TSIS / SORCE News

Total & Spectral Solar Irradiance Sensor / Solar Radiation & Climate Experiment

April-June 2020

PI Changes for TSIS

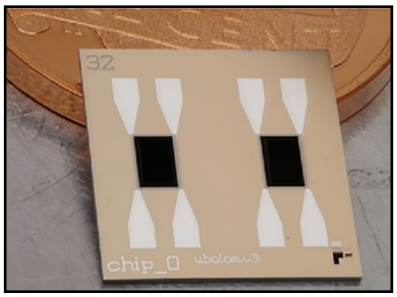
By Peter Pilewskie – LASP, University of Colorado

The TSIS-1 and TSIS-2 missions have made a few leadership changes recently. PI Peter Pilewskie is stepping aside to lead another exciting program (more on this below), and Tom Woods and Erik Richard are stepping in as TSIS-1 PI and TSIS-2 PI, respectively. Both Tom and Erik have always been TSIS team members and they are very familiar with the science, instruments, and management requirements. The transition will be extremely easy.

EVC-1 Libera

Peter Pilewskie has been awarded an exciting new mission in the Earth radiation research community. "Libera" (pronounced like "liberal", dropping the final "l" with stress on the first syllable) is CU/LASP's winning proposal submitted to NASA's Earth Venture Continuity (EVC) opportunity. The award is for a flight program, with a 78-month development phase, and a launch by December 2027. The Libera instrument will be hosted on NOAA's JPSS-3 spacecraft for a 5-year mission. Peter and LASP Project Manager Brian Boyle will be working with NIST, Ball Aerospace, Space Dynamics Lab, and a science team of experts in the field.

Libera will measure outgoing Earth radiation, a critical measurement that contributes to a long-standing Climate Data Record and an Earth-viewing analogue to LASP's SORCE and TSIS missions. The balance between incoming and outgoing radiation balance is a key factor in determining our climate: if Earth absorbs more radiative energy than it emits, it warms; if it emits more than it absorbs, it cools. Since 2003 LASP has been measuring the incoming side of the energy budget equation with its TSI measurements from SORCE, TCTE and now TSIS. Through Libera, we will soon be measuring the outgoing side of the equation.



Libera prototype detector shown with a penny. Libera utilizes advanced carbon nanotube detector technology developed by LASP and NIST over a number of IIP projects including BABAR ACT, CTIM-FD, CAESR, and CSIM-FD.

COVID-19 Impacts

By David Gathright and Tom Woods – LASP, University of Colorado

CU/LASP has been working remotely since March 18, except for "essential" personnel, who are required to be onsite for a specific task. Adjusting to COVID-19 conditions is new for everyone and the team has been quick to learn how to be productive and efficient in a remote working environment where communications and teamwork are significantly different. The situation has brought out the best in people, showing how adaptable and creative they can be.

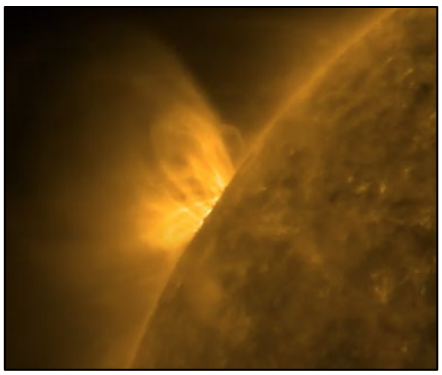
TSIS-1 operations have continued with minimal impacts as mission/science operations and data processing are mostly automated for easy remote access. TSIS-2 fabrication, assembly, and testing has been slightly impacted. TSIS-2 completed CDR in January and team members are actively working to get parts fabricated and ready for instrument and electronics box assembly. COVID-19 has affected both in-house and external parts production. For example, with the pandemic distancing requirements, it is necessary to coordinate schedules for people to come in to the lab to work serially instead of in parallel. This introduces delays and slows down activities such as assembly, inspection, and troubleshooting. One TSIS-2 activity that does not seem to have been impacted by the pandemic is the procurement of the host spacecraft. GSFC indicates that the S/C procurement process is proceeding and an announcement should be made in the coming weeks.

The SORCE science and data processing personnel are busy preparing the final data products and have had reviews of their updated Algorithm Theoretical Basis Documents (ATBDs). There is some delay in these preparations as related to the COVID-19 work isolation changes and to the delay of the SORCE passivation date in order to support the international Whole Heliosphere and Planetary Interactions (WHPI) campaign in January-February 2020.

Solar Cycle 25 Excitement

B Tom Woods – LASP, University of Colorado

Solar cycle 25 (SC-25) took off on May 29, 2020, with its first major flare for this solar cycle. While the solar X-ray intensity increased by a factor of 1000 for this M1.2 class flare, the flare increase in the TSI and visible is very small. Nonetheless, this major flare is a good indication that the Sun is waking up in preparation for an exciting SC-25!



The first major (class M1.2) flare of solar cycle 25 occurred on the Sun's east limb at about 7 UT on May 29, 2020. This is a solar extreme ultraviolet image of the flaring region from the SDO AIA instrument.

For solar data, visit the following websites:
TSIS-1: http://lasp.colorado.edu/home/tsis/data/
SORCE: http://lasp.colorado.edu/home/sorce/data/
GOES EXIS: https://www.ngdc.noaa.gov/stp/satellite/goes-r.html
TIMED SEE: http://lasp.colorado.edu/home/see/data/
SDO solar images: https://suntoday.lmsal.com/suntoday/

TSIS-1 SIM Instrument Paper

By Vanessa George and Erik Richard – LASP, University of Colorado

The TSIS-1 SIM team has just had a paper published describing the optical design and pre-flight calibrations for the TSIS-1 SIM instrument. This paper, titled "SI-traceable Spectral Irradiance Radiometric Characterization and Absolute Calibration of the TSIS-1 Spectral Irradiance Monitor (SIM)", was accepted for publishing in *Remote Sensing* as part of the Special Issue entitled 'The Needs and Path Toward an SI-Traceable Space-based Climate Observing System'.

Citation: Richard, E., D. Harber, O. Coddington, G. Drake, J. Rutkowski, M. Triplett, P. Pilewskie, and T. Woods (2020), SI-traceable Spectral Irradiance Radiometric Characterization and Absolute Calibration of the TSIS-1 Spectral Irradiance Monitor (SIM), *Remote Sens.,* 12, 1818.

Online at:
https://www.mdpi.com/2072-4292/12/11/1818/pdf.
https://www.mdpi.com/2072-4292/12/11/1818

Abstract: The current implementation for continuous, long-term solar spectral irradiance (SSI) monitoring is the Total and Spectral Solar Irradiance Sensor (TSIS-1) Spectral Irradiance Monitor (SIM) that began operations from the International Space Station (ISS) in March 2018 and nominally provides an SSI spectrum every 12 hours. Advances in both instrument design and spectral irradiance calibration techniques have resulted in the TSIS-1 SIM achieving higher absolute accuracy than its predecessor instrument in the wavelength range (200–2400 nm). A comprehensive detector-based Spectral Radiometer Facility (SRF) was developed in collaboration with the US National Institute for Standards and Technology (NIST) to ensure the ties to spectral SI standards in power and irradiance. Traceability is achieved via direct laser calibration of a focal plane electrical substitution radiometer (ESR) against a cryogenic radiometer in power and also irradiance responsivity via calibrated apertures. The SIM accuracy definition followed an absolute sensor approach based on a full radiometric measurement equation where component-level performance characterizations and calibrations were quantified with an associated uncertainty error budget and verified by independent measurements for each parameter. Unit-level characterizations were completed over the full operational envelope of external driving factors (e.g., pointing and temperature ranges) and were allowed for the independent parameterization of sub-assembly performance for expected operating conditions. Validation and final instrument end-to-end absolute calibration in the CU/LASP-SRF achieved low combined standard uncertainty (u_C<0.25%, k=1) in spectral irradiance.

TSIS-1 Data Releases

By Brandon Stone, Stéphane Béland, and Mike Chmbliss – LASP, University of Colorado

TIM – Version 03

Version 03 (V03) has recently been released, replacing V02. Calibration updates have decreased the measurements uncertainties and an updated servo gain calibration was implemented. The release notes are at: https://lasp.colorado.edu/home/tsis/data/tsi-data/tim-tsi-release-notes/.

Normal science operations continue and V03 of level2 and level3 products are being processed and published daily. Processing lags behind observations by 4 days to allow for telemetry gaps to be filled. Public release lags one additional day to ensure data quality.

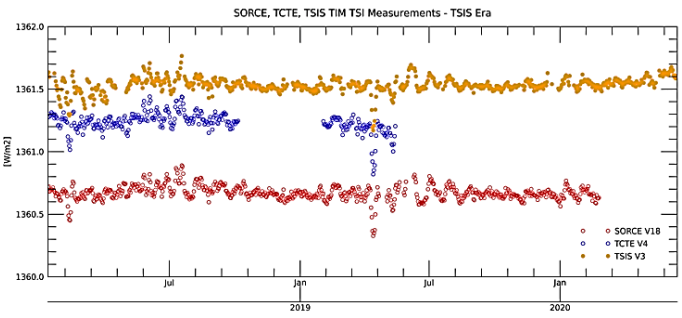
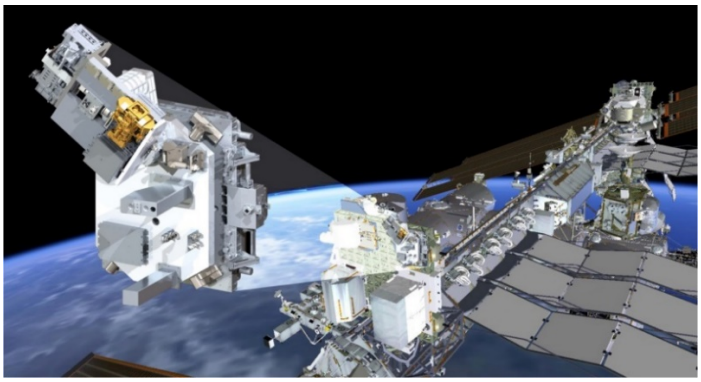


Fig. 1: Total Solar Irradiance as measured by SORCE, TCTE and TSIS-1 TIM instruments since the start of the TSIS-1 mission. The absolute TSI values are within each instrument's uncertainties.

The TSIS-1 TIM data availability is in order of 73% for 6-hour and 87% for the 24-hour data product for the whole

mission. With improved knowledge of ISS obstructions, the levels have been increased to 76% and 91% for each data products respectively since the start of 2020.

Current work is focused on adding support for a new data processing approach — DC Subtraction, an alternative to the current processing algorithm, Phase Sensitive Detection. DC Subtraction is being evaluated as a method to improve the inter-cavity consistency. The latest release includes updated non-equivalence ratio calibrations that were derived from an analysis of Level-2 data products that were processed utilizing DC Subtraction. Past, present and future TIM instruments will have the option of using either processing algorithm.



TSIS-1 highlighted from its position on the International Space Station.

SIM – Version 04

TSIS-SIM version 04 (V04) of the calibrated data was released on May 31, 2020. This version uses updated degradation corrections utilizing Channel C scans from early April 2020 and an improved Channel C degradation correction based on the amount of solar exposure on this reference channel (changes in irradiances from 0 to 350 ppm with the larger corrections in the UV). A small (+/- 70ppm) Doppler correction to the irradiance was also implemented in V04. The release notes are available at: http://lasp.colorado.edu/data/tsis/ssi_data/release_notes/TSIS_SIM_V04_Release_Notes.pdf.

Normal science operations continue and Level2 products are being generated daily with a latency of 3 days after observations. Level3 products and the public data text file are generated and uploaded after each new set of Channel B calibration scans. The new degradation method requires the full ESR cycle on Channel B increasing our lag time to nominally 25 days. The TSIS-1 SIM data is available at:

- LISIRD website: http://lasp.colorado.edu/lisird/data/tsis_ssi_24hr
- the TSIS website: http://lasp.colorado.edu/home/tsis/data/
- NASA DAAC https://disc.gsfc.nasa.gov/datasets/

The following figure represents the TSIS-1 SIM instrument time and wavelength coverage since the beginning of the mission. The data availability is in order of 75% for 12-hour and 81% for the 24-hour data product for the whole mission. With improved knowledge of ISS obstructions and updated observation plans, the levels have been increased to 84% and 90% for each data products respectively since the start of 2020.

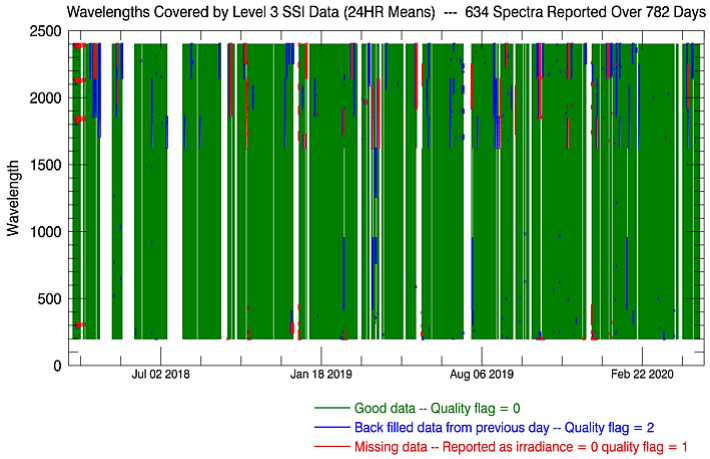


Fig. 2: TSIS-1 SIM time and wavelength data coverage since the start of the mission.

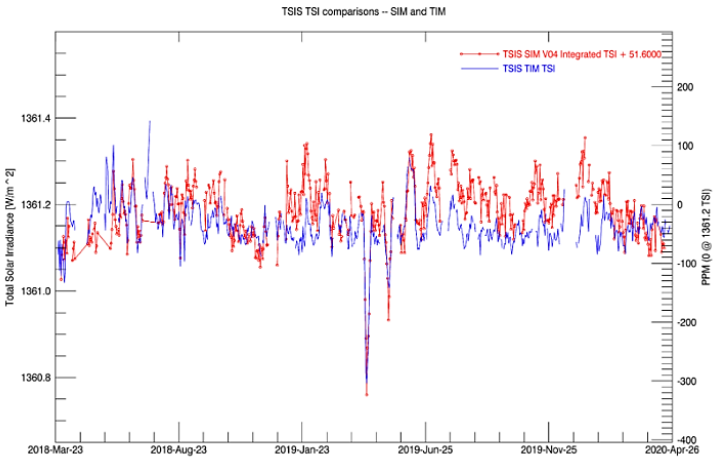


Fig. 3: TSIS-1 SIM Integrated SSI measurements (adjusted by 51.60 W/m^2) compared to TSIS-1 TIM measurements.

Current work in progress for version 05 includes:

- fleshing out more of the design for our python implementation of the degradation correction algorithm,
- implementing a residual temperature correction seen at the most extreme temperature ranges, and
- implementing a degradation correction which isn't so sensitive to the ESR measurement repeatability.

Recent SORCE Data Releases

By Stéphane Béland, Steven Penton, Joshua Elliott – LASP, University of Colorado

The latest SORCE datasets are available from the following sites:

- LISIRD website http://lasp.colorado.edu/lisird/sorce/
- SORCE website http://lasp.colorado.edu/home/sorce/data/
- NASA DAAC https://disc.gsfc.nasa.gov/datasets?keywords=SORCE&page=1

SIM – Version 26

SORCE SIM version 26 of the calibrated spectral irradiances was released in February 2020. A new algorithm to calculate the dark counts for the diodes was implemented, reducing the number of outliers. The prism degradation was updated over the whole mission with better filtering and fitting functions. Also, using the latest sets of full ESR scans, new diode degradation corrections were calculated and implemented. These had been extrapolated since February 2011. The complete set of release notes can be found at: https://lasp.colorado.edu/home/sorce/instruments/sim/sorce-sim-data-products-release-notes/.

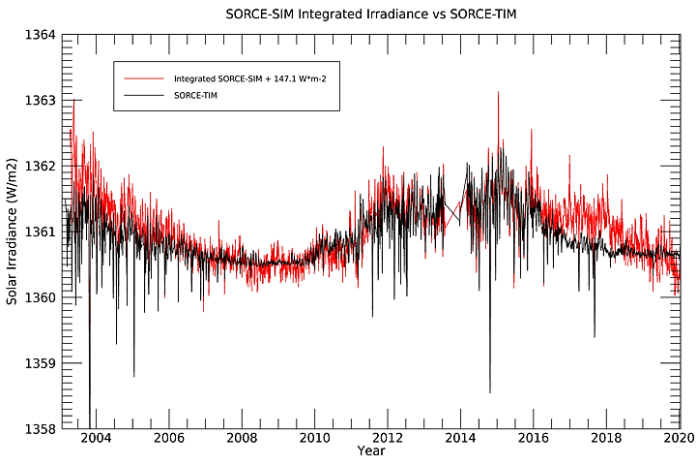


Fig. 4: Integrated SORCE-SIM v26 (UV+VIS+IR) compared to SORCE-TIM v18. The SIM values were adjusted by 147.1 W/m2 to align with the TIM measurements.

Current work focuses on an improved IR diode temperature correction and prism degradation correction.

SOLSTICE – Version 17

SORCE SOLSTICE Version 17 was released in January 2020. This version implements an updated Field-of-View degradation correction with an improved exposure-time based detector degradation. Different observation techniques were used at different times during the mission to measure the FOV map. These measurements were combined into a single continuous model.

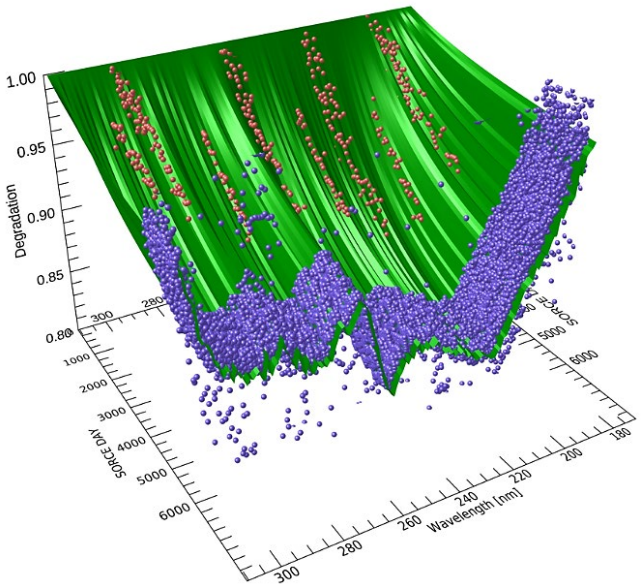


Fig. 5: SOLSTICE Haystack model (red points), Off-pointing (blue points), combined FOV model (green surface).

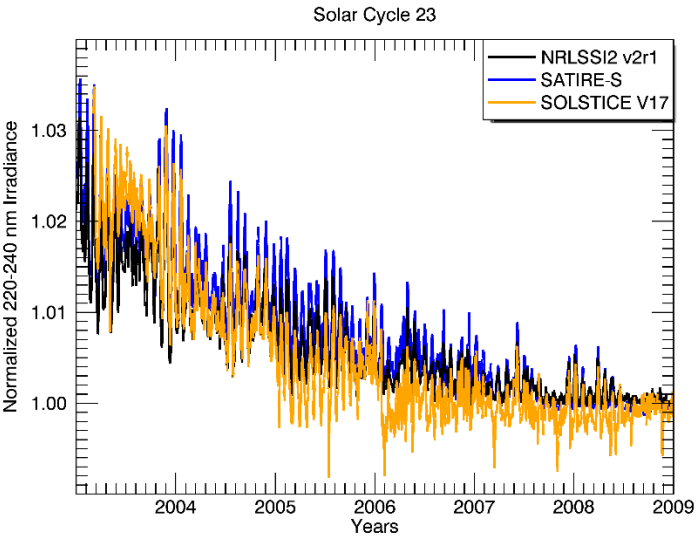


Fig. 6: Version 17 SOLSTICE data integrated from 220-240 nm compared to NRLSSI2 and SATIRE-S models. The new version of SOLSTICE is in much better agreement with the models than previous data versions. The main difference is the analysis of the recent SOLSTICE data as shown in Figure 5.

The release notes can be found at the following website: https://lasp.colorado.edu/home/sorce/instruments/solstice/solstice-data-product-release-notes/.

XPS – Version 12

Version 12 has recently been released for SORCE XPS Level 3 data products, replacing V11. There are several improvements in XPS Version 12 for the trending of the sensor dark and visible signals over the mission, as well as improved degradation corrections over the mission using the final in-flight calibration data with redundant channels in January-February 2020.

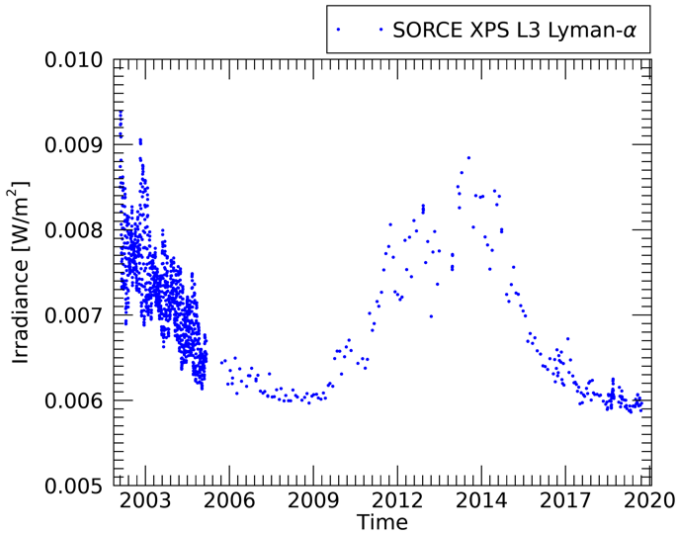


Fig. 7: SORCE XPS Lyman-alpha with improved degradation..

The final version for the XPS data archive will be Version 13 to include updated solar spectral models for the XPS Level 4 product. These XPS Version 12 data will be available soon from the SORCE data site at: https://lasp.colorado.edu/home/sorce/data/.

SORCE Phase F / Data Products

By Laura Sandoval – LASP, University of Colorado

Phase F data archiving activities are well underway for the SORCE mission. In the past couple months all instrument teams have held detailed reviews to discuss the final data products and updates for the processing algorithms and related revisions for instrument trends of dark signals and degradation. The process involves updating all instrument ATBDs (Algorithm Theoretical Basis Document) with a post-launch update. The original and the updated ATBD describe the scientific basis of the Level-1 processing algorithms used for each SORCE instrument for converting from the raw signals to solar irradiance products. This document represents an update to the pre-launch ATBD that was reviewed and published April 2000 and applies specifically to the algorithms developed and/or refined to support post-launch. The ATBD provides the scientific motivation and goal of the SORCE mission, a brief introduction to each instrument and a detailed discussion of the updated algorithms utilized in the production of scientific results since the original SORCE ATBD. The updated ATBD complements other individual instrument papers and other data information released with the SORCE data products.

Now that the SORCE instrument ATBDs have all been reviewed, the four SORCE instrument teams are making the updated algorithm changes before reprocessing is done in July. Those revised data products will then be validated and then will be archived at NASA's Goddard Earth Sciences Data and Information Services Center (GES DISC).

2020 REU Program Goes Virtual

By Marty Snow – LASP, University of Colorado

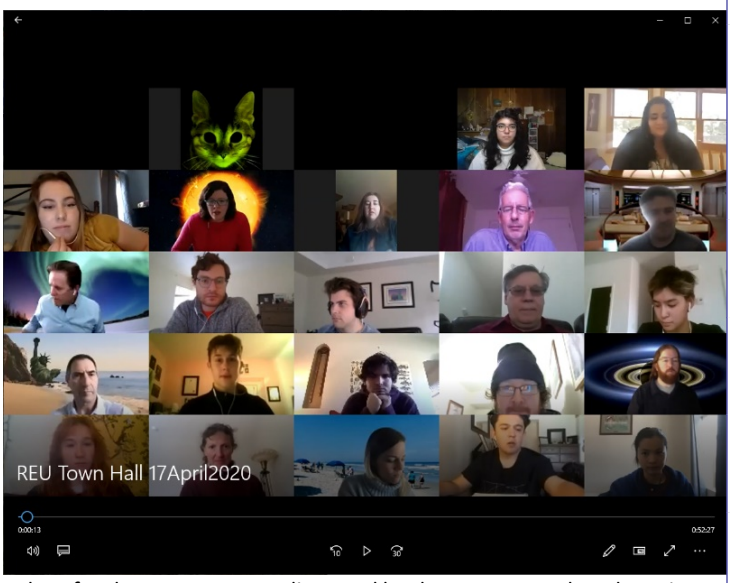
Safer-at-home orders have disrupted all campus events this year, and the LASP-led Research Experience for Undergraduates (REU) program is no different. After accepting 24 students to this year's program, we had to pivot and transform into a virtual research experience. LASP HR and our grant analyst have helped us overcome all the logistical issues of supporting so many new remote employees.

Colleen Everett (University of Southern Alabama) is working with Josh Elliott on combining data from SORCE SOLSTICE and CASSINI UVIS to determine if there is a spectral dependence in the ultraviolet phase curves of Saturn's rings.

Peter Breslin (Trinity College Dublin) is working with mentors Steve Penton and Stéphane Béland. The project, "*Time Analysis of the SORCE and TSIS SimilaritY*" (TASTY) will allow a statistical analysis of the SORCE SIM and TSIS SIM overlapping measurements.

Rudy Parra (Central New Mexico Community College) is working with Serena Criscuoli (NSO) and Marty Snow on analyzing the variability of H-alpha in the solar atmosphere.

Zoom will be used for group activities, lectures, and one-on-one mentoring. Students will be working from their individual locations, separated by many time zones. The mentors all agree that a virtual REU is better than no REU at all. But it's not all gloom and doom, we are taking advantage of the situation and inviting guest speakers from all over the country to participate. There will be the usual final talks, and we have some great ideas for the remote poster session! We hope that all interested scientists will get to join in the fun!



Plans for the summer were discussed by the mentors and students in a zoom Town Hall.

2020 AGU – Atmospheric Sciences

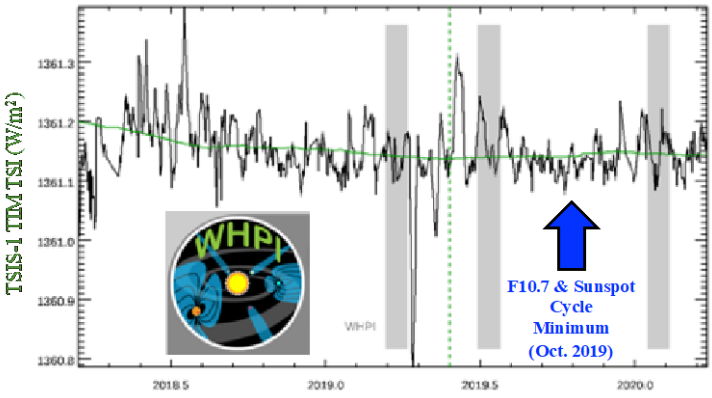
San Francisco, CA
Dec. 7-11, 2020
https://www.agu.org/Fall-Meeting
Abstract Due: July 29

Join us! TSIS and SORCE scientists have a session accepted for the 2020 Fall AGU Meeting, "Shaping the Future of Science." The format of this year's meeting in San Francisco, Dec. 10-14, is mostly virtual, but it promises to be just as interactive as previous years. We hope you will consider submitting an abstract to the following Atmospheric Sciences session:

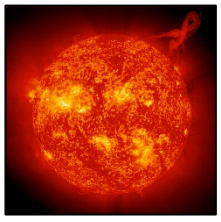
Sunset of SORCE, Sunrise of TSIS: sun-climate changes over two solar cycles

Conveners: Tom Woods (primary) and Odele Coddington, LASP/Univ. of Colorado; Jae Lee and Dong Wu, NASA/GSFC

Website:
https://agu.confex.com/agu/fm20/prelim.cgi/Session/103629



The solar cycle minimum for the solar variability indictors of the F10.7 and sunspot number appears to be in October 2019, whereas the TSI record from TSIS-1 TIM indicates a solar minimum earlier in 2019 for the 13-month smoothing (green line).



AGU Session Summary: The 11-year solar cycle is now heading into cycle 25, and the minimum between cycles 24 and 25 appears to have occurred in late 2019 – early 2020. The magnitude of the Sun's irradiance, the solar cycle 24 variations, and the long-term variations between this recent minimum and the last cycle minimum in 2008-2009, are key inputs for atmosphere and climate modeling, energy balance modeling, and remote sensing for NASA's Earth Observing System. The NASA Solar Radiation and Climate Experiment (SORCE) mission ended on February 25, 2020 after completing more than 17 years of excellent observations of the total solar irradiance (TSI) and spectral solar irradiance (SSI) between 1 nm and 2400 nm. The new NASA Total and Spectral solar Irradiance Sensor (TSIS-1) observations began in early 2018 to continue the four-decade-long TSI climate data record, as well as continuing the SSI 200-2400 nm climate data record that SORCE initiated for the 400-2400 nm range. These TSI and SSI measurements, as well as those from the NASA Ozone Monitoring Instrument (OMI) and a couple of European Space Agency missions, are crucial observations for understanding the variations during the past two solar cycles and for the potential discovery of any secular trending between the two cycle minima in 2008-2009 and 2019-2020. We solicit contributions on solar variability measurements, causes, and models and their contributions to Earth-climate studies.

Upcoming Meetings / Talks

With COVID-19 upon us, some of the meetings below are becoming virtual gatherings, postponed or canceled. TSIS/SORCE scientists are planning to present papers or attend the following 2020-2021 meetings/workshops:

2020-2021

AGU Fall Meeting, San Francisco, CA (or possibly virtual), Dec. 7-11, 2020
International Radiation Symposium (IRS), Thessaloniki, Greece – postponed to June 14-18, 2021
New Developments and Applications in Optical Radiometry (NEWRAD), Boulder, CO – postponed to June 28-July 1, 2021 (tentative)
SDO Science Workshop, Vancouver, Canada – postponed to June 28-July 2, 2021
Whole Heliosphere and Planetary Interactions (WHPI) Workshop, Boulder, CO – postponed to 2021, date TBD

ROSES-2020: B.5. Living With a Star Science

B.5 Living With a Star Science
Of note – Focused Science Topic #4:
Long Term Variability and Predictability of the Sun-Climate System (described in Sec. 5)
Deadlines: Step-1 due: Aug. 27, Step-2 due: Nov. 12

Happy Summer!