TIMED Solar EUV Experiment: Phase E Progress Report for 2008

Submitted for NASA Grant NNX07AB68G
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SEE Science Team

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NRL: Judith Lean

SET: Kent Tobiska

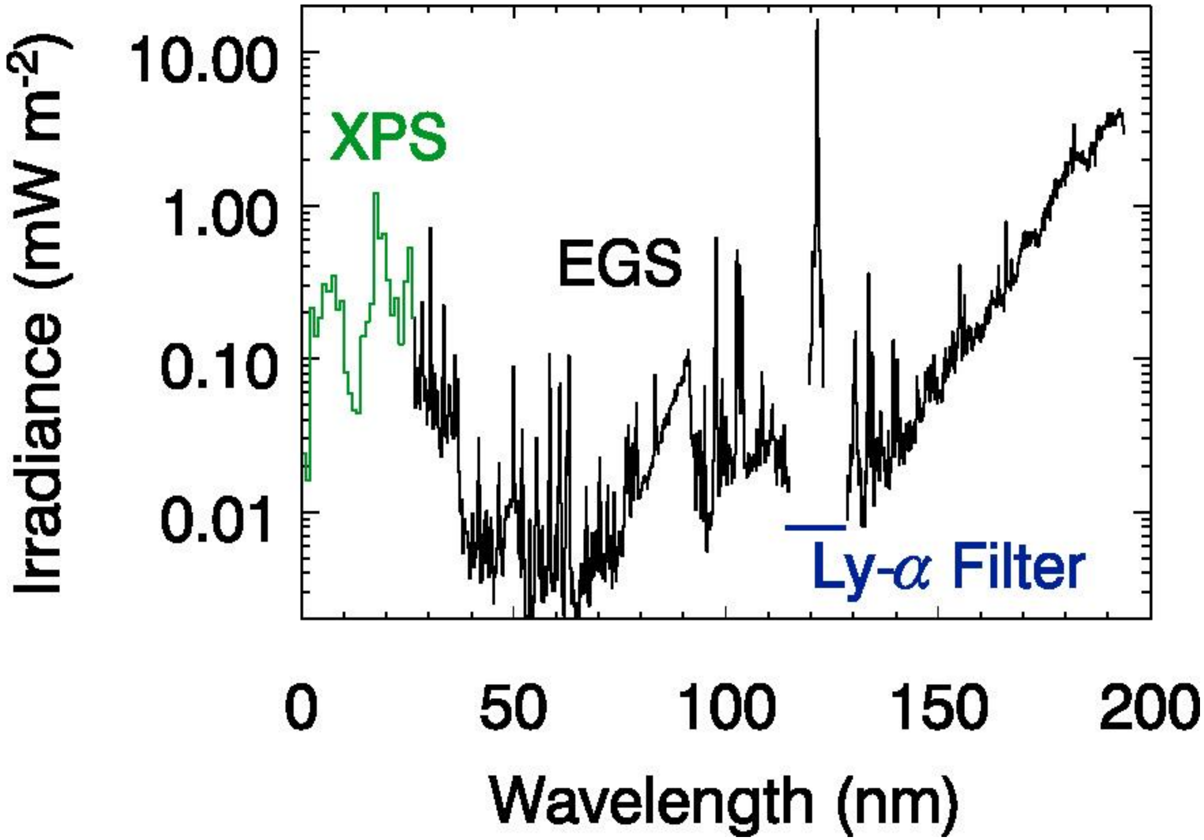
Virginia Tech: Scott Bailey

Report Outline

- SEE Instrument Operations and Instrument Status
- SEE Data Products
- New XPS Level 4 Data Product and Results
- SEE Science Overview
- Summary of SEE Results
  - Solar Cycle Variability
  - Solar Irradiance Model Updates from NRL, SOLAR2000, FISM
  - Atmospheric Response to Solar Variability
- Summary of SEE Related Talks and Papers
- Future Plans for SEE Team

Overview of Operations and Data Processing

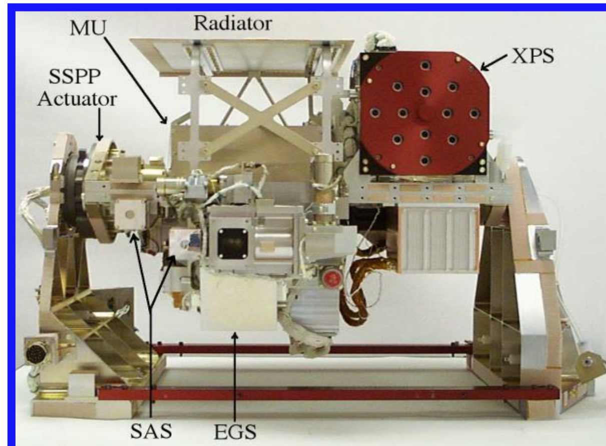
SEE Measures the Solar VUV Irradiance



XUV	EUV	FUV

EGS 27-194 nm with $\Delta\lambda$=0.4 nm

XPS 0.1-34 nm with $\Delta\lambda$=7-10 nm
and Ly-α (121.6 nm) with $\Delta\lambda$=2 nm



EGS = EUV Grating Spectrograph

Rowland-circle grating spectrograph with 64x1024 CODACON (MCP-based) detector

XPS = XUV Photometer System

Set of 12 Si photodiodes - 8 for XUV, 1 for Ly-α, and 3 for window calibrations

FUV = Far UltraViolet: 115-200 nm
EUV = Extreme UltraViolet: 30-115 nm
XUV = X-ray UltraViolet: 0-30 nm

EGS = EUV Grating Spectrograph
XPS = XUV Photometer System

Summary of SEE Flight Operations

- Planned Experiments (through Oct 20, 2008)
  - Number of normal solar experiments = 35,031
- Actual Experiments (through Oct 20, 2008)
  - Number of normal solar experiments = 34,145 (97%)
- Calibration rockets provide degradation rates for SEE
  - NASA 36.192 launched on Feb. 8, 2002, complete success
    - Rocket results incorporated into Version 6 data
  - NASA 36.205 launched on Aug. 12, 2003, complete success
    - Rocket results incorporated into Version 7 data
  - NASA 36.217 launched on Oct. 15, 2004, complete success
    - Rocket results incorporated into Version 8 data
  - NASA 36.233 launched on Oct. 28, 2006
    - Partial success (only 0.1-36 nm and 121.6 nm irradiance measured)
  - NASA 36.240 launched on April 14, 2008, complete success
    - Rocket results incorporated into Version 10 data

List of SEE Data Gaps - Very Few Gaps

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 (normally 15 sec)	Both	Part day (after SSR allocation reached)

List of SEE Data Gaps - 2

Date	State	Sensor(s)	Science Data Affected
Aug 16-18, 2006	Safe Mode	Both	Partial day on 16th All day on 17th Partial day on 18th
July 25-26, 2007	Safe Mode	Both	Partial day
Nov. 19, 2007	Safe Mode	Both	Partial day
Jan. 8-15, 2008	Safe Mode	Both	Partial day on the 8th All day from 9-15
May 24-25, 2008	Safe Mode	Both	Partial day on 24th All day on the 25th
July 7, 2008	Planning Anomaly	Both	Partial day

Status of SEE Instruments

No recent changes for SEE

- **EUV Grating Spectrograph (EGS) - fully functional**
  - The EUV (λ < 115 nm) has degradation mostly at the bright lines on the CODACON (MCP-based) detector, but it is being tracked with on-board redundant channel and flat-field detector lamp weekly experiments
  - The FUV (115-195 nm) has small recovery rate that is corrected using UARS, SORCE, and XPS comparisons
- **XUV Photometer System (XPS) - 3 channels functional**
  - Fully functional until 2002/205 when there was a filter wheel anomaly (filter wheel stuck in position 6)
  - Three channels providing solar measurements
  - No spectral gaps in the XUV though because of new XPS Level 4 algorithm
- **Microprocessor Unit (MU) - fully functional**
- **SEE Solar Pointing Platform (SSPP) - fully functional**

Potential Life Issues for SEE

- EGS (grating spectrograph)
  - MCP-based detector has significant degradation at a few wavelengths (~5% of spectral range). Accuracy already degraded at those wavelengths. Degradation has slowed down with time, but still expect this degradation to continue during extended mission.
  - No degradation or anomalies for HV supply or slit changer mechanism; expect them to perform well for several more years
- XPS (set of photometers)
  - None: filter wheel mechanism is not used anymore
  - Lower priority than EGS as have SORCE XPS
- SSPP (pointing platform)
  - No degradation or anomalies for SSPP; expect it to perform well for several more years
- Recent change in Sept. 2008 is to perform calibration channel observations once a day (instead of once a week)
    - This is improve EGS data products due to EGS detector degradation for normal channel.
    - Due to being at solar minimum, don't expect any more degradation now with daily observations as with weekly observations during solar cycle maximum

SEE Data Products

SEE Version 9 Data

- Version 9 released in April 2007
- Version 10 to be released soon
  - No additional new products
  - EGS revisions
    - Vastly improved FOV correction now uses long-term information
      - Corrects small daily jumps
    - Smaller degradation bins help with heavily degraded regions
    - Improved Gain correction now possible because of the better FOV
    - Will update FUV degradation rates from comparison to SORCE
    - Will include updated EUV degradation rates using latest cal rocket
  - XPS revisions
    - Updated radiometric calibrations and updated XUV degradation rates
    - Improved empirical Gain correction
- **LASP Interactive Solar IRradiance Datacenter (LISIRD)**
  - Relatively new data center at LASP for its solar irradiance data products
    - SME, UARS SOLSTICE, TIMED SEE, SORCE, rocket experiments
    - Future missions: Glory TIM, SDO EVE
  - http://lasp.colorado.edu/LISIRD/

Summary of SEE Data Products

http://lasp.colorado.edu/see/

- Download data for individual days or merged set for the full mission
- Download IDL read / plot code
- Plot / browse data (ION script interface)

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

Example TIMED SEE Data Web Page (Table)

SEE Data

Title	Description	Data Types				Helpful IDL Procedures
		Calendar	FTP Directory	Merged NetCDF	Plot/Browse	
Space Weather README	SpWx	NA	2002 2003 2004 2005 2006 2007	NA	latest plots	plot_see_spwx.pro plots space weather data plot_see_spwx.zip contains complete IDL code bundle
Level 3 README	L3	2002 2003 2004 2005 2006 2007	2002 2003 2004 2005 2006 2007	L3	Plot **Browse**	plot_see.pro plots level 3 data (works with the level 3 merged data file) plot_see_code.zip plots level 3 data for planet applications (works with the level 3 merged data file)
Level 3A README	L3A	2002 2003 2004 2005 2006 2007	2002 2003 2004 2005 2006 2007	L3A	Plot **Browse**	plot_see3a.pro plots level 3a data (works with the level 3A merged data file)
Level 2 XPS README	XPS	2002 2003 2004 2005 2006 2007	2002 2003 2004 2005 2006 2007	L2 XPS	Plot	plotxps_ts.pro Plots a time series of XPS Level 2 data
Level 2a XPS README	XPS_2A	2002 2003 2004 2005 2006 2007	2002 2003 2004 2005 2006 2007		Plot	plotxps_2a_ts.pro Plots a time series of XPS Level 2a data
Level 2 EGS README	EGS	2002 2003 2004 2005 2006 2007	2002 2003 2004 2005 2006 2007	L2 EGS	Plot	plotegs_ts.pro Plots a time series of EGS Level 2 data plotegs_sp.pro Plots a daily averaged spectrum from one EGS Level 2 data file
Level 2a EGS README	EGS_2A	2002 2003 2004 2005 2006 2007	2002 2003 2004 2005 2006 2007		Plot	plotegs_2a_ts.pro Plots a time series of EGS Level 2a data plotegs_2a_sp.pro Plots all observation average spectra from one EGS Level 2a data file

Example TIMED SEE Data Browser

User Input

Select a date range

Start Year: 2002 | Start Date: 039 or /

End Year: 2007 | End Date: 299 or /

e.g. 2002/039 was 02/08, (the first rocket underflight calibration)

Select wavelength range OR Solar line OR XPS diode

Start (nm)	End (nm)	Solar Lines (EGS)	XPS Diode
21	22	28.4 nm Fe XV	1 Ti/C 0.1- 7.0
22	23	30.4 nm He II	2 Ti/C 0.1- 7.0
23	24	33.5 nm Fe XVI	3 Al/Sc/C 17.0- 23.0
24	25	36.1 nm Fe XVI	5 Ti/Pd 0.1- 10.0
25	26	36.8 nm Mg IX	6 Ti/Zr/Au 0.1- 10.0
26	27	41.7 nm Fe XV	7 Al/Nb/C 17.0- 21.0
27	28	46.5 nm Ne VII	9 Al/Mn 0.1- 7.0
28	29	49.9 nm Si XII	10 Cr/Al 0.1- 7.0
29	30	52.1 nm Si XII	11 Ly-alpha 121.0-122.0
30	31	53.7 nm He I	

Hide TEXT

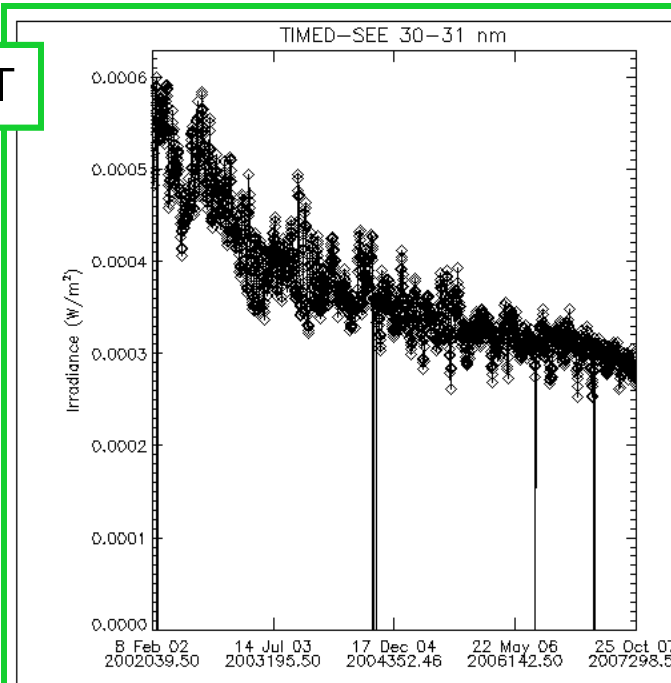
Hide PLOT

Select the type of data to be viewed

- All spectra in date range
- Selected wavelength time series
- Selected line time series
- XPS diode time series

Remove 1-AU correction

PLOT



TEXT LISTING

```
ngth range = 30 to 31 nm
year: 2002 DOY: 039 mm/dd: 02/08
year: 2007 DOY: 299 mm/dd: 10/26
 =009
```

YEAR	DOY	MM	DD	YFRAC	JULIAN	Irradiance(W/m^2)
2002	039	02	08	2002.1055	2452314.0	0.00000e+00
2002	040	02	09	2002.1082	2452315.0	5.48618e-04
2002	041	02	10	2002.1110	2452316.0	5.44895e-04
2002	042	02	11	2002.1137	2452317.0	5.24766e-04
2002	043	02	12	2002.1164	2452318.0	5.18884e-04
2002	044	02	13	2002.1192	2452319.0	4.98147e-04
2002	045	02	14	2002.1219	2452320.0	4.98030e-04
2002	046	02	15	2002.1247	2452321.0	4.82201e-04
2002	047	02	16	2002.1274	2452322.0	4.94120e-04
2002	048	02	17	2002.1301	2452323.0	5.17029e-04
2002	049	02	18	2002.1329	2452324.0	5.27856e-04
2002	050	02	19	2002.1356	2452325.0	5.38333e-04
2002	051	02	20	2002.1384	2452326.0	5.61549e-04
2002	052	02	21	2002.1411	2452327.0	5.71010e-04

Example SEE Flare Catalog

TIMED-SEE Flare Catalog

This page is a catalog of flare events observed by TIMED-SEE. Each row contains NOAA SEC flare information from the daily edited event reports for periods when TIMED-SEE was observing the sun anywhere between the start and stop times of these events. Events have been filtered to exclude periods when no appreciable increases were detected by SEE. Catalog last updated on Wed Sep 26 16:47:09 2007. An excel-compatible CSV file is also available.

Show/hide column descriptions. Columns can be sorted by clicking on the column headings.

A comprehensive list of SEE data products are available for download.

Year/Doy mo-dd	start hhmm	peak	stop	Class	Solar Longitude (deg)	Solar Latitude (deg)	Region	Event	SEE-XPS Index ▲	SEE-EGS Index	SEE obs (seconds after peak)	SEE data	Plot
2003/308 11-04	1929	1953	2006	X 17.4	19	-83	0486	8080	61.11	2.13	-282	Level 3A data	Plot SEE L3A
2003/301 10-28	0951	1110	1124	X 17.2	-16	-8	0486	5120	30.77	2.37	454	Level 3A data	Plot SEE L3A
2005/020 01-20	0636	0701	0726	X 7.1	14	61	0720	4270	24.53	1.28	-79	Level 3A data	Plot SEE L3A
2005/256 09-13	1919	1927	2057	X 1.5	-9	-10	0808	9710	15.06	1.41	2944	Level 3A data	Plot SEE L3A
2003/306 11-02	1703	1725	1739	X 8.3	14	-56	0486	7360	15.00	1.42	694	Level 3A data	Plot SEE L3A
2003/147 05-27	2256	2307	2313	X 1.3	7	-17	0365	5610	11.03	1.40	110	Level 3A data	Plot SEE L3A
2005/015 01-15	2225	2302	2331	X 2.6	15	5	0720	3090	10.81	1.11	1315	Level 3A data	Plot SEE L3A
2005/253 09-10	2130	2211	2243	X 2.1	-13	-47	0808	8920	9.82	1.13	1773	Level 3A data	Plot SEE L3A
2003/149 05-29	0051	0105	0112	X 1.2	6	-37	0365	6110	9.10	1.68	-71	Level 3A data	Plot SEE L3A
2005/133 05-13	1613	1657	1728	M 8.0	-12	11	0759	9150	8.91	1.13	1194	Level 3A data	Plot SEE L3A
2003/166 06-15	2325	2356	0025	X 1.3	-7	-80	0386	2580	8.65	1.19	124	Level 3A data	Plot SEE L3A

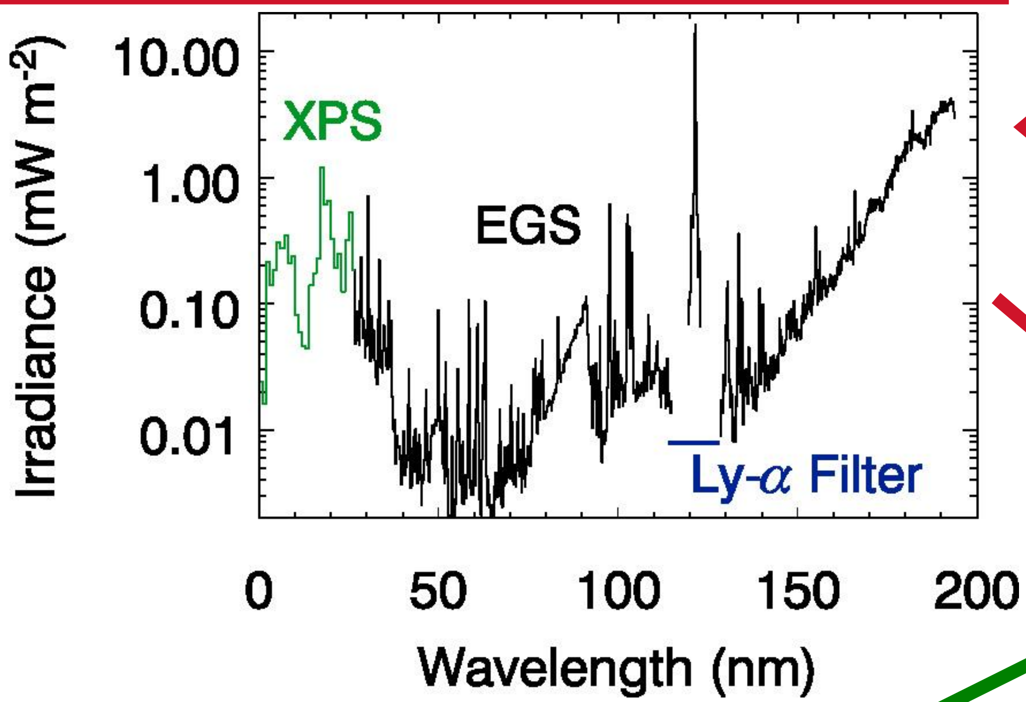
Future SEE Data Products

- No new SEE data products are planned
- Future SEE data versions
  - Version 10 (in progress)
    - Update instrument degradation functions (calibration rocket in Apr. 2008)
    - Address EGS time series dips at some EUV wavelengths
    - Will incorporate calibration channel measurements in Level 3
  - Version 11 (after end of operations)
    - Expected final release will include overlap measurements with SDO-EVE and rocket underflights
    - Final clean-up of production processing code
    - Prepare products for delivery to archive center
- Updated solar irradiance models (using SEE Version 9 data)
  - FISM - Phil Chamberlin
    - 0-190 nm with 1-min cadence (flares)
    - Updated with latest SEE and SORCE latest data versions
  - SIP (SOLAR2000) - Kent Tobiska
    - Updated with flare components
    - Updated with latest data versions

SEE Science Overview

SEE Science Plans

Solar UV Irradiance Measurements



Obj. #1

Validations

Internal Calibrations,
Underflight Calibrations
SOHO, SNOE,
UARS, SORCE

Eparvier, Woods, Bailey, Rottman

Obj. #2

Solar UV Variability

Function of wavelength
Over time scales of minutes to years

All

Obj. #4

Modeling Solar Variation

Study variations related to active region evolution derived from solar images
Improve the **NRLEUV, SOLAR2000,** and **SunRise** solar irradiance models

Lean, Tobiska, Chamberlin, Woods

Obj. #3

Obj. #5

Study Earth's Response

Photoelectron analysis with FAST data and using the ***glow*** model
Atmospheric response studies using HAO's **TIM-GCM**

Solomon, Roble, Bailey, Eparvier

Overview of SEE Science Objectives

1. Accurately and precisely determine the time-dependent solar vacuum ultraviolet (VUV: below 200 nm) spectral irradiance
2. Study solar VUV variability (27-day rotations, solar cycle changes) and its sources
3. Study the solar-terrestrial relationships utilizing atmospheric models, primarily the TIME-GCM at HAO/NCAR
4. Improve proxy models of the solar VUV irradiance
5. Determine the thermospheric neutral densities (O_2, N_2 and O) from solar occultations

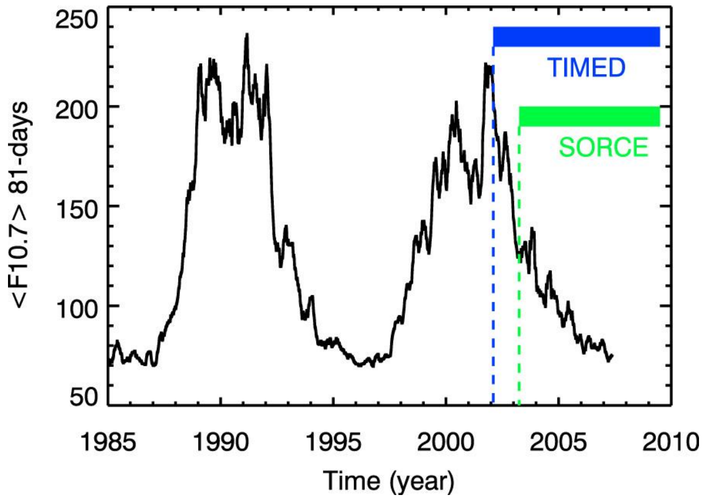
Summary of SEE Results - 1

- **Objective 1: solar VUV spectral irradiance measurements**
  - Daily measurements since Jan. 22, 2002 with very few gaps
  - SEE solar EUV irradiance (version 9) and GUVI QEUV (0-45 nm) have less differences with recent improvements / calibrations for GUVI QEUV and for new XPS Level 4 algorithm for the 0.1-27 nm range [Woods, Meier, Lean]
  - New reference spectra for solar cycle minimum conditions as part of the international Whole Heliosphere Interval (WHI) campaign [Woods, Chamberlin]
- **Objective 2: solar variability**
  - Updated results on solar rotation and solar cycle variations [Woods et al.]
  - Updated results on flare variability as SEE has observed about 100 flares
    - New flare catalog on-line to make access to SEE's flare data quick and easy [Chamberlin, Woods]
- **Objective 3: model solar response in Earth's atmosphere**
  - Use of SEE solar data and FAST photoelectron data [Peterson, Richards]
  - Use of HAO TIME-GCM for atmospheric response to SEE's solar input [Solomon, Roble, Qian, Lu]
  - Analysis of GUVI FUV airglow data during flare events [Strickland, Lean, Woods]
  - Satellite drag modeling / analysis indicating importance of solar EUV and FUV [Tobiska, Bowman, Solomon, Qian, Woodraska, Sutton, Forbes]

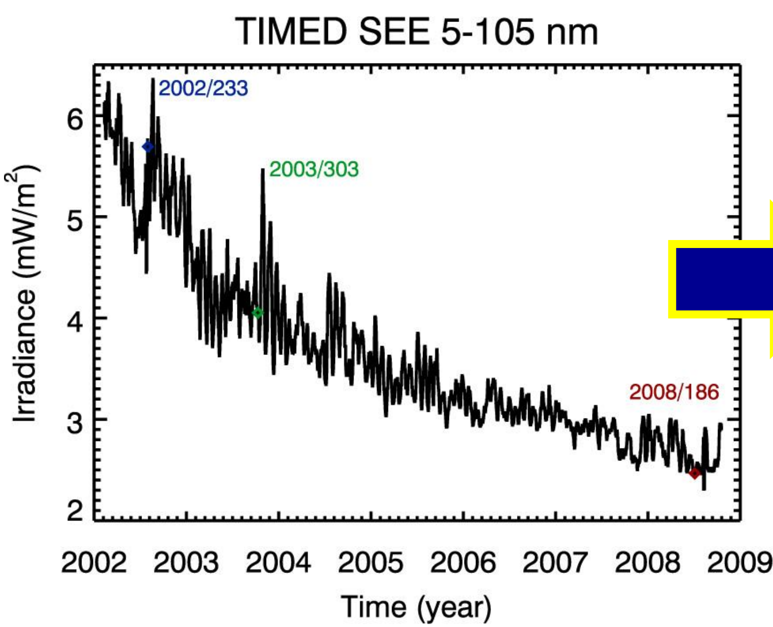
Summary of SEE Results - 2

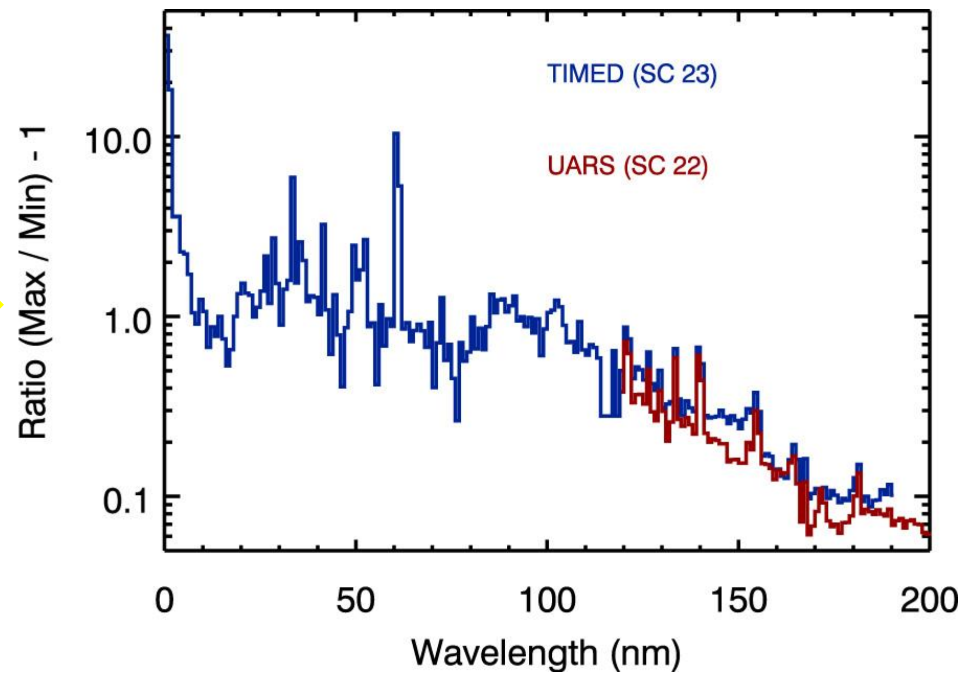
- **Objective 4: solar irradiance modeling**
  - SOLAR2000 (S2K) model improvements [Tobiska]
  - NRLEUV model improvements [Lean, Warren]
  - HEUVAC model improvements [Richards]
  - Flare Irradiance Spectral Model (FISM) improvements [Chamberlin]
    - SEE data used to parameterize FISM - daily components and 1-min flare components
- **Objective 5: atmospheric density from solar occultations**
  - New EGS Level 2B solar occultation data product released (version 9) [Eparvier]

Solar Cycle Irradiance Variations



- TIMED Max = 2002/233
- SORCE Max = 2003/303
- Solar Cycle Min = 2008/186





Solar Irradiance Reference Spectra (SIRS)

Tom Woods, Phil Chamberlin, Rachel Hock, Marty Snow, Jerry Harder

LASP / CU

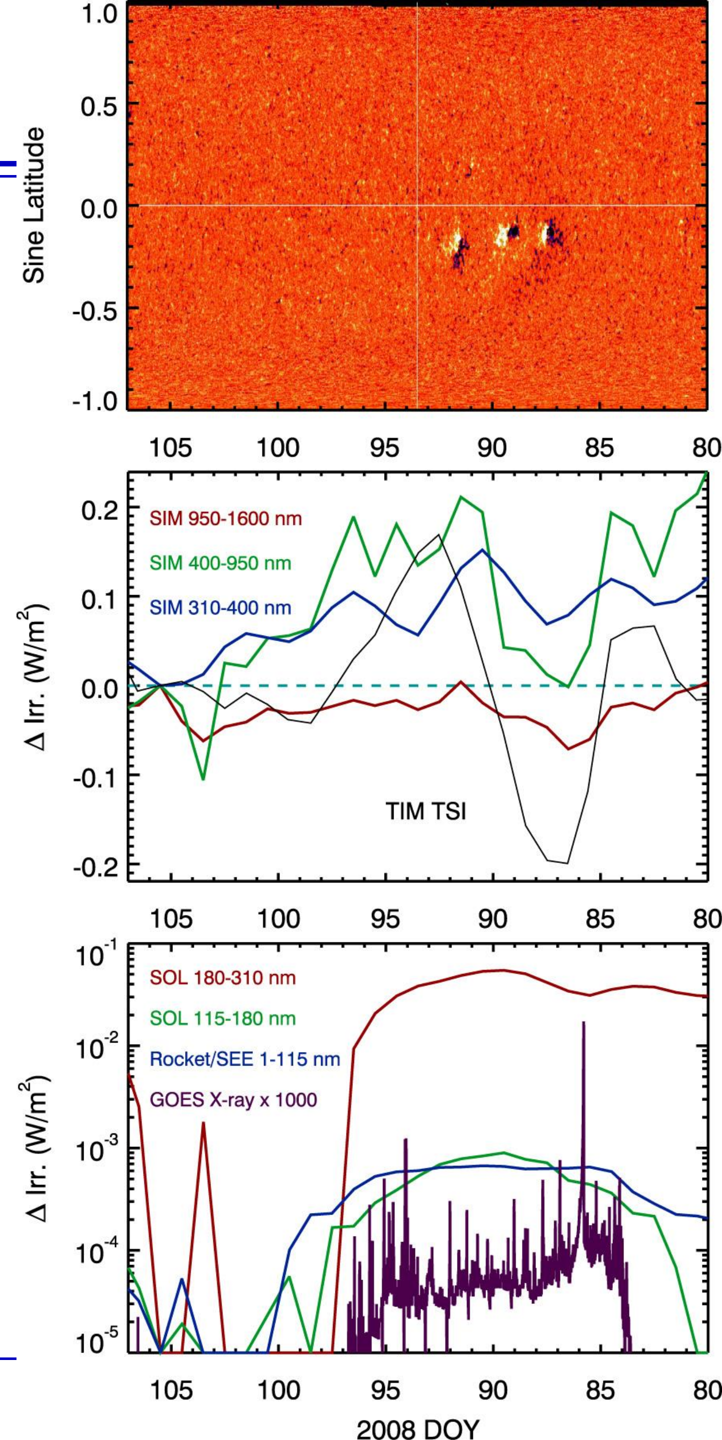
Solar Irradiance Reference Spectra (SIRS)

- Three new reference spectra for the Whole Heliosphere Interval (WHI) campaign during March-April 2008
  - Minimum (quiet Sun)
  - Sunspot Active
  - Faculae Active
- Variability is representative of solar rotation (but much smaller than solar cycle)
  - UV active variability is all positive at $\lambda < 260$ nm
    - Indicates lower chromosphere global-average temperature change of about +5 K
  - NUV-Vis-NIR sunspot variability is mostly negative
    - Indicates photospheric global-average temperature change of about -0.2 K
- SIRS Minimum spectrum compares well with the ATLAS-3 reference spectrum (Thuillier et al., 2004)
  - Differences are mostly within instrument uncertainties (accuracy)
  - ATLAS-3 was not at solar minimum though

IHY2007 - WHI

- Whole Heliosphere Interval (WHI) is an international coordinated observing and modeling effort to characterize the 3-dimensional interconnected solar-heliospheric-planetary system.

- Period is March 20, 2008 to April 16, 2008
  - Solar Carrington Rotation 2068



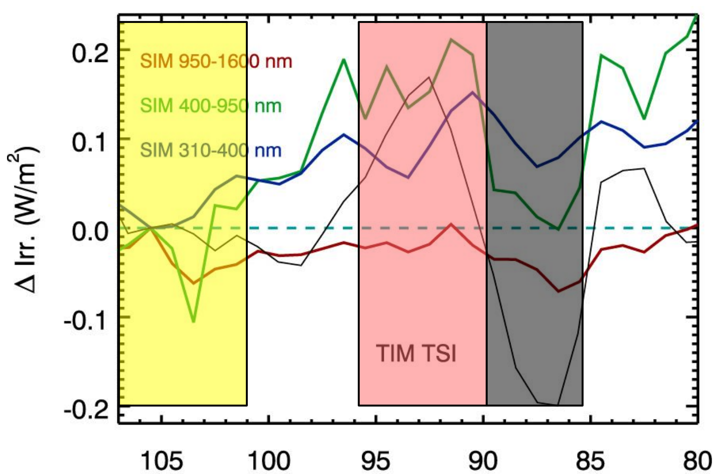
TIMED SEE

Three Spectra for WHI Interval

- "Quiet Sun" (solar cycle minimum) Reference Spectrum
  – WHI Quiet Sun dates of Apr 10-16 (Rocket 14-Apr-2008)

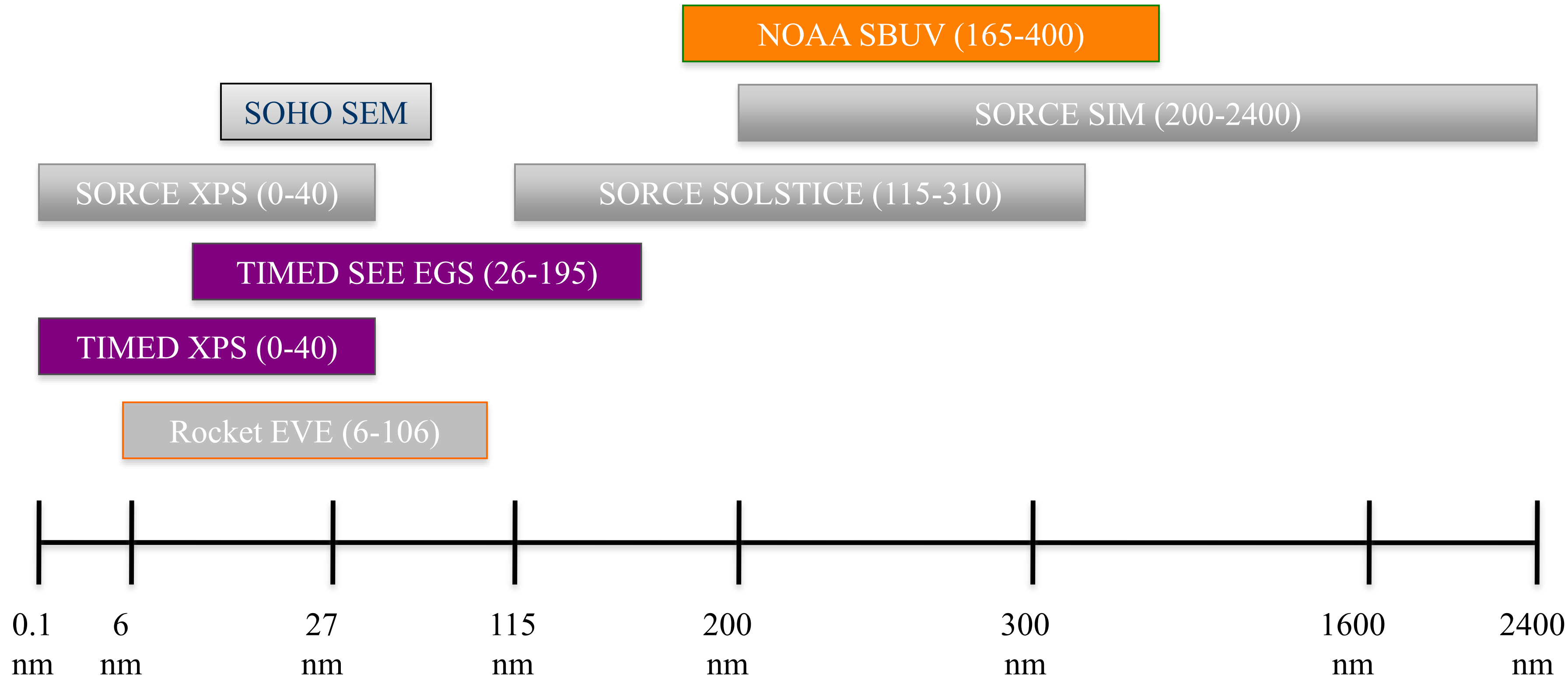
- "Active" Reference Spectra
  – "Sunspot" Darkening (TSI) : Mar 25-29
  – "Faculae" Brightening (TSI): Mar 30 – Apr 4

Quiet Sun Faculae Sunspot



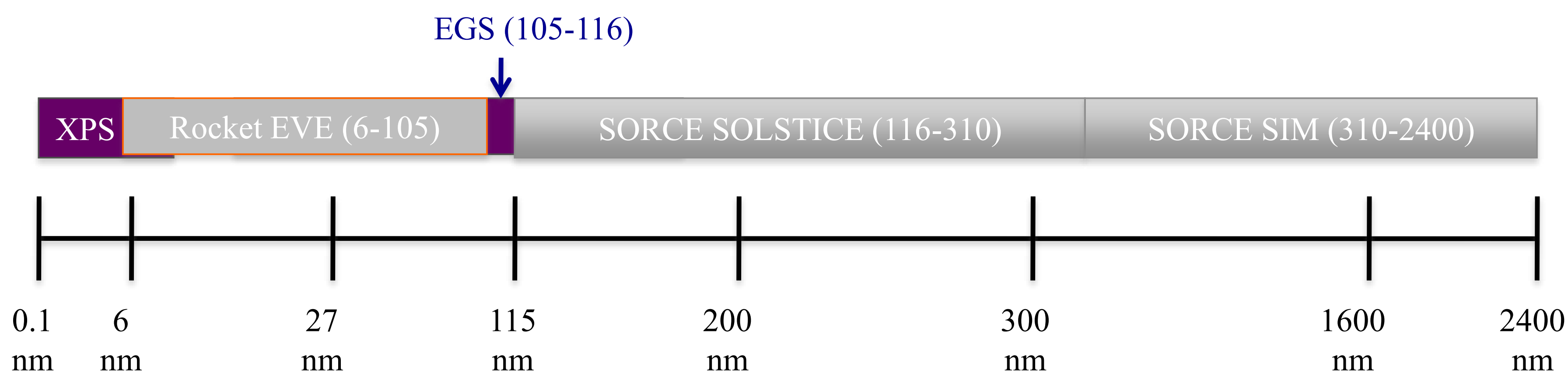
Spectral Distributions for WHI Irradiance Sets

- **How to combine?**
  - consider accuracy, spectral resolution, degradation, etc.
  - select wavelength boundaries or averages ?



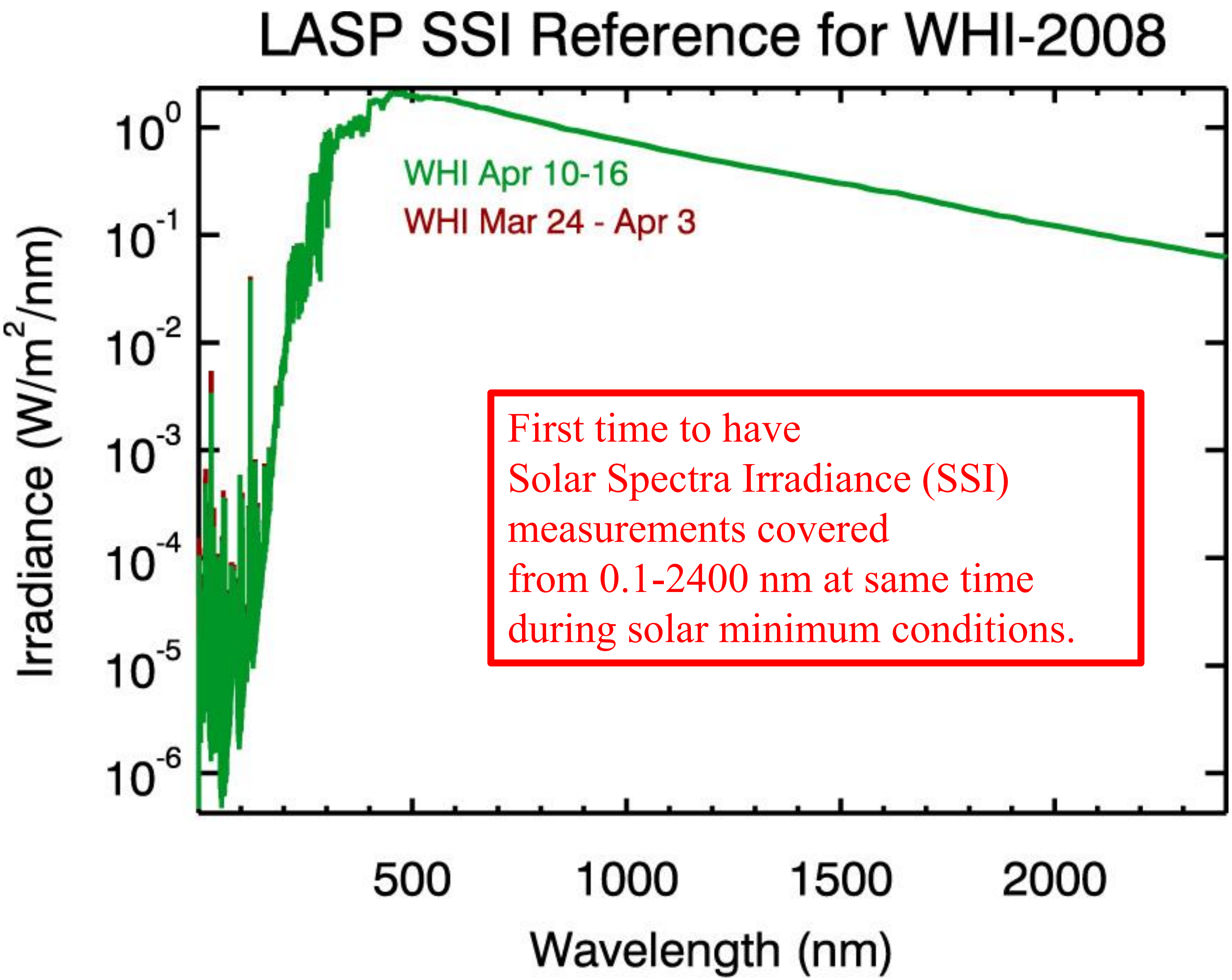
Solution for WHI Reference Spectra

- **Spectral Intervals / Resolution**
  - 0.1-nm intervals on 0.05-nm centers
  - Note that SIM instrument resolution (above 310 nm) is much less than 0.1-nm
- **Selected Wavelength Intervals**
  - Did have to fill 113-116 nm (no measurements)



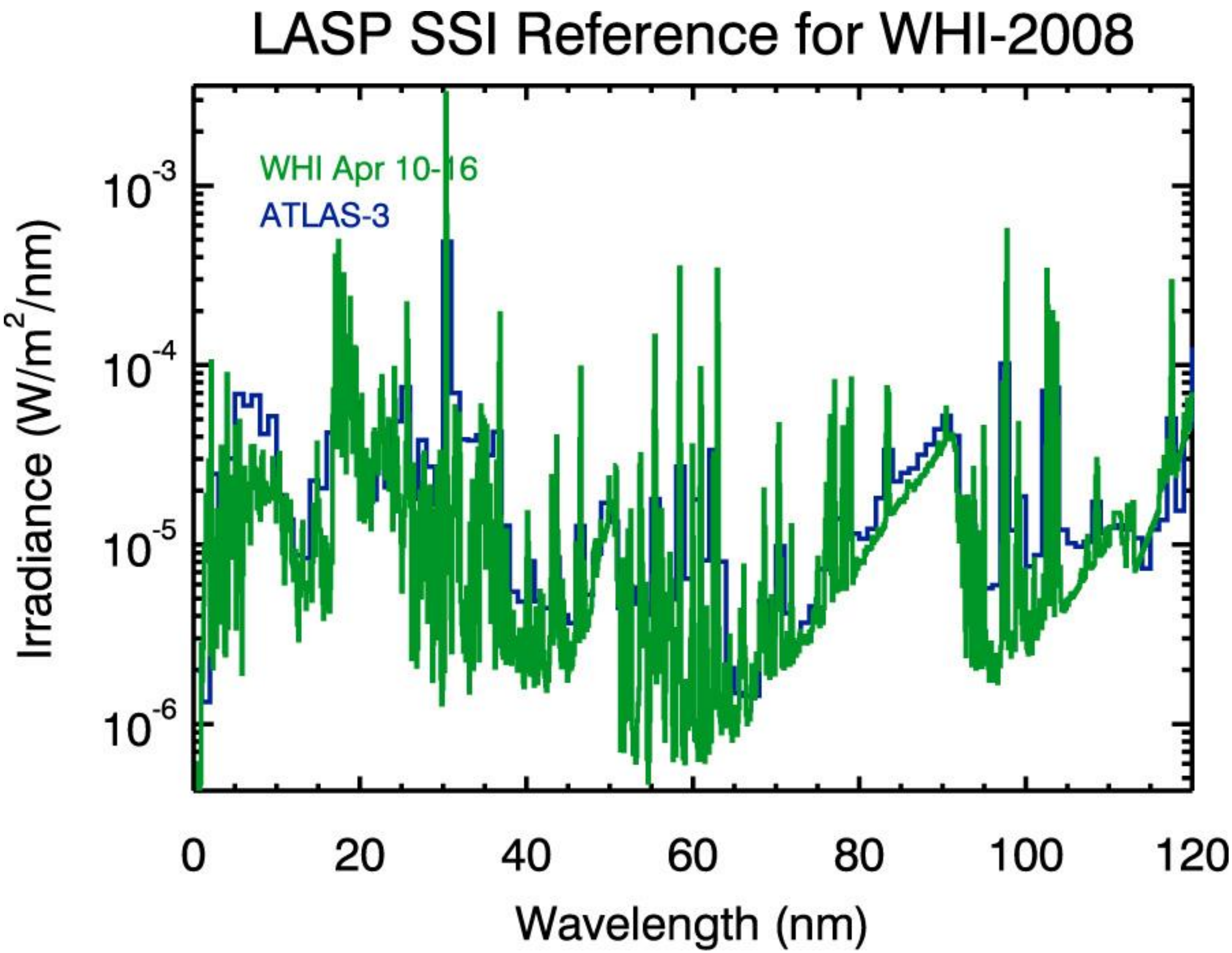
DATA: http://ihy2007.org/WHI/ and http://lasp.colorado.edu/lisird/

WHI Solar Irradiance – Full Range 0-2400 nm



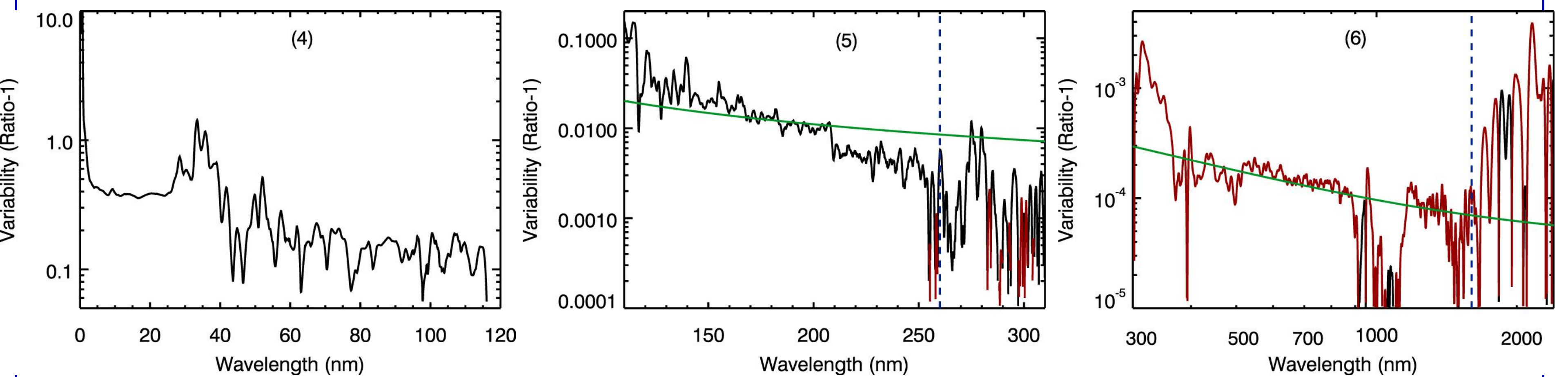
First time to have
Solar Spectra Irradiance (SSI)
measurements covered
from 0.1-2400 nm at same time
during solar minimum conditions.

WHI Solar Irradiance: Rocket EVE & SEE



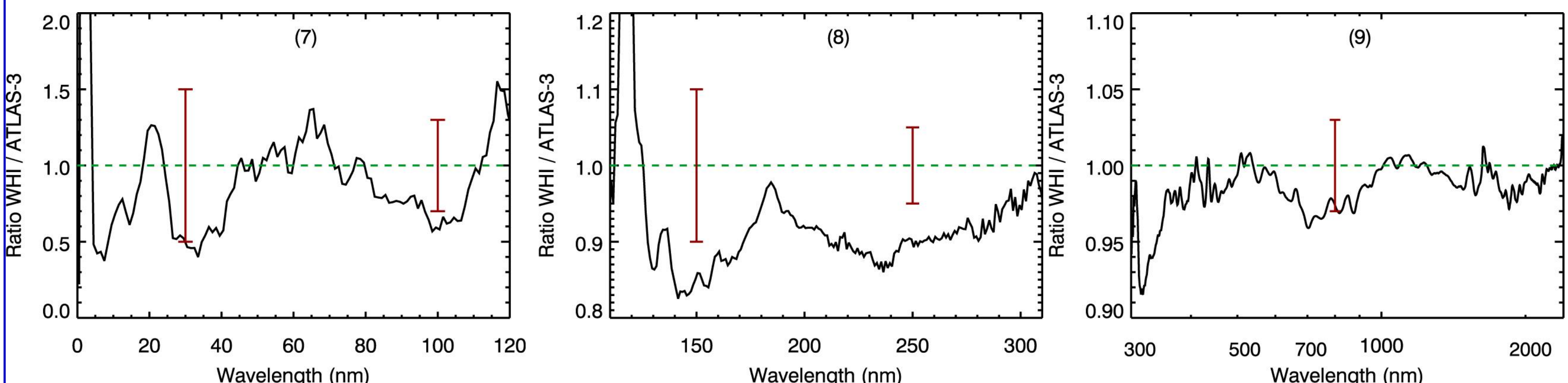
WHI Solar Irradiance: Solar Variability

- UV variability
  - 1% at 200 nm   and > 10% for λ < 110 nm
  - Lower chromosphere (200 nm, Mg II 280 nm) similar to Planck function change in temperature by +5 K (green line)
- NUV-Visible-NIR variability
  - Sunspot / Faculae ratio shown in panel (6)
  - Photosphere variability (sunspot darkening) similar to Planck function change in temperature by -0.2 K (green line)



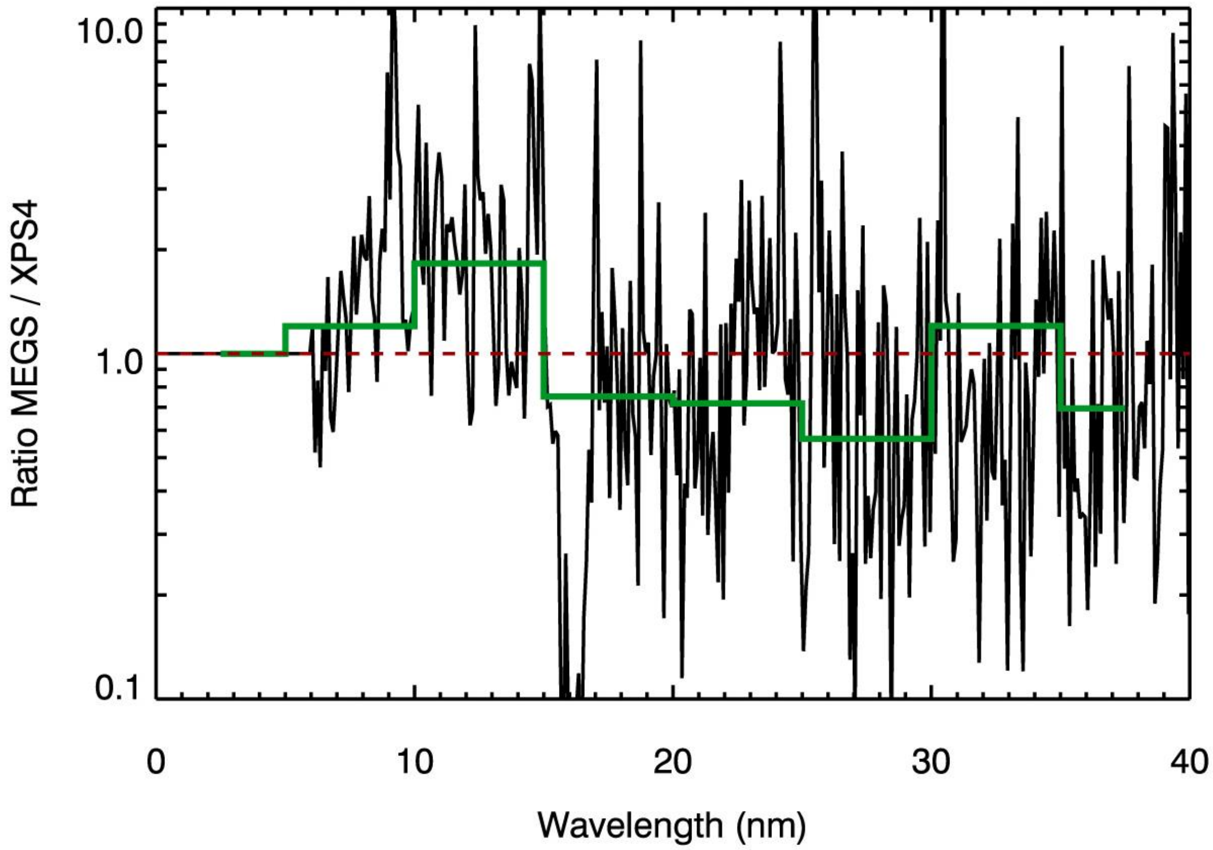
Comparison To ATLAS-3 Reference Spectrum

- Thuillier et al. (2004) included ATLAS 3 reference spectrum near minimum
  - May 1997 rocket measurement for < 119 nm
  - March 1995 UARS and ATLAS-3 observations for > 119 nm
- Expect SIRS Minimum / ATLAS-3 ratio to be less than 1 (ATLAS-3 not at minimum)
- Differences are mostly within instrument uncertainties (red)



Comparison to XPS Level 4 (CHIANTI)

- Differences by factors of 10 at high resolution
- Much better agreement at 5-nm resolution (green)



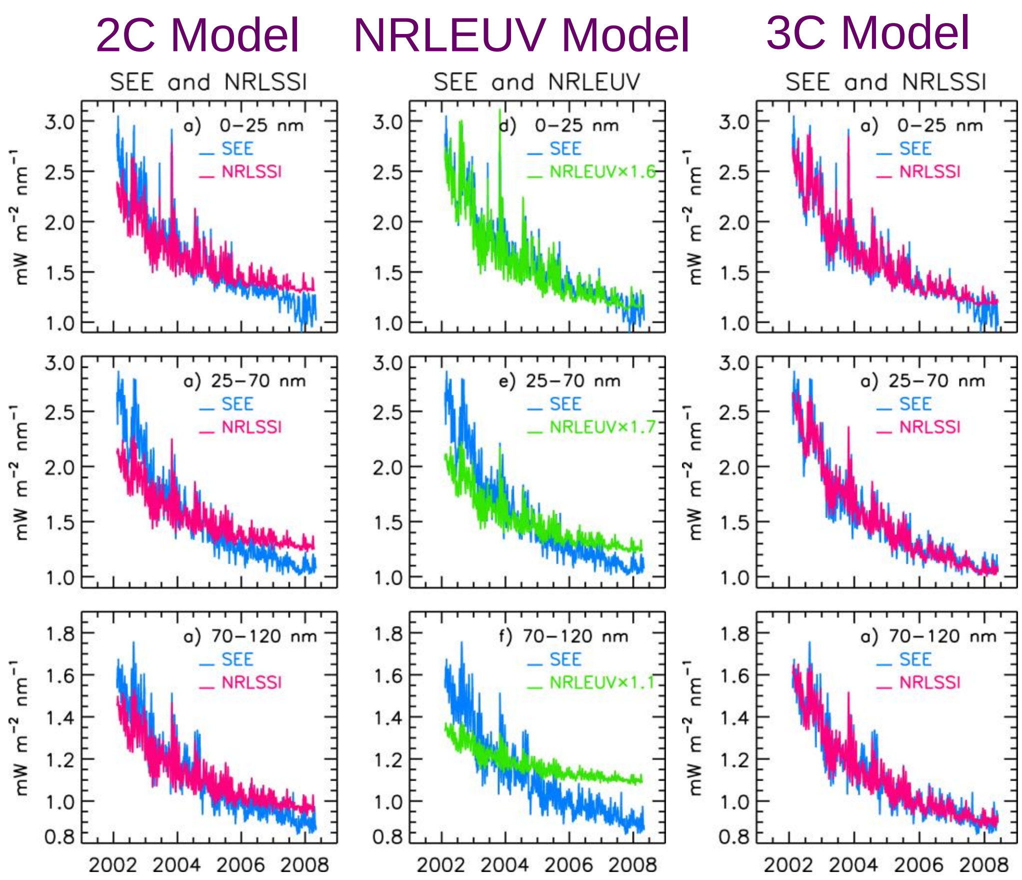
Solar Irradiance Variability and Forecast Tools

Judith Lean

Naval Research Laboratory

NRL Solar Spectral Irradiance Variability Models

- 2-component (2C) model (left) tracks SEE V9 short term changes but underestimates long term changes……
  the 2C model was constructed by multiple regression scaling of SEE irradiances with Mg and $F_{10.7}$ using rotational modulation only (i.e., excluding long-term trends which are less reliable).
- 3-component (3C) model (right) tracks SEE V9 during both rotational modulation and the solar cycle .....
  the 3C model was constructed by multiple regression scaling of SEE irradiances with Mg, Mg^{AV} and $F_{10.7}$ using SEE V9 time series (i.e., including long-term trends).
- NRLEUV model (center) significantly underestimates both rotational modulation and long term trends at EUV wavelengths longer than 50 nm.....
  NRLEUV was constructed from differential emission measures and active region areas in CaK images during solar cycle 22, extended to cycle 23 using Mg. Mg^{AV} and $F_{10.7}$ proxies

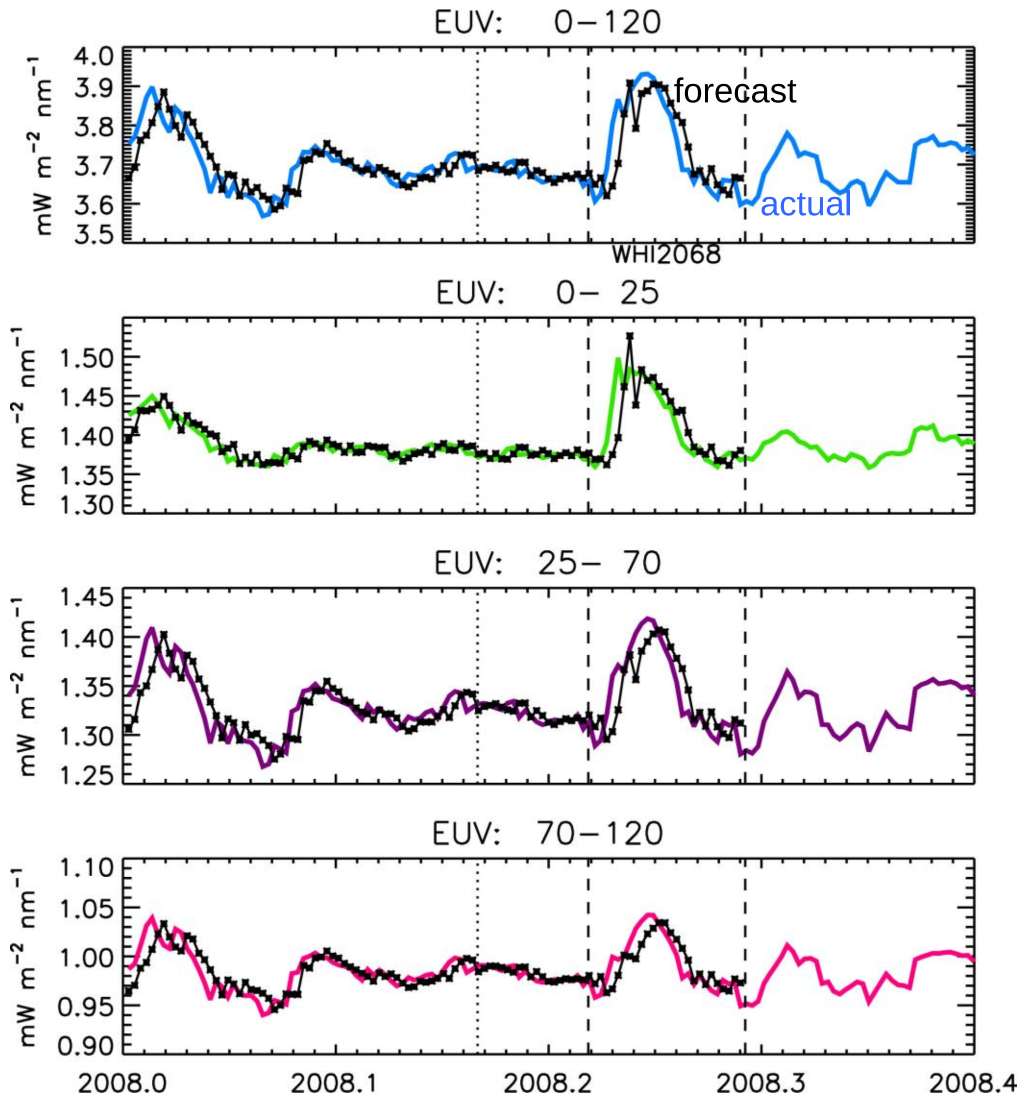


Are part of the long-term trends in SEE V9 irradiances instrumental?

- V10 will include rocket calibration and other improvements
- onset of cycle 24 will aid in differentiating real solar versus instrumental trends

Forecasting EUV Spectra with NRL 2C Model

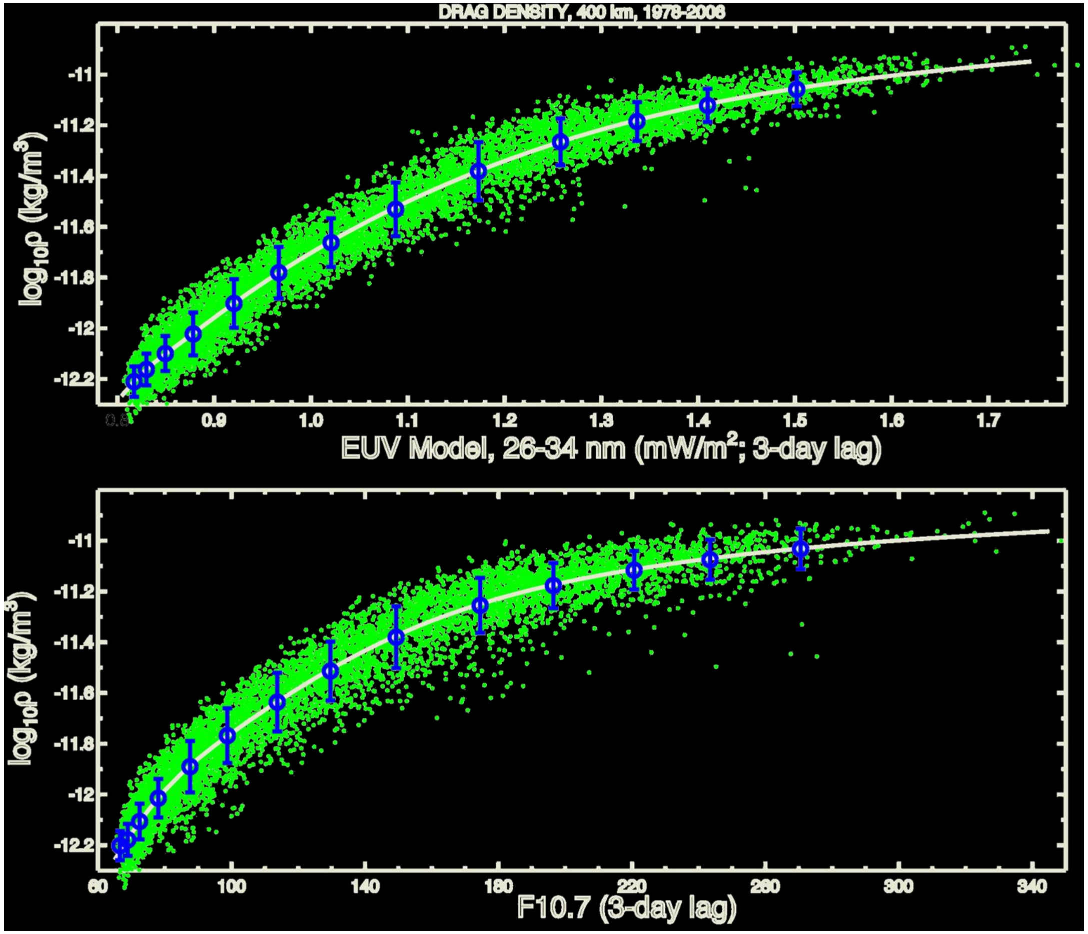
- 3rd order autoregressive algorithms developed to forecast both *Mg* and $F_{10.7}$ enable forecasts of EUV spectra 1 to 10 days ahead, for input to geospace models.
- Actual and forecast EUV spectra during current solar minimum are input to SAMI3 ionosphere model.
- Comparisons of modeled and observed total electron content (TEC) responses to solar EUV irradiance changes during solar minimum have commenced.



New Mass Density Model Utilizes EUV Spectra

John Emmert, NRL, is incorporating EUV modeled spectra from 1950 to 2007 in a new density specification model, based on drag-derived densities.

- Globally averaged total mass density from 200 to 600 km
- 1967-Present
- Based on historical orbit data of ~5000 objects
- Temporal resolution ~3 days
- Nearly continuous coverage
- Drag-derived density variations are better represented by EUV model flux than by $F_{10.7}$ index

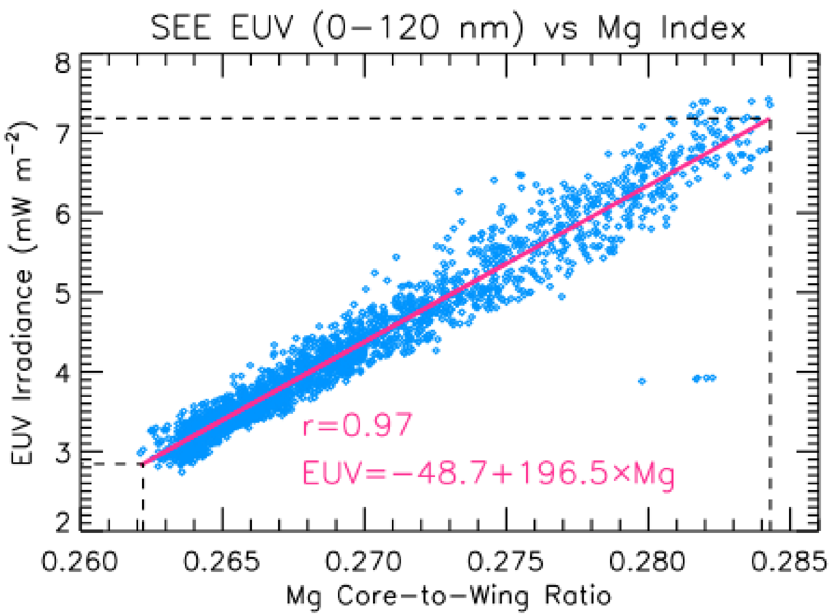


SEE EUV Observations and TEC Variations

Comment on "Oscillations of global mean TEC" by Hocke
J. T. Emmert, J. L. Lean, J. M. Picone
Submitted to JGR, 2008

Earth's global mean total electron content (TEC), *Hocke [2008]* concludes that Chapman theory cannot explain the observed response of TEC to solar extreme ultraviolet (EUV) irradiance variations during solar cycle 23, and that other processes significantly amplify the response, with amplification factors that depend on the period of the variation.

Several of the principal conclusions of Hocke [2008] are incorrect, and many aspects of the analysis are seriously flawed, because the Mg II index was used in its native units as an absolute, rather than a relative, index of solar EUV irradiance variations.



According to the SEE measurements, total EUV energy ranges from 2.844 to 7.188 mW per m^2, so that (*EUVmax–EUVmin) /(EUVmax+EUVmin) = 43%,* a factor of 10 larger than the variational amplitude in Mg of approximately (*Mgmax–Mgmin) / (Mgmax+Mgmin) = 4%.*

Solar Irradiance Platform:
Improvements using TIMED SEE Data

Kent Tobiska

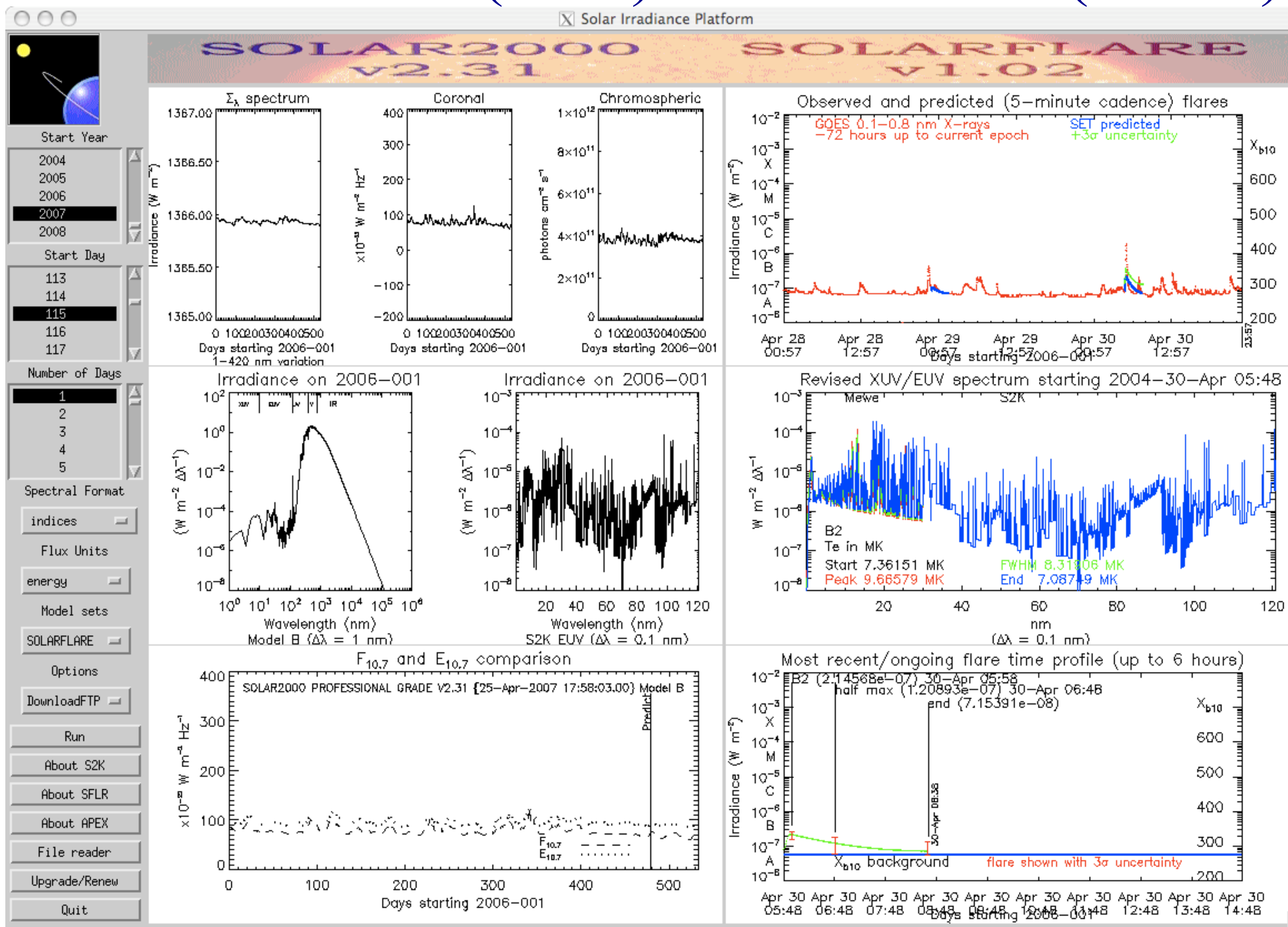
SET Inc.

Models: Solar Irradiance Platform

Solar2000 (S2K) SolarFlare (SFLR)

SIP provides historical, nowcast, and operational forecast XUV-UV variability in several spectral and proxy formats using the IDL Virtual Machine that runs on any platform

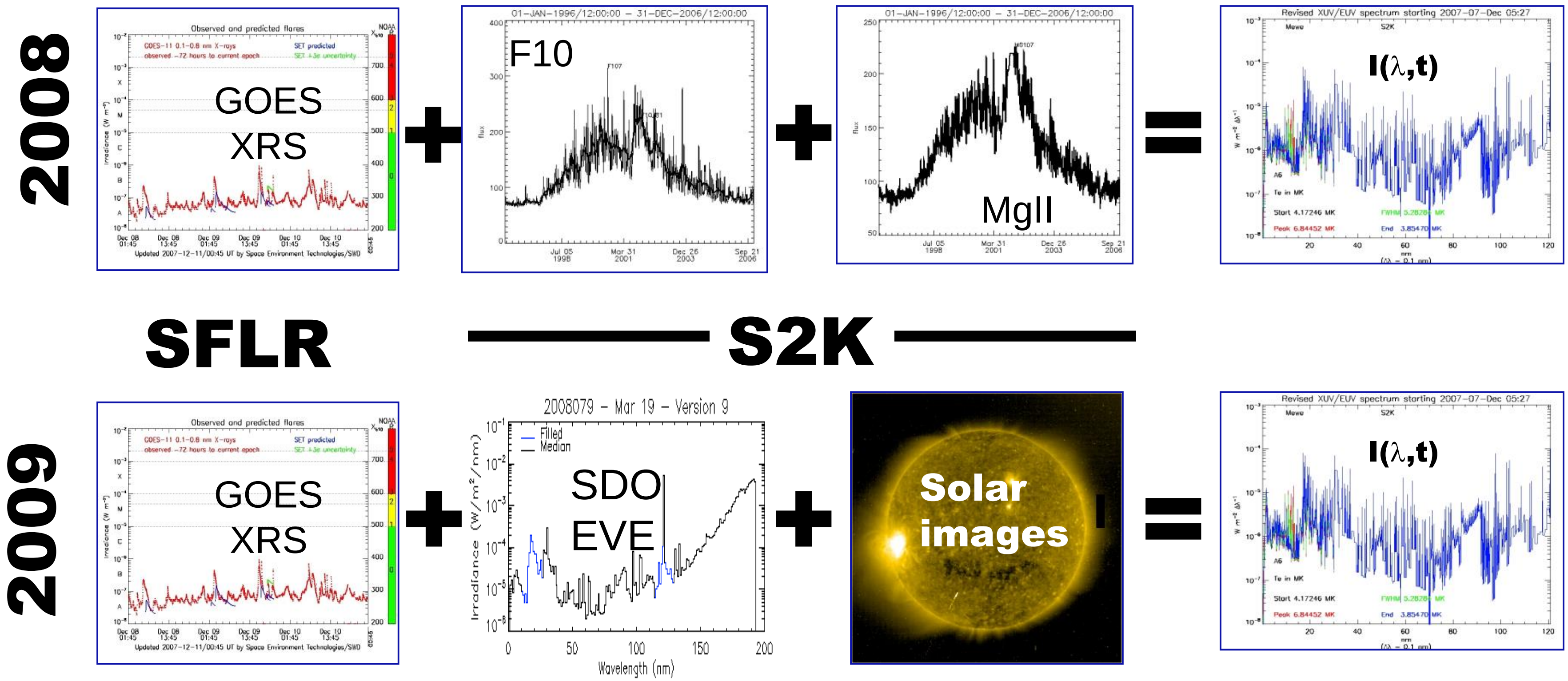
http://spacewx.com



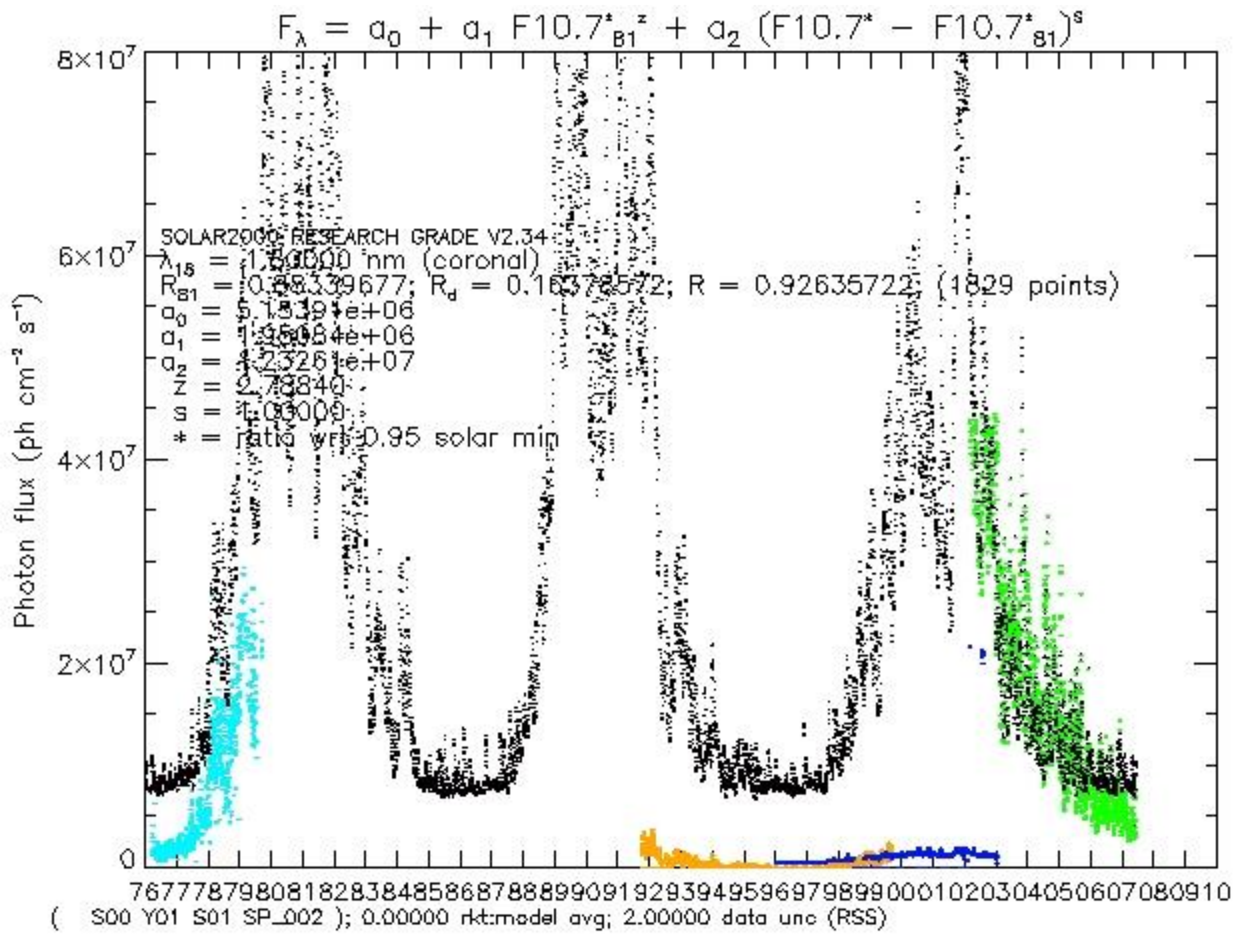
From Kent Tobiska

TIMED SEE

EUV and XUV spectral irradiances are generated with 1-minute and 0.1 nm resolution every 4 minutes

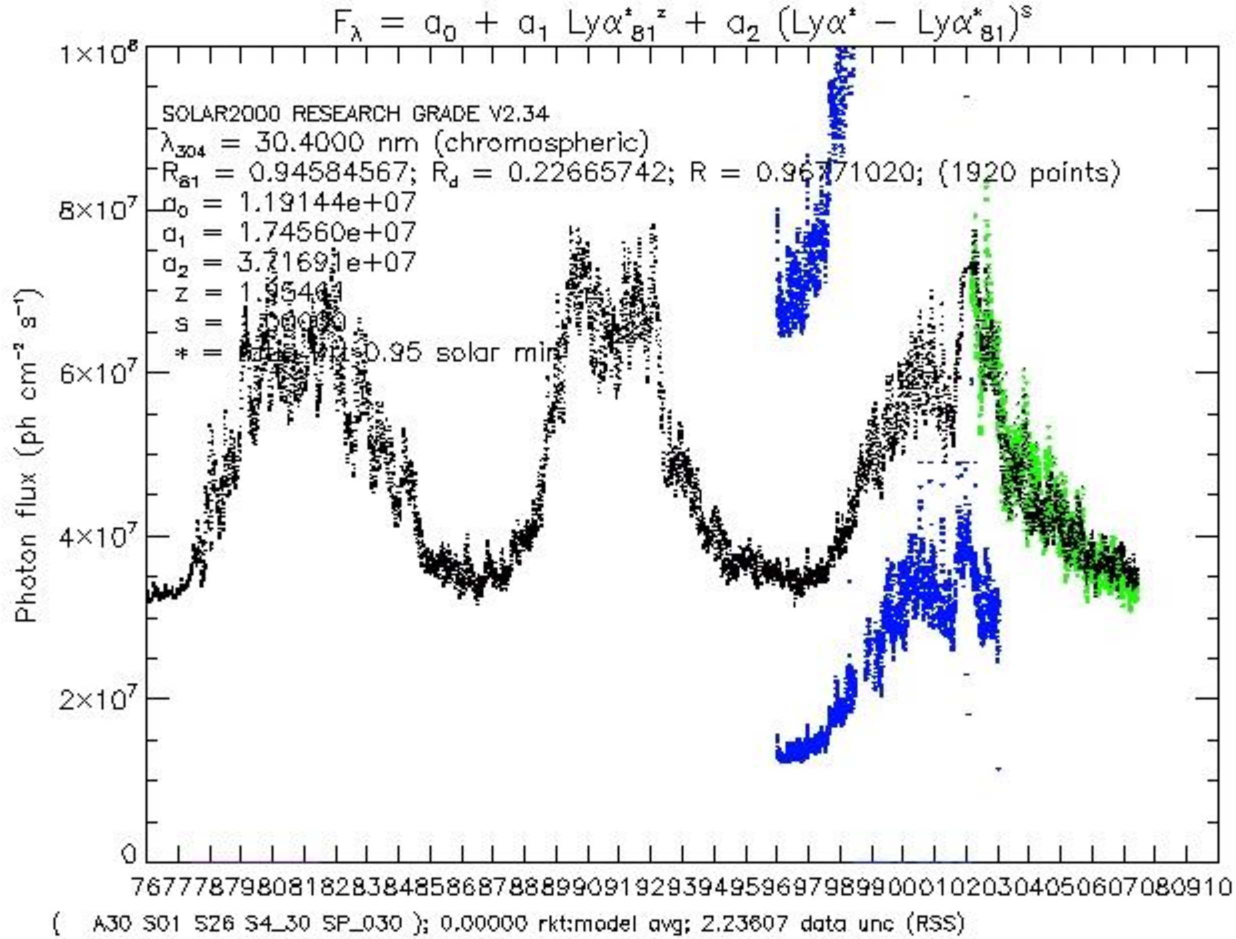


S2K v2.34 soft X-rays & SEE v9: 1.6 nm



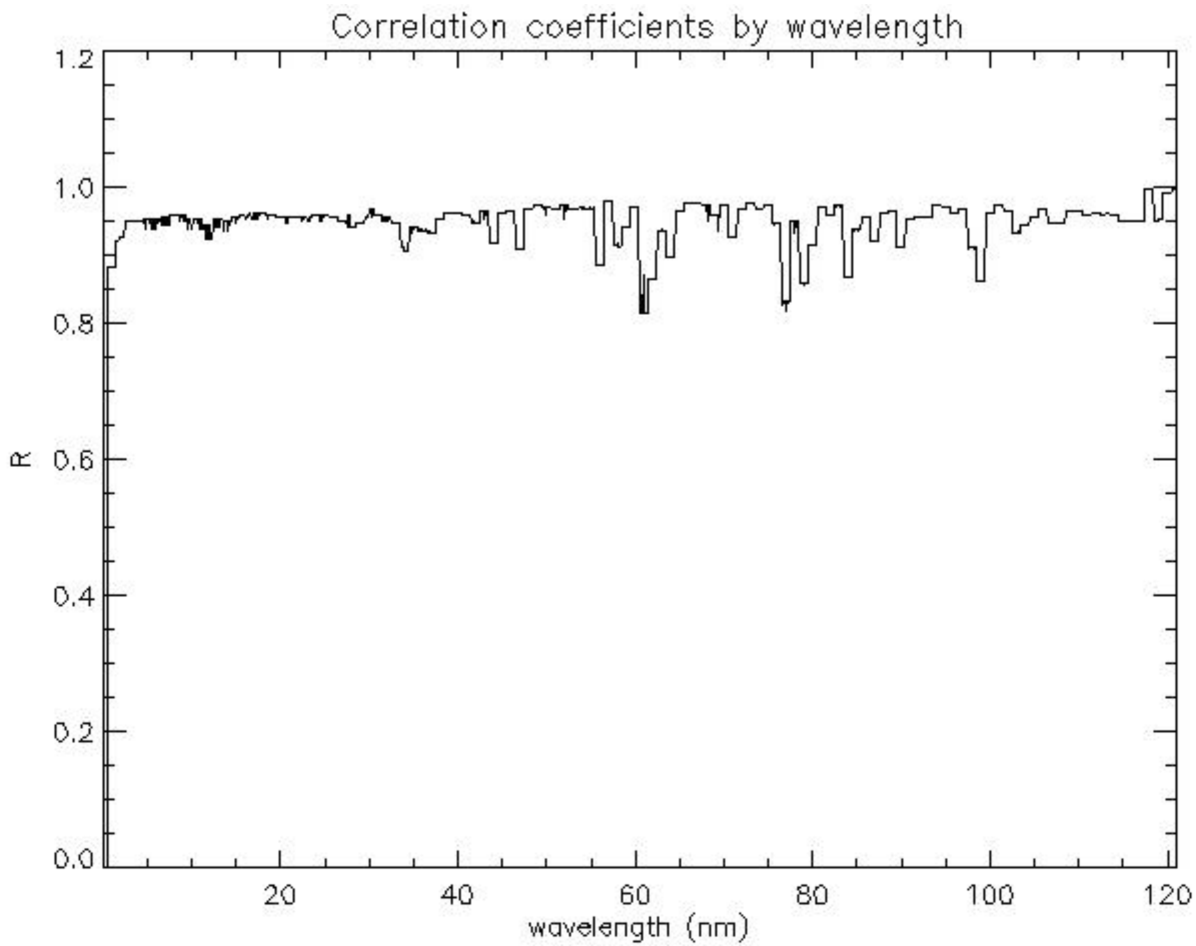
From Kent Tobiska

S2K v2.34 EUV & SEE v9: 30.4 nm



S2K v2.34 correlation coefs

S2K correlates very well with SEE solar irradiance measurements

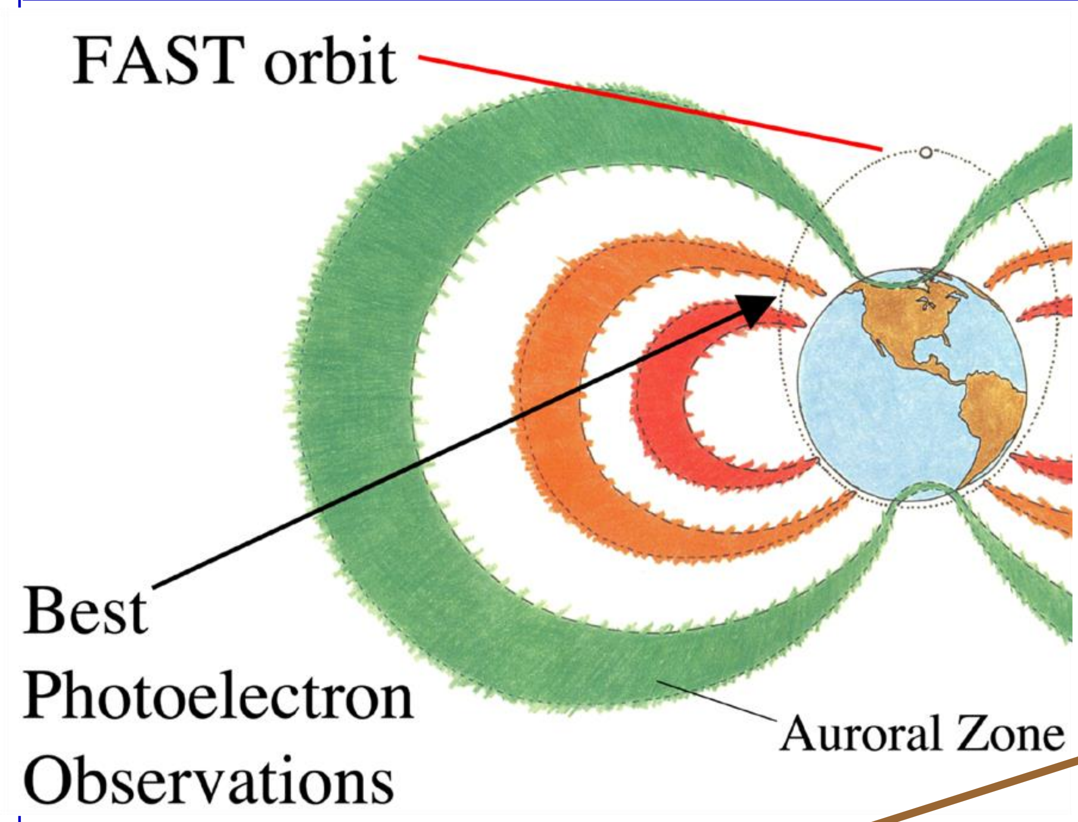


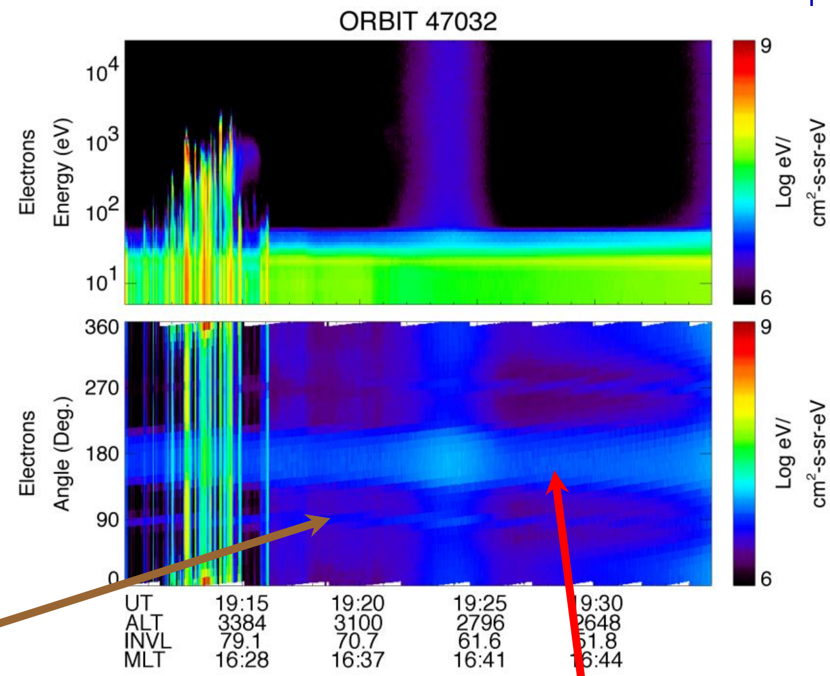
FAST Photoelectrons:
Relationship to Solar EUV Irradiance

Bill Peterson

LASP / CU

FAST Photoelectrons and Solar EUV



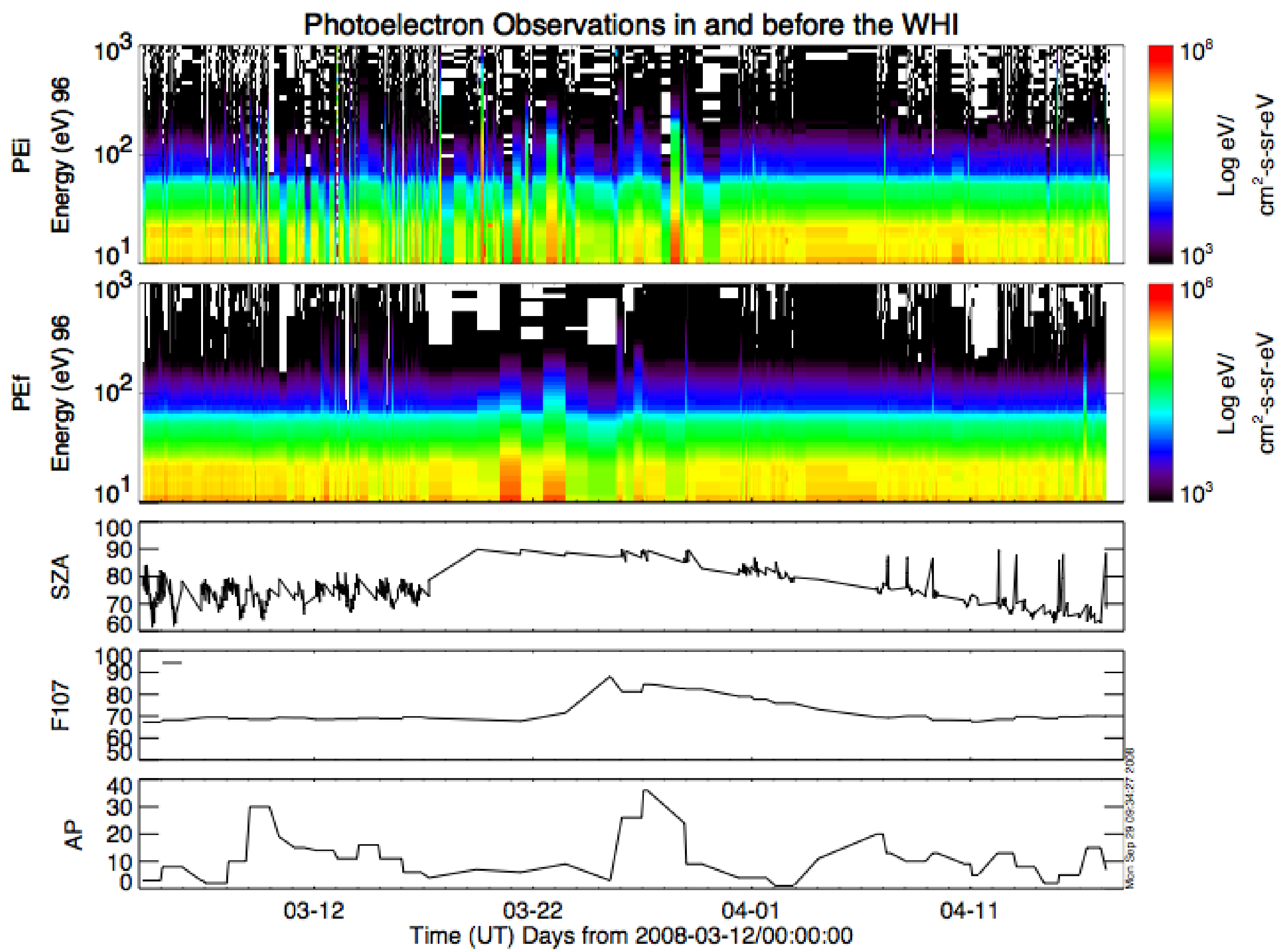


Photoelectrons from the spacecraft have pitch angles near 90°.

Photoelectrons from the ionosphere Are field aligned and in the “source cone”

FAST Solar Minimum Observations

Filtered data corrected for the spacecraft potential



March 3 through April 17, 2008   The Rocket Calibration was on April14

FAST Observation-Model / Model

OBS-Ave/Ave

FLIP-Rocket

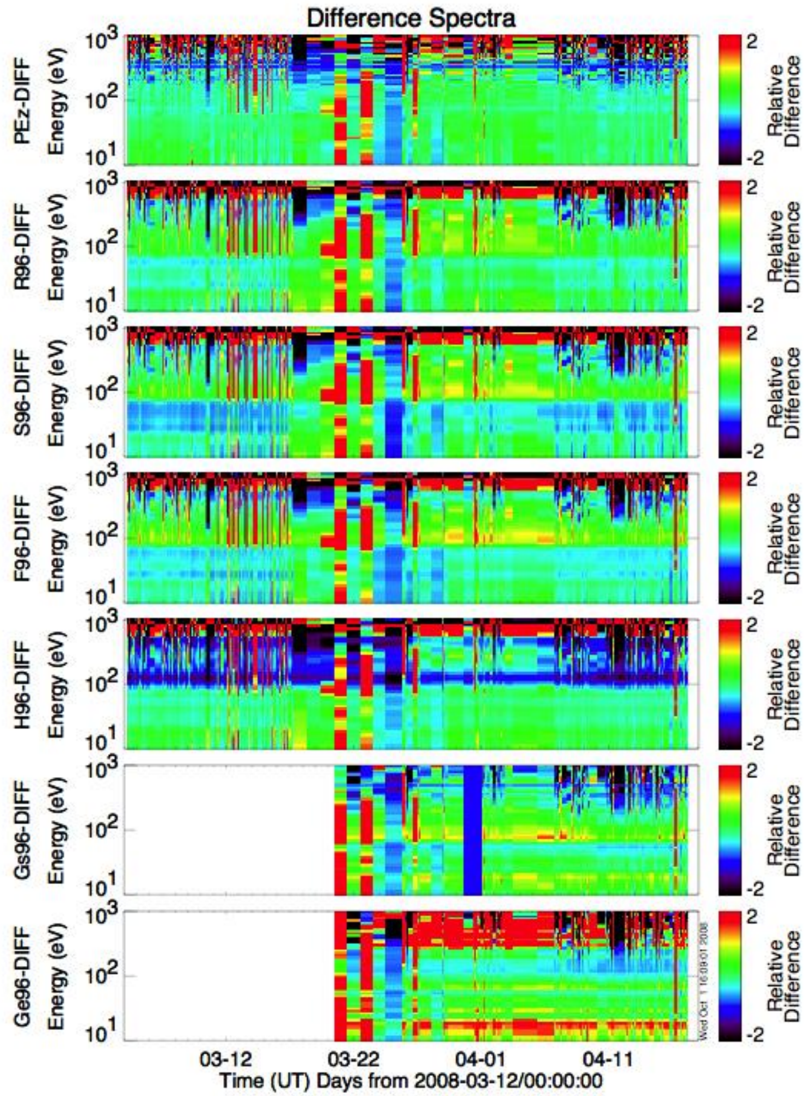
FLIP-SEE(mod)

FLIP-FISM

FLIP-HEUVAC

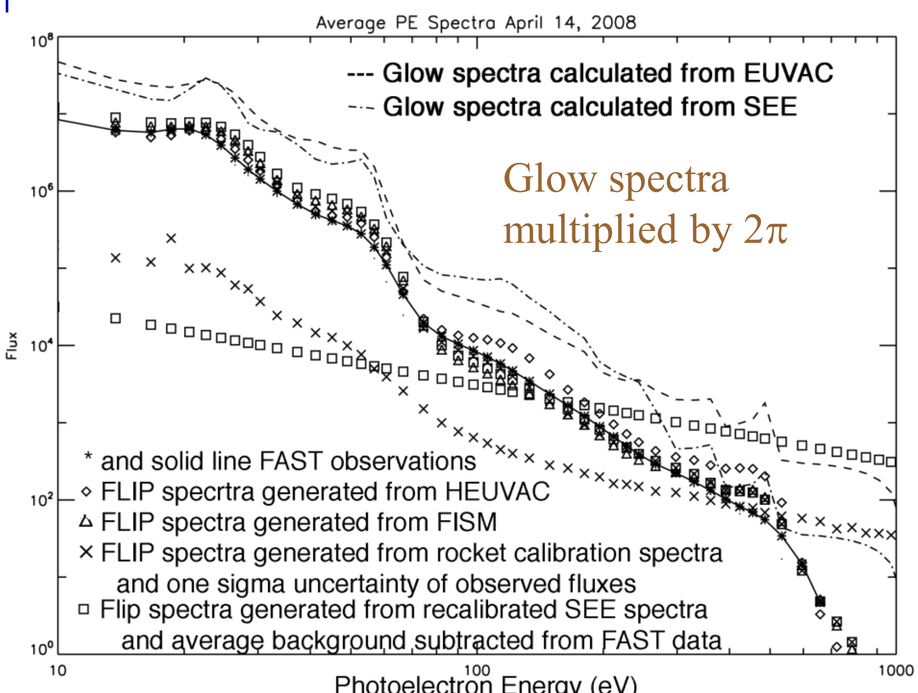
GLOW-SEE

GLOW-EUVAC

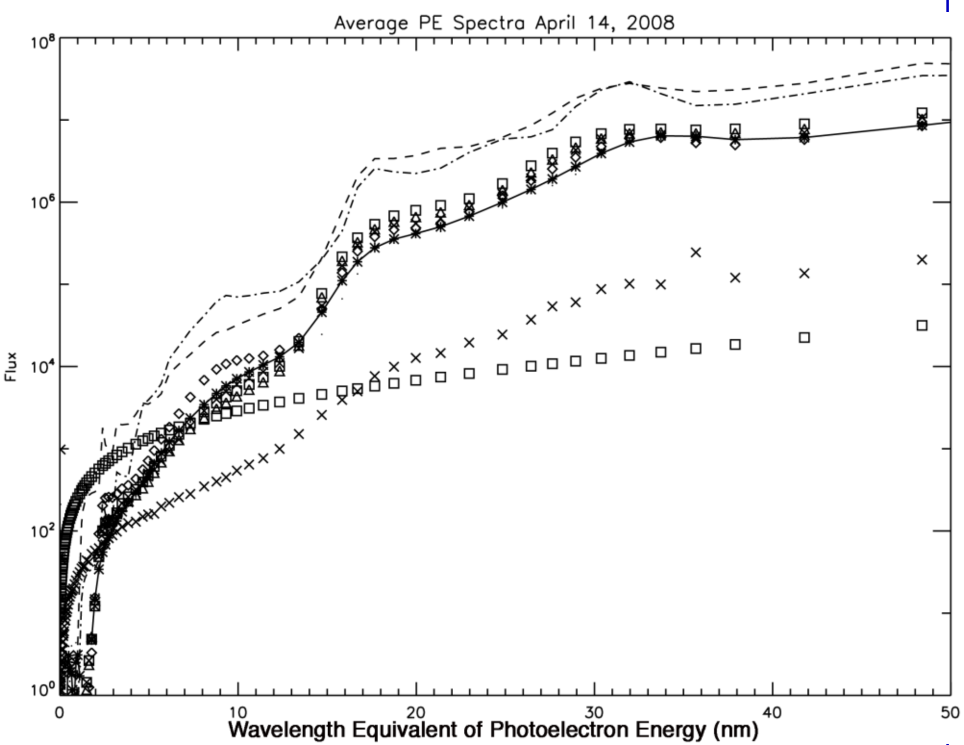


We focus on April 14, the day of the rocket calibration flight

FAST April 14, 2008 Observations



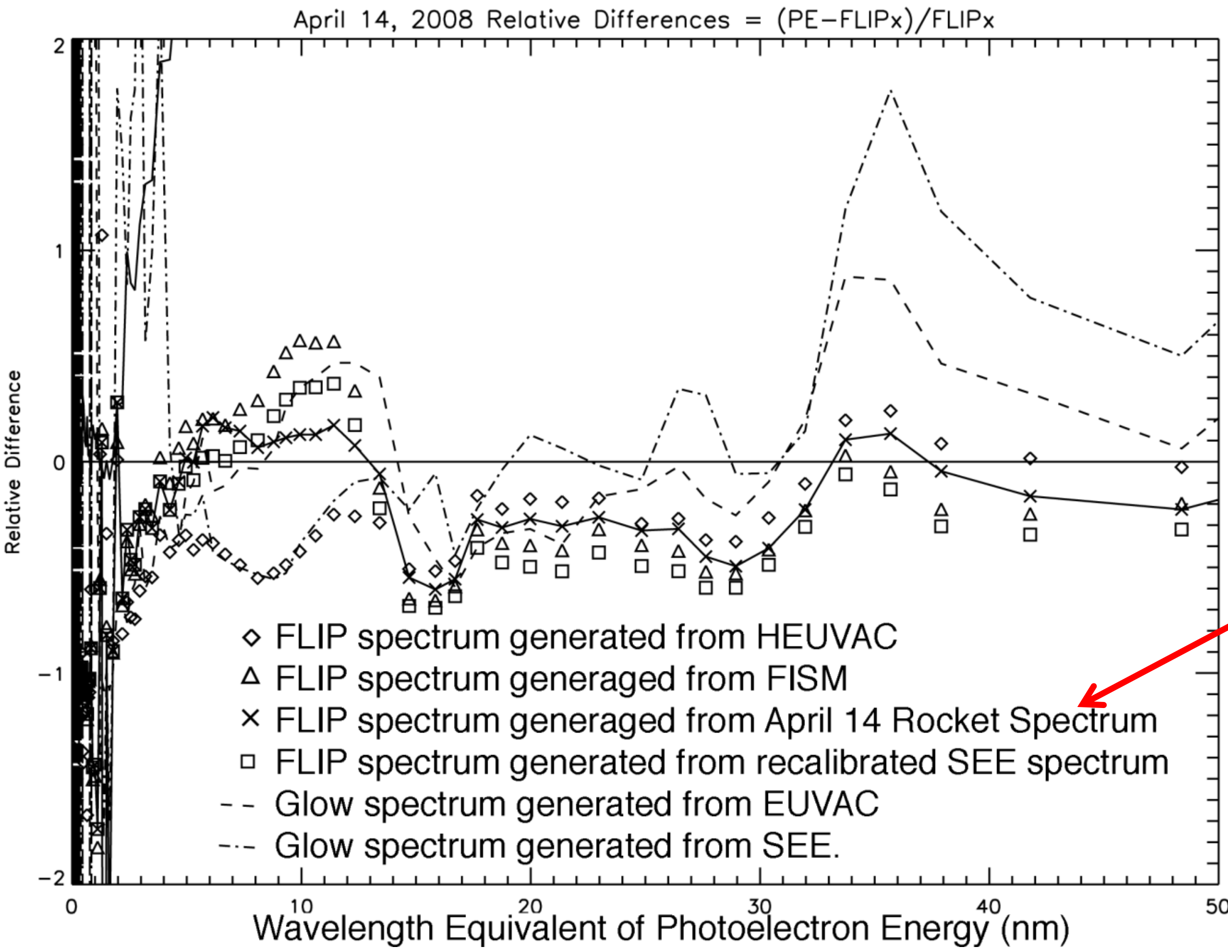
Average spectra from 51 one-minute intervals taken during the day.



Both plots have the same data
Above vs. Energy (eV)
Right vs. Wavelength (nm)

FAST April 14, 2008 Calibration

Relative Difference =
(FAST PE observations - Model) / Model



Two issues:

1) Absolute and
2) Relative agreement

FLIP driven by the rocket spectra has the best overall agreement with data

Nitric Oxide and the Solar Soft X-ray Irradiance

Scott M. Bailey

Justin Yonker

Virginia Tech

Photochemistry for Nitric Oxide (NO):
Abundance of NO is Very Sensitive to Solar 2-7 nm Irradiance

Production of Nitric Oxide

NO is primarily created through the reaction of excited atomic nitrogen with molecular oxygen:

$$N(^2D) + O_2 \rightarrow NO + O$$

A major source of excited atomic nitrogen is energetic electron impact with molecular nitrogen:

$$e^* + N_2 \rightarrow N(^2D) + N + e^*$$

Destruction of Nitric Oxide

NO is primarily destroyed through the reaction with ground state atomic nitrogen:

$$NO + N(^4S) \rightarrow N_2 + O$$

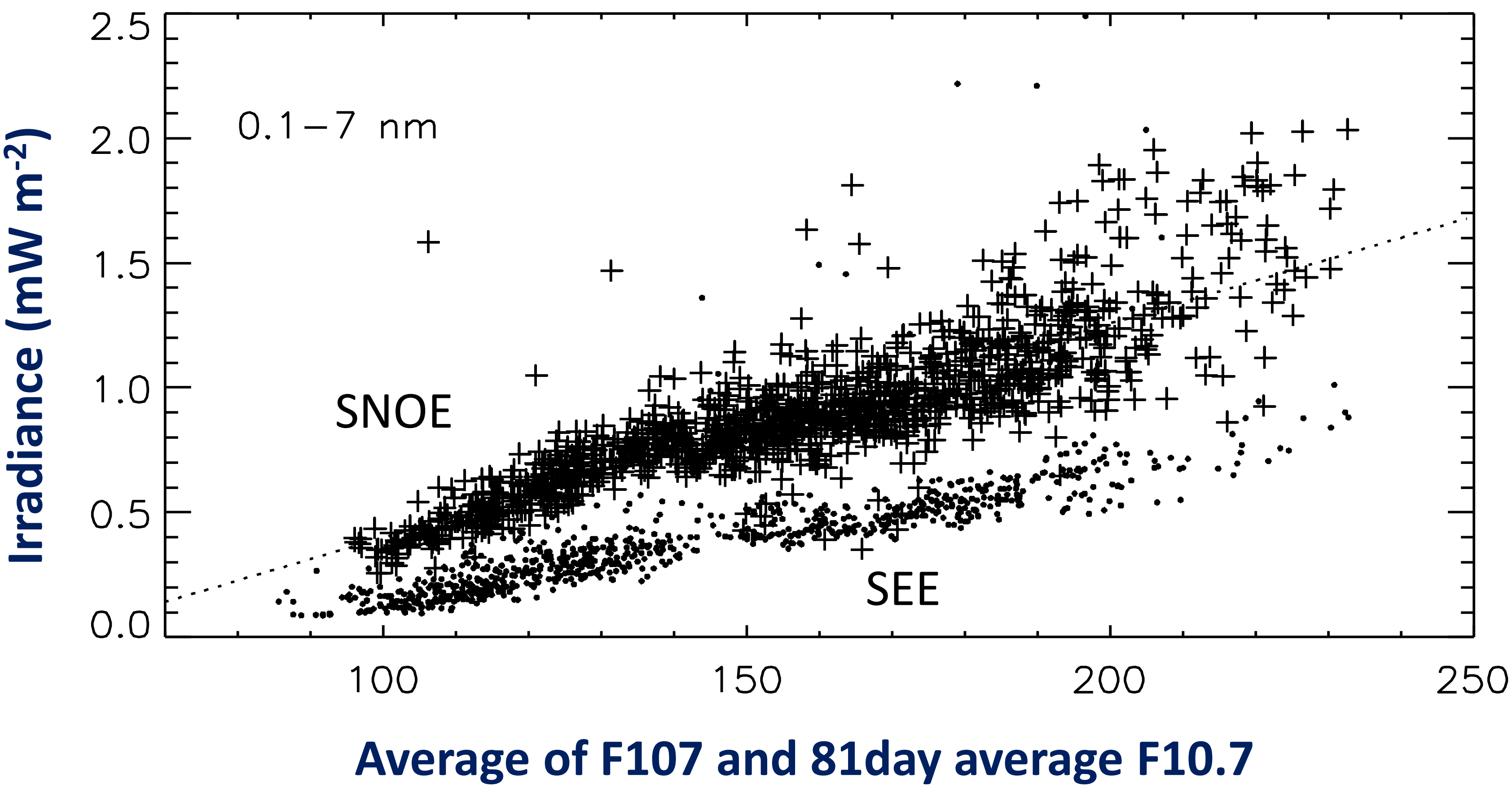
NO is also destroyed through photodissociation:

$$NO + h\nu \rightarrow N(^4S) + O$$

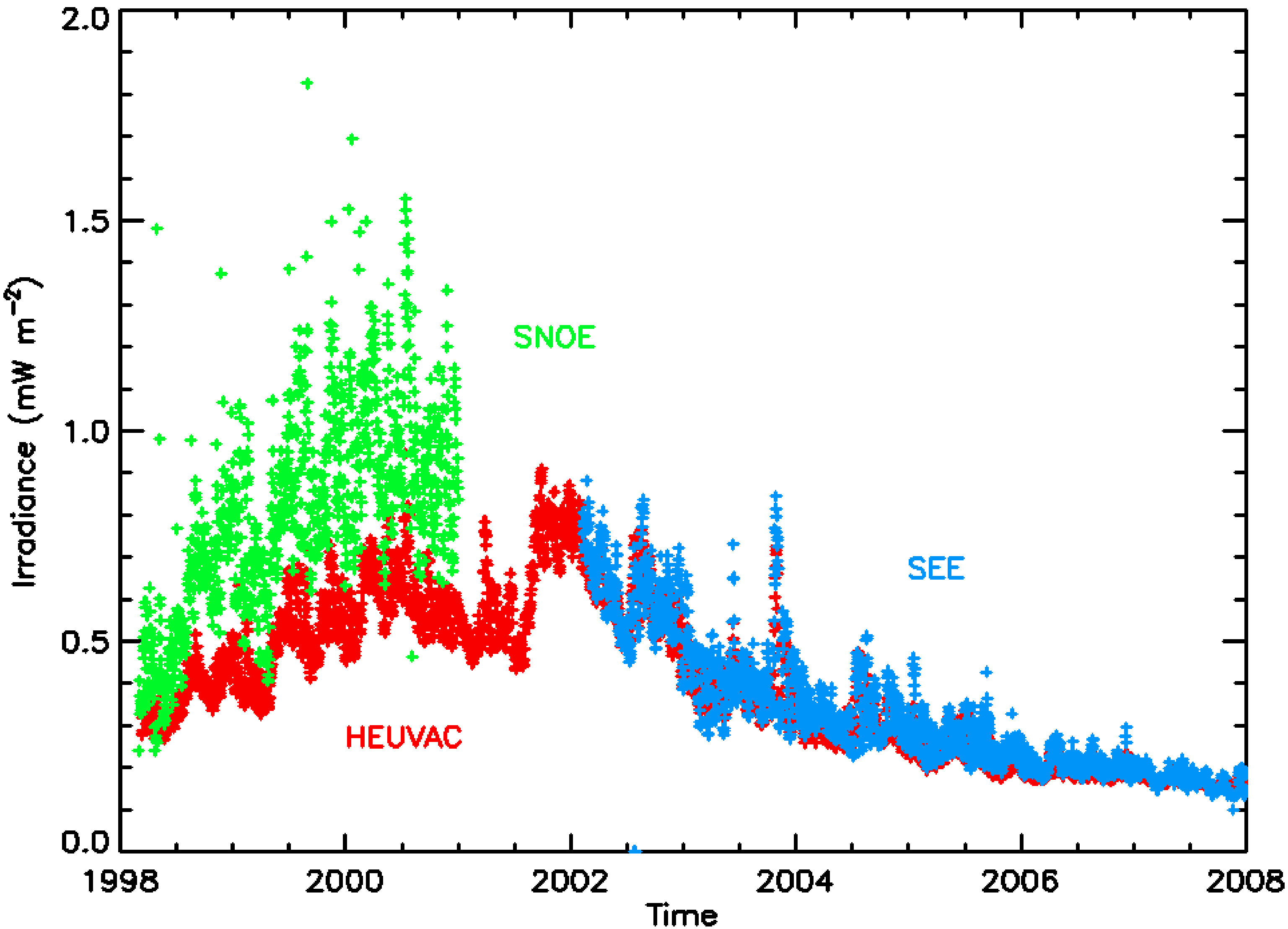
Note that this reaction is doubly effective since it creates a ground state N atom which can also destroy NO.

The effective lifetime of an NO molecule is about 1 day under sunlit conditions.

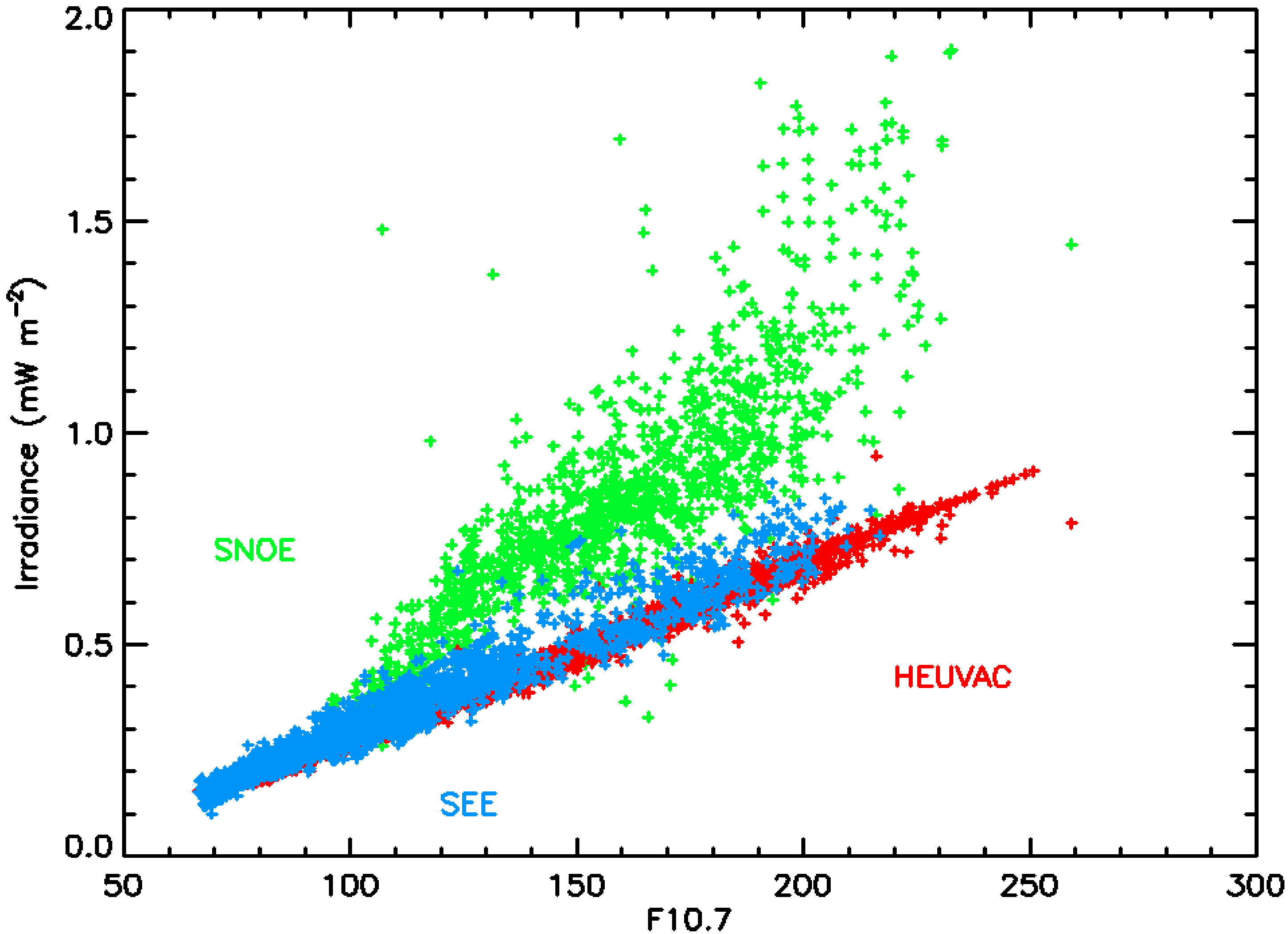
Comparison of SNOE and SEE 0 – 7nm Irradiance as of 2005



Comparison of SNOE and SEE 0 – 7nm Irradiance Today



Comparison of SNOE and SEE 0 – 7nm Irradiance Today

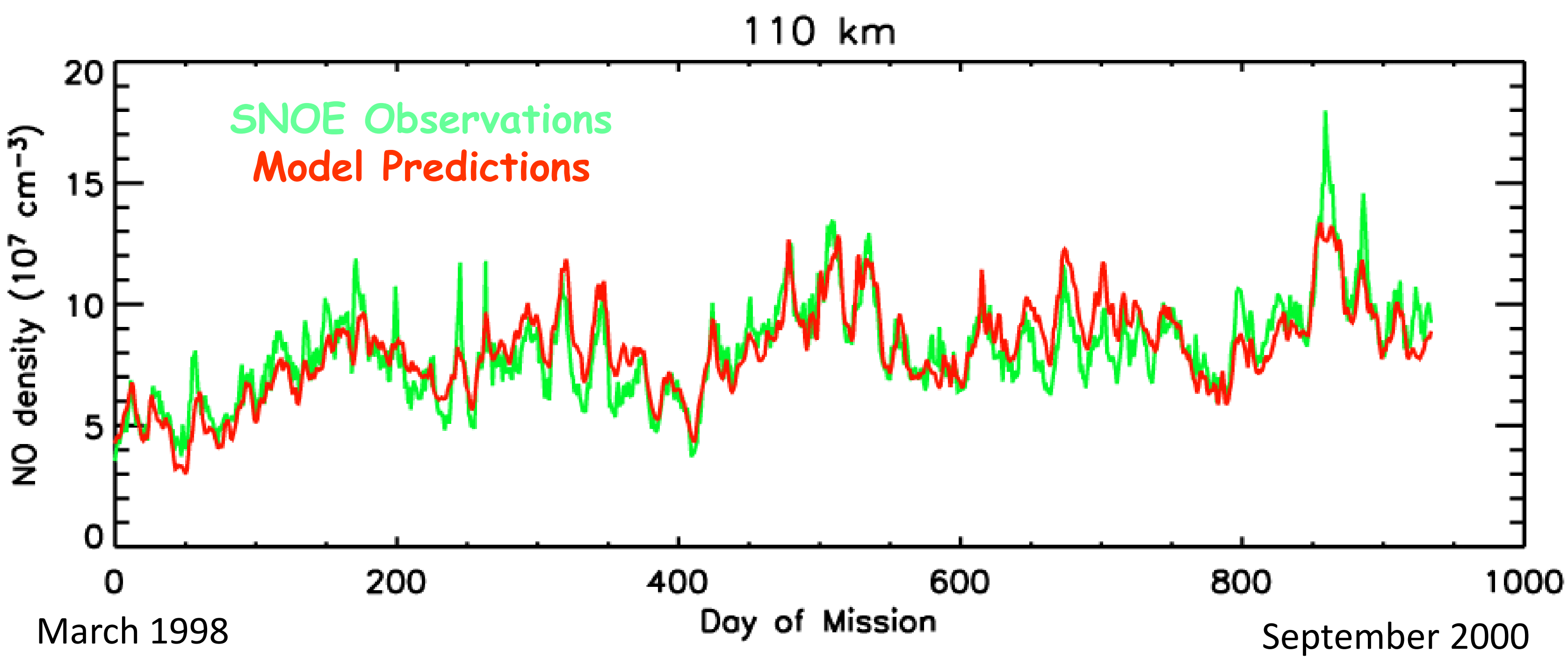


Modeling Equatorial NO Agrees Well with SNOE NO Measurements

A one-dimensional chemical model reproduced observed equatorial altitude profiles

Model Incorporates:

- Solar soft X-ray irradiance, λ < 20 nm, measured by SNOE
- Relevant photochemistry, 35 reactions
- Vertical diffusion
- MSIS neutral atmosphere, GLOW energetic electron transport code



Parameterization of Solar EUV Processes for Global Models

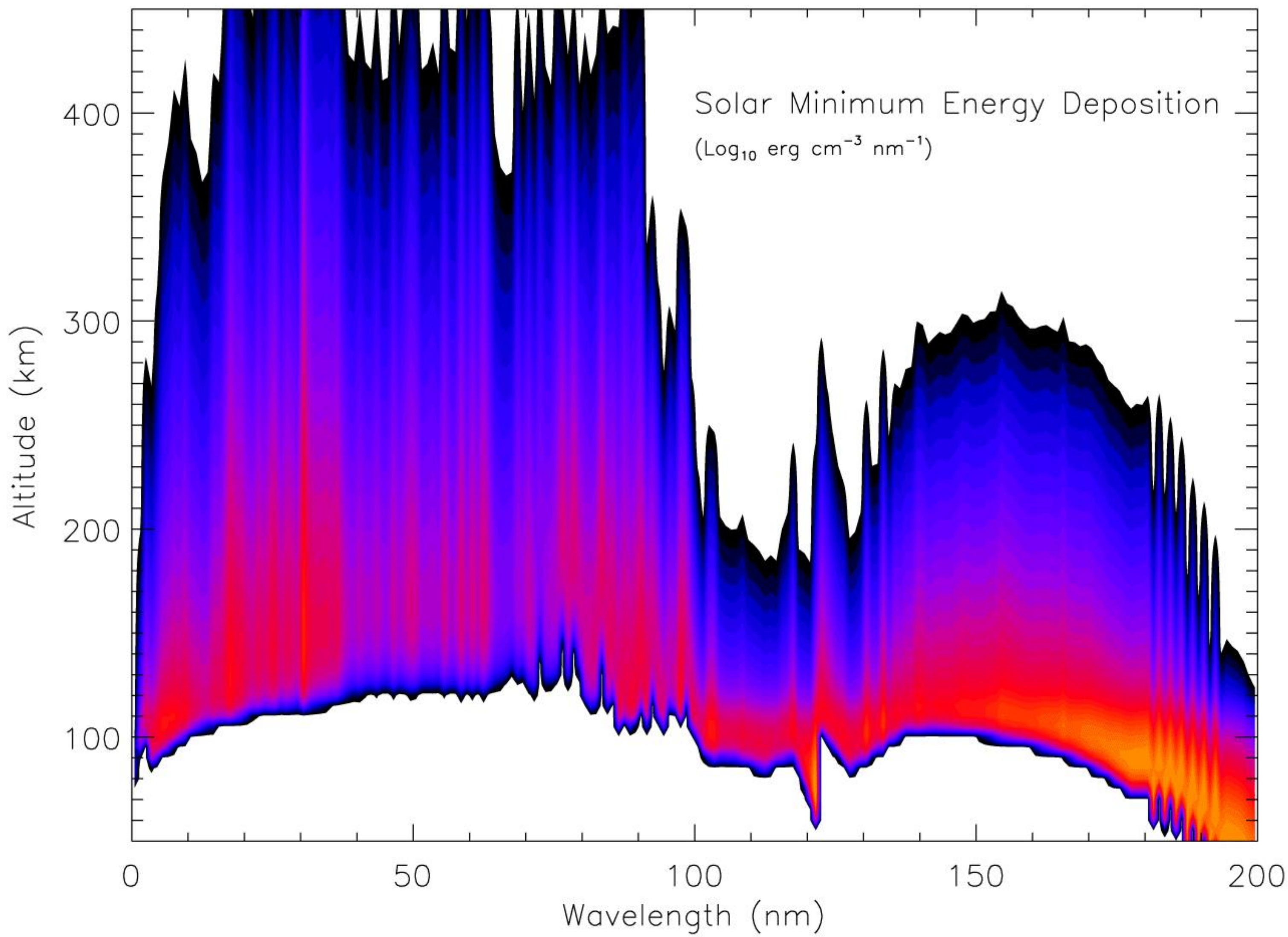
Stan Solomon

Liying Qian

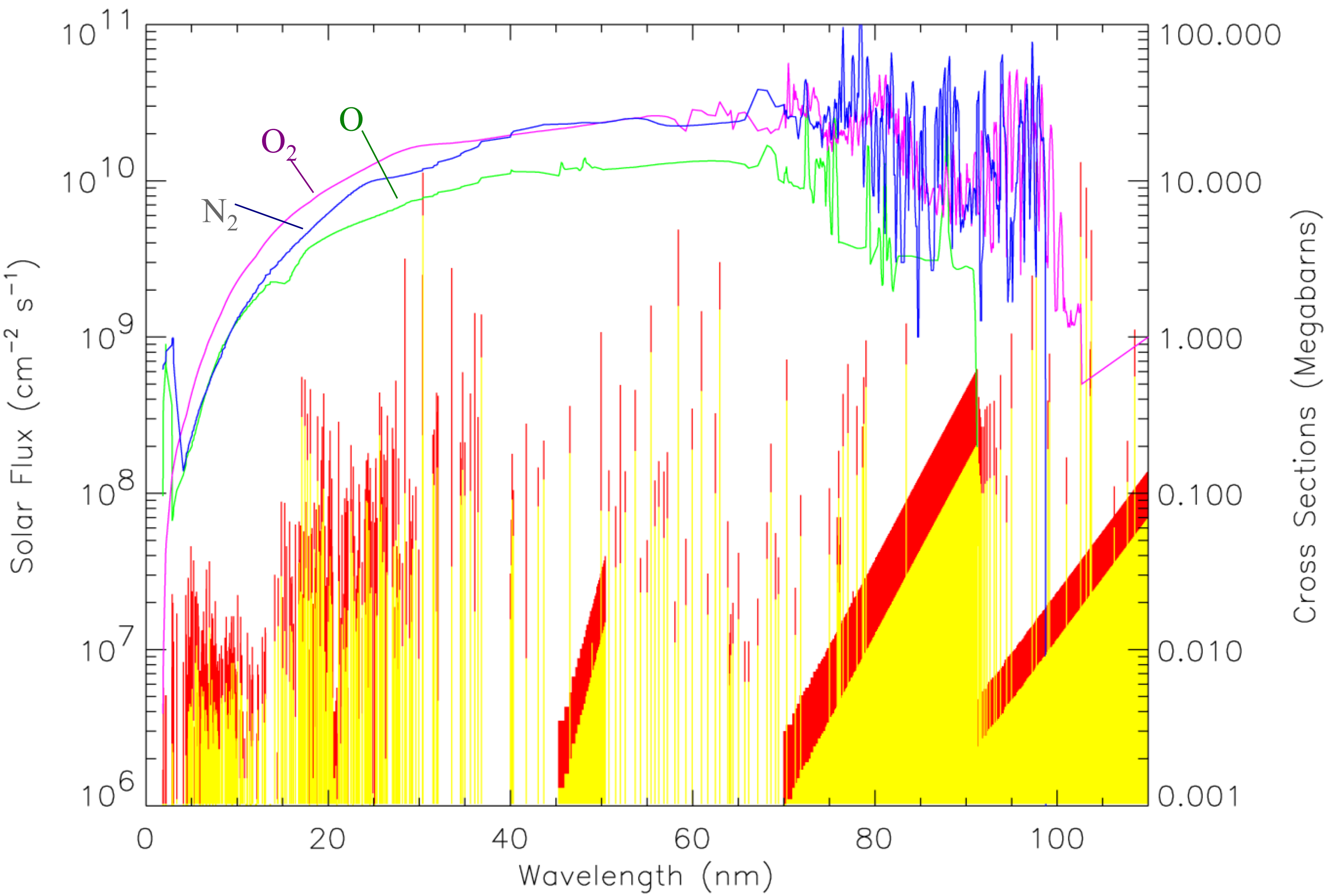
High Altitude Observatory

National Center for Atmospheric Research

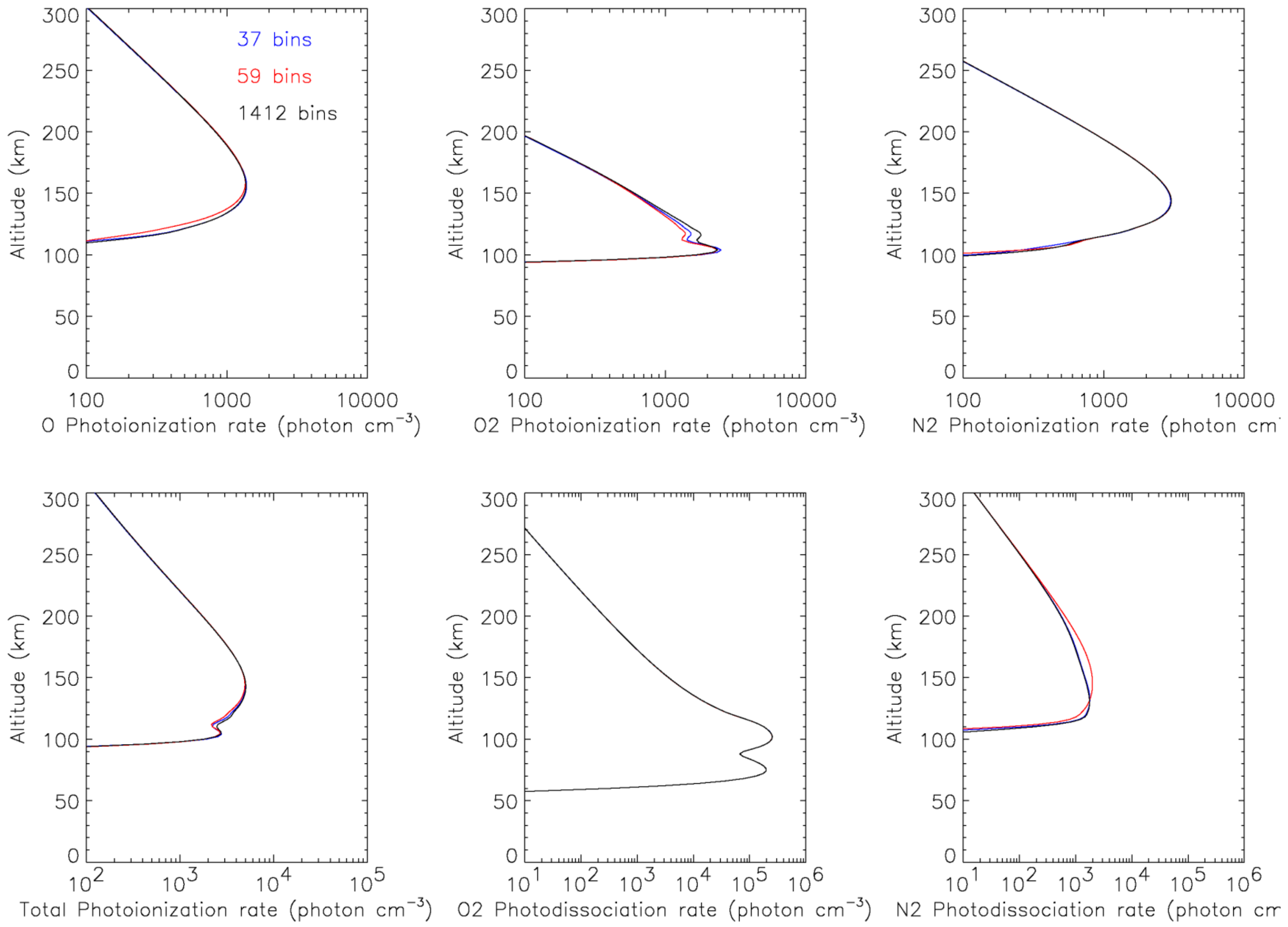
Altitude Dependence of Solar Energy Deposition



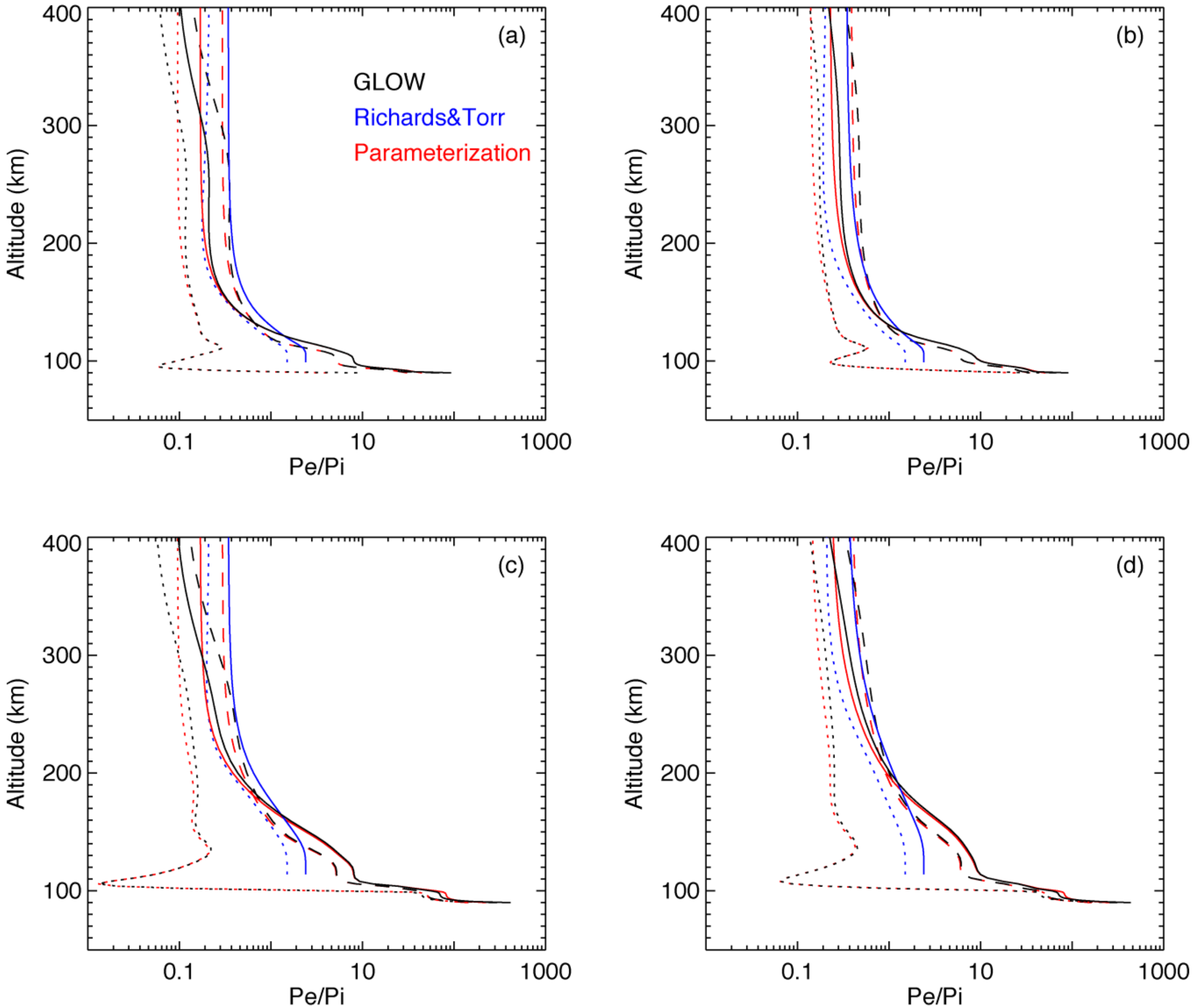
Solar Spectrum and Atmospheric Cross-Sections



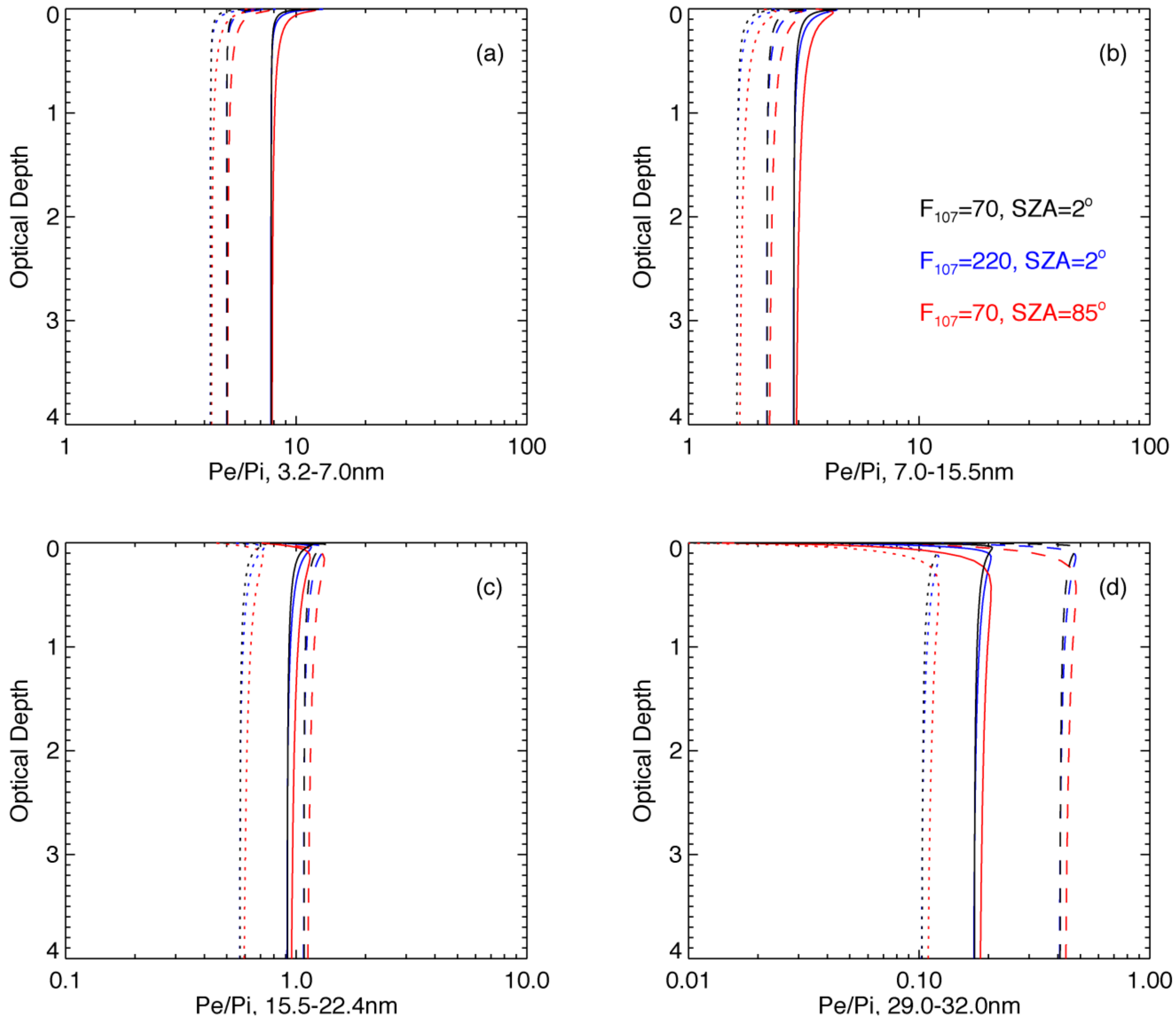
Photoionization and Photodissociation Rates



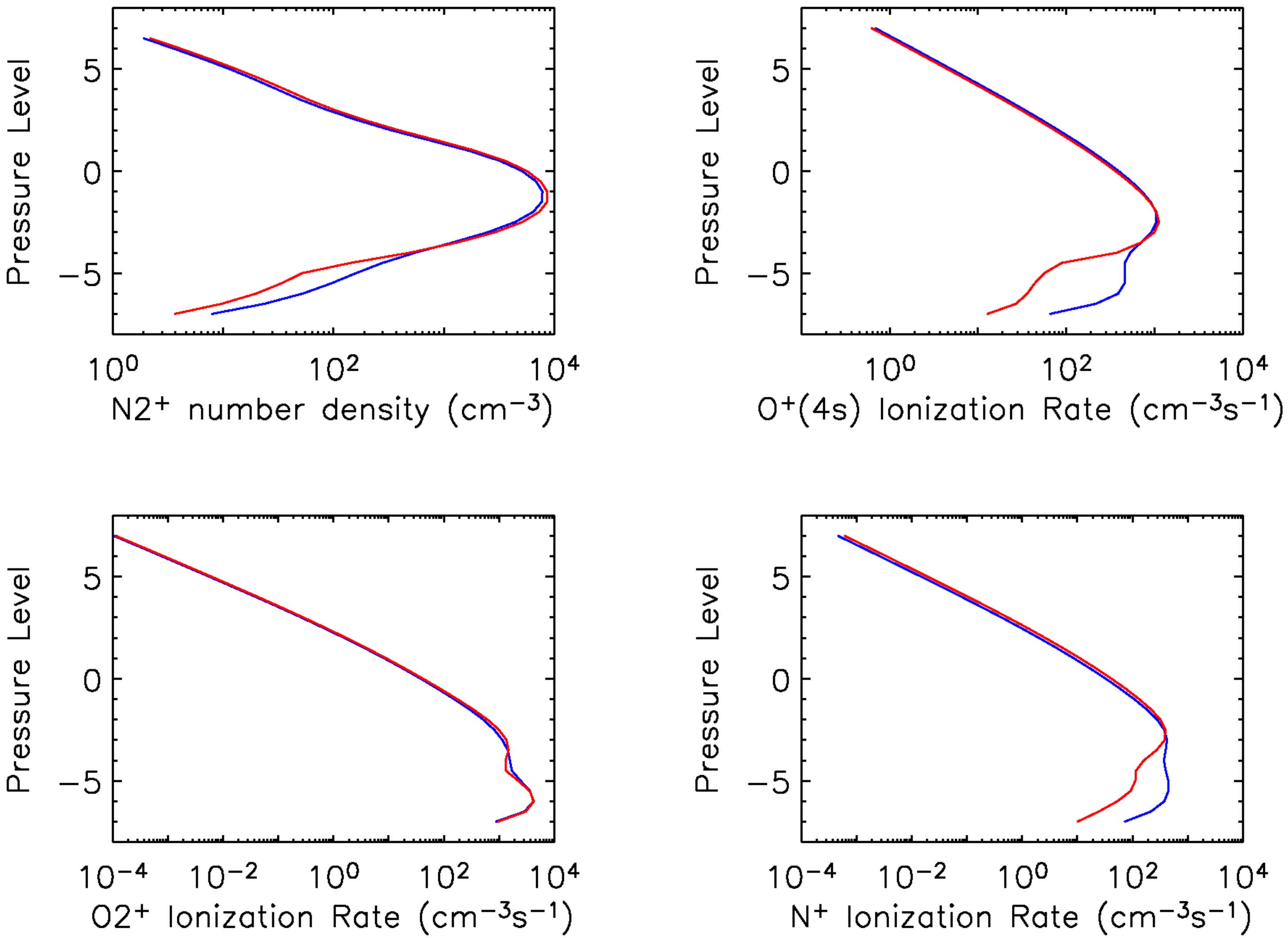
Ionization by Photoelectrons



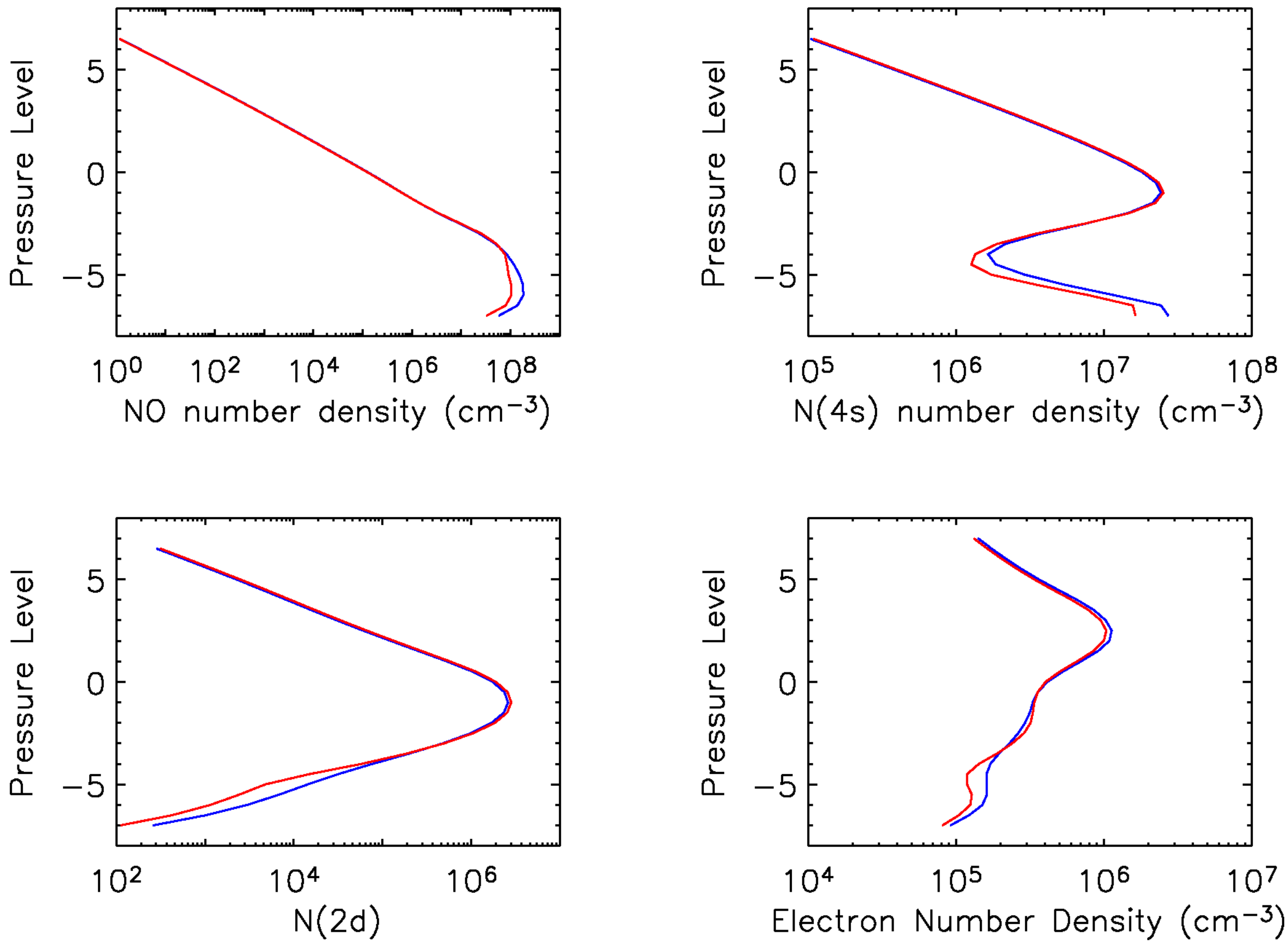
Wavelength-Dependant Photoelectron Ionization Factors



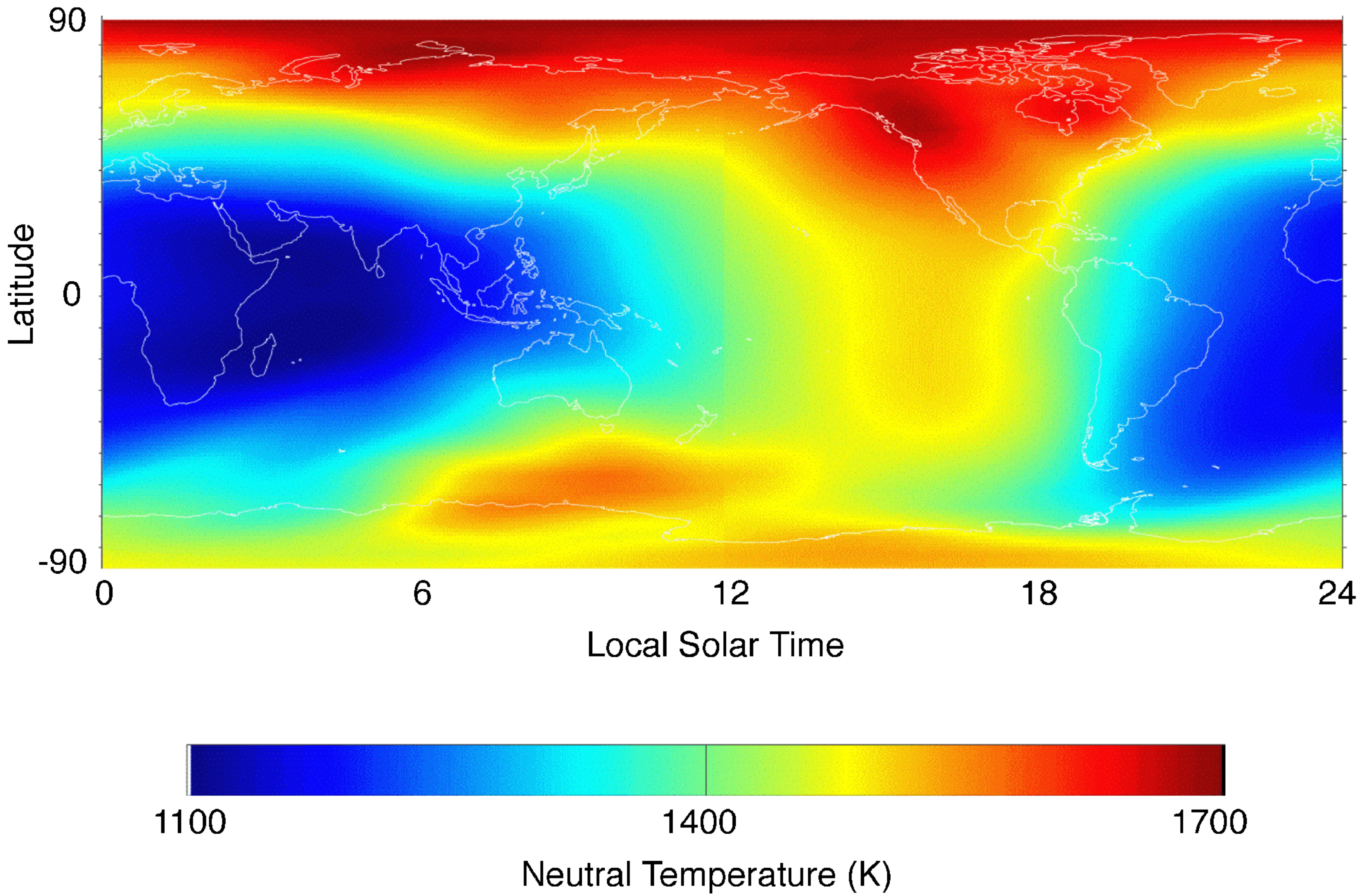
Comparison of Parameterizations in the NCAR TIE-GCM



Comparison of Parameterizations in the NCAR TIE-GCM

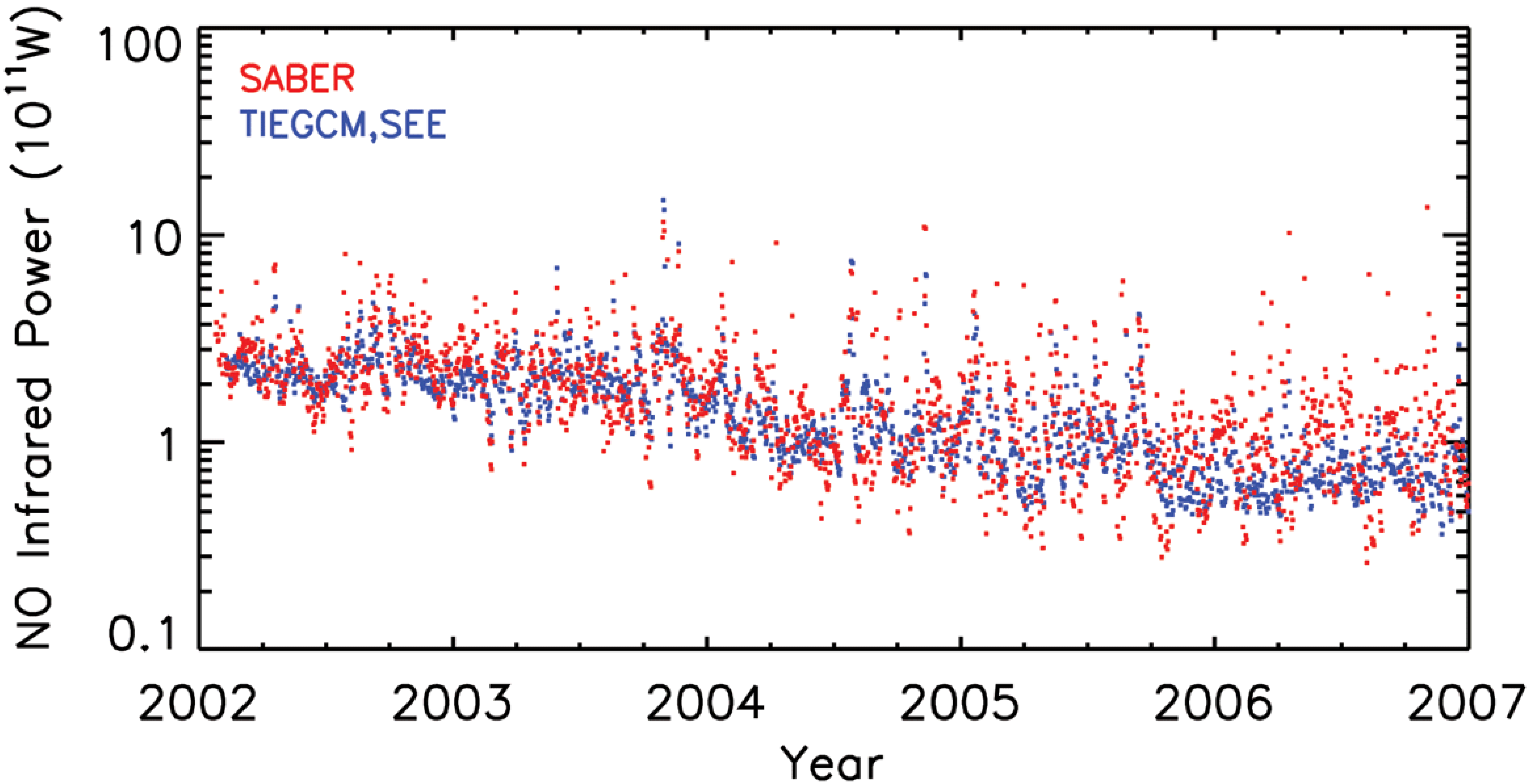


Global Calculations by the NCAR TIE-GCM



The Thermospheric Thermostat:

Comparison of Simulated Nitric Oxide Cooling to Global Observations by TIMED/SABER



Comparison of measurements from the SABER instrument on TIMED [Mlynczak et al., 2008] of the global thermospheric nitric oxide cooling rate, with simulations by the NCAR TIE-GCM using SEE solar observations as input. The storm-time, solar rotational, and solar cycle agreement is good, but SABER measurements do exhibit more short-term variability than the model simulations.

SEE Related Talks and Papers

SEE Related Talks in 2008

- AGU, December 07, 2 talks
- AGU, May 08, 2 talks
- SCOSTEP/CAWSES, June 08, 2 talks
- CEDAR Workshop, June 08, 1 talk
- COSPAR, July 08, 5 talks
- IHY WHI Workshop, August 08, 4 presentations
- Chamberlin: GSFC invited talk in Sept. 08
- Lean: invited presentations for SWEF

SEE Related Papers in 2008 – Page 1

- Peterson, W. K., P. C. Chamberlin, T. N. Woods, and P. G. Richards, Temporal and spectral variations of the photoelectron flux and solar irradiance during an X class solar flare, *Geophys. Res. Lett.*, 35, L12102, doi:10.1029/2008GL033746, 2008.
- Chamberlin, P. C., T. N. Woods, and F. G. Eparvier, Flare Irradiance Spectral Model (FISM): Flare component algorithms and results, *Space Weather J.,* 6, S05001, doi:10.1029/2007SW000372, 2008.
- Woods, T. N., P. C. Chamberlin, W. K. Peterson, R. R. Meier, P. G. Richards, D. J. Strickland, G. Lu, L. Qian, S. C. Solomon, B. A. Iijima, A. J. Mannucci, and B. T. Tsurutani, XUV Photometer System (XPS): Improved irradiance algorithm using CHIANTI spectral models, *Solar Physics*, 249, doi 10.1007/s11207-008-9196-6, 2008.
- Mlynczak, M. G., F. J. Martin-Torres, C. J. Mertens, B. T. Marshall, E. R. Thompson, J. U. Kozyra, E. E. Remsberg, L. L. Gordley, J. M. Russell, and T. Woods, Solar-terrestrial coupling evidenced by periodic behavior in geomagnetic indexes and the infrared energy budget of the thermosphere, *Geophys. Res. Lett.*, 35, L05805, doi: 10.1029/2007GL032620, 2008.
- Paulson, D. B., W. D. Pesnell, L. D. Deming, M. Snow, T. S. Metcalfe, T. Woods, and B. Hesman, Chromospheric lines as diagnostics of stellar oscillations, in Proc. Of the ESO/Lisbon/Aveiro Conf. held in Aveirgo, Portugal, 11-15 Sept. 2006, eds. N. C. Santos, L. Pasquini, A. C. M. Correia, and M. Romanielleo, Springer, Garching, Germany, pp. 311-312, 2008.
- Sternovsky, Z., P. Chamberlin, M. Horanyi, S. Robertson, and X. Wang, Variability of the lunar photoelectron sheath and dust mobility due to solar activity, *J. Geophys. Res.*, 113, A10104, doi: 10.1029/2008JA013487, 2008.
- Lean, J., Changing Sun, Changing Earth, *Earthzine* web publication, Aug. 28, 2008, http://www.earthzine.org/2008/08/28/changing-sun-changing-earth/, 2008.
- Woods, T. N., Recent advances in observations and modeling of the solar ultraviolet and X-ray irradiance, *Adv. Space Res.*, 42, 5,895-902, doi: 10.1016/j.asar.2007.09.026, 2008.
- Dudok de Wit, T., M. Kretzschmar, J. Aboudarham, P.-O. Amblard, F. Auchère, and J. Lilensten, Which Solar EUV Indices are Best for Reconstructing the Solar EUV Irradiance?, *Adv. Space Res.*, 42, 5, 903-911, doi: 10.1016/j.asar.2007.04.019, 2008.
- Chamberlin, P., T. N. Woods, and F. G. Eparvier, New flare model using recent measurements of the solar ultraviolet irradiance, *Adv. Space Res.*, 42, 5, 912-916, doi: 10.1016/j.asar.2007.09.009, 2008.

SEE Related Papers in 2008 – Page 2

- Barra, V., V. Delouille, and J. Hochedez, Segmentation of Extreme Ultraviolet Solar Images Via Multichannel Fuzzy Clustering, *Adv. Space Res*., 42, 5, 917-925, doi: 10.1016/j.asar.2007.10.021, 2008.
- Qian, L., S. C. Solomon, R. G. Roble, B. R. Bowman, and F. A. Marcos, Thermospheric neutral density response to solar forcing, *Adv. Space Res.*, 42, 5, 926-932, doi: 10.1016/j.asar.2007.10.019, 2008.
- Liu, G., and G. G. Shepherd, An Investigation of the Solar Cycle Impact on the Lower Thermosphere O(1S) Nightglow Emission as Observed by WINDII/UARS, *Adv. Space Res*., 42, 5, 933-938, doi: 10.1016/j.asar.2007.09.004, 2008.
- Zhang, Zhang, S. P., and G. G. Shepherd, Variations of the O(1D) and O(1S) Peak Volume Emission Rates Without Direct Solar Effects, *Adv. Space Res*., 42, 5, 939-946, doi: 10.1016/j.asar.2007.10.008, 2008.
- Peterson, W. K., P. C. Chamberlin, T. N. Woods, and P. Richards, Variations of the solar flux in the 1 to 50 nm range over a solar rotation inferred from observations of photoelectrons with energies from 0.01 to 1 keV from the FAST satellite, *Adv. Space Res*., 42, 5, 947-956, doi: 10.1016/j.asar.2007.08.038, 2008.
- Qian, L., R. G. Roble, S. C. Solomon, and T. J. Kane, Model simulations of global change in the ionosphere, Geophys. Res. Lett., 35, L07811, doi:10.1029/2007GL033156, 2008.
- Smithtro, C. G., and S. C. Solomon, An improved parameterization of thermal electron heating by photoelectrons, with application to an X17 flare, J. Geophys. Res., 113, A08307, doi:10.1029/2008JA013077, 2008.
- Tian, F., S. C. Solomon, L. Qian, J. Lei, and R. G. Roble, Hydrodynamic planetary thermosphere model, II: Coupling of energetic electron transport model, J. Geophys. Res., 113, E07005, doi:10.1029/2007JE003043, 2008.
- Qian, L., S. C. Solomon, and T. J. Kane, Seasonal variation of thermospheric density in response to forcing by the lower atmosphere, J. Geophys. Res., submitted, 2008.
- Woods, T. N., P. C. Chamberlin, J. W. Harder, R. A. Hock, M. Snow, F. G. Eparvier, J. Fontenla, W. E. McClintock, and E. C. Richard, Solar Irradiance Reference Spectra (SIRS) for the 2008 Whole Heliosphere Interval (WHI), *Geophys. Res. Lett*., submitted, 2008.
- Chamberlin, P. C., T. N. Woods, D. A. Crotser, F. G. Eparvier, R. A. Hock, and D. L. Woodraska, New, Higher Resolution Solar Extreme Ultraviolet (EUV) Irradiance Results for Solar Cycle Minimum Conditions on April 14, 2008, *Geophys. Res. Lett.,* submitted, 2008.

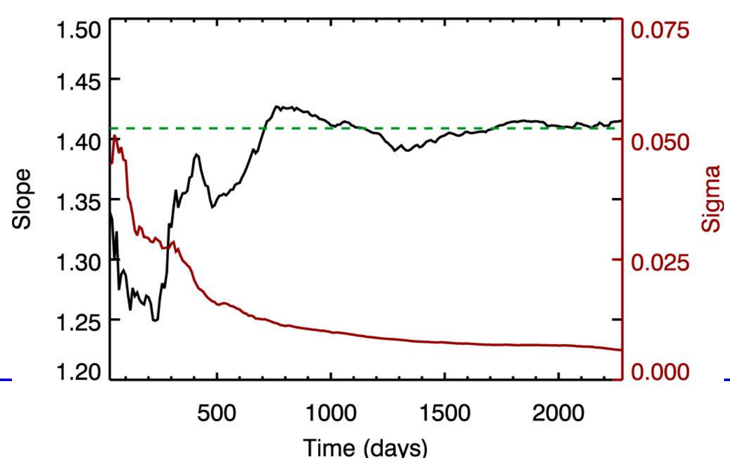
Conclusions and Future Plans

Summary of SEE Observations

- TIMED SEE has been very successful in obtaining new, accurate measurements of the solar EUV irradiance
  - SEE data available from http: //lasp.colorado.edu/see/
- More than 100 flares have been observed by SEE
  - Extreme flare periods are April 2002, July 2002, May-June 2003, Oct.-Nov. 2003, July 2004, Jan. 2005, Sept. 2005, and Dec. 2006
  - Large flares vary as much as 11-year solar cycle variations
  - New flare models have been developed with SEE observations
- More than 90 solar rotations have been observed by SEE
  - Variability of 5-70% observed (wavelength dependent)
- TIMED mission has observed solar maximum and minimum activity during solar cycle 23
  - Extended TIMED mission would observe solar cycle rising activity, perhaps starting in 2009

SEE Plans for 2009

- Daily mission operations and data processing for SEE
  - Release of Version 10 data products is expected in fall 2008
- Provide SEE data and model products for space weather operations
  - Continue to provide SEE Space Weather data product to Air Force and NOAA SEC for daily space weather operations
- Detailed modeling of Earth's response to solar cycle changes
  - Composition, dynamics, temperature using TIME-GCM for solar cycle variations
- Overlap with NASA Solar Dynamics Observatory (SDO) mission
  - EUV Variability Experiment (EVE) on SDO will provide 0.1-105 nm solar EUV irradiance with 0.1 nm spectral resolution
  - SDO's launch is planned for June 2009, but due to launch vehicle manifest, SDO might not be launched until January 2010



SEE-EVE overlap needs to be for at least 1 year to provide accurate continuation of the solar EUV time series.

Plot shows how uncertainty (sigma) of combining 2 solar data sets decreases with longer overlap time.