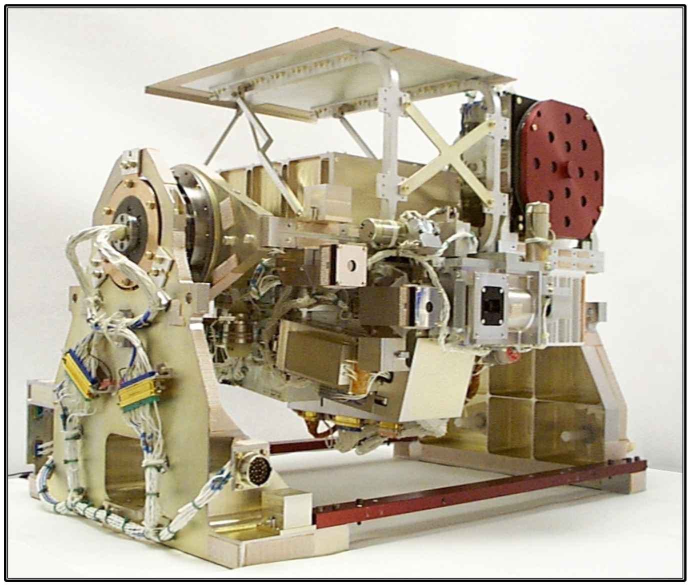
Summary of Research Report for *TIMED Solar EUV Experiment (SEE)* November 2014



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Note that Dr. Woods and Dr. Eparvier are the only ones funded by this grant; the other SEE team members are funded through ROSES or other opportunities.

Report Outline:
1. SEE Science Overview
2. SEE Mission Operations
3. SEE Data Processing and Data Products

1. Solar EUV Experiment (SEE) Science Overview

The NASA Thermosphere-Ionosphere-Mesosphere-Energetics-Dynamics mission was launched on December 7, 2001, and normal science operations began in January 2002. The Solar Extreme ultraviolet Experiment (SEE) is one of the four instruments aboard the TIMED spacecraft. The SEE instrument is designed to daily observe the solar extreme ultraviolet (EUV) and soft X-ray (XUV) irradiance. The SEE channels include the EUV Grating Spectrograph (EGS) that measures the solar EUV spectrum from 27 nm to 195 nm with about 0.4 nm spectral resolution and the XUV Photometer System (XPS) that measures the solar XUV radiation in broadbands below 40 nm. Woods *et al.* [2005] provide detailed overviews of the SEE science goals, instrument design, pre-flight calibrations, data processing algorithms, and first results. An example of the solar spectrum from TIMED SEE is shown in Figure 1.1.

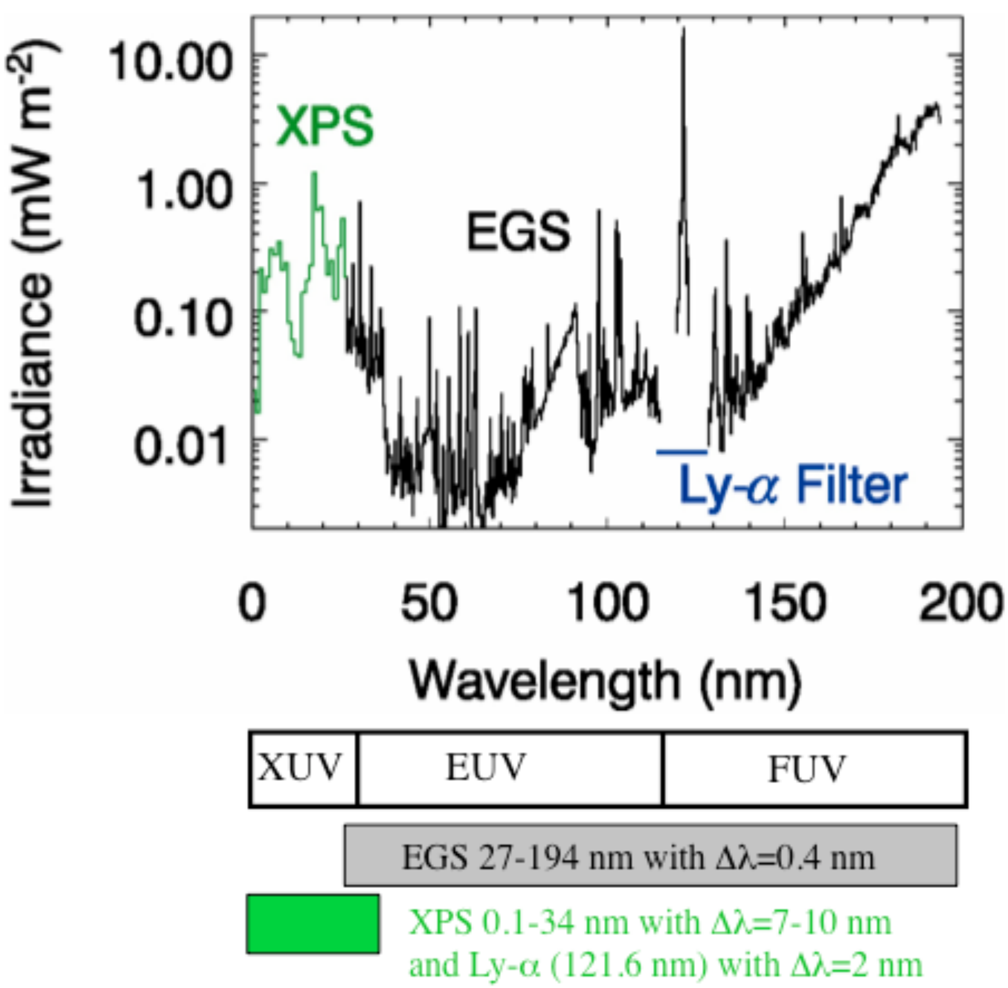

Figure 1.1. Example Solar Spectrum from TIMED SEE.

There are very few observation gaps in the daily record of the solar UV irradiance from TIMED SEE (more details given in Section 2), and there has only been one instrument anomaly that has limited SEE's observations. This anomaly is the XPS filter wheel mechanism became stuck in position 6 on day 2002/205; consequently, the XPS solar observations are limited to 3 XUV channels instead of its 9 channels. Nonetheless, these 3 XPS channels have been adequate to provide the solar XUV irradiance below 27 nm.

The primary objective for SEE science analysis during this past year has been studying the solar irradiance variability during solar cycle 24 (2009-present) and comparison of that variability to solar cycle 23 (1997-2008). Figure 1.2 shows the variation of some of the solar EUV emission lines during the TIMED mission and in context with solar variability from the previous solar cycle. Another important aspect of the SEE solar EUV-FUV irradiance record is to combine the TIMED record with earlier data to make an even longer term solar irradiance climate record. This study is important because long-term (years) changes of the ionosphere-thermosphere-mesosphere (ITM) are heavily modulated by the solar cycle (11-year) irradiance variations and also by anthropogenic forcing from below. For example, a reduced solar energy input will lower the ionosphere density and peak altitude, and the thermosphere will be cooler.

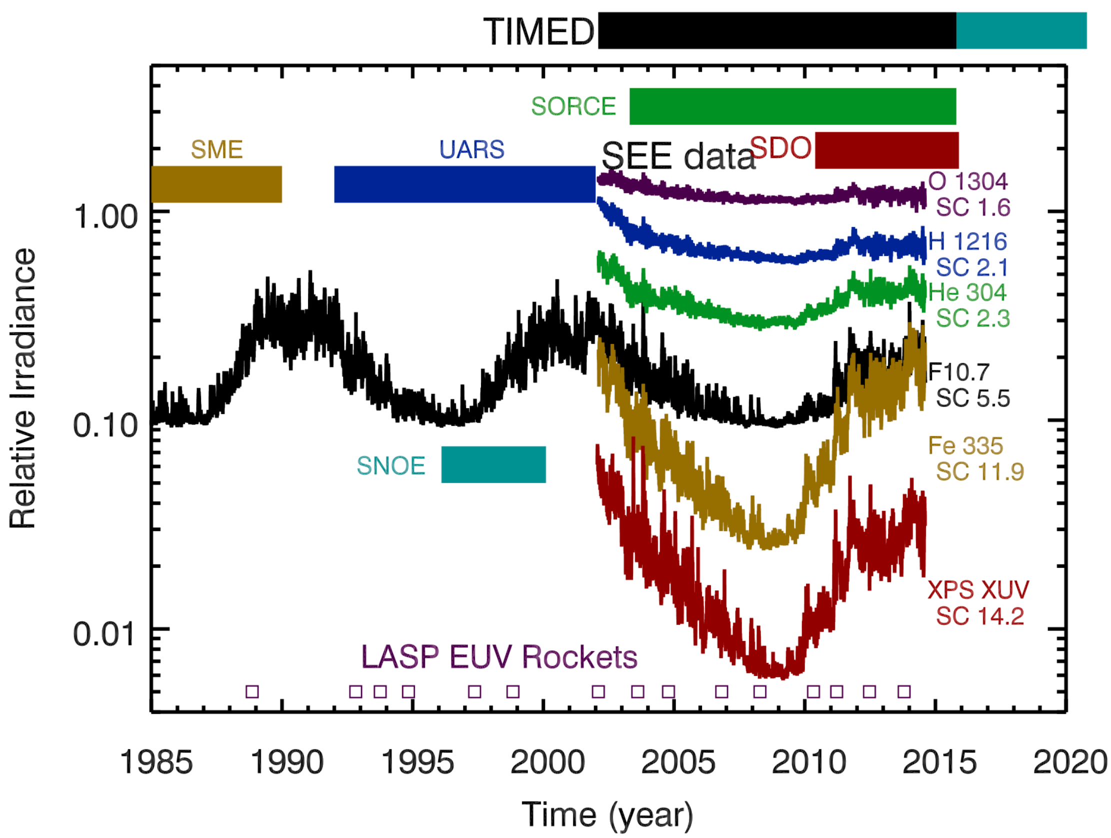

Figure 1.2. Solar variations during the TIMED mission as observed by SEE. The "SC" values are the solar cycle variations. The F10.7 is the 10.7 cm radio flux and is not measured by SEE. The TIMED measurements overlap with other solar EUV-FUV irradiance measurements from SORCE and SDO.

Solar EUV and particle input is lower in SC-24 than in SC-23, so ITM response is expected to be much lower during SC-24 maximum (2011-2014) than during SC-23 maximum (2002) in the TIMED data set. Figure 1.3 shows that the solar EUV irradiance variation (maximum minus minimum) is half as much in 2012 than it was in 2002. A cooler thermosphere has already been observed by TIMED SABER [Mlynczak *et al.*, 2014] and other satellites, and the primary contribution is from the reduction of the solar EUV irradiance [Solomon *et al*., 2011]. There is still much to study concerning the solar cycle variations, both in the solar EUV irradiance and in the solar forcing (response) in Earth's upper atmosphere, and we will continue to study these with the TIMED science team and the broader ITM community.

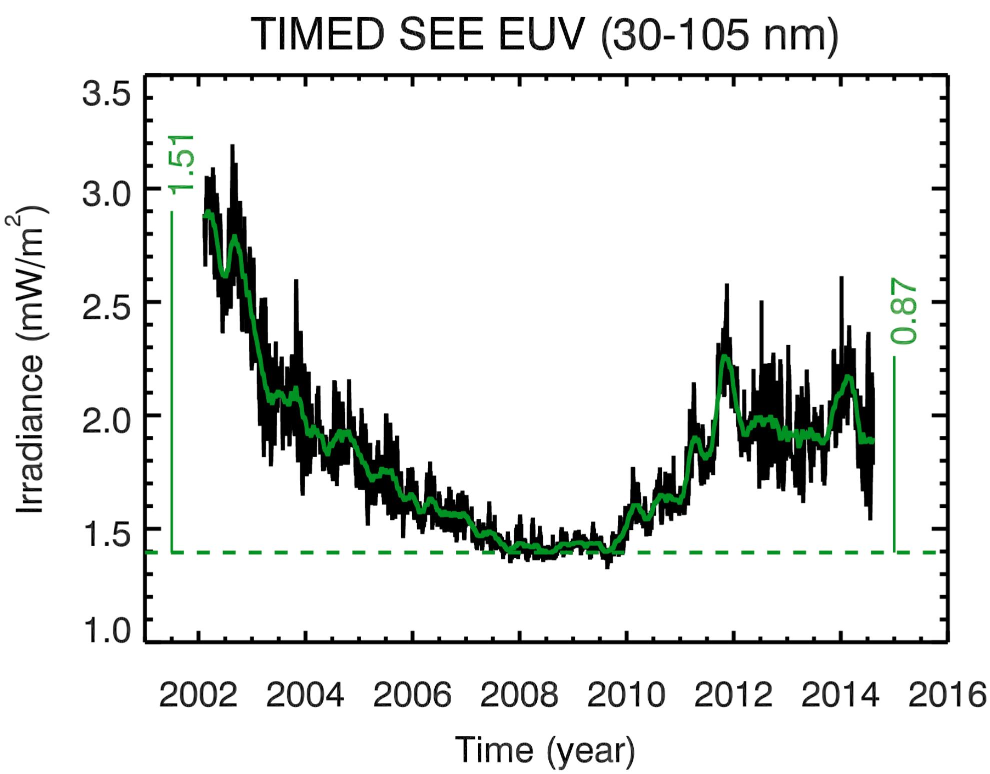

Figure 1.3. The solar cycle variations for the integrated solar EUV irradiance (30-105 nm). The solar EUV variation (maximum – minimum) is about half as much for solar cycle 24 (2009-present) as compared to solar cycle 23 (1997-2008).

References

Mlynczak, M. G, L. A. Hunt, C J. Mertens, B. T Marshall, J. M. Russell III, T. Woods, R. E. Thompson, and L. L. Gordley, Influence of solar variability of the infrared radiative cooling of the thermosphere from 2002 to 2014, *Geophys. Res. Lett*., 41, dio:10.1002/2014GL059556, 2014.

Solomon, S. C., L. Qian, L. V. Didkovsky, R. A. Viereck, and T. N. Woods, Causes of low thermospheric density during the 2007–2009 solar minimum, *J. Geophys. Res.,* 116, A00H07, doi: 10.1029/2011JA016508, 2011.

Woods, T. N., F. G. Eparvier, S. M. Bailey, P. C. Chamberlin, J. Lean, G. J. Rottman, S. C. Solomon, W. K. Tobiska, and D. L. Woodraska, The Solar EUV Experiment (SEE): Mission overview and first results, *J. Geophys. Res.,* 110, A01312, doi: 10.1029/2004JA010765, 2005.

2. SEE Mission Operations

Through November 14, 2014, SEE successfully completed 65,071 normal solar experiments out of the 66,233 experiments planned. This success rate is 98%, which meets the minimum NASA mission criteria. Throughout the entire mission SEE has consistently been well above the acceptable levels. As shown in Table 2.1, there have been very few observational gaps since TIMED normal operations began in January 2002. The SEE normal operations ended in April 2011, but SEE has remained on for overlapping measurements with the Solar Dynamics Observatory (SDO) EUV Variability Experiment (EVE) in 2010-2014. This extension is being operated with automatic operations and data processing (minimal funding).

Table 2.1. List of TIMED SEE Data Gaps. SEE Sensors are EGS and XPS.

Date	State	Sensor(s)	Science Data Affected
March 1, 2002	Safe Mode	Both	Part Day
March 2, 2002	Safe Mode	Both	All Day
March 4, 2002	Ground SW Anomaly	EGS	All Day
March 5, 2002	Ground SW Anomaly	EGS	Part Day
March 19, 2002	Safe Mode	Both	Part Day
March 29, 2002	Safe Mode	Both	Part Day
July 24 – 30, 2002	XPS Filter Wheel Anomaly	XPS	All Days
Nov. 18 – 19, 2002	Leonid Safing	Both	Part Day
Sept. 16 – 21, 2004	TIMED Flight Software Load	Both	Sept. 16, 21: Part Day Sept. 17 – 20: All Day
Sept. 29 – Oct. 1, 2004	TIMED Flight Software Load	Both	Sept. 29, Oct. 1: Part Day Sept. 30: All Day
May 4, 2005	Lost data due to HK rate being at 5 sec (nominally at 15 sec)	Both	Part Day (after SSR allocation reached)
Aug. 16 – 18, 2006	Safe Mode	Both	Aug. 16, 18: Part Day Aug. 17: All Day
July 25 – 26, 2007	Safe Mode	Both	Part Day
Nov. 19, 2007	Safe Mode	Both	Part Day
Jan. 8 – 15, 2008	Safe Mode	Both	Jan. 8: Part Day Jan. 9 – 15: All Day
May 24 – 25, 2008	Safe Mode	Both	May 24: Part Day May 25: All Day
July 7, 2008	Planning Anomaly	Both	Part Day
June 14 – 23, 2009	Safe Mode	Both	June 14 - 22: All Day June 23: Part Day
Dec. 2 – 3, 2009	Safe Mode	Both	Dec. 2: All Day Dec. 3: Part Day
Nov. 27 – 28, 2011	Safe Mode	Both	Part Day
Jan. 28 – Feb. 17, 2013	Default ODC due to planning computer anomaly	Both	All Day
July 8, 2014	SEE Power Off	Both	Part Day

3. SEE Data Processing and Data Products

The TIMED SEE data products are currently at Version 11, and the products through 2012 have been archived at JHU/APL. The SEE data processing is automated and produces new products each day.

All SEE data products are available from the SEE web site (http://lasp.colorado.edu/see), but the TIMED archive site will be the long-term residence for the SEE data products. The SEE data product types are listed in Table 3.1. Most research papers have used the SEE L3 and L3A products. The SEE version 12 products are expected to be released in 2015 and will include updated corrections for the instrument degradation trends.

The SEE Level 3 data product and Composite Lyman-alpha time series is also available on the LASP Interactive Solar Irradiance Datacenter (LISIRD) website – http://lasp.colorado.edu/LISIRD

Table 3.1. List of TIMED SEE Data Products

Data Product	Period	Description
SEE L2A SpWx	Orbit	8 solar indices (emissions/bands) for SpWx Ops
SEE L3	Day	1-nm spectrum from 0.5 nm to 194.5 nm, 38 emission lines, XPS 9 bands
SEE L3A	Orbit	Same as L3 but for orbit average (3-min avg)
EGS L2, L2A	D & O	0.1-nm spectrum from 27 nm to 195 nm
XPS L2, L2A	D & O	XPS 9 bands
XPS L4, L4A	D & O	0.1-nm spectral model from 0 to 40 nm
EGS L2B (Occ)	Orbit	Atmospheric transmission (single altitude)
Composite Ly-α	Day	H I Lyman-α irradiance from 1947 to present