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# Recent advances in observations and modeling of the solar ultraviolet and X-ray spectral irradiance

Thomas N. Woods

*Laboratory for Atmospheric and Space Physics (LASP), University of Colorado, 1234 Innovation Drive, Boulder, CO 80303, USA*

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**Abstract**

There have been significant, recent advances in understanding the solar ultraviolet (UV) and X-ray spectral irradiance from several different satellite missions and from new efforts in modeling the variations of the solar spectral irradiance. The recent satellite missions with solar UV and X-ray spectral irradiance observations include the X-ray Sensor (XRS) aboard the series of NOAA GOES spacecraft, the Upper Atmosphere Research Satellite (UARS), the SOHO Solar EUV Monitor (SEM), the Solar XUV Photometers (SXP) on the Student Nitric Oxide Explorer (SNOE), the Solar EUV Experiment (SEE) aboard the Thermosphere, Ionosphere, Mesosphere, Dynamics, and Energetics (TIMED) satellite, and the Solar Radiation and Climate Experiment (SORCE) satellite. The combination of these measurements is providing new results on the variability of the solar ultraviolet irradiance throughout the ultraviolet range shortward of 200 nm and over a wide range of time scales ranging from years to seconds. The solar UV variations of flares are especially important for space weather applications and upper atmosphere research, and the period of intense solar storms in October–November 2003 has provided a wealth of new information about solar flares. The new efforts in modeling these solar UV spectral irradiance variations range from simple empirical models that use solar proxies to more complicated physics-based models that use emission measure techniques. These new models provide better understanding and insight into why the solar UV irradiance varies, and they can be used at times when solar observations are not available for atmospheric studies.


*Keywords:* Solar EUV irradiance; Solar variability; Measurements; Models

## 1. Introduction

The solar ultraviolet (UV) radiation is an important source of energy for aeronomic processes throughout the solar system. For example, the solar UV photons are absorbed in planetary atmospheres via photodissociation of molecules, photoionization of molecules and atoms, and photoexcitation including resonance scattering (e.g., see Chamberlain, 1978). All of the atmospheric processes are wavelength dependent and are expected to be as variable as the intrinsic solar variability at the appropriate wavelengths. Therefore, accurate measurements of the solar UV spectral irradiance, along with an understanding of its variability, are important for detailed studies of the atmospheric processes. One of the practical applications is for space weather operations, including solar UV irradiance effects on satellite drag due to thermospheric density changes and on communication and navigation accuracy and disruptions due to ionospheric fluctuations.

The subdivisions of the UV spectral range include the near ultraviolet (NUV) at wavelengths from 300 to 400 nm range, the middle ultraviolet (MUV) from 200 to 300 nm, the far ultraviolet (FUV) from 120 to 200 nm range, the extreme ultraviolet (EUV) from 10 to 120 nm range, the soft X-ray from 0.1 to 10 nm range, and hard X-rays at wavelengths less than 0.1 nm. The vacuum ultraviolet (VUV) is defined for all wavelengths shortward of 200 nm. We also define the X-ray ultraviolet (XUV) to be 0.1–30 nm, which overlaps the X-ray and EUV ranges

*E-mail address:* tom.woods@lasp.colorado.edu

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because the instrument technology is different for wavelengths shortward of 30 nm. The focus here is the solar X-ray, EUV, and FUV irradiance and its variability.

Emission lines and ionization continua from the solar upper atmosphere dominate the solar EUV spectrum. The emission lines arise from the dominant species, H and He, and the many minor species as a non-local thermodynamic equilibrium (non-LTE) effect and are strongly sensitive to the magnetic activity on the Sun. The solar EUV emissions also include ionization continua, such as the bright H ionization continuum shortward of 91 nm. These general characteristics of the solar UV spectrum are evident in Fig. 1, which includes a solar spectrum at 1 nm spectral resolution (Woods et al., 2005a). This spectrum and others discussed here are the solar spectral irradiance, which is the spectral radiance (or intensity) at a single wavelength integrated over the full disk of the Sun and observed at a distance of 1 AU. The distribution of the emission features with wavelength is caused by the complex atomic energy levels of the source gases, so there is not a general relation of irradiance or its variability with wavelength. However, there are better relations between the irradiance variability and the different layers of the solar atmosphere, being the photosphere, chromosphere, transition region, and corona. With the density decreasing with altitude and the temperature increasing at higher layers of the solar atmosphere, the radiation from the higher layers is, in general, more variable. In other words, the coronal emissions vary more than the transition region emissions, which in turn vary more than the chromospheric emissions.

## 2. Observations

Because of atmospheric absorption space-based observations are required to measure the solar UV irradiance. The earliest spacecraft measurements are in the 1960s from the SOLRAD (Kreplin, 1970; Kreplin and Horan, 1992), the Orbiting Solar Observatory (OSO), and the Atmospheric Explorer (AE) series of satellites (Gibson and Van Allen, 1970). The AEROS series of satellites followed in the 1970s (Schmidtke et al., 1974, 1977), then there was

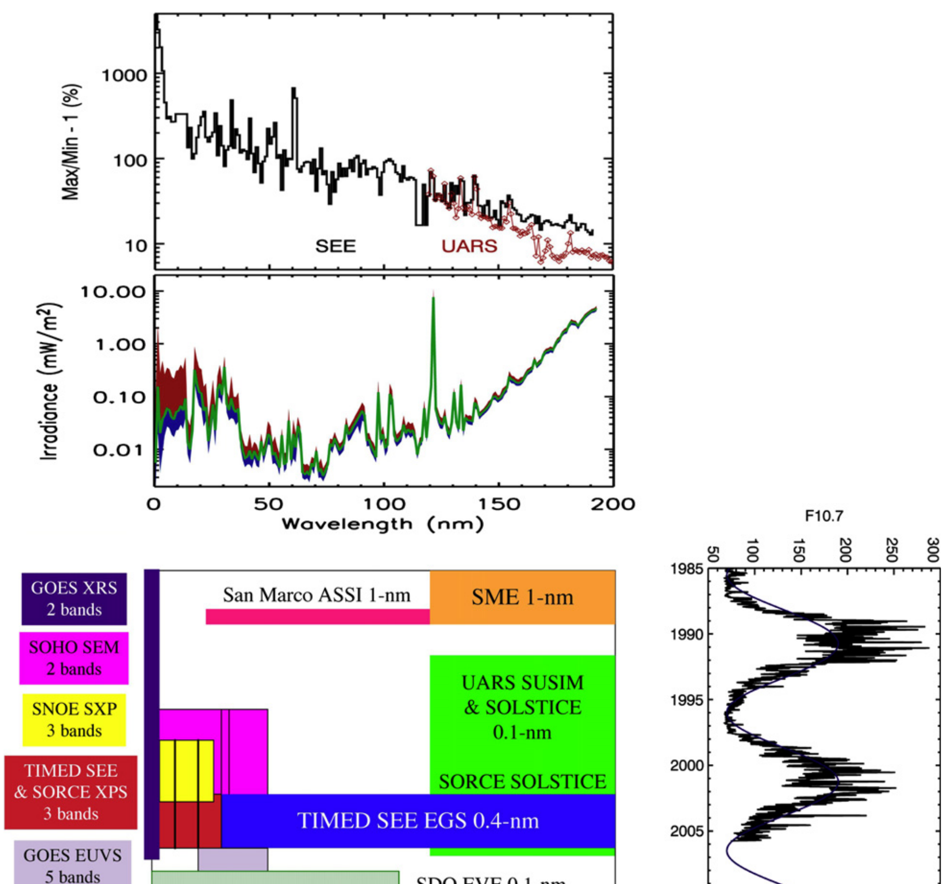


Fig. 1. Solar UV irradiance observations. The recent observations of the solar EUV and FUV irradiance are depicted in reference to wavelength shown in the top plots of the solar spectrum and to time shown in the right plot of the 10.7 cm radio flux (F10.7). The solar spectra in the top plot are the TIMED SEE measurements at 1 nm resolution. The middle (green) spectrum is the median value over the TIMED mission. The upper (red) and lower (blue) ranges indicate the variability of the daily irradiances during 2002–2005. The solar cycle ratio of the SEE spectrum on 2002/233 (Aug. 21) to that on 2006/068 (Mar. 9) is shown in the top most plot as the black solid line. The line with diamonds (red) in this plot is the FUV variation predicted by a model based on the UARS SOLSTICE measurements (Woods and Rottman, 2002).