2020 Sun-Climate Symposium – Poster Abstracts

"What is the Quiet Sun and What are the Subsequent Climate Implications"

In alphabetical order (as of 20 January 2020):

Total Solar Irradiance Diverges from Sunspot Record during Solar Cycle Minima

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Total Solar Irradiance (TSI) reconstructions using sunspot area and facular brightening as predictors capture most TSI variability observed by satellites, and are used to estimate solar forcing since 1610 through sunspot count records. Interdecadal and longer timescale variability in TSI is difficult to constrain, however, due to two major sources of uncertainty. First, the stability of the satellite-derived TSI record is hampered by long-term drift due to instrumentation degradation, calibrations between up to 9 satellite records with varying instrumental configurations, and limited periods of overlap between observing missions. Second, TSI reconstructions using sunspot counts are susceptible to uncertainties in the sunspot record, as well as nonlinearity or nonstationarity in the sunspot-TSI relationship. We present a linear mixed-effects model framework to evaluate the degree to which sunspots are an accurate and stationary predictor of TSI. We explore the sunspot-TSI relationship between solar cycles using magnetic activity proxies, including solar radio flux and the Mg II index. This analysis provides an estimate of the inter-cycle variability of TSI during solar minima, which is relevant for exploring whether a grand minima of solar activity, such as the Maunder Minimum, maintains an accurate and stable sunspot-TSI relationship. An improved record of long-term solar forcing will help distinguish between internal variability and external forcing as sources of climate variability.

Detection of Explosive Events in SORCE-Calibrated IRIS Full-disk Mosaics

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The *Interface Region Imaging Spectrograph* (IRIS) is a high-resolution UV imaging spectrograph that takes monthly full-disk mosaics (FDMs) of six solar transition region (TR) spectral lines. We have calibrated these IRIS FDMs using spectral data from the *SOlar Stellar Irradiance Comparison Experiment* (SOLSTICE) which was launched as part of the *Solar Radiation and Climate Experiment* (SORCE). Objects of interest to us, known as explosive events (EEs), appear as suprathermal broadenings in TR emission line observations. If the disk-integrated signature of EEs in the wings of TR emission lines can be clearly separated from continuum and instrumental backgrounds, then it will open a window to comparing solar and stellar atmospheres in quiescent (non-flaring) conditions. EEs have been identified in the calibrated IRIS FDMs, and their contribution to the full-disk integrated spectrum of strong TR lines has been quantified. These spectra could be compared directly to Hubble Space Telescope (HST) spectra of Sun-like stars. This study is inspired by the NASA suborbital sounding rocket mission known as the *Full-sun Ultraviolet Rocket SpecTrometer* (FURST) that is being developed for launch in 2022. FURST will obtain the first high-resolution, high-quality VUV spectrum of the Sun as a star, which will have broad applications in climate and solar system sciences, as well as solar and stellar physics. The calibrated IRIS FDMs can be used to simulate a small set of spectral lines in the FURST passband, allowing us to gauge whether detection of EEs may be accomplished using FURST spectra.

Total Solar Irradiance and Photometric Indices during the Activity Minimum between Solar Cycles 23 and 24

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The minimum between Solar Cycles 23 and 24 has been the subject of a number of studies due to its long duration and number of spotless days. For this time period, we investigate the short-term temporal variability of the Total Solar Irradiance (TSI) from the Total Irradiance Monitor (TIM) on board the SOlar Radiation and Climate Experiment (SORCE) spacecraft, in comparison with the photometric indices derived from red and K-line images obtained on a daily basis at the San Fernando Observatory (SFO). We use an autoregressive gap-filling method to construct continuous series which can be analyzed via Fourier and wavelet spectral techniques in order to investigate the characteristics of the time signals on short temporal scales. Lomb-Scargle periodograms, which can handle time series with missing data, are used for comparison to ascertain that the gap-filling method does not affect the results. The cross-wavelet transforms between the TSI and the photometric indices signals are used to identify regions of high common power in the time-frequency maps. The wavelet transform coherence indicates local periods and times during which the photometric indices signals and TSI have significant coherence and phase locking, independent of the power. We find that variations in the TSI appear to be related to variations both in the photometric index ΣK, calculated from Ca II K-line photometric sums, and in the magnetic flux in the solar activity latitudinal band (as found in Benevolenskaya & Kostuchenko, 2013). This suggests that the TSI changes during the minimum are caused by the reduced line-blanketing effect of diffused magnetic field.

Short-term Solar Irradiance Variability as Observed by TSIS SIM

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The combination of the emergence and evolution of solar active regions with the 27-day solar rotation period axis alters the population of faculae and sunspots projected toward Earth and produces irradiance modulations. The irradiance modulations are wavelength-dependent because the relative influences of sunspots and faculae on solar irradiance change as a function of wavelength. For example, irradiance enhancements due to facular brightening dominate at wavelengths shorter than approximately 285 nm while variability at longer wavelengths has contributions from sunspots and faculae.

Since early 2018, the Total and Spectral Solar Irradiance Sensor (TSIS-1) mission has been making daily observations of solar spectral irradiance (SSI) from 200 nm to 2400 nm with the Spectral Irradiance Monitor (SIM). Technological advances of TSIS SIM, based on lessons learned from the heritage SIM instrument on the SOlar Radiation and Climate Experiment (SORCE) mission, provide a SSI dataset of higher precision, accuracy, and stability than previously attained.

In this work, we present the spectrum of the magnitude of short-term irradiance change observed by TSIS SIM as active regions rotated across the Sun's disk in April and May 2019. We compare the case study results to independent observations and to the Naval Research Laboratory solar spectral irradiance model, NRLSSI2. We discuss prospects for future model improvements and validation based on the TSIS SIM observations, particularly as solar activity begins to rise with the next cycle.

Progress toward the Next Generation Solar Irradiance Variability Models

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Advances in specifying and modeling solar irradiance variability achieved by the NASA Solar Irradiance Science Team (SIST) during 2015-2018 (i.e. during the SIST-1 program) are being utilized in the construction of the next generation of solar irradiance variability models as part of the SIST-2 program. The next generation models will have enhanced community and operational utility and will ultimately be transitioned to a new version of the NOAA National Centers for Environmental Information Solar Irradiance Climate Data Record.

Enhanced operational utility and model reliability will be achieved through incorporating operational, GOES-16 Mg II index observations as the facular brightening model input and through improved calibration of the USAF/SOON sunspot area record used as the sunspot darkening model input. Operational utility and model reliability is also being enhanced with new spectral irradiance modeling capabilities that utilize model indices derived from the observed total solar irradiance record. Concurrently, a high spectral resolution model of 0.1 nm in the 115 nm to 500 nm spectral range is being developed to complement the current 1-nm resolution models spanning 115 to 100 μm. Higher spectral resolution models will have enhanced utility for the radiative transfer modeling and remote sensing science communities.

We present the progress of this SIST-2 team's efforts in constructing the next-generation solar irradiance variability models.

Analysis of Photometric Images of the Quiet Sun during Solar Minimum

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The variation in the Total Solar Irradiance (TSI) has been shown by spacecraft experiments to follow the solar activity cycle, with maximum irradiance at times of maximum activity. Full-disk multi-wavelength photometry at the San Fernando Observatory (SFO) correlates well with the TSI variation, producing correlation coefficients of 0.95 or higher. Several solar indices are based on magnetic features, mainly sunspots and faculae, and the correlations assume a non-varying quiet Sun over the entire solar cycle. Just as space-based instruments and related data collection are continually re-examined to ensure their reliability and accuracy, so are the SFO instruments and algorithms in order to ensure we build the most accurate data set we can. When identifying solar features on SFO images, where small-scale brightness fluctuations are used to set limits on the detection of faint solar features, it's important to understand the extent of introduced noise. Here, we investigate the background quiet Sun, in a statistical manner, at cycle minima, in order to better characterize the background noise, both solar and instrumental, in SFO images.

The SoSWEET-SOUP (SOlar, Space Weather Extreme EvenTs and Stratospheric Ozone Ultimate Profiles) Constellation Mission

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SoSWEET-SOUP is an innovative small satellites constellation which aims to measure on complementary platforms the solar influence on climate and the Earth radiation budget, with a particular focus on UV spectrum and ozone layer, which are most sensitive to solar variability. Another major scientific and operational objective is Space Weather extreme events detection in Lyman Alpha, 3 orders of magnitude more sensitive than H Alpha and with high resolution and contrast (> to He II 304). Previsions are possible hours in advance (flux rope deformation). The mission combine the scientific advantages of associating a constellation of 12 nanosatellites (20-30 kg, 12 to 24 "U") on equatorial orbits (+/- 20°) to a small polar satellite of 100-120 kg on a OneWeb Arrow like platform for an almost continuous solar viewing (including arctic and antarctic regions).

SoSWEET-SOUP model payload definition is still open but will include, on the polar satellite, SUAVE (Solar Ultraviolet Advanced Variability Experiment), an optimized heavy-duty thermally stable SiC telescope for FUV (Lyman-Alpha) and MUV (200–220 nm) imaging (sources of variability, extreme events), and SOLSIM (SOLar Spectral Irradiance Monitor), a newly designed UV double-monochromator covering 170-340 nm with 0.65 nm resolution. Other instruments may include another SSI instrument (C-SIM or C-SOL declination for absolute intercalibrations), a small coronagraph, new UVC detectors (for Herzberg continuum), ozone radiometers, Earth radiative budget, Electron-Proton detectors and vector magnetometer. Constellation satellites include: precise ozone profiles (miniGOMOS with dual Sun and stars occultations), temperature and detailed energy radiative budget monitors (miniSCARAB evolved type). Science objectives, mission profiles and payload (insisting on SSI) will be presented and opportunities of missions and potential collaborations discussed.

Evaluation of "Quiet Sun" Trends in SSI Observations

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Determination of possible multi-decadal trends in solar spectral irradiance (SSI) is challenging. Activity levels during solar maximum vary significantly between cycles, so solar minimum observations must be compared to evaluate possible changes in "quiet Sun" irradiance. Any single instrument must have a sufficiently long lifetime (10+ years) and the appropriate phasing in order to observe two consecutive solar minima. The required long-term characterization accuracy needed to identify possible minimum-to-minimum changes that may be only 5-10% of solar cycle amplitude is stringent, particularly at wavelengths longward of ~300 nm. Assessment of possible quiet Sun SSI changes over two or more solar cycles requires the use of multiple instruments, which introduces the additional complexity of combining these data sets into a single composite product. We present results from individual instruments that have made SSI observations over two solar minima [NOAA-9 SBUV/2, SORCE SOLSTICE, SORCE SIM, Aura OMI], as well as results from the GSFCSSI2 composite SSI data product that covers four solar minima.

Understanding the Sources of Variability in the MgII Index

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The solar MgII core-to-wing ratio has been a well-studied proxy for chromospheric activity since 1978 but spatially resolved MgII spectra were very limited until the launch of the Interface Region Imaging Spectrohraph (IRIS). IRIS provides high-spectral and spatial resolution spectra of the MgII h and k lines on a daily basis. Full-disk mosaics have been acquired approximately once a month since September 2013. This large dataset, which spans from solar maximum to solar minimum conditions, allows us to get new insight on the sources of variability in the disk-integrated MgII irradiance data.

We used the IRIS data, in combination with HMI and AIA data, to classify spectra in different magnetic structures, from sunspots to active network to quiet Sun. We present examples of how the MgII profiles vary as a function of magnetic flux and disk position and provide some preliminary thoughts on how the Mg II profile variation impacts on the Mg II index. We focus, in particular, on the magnetic regions found on the Sun during quiescent conditions: network, intra-network, filaments, and coronal holes.

A Dissipation of Solar Transition Region Network Cells as a Proxy of Activity Decrease

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Solar EUV He II (30.4 nm) network scale variations are analyzed and compared to the changes of concentration of spotless days for 1996 – 2019. Transition Region (TR) network scale variations are determined using spatial power spectra of SOHO/EIT and SDO/AIA images. These spectra show some dissipation of the mid-size EUV network scale compared to the spectra for Solar Cycle 22/23 minimum. The rate of dissipation for 2010 – 2018 does not follow the AIA instrumental degradation and is caused by solar changes within the TR. A comparison of groups of continuous spotless days during 1996, 2008-09, and 2019 with the same time interval around activity minima demonstrates some larger concentration of extended spotless groups toward the end of 2019, which is consistent with the changes of the EUV network scale. Spatial power spectra which could be calculated a number of years before expected solar minimum would provide a proxy of activity decrease in addition to the other methods predicting solar cycle activity and upcoming solar minimum.

Eigenspectra of Active Region Long-period Oscillations Obtained using the Image Processing Moment Method

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The long-period (≥ 2 hour) oscillations of the active regions (ARs) have been studied. The investigation is based on an analysis of time series built from SDO/HMI magnetograms, and represents the case study of several typically structured ARs. The time series of AR characteristic parameters have been measured and recorded by using the image moment calculation method. Three different method of spectral analysis were applied: analysis of fft spectra; analysis of rebinned fft spectra; and analysis of combination of fft of autocorrelation function and fitting of sine functions to the time series. The Gaussian apodization and zero padding were used to the data sets. The data processing and analysis showed that there are some sequences of periods that may give the spectra which can have a signature of standing oscillations.

The Latest SORCE SOLSTICE Calibrations and Data Products

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We present the latest data products for the SOLar STellar Irradiance Comparison Experiment (SOLSTICE) onboard the Solar Radiation & Climate Experiment (SORCE) spacecraft. SORCE SOLSTICE provides a long-term record of the Solar Spectral Irradiance (SSI) of our home star. SOLSTICE measures the FUV and MUV portions of the solar spectrum of our home star.

Updates to the SOLSTICE degradation correction will be discussed as well as updates to the uncertainty calculation for the higher-level (SSI) data products. The improved degradation correction utilizes special off-pointed spectra collected in recent years in order to better understand the degradation as a function of wavelength. These measurements are then compared to degradation measurements taken earlier in the mission to create a model for instrument degradation for the entire mission dataset.

The Latest SORCE XUV Photometer System (XPS) Calibrations and Data Products

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We present the latest data products for the XUV Photometer System (XPS) instrument on board the SOlar Radiation and Climate Experiment (SORCE) spacecraft. SORCE XPS provides a long-term record of the solar soft X-ray (0.1-40 nm) output of our home star. We present updated calibrations and data products for the entire mission.

We will present updated dark-count and visible-light-count models which are time and temperature dependent and allow us to extrapolate these values when such measurements are unavailable. This is needed due to changes in instrument operations that have occurred during the mission which limit our ability to collect dark and visible counts to only once per week, rather than for every observation as was previously done earlier in the mission.

In addition, recent special experiments conducted in 2019 allow the instrument to collect data from its full set of diodes and filter-wheel positions, which had not been done since late 2005 due to a filter-wheel anomaly that occurred at the time. The results from these experiments can be used for long term trending analysis of the instrument and improved data products.

Results from the Pre-Launch Calibration of DARA for JTSIM

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DARA for JTSIM is a TSI radiometer that will fly on the Chinese Meteorological Administration's upcoming FY-3E mission alongside the Chinese-built TSI radiometer SIAR. We present the results from the calibration campaign of DARA, which includes laboratory experiments at PMOD/WRC as well as outdoor calibration of the DARA against the World Radiometric Reference (WRR) with the Sun as a source. DARA and SIAR were also cross-calibrated during ground-testing at Lijiang, China.

Identifying Events with Time Lag between Change in Total Solar Irradiance and Sunspot Area

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The Total Solar Irradiance (TSI) of the sun is the quantity of radiant energy that the Earth receives from the Sun. Classically known as the solar constant, this value has been proved not to be constant but rather to fluctuate with solar activities and solar events. These events correspond to changes in the sunspot area as well. However, these changes are not always consistent in time with the changes in the brightness of the Sun, TSI. Fifteen cases of large solar events (change in TSI greater than 1 w/m^2) between 2010 and 2015 were identified and analyzed with SOlar Radiation and Climate Experiment (SORCE) measured TSI and Solar Dynamics Observatory (SDO) measured sunspot area. Out of the 15 identified cases, five appeared to have the TSI changes leading by one or more days. To confirm this relationship, the cross-correlation coefficient was calculated for all 15 events as well. This value was found by offsetting the data of the sunspot area from five days behind to five days ahead. In addition to the sunspot area, three other values were compared to TSI. These variables were Helioseismic and Magnetic Imager (HMI) Active Region Patch (HARP) regions, umbra and penumbra magnetic area, and HMI median intensity in the visible continuum. Out of the four variables, the sunspot area and HMI intensity were the most consistent with the changes in TSI, while both cases of magnetic area had a wider spread of correlation coefficients. Further work will be needed to be done to expand the data set of large solar events and to explain why some large events have this lag and others do not.

New Historical TSI Reconstructions Based on the Revised 400-Year Sunspot Record

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The four-decade-long total solar irradiance (TSI) space-borne measurement record is extended to historical times for long-term solar-variability and Earth-climate studies via solar models incorporating the 400-year-long series of sunspot measurements. Those sunspot records were recently revised using updated multi-observer composite-creation methods and newly-recovered measurement records from various observers. These revisions, the Sunspot Indices and Long-term Solar Observations (SILSO) V2.0 sunspot-nu mber and a new group-sunspot-number composite, were released in 2015. Since the solar-irradiance models rely on the sunspot records for their historical reconstructions, the sunspot-record revisions affect the TSI reconstructions. Preliminary estimates of these effects for the two most prominent TSI models, the Naval Research Laboratory TSI (NRLTSI) model and the Spectral And Total Irradiance REconstructions (SATIRE) model, were described by Kopp *et al*. (*Solar Physics*, Vol. **291**, 2016). Wu *et al*. refined the SATIRE historical reconstruction (*A&A* 2018) and similar efforts are underway for the NRLTSI model by a NASA Solar Irradiance Science Team (SIST). These TSI model refinements depend on new calculations of flux emergence and transport based on the updated sunspot-number records. The NRLTSI model improvements will incorporate results from the Advective Flux Transport (AFT) model (Upton and Hathaway, *Ap.J*. **780**, 2014). We present here this SIST team's efforts to continue updates to the spaceborne-era TSI composite and extend it backward in time via refined historical TSI reconstructions based on the revised sunspot records.

LISIRD: An Online Resource for Making Solar Data More Accessible

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Finding quality solar data can be difficult, and getting the data in a format that you can analyze can be even more cumbersome. The LASP Interactive Solar IRradiance Datacenter (LISIRD), http://lasp.colorado.edu/lisird/, seeks to eliminate these burdens. LISIRD is a website where researchers can discover, visualize, and download solar data from a variety of space missions, instruments, models, and laboratories. LISIRD seeks to empower solar researchers by making solar data openly available and easy to analyze through an intuitive user interface, detailed metadata, interactive plotting capabilities, numerous download customization options, and a catalog of over 75 datasets.

I will demonstrate the key features of LISIRD, provide details on the datasets it serves, outline plans for improvement and growth, and discuss how it can be used as a valuable resource in your work.

SALSA: Solar Applied pLanetary dataSet cAlibration

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Solar Applied pLanetary dataSet cAlibration, or SALSA, is a python tool that calibrates solar irradiance from NASA's Solar Radiation Climate Experiment (SORCE) corresponding to a spectral dataset provided by the user. Solar irradiance is measured at or around the Earth so when observations are taken of another body in the solar system, this data has to be calibrated such that the solar data is corrected for the distance and position of the object being observed. Only after the solar irradiance is calibrated accordingly can measurements and analyses be done on the planetary spectra; measurements such as surface reflectance and atmospheric or surface compositions. Correcting spectral data of objects in the solar system is something a majority of planetary scientist have to do, and a coherent tool to perform these necessary calibrations does not yet exist in this way. SALSA is designed to allow planetary scientists to input their spectra of a planet or moon and it will produce a number of results. The package performs geometrical calculations, automatic data querying, kernel manipulation, point-spread function convolutions, and spectral calibrations. The program also has implemented tests and produces plots and uncertainties.

The GOES-R Extreme Ultraviolet and X-ray Irradiance Sensors (EXIS)

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This presentation will describe the measurements and data products from the GOES-R series Extreme Ultraviolet and X-ray Irradiance Sensors (EXIS). It will also discuss ways in which SORCE SOLSTICE has been key in ultraviolet calibrations for GOES satellites. The first two (of four) GOES-R satellites launched in 2016 and 2019. The EXIS Extreme Ultraviolet Sensor (EUVS) measures irradiances for 7 solar lines and Mg II. EUVS products include irradiances and a solar spectral model from 5-127 nm. The EXIS X-ray Sensor (XRS) measures the two traditional GOES XRS bands that have been measured since 1974 but the flux calibrations for the new and earlier GOES satellites have been recently revised.

Response of Polar Mesospheric Clouds to the 11-Year Solar Cycle

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The response of the polar mesosphere to the 11-year solar cycle is investigated using satellite observations from 1979 – 2018 and modeling runs from WACCM-PMC. The occurrence and density of Polar Mesospheric Clouds (PMC), which occur in the cold summer polar mesopause, are controlled by the local temperature and water vapor. Solar maximum is expected to cause higher temperatures and lower water vapor in the upper mesosphere, thus reducing the amount of ice PMCs. The long record from SBUV observations of PMCs have suggested that the ice clouds respond to the solar cycle. While PMCs showed a clear anti-correlation with the solar cycle before roughly 2002, this response is curiously absent during recent years. The observations imply that the main cause of the diminished solar cycle in PMCs near 68°S and 68°N appears to be a dramatic suppression of the solar cycle response of water vapor. The solar cycle response of temperature also decreases after 2002, but observations show that the decreased H2O response had more than three times the impact on PMCs than the reduction in temperature response. Attribution studies from the WACCM-PMC model help to understand why the solar cycle response in PMCs in the recent 16 years appears to have gone away.

Quantification and Effects of Diode Detector Degradation in the SORCE SIM Instrument

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Degradation of the diode detectors in the SORCE SIM instrument due to cumulative solar exposure represents a significant portion of the total degradation experienced by SIM. Quantifying and correcting the effects of this diode degradation is essential for producing a consistent, long-term solar irradiance data record. This degradation is calculated by comparing diode irradiance to irradiance measured by the ESR detector, which does not degrade on orbit. In this comparison, we assume the same prism degradation for both the diode and ESR. Once the prism degradation is corrected, the residual difference between the diode and ESR is attributed to the diode degradation.

The ESR data for this comparison is obtained via a special observing activity called an ESR full scan. During the primary mission of SORCE, these full scans were taken regularly. When day-only operations began, full scans were not taken. We obtained new ESR full scan data in December 2018 and June 2019. Using this new full scan data, the diode degradation correction has been recalculated for SIM Version 26 data. This new diode degradation correction removes incorrect trends from previous versions of the SIM data and represents an improved understanding of the ESR-diode comparison algorithm.

Additional ESR full scan observations are planned for December 2019. This new data will be used for recalculation of the diode degradation correction for Version 27 of the SORCE SIM data, to be released in 2020.

VUV Line Profiles of Sun as a Star from SUMER

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We are analyzing full disk scans of VUV emission lines from SUMER onboard SOHO. With this data, we are trying to find explosive events to see how they affect the overall spectrum of the Sun. The explosive events generally have broadened spectra corresponding to Doppler shifts of ~100km/s. We expect that this will lead to broadening of the spectral line wings in the full disk spectra. We also want to see the changes in line profile as we go from center to limb of the Sun. This analysis is especially helpful in light of the planned launch of Full-sun Ultraviolet Rocket SpecTrometer (FURST), in 2022. FURST is a sounding rocket spectrometer that aims to obtain full disk spectra of the Sun in VUV in high resolution. With SUMER data we want to have an idea about what FURST is going to see when it launches.

SORCE Solar Spectral Irradiance Monitor Data Release V26, and a Look Forward to V27

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The Spectral Irradiance Monitor (SIM) onboard the Solar Radiation and Climate Experiment (SORCE) mission has been taking daily Solar Spectral Irradiance (SSI) measurements from low-Earth orbit (400 miles) since April 2003. We present the latest data release from SORCE-SIM, focusing on the improvements in the new Version 26 (V26) data release.

V26 of the SORCE-SIM data release includes enhancements to the detector background calculation, VIS diode degradation corrections, CCD shift calculations, UV and VIS prism degradation enhancements, and improved UV/VIS gap coverage calibration. Additional discontinuous changes in instrument responsivity at safe-hold boundaries (aka, "jump") corrections have been added to compensate for spacecraft aberrations since the release of V25. We discuss these improvements through a comparison of the SSI and TSI to other instruments (e.g., TSIS).

V27 will be the final SORCE-SIM data release in 2020. Plans for upcoming calibration enhancements will be also be presented.

Degradation Process Due to UV Radiation and Future Radiometers

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Among all the potential degradation processes that may occur in space, UV radiation is the most likely to be the most contributive one. UV radiation is the most likely explanation for the difference in the degradation that the exposed cavities suffer in respect with the not exposed one. We analyzed different measurements from instruments measuring TSI and their degradation effect during their mission. Then we performed an experiment with a UV lamp (deuterium source) and compere the effect produced in the laboratory with the degradation curved obtained in PREMOS [1] or the SOVA cavities [2].

We will also show the next generation of radiometers that we are developing in the PMOD/WRC, applying carbon nanotubes as an observer and letting behind the silicon or polyurethane base coatings. As well, a new geometry has been designed for these new sensors, instated of a cavity-shape absorber we manufactured a flat detector with an ellipsoidal reflective dome. All these changes will improve the reproducibility and stability of the detector obtaining a more accurate measurements and enhancing the operational life of the instruments, which will allow us to study the evolution of the Sun along multiple solar cycles.

[1] Schmutz, W., A. Fehlmann, W. Finsterle, G. Kopp, and G. Thuillier, Total solar irradiance measurements with PREMOS/PICARD, *AIP Conference Proceedings*, 1531, 624 (2013).

[2] Romera, J., Ch. Wehrli, and C. Fröhlich, Solar total irradiance variability from SOVA 2 on board EURECA, *Solar Phys.,* 152: 23 (1994).

Laboratory Experiments: Characterization of new flat detector and its dome and degradation process in TSI radiometer

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Here we can find an overview of the experiment performed to study the degradation process in TSI radiometers due UV radiation. An UV lamp (deuterium source) in vacuum hitting directly a sample of the coating used in different radiometers [1]. After every hour of exposition, we analyze the changes in the absorptivity of the coating. As well, we will explain all the improvements achieved with the new geometry on our detectors and the methodology followed, measuring reflectance and transmittance of the detector and analyzing the gain factor of the dome.

[1] Walter, B., P-L. Levesque, G. Kopp, B. Andersen, I. Beck, W. Finsterle, M. Gyo, K. Heuerman, S. Koller, N. Mingard, A. Remesal Oliva, D. Pfiffner, R. Soder, M. Spescha, M. Suter, and W. Schmutz, The CLARA/NORSAT-1 solar absolute radiometer: instrument design, characterization and calibration, *Metrologia,* 54, 5, 674 (2017).

Maybe a Second Best Way to Measure TSI

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The Astrophysical Observatory (APO) of the Smithsonian Institution made systematic observations of TSI from 1902 until 1962 from many diverse locations on the Earth. Typical instruments included pyrheliometers, pyranometers, spectrobolometer, and theodolites. Those TSI measurements (referred to back then as the solar constant) were thought to be a potential, important cause of climate change, a sentiment shared by today's climate scientists. Notable, early observers and experimentalists have their names associated with these first measurements, including the likes of Abbot, Aldrich and Clayton inferring that the Sun showed real variations while others — Angstrom, Sterne, and Kimball saw no such proof of solar variability. Imagine the difficulty of measuring the Sun from the ground at different zenith angles and extrapolating to "zero" air mass. Volcanoes world-wide would easily lead to 5% and greater decreases in observed values.

It is also important that today's TSI community recognize the contributions of the APO pioneers. For although their measurements did not determine true solar variability, they did establish the required capabilities for future observing programs. A true measurement would require long-term instrument stability of better than 0.1% over 30 years. It is also noteworthy that their value of TSI (with some long-term averaging) agrees with todays accepted value of 1361 W/m^2 to well within 1%.

(This is not original work but summarizes the 1979 paper of Douglas Hoyt, *The Smithsonian Astrophysical Observatory Solar Constant Program,* in *Reviews of Geophysics and Space Physics,* Vol. 17, No. 3.)

<u>SORCE Phase-F</u>

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The Spectral Irradiance Monitor (SIM), the SOlar Stellar Irradiance Comparison Experiment (SOLSTICE), the XUV Photometer System (XPS), and the Total Irradiance Monitor (TIM) instruments on board the Solar Radiation and Climate Experiment (SORCE) satellite have been taking daily solar spectral irradiance (SSI) measurements since April 2003. SORCE is scheduled to be decommissioned on February 25, 2020 at which time the SORCE mission will begin the final phase (Phase-F). During this timeframe, the final data products and documents, as well as all selected ancillary information, organized in compliance with NASA Earth Science Data Preservation Content Specification (423-SPEC-001), will be archived and made available to the public. We describe the data, documentation, and the various formats that have been selected for archival.

<u>Three Centuries of Monthly Sunspot Group Numbers</u>

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Svalgaard & Schatten (2016) used a 'backbone' method to reconstruct the Sunspot Group Number since 1610. Five backbones were used, centered and anchored on the Wolfer Backbone, which then defines the scale of the series. Backbones are constructed by scaling observers directly to the primary observer (e.g. Wolfer) without daisy-chaining through intermediary observers thus avoiding accumulation of errors. To improve the time resolution (with better determination of error bars) the new Backbones have monthly resolution rather than the previous one's yearly values. There seems to be several different 'populations' of sunspot group counts by observers over time. One cannot blindly assume the statistical properties of one population to hold about the other. Speculatively we identify four populations the last 400 years. One major population belongs to years before 1881 followed by another major one after ~1915, separated by a transitional period between 1881 and ~1915. Those major populations differ by ~40%. The difference is poorly understood, but may be due to evolving telescope technology and/or increasing understanding of what constitutes a group. The average number of groups over a year by all observers with no normalization at all closely matches (i.e. are proportional to) the yearly numbers of groups in backbones constructed within each population showing that elaborate normalization procedures have almost no effect on the result. This means that we can dispense with the normalization altogether; although adjacent, overlapping backbone segments still have to be stitched together by par-wise comparison. So, it seems that we have a nice non-parametric, non-overlapping, non-k-value-regression, no selection effect, no ranking, no pair-wise comparison, no ADF- or PDF-based, non-whatever method for constructing a backbone segment including estimating its time-varying error bars (from the spread of the observations).

From Aleph to TAV: SORCE/SIM Recalibration using TSIS

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The Spectral Irradiance Monitor (SIM), a Féry prism spectrometer onboard the Solar Radiation and Climate Experiment (SORCE) mission, has been taking daily solar spectral irradiance (SSI) measurements from a ~90-minute low-Earth orbit since April 2003. We present a comparison of SORCE/SIM SSI measurements to near-simultaneous Total and Spectral Solar Irradiance Sensor (TSIS) observations. TSIS has been taking data from the International Space Station since March 14, 2018.

We selected six distinct 28-day periods of SORCE/SIM-TSIS/SIM overlap (Mar, Jun, Oct, and Nov 2018, and Feb and May 2019). During these periods (all ~ solar minimum), SORCE and TSIS produced near-continuous SSI measurements during times of low solar variability. These periods were selected to be 28 days to each cover a full Carrington rotation (~27.3 days). Post-processing of publicly available data included: 1) a daily zero-point wavelength alignment of each SORCE/SIM diode bandpass, and 2) a spectral convolution to account for the spectral resolution difference of SORCE/SIM to TSIS/SIM.

During the commissioning of SORCE/SIM, its absolute irradiance scale was defined by a comparison to the best available solar spectrum at the time (Harder et al., 2009). This process was given the name "ALEPH"-correction, as aleph is the first letter in the Hebrew alphabet. Here, we repeat a similar process, but with the TSIS data release V03 spectra. As "TAV" is the last letter in the Hebrew alphabet, we designate our correction as the TSIS Adjusted Value, or "TAV" correction. The TAV correction allows a recalibration of the entire SORCE/SIM mission, resulting in improved constraints on solar models. For example, here we examine its impact on the solar brightness temperature (TB), i.e. solving the Planck equation for brightness and temperature based on our corrected SORCE/SIM SSI measurements.

CO_2 Naturally Follows Solar-driven Climate Extremes

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Modern solar and climate data enables finer analysis of causal relationships than was possible when Svante Arrhenius established the scientific foundation of the greenhouse gas (GHG) theory of climate change that now includes human emissions. The IPCC AR5 WG1 depicts CO_2 as largely man-made and more powerful than irradiance changes, a view challenged here by evidence for >95% significance solar activity driven and deterministic atmospheric CO_2 levels and climate change. A Nino Intrayear Ratio (NIR) timeseries is introduced as annual ratios since 1870, calculated from each year's area-weighted Nino1-4 monthly averages first to second half. NIR 30-year average (30ya) lags the Solar Influences Data Center (SIDC) v2 sunspot number (SN) 30ya by 13 years and positive above SIDC 87 v2 SN, peaking in the 1990s. The detrended cumulative departure from average of annual Mauna Loa (ML) atmospheric CO_2 change was maximized during strong solar cycles 21-23, following a long-term increase in NIR, lagging the 30ya NIR by 1 year, both now declining from lower solar activity, positive above 106.7 SN. CO_2 acceleration correlates with NIR acceleration at zero lag. Nino34 regions define the Multi-Variate ENSO Index (MEI) with zero lag. Since 1980, 30ya HadSST3 global temperature was linear with and lagging 30y integrated MEI (iMEI). High sunspot activity and irradiance in the first half of each year enhances cyclic tropical ocean temperature and CO_2 outgassing from coral reef bleaching and $CaCO_3$ breakdown. Henry's Law (1803) solubility curve for CO_2 is replicated using Nino and ML data, CO_2 outgasses above 25.6°C, lagging HadSST3 by 10 months, leading to the conclusion that most atmospheric CO_2 is naturally produced, as is climate change. Future long duration low sunspot activity insures less CO_2 and a cooler, drier climate with possible dust bowl(s) while long high activity will again produce a wet warm green climate.

TSI Sun-Climate Prediction Theory

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Practical solar-based weather and climate forecasting is now possible due to cumulative advances in TSI, solar, and climate data collection and distribution. Sunspot number and F10.7cm flux forecasts from the NOAA Space Weather Prediction Center (SWPC) were used by the author to successfully predict the onset of the 2015/16 El Nino, the subsequent decline and the year-to year HadSST3 change at year end, based on deviations from his TSI-ocean warming threshold of 1361.25 W/m^2 (SORCE 1AU) determined in 2014/15, and on empirically derived year-year TSI forecasted changes. Early hard winters were forecast in Dec 2018 based on extended low TSI, to last until TSI rises above this threshold. Predictions of future TSI to judge the timing and severity towards either extreme in TSI away from the 90-day mean and 1361.25 W/m^2 threshold are based on solar data, prior history, and center disk coronal holes. The equivalent v2 sunspot number to 1361.25 is 95, and 120 sfu for observed F10.7cm flux. Longer-term forecasts involve projections of a cumulative sum of the indice above or below the respective warming threshold for a realistic range of estimated solar activity indices, modeled on former solar cycles. A typical solar cycle onset El Nino is anticipated from the TSI rise in solar cycle 25, likely in 2020. The role of clouds is connected to the Multi-Variate ENSO Index (MEI) and Central Pacific Outgoing Longwave Radiation (CP OLR), all connected to solar activity. This new cycle onset ENSO ends with a typical La Nina in 2021±1 year, at the lowest point of the cumulative threshold-based solar input. The ocean then warms by 0.5°C/W/yr after TSI reaches the threshold, governed by the rate and strength of ascending phase magnetic activity, followed by TSI declining phase ocean cooling and increasing ice risk if cycle 25 is very weak.

Increases of Reflected Solar Radiation as Observed by MISR from Volcanic Eruptions in 2000-2018

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Stratospheric volcanic aerosols (SVAs), a natural variability, play an important role in Earth climate system by cooling the surface temperature and the troposphere for a period of several months to over a year. The 16-year MISR monthly radiances show significant enhancements of anisotropic scattering at high latitudes after several major volcanic eruptions with injection heights greater than 14 km. The anomaly of de-seasonalized radiance anisotropy between MISR's DF and DA views (70.5° forward and aft) is largest in the blue band with amplitudes amounting to 5-15% of the mean radiance. A similar magnitude of the reflected shortwave radiation increases is expected in the polar region. The anomalous radiance anisotropy is a manifestation of the stronger forward scattering of reflected sunlight due to the direct and indirect effects of SVAs. The perturbations of MISR radiance anisotropy from the Kasatochi (August 2008), Sarychev (June 2009), Nabro (June 2011) and Calbuco (April 2015) eruptions are consistent with the poleward transported SVAs observed by CALIOP and OMPS-LP.