The EUV Variability Experiment (EVE) on the solar dynamics observatory (SDO): Science plans and instrument overview

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Abstract. The highly variable solar extreme ultraviolet (EUV) radiation is the major energy input to the Earth's upper atmosphere, strongly impacting the geospace environment, affecting satellite operations, communications, and navigation. The Extreme ultraviolet Variability Experiment (EVE) onboard the NASA Solar Dynamics Observatory (SDO) will measure the solar EUV irradiance from 0.1 to 105 nm with unprecedented spectral resolution (0.1 nm), temporal cadence (10 sec), and accuracy (20%). The EVE program will provide solar EUV irradiance data for NASA's Living With the Star (LWS) program, including near real-time data products for use in operational atmospheric models that specify the space environment and to assist in forecasting space weather operations. The EVE program will advance understanding of the physics of the solar EUV irradiance variations on time scales from flares to the solar cycle. This progress, which includes providing better predictions, will result from simultaneous measurements of the solar EUV irradiance and full Sun images of magnetic fields and brightness at wavelengths emitted from the chromosphere, transition region, and corona, which are obtained by other SDO instruments. The EVE includes several instruments that measure EUV irradiance over a wide range of wavelengths. The Multiple EUV Grating Spectrographs (MEGS) A is a grazing-incidence spectrograph that measures the solar EUV irradiance in the 5 to 37 nm range with 0.1 nm resolution, and the MEGS-B is a normal-incidence, dual-pass spectrograph that measures the solar EUV irradiance in the 35 to 105 nm range with 0.1 nm resolution. Both MEGS channels have filter wheel mechanisms, holographic gratings, and cooled CCD detectors. For MEGS in-flight calibration, the EUV SpectroPhotometer (ESP) measures the solar EUV irradiance in broad bands between 0.1 and 39 nm, and a MEGS-Photometer measures the Sun's bright hydrogen emission at 121.5 nm. In addition, underflight rocket experiments are planned annually to ensure that the EVE measurements have an absolute accuracy of better than 25% over the five-year SDO mission.

Index Terms. EVE, SDO, solar EUV irradiance, space weather research.

1. Introduction

The Solar Dynamics Observatory (SDO) is the first spacecraft in NASA's Living With a Star (LWS) program, scheduled for a nominal five-year mission following launch in August 2008. The goal of the SDO mission is to understand solar variability and its societal and technological effects. SDO will address how the Sun's magnetic field is generated and structured and how this stored energy is converted and released into the heliosphere and geospace environment through the solar wind, energetic particles, and photon output. An underlying theme of SDO is scientific research to enable improved space weather predictive capabilities, thus transitioning research to operations.

The EUV Variability Experiment (EVE) is one of three instruments onboard SDO. EVE will measure the solar extreme ultraviolet (EUV) and soft X-ray (XUV) spectral irradiance in order to better understand how solar magnetic activity is manifest in the ultraviolet wavelength ranges that drive the terrestrial upper atmosphere. The Helioseismic and Magnetic Imager (HMI) is a vector magnetograph designed to understand magnetic activity, which is the dominant source for solar variability. The Atmospheric Imaging Assembly (AIA) will make full-disk solar images at multiple wavelengths to link magnetic changes on the surface and interior to those in the solar atmosphere. As depicted in Fig. 1, the SDO measurements from EVE, HMI and AIA will facilitate improved understanding of irradiance variations, flares and coronal mass ejections (CMEs), for use in ionosphere and thermosphere models for space weather operations, to better track satellites and manage communication and navigation systems. This paper describes the science plans and instrumentation for the EVE program.

2. EVE science plan

The EUV photons that EVE measures originate in the Sun's chromosphere and corona and deposit their energy in the Earth's ionosphere and thermosphere, thus directly connecting the Sun and the Earth in just eight minutes. The solar output in the EUV and XUV spectrum (wavelengths shortward of 120 nm) varies with solar activity from a factor of 2 to several orders of magnitude depending on

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wavelength, and on timescales from seconds and minutes (flares) to days and months (solar rotation) to years and decades (solar sunspot or magnetic cycle) (Woods and Rottman, 2002). The EUV and XUV irradiance is the primary energy input to the Earth's upper atmosphere, heating the thermosphere, creating the ionosphere, and initiating many complex photochemical reactions and dynamical motions. Fluctuating EUV and XUV irradiance drives variability in the atmosphere, affecting satellite operations, navigation systems, and communications. For example, the heating of the thermosphere by solar EUV radiation increases the neutral density with higher levels of solar activity and thus increases satellite drag. While a small number of previous missions have measured the solar EUV and produced daily-averaged irradiance spectra (Woods *et al.*, 2004), none has done so with the accuracy and high time cadence of EVE. EVE will undertake the first comprehensive study of the solar EUV irradiance variability on the time scale of flares.

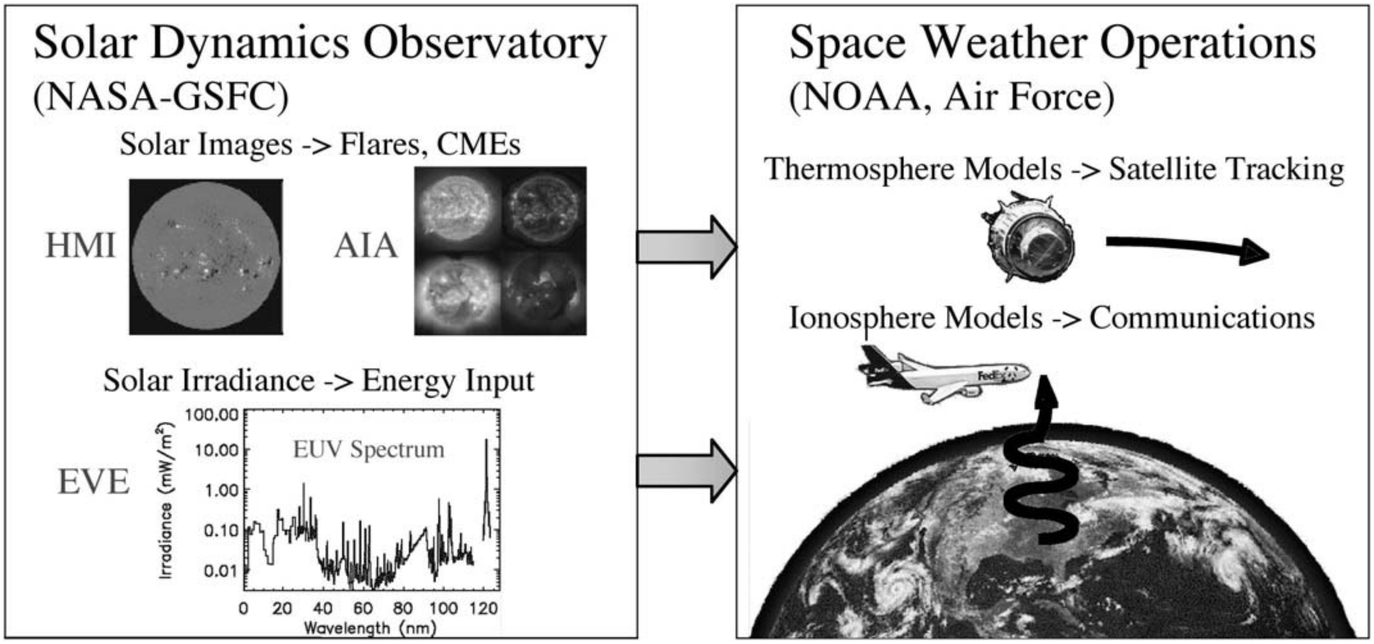


Fig. 1. The SDO mission includes the EVE, HMI and AIA instruments that measure solar EUV irradiance and image solar magnetic fields and emissions at a variety of temperatures. These SDO measurements, along with new, improved models of solar irradiance variations and eruptive events, will be used for space weather research and operations.

2.1. EVE science objectives

EVE's measurements, modeling activities, and collaborations with the other SDO instruments pursue the following four scientific objectives:

(1) specify the solar EUV irradiance and its variability on multiple times scales from seconds to years,

(2) advance current understanding of how and why the solar EUV spectral irradiance varies,

(3) improve the capability to predict (both nowcast and forecast) the EUV spectral variability, and

(4) understand the response of the geospace environment to variations in the solar EUV spectral irradiance and the impact on human endeavors.

2.1.1. EVE objective 1 – specify solar EUV irradiance

The first objective of EVE, and its highest priority, is the acquisition of a suitable database to characterize the solar EUV irradiance spectrum and its variations during flares, active region evolution, and the solar cycle. Without such observations, LWS will not be able to develop reliable space environment climatologies. Fig. 2 illustrates modeled variations in the total EUV energy (Lean *et al.*, 2003), compared with that of solar wind particles, during recent solar cycles.

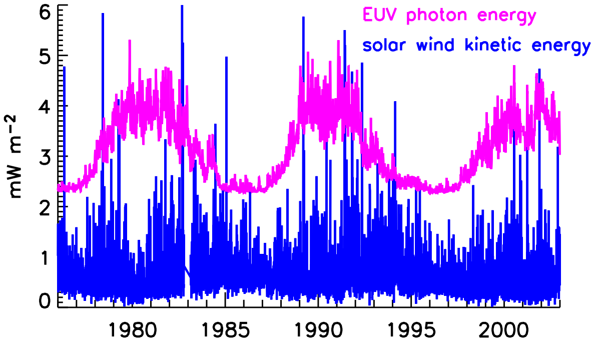


Fig. 2. Shown are variations in the daily total energy of EUV photons at wavelengths less than 120 nm, compared with the kinetic energy in solar wind particles (mainly protons) (Lean, 2005).

The solar EUV spectrum (Fig. 1) is comprised of thousands of emission lines and a few continua whose irradiances span more than four orders of magnitude. This radiation is emitted from the Sun’s chromosphere, transition region, and corona at temperatures in the 10^4 to 10^6 K range. EUV radiation varies continuously at all wavelengths with hotter emissions generally varying more. Because lines at similar wavelengths can originate from sources on the Sun with different temperatures and densities, the EUV irradiance variability displays complex time-dependent wavelength dependences (*e.g.*, Woods and Rottman, 2002). The current TIMED Solar EUV Experiment (SEE) measurements (Woods *et al.*, 2005) have improved the accuracy of the solar EUV spectral irradiances to about 20%, and the EVE measurements will further increase this accuracy at some wavelengths to about 10% and with much higher spectral resolution of 0.1 nm.

The historical solar EUV irradiance database, including the TIMED SEE measurements, consists mainly of daily measurements, albeit with many large gaps such as from 1979 to 2002. Observations of the solar EUV irradiance with higher time cadence, as needed to study flares, are severely limited. The SOHO SEM (Judge *et al.*, 1998) and GOES XRS (Garcia, 1994) measurements do provide high time cadence but only in a few broad wavelength bands. EVE’s spectrally resolved observations with a time cadence of 10 sec will greatly advance the specification and understanding of the spectral variations during flare events throughout the XUV and EUV spectrum.

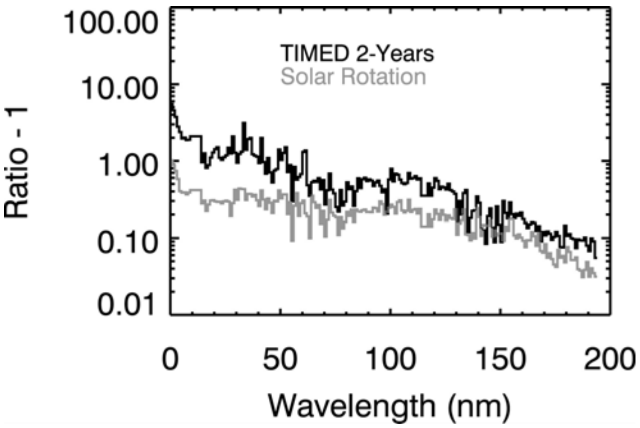


Fig. 3. Comparison of the solar variation over the TIMED 2-year mission (black) to solar rotation (grey) variations shows similarity in wavelength (Woods *et al*., 2005).

2.1.2. EVE objective 2 – understand why solar EUV varies

Extensive, multi-faceted investigations are planned to advance understanding of the sources of EUV irradiance variations within a physical framework. This understanding is needed to develop a predictive capability for past and future space environment climatologies, and for verifying the direct EUV irradiance observations. Models will be developed to account for the observed EUV irradiances and their variations, with traceability to magnetic flux emergence and the solar dynamo. This approach will be accomplished in collaboration with complementary SDO efforts, including those of the HMI and AIA instruments and other satellite missions. Auxiliary data from space and from the ground, *e.g.* by the Synoptic Optical Long-term Investigations of the Sun (SOLIS) and Big Bear Solar Observatory programs, will also be used.

EUV radiation emerges from the outer layers of the Sun’s atmosphere, which are sufficiently hot to excite highly ionized species of gases; however, the solar atmosphere is not homogeneous, as the images made by the EUV Imaging Telescope (EIT) on the Solar and Heliospheric Observatory (SOHO), shown in Fig. 4, clearly illustrate. The EUV brightness inhomogeneities on the Sun are regions where magnetic fields alter the solar atmosphere. The fundamental determinant of the EUV spectrum is therefore the solar dynamo. There is a broad conceptual appreciation of the connections that relate the solar dynamo to surface magnetic flux emergence, upward field propagation and expansion, active region and coronal hole formation, and EUV irradiance modulation, but the physical links remain largely undetermined. A self-consistent, end-to-end formulation that quantitatively relates the net EUV radiation to subsurface magnetic fields does not yet exist.

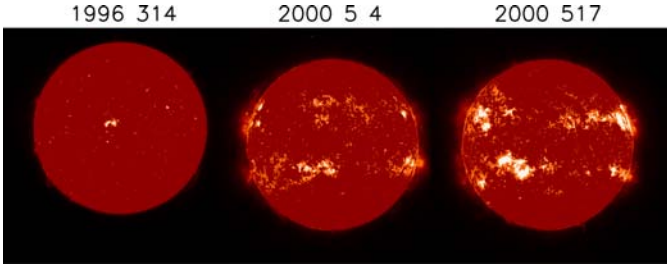


Fig. 4. Images of the Sun’s emission at 30.4 nm, during solar cycle minimum (March 1996) and maximum (May 2000), made by the EIT instrument on SOHO, show the increased occurrence of bright active region sources of enhanced EUV radiation (plage) during times of high solar activity.

The recent approach of using differential emission measures to model solar EUV irradiance variations (Warren, Mariska, and Lean, 2001) is the first step to quantify crucial physical processes. Emission measure distributions are derived from spatially and spectrally resolved measurements of line intensities, and describe the temperature and density structure of the solar atmosphere. A quantitative estimate of the EUV radiation spectrum is possible by combining intensities calculated from emission measure distributions of representative EUV sources, determinations from full disk images (such as those in Fig. 4) of the fractional coverage of these sources, limb brightening, atomic properties, and abundances of solar gases. The EVE investigation will utilize the AIA full disk images to quantify and track the fractional occurrence of EUV irradiance sources (*e.g.* active regions, active network, coronal holes) throughout the SDO mission. Comparisons of the EUV irradiance modeled from AIA observations with the direct EVE measurements will reveal how well, or how poorly, this physical theory accounts for irradiance variations.

With quantitative relationships between magnetic structures in the solar images and the measured EUV irradiance established, subsequent exploration of the physical connections between EUV irradiance and surface magnetic fields becomes possible. SDO's HMI (and also ground-based magnetograms) map surface magnetic fields. Combining the HMI and AIA images (made at different temperatures) provides empirical tracing of magnetic fields from their relatively compact photosphere footprints to the more expanded EUV sources. Comparisons with modeled extrapolations of surface fields will help characterize the relationship between the fields and EUV brightness. Initial simulations have elucidated the primary role of footprint field strength and the less important role of loop length in accounting for observed coronal irradiance changes during solar rotation and the solar cycle. Analogous studies will combine data and results from the EVE instruments and other SDO instruments to quantify the relationship between surface magnetic structures and the EUV irradiance.

Once the coronal and chromospheric magnetic field configurations that cause bright and dark EUV sources are properly connected to surface magnetic fields, the EUV irradiance variations become amenable to study in terms of source emergence, meridional transport and diffusion, as encapsulated in current flux transport models (Wang, Lean, and Sheeley, 2000; Wang, Sheeley, and Lean, 2000). For example, the NRL flux transport model (Wang and Sheeley, 1991) may be used to simulate the evolution of the large-scale surface magnetic field for comparison with synoptic changes in the chromosphere and corona deduced from the AIA images. Relationships between sub-surface signatures of flux emergence derived from HMI images, and their surface manifestations ultimately link the solar dynamo and the EUV radiation. New understanding of the solar dynamo and its possible long-term evolution and intermittent behavior (such as since the Maunder Minimum) will then be directly applicable to studying the EUV irradiance variations on longer time scales, beyond those accessible to space-based observations (*e.g.*, Wang *et al*., 2005).

2.1.3. EVE objective 3 – forecast solar EUV variations

The application of the physical understanding and specification of the solar EUV irradiance developed in EVE Objectives 1 and 2 will facilitate a unique, and hitherto unavailable, capability for EUV irradiance predictions on multiple time scales associated with the solar cycle, rotation, and flares. Predictions for the various time scales ranging from the long-term solar cycle to the short-term flare eruptions require different techniques.

Solar activity cycles are currently predicted in terms of sunspot numbers or 10.7 cm radio fluxes. NASA uses such predictions for planning shuttle and space station activities, for example. Most previous predictions use either statistical regression techniques based on average properties and mean behavior of sunspot patterns or the geophysical precursor technique, which recognizes the extended nature of the solar cycle (Hathaway, Wilson, and Reichmann, 1999). Were the EUV irradiance and its variability better known, these predictions could be transformed empirically to much improved equivalent EUV energies. EVE measurements, with high accuracy and repeatability, will greatly improve the specification of the relationship of EUV irradiance and sunspot numbers (or 10.7 cm fluxes) to facilitate useful nowcasts and forecasts of present and future long-term irradiance cycles.

Predicting the details of day-to-day EUV irradiance variations associated with solar rotations requires a different approach. The US Air Force and NOAA, working cooperatively, have an operational need for predicting space weather at 1 to 45 days. The predictions rely heavily on forecasts of future solar EUV irradiance. A new capability will be developed to predict day-to-day EUV irradiances by using HMI far-side images and AIA limb emission to quantify emerging flux and active regions soon to rotate onto the face of the Sun visible at the Earth. The physical associations between surface fields and active regions in the chromosphere and corona (developed in EVE Objective 2) then permit quantitative forecasts of EUV irradiance using the far-side and east-limb active regions.

As Fig. 5 demonstrates, the emission on the east limb of the solar disk is a useful predictor of full disk flux (irradiance) from 3 to 9 days later. Separately, EVE's direct observations acquired in Objective 1 provide a database to quantify and validate this association using AIA images, and to develop, as well, an independent statistical predictive capability from accumulated characterizations of EUV irradiance variations at particular phases of the solar cycle. Together, the complementary physical and statistical approaches enable state-of-the-art near-term EUV irradiance forecasts. The database of 10-sec EUV irradiance spectra will be particularly useful for nowcasting space weather.

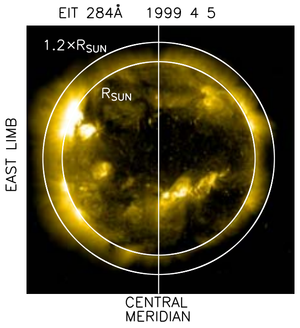
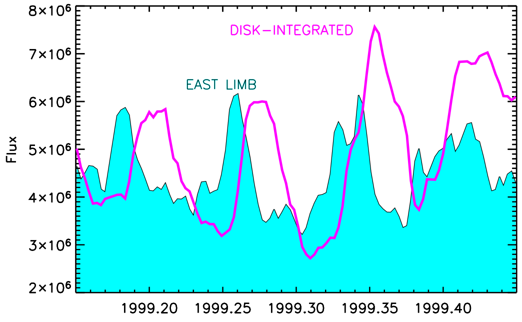


Fig. 5. Shown on the left are aspects of the solar disk utilized to develop a predictive capability. Compared below are two time series derived from two different non-intersecting subsets of the EIT 284 Å images. The east limb flux (shaded region) is the signal from only those pixels between 1 and 1.2×R$_{SUN}$ in the eastern half of the image. The disk-integrated flux (solid line) is the signal from all pixels on the disk.



The ability to forecast short-term solar eruptions has progressed in the past few years as a result of empirical associations between certain magnetic field configurations (such as helicity features, dimmings, and shadows) and subsequent flares and coronal mass ejections. With its high time cadence EVE will record the increase in EUV irradiance that accompanies each and every flare throughout the SDO mission. This unique database will enable classifications of the types and nature of geoeffective flares, ones that have sufficient brightness to dominate the disk-integrated signal during an eruptive event. This database will enable empirical associations with flare precursors detected in HMI and AIA images. EVE will develop, in collaboration with the SDO imaging teams, physical descriptions of the associations of precursor magnetic field configurations and subsequent EUV irradiance enhancements. These studies will contribute to more reliable short-term forecasts of EUV irradiance levels and hence of abrupt space weather phenomena.

2.1.4. EVE objective 4 – understand response of geospace environment

EVE will provide reliable knowledge of the solar EUV spectrum and its variability that the geophysics community has sought for decades, and without which LWS cannot fully succeed. Variations in EUV irradiance initiate space weather phenomena through both direct and indirect processes and are, consequently, crucial inputs for many geospace models. The direct terrestrial effects of solar EUV electromagnetic radiation are well recognized (*National Space Weather Plan*, 2000). The EUV irradiances specified by EVE will enable progress in understanding, specifying, and forecasting myriad space weather phenomena, including spacecraft drag, communications, and navigation. Fig. 6 demonstrates the close association of accelerated orbital decay with increased solar EUV irradiance.

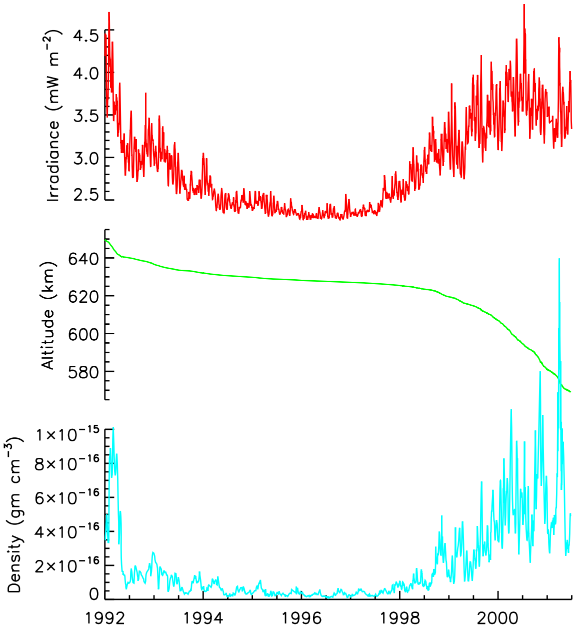


Fig. 6. Shown in the top panel are daily variations in the total EUV photon energy during the Yohkoh mission. The altitude of the Yohkoh orbit is shown in the middle panel, and in the lower panel are thermospheric densities derived from the orbital elements (Picone *et al*., 2005).

Through both direct and collaborative methods, the EVE team will support modeling and interpretation of the neutral atmosphere and ionosphere responses to EUV irradiance variations. Examples of such studies include simulations using the NOAA three-dimensional Coupled Thermosphere Ionosphere Model (CTIM) (Fuller-Rowell *et al.*, 1996) and the Utah State University Time-Dependent Ionospheric Model (TDIM) (Sojka, 1989; Schunk *et al.*, 2002) with a hierarchy of inputs ranging from direct high time cadence observations of flares, modeled flare spectra, active region time scale and near-term forecast responses, solar cycle-induced variations and extreme conditions of solar activity. EVE will enable the solar component in the day-to-day variability of ionospheric electron density and total electron content to be quantified for the first time. Such a comprehensive study of atmosphere-ionosphere responses to EUV radiation has never been conducted. Prior studies, undertaken only infrequently because of their interdisciplinary nature, have suffered from the quality of their adopted EUV irradiance inputs. Only very recently, for example, were sufficient interdisciplinary resources brought together to simulate the ionospheric response to EUV spectrum changes during a flare.

2.2. EVE science team

In addition to the EVE Principal Investigator, Dr. Tom Woods (University of Colorado’s Laboratory for Atmospheric and Space Physics. LASP), EVE scientists include Frank Eparvier and Gary Rottman (LASP), Darrell Judge and Andrew Jones (University of Southern California, USC), Don McMullin (Praxis, Inc.), Greg Berthiaume (Massachusetts Institute of Technology, MIT), Scott Bailey (University of Alaska at Fairbanks, UAF), and Judith Lean, John Mariska and Harry Warren (Naval Research Laboratory, NRL).

LASP provides overall EVE project management, instrument design, fabrication, calibration, instrument operations, and data processing software development. USC contributes a portion of the flight hardware and significant expertise and experience in solar EUV irradiance measurements. MIT leads the development of CCD detectors. UAF provides calibration and geospace modelling expertise, and NRL undertakes solar spectral irradiance modelling, in particular improvements to the NRLEUV semi-empirical irradiance variability model (Warren, Mariska and Lean, 2001; Lean, Warren, Mariska and Bishop, 2003).

The EVE Science Team also includes several collaborators whose participation is vital to EVE’s success. Drs. Tim Fuller-Rowell and Rodney Viereck (NOAA Space Environment Center, SEC), Dr. Jan Sojka (Utah State University, USU), and Dr. Kent Tobiska (Space Environment Technologies, SET) participate in various aspects of the space weather and operations effort through geospace and solar operational modelling. They will assist in transitioning EVE research to operations. In particular, EVE data will be used to improve, validate, or constrain such atmospheric models as CTIM (Fuller-Rowell *et al*., 1996), GAIM (Schunk *et al*., 2002) and NRLMSIS (Picone *et al*., 2002), and the SOLAR2000 empirical solar irradiance model (Tobiska *et al*., 2000).

2.3. EVE measurements and data products

To help meet the EVE objectives, the EVE instrument suite will measure the spectral irradiance from 0.1 to 5 nm at 1 nm resolution, from 5 to 105 nm with a resolution of 0.1 nm, plus the hydrogen Lyman-α line at 121.5 nm with 1 nm resolution. The full spectral range will be measured every 10 seconds, continuously (except during satellite eclipse periods and planned calibration activities). The absolute accuracy of EVE's spectral irradiance measurements will be better than 25% throughout the nominal five-year mission.

The primary EVE data products are solar EUV irradiances at 0.1 nm and 1 nm resolution at a 10-sec time cadence and as daily averages. In addition, specific solar emission lines and broadband irradiances will be extracted and provided at both time cadences. These data products will be available within a day or so of receipt on the ground. Near real-time data products for space weather operations will also be produced and available within approximately fifteen minutes of ground receipt. The space weather products will not be as fully corrected or processed as the primary data products, and may consist of solar indices and spectra with preliminary calibration, but can be used in assimilative models and as "nowcasting" tools for short time-scale solar events such as flares, that may have immediate effects on the geospace environment.

3. EVE instrumentation

To meet the measurement and accuracy requirements, the EVE instrument is composed of several channels. The wavelength coverage of all channels is shown in Fig. 7, along with a sample solar spectrum. Eparvier *et al.* (2004) provides details of the optical designs for the EVE channels.

The primary, high spectral resolution irradiance measurements are made by the Multiple EUV Grating Spectrographs (MEGS) (Crotser *et al*., 2004), which have heritage from the TIMED-SEE EUV Grating Spectrograph (EGS) (Woods *et al*., 2005). The MEGS is composed of two spectrographs: MEGS-A is a grazing incidence spectrograph covering the 5 to 37 nm range, and MEGS B is a two-grating, cross-dispersing spectrograph covering the 35 to 105 nm range. Included as part of the MEGS-A package is a pinhole camera for use as a solar aspect monitor (MEGS-SAM) to provide a pointing reference for the EVE channels. MEGS-SAM will also make a spectral measurement of the solar irradiance in the 0.1 to 5 nm wavelength range at approximately 1 nm resolution. In addition, a photodiode with a filter to isolate Lyman-α at 121.5 nm (MEGS-P) is part of the MEGS-B. This measurement is used to track potential changes in the sensitivity of the MEGS on timescales of weeks and months. Annual sounding rocket underflights of similar instruments will track longer-term changes in the sensitivity of the EVE channels.

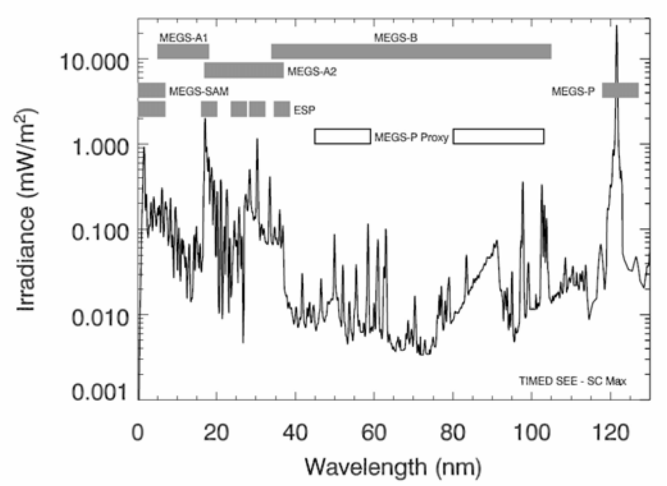


Fig. 7. The wavelength coverage of the various EVE channels plotted over a sample irradiance spectrum for solar maximum conditions (from the TIMED SEE instrument).

Additional onboard short-term calibration tracking is achieved by redundant, lower spectral resolution measurements at select bandpasses, made by the EUV Spectrophotometer (ESP). The ESP is a transmission grating and photodiode instrument similar to the SOHO SEM (Judge *et al*., 1998). ESP has four channels centered on 18.2, 25.7, 30.4, and 36.6 nm that are each approximately 4 nm in spectral width. The ESP also has a central, zeroth-order diode with a filter to make the primary irradiance measurement in the 0.1 to 7 nm range. The ESP measurements are made at a high time-cadence (0.25 sec) and so are useful as quick indicators of space weather events such as flares.

3.1. MEGS-A channel

The MEGS-A channel is a 80˚ grazing incidence, off-Rowland circle spectrograph with a CCD detector to measure the solar spectrum between 5-37 nm at a resolution just less than 0.1 nm. MEGS-A has two entrance slits, each 20 microns wide and 2 mm high, oriented top-to-bottom. In front of the slits is a filter wheel mechanism with bandpass-limiting thin foil filters (made by Luxel Corp.). The primary science filters are Zr/C for slit 1 to isolate 5 to 18 nm and Al/Ge/C for slit 2 to isolate 17-37 nm. Secondary filters are available to further limit the bandpasses of each slit to provide an occasional check on higher orders (Zr/Si/C for slit 1 to pass 13 to 18 nm, and Al/Mg/C to pass 25 to 37 nm for slit 2). The filter wheel mechanism also has a blanked-off position for dark measurements. The grating, produced by Jobin Yvon (JY), is a spherical holographic grating with a radius of curvature of 600 mm, platinum coating, and 767 grooves/mm with a laminar groove profile to suppress even orders. The detector for MEGS-A is a back-thinned, back-illuminated, split-frame transfer CCD with 1024x2048 pixels, built by MIT-LL. The CCD is maintained at -90˚C to suppress noise and to minimize radiation damage in the geosynchronous environment.

3.2. MEGS-B channel

The MEGS-B channel is a normal incidence, double-pass, cross-dispersing Rowland circle spectrograph with a CCD detector to measure the solar spectrum between 35 to 105 nm at a resolution just less than 0.1 nm. MEGS-B has a single entrance slit, 35 microns wide and 3.5 mm high. There are no known reliable bandpass filters for the MEGS-B wavelength range, so a two-grating design isolates the entire 35 to 105 nm range. A filter wheel mechanism is also included with clear positions for primary science measurements, a foil filter for higher order checks, and a blanked-off position for dark measurements. Both MEGS-B gratings are also produced by JY, and are spherical holographic gratings with platinum coating and laminar groove profiles to suppress even orders. The first grating has 900 grooves/mm and the second has 2140 grooves/mm. The detector for MEGS-B is identical to the MEGS-A detector.

3.3. MEGS-SAM channel

The MEGS-SAM channel is a pinhole camera within the MEGS-A housing, using a separate aperture, but focusing an image of the Sun onto a portion of the MEGS-A CCD where the bandpass filter for slit 2 blocks essentially all light. The SAM aperture has a separate filter wheel mechanism that allows three modes. In aspect monitor mode a UV filter is in place and the resultant image of the Sun is centroided to give pointing information for all of EVE relative to the boresights established during pre-flight calibrations to roughly 1 arcminute accuracy. In XUV photon-counting mode a Ti foil filter is in place to isolate 0.1 to 7 nm. The pinhole and filter are optimized so that in this mode only single photon events occur per pixel per 10-sec CCD integration. In this way the energy (or wavelength) is determined from the magnitude of each photon event. Binning photon events from over the entire image of the Sun gives a low (~ 1 nm) spectral resolution for the SAM XUV bandpass. Summing consecutive integrations over a few minutes generates XUV images of the Sun. The third mode for SAM has the filter wheel in a blanked off position for dark measurements.

3.4. MEGS-P channel

The MEGS-P channel is an IRD silicon photodiode placed at the -1st order of the first MEGS-B grating. In front of the diode is an Acton interference filter to isolate the solar hydrogen Lyman-α line at 121.5 nm. The filter has a bandwidth of 10 nm, but the solar spectrum is such that greater than 99% of the signal is due to Lyman-α. Next to the primary MEGS-P diode is an identical diode that is masked to give simultaneous dark information, used to correct the MEGS-P measurements for background noise induced by particle radiation.

3.5. ESP channel

The ESP channel is a non-focusing, broadband spectrograph with a transmission grating and IRD silicon photodiodes. In front of the entrance slit is an Al foil filter made by Luxel Corp. to limit the out-of-band light that enters the instrument. The transmission grating, made by X-Opt, is essentially a set of thin wires with no substrate, spaced so that there are 2500 lines/mm. Silicon photodiodes are placed at both plus and minus first orders and positioned so that the bandpass centers are at 18.2, 25.7, 30.4, and 36.6 nm. The diodes are sized to give approximately 4-nm bandpasses centered on each of these wavelengths. The central, zeroth order position has a silicon quadrant photodiode with an additional thin foil filter to isolate 0.1 to 7 nm. The sum of the quadrants gives the solar irradiance in this bandpass. Differencing the quadrants allows for determination of the pointing of the ESP. The ESP has a filter wheel mechanism with open (Al foil filter) and blanked off positions for solar and dark measurements. The ESP has the fastest measurement cadence of all of the instruments in the EVE suite at 0.25 seconds.

3.6. Summary of EVE subsystems

The EVE channels are packaged together onto the EVE Optical Package (EOP) as shown in Fig. 8. The EOP is mounted to the SDO spacecraft deck using three Ti-flex structures. The microprocessor, interface electronics, control electronics, and most of the power conditioning and regulation electronics are housed in the EVE Electronics Box (EEB). The EEB resides behind the EOP and directly mounts to the SDO spacecraft deck. The interfaces to the SDO spacecraft include unregulated 28 V DC for power, 1553 for commands and housekeeping telemetry, and High Speed Bus (HSB) for science telemetry. Several radiators are also part of the EVE package, to passively remove heat by radiating to deep space. The resources for EVE include mass of 54 kg, orbit-average power of 44 W, housekeeping telemetry of 2 kilobits per sec (kbps), and science telemetry of 7 Megabits per sec (Mbps).

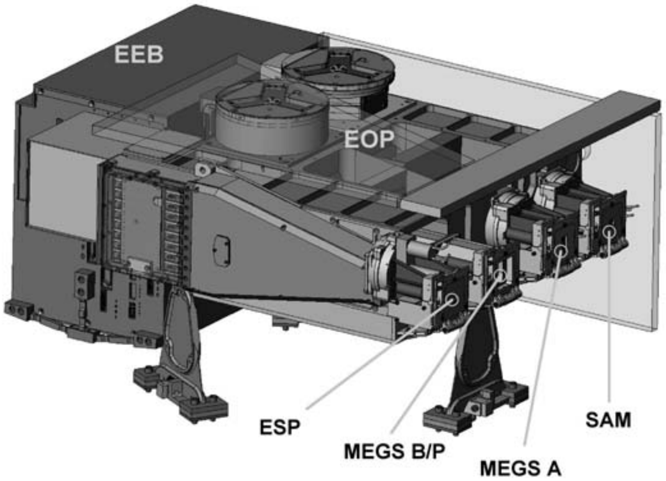


Fig. 8. The EVE channels are mounted on the EVE Optical Package (EOP), and the EVE Electronics Box (EEB) provides the electrical interfaces to the

SDO spacecraft. The entrance baffle in the door mechanisms are indicated for the various MEGS and ESP channels.

4. Summary

SDO EVE will measure solar EUV spectral irradiance with unprecedented spectral and temporal resolution and accuracy. These measurements will contribute to space weather operations, and solar and atmospheric physics research, particularly solar flares and their effects on the geospace environment. EVE research will help validate and improve empirical and first principle models of the solar irradiance variability and of the geospace environment. The EVE has been carefully designed to meet or exceed all of its scientific objectives. It is being assembled in 2006, with spacecraft integration and test (I&T) in 2007. Managed by NASA's Goddard Space Flight Center (GSFC), SDO will be launched in August 2008 into geosynchronous orbit for a nominal five-year mission.

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