Past, Present, and Future Role of Earth Science Research

SORCE's 5th Anniversary Science Meeting
February 5-7, 2008, Santa Fe, NM

Abstracts – Poster Presentations

Session 1: Variability of the Solar Irradiance Over the Solar Cycle

Using SORCE Data in the College Classroom

Douglas Allen [dallen@dordt.edu], Dordt College, Sioux Center, IA.

The Sun provides a powerful unifying factor for a number of college science courses in areas such as astronomy, physics, environmental science, and engineering. Teaching about science using actual data, rather than solely textbook material, appeals to today's students, who benefit from "hands-on" experiences. The success of projects such as EdGCM (edgcm.columbia.edu) attests to the value of having students explore the sciences in the same way that actual research scientists do. This paper presents a number of examples of how SORCE data are being used at Dordt College (Sioux Center, Iowa) in courses such as solar system astronomy, stellar astronomy, introductory physics, and meteorology/climate change. The author also solicits ideas for further applications of solar and atmospheric data that can be incorporated into the college classroom.

TSI and Ground-Based Data: What Can be Learned?

Gary Chapman, Angie Cookson [angie.cookson@csun.edu], and Dora Preminger, San Fernando Observatory, California State University, Northridge.

The San Fernando Observatory (SFO) has 20+ years of ground-based photometric data taken in the red (672.3 nm), blue (472.3 nm), and CaII K-line (393.4 nm) wavelengths. Models using SFO data correlate well with satellite data and can help determine the contribution of sunspots and faculae/network to total solar irradiance (TSI). PSPT provides similar ground-based data. Currently, TSI composites based on data from several different space-borne instruments are being proposed. How well do SFO's models, as well as those using PSPT data, correlate with each of these composites and what can be learned from such an exercise?

Spectral Decomposition of the TSI Record Using the SORCE TIM and SIM Instruments

Jerry Harder [jerry.harder@lasp.colorado.edu], Erik Richard, Juan Fontenla, Peter Pilewskie, and Greg Kopp, LASP, University of Colorado, Boulder.

The SORCE SIM and TIM instruments have been making concurrent measurements of the total and spectral solar irradiance (TSI and SSI, respectively) since August 2003 up to the present solar minimum time frame. The SIM instrument measures spectral irradiance in the 200-2400 nm region covering 97.1% of the TSI with a resolving power ranging from 280 in the near UV to a minimum of 37 at 1260 nm. With this full spectral coverage, the spectral irradiance time series can be integrated into sub-ranges and compared to the TSI record, showing that different spectral regions provide different components to the total record with some offsetting long-term trends.

The SORCE SIM record also provides the best understanding of the long-term trends in the infrared portion of the spectrum. In particular, the very high precision of the SIM near-infrared measurements provide a direct determination of the wavelength dependence of the facular and sunspot contrasts and serve to refine solar atmospheric models of the solar magnetic features that produce irradiance variability in emission from the deepest photospheric layers.

The Relationship between Sunspots and the Variability of the Solar Corona

Dora Preminger [dora.preminger@csun.edu] and Gary Chapman, San Fernando Observatory, California State University, Northridge.

The San Fernando Observatory has continuous, photometric observations of sunspots since 1986. Sunspot areas are also available from the Greenwich database since 1874. We show that a sunspot measure, such as area or deficit, can be used in a simple, single-parameter model to reconstruct daily variations in the Coronal Index. Our model shows that the Coronal Index can be related to a sunspot measure by convolution with a finite impulse response function (FIR). The FIR is physically meaningful. It is an extended function of time that describes the evolution of an active region in the solar corona, relative to its associated photospheric sunspots. The FIR appears to exhibit a pre-sunspot component, suggesting the possibility of using coronal observations to predict sunspot emergence.

Ultraviolet SSI Variability from two SOLSTICEs

Martin Snow [snow@lasp.colorado.edu], William McClintock, and Tom Woods, LASP, University of Colorado, Boulder.

The SOLar-STellar Irradiance Comparison Experiments (SOLSTICE) on the Upper Atmosphere Research Satellite (UARS) and the Solar Radiation and Climate Experiment (SORCE) have been measuring the solar spectral irradiance (SSI) in the ultraviolet since 1991. This time period includes two solar maxima and two solar minima (almost). We will present measurements of the irradiance variability in the wavelength range of 120-300 nm over the past 16 years and discuss differences in SSI variability between the two solar cycles.

Solar EUV Observations from the NOAA GOES 13 Satellite

Rodney Viereck [rodney.viereck@noaa.gov], NOAA Space Weather Prediction Center, Boulder, CO; Don McMullin, Naval Research Laboratory, Washington; and Doug Strickland, Computational Physics, Inc., Springfield, VA.

A new solar EUV irradiance sensor was launched on the NOAA GOES 13 satellite in May 2006. This sensor is intended to provide solar EUV irradiance data for use in models of the upper atmosphere, thermosphere, and ionosphere. The sensor underwent a six month test period before it the satellite was put into storage mode. Data taken during this six month period will be presented and compared with other EUV observations. Sensor performance and response will be described. Analysis of some of the sensor design characteristics will also be presented. Once the GOES 13 satellite is brought out of storage and into operations, the EUV sensor will become the first of many operational solar EUV sensors making continuous observations of the solar EUV irradiance. In general, the GOES 13 EUV sensor appears to be performing quite well and should provide excellent solar EUV data for years to come.

XUV Photometer System (XPS): Improved Solar Irradiance Algorithm Using CHIANTI Spectral Models

Thomas N. Woods [tom.woods@lasp.colorado.edu], Phillip C. Chamberlin, and W. K. Peterson, LASP, University of Colorado, Boulder; R. R. Meier and Phil G. Richards, George Mason University, Fairfax, VA; Douglas J. Strickland, Computational Physics, Inc., Springfield, VA; and Gang LU, Liying Qian, and Stanley C. Solomon, High Altitude Observatory, National Center for Atmospheric Research, Boulder, CO.

The solar soft X-ray (XUV) radiation is highly variable on all time scales and strongly affects Earth's ionosphere and upper atmosphere; consequently, the solar XUV irradiance is important for atmospheric studies and for space weather applications. While there have been several recent measurements of the solar XUV irradiance, detailed understanding of the solar XUV irradiance, especially its variability during flares, has been hampered by the broad bands measured in the XUV range. In particular, the simple conversion of the XUV photometer signal into irradiance, which assumes a static solar spectrum, over estimates the flare variations by more than a factor of two as compared to the atmospheric response to the flares. To address this deficiency in the simple conversion, an improved algorithm using CHIANTI spectral models has been developed to process the XUV Photometer System (XPS) measurements with its broad band photometers. Model spectra representative of quiet Sun, active region, and flares are combined to match the signals from the XPS and produce spectra from 0.1 to 40 nm in 0.1 nm intervals for the XPS Level 4 data product. The two XPS instruments are aboard NASA's Solar Radiation and Climate Experiment (SORCE) and Thermosphere, Ionosphere, Mesosphere, Energetics, and Dynamics (TIMED) satellites. In addition, the XPS responsivities have been updated for the latest XPS data processing version. The new XPS results are consistent with daily variations from the previous simple conversion technique used for XPS and are also consistent with spectral measurements made at wavelengths longer than 27 nm. Most importantly, the XPS flare variations are reduced by factors of 2 to 4 at wavelengths shorter than 14 nm and are more consistent, for the first time, with atmospheric response to solar flares. Along with the details of the new XPS algorithm, several comparisons to dayglow and photoelectron measurements and model results are also presented to help verify the accuracy of the new XUV irradiance spectra.

Solar Spectral Irradiance Variability in the Near-Infrared and Correlations to the Variability of Total Solar Irradiance during the Declining Phase of Solar Cycle 23

Erik C. Richard, Jerald W. Harder, Juan Fontenla, Peter Pilewskie, Greg Kopp, and Tom Woods, LASP, University of Colorado, Boulder.

The Spectral Irradiance Monitor (SIM) as part of the NASA EOS SORCE mission continuously monitors the solar spectral irradiance (SSI) across the wavelength region spanning the ultraviolet, visible and near infrared (a region encompassing >97 of the TSI measured by the SORCE Total Irradiance Monitor, TIM). These are the first daily measurements from space with the required precision to detect real changes in SSI. The record of TSI measured from space tracks changes in solar total energy output and establishes the baseline for energy input for the Earth. Where this radiative energy is deposited into the Earth system, how the climate responds to solar variability, and the mechanisms of climate response, are determined by how the incident solar radiation is distributed with wavelength, the SSI. For the near IR region in particular, spectral decomposition of the TSI variability provides TOA constraints on the direct input for atmospheric heating simulations. We present here the first long-term, continuous measurements of the near infrared variability of solar spectral irradiance and establish quantitative correlations of near infrared variability across the spectral region of the solar H-minus opacity minimum with TSI

variability. The unprecedented precision of the SIM near-infrared measurements provide a direct determination of the wavelength dependence of the facular and sunspot contrasts and serve to refine solar atmospheric models of the solar magnetic features that produce irradiance variability in emission from the deepest photospheric layers.

Absolute Optical Power and Irradiance Comparisons with SORCE/TIM and Glory/TIM Instruments

David Harber [dave.harber@lasp.colorado.edu], Karl Heuerman, Ginger Drake, and Greg Kopp, LASP, University of Colorado, Boulder.

The total solar irradiance (TSI) climate data record began with spacecraft measurements nearly 30 years ago. While each instrument demonstrates the sensitivity to detect small changes in the Sun's radiant energy and many instruments can even track internal on-orbit degradation, the offsets between these instruments on an absolute scale generally exceed the stated instrument uncertainties. As a first step to address these offsets, optical power comparisons of ground-based TSI instruments representative of those on orbit against a NIST optical power standard were proposed. The ground-based Witness unit of the Total Irradiance Monitor (TIM) currently flying on the SOlar Radiation and Climate Experiment (SORCE) was the first TSI instrument to perform this comparison, which was completed at NIST/Gaithersburg in 2006. We report on the findings of this comparison. One conclusion is that the TIM is not measuring optical power erroneously low by the net difference between it and the other TSI instruments, which have yet to perform this optical power comparison.

The next important step in addressing TSI instrument offsets is to perform comparisons in irradiance, rather than optical power, mode. The NASA Glory mission is funding the creation of the TSI Radiometer Facility (TRF) for such solar-power level irradiance calibrations. We describe here the details of the TRF, which is designed to achieve 0.01% absolute accuracy and operate the instruments in flight-like conditions.

Thanks to Allan Smith and Joe Rice at NIST.

NRL Long Term Solar UV Irradiance Model: Status and Future Plans

Jeff Morrill [jeff.morrill@nrl.navy.mil], Naval Research Laboratory, Washington, DC; Linton Floyd, Interferometrics Inc., Herndon, VA; Don McMullin, Praxis, Inc., Alexandria, VA; and R. Ulrich, University of California, Los Angeles.

An empirical model of solar UV spectral irradiance has been developed at the Naval Research Laboratory under the NASA-LWS program. This model uses observed spectra and CaII-K images to identify solar surface features. The initial wavelength range was near Mg II at 280 nm but this range has been expanded to cover wavelengths from 30 to 400 nm using SKYLAB, TIMED/SEE, and other observations. The short wavelength portion of the model uses linear regressions to estimate the solar EUV spectrum using correlations between the NOAA Mg II index or total activity and observed EUV spectra. Model efforts have concentrated on the 1990-1995 time period. Current efforts will extend estimated spectral irradiance back to the early 1900’s using Ca II K images from Mt Wilson Observatory (MWO) for use as input to long term climate models. In this presentation, we review the status of the model and model inputs, output UV/EUV spectra, and the recent methods being developed for correction of the MWO images.

SORCE Solar Irradiance Data Products

Doug Lindholm [doug.lindholm@lasp.colorado.edu], Christopher Pankratz, Barry Knapp, Randy Meisner, Juan Fontenla, Jerald Harder, William McClintock, Greg Kopp, Martin Snow, and Tom Woods, LASP, University of Colorado, Boulder.

The Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado manages the SOlar Radiation and Climate Experiment (SORCE) Science Data System. This data processing system routinely produces Total Solar Irradiance (TSI) and Spectral Solar Irradiance (SSI) data products, which are formulated using measurements from the four primary instruments on board the SORCE spacecraft. The TIM instrument provides measurements of the TSI, whereas the SIM, SOLSTICE, and XPS instruments collectively provide measurements of the solar irradiance spectrum from 1 nm to 2400 nm (excluding 31-115 nm, which is measured by the SEE instrument on NASA's TIMED mission). The SORCE Science Data System utilizes raw spacecraft and instrument telemetry, calibration data, and other ancillary information to produce a variety of solar irradiance data products that have been corrected for all known instrumental and operational factors. Since launch of the SORCE spacecraft in January 2003, science processing algorithms have continued to mature, and "Level 3" data products (time-averaged and/or spectrally re-sampled onto uniform wavelength scales) are routinely being produced and delivered to the public via the SORCE web site, and are archived at the Goddard Earth Sciences (GES) Data and Information Services Center (DISC, formerly DAAC). This poster provides an overview of the SORCE data processing system, summarizes the present state of the processing algorithms and future plans, describes the quality of the current SORCE data products, and provides details on how to access SORCE science data.

The LASP Interactive Solar IRradiance Datacenter (LISIRD)

Christopher Pankratz [chris.pankratz@lasp.colorado.edu], D. M. Lindholm, M. Snow, B. Knapp, D. Woodraska, B. Templeman, T. N. Woods, F. G. Eparvier, J. Fontenla, J. Harder, and W. E. McClintock, LASP, University of Colorado, Boulder.

The Laboratory for Atmospheric and Space Physics (LASP) has been making space-based measurements of solar irradiance for many decades, and thus has established an extensive catalog of past and ongoing space-based solar irradiance measurements. In order to maximize the accessibility and usability of solar irradiance data and information from multiple missions, LASP is developing the LASP Interactive Solar IRradiance Datacenter (LISIRD) to better serve the needs of researchers, educators, and the general public. This data center is providing interactive and direct access to a comprehensive set of solar spectral irradiance measurements from the soft X-ray (XUV) at 0.1 nm up to the near infrared (NIR) at 2400 nm, as well as state-of-the-art measurements of Total Solar Irradiance (TSI). LASP researchers are also responsible for an extensive set of solar irradiance models and historical solar irradiance reconstructions, which will also be accessible via this data center over time. LISIRD currently provides access to solar irradiance data sets from the SORCE, TIMED-SEE, UARS-SOLSTICE, and SME instruments, spanning 1981 to the present, as well as a Lyman Alpha composite that is available from 1947 to the present. LISIRD also provides data products of interest to the space weather community, whose needs demand high time cadence and near real-time data delivery. This poster provides an overview of the LISIRD system, summarizes the data sets currently available, describes future plans and capabilities, and provides details on how to access solar irradiance data through LISIRD's various interfaces.

Session 2: Atmospheric Models, Processes, and Solar Irradiance

Extragalactic Cosmic Rays Can Affect Sun-Earth Environment and Environment of the Earth

Dr. Saumitra Mukherjee [dr.saumitramukherjee@usa.net], School of Environmental Sciences, Jawaharlal Nehru University, New Delhi-110067, India.

Extragalactic cosmic rays have the potential to influence the triggering of the variation in the Sun. It has been observed that although solar maximum and minimum is a periodic phenomenon but the relationship of extragalactic cosmic rays generated by the changes in the faculae of distant stars. These changes may occur irrespective of routine solar variability. These changes are being recorded and correlated with the electron flux and planetary indices variations measured by SOHO satellite data. The changes in the thermosphere, ionosphere, atmosphere and geosphere of the earth are found to be changing abruptly. These findings may contradict the existing finding of Intergovernmental Panel for Climate Change (IPCC).

The Role of Solar Forcing in the Tropical Circulation

Jae N. Lee [jaelee@atmsci.msrc.sunysb.edu], Stony Brook University, New York; Drew Shindell, NASA GISS and Columbia University; and Sultan Hameed, Stony Brook University.

This paper studies the response of the seasonal tropical circulation to the solar forcing with the Goddard Institute for Space Studies (GISS) ModelE that includes the fully interactive atmospheric chemistry. To identify characteristic solar signals in the tropical circulation, the model experiments are carried out with certain imposed conditions: a doubly amplified solar forcing, the present day and preindustrial greenhouse gases and aerosol conditions, with the mixed layer or fully coupled dynamic ocean model. From both the model and the NCEP reanalysis, the tropical humidity responses to the solar forcing are found to be statistically significant in both seasons. Statistically significant changes are also found in the vertical velocities for both the Hadley and the Walker circulations over the Pacific region.

Session 3: Models of Solar Processes Affecting Climate

Michelson Doppler Imager Observations of the Solar Radius over Cycle 23

Rock I. Bush [rbush@solar.stanford.edu], Solar Physics Group, Stanford University, California; J. Kuhn, Institute for Astronomy, University of Hawaii, Honolulu; and M. Emilio, Universidade Estadual de Ponta Grossa, Parana, Brazil.

The Michelson Doppler Imager (MDI) instrument on the SOHO spacecraft has been observing the Sun since early 1996. Full disk continuum images with 4 arc-second resolution provide reliable long term observations of the solar limb. The position of solar limb is measured by fitting the observed limb darkening function from which an apparent solar radius is determined.

The solar radius obtained from these images must be corrected for instrument focus adjustments made to compensate for aging of the entrance filter window and for temperature variations in the MDI optics package. An a priori instrument model of the MDI optical and thermal performance has been produced to correct the solar radius determination.

The previous MDI solar radius determinations have been extended by another 4 years and now provide excellent coverage of the entire solar cycle 23. Analysis of these additional measurements is being completed, and will provide an upper bound if not a definitive measure of the solar radius variation over a solar cycle.

This research is supported by NASA grant NAG5-13261 at Stanford University.

Reconstructing Solar Variability over Multiple Timescales

Dibyendu Nandy [nandi@mithra.physics.montana.edu], Montana State University; Sarah Joy, University of Florida; Andres Munoz, Montana State University; and P.C.H. Martens, Harvard Smithsonian Center for Astrophysics.

The variable magnetism of the Sun modulates its radiative output and open flux – both of which are believed to play important roles in climate processes. This solar variability occurs over multiple timescales, ranging from billions of years to tens of years. While the longer timescale is relevant for the evolution of planetary atmospheres and understanding the radiation environment of the young Earth, the shorter timescale is relevant for understanding the more immediate impact of solar forcing on the Earth's climate and developing technologies. Deciphering the Sun's variability distributed over such long timescales can only be achieved through diverse methods, including but not limited to, activity observations and modeling of solar-like stars and sunspot activity reconstructions. Here we present our efforts in this direction.

Reconstructing TSI from Heliospheric Magnetic Field as Deduced byMcCracken from Cosmic Ray Modulation

Leif Svalgaard [leif@leif.org], ETK, Houston, TX.

We have used a recent reconstruction of the long-term solar wind magnetic field based on cosmic ray data [McCracken, 2007; McCracken and Beer, 2007] to infer the secular variation in TSI, based on a sensitivity of 0.5 Wm2/nT. The TSI inferred in this manner increases by ~3 W/m2 (~0.22%), from 1428-2005. Even more remarkably, the TSI reconstruction based on McCracken's deduced HMF strength increased by nearly 3 W/m2 in the first half of the 20th Century, a result that finds no support in other recent TSI reconstructions which show at most a ~0.5 W/m2 increase over this period. This result casts further doubt on the McCracken [2007] solar wind magnetic field reconstruction which is at strong variance with other recent HMF reconstructions. Alternatively, the sensitivity of TSI to HMF could be much smaller than the 0.5 Wm2/nT suggested by Fröhlich [2008].

Session 4: Climate Models, Processes, and Solar Irradiance

Applying Relativity to Earth Climate Data: The Damhsa Theory Signs of the Inflationary Universe

Sheila A. Lynch [slynch@navc.org], Northeast Advanced Vehicle Consortium (NAVC), Boston, MA.

Multi-million year climate data through proxies have recently been published that point to a clear trend of temperature differentials through time. In the past theories have been used to explain the broad ice ages by orbital forcing using Newtonian physics. The Damhsa (Gaelic for Dance) Theory is formulated by analyzing climate data and applying the General

Relativity Theory and orbital forcing to the time series and proposes a solution to the variable data. This solution is gravitational waves. New theories on the inflation of the universe predict gravitational waves also. This change is extremely slow and not perceptible to human scale time but can explain the complex interactions of large-scale climate change and time. The climate fluctuations in time can be explained by gravitational waves of the expanding universe. The Earth's position in space changes as the effects of gravitational waves as predicted by Einstein. Recent climate data shows wave patterns of a non-linear nature, which would correspond with a large mass in space, such as Earth, exhibiting the effects of gravitational waves by slight changes in the position of Earth to the Sun, which would slowly affect climate over large timescales. Oscillating gravitational waves are the signature of the universe expanding.

Modeling Lunar Borehole Temperature in order to Reconstruct Historical TSI and Estimate Surface Temperature in Permanently Shadowed Regions

Guoyong Wen [wen@climate.gsfc.nasa.gov], NASA Goddard Space Flight Center & UMBC; Robert F. Cahalan, NASA Goddard Space Flight Center; Hiroko Miyahara, University of Tokyo, Japan; and Atsumu Ohmura, Institute for Atmospheric and Climate Sciences, Zurich, Switzerland.

The Moon is an ideal place to reconstruct historical total solar irradiance (TSI). The undisturbed lunar surface albedo and thermal properties allow us to relate historical changes in TSI to the present day lunar borehole temperatures. Using regolith thermal properties from Apollo, and two reconstructed TSI time series from 1610 to 2000 (Lean, 2000; Wang, Lean, and Sheeley, 2005), we conclude that the two scenarios can be distinguished by detectable differences in regolith temperature, with the peak difference of about 10 mK occurring at a depth of about 10 m (Miyahara *et al.*, 2007).

"Turning off" the Sun in our time dependent model, we found it would take several hundred years for the surface temperature to drop from ~80K immediately after sunset down to a nearly constant equilibrium temperature of about ~24-38 K for terrestrial Earth's radiation from 0 up to about 0.1W/m^2 at maximum Earth phase. A simple equilibrium model (e.g., Huang, 2007) is inappropriate to relate the Apollo-observed nighttime temperature to Earth's radiation budget, given the long multi-centennial time scale needed for equilibration of the lunar surface layer after sunset.

References:

Huang, S., (2007), Surface Temperatures at the Nearside of the Moon as a Record of the Radiation Budget of Earth's Climate System, *Advances in Space Research*, doi: 10.1016/j.asr.2007.04.093.

Lean, J., *Geophys. Res. Lett.*, (2000), 27(16), 2425-2428.

Miyahara, H., G. Wen, R. F. Cahalan, and A. Ohmura, (2007), *Geophy. Res. Lett.*, doi: 10.1029/2007GL032171, in press.

Wang, Y. M., J. L. Lean, and N. R. Sheeley (2005), *Astrophys. J.*, 625, 522-538.