2024 IRC Solar Irradiance Working Group Annual Report

Reporting Period: July 2023 - June 2024

Opening Statement

Development activities of the Solar Irradiance Working Group (SIWG) began in Spring, 2022 after the working group proposal was selected and the membership roster formulated. This current report reflects our expanding connection to the user/application science community as well as the status of the field. The SIWG meets approximately every two months.

Mission Statement

To facilitate the proper representation of total solar irradiance (TSI) and solar spectral irradiance (SSI) on multiple time scales we will specify and understand solar irradiance and its variability using measurements and models, define application-based measurement requirements for solar irradiance, and communicate recommendations to national and international scientific organizations and to the research community.

Our User Community & Relevance to Other IRC Working Groups

The total solar irradiance (TSI) and solar spectral irradiance (SSI) are key data records for diverse earth science investigations such as radiative transfer modeling, developing and applying remote sensing algorithms, performing instrument radiometric calibration and intercalibration, and studying climate with global earth atmosphere models (e.g., general circulation and chemistry transport models).

Since July 2023, members of the SIWG have been an expert resource to provide guidance and recommendations to a broad user community in these topical areas:

- the Solar Forcing Working Group responsible for defining the solar forcing dataset of the 7th Coupled Model Intercomparison Project (CMIP7),
- numerous users of the Total and Spectral Solar Irradiance Sensor (TSIS-1) Hybrid Solar Reference Spectrum (HSRS) interested in:
    - calibration & intercalibration (e.g., the GSICS Working Group on Calibration and Validation has spun up a sub-working group focused on differences in solar irradiance datasets and their potential impacts to cal/val),
    - global aerosol retrievals (e.g., the NASA Aerosol Robotic Network),

    - a time-varying solar irradiance forcing in radiative transfer models (e.g., RRTMG),
    - as the new, baseline irradiance spectrum of the European Centre for Medium-Range Weather Forecasts (ECMWF) model
- members of the Committee on Earth Observation Satellites (CEOS) Working Group on Calibration and Validation that held discussions to increase the visibility and encourage the use of the CEOS-recommended TSIS-1 HSRS spectrum
- users of a new disk-center high-resolution solar spectrum (SOLAR-HRS) that includes additional spectra for ten solar view angles ranging from $\mu = 0.9$ to $\mu = 0.05$
- users of the NOAA/NCEI Solar Irradiance Climate Data Record (CDR)
- 'brokering' the SSI product of the NOAA/NCEI Solar Irradiance CDR in the European Union's 'Copernicus Climate Change Service (C3S)' that provides data and services to European authorities and the public (https://climate.copernicus.eu/),
- the SCOSTEP representatives of the current PRESTO program (Predictability of Variable Solar Terrestrial Coupling; ending in 2024) to establish international & interdisciplinary scientific programs related to solar activity and its influence on climate

Furthermore, members of the SWIG are active in various research activities, science teams and new international initiatives. For example:

- applying instrument calibrations and publishing data from several on-orbit solar irradiance satellite sensors including the Davos Absolute Radiometer (DARA) on the Chinese FY-3E platform, the Chinese Solar Irradiance Monitor (SIM) and Spectral Solar Irradiance Monitor (SSIM) instrument on FY-3E platform, the Total Irradiance Monitor (TIM) and Spectral Irradiance Monitor (SIM) on TSIS-1, and Extreme Ultraviolet Sensor (EUVS) observations from the GOES platform
- analysis and validation of data from new instrument developments (e.g., Compact Total Irradiance Monitor, Compact Spectral Irradiance Monitor) and preparation of new, innovative approaches to acquire extraterrestrial solar irradiance into the future (Compact TSIS, and Uvsq-SAT NG).
- NASA's Solar Irradiance Science Team focuses on developing consistent, long-term records of TSI and SSI and team members rigorously analyze direct irradiance observations, solar activity indices, and solar proxies, develop composite records, and develop/improve solar irradiance models.
- the developing European Space Agency initiative "TRUTHS for Climate Workshop" to develop and prepare the TRUTHS user communities, discuss intercalibration strategies and priorities to harmonize fundamental and thematic climate data records
- Providing awareness of the importance of auxiliary, ground-based, measurements (e.g., CaK, F10.7, sunspot area and number, etc.) that are complimentary to space-based datasets and essential for reconstructing past climate.
- Advocating for retaining and expanding the study of solar variability for Earth's climate in the future SCOSTEP program being developed now (beginning in 2025).
- Proposing to establish a virtual sun-climate data institute under NASA's Heliophysics Innovation in Technology and Science program to support the stewardship and transparency of key data records used in climate assessment studies such as CMIP and IPCC

Recommendations

On May 10th 2024, the CMIP7 solar forcing working group recommended the NRLSSI4 dataset as the official CMIP7 solar irradiance reference (with no averaging with other datasets as was done in CMIP6). The SATIRE model output will be an independent dataset used to estimate confidence intervals and will be included as an independent dataset for those who would like to test their climate models with a different forcing.

Key Focus Areas of Activity

As described above, solar irradiance is a key variable at the intersection of many science disciplines such as Earth and planetary science, solar and stellar science, and space weather. The following focus areas will guide the SIWG activities towards achieving its stated mission. These focus areas are specific to the SIWG and may differ from general extraterrestrial solar irradiance updates provided in Section

Focus Areas	**Approach**
Specify and understand solar irradiance and its variability using measurements and models	• understanding the absolute width and depth of specific solar lines, • investigating the consistency of observed versus modeled (from atomic line databases) solar lines • making new and/or improved limb darkening measurements, and • understanding solar irradiance variability as a function of active feature position and spectral resolution.
Define application-based requirements (absolute accuracy, spectral range and resolution, temporal variability) on solar irradiance	• tabulating current observational capabilities, • gathering application-based needs from the science disciplines, and • synthesizing those needs into solar irradiance requirements
Communicate recommendations to national and international scientific organizations	• Attend IRC and other large international meetings, • participate in working groups, • actively engage with the science community

The Japanese Space Agency (JAXA) GOSAT team will be providing their updated record of monthly solar calibration data at very high spectral resolution (0.1 cm-1) for our use in studying the variability in line width's and depths with solar activity (Focus Area 1). This will be an activity in 2024-2025 leading, potentially, to the development of an empirical very high-resolution solar variability model.

Additionally, initial progress has been made towards identifying/tabulating gaps in solar irradiance observational capabilities (Focus Area 2). We anticipate continued progress in 2024-2025 as our working group continues to acquire and synthesize applications-based needs on solar

irradiance from various science disciplines and as we continue to develop our presence within the International Radiation Commission.

Membership Roster

Our membership is drawn from the international community and reflects expertise in solar irradiance measurements & modeling, solar activity indices and proxies of solar activity, the development of solar reference spectra and the development of composite irradiance records.

Name	Affiliation	Country
Odele Coddington - Chair	University of Colorado and the Laboratory for Atmospheric and Space Physics (LASP, University of Colorado)	USA
Mustapha Meftah - co Chair	Laboratoire Atmosphères, Milieux, Observations Spatiales (LATMOS)	France
Wolfgang Finsterle	Physical Meteorological Observatory in Davos (PMOD)	Switzerland
Margit Haberreiter	Physical Meteorological Observatory in Davos (PMOD)	Switzerland
Natalie Krivova	Max Planck Institute for Solar System Research (MPS)	Germany
Judith Lean	Laboratory for Atmospheric and Space Physics (LASP, University of Colorado)	USA
Janet Machol	University of Colorado and the National Oceanic and Atmospheric Administration (NOAA)	USA
Erik Richard	University of Colorado and the Laboratory for Atmospheric and Space Physics (LASP, University of Colorado)	USA
Martin Snow	South African National Space Agency (SANSA)	South Africa
Mark Weber	University of Bremen	Germany
Peng Zhang	Director General, Meteorological Observation Center, China Meteorological Administration	China

General Extraterrestrial Solar Irradiance Updates for 2023-24

1. The Naval Research Laboratory (NRL) Solar Variability Models: New Climate Data Record, New Recommendation, and New Name – *by Odele Coddington*

The current operational version (version 2) of the NOAA NCEI Solar Irradiance CDR is version 2 of the Naval Research Laboratory (NRL) solar variability models, NRLTSI2 and NRLSSI2.

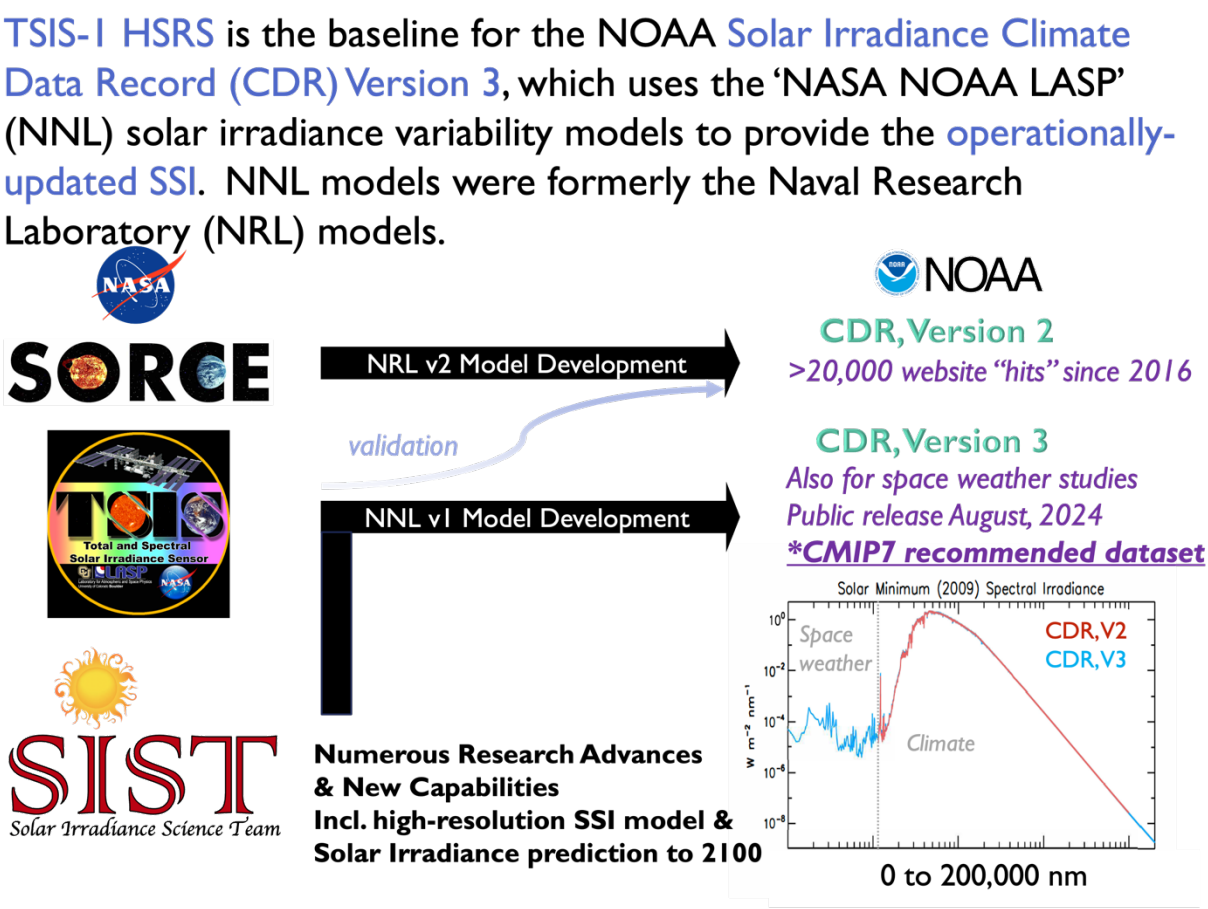
The NRL modelsare observation-based empirical models developed from space-based irradiance observations and proxies of solar magnetic activity (i.e., faculae and sunspots).

Version 3 of the NOAA/NCEI Solar Irradiance CDR will be released to the public in August 2024. The NASA NOAA LASP (NNL) solar variability models, Version 1, will prescribe the NOAA CDR V3. **The NNL solar variability models were previously known as the Naval Research Laboratory (NRL).** The new name was adopted to reflect the agency support and evolving heritage and operations of these solar irradiance variability models. (The NNL Version 1 models map to NRL Version 4

The numerous research advances embodied in v03r00 of the CDR relative to the (current) CDR v02r01 include:

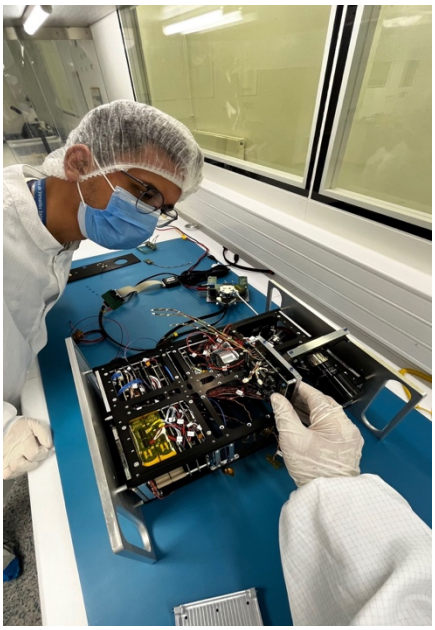
- an expanded spectral range from ~0 nm to 200,000 nm to provide SSI useful for the space weather, earth chemistry/climate and Sun-Earth system communities
- revised model coefficients derived at wavelengths longer than 115 nm from higher-quality TSIS-1 SSI observations and a longer record of SSI and TSI
- new model coefficients derived at wavelengths shorter than 115 nm from TIMED-SEE observations
- a new absolute irradiance scale for total and spectral irradiance based on TSIS-1 and the Compact TIM (CTIM) measurement records
- the determination of new bolometric facular and sunspot indices from the separate NOAA/GOES and NSF/GONG operational programs
- revised reconstructions of facular brightness, sunspot darkening and solar irradiance since the seventeenth century Maunder Minimum based on new, improved, magnetic flux transport calculations and a longer composite total solar irradiance record
- a new separate, high spectral resolution (0.1 to 0.5 nm) SSI product between 115 and 500 nm, that is numerically consistent with the standard SSI product in 1-nm bins
- updated TSI observational composite comprising SORCE, the TSI Continuity Transfer Experiment (TCTE), TSIS-1, and CTIM observations on the CTIM absolute irradiance scale
- updated modeled solar reference spectra for varying solar activity levels, including the Maunder Minimum period, based on the numerous advances summarized above.
- projections of solar irradiance to 2100.

On May 10th 2024, the CMIP7 solar forcing working group recommended the new NNLSSI1 (formerly known as NRLSSI4) dataset as the official CMIP7 solar irradiance reference (with no averaging with other datasets as was done in CMIP6). The SATIRE model output will be an independent dataset used to estimate confidence intervals and will be included as an independent dataset for those who would like to test their climate models with a different forcing.



2. New High-Resolution Solar Reference Spectrum for Disk-Integrated, Disk-Center, and Intermediate Cases – *by Mustapha Meftah*

A comprehensive set of high-resolution solar spectra, termed SOLAR-HRS, has been developed by normalizing solar line data to the absolute irradiance scale of the SOLAR-ISS reference spectrum. These spectra cover a wide wavelength range (0.5–4400 nm) with spectral resolutions ranging from 0.001 to 1 nm. Additionally, a new high-resolution solar spectrum at the disk-center has been introduced, spanning 650–4400 nm with resolutions of 0.001 to 0.02 nm. Further analysis includes spectra for ten solar view angles ranging from $\mu = 0.9$ to $\mu = 0.05$ (SOLAR-HRS intermediate cases). To complement these, Merged Parallelised Simplified ATLAS spectra (MPS-ATLAS) have been developed based on solar modeling with Kurucz and Vald3 solar linelists. The solar reference spectra used in this work are available online: https://cdsarc.cds.unistra.fr/viz-bin/cat/VI/159.



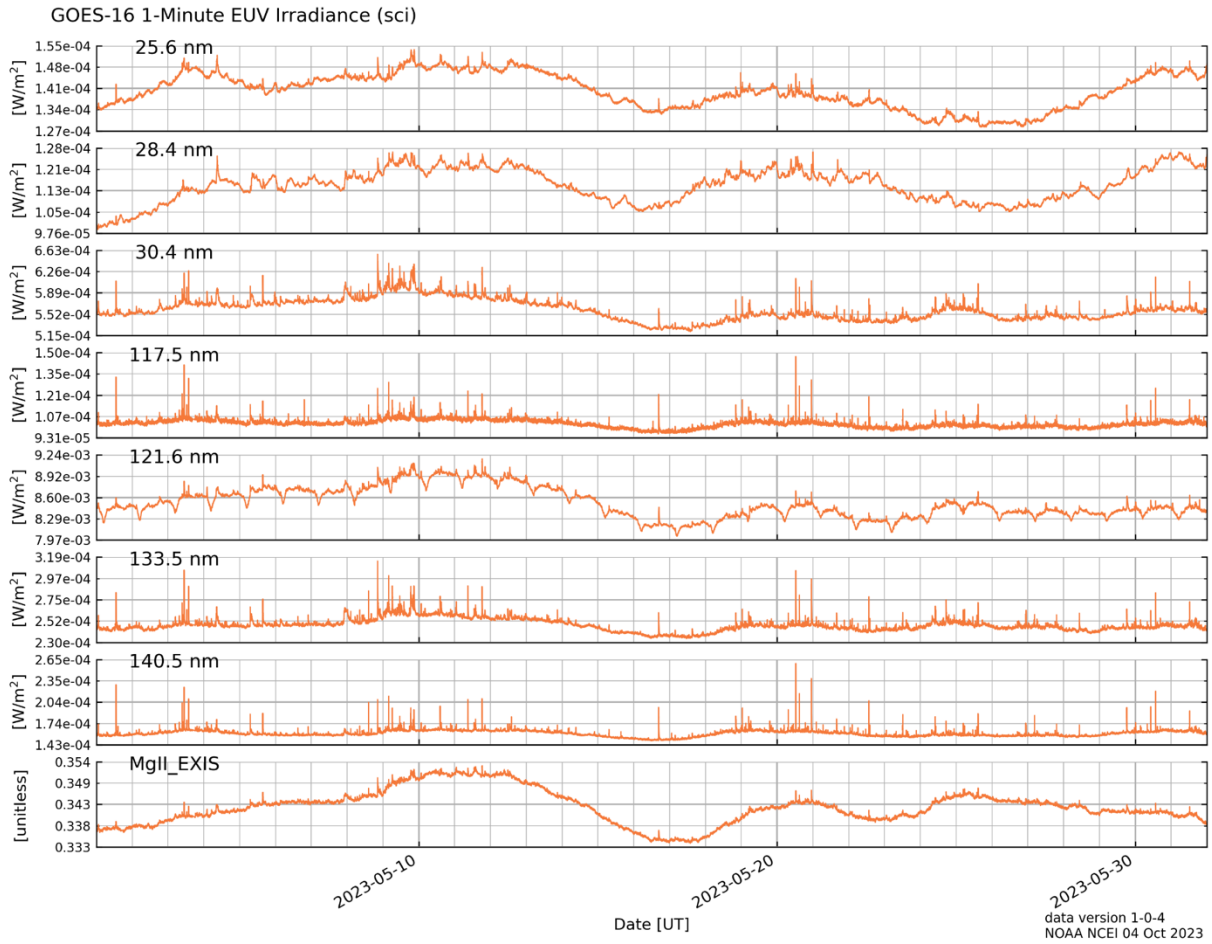
These advancements aim to support the MicroCarb space mission's objectives, particularly in measuring greenhouse gas emissions. Furthermore, this advancement will be used to calibrate (radiometric and wavelength-scale) a French 6-U CubeSat pathfinder development (Uvsq-Sat NG) for continuity of the broadband Earth radiation budget at coarse spatial resolution (2500 km) and for concentrations of atmospheric greenhouse gases derived from a near-infrared spectrometer (1200-2000 nm) at moderate spatial resolution (2-10 km). All solar data generated in this study are openly available for research and application purposes.

Photograph of the Uvsq-Sat NG development (March 2024).

3. New Science-Quality GOES EUV Solar Irradiance Data – *by Janet Machol*

In the past year, new science quality data versions of GOES satellite EUV data have been released for GOES-R (GOES-16 through -18) and for GOES-14 and -15. On the GOES-R series satellites, the EUVS instrument is part of the Extreme Ultraviolet and X-ray Irradiance Sensors (EXIS) instrument suite. EUVS measures extreme ultraviolet (EUV) and far ultraviolet (FUV) solar emission lines representative of different layers of the solar atmosphere. EUVS measures irradiance for seven solar lines (25.6, 30.4, 28.6, 117, 121, 131, and 140 nm) and the Mg II core-to-wing ratio (Mg II index). The data products include 30-s, 1-min, and daily averages of the solar lines and the Mg II index, as well as an empirically modelled EUV spectrum from 5 to 127 nm.

The GOES-R EUVS Level 1b (L1b) and Level 2 (L2) science-quality datasets begin in February 2017. The data is available as daily, yearly, and mission-length aggregations in netCDF format and is updated daily. Data, plots, documentation, and sample Python code are available from the 'Level 2 Data' tab at https://www.ngdc.noaa.gov/stp/satellite/goes-r.html. This release (L1b: Version 1.0.2, L2: Version 1.0.4) includes the first public data release of the GOES-18 EUVS data from NCEI.



For GOES-14 and -15, new (Version 5) science-quality Lyman alpha (121.6 nm) irradiances have been created that covers the full mission periods from 2009 to 2020. The file formats are similar to the GOES-R EUVS data.

We acknowledge many people on the EXIS teams at the University of Colorado CIRES and LASP for their work to produce this data. Data, plots, documentation, and sample Python code are available from the 'Level 2 Data' and 'GOES 1-15' tabs at https://www.ngdc.noaa.gov/stp/satellite/goes-r.html.

4. New Repository of Solar Proxy Records for Irradiance Reconstructions – *by Mark Weber*

The Mg II index, based on the wing-to-core ratio of the solar Mg II line at 280 nm, correlates well with ultraviolet solar spectral irradiance (SSI) variations and has been used for irradiance reconstruction, e.g. version 2 of the Naval Research Laboratory Solar Spectral Irradiance model (NRLSSI-2) that forms the NOAA/NCEI Solar Irradiance CDR V2. A Mg II index with minute time sampling is provided by the GOES-R series of satellites and, a TSIS-1 SIM Mg II product is under development with sub-daily sampling.

Another popular solar proxy is the ground-based radio solar fluxes. Since 2004, Space Weather Canada (https://www.spaceweather.gc.ca/forecast-prevision/solar-solaire/solarflux/sx-5-en.php/) has been providing daily updated F10.7 cm solar radio flux data. The F10.7 cm radio flux has a historical record dating back to 1947, and older data can be retrieved from the NOAA website.[1]

Solar fluxes at other radio wavelengths (e.g. F30 cm) have been measured daily from three radio polarimeters in Japan and are available from http://solar.nro.nao.ac.jp/norp/html/daily_flux.html.

As the Mg II index shows better correlations with UV SSI, the composite Mg II index has been extended back to 1947 by successive scaling (and gap-filling) the F30.7 cm flux and then F10.7 cm flux to the composite Mg II index data record.

To better serve solar proxy data to the public, a repository for several high-impact datasets has been developed at the University of Bremen (https://www.iup.uni-bremen.de/UVSAT/data/). Available from this website is: a daily updated composite Mg II index starting in 1978, assembled from many satellite observations; a combined F10.7 cm radio flux record from 1947 to today; a combined record from all three Japanese radio polarimeters can be obtained from https://www.iup.uni-bremen.de/UVSAT/data/, from 1951 until today.

5. The Total and Spectral solar Irradiance Sensors (TSIS-1) mission – by *Erik Richard*

The first implementation of NASA's *Total and Spectral Solar Irradiance Sensor* (TSIS-1) launched on December 15th, 2017 and was integrated on the International Space Station (ISS) to measure both the total solar irradiance (TSI) and the solar spectral irradiance (SSI). The direct measurement of the TSI and SSI are made by the LASP Total Irradiance Monitor (TIM) and Spectral Irradiance Monitor (SIM), respectively, and together provide data essential to interpreting how the Earth system responds to solar variability. The TSIS-1 mission completed its 5-year prime mission in March of 2023 and is now operating in extended mission.

A key objective of the TSIS-1 mission is to extend the solar irradiance data records of TSI and SSI variability from the SORCE mission. The TSIS-1 measurements cover a time-period that includes the last activity features of solar cycle 24 (SC24) and the early ascending phase of the onset of solar cycle 25 (SC25) with a solar minimum during late 2019. The TSIS-1 TIM measurements continue the 44-year record of continuous, overlapping observations with greatly improved absolute accuracy and stability. For the TSIS-1 SIM measurements, the SSI spectrum is found to have significant decreases by as much as 6% in IR irradiance (900 – 2400nm) in comparison to several previous published SSI reference spectra.

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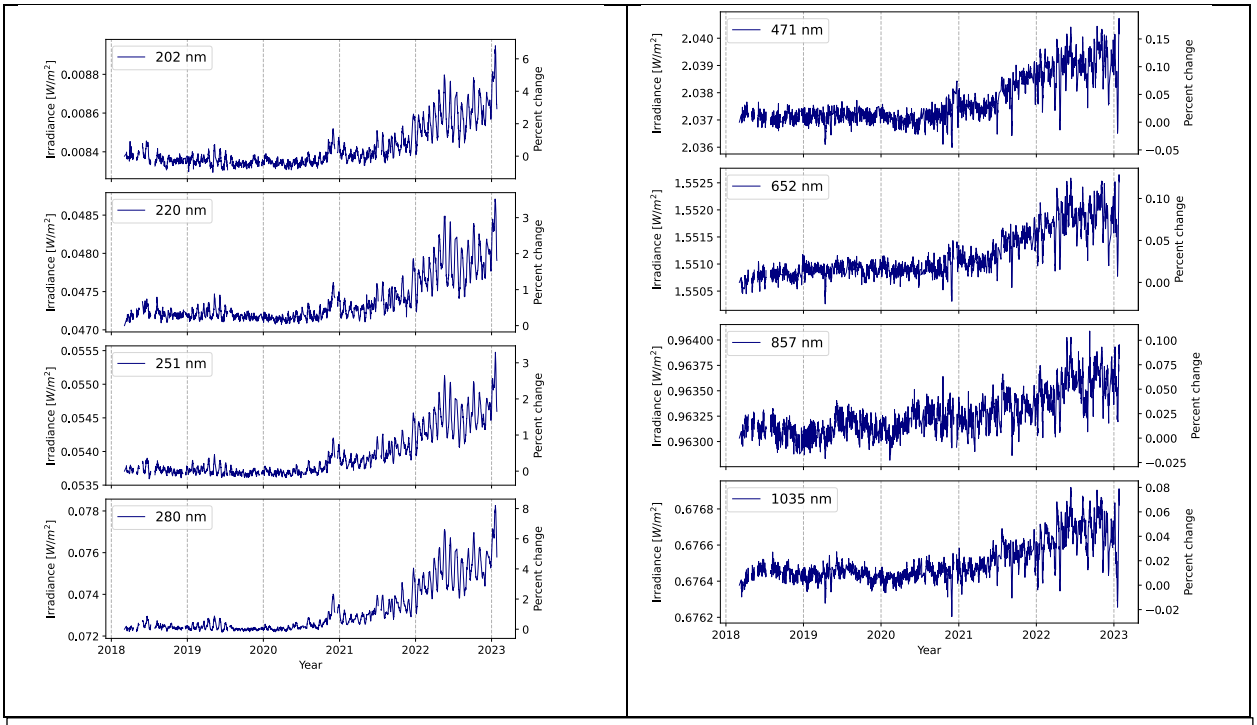
1 ftp://ftp.ngdc.noaa.gov/STP/space-weather/solar-data/solar-features/solar-radio/noontime-flux/penticton/penticton_adjusted/listings/listing_drao_noontime-flux-adjusted_daily.txt

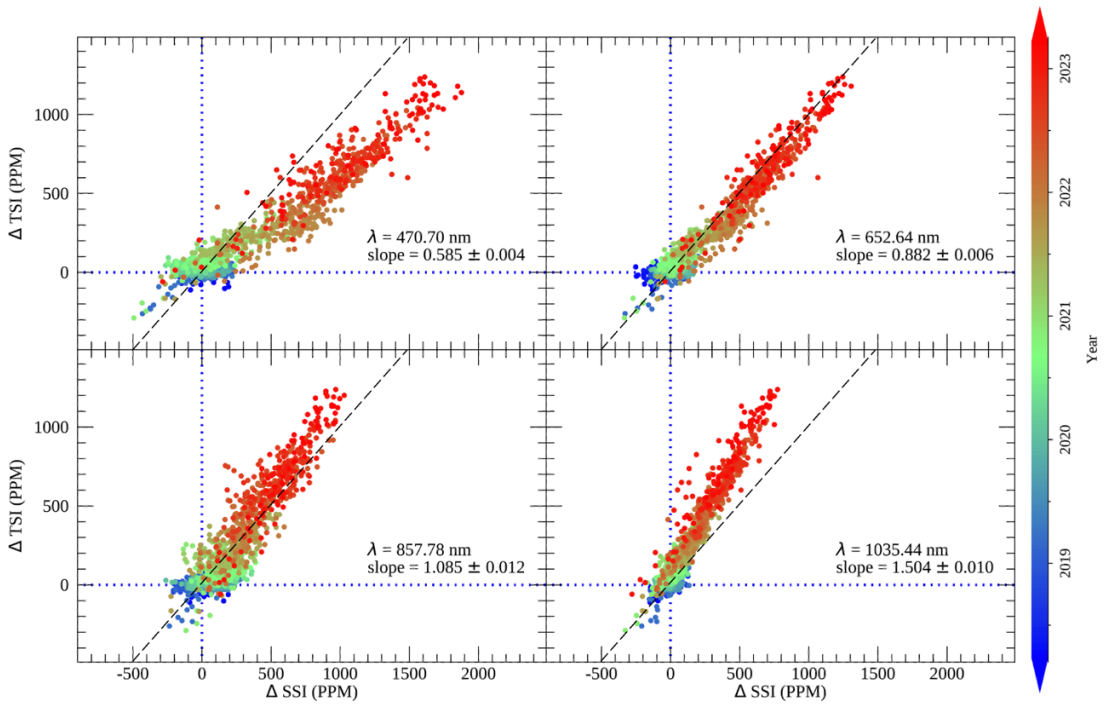
Additionally, the TSIS-1 SIM SSI observations over the 6+ years of operations has demonstrated improved long-term spectral stability with lower trend uncertainties. Moreover, the spectrally integrated SSI variability is highly consistent with the directly measured TSI variability with a long-term standard deviation of ~50 ppm difference over the mission. All wavelengths are shown to be in-phase with TSI variability within the measurement stability uncertainties, unlike



The TSIS-1 SIM (V10) time series is shown at selected wavelengths from the UV, the visible, and near IR over the first 5 years of the mission. Left axis shows the absolute irradiance and the right axis shows the relative change (in %) from the first day of operations (March 14, 2018).

previous SORCE SIM results in the visible and near IR during the declining phase of SC23. Specifically, the TSIS-1 SSI to TSI visible and near IR variability correlation plots (DTSI/DSSI) are nearly linear over the recent rise of SC25 showing an SSI variability near 470 nm ~70% greater than that of the TSI variability whereas in the near IR at 1035 nm the SSI variability is ~30% less than the TSI variability.

Ongoing active efforts and initial comparisons and of these new SSI observations to SSI model outcomes are providing validation opportunities during the onset of the current solar activity cycle. Both short-term (solar rotation) and longer-term (ascending phase of SC25) solar variability comparisons to the models shows overall good agreement but point to spectral differences between the models in both short-term UV active region contrasts and long-term infrared solar cycle irradiance increases.



Correlations between TSIS-1 TIM TSI and SIM SSI variability during the ascending phase of SC25 for selected visible and near IR wavelengths. All cases show strong, positive (i.e. in-phase) correlations against the TSI.

Data Product Summary (transfer to a table TBD)

- GOES-16 Mg II Index product is available at https://www.ngdc.noaa.gov/stp/satellite/goes-r.html
- GOES-16 EUVS data (7 EUV solar lines and a coarse modeled spectrum from 5-127 nm) is available from: https://www.ngdc.noaa.gov/stp/satellite/goes-r.html
- VIRGO solar irradiance data is available from: https://archives.esac.esa.int/doi/html/data/heliophysics/soho/VIRGO.html
- TSIS-1 SSI (from 200 - 2400 nm) is available from: https://lasp.colorado.edu/lisird/data/tsis_ssi_24hr/
- TSIS-1 TSI is available from: https://lasp.colorado.edu/lisird/data/tsis_tsi_24hr/
- SORCE TSI and SSI (from 115 nm to 2400 nm) is also available from LASP's LISIRD server: https://lasp.colorado.edu/lisird/
- SORCE SSI datasets (including high cadence Lyman alpha scans) are available from https://lasp.colorado.edu/sorce/data
- Final version of SORCE/SOLSTICE (V18) released (Snow et al. 2022)
- The TSIS-1 HSRS solar reference spectrum is available from https://lasp.colorado.edu/lisird/data/tsis1_hsrs
- The full-spectrum extension of the TSIS-1 HSRS (manuscript in preparation), spanning 115 nm to 200 microns is available by request (preliminary status acknowledged) from O. Coddington

- High-resolution extraterrestrial solar Reference Spectra (HRS) (http://doi.latmos.ipsl.fr/DOI_SOLAR_HRS.v1.1.html) and various new high-resolution solar reference spectra derived from this work are available from the VOSCAT portal.
    - the high resolution solar spectrum disk integrated (SOLAR-HRS Disk-Integrated Spectrum)
    - the high resolution solar spectrum at disk center (SOLAR-HRS Disk center)
    - the high resolution solar spectrum at solar positions (SOLAR-HRS Solar positions)
    - the high resolution solar spectrum Disk-Integrated at Air Mass 1.5 (SOLAR-HRS AM1.5)
    - the high resolution solar spectrum Disk-Integrated at Air Mass 1.5 (air) (SOLAR-HRS AM1.5 (air))
    - the high resolution solar spectrum ATLAS Kurucz model integrated disk (MPS-ATLAS-Kurucz Disk-Integrated Spectrum)
    - the high resolution solar spectrum ATLAS Kurucz model disk center (MPS-ATLAS-Kurucz Disk center)
    - the high resolution solar spectrum ATLAS Vald3 model integrated disk (MPS-ATLAS-Vald3 Disk-Integrated Spectrum)
    - the high resolution solar spectrum ATLAS Vald3 model disk center (MPS-ATLAS-Vald3 Disk center)
- High-resolution extraterrestrial solar reference spectra (SOLAR-HRS) for disk-integrated, disk-center, and intermediate cases : https://cdsarc.cds.unistra.fr/viz-bin/cat/VI/159.
- Daily-, monthly-, and annually-averaged modeled spectral irradiances are available from NOAA/NCEI at https://www.ncei.noaa.gov/products/climate-data-records/solar-spectral-irradiance. Similarly, for TSI at https://www.ncei.noaa.gov/products/climate-data-records/total-solar-irradiance
- Version 3 of the NRL model data is available by request from J. Lean and/or O. Coddington
- Spectral irradiance modelled with a semi-empirical SATIRE model is available at http://www2.mps.mpg.de/projects/sun-climate/data.html (Daily since 1610 and decadal since 6755 BCE)
- Daily spectral irradiance reconstruction since 1947 with an empirical EMPIRE model is available at: http://www2.mps.mpg.de/projects/sun-climate/data.html
- Daily physical reconstruction (that is without a calibration to the irradiance measurements) of the total solar irradiance since 2010 is available at: http://www2.mps.mpg.de/projects/sun-climate/data.html
- Reconstructed daily F10.7 flux since 1974 is available at http://www2.mps.mpg.de/projects/sun-climate/data.html
- New repository of solar proxies at the University of Bremen: https://www.iup.uni-bremen.de/UVSAT/data/
    - a daily updated composite Mg II index starting in 1978, assembled from many satellite observations
    - a combined F10.7 cm radio flux record from 1947 to today;
    - a combined record from all three Japanese radio polarimeters from 1951 until today.

- The high spectral resolution modelled irradiances (0.1 nm from 115 to 500 nm) is available by request from J. Lean and/or O. Coddington
- The COSI reference spectrum is available at 1-nm and high resolution is available on request from M. Haberreiter
- International Sunspot Number (ISN) v2.0 is available at the SILSO webpage: https://www.sidc.be/silso/datafiles
- Updated and revised composite of the daily, monthly and annual Group Sunspot Number since 1739 is available at: http://cdsarc.u-strasbg.fr/viz-bin/qcat?J/A+A/602/A69 and at http://www2.mps.mpg.de/projects/sun-climate/data.html
- Decadal sunspot number reconstructed from a composite of cosmogenic isotope data is available from: http://www2.mps.mpg.de/projects/sun-climate/data.html
- Composite of daily, monthly and annual plage area in the Ca II K line over 1892-2019 calculated after cross-calibration of Ca II K spectroheliograms and filtergrams from 38 observatories is available at http://www2.mps.mpg.de/projects/sun-climate/data.html

Major Conferences with SIWG Representation in 2023-24

International Radiation Symposium, Hangzhou, China, 17-21 June 2024: http://www.irs2024.org/irs2024/index.html?time=1717542125068

European Geophysical Union, Vienna, Austria, 14-19 April 2024: https://meetingorganizer.copernicus.org/EGU24/

XXXII IAU General Assembly, Cape Town, South Africa, 13-14 August 2024: https://sun.njit.edu/IAU_FM8/

IAU Symposium, Yerevan, Armenia, 21-25 August 2023: https://iaus365.sinp.msu.ru/

ICTP-SCOSTEP-ISWI Workshop on the Predictability of the Variable Solar-Terrestrial Coupling (PRESTO), Trieste, Italy, May 29-June 2, 2023: https://indico.ictp.it/event/10176/

23rd Sun-Climate Symposium, Flagstaff, AZ, 16-20 September 2023: https://lasp.colorado.edu/meetings/2023-sun-climate-symposium/

American Geophysical Union, San Francisco, CA, 11-15 December 2023: https://www.agu.org/fall-meeting

Seminars & Presentations

Case, T., S. Criscuoli, and O. Coddington (2023), Validating Solar atmosphere models using high spectral resolution, center-to-limb observations of solar Balmer lines, AAS, Albuquerque, NM, 4-8 June, 2023.

Coddington, O., and J. Lean (2023), The Magnitude and Variability of Extraterrestrial Solar Spectral Irradiance, AGU Annual Meeting, Dec 2023, *invited*.

Coddington, O., J. Lean, and E. Richard (2023), Solar Spectral Irradiance Variability in Solar Cycle 25 in Direct Observations and in a New, Improved Solar Variability Model, Sun-Climate Symposium, Flagstaff, AZ, Oct 16-20, 2023.

Coddington, O., J. Lean, E. Richard, and P. Pilewskie (2023), Empirical Studies of Faculae and Sunspot Contrasts Derived from the Direct TSIS-1 SIM Observations, IUGG, Berlin, Germany, July 2023.

De Vis, P., M. Bachman, R. d.L. Reyes, A. Howes, O. Coddington, and N. Fox (2023), Using the CEOS-WGCV recommended solar irradiance model: impacts and recommendations, CEOS-WGCV-IVOS subgroup, Oct. 2023

Kopp, G., O. Coddington, L. Floyd, B. Jha, J. Lean, L. Upton, and Y-M. Wang (2023), Historical Solar-Irradiance Reconstructions Based on Advective Flux Transport Model Simulations and Latest Sunspot Records, Sun-Climate Symposium, Flagstaff, AZ, Oct 16-20, 2023.

Richard, E, Overview of LASP/NASA Sun-Climate Missions and Research Projects, Sun-Climate Symposium, Flagstaff, AZ, Oct 16-20, 2023.

Richard, E., O. Coddington, D. Harber, et al. (2023), Solar Irradiance: seconds to centuries. Long-term Solar Spectral Irradiance Observations by the TSIS-1 Spectral Irradiance Monitor, EGU, Vienna, Austria 14-19 April 2024, *invited*.

Snow, M., S. Penton, S. Beland, O. Coddington, and D. Woodraska (2023), Validation of operational TSI using TSIS-1/SIM data, Sun-Climate Symposium, Flagstaff, AZ, Oct 16-20, 2023.

Woods, T., O. Coddington, S. Penton, and E. Richard (2023), Next-generation Irradiance Proxies using TSIS-1 Data, Sun-Climate Symposium, Flagstaff, AZ, Oct 16-20, 2023.

Relevant Publications

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