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TOTAL AND SPECTRAL SOLAR IRRADIANCE SENSOR (TSIS-1)

SCIENCE DATA PRODUCTS GUIDE

Document No. 159520

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CHANGE RECORD PAGE

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1 INTRODUCTION

1.1 Purpose and Scope

This document describes the Science Data Products for the Total and Spectral Solar Irradiance Sensor (TSIS-1) mission. It describes the mission's data products content and format as delivered to the scientific community. This document is intended to be a guide for the end users describing the data generated, where and how to access the data, as well as information about the specific data fields and features they should be aware of.

1.2 Relevant Documents

Relevant documents that support details provided in this Science Data Products Guide (SDPG) are listed in Table 1: Relevant Documents

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Document Reference	Title
TBD	Program-Level Requirements of the (TSIS-1) on the International Space Station (ISS) Project
LASP Doc. 145520	TSIS-1 Data Management Plan
LASP Doc. 110249	*TSIS Instrument Operations Concept*
LASP Doc. 151430	*TSIS Algorithm Theoretical Basis Document (ATBD)*

Table 1: Relevant Documents

2 DATA PRODUCTS OVERVIEW

2.1 Data Product Definition

The TSIS-1 project will use the data level definitions that are identical to those used for both the SORCE and TCTE projects and are consistent with NASA Earth Science conventions as described in the *Earth Science Reference Handbook – A guide to NASA's Earth Science Program and Earth Observing Satellite Missions* [available via *http://eospso.nasa.gov/publications/56*].

The TSIS-1 standard data products consist of three levels of processing: Full resolution, time-referenced data with all calibration information for each instrument (Level 1); Calibrated, sorted TIM and SIM irradiance data (Level 2); Daily and 6-hourly mean TSI and daily and 12-hourly mean SSI measurements (Level 3). The specific level definitions pertaining to TSIS are shown in **Error! Reference source not found.**. Level 0 TSIS raw data records (RDR) collected on ISS will be processed into these higher-level sensor data records (SDR) as indicated in this table.

	TIM	SIM
Level 0 (RDR)	Reconstructed, unprocessed TSIS-1 and ISS ancillary data at full resolution	
Level 1 (SDR)	Unprocessed TSIS-1 data at full resolution, time-referenced and sorted by instrument (TIM, SIM) accompanied by all correction and calibration factors and attitude/ ephemeris parameters required for converting the TIM and SIM data into physical units	
Level 2 (SDR)	Sorted data processed into physical units with all applicable conversions and calibrations applied	
Level 3 (SDR)	TSI data averaged and reported at a daily and 6-hourly time cadence	SSI data averaged onto a standard spectral grid and reported at a daily and 12-hourly fixed time cadence

Table 2: TSIS Data Level Definitions

2.2   Data Processing Levels

The TSIS Science Data System (TSDS) delivers Levels 0, 1, 2 and 3 total and spectral solar irradiance data products to the GES DISC on a monthly cadence. File formats are chosen for consistency with SORCE and TCTE data, and for compatibility with existing systems and interfaces at LASP and the GES DISC. The following formats will be used for TSIS-1 data:

	TIM	SIM
Level 0	Raw Binary	
Level 1	HDF5/NetCDF	
Level 2	HDF5/NetCDF	HDF5/NetCDF
Level 3	ASCII	ASCII

Table 3: Data File Format

The TSDS **only** makes available the fully calibrated Level-3 data product to the science community and general public. Lower-level data products (e.g., Level 2) have limited scientific value due to data gaps and instrument artifacts (which are precluded from Level 3 data via quality flags) and are therefore not made publicly available. Short time-ranges of these data will, however, be available upon request from the TSIS science team for specific, well-defined research efforts.

2.3   Data Flow

The TSIS-1 ground system supports on-orbit operations of the TSIS-1 instruments, as well as the production, storage, management, and dissemination of the TSIS science data

products. The TSIS-1 ground system consists of the functional elements depicted in **Error! Reference source not found.**1.
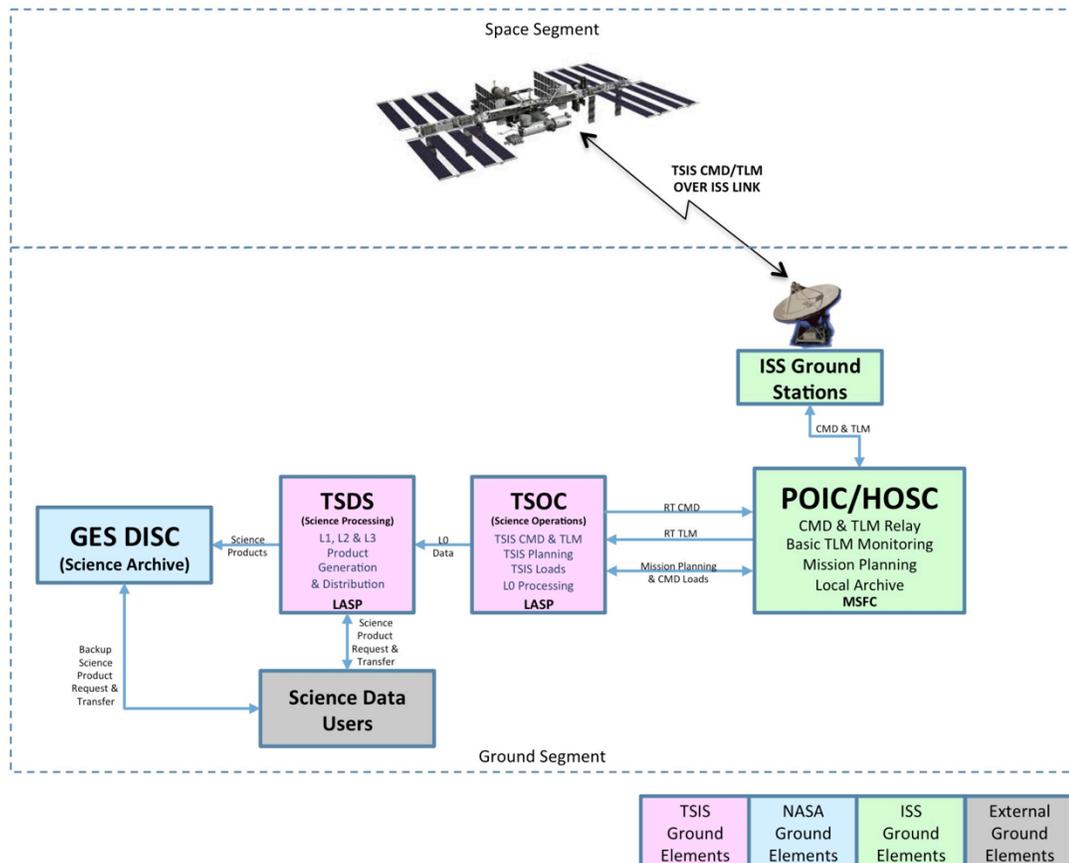

Figure 1: TSIS Ground System Architecture

The TSIS-1 ground system elements include:

- TSIS Science Operations Center (TSOC) - Located at LASP in Boulder, Colorado. Responsible for TSIS-1 instrument mission planning, routine state-of-health monitoring, and instrument suite commanding

- TSIS Science Data Systems (TSDS) - Located at LASP in Boulder, Colorado. Responsible for instrument calibration, science data processing and data product generation, science data management, data validation, public data dissemination, and distribution of data to the GES DISC

- Earth Observing System Data and Information System (EOSDIS) data archive and distribution/Goddard Earth Science Data and Information Services Center (GES DISC)

The NASA ISS ground system elements include:

- NASA ISS ground stations

- NASA Huntsville Operations Support Center (HOSC)

- NASA POIC - Located at NASA MSFC. The POIC facilitates TSIS-1 remote payload operations by routing TSIS-1 payload commands to the ISS, retrieving and temporally archiving payload data and ISS data such as attitude and ephemeris, routinely transmitting stored data to the LASP TSOC, and performing mission critical payload health and status monitoring.

- NASA GES DISC. Located at NASA GSFC in Greenbelt, MD. The GES DISC is responsible for science data archiving and distribution.

3   Level 3 Data Products

The Level 3 data consist of daily and 6-hourly averaged total solar irradiance (TSI), and daily and 12-hourly averaged spectral solar irradiance (SSI). The Level 3 SIM data are binned to a pre-defined wavelength grid, providing data in a format most familiar to the scientific community.

Within 24 hours of Level 2 and calibration data availability, all instrument science data and spacecraft engineering data are processed to derive Level 3 science data products in standard geophysical units (W m^{-2} for TSI and W m^{-2} nm^{-1} for SSI). These data are made available to the scientific community through data distribution centers.

3.1   TIM Processing

The processing of the TSIS-1 TIM data is based on existing code, originally adapted from SORCE TIM, now shared by the SORCE, TCTE and TSIS missions. Changes were made to account for the different telemetry format, the addition of the SPICE software (https://naif.jpl.nasa.gov) for handling the complex ISS and TPS pointing, and the added ISS obstruction information (ISS Pointing Office).

The production of the calibrated TSI from TIM raw data takes the following processing steps (depicted in Figure 2):

1. Unpack high-rate science telemetry into L1S database tables
2. Create SPICE kernels for attitude and ephemeris calculations
3. Calculate Preliminary irradiance calculations
4. Determine quality flag based on L1 telemetry, obstruction reports, instrument pointing (SPICE) and intermediary L2 values
5. Calculate dark irradiance using the dark model
6. Calculate TIM solar exposure and instrument degradation
7. Calculate 1AU corrected irradiance using dark irradiance, solar distance and Doppler correction
8. Calculate fully corrected irradiance with instrument degradation correction
9. Calculate True Earth corrected irradiance

10. Calculate Level 3 Total Solar Irradiance (1AU and True Earth) averages at 6-hourly and daily cadence
11. Archive all Level 1-3 data products and publish Level 3 data products
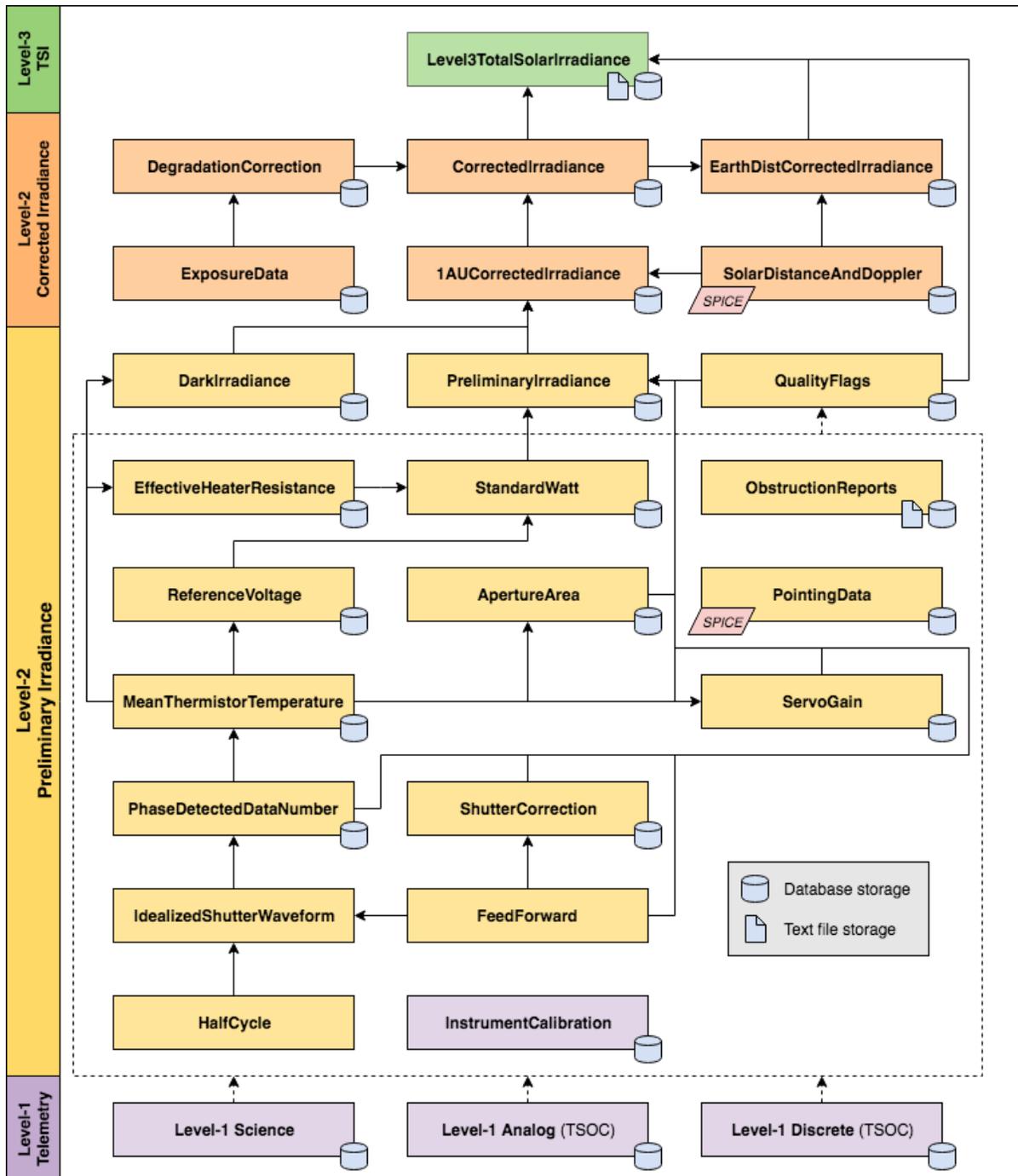

Figure 2: TSIS TIM data flow for Total Solar Irradiance calculations

3.2 SIM Processing

The processing of the TSIS-1 SIM data is based on the measurement equation provided in the ATBD and shown in the equation below. The implementation of this measurement

equation in the data processing system leverages the SORCE experiences, but is optimized for TSIS considering the significant differences with SORCE SIM in the various operational modes (different type of diode readout and ESR measurements).

$$\mathcal{E}(\lambda_s) = \frac{\mathcal{P}_{ESR}(\lambda_s)}{A_{slit} \int \alpha_\lambda \mathcal{T}_\lambda \Phi_\lambda S(\lambda,\lambda_s)\, d\lambda} \quad or \quad \mathcal{E}(\lambda_s) = \frac{\mathcal{I}_{photodiode}(\lambda_s)}{A_{slit} \int \mathcal{R}_\lambda \mathcal{T}_\lambda \Phi_\lambda S(\lambda,\lambda_s)\, d\lambda}$$

where: A_{slit} is the aperture area, T_λ is the prism transmission, ϕ_λ is the slit diffraction, $S(\lambda,\lambda_s)$ is the spectral transfer function and $P_{ESR}(\lambda_s)/\int\alpha_\lambda$ is the ESR optical power and $I_{photodiode}(\lambda_s)/R_\lambda$ is the photodiode optical power (watts).

The production of the calibrated SSI from SIM raw data takes the following processing steps:

1. Telemetry unpacking into L1S tables
2. Wavelength determination/assignment
3. Calculate and apply Dark counts
4. Calculate instrument profile (versus λ)
5. Calculate diode responsivity temperature correction (versus λ)
6. Calculate 1AU adjusted Uncorrected SSI (versus λ)
7. Calculate the prism degradation (versus λ)
8. Calculate the diode degradation (versus λ)
9. Calculate Corrected SSI (Level 2)
10. Calculate Level 3 Calibrated Daily SSI
11. Archive and publish all Level 3 data product

The processing of the ESR data differs from the diode processing in the determination of the phase-detection calculation to obtain the initial data numbers at each prism position compared to the PhotoDiode Acquisition Rate (PDAR) method used for the diodes.
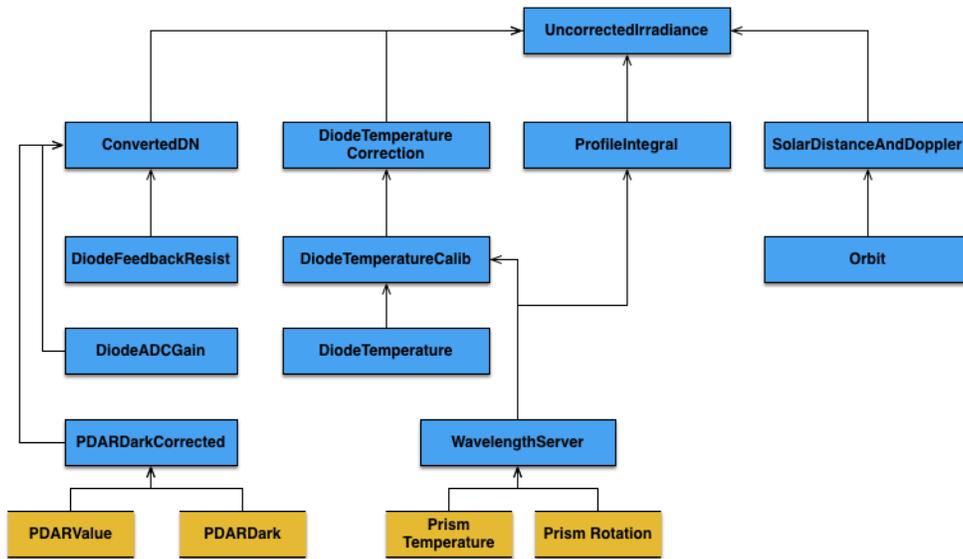
Figure 3: TSIS SIM data flow for uncorrected irradiance calculations
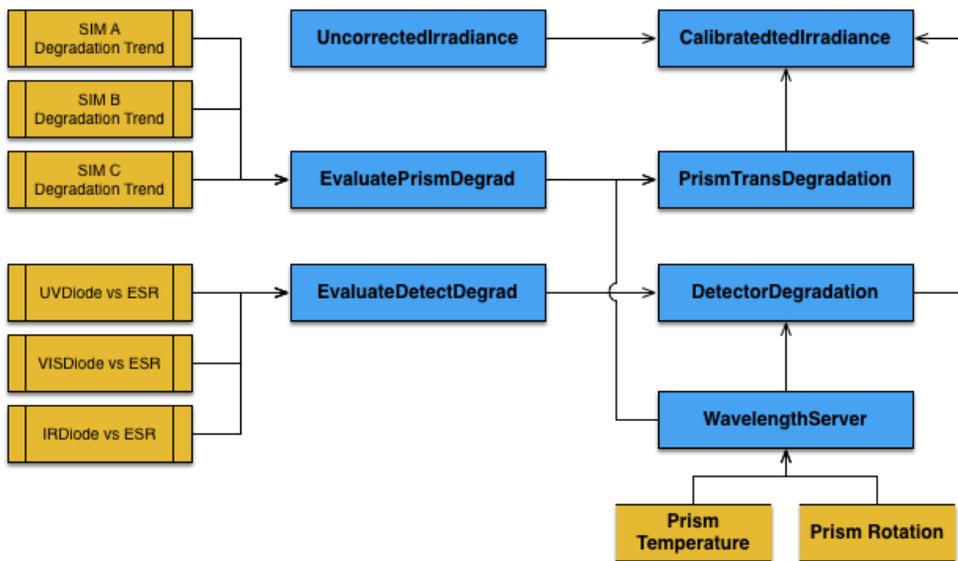

Figure 4: TSIS SIM data flow for calibrated irradiance calculations

4   DATA ACCESS AND AVAILABILITY

The primary data archive for the TSIS-1 data is located at the Goddard Earth Sciences - Data and Information Services Center (GES DISC) where the data can be downloaded

directly. The TSDS also provides a TSIS-mission website with the Level 3 data in different download formats as well as a web interface to plot and inspect the data with the LASP Interactive Solar Irradiance Datacenter (LISIRD). Table 4 provides a list of URLs for these three sites where the data are available. Additional Release Notes are available at those sites describing detailed changes to the data processing or data products with each new release. Table 5 contains a list of the data products characteristics.

Location	URL	Content
GES DISC	https://disc.gsfc.nasa.gov/datasets?keywords=TSIS	Archived Level 0 and science products
LASP TSIS	http://lasp.colorado.edu/home/tsis/data/	Full product documentation and direct downloads
LISIRD	http://lasp.colorado.edu/lisird/	Solar irradiance data from TSIS and other missions via interactive tools and common interfaces

Table 4 Data Availability Sites.

Characteristic	Total Solar Irradiance (TSI)	Solar Spectral Irradiance (SSI)
Coverage	Full Solar disk	Full Solar disk
Temporal Characteristics	6-Hourly and Daily	12-Hourly and Daily
Spectral Coverage	All wavelengths	200-2400 nm
Spectral Resolution	Total Solar Irradiance	Instrument and wavelength dependent, 34 nm for SIM at 2000 nm
Key Geophysical Parameters	Total Solar Irradiance	Incoming Solar Irradiance
Absolute Accuracy (Relative Standard Uncertainty, 1 sigma)	0.01% (100 parts per million)	Varies per spectral region, Please see TSIS Instrument Overview for measurement objectives and the SSI web page for current status.
Relative Accuracy	0.001% (10 ppm) per year	Varies with spectral region, Please see TSIS Instrument Overview for measurement objectives and the SSI web page for current status.

Table 5 Data Product Characteristics

5   DATA FILE FORMAT AND DATA DEFINITIONS

The GES DISC and the LASP TSIS web site provide the Level 3 data products as text files covering the whole mission. Additionally, the LASP website provides IDL 'save' files with the data in the form of a data structure and an IDL routine to read the text files into data structures.

5.1   TIM

The TIM ASCII files available from GES DISC and the LASP website have the same fixed format described below.

Data Definition	Description
nominal_date_yyyymmdd	Nominal Data Time, YYYYMMD
nominal_date_jdn	Nominal Data Time, Julian Day Number
avg_measurement_date_jdn	Average Data Time, Julian Day Number
std_dev_measurement_date	Stdev of Average Data Time, days, 1 sigma
tsi_1au	Total Solar Irradiance (TSI) at 1-AU, W/m^2
instrument_accuracy_1au	Instrument Accuracy in 1-AU TSI, W/m^2, 1 sigma
instrument_precision_1au	Instrument Precision in TSI at 1-AU, W/m^2, 1 sigma
solar_standard_deviation_1au	Solar Standard Deviation in 1-AU TSI, W/m^2, 1 sigma
measurement_uncertainty_1au	Total Uncertainty in TSI at 1-AU, W/m^2, 1 sigma
tsi_true_earth	Total Solar Irradiance at Earth distance, W/m^2
instrument_accuracy_true_earth	Instrument Accuracy at Earth distance, W/m^2, 1 sigma
instrument_precision_true_earth	Instrument Precision at Earth distance, W/m^2, 1 sigma
solar_standard_deviation_true_earth	Solar Standard Deviation in TSI at Earth, W/m^2, 1 sigma
measurement_uncertainty_true_earth	Total Uncertainty in TSI at Earth distance, W/m^2, 1 sigma
provisional_flag	Provisional Flag, 1=provisional data, 0=final data

Table 6: TSIS TIM Data Definition

The following paragraphs discuss the four different uncertainties reported with the TSI measurements.

Instrument Uncertainty reflects the instrument's relative standard uncertainty (absolute accuracy) and includes all known uncertainties from ground- and space-based calibrations plus a time-dependent estimate of uncertainty due to degradation. This value is currently reported as 410 ppm, but is expected to be refined lower with new calibrations and on-orbit validations. This uncertainty varies slightly with measured instrument temperature and the time to the nearest on-orbit calibrations. This value is useful when comparing different TSI instruments reporting data from the same time range on an absolute scale.

Instrument Precision reflects the TIM's sensitivity to a change in signal, and is useful for determining relative changes in the TIM TSI due purely to the Sun over timescales of two months or less (so that degradation uncertainty does not have a significant effect). This value of 5 ppm is constant, and indicates the instrument's noise level.

High-cadence Level 2 data are averaged (via an un-weighted mean) to produce daily and 6-hourly averaged Level 3 data. The standard deviation of the Level 2 values averaged to produce each Level 3 value is indicative of the solar variability during the reported Level 3 measurement interval, and is called the **Solar Standard Deviation**. This uncertainty redundantly includes (but is generally much larger than) the Instrument Precision. The Solar Standard Deviation is useful for estimating potential variations in the TSI within the time range of a Level 3 data value, such as when comparing TIM TSI values with solar images or other TSI instruments reporting data at slightly different times.

Measurement Uncertainty is the net uncertainty of a reported Level 3 data value, and is the root sum square of Instrument Uncertainty and Solar Standard Deviation. Measurement Uncertainty is the value that should be used when comparing absolute scale TSI data from non-identical time ranges.

5.2   SIM

The SIM ASCII files available from GES DISC and the LASP website have the same fix format described in Table 7 below.

Data Definition	Description
nominal_date_yyyymmdd	Nominal Data Time, YYYYMMD
nominal_date_jdn	Nominal Data Time, Julian Day Number
wavelength	Wavelength at the center of the measurement, nm
instrument_mode_id	Instrument Mode 86 (UV), 85 (VIS), 84 (IR), 83 (ESR)
data_version	Data Release version
irradiance_1AU	Solar Spectral Irradiance at 1-AU TSI, W/m^2/nm
instrument_uncertainty	Instrument Uncertainty, W/m^2/nm, 1 sigma
measurement_precision	Measurement Precision, W/m^2/nm, 1 sigma
measurement_uncertainty	Total Uncertainty, W/m^2/nm, 1 sigma
quality	Data Quality Flag: '0' for good data, '1' indicates missing data, and '2' indicates data has been filled from the previous day

Table 7: TSIS SIM Data Definition

The following paragraphs discuss the three different uncertainties reported with the SSI measurements.

Instrument Uncertainty is a pre-launch measure of instrument 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.

Measurement Precision is derived from a measure of the on-orbit variance in the scan-to-scan repeatability in the observed spectral irradiances. This value is an upper limit of measurement precision.

Measurement Uncertainty is a metric of the overall on-orbit uncertainty. It has contributions from instrument uncertainty, uncertainty due to post-processing of data (including correction of instrument degradation), and uncertainty due to differences between observed irradiances for the 3 separate SIM channels.

6   DATA RELEASE NOTES

It is important for the user of these data products to read the release notes associated with each dataset. These will contain critical information related to data processing, data quality, and possible data issues related to the data products. The release notes are available at the same sites as the data (see Section 4 above).