Sun-Climate Symposium

"Multi-Decadal Variability in Sun and Earth during the Space Era"

Nov. 10-13, 2015 * Savannah, Georgia

Poster Session Abstracts
4:45 – 6:30 pm, Thursday, Nov. 12

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Study of Polar Cap Potential and Merging Electric Field during High Intensity Long Duration Continuous Auroral Activity

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The polar cap potential (PCV) has long been considered as a key parameter for describing the state of the magnetosphere/ionosphere system. The relationship between the solar wind parameters and the PCV is important to understand the coupling process between solar wind-magnetosphere-ionosphere. In this work, we have estimated PCV and merging electric (Em) during two different high intensity long duration continuous auroral activity (HILDCAA) events. For each event, we examine the solar wind parameters, magnitude of interplanetary magnetic field (IMF) and components, interplanetary electric field (IEF), PCV, Em and geomagnetic indices (i.e., SYM-H, geomagnetic auroral electrojet (AE) index, polar cap index (PCI) and auroral electrojet index lower (AL), respectively). We also study the role of PCI and AL indices to monitor polar cap (PC) activity during HILDCAAs.

In order to verify their role, we use wavelet transform and cross-correlation techniques. For the three events studied here, the results obtained from continuous wavelet transform (CWT) and discrete wavelet transform (DWT) are different, however the effect of HILDCAA can be easily identified. We also observe the cross-correlation of PCI and PCV with AL, SYM-H, Bz component of the IMF and Ey component of the IEF individually. Both PCI and PCV show very good correlation with AL and SYM-H indices during the events. Observing these results, it can be suggested that PCI and AL indices play a significant role to monitor geomagnetic activity generated by geoeffective solar wind parameters.

The Latest SORCE SIM Degradation Model and the Resulting SSI Measurements from 2003 to 2015

Stephane Béland *[Stephane.Beland@lasp.colorado.edu], J. Harder, C. Lindholm, and T. Woods, Laboratory for Atmospheric and Space Physics (LASP), University of Colorado, Boulder, CO, USA*

The Spectral Irradiance Monitor (SIM) instrument on board the Solar Radiation and Climate Experiment (SORCE) mission has been taking daily Solar spectral irradiance (SSI) measurements since April 2003. A new mode of operation was introduced in March 2014 to address issues with depleted battery life and daily operations was resumed after 6 months of interrupted observations.

It is critical to accurately track the instrument degradation over time to be able to measure the small SSI variations over the solar cycle for the wavelength range covered by SIM (220-2400nm). The instrument degradation is constantly being updated and the corresponding model has been refined over the years to account for changes and a better understanding of the instrument's behavior over time.

This presentation will describe the latest SIM degradation model, how the various components were measured and how they affect the final degradation values. We'll compare the results from both channels on SIM with the SORCE-SOLSTICE data covering the overlapping wavelengths. We'll also present the integrated SIM SSI compared with the SORCE-TIM measurements.

Intensity Contrasts of Bright Solar Surface Features in Continuum and Absorption Bands at Disk Center

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Many solar irradiance reconstruction techniques make use of one-dimensional (1D) static atmosphere models to reproduce the radiative output of magnetic and quiet features observed over the solar photosphere. In the past years, several sets of models have been presented in the literature, each reproducing spectral irradiance variations with different degrees of accuracy. However, three dimensional magnetohydrodynamic (MHD) simulations of the solar photosphere are known to better reproduce the fine spatial and temporal structure of the solar photosphere, rendering them promising tools for improving our understanding of and capability to reproduce irradiance variations.

In this work we compute the photometric intensity contrast in the blue continuum (409.4 nm, FWHM 0.3 nm), the red continuum (607.1 nm, FWHM 0.5 nm), and the g-band (430.6 nm, FWHM 1.2 nm) at disk center (μ=1) using 1D FAL models, and 3-D MHD simulations, and we compare them with full-disk observations obtained with the Rome Precision Solar Photometric Telescope (PSPT). We find that the most recent FAL 2011 models best agree with results from MHD simulations, while comparison with observations is strongly hampered by scattered-light effects.

Sunspots: SFO Areas vs. SILSO's Revised Sunspot Numbers

Angela Cookson *[angela.cookson@csun.edu] and Gary Chapman, San Fernando Observatory, California State University Northridge, CA, USA*

Long time series of sunspot areas have been shown to correlate well with sunspot numbers and are used in the modeling and reconstruction of solar irradiance. We look at 28 years of San Fernando Observatory sunspot areas vs. SILSO's revised sunspot numbers, comparing it to the long-standing Zurich sunspot numbers, and paying special attention to the inter-cycle periods of Cycles 22-23 and 23-24.

Relation between Intensity Contrast and Magnetic Field for Active and Quiet Regions Observed on the Solar Photosphere

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Recent high spatial resolution observations and simulations indicate that radiative properties of magnetic elements depend not only on their size and magnetic field intensity, but also on the properties of the plasma that surround them. Such simulations and observations are typically limited to few line-of-sights.

Some irradiance reconstruction techniques rely on the relation magnetic field intensity – intensity contrast to identify magnetic features and model their radiative contribution. Therefore, understanding the center-to-limb variation of these different radiative properties and, eventually, whether and how they change with the magnetic activity cycle, can improve our capability to model solar irradiance. In this work we analyze full-disk Helioseismic and Magnetic Imager (HMI) data products obtained at the 6173 Å spectral range and corrected for scattered light in order to investigate the different radiative properties of magnetic features observed in Quiet and Active Regions at various positions over the solar disk. In agreement with high spatial resolution observations and simulation we find that, at all positions on the solar-disk, magnetic elements located in quiet regions are characterized by higher photometric contrast than magnetic elements located in active regions and that these latter present negative contrast close to disk center.

Forecasting Solar Forcing up to 2300: Why, and How?

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The latest assessment report of the IPCC highlights the need for having better projections of future climate change at least up to 2100, including more realistic forecasts of solar activity on multi-decadal time scales. We cannot predict the level of solar activity on such time-scales. However, assessments of plausible scenarios are possible, though challenging.

The 9 members of this ISSI team are preparing a data set with two realistic scenarios up to 2300, including particle forcing, and solar radiative forcing. These scenarios will serve as inputs for the forthcoming SPARC-CCMI (Chemistry-Climate Model Intercomparison) and CMIP6 (Coupled Model Intercomparison Project) climate model experiments.

Here we shall concentrate on the building of these scenarios. We considered various reconstructions of past solar activity from cosmogenic isotopes, and subjected them to a series of forecasting methods. Most reveal a distinctive pattern for the 21st century. They also shed new light on the puzzling occurrence of decadal and centennial cycles in solar forcing.

The Calibration of the CLARA Radiometer

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The Compact and Lightweight Absolute Radiometer, CLARA, will be launched in April 2016 on the Norwegian NORSAT-1 mission. CLARA is an electrical substitution radiometer for TSI measurements. It is based on a new design with three cavities to offer built-in redundancy and degradation tracking capability while minimizing size and weight. The CLARA flight spare instrument has recently been characterized and calibrated against the World Radiometric Reference (WRR) in Davos, Switzerland and the TSI Radiometer Facility (TRF) at LASP in Boulder, CO. The flight model is planned to be calibrated in September. We will present the results of the characterization and calibration experiments.

Photometric Sunspot Index 1875 to Present, an Update

Claus Fröhlich *[cfrohlich@pmodwrc.ch], CH-7265 Davos Wolfgang, Switzerland*

Data sets of sunspot areas and position from the Royal Greenwich Observatory (RGO) from 1874--1976, the NOAA-SEL network (including observations from USAF) from 1976--1981 and the Solar Optical Observing Network (SOON) from 1981-present can be used to calculate the

Photometric Sunspot Index (PSI) which represents the sunspot influence on total solar irradiance (TSI). There is a systematic difference of about 40\% between the RGO and the NOAA-SEL/SOON data records which needs to be removed. In order to provide more details about these differences the hemispheric and disk areas of the SOON record are compared to those determined by MDI/SOHO, HMI/SDO and the data series from the Debrecen Observatory. These comparison provide detailed information of the corrections needed for the SOON data and confirm the main reason for the difference between the RGO and SOON records - the lack of small spots in the latter. This effect is further amplified by the size dependent contrast of the sunspots. As a side product PSI can be used to determine the times of solar activity minima by comparing the temporal behaviour of the high and low latitude spots which is independent of the minimum values of any activity parameter. Albeit the limitations the almost 150-year-long PSI time series can now be used together with the other components of the proxy model to reconstruct TSI back in time. Moreover, the use of the Debrecen record as a continuation of the RGO will lead to a consistent and reliable record of the sunspot areas and PSI since 1874 which is work in progress.

Modeling Electron Density, Temperature Distribution in the Solar Corona Based on Solar Surface Magnetic Field Observations

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Magnetic fields constitute a natural link between the Sun, the Earth and the Heliosphere in general. The structure of the solar corona is mostly determined by the configuration and evolution of the magnetic field. While open magnetic field lines carry plasma into the heliosphere, closed field lines confine plasma. Additionally, key physical processes that impact the evolution of Earth's atmosphere on time-scale from days to millennia, such as the soft X-ray and EUV emission, are also determined by the solar magnetic field. However, observations of the solar spectral irradiance are restricted to the last few solar cycles and are subject to large uncertainties. Here we present a physics-based model to reconstruct in near-real time the evolution of the solar EUV emission based on the configuration of the magnetic field imprinted on the solar surface and assuming that the emission lines are optically thin. The structure of the coronal magnetic field is estimated employing a potential field source surface extrapolation based on synoptic charts. A hydrostatic model describes the coronal plasma temperature and density. The emission is estimated to employ the CHIANTI database. The performance of the model is compared to the emission observed by EVE instrument on board SDO spacecraft for two different wavelengths. The preliminary results and uncertainties are discussed in details. Furthermore, we examine the possibility of delivering the reconstruction of the solar spectral irradiance in near-real time using the infrastructure the infrastructure provided by the Brazilian Space weather program (EMBRACE/INPE). This work is partially supported by CNPq/Brazil under the grant agreement no. 140779/2015-9.

A Combined Solar and Geomagnetic Index for Thermospheric Climate

Linda A. Hunt [1] *[Linda.A.Hunt@nasa.gov] and Martin G. Mlynczak*[2]

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Infrared radiation from nitric oxide (NO) at 5.3 μm is a primary mechanism by which the thermosphere cools to space. The SABER instrument on the NASA TIMED satellite has been measuring thermospheric cooling by NO for over 13 years. Physically, changes in NO emission are due to changes in temperature, atomic oxygen, and the NO density. These physical changes however are driven by changes in solar irradiance and changes in geomagnetic conditions. We show that the SABER time series of globally integrated infrared power (Watts) radiated by NO can be replicated accurately by a multiple linear regression fit using the F10.7, Ap, and Dst indices. This fit enables several fundamental properties of NO cooling to be determined as well as their variability with time, permitting reconstruction of the NO power time series back nearly 70 years with extant databases of these indices. The relative roles of solar ultraviolet and geomagnetic processes in determining the NO cooling are derived and shown to be solar cycle dependent. This reconstruction provides a long-term time series of an integral radiative constraint on thermospheric climate that can be used to test climate models.

The Four Flight Total Irradiance Monitors

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The first Total Irradiance Monitor (TIM) launched on NASA's SORCE mission in 2003 and proved to be the most accurate and stable instrument on orbit for measuring the total solar irradiance (TSI) thanks to its new instrument layout and improved calibrations. The TIM's design improvements over the older classical radiometers led to its selection on subsequent missions including NASA's Glory (2011), NOAA's TSI Calibration Transfer Experiment (2013), and NASA's upcoming series of Total and Spectral Solar Irradiance Sensors. I will summarize the status of and differences between each of these TIMs.

Comparison of OLR Datasets from AIRS, CERES, and MERRA2

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This presentation compares spatial and temporal characteristics of OLR (Outgoing Longwave Radiation) and OLR_{CLR} (Clear Sky OLR) as determined using observations from AIRS and CERES over the time period September 2002 through January 2015. We find excellent agreement of the two OLR data sets, derived from observations by two different instruments, which implies high stability of both sets of OLR. The 1:30 AM/PM average of AIRS Version-6 OLR products display a positive bias compared to CERES EBAF Edition-2.8 OLR on the order 3.5 W/m^2 which is essentially constant in time. Spatial patterns of January and July climatologies of AIRS and CERES OLR show that this bias is essentially constant in space as well. The global mean bias has at best only a very small annual cycle and it shows essentially no drift over the 12 plus years of the data sets we have compared.

This presentation also examines the mean and anomaly patterns of OLR and OLR_{CLR} from MERRA2, as well as those of other variables from AIRS and MERRA2. We compare the correlation of mean OLR anomalies with the El Niño Index by showing coherent temporal changes of OLR within two spatial regions, one to the east of, and one to the west of, the Niño-4 region, in which anomalies of cloud cover and mid-tropospheric water vapor are both highly negatively correlated with OLR.

Exospheric Hydrogen Density Determined from Lyman-α Irradiance

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We use extreme ultraviolet (EUV) measurements of solar irradiance from GOES satellites to derive daily hydrogen (H) density distributions of the terrestrial upper atmosphere. GOES satellites are in geostationary orbit and measure solar irradiance in a wavelength band around the Lyman-alpha line. When the satellite is on the night-side of the Earth looking through the atmosphere at the Sun, the irradiance exhibits absorption/scattering loss. Using these daily dips in the measured irradiance, we can estimate a simple hydrogen density distribution for the exosphere based on the integrated scattering loss along the line of sight towards the Sun. We show preliminary results from this technique and compare the derived exospheric H density distributions with other data sets for different solar, geomagnetic and atmospheric conditions. The GOES observations will be available for many years into the future and so potentially can provide continuous monitoring of exospheric H density for use in full atmospheric models. Such measurements may be useful to better understand upper atmospheric coupling, to monitor impacts of climate change, to study the decay of the ions in the magnetospheric ring current during geomagnetic storms, and to improve satellite drag models. We will also discuss planned improvements to this technique.

Evolution of the Total Solar Irradiance during the Rising Phase of Solar Cycle 24

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To determine the total solar irradiance (TSI) from SOlar VAriability Picard (SOVAP) we established a new instrumental equation. A new parameter was integrated from a theoretical analysis that highlighted the thermo-electrical non-equivalence of the radiometric cavity. From this new approach, we obtained values that are lower than those previously provided with the same type of instruments. Based on SOVAP data, we obtained that the TSI input at the top of the Earth's atmosphere at a distance of one astronomical unit from the Sun is 1362.1 Wm^{-2}. In this talk, we describe the method, and then present results about TSI variations during the rising phase of solar cycle (from 2010 to 2014) and linkages between measurements and other solar parameters (solar radius and magnetic field). We are also going to talk about the implications of the harsh space environment on TSI measurements and how it is difficult to obtain absolute level of the TSI with a high degree of accuracy.

Vitalizing Four Solar Cycles of Kitt Peak Synoptic Magnetograms

Andrés Muñoz-Jaramillo[1] *[amunozj@gsu.edu] and John Harvey*[2]

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Solar magnetism spans many decades of spatial and temporal scales. Studies of the larger end of these ranges requires frequent observations of the full solar disk over long durations. To aid investigations of the solar cycle and individual active region evolution, nearly daily magnetograms have been observed from Kitt Peak during solar cycles 20-23. These data were used in real time for space weather predictions, and archived observations have so far served more than 1500 refereed research publications (including reconstructions of solar irradiance).

Unfortunately, these observations still suffer from various instrumental problems. We report ongoing efforts to restore and correct observations from 1970-2003 in order to maximize their scientific value. The main improvements are reductions of certain instrumental noise, signal biases, imperfect scanning geometry, and gain discrepancies. The improved data will be used the make synchronic and diachronic synoptic maps, a catalog of active region properties, and estimates of tracer flow patterns.

In addition to base funding from NSF, NASA and NOAA have provided substantial support of the Kitt Peak synoptic observations. The current revitalization project is funded by NASA's Living With a Star program

Magnetic Energy Coupling Across Broad Solar Atmospheric Plasma Conditions and Temperature Scales

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Investigations of solar variability and its magnetic energy coupling are paramount to solving many key solar and stellar physics problems. Particularly, understanding the temporal variability of magnetic energy redistribution and heating processes. Using observations covering a portion of Cycle 24, from the Solar Dynamics Observatory's Atmospheric Imagining Assembly and Helioseismic Magnetic Imager, radiative and magnetic fluxes, respectively, were measured from coronal hole (CH), quiet Sun (QS), active regions (ARs), active region cores (ARCs), and at full-disk (FD) scales. Radiative flux modulations and magnetic energy couplings reveal a self-similarity throughout CH, QS, ARs, and FD features; consistent with notions of a similar central engine. A mathematical formula describing temporal thermal variability of our feature set is suggestive to a coupling of such to the solar atmospheric activity cycle. We also present, and mathematically describe, the coupling of radiative fluxes, across broad regimes of the electromagnetic spectrum (covering photospheric through coronal plasmas), to the available magnetic energy. A comparison of the typical approach describing solar atmospheric radiative to magnetic coupling (i.e., strictly linearly and confined to small energy ranges of the electromagnetic spectrum) is performed against our extended description, which utilizes a broken power-law, and reveals an entanglement of thermodynamic and magnetic energy contributions in previous literature. Additionally, our work suggests that stellar X-ray observations could populate radiation distributions in spectral ranges that are currently undetectable.

Connecting Solar and Stellar Brightness Variations

Alexander I. Shapiro[1] *[shapiroa@mps.mpg.de], S. K. Solanki* [1,2]*, and N. A. Krivova*[1]

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We expand SATIRE, which is a successful model of solar brightness variability, from the Sun to other stars. This allows constraining SATIRE over wide space of possible stellar parameters and thus, along with interpreting stellar data, it helps to better identify the mechanisms of solar variability. This is, in turn, important for better understanding the solar-terrestrial connection.

Our results suggest that the solar paradigm is remarkably successful in explaining the stellar brightens variations on the activity cycle timescale. In particular, the model reproduces the observed reversal of the in-phase activity-brightness relationship for low-activity stars to an anti-phase one for more active stars.

We simulate the solar variability as it would be measured out-of-ecliptic by Kepler and CoRoT and discuss the relative contributions of spots and faculae to the photometric stellar variability.

SORCE Undergraduate Researchers

Marty Snow *[marty.snow@lasp.colorado.edu] and Erin Wood, Laboratory for Atmospheric and Space Physics (LASP), University of Colorado, Boulder, CO, USA*

The SOlar Radiation and Climate Experiment (SORCE) supports undergraduate researchers from around the country at the University of Colorado. These students participate in a Research Experience for Undergraduates (REU) program focused on Solar and Space Physics. This poster will showcase some of their work with mentors from the SORCE science team.

Preliminary Design of the Brazilian Experiential Broadband Radiometer

Luis Eduardo Antunes Vieira[1] *[luis.vieira71@googlemail.com], Alisson Dal Lago*[1]*, Maria Jose Faria Barbosa*[1]*, Marcelo Sampaio*[1]*, José Vitor de Vilas Boas*[1]*, Odim Mendes Jr.*[1]*, Ligia Alves da Silva*[1]*, Jenny Marcela Rodríguez Gómez*[1] *,Alessandro da Silva Paula*[2]*, Francisco Rodrigues*[2]*, Jesulino B. Dos Santos*[2]*, and Bruno Vaz Castilho de Souza*[2]

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The total solar irradiance (TSI) is a fundamental quantity to understand the evolution of the highly coupled Earth's atmosphere/ocean system. However, its estimate requires very well calibrated and stable instruments. Here we discuss the system requirements and the preliminary design of the broadband radiometer that is being jointly developed by the Brazilian's National Institute for Space Research (INPE) and the Brazilian's National Laboratory for Astrophysics (LNA). The instrument is being designed to operate on artificial satellites with mass lower than 10 (ten) kilograms. Following the design of other radiometers, the instrument is composed of four quasi-identical active cavities and the corresponding precision apertures. The mass and dimensions of the platform impose strict constraints on the design of the radiometer. In special, the power available, pointing precision, and thermal structure of the platform affect directly the level of uncertainties and the operation of the instrument. On the other hand, the costs to develop and delivery dedicated low-mass platforms are low compared to current multi-instrument solar missions.

Terrestrial Solar Irradiance Measurements with a Cryogenic Solar Absolut Radiometer

Benjamin Walter[1] *[Benjamin.Walter@pmodwrc.ch], Rainer Winkler*[2]*, Wolfgang Finsterle*[1]*, Andre Fehlmann*[3]*, and Werner Schmutz*[1]

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The Cryogenic Solar Absolut Radiometer (CSAR) developed and built at the National Physics Laboratory in London (NPL) and the Physikalisch Meteorologisches Observatorium Davos (PMOD/WRC) aims to provide a better traceability of terrestrial Direct Solar Irradiance (DSI) measurements to the International System of Units (SI), and to improve the accuracy of DSI measurements from 0.3% to 0.01%. Because the solar irradiance entering CSAR is partly reflected by the entrance window, the spectrally dependent integral transmittance of the broad band solar irradiance needs to be determined simultaneously to the CSAR measurements to correct the power reading of CSAR for these losses. Therefore, the Monitor to Measure the Spectrally Integrated Transmittance of Windows (MITRA) aims to measure the window transmittance with an uncertainty of 0.01% or less.

We present the measurement principle and the uncertainties of both, the CSAR and the MITRA instrument together with the latest DSI measurement results obtained during the International Pyrheliometer Comparison (IPC-II) at PMOD in September 2015. The uncertainty for the window transmittance measurements is currently about 0.015% for perfect measurement conditions, meaning no wind and a clear sky. A comparison of CSAR with the International System of Units (SI) recently performed at the NPL showed good agreement between the CSAR and the NPL primary standard absolute radiometer within the stated measurement uncertainty of 0.028% (k = 2). First solar irradiance measurements recently performed at PMOD showed a typical offset of about 0.2-0.3% to the World Standard Group (WSG) as already found during IPC-XI.

Technology Advances Enable Science-Oriented CubeSat Missions

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Key enabling technologies for most solar science missions include the sensors for the science instruments, 3-axis precision pointing by the spacecraft attitude determination and control systems (ADCS), and high data rates for communication downlink. There are now commercial off-the-shelf (COTS) solutions for the later two technologies for nanosatellites (e.g., CubeSats), such as the Blue Canyon Technologies' ADCS with better than 7 arc-sec pointing capability in 3 axes and Syrlinks X-band radio with better than 50 Mbits/sec (Mbps) downlink capability. With these CubeSat technology advances, there is now a great desire to compact the science instruments, not in capability but in size, mass, and power. We anticipate that the next generation of small solar missions could include compact magnetographs, solar imagers, and solar irradiance spectrometers and radiometers to further advance the understanding of the solar dynamo, solar eruptive events (SEEs), and solar irradiance variability important for climate change and space weather research. The technology and science of the Miniature X-ray Solar Spectrometer (MinXSS) CubeSat is presented as an example for a science-oriented CubeSat mission. The objective for the MinXSS mission is to better understand the energy distribution of solar soft X-ray (SXR) emissions and their impact on Earth's ionosphere, thermosphere, and mesosphere (ITM). MinXSS is a solar-pointed, 3-axis-controlled, 3 Unit (3U) CubeSat to observe the solar SXR spectrum between 0.04 and 2.5 nm (0.5 to 30 keV). The MinXSS is scheduled to launch to the International Space Station (ISS) in November 2015 and then be deployed from ISS in January 2016.