncertainties are slightly larger in V07 than V06 as we are using conservative uncertainty estimates, while we further analyze the observed degradation trends.
   - Wavelengths 306-312 nm before Oct 2018 show elevated values that are being investigated.

3. Improved Data Flagging
   - V07 debuts the use of data quality flags (DQFs) for L2 data. Previously out of limit data was discarded at L2. With this change we process and flag all L2 data and discard it before L3.

4. Improved Quad-Diode Filtering
   - V06 introduced a low-temperature and obstruction-detection (shadow) algorithm using the FSSB quad diode, which included a time-dependent quad-diode power-law degradation model. The following improvements have been made for V07:
     - Quad-diode degradation power-law coefficients have been updated based on the additional data obtained since the V06 data release.
     - L2 data obtained when the quad-diode signal was below the threshold were previously discarded, data are now flagged instead.
     - There can be up to a 20-second time difference between the FSSB and SIM shadow. V07 uses a ± 20-second time buffer from low FSSB events for SIM flagging.
     - L2 data are now flagged when the quad-diode signal is above a threshold (e.g., reflections). No time delay was observed for these events between FSSB and SIM, so no time buffer is used.

5. Improved Doppler and 1AU corrections
   - Added filtering and smoothing to the Doppler and 1AU corrections. This allows for catching significant errors that would occasionally occur after temporal gaps in the ISS ephemeris data. This filtering method also enables the correction of small (in magnitude), but more frequent, issues in the Doppler correction.

6. NetCDF Level3 Data Product
   - The L3 netCDF file is now available on the LASP TSIS website
   - NetCDF files conform to CF (Climate and Forecast) V1.8 metadata conventions (CF-1.8).
   - IDL users can read in the entire L3 data record with the following command:
     - IDL> L3S=(ncdf_parse("tsis_ssi_L3_c24h_latest.nc",/read)).tostruct(/recursive)

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 SIM 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. This value is an upper limit of measurement precision.

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. The precision of the three instrument channels is added to the reported stability as a residual sum of squares. 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 bi-annual Channel C calibration scans. The bi-annual Channel C scans trigger a new data release version, so there could be up to six months of measurement stability values that are 0.0 until they are determined during the creation of the next data release.

5) Additional Notes

Larger than anticipated temperature fluctuations have been observed, mainly during three time periods: Jan. 13–23, & Nov. 09–24, 2019, and Jan. 11–23, 2020. Data during these time periods show as yet uncorrected instrumental effects. The temperature excursions during scans tend to be associated with high beta angles. Analysis is ongoing to extend instrument corrections, with their associated uncertainties, into these temperature ranges for use in future data releases. The temperature effects were primarily observed in ESR secondary channel data. With the introduction of the two-term exponential fits to the degradation model, the effect of these few days of data are minimized.