TIMED Solar EUV Experiment: Phase E Annual Report for 2002

Submitted for NASA Grant NAG5-11408
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SEE Science Team

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NRL: Judith Lean

SpaceWx: Kent Tobiska

GI/UAF: Scott Bailey

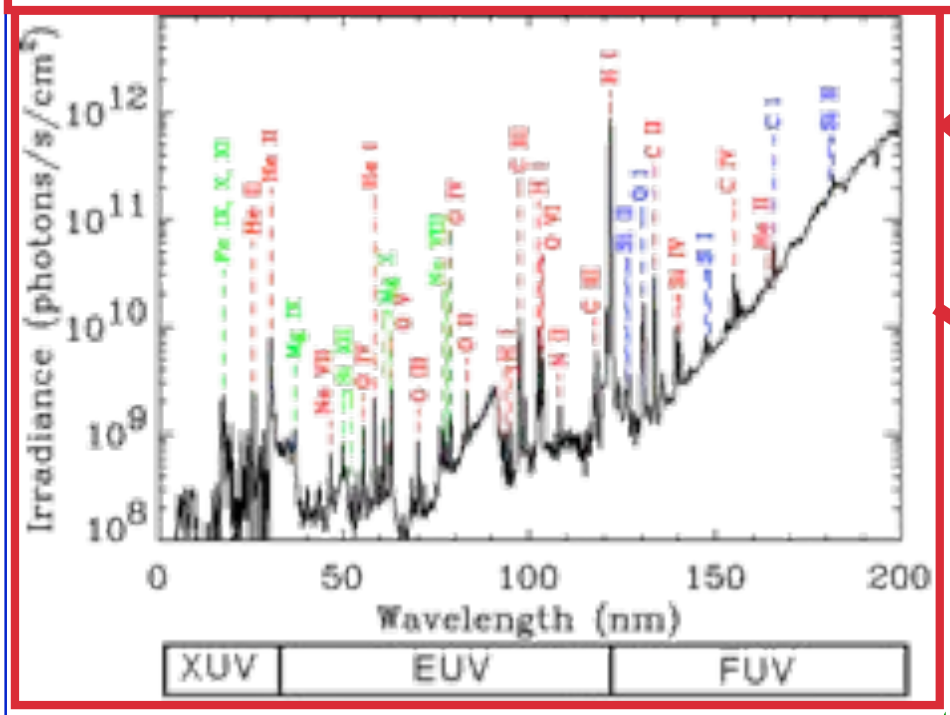
Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Aeronautics and Space Administration.

Report Outline

- SEE Science Overview
- SEE Instrument Overview and Status
- Summary of SEE Data Products
- Summary of SEE Results
- Summary of SEE Related Talks and Papers
- Future Plans for SEE Team

SEE Science Plans

Solar UV Irradiance Measurements



Validations

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

Eparvier, Woods, Bailey, Rottman

All

Solar UV Variability

Function of wavelength
Over time scales of minutes to years

Study Earth's Response

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

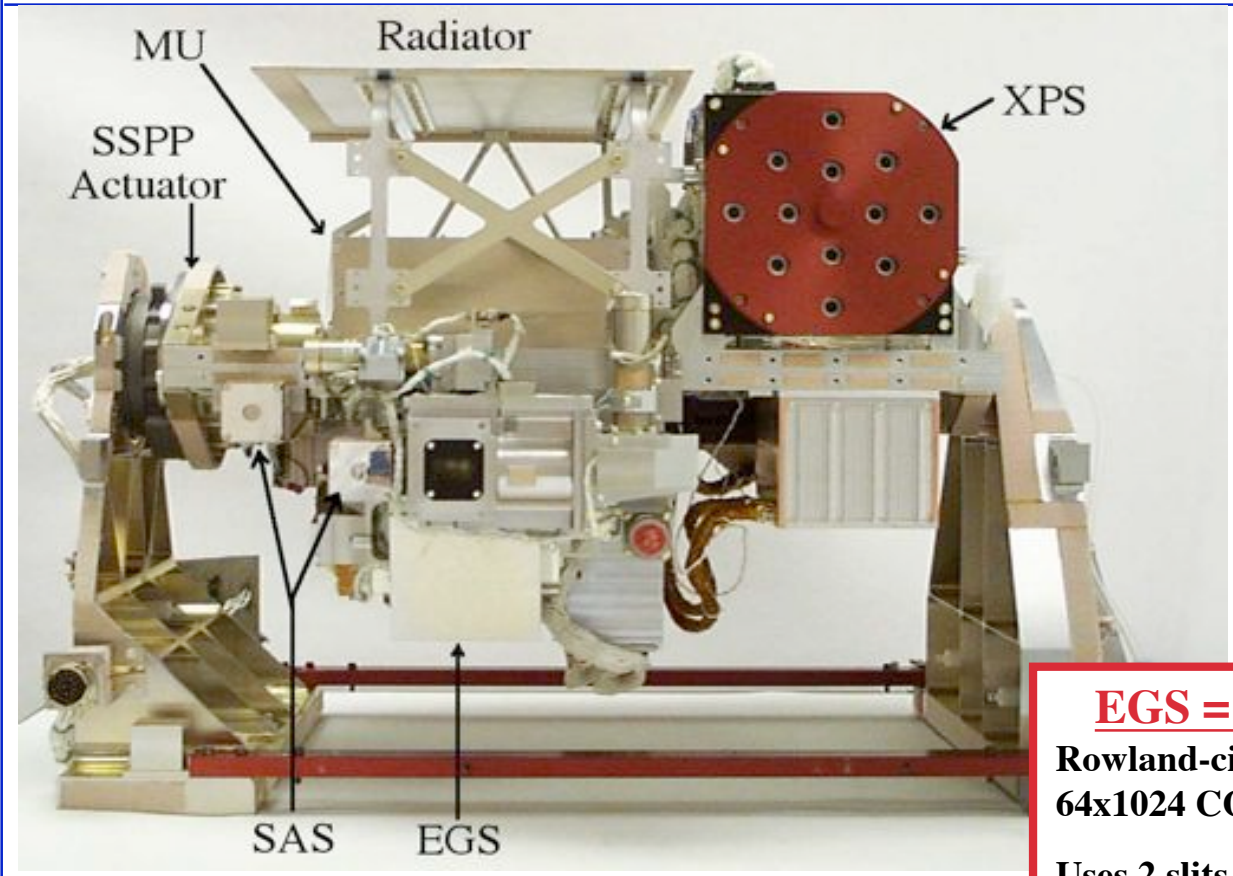
Solomon, Roble, Bailey, Eparvier

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, White, Fox, Woods

TIMED Solar EUV Experiment



Measures the solar vacuum ultraviolet (VUV) irradiance

Range:

0.1-194 nm

Resolution:

0.4 nm EGS (27-194 nm)

5-10 nm XPS (0.1-34 nm)

Frequency:

10-sec integrations, but only for 3 min per orbit (96 min)

MU = Microprocessor Unit
SSPP = SEE Solar Pointing Platform
SAS = Solar Aspect Sensor (2)

EGS = EUV Grating Spectrograph

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

Uses 2 slits to provide redundant measurements

XPS = XUV Photometer System

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

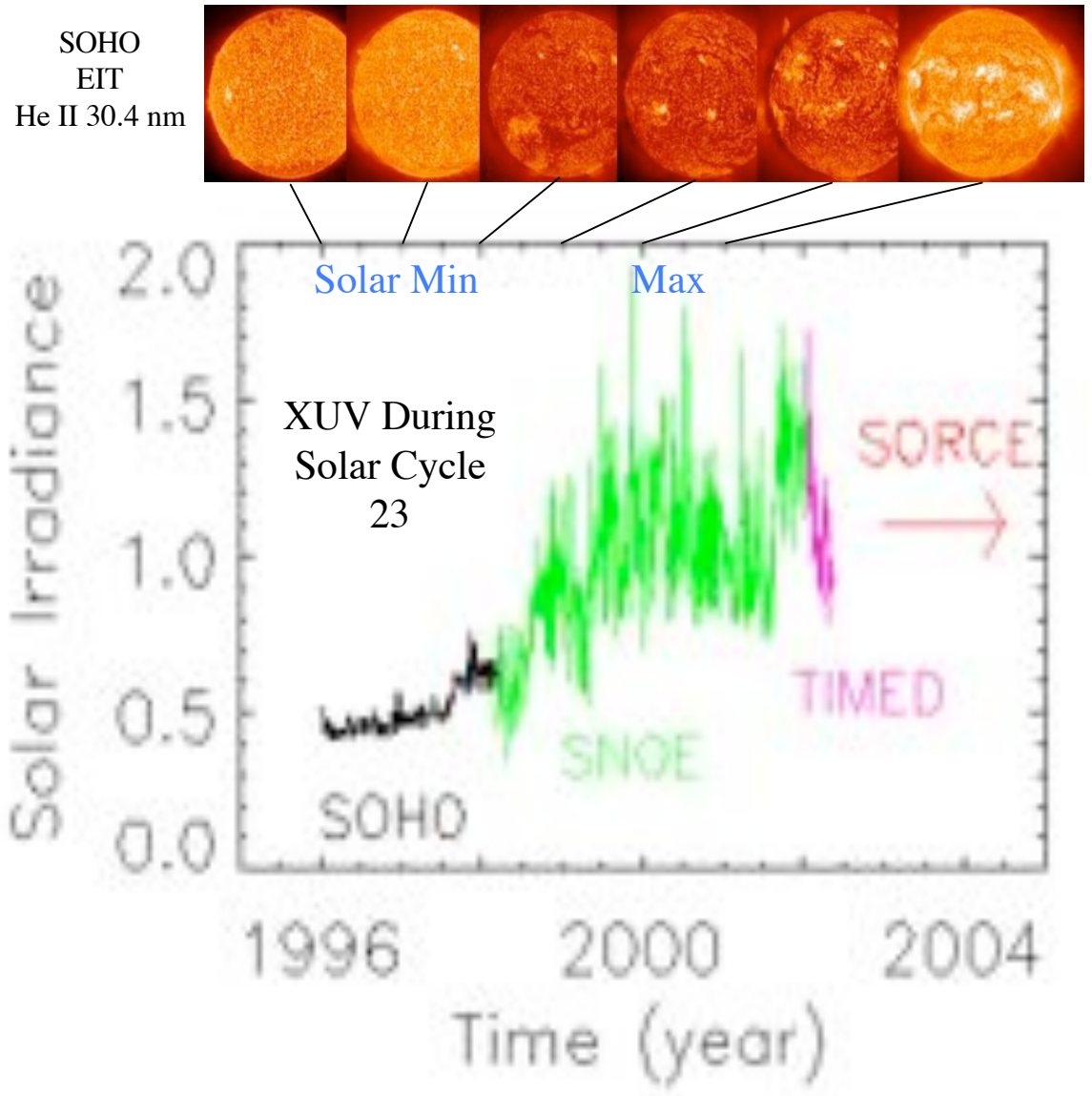
Includes 3 redundant photodiodes

Status of SEE Instrument

- **EUV Grating Spectrograph (EGS)**
  - Vacuum door anomaly on 2002/005, solved on 2002/011
  - Fully functional instrument
  - Some degradation, mostly at the bright lines on the CODACON (MCP-based) detector, but is tracked well with on-board redundant channel and flat-field detector lamp weekly experiments
- **XUV Photometer System (XPS)**
  - Fully functional until 2002/205 when there was a filter wheel anomaly (filter wheel stuck in position 6)
  - 3 channels continue to make good solar measurements
  - SORCE, with identical XPS, launches in Jan. 2003
  - No detectable degradation, except for slight degradation for the Lyman-α channel, as determined by redundant channels used up to 2002/205
- **Microprocessor Unit (MU)**
  - Fully functional
- **SEE Solar Pointing Platform (SSPP)**
  - Fully functional

TIMED Mission Began at Solar Maximum

- TIMED was just in time for solar maximum
- Solar cycle 23 is now dropping towards solar minimum
- SEE's daily observations began on Jan. 22, 2002



Summary of SEE Observations

- Results are for the period of Jan. 22 - Dec. 11, 2002
- Observations in 2002
  - 4,798 orbits (96%) with solar observations
  - 322 days (99.4%) with EGS observations
  - 318 days (98.1%) with XPS observations
  - 184 calibration (redundant channel) solar observations
  - 149 EGS detector flat-field calibrations (Hg lamp)
  - 80 solar occultation experiments (90-500 km tangent height range)
  - Special underflight calibration rocket
    - NASA 36.192 launched on Feb. 8, 2002, complete success
- Data Gaps in 2002
  - January 1-21: still in instrument commissioning phase
  - March 2: S/C safehold (yaw around error)
  - March 4: gap for EGS only due to improper slit command (ground S/W error)
  - July 25-29: gap for XPS only due to its filter wheel anomaly

Status of SEE Data Processing

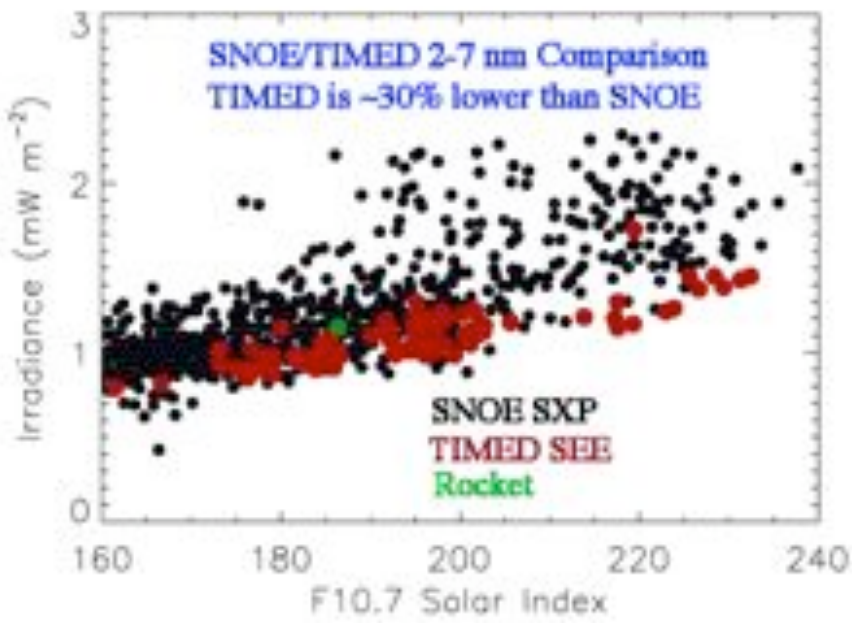
- SEE data products are being generated daily
  - Version 5 is current version
- SEE XPS and EGS Level 2 data products are available now
  - Daily average, instrument resolution, atmospheric absorption corrected, degradation corrected, normalized to 1 AU
  - NetCDF format: use IDL read_netcdf.pro to read SEE data products
  - Quick-look: use IDL plotxps_ts.pro or plotegs_ts.pro to plot time series
- SEE Level 3 data products will be available in Version 6 release
  - SEE Level 3 is the solar irradiance in 1 nm bins on 0.5 nm centers from 0-195 nm along with a list of the irradiances of the brighter emission lines
  - EGS data is used above 27 nm and XPS data with a solar model is used below 27 nm
  - These Version 6 data will be a more fully ***validated*** data set. Version 5 data have calibration issues related to broadband sensitivity for XPS and order sorting for EGS. Release of SEE Version 6 is expected in early 2003.

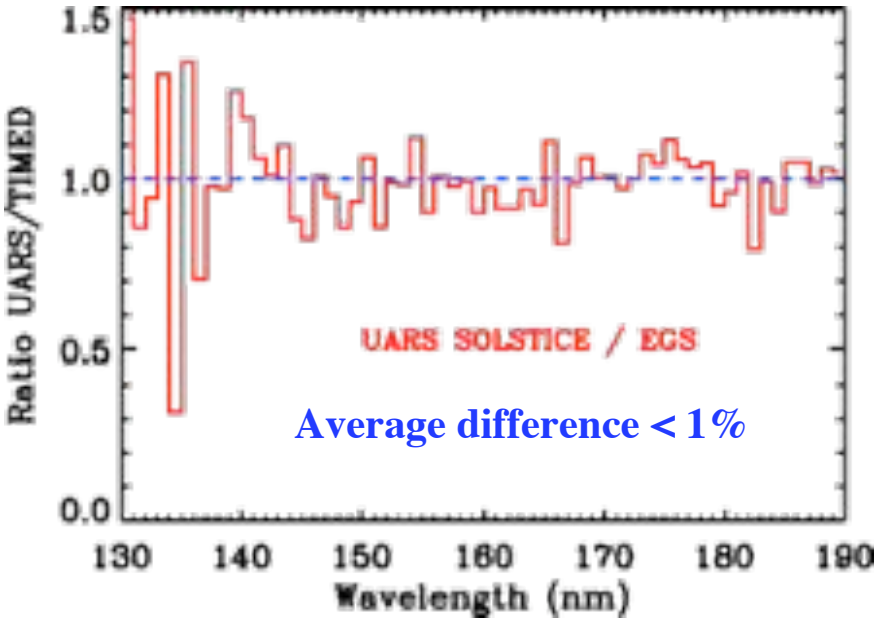
http://lasp.colorado.edu/see/

Summary of SEE Data Products

- Summary is for all versions
- SEE Low Level (raw) Data Products (file per day)
  - Level 0A (TP) files: 389
- XPS Data Products (file per day)
  - Level 0B files: 682
  - Level 1 files: 702
  - Level 2 files (access to public): 813
- EGS Data Products (file per day)
  - Level 0B files: 1110
  - Level 1 files: 711
  - Level 2 files (access to public): 1433
- SEE Level 3 (1 nm merged) Data Products (file per day)
  - Level 3 files: 717
  - Will be made public for SEE Version 6 data products

SEE Validation Results : Data Quality

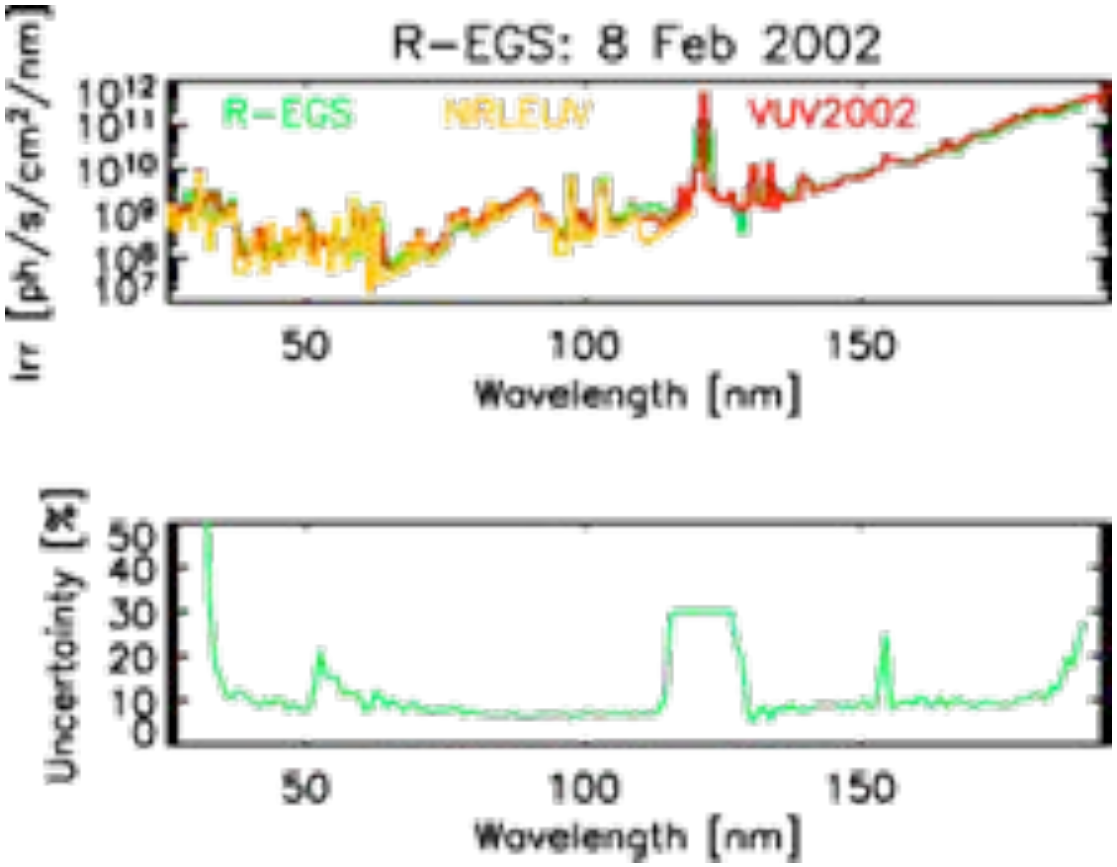




- Good agreement between XPS and SNOE below 17 nm
- Excellent agreement between EGS and UARS above 119 nm
- Issues to be resolved in Version 6 data are:
  - XPS 17-21 nm issue (0-7 nm contamination for the Al/Nb photometer)
  - EGS 26-115 nm issue (higher grating order correction for rocket EGS)

Rocket EGS Calibration Results

- Rocket EGS measurements made on 8 Feb 2002 will be used to normalize the SEE EGS measurements
- Uncertainty for the rocket measurements is about 10%



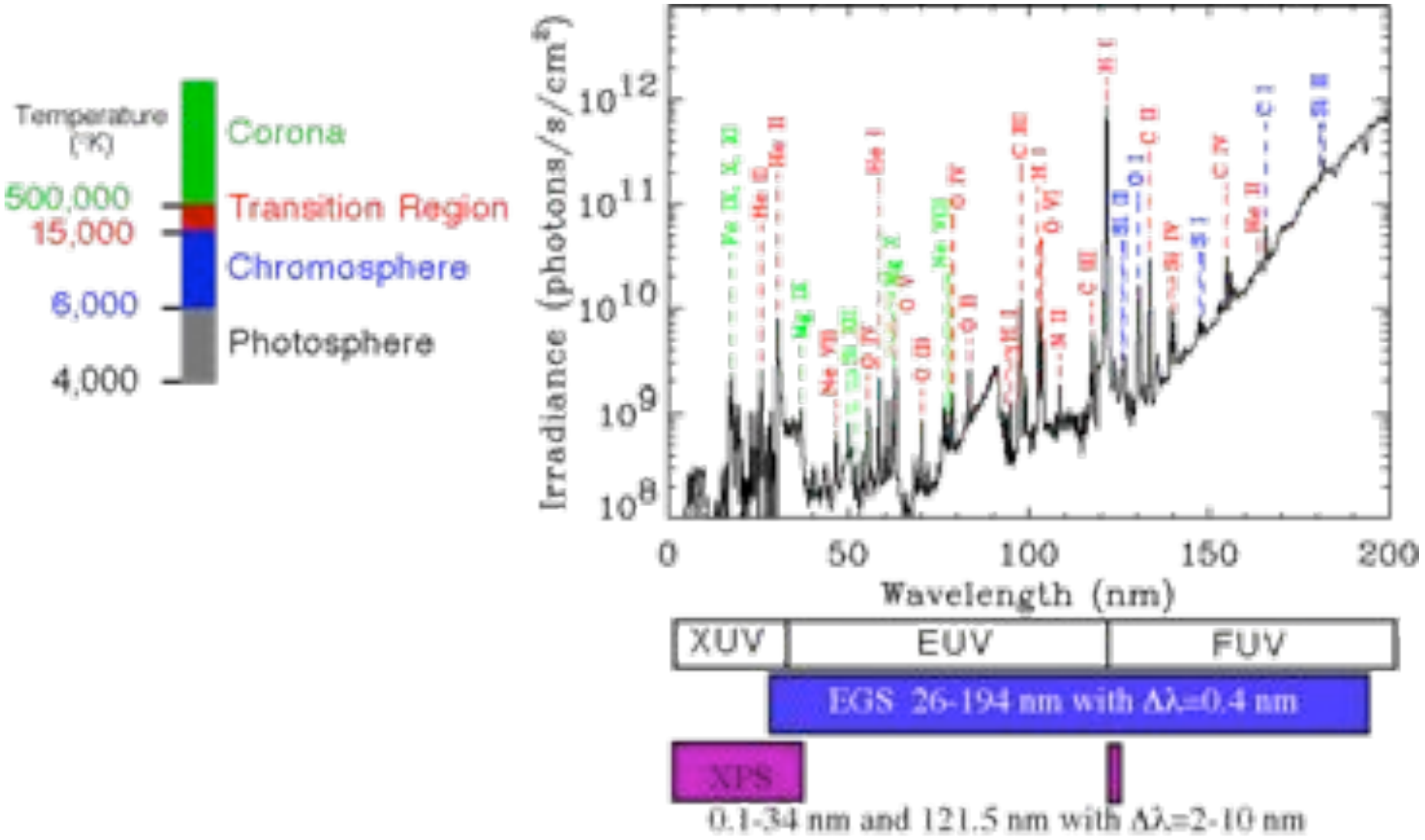
Overview of SEE Science Objectives

1. Accurately and precisely determine the time-dependent solar vacuum ultraviolet (VUV: below 200 nm) spectral irradiance
2. Study the solar-terrestrial relationships utilizing atmospheric models, primarily the TIME-GCM at HAO/NCAR
3. Study solar VUV variability (27-day rotations, solar cycle changes) and its sources
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

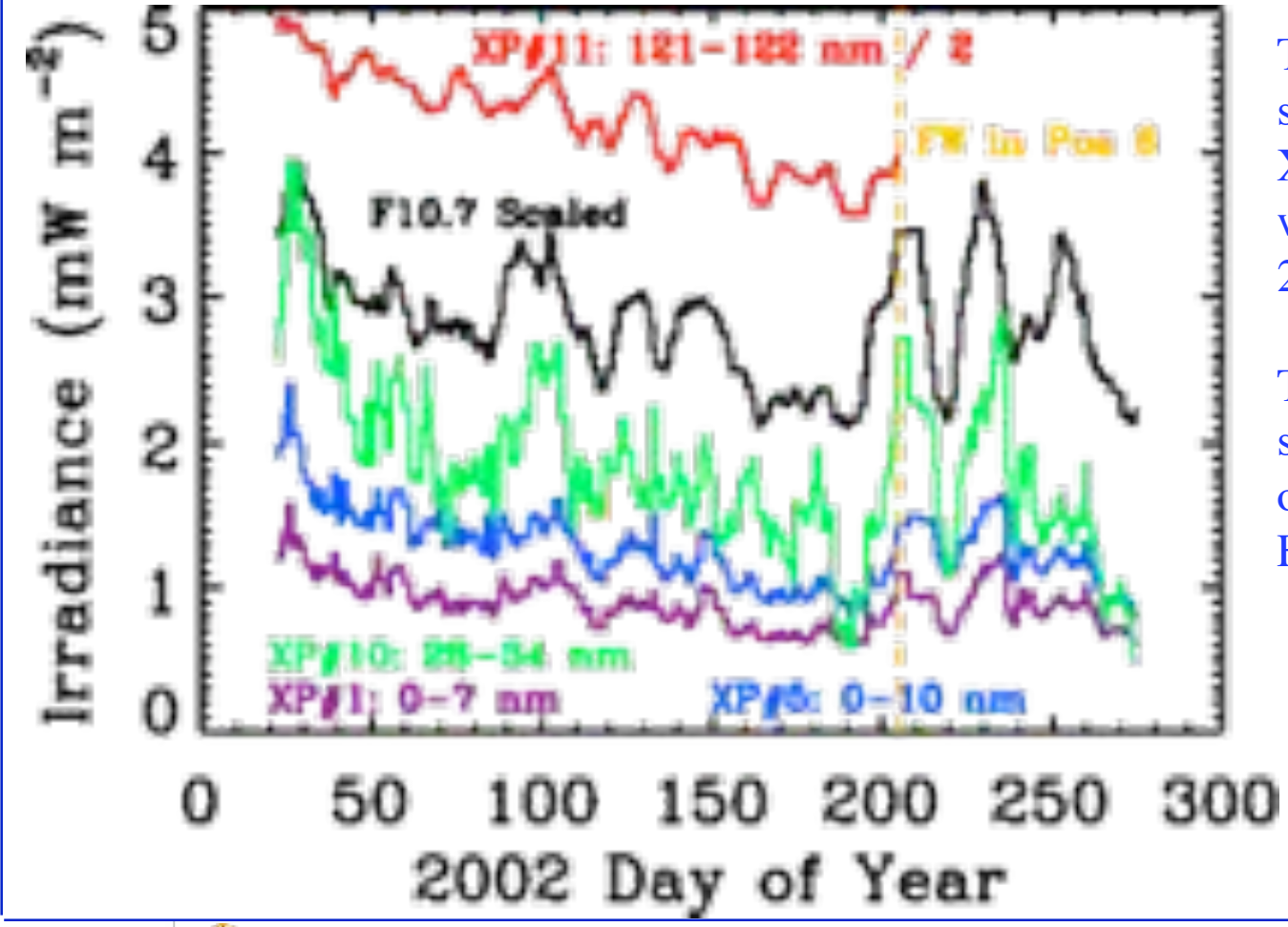
- **Objective 1: solar VUV spectral irradiance measurements**
  - Daily measurements since Jan. 22, 2002
  - On-going validation effort to verify 10-20% accuracy and 2-4% precision
- **Objective 2: model solar response in Earth's atmosphere**
  - Use of *glow* model with SEE solar data and FAST photoelectron data
- **Objective 3: solar variability**
  - Several solar rotations (11) observed during solar maximum conditions
  - Many flares (> 30) observed by SEE during TIMED mission
    - New, unexpected results from SEE !
- **Objective 4: solar irradiance modeling**
  - NRLEUV model improvements: extended below 5 nm and added flare DEM
  - SOLAR2000 model improvements: improved <50 nm accuracy, USAF 3-day forecast, ISO solar irradiance standard, and extended to 300 nm
- **Objective 5: densities from solar occultation**
  - Several occultation observations obtained, but only preliminary analysis to date

Example Solar VUV (0-200 nm) Spectrum



Example Solar Variations from XPS

XPS has observed over 30 flares, including 3 large X-class flares.
XUV variations are a factor of about 3 during 2002.
Lyman-α variations are less, as expected, at about 40%.

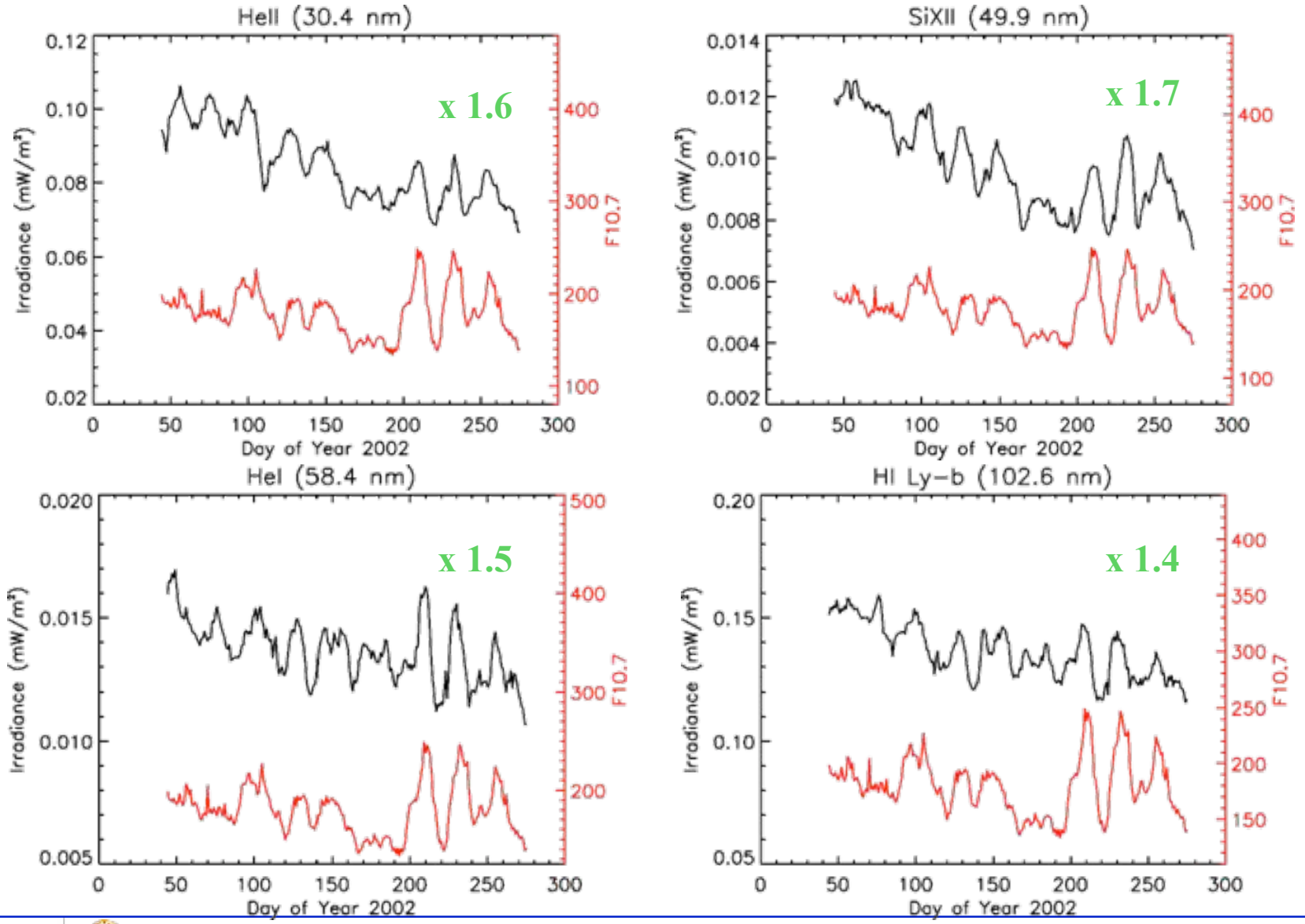


There are now only 3 solar measurements from XPS since the XPS filter wheel anomaly on day 2002/205 (July 24).

The XPS on the SORCE satellite will start a full set of XUV measurements in Feb. 2003.

Shown are the XPS Level 2 data (daily averaged)

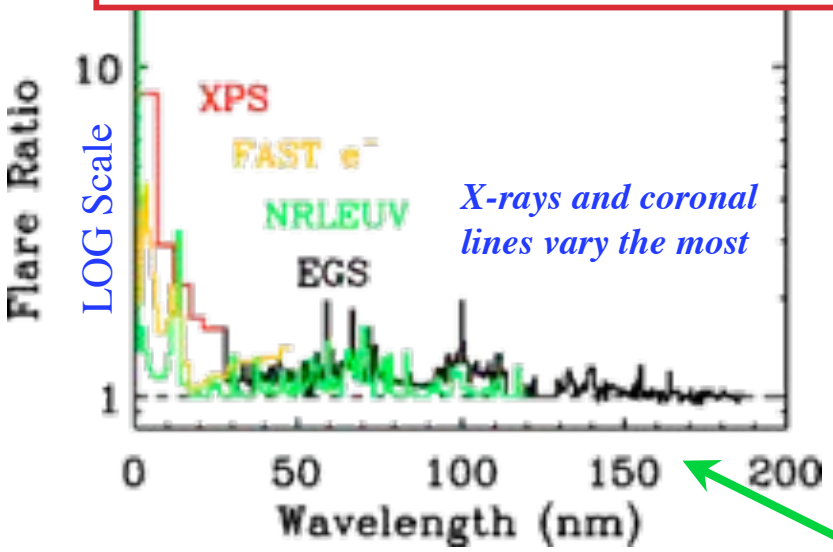
Example Solar Variations from EGS



Special Study is Large Flare on April 21, 2002

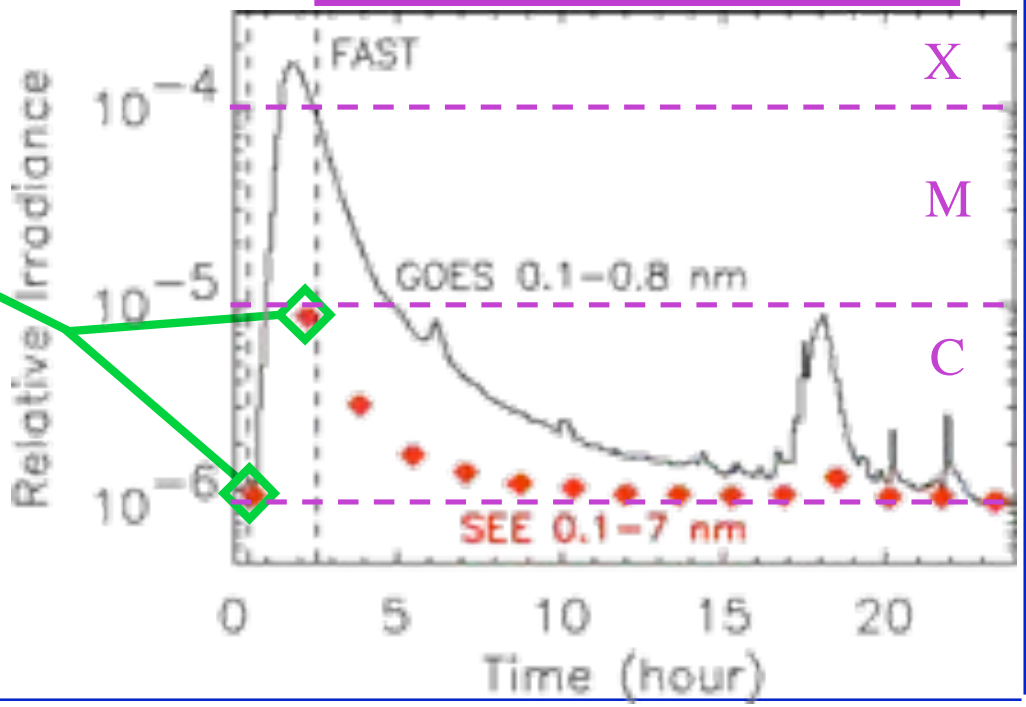
- X-ray increased by factor of 8, **peak appears to be near 2 nm**
- Longer wavelengths enhanced much less (10-40%)

The SEE measurements are key for the study of the solar photon energy input during the April storms.



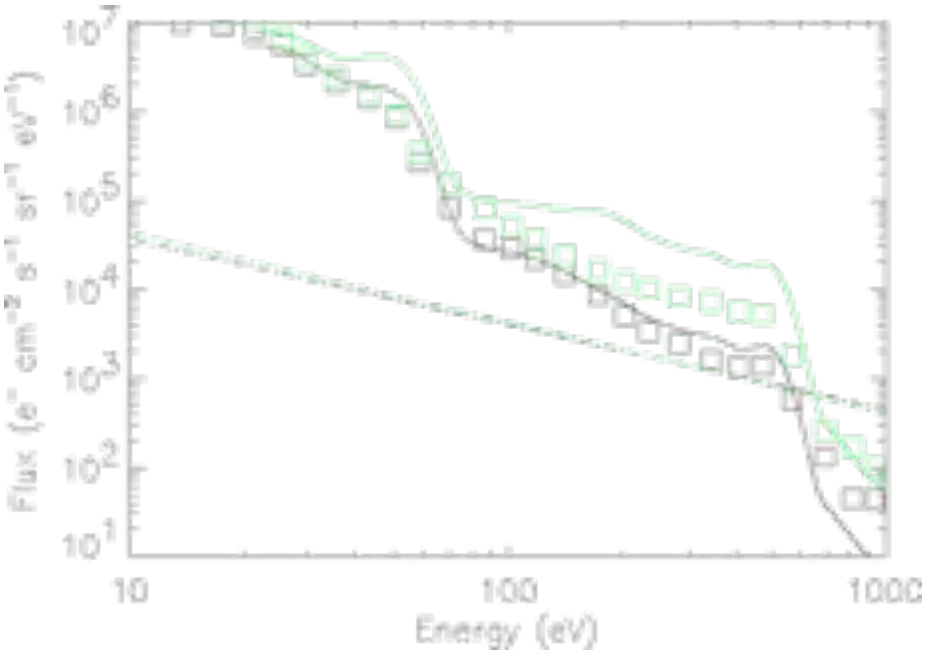
Results of SEE solar irradiance measurements and FAST photoelectron measurements are given in Woods et al. [GRL, submitted, 2002].

- X1.5 class flare at ~2 UT
- C8 class flare at ~18 UT



Modeling Photoelectron Data

- Obtained FAST photoelectron data (shown as the square symbols) at nearly the same time as the SEE measurements during the April 21, 2002 X-class flare event. The dashed line is the photoelectron background signal level that has already been removed.
- The *glow* model (results shown as the solid lines) uses the SEE solar irradiances as input
- The *glow* model result for the pre-flare condition is in good agreement with the photoelectron data
- The glow model result for near the flare peak is higher than the data, partially because the SEE solar irradiance is closer to the flare peak than the photoelectron data



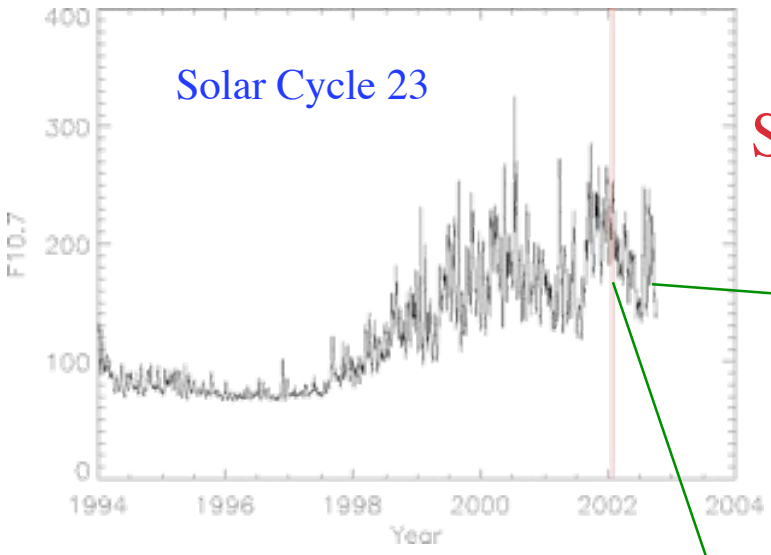
Pre-flare FAST photoelectron flux

Flare FAST photoelectron flux

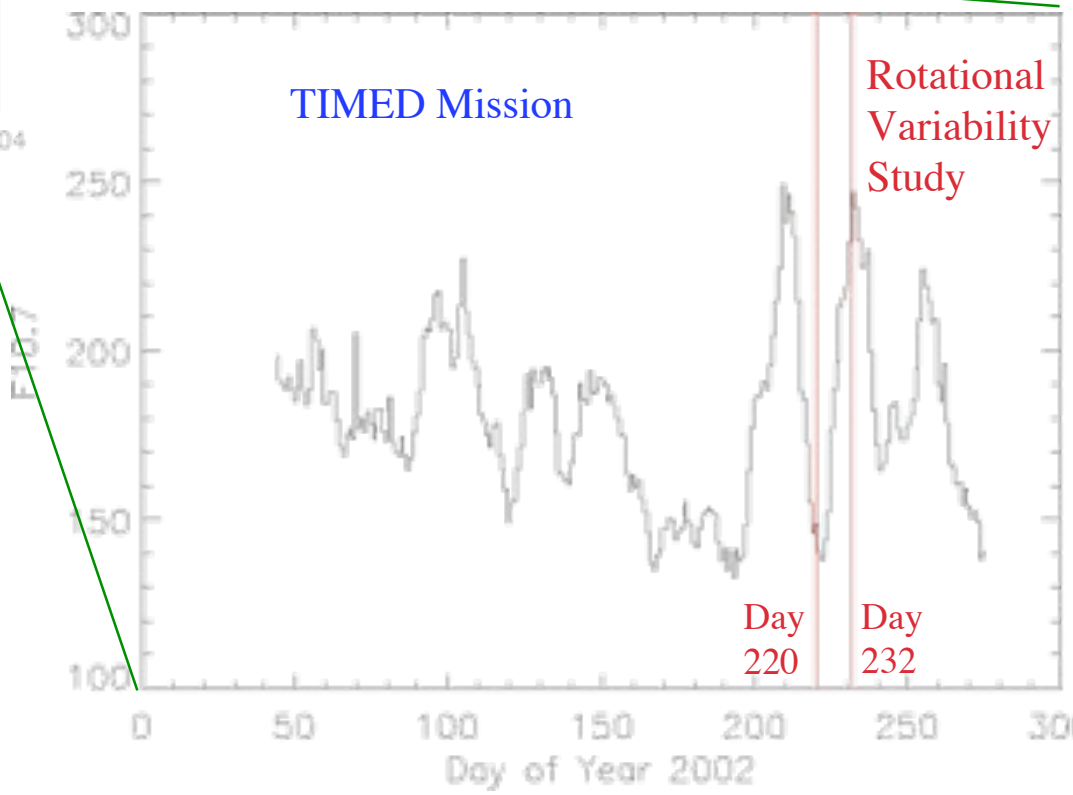
Pre-flare *glow* model result

Flare *glow* model result

New Measurements of the Solar Rotation Variability

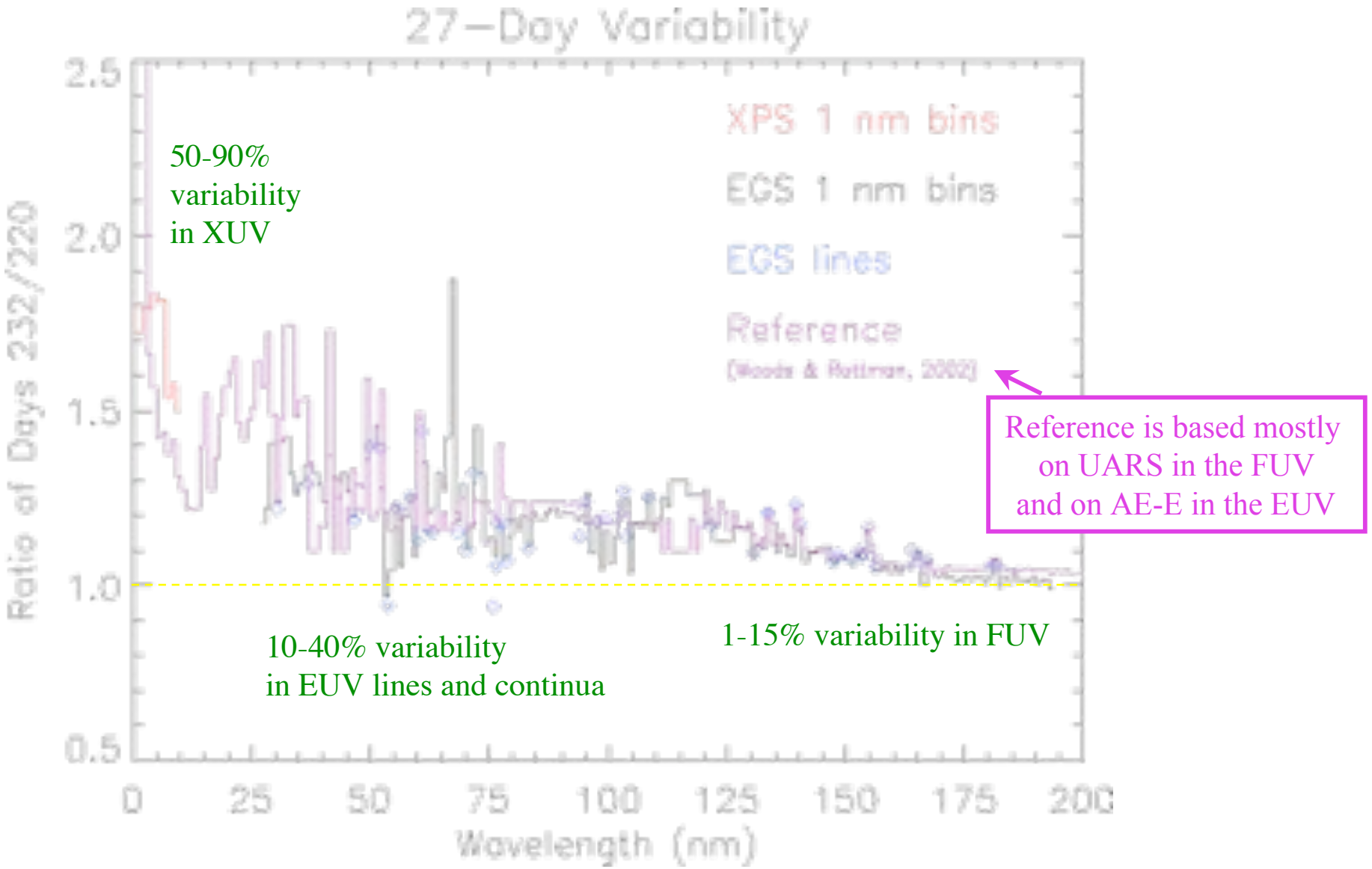


SEE has observed 10 solar rotations so far.



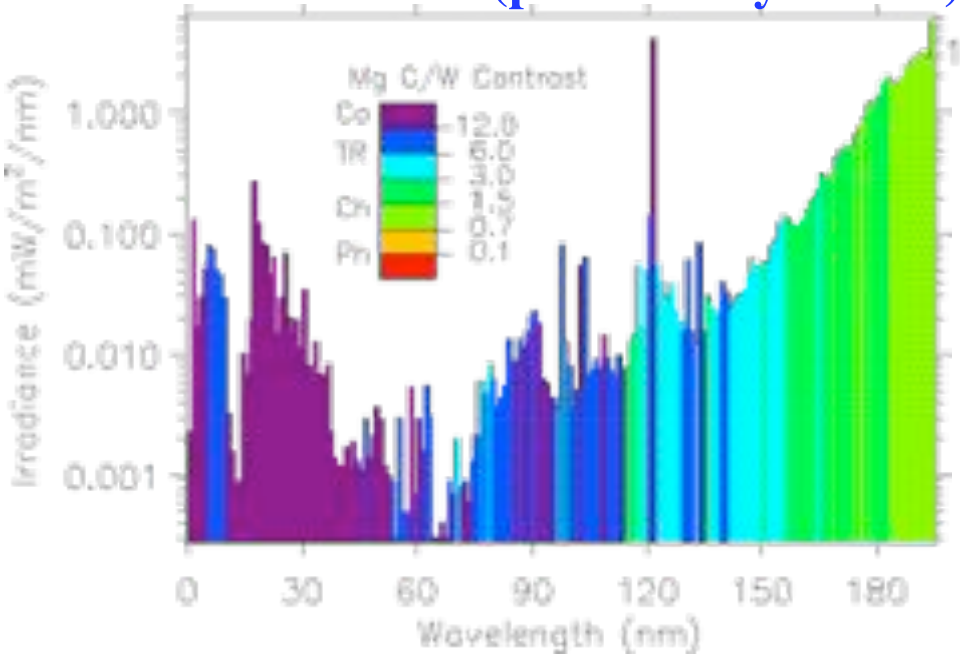
Choose a particularly strong solar rotation for comparison study: Day 220 to Day 232 (Aug. 8 to Aug. 20, 2002)

Example Spectrum of Solar Rotation Variability

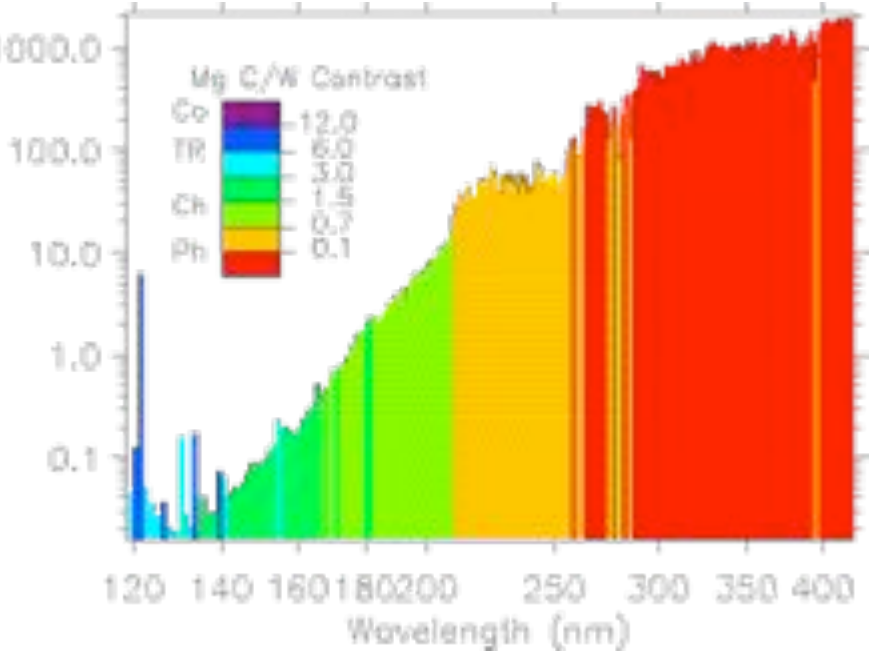


Classification of Solar Emissions

TIMED SEE (preliminary results)



UARS SOLSTICE



- Classify emission type by:
  - Photosphere
  - Chromosphere
  - Transition Region
  - Corona

3-Parameter Model with Mg II C/W Index

$$E = E_{\min}\left(1 + C_S \frac{Mg - Mg_{54}}{Mg_{\min}} + C_L \frac{Mg_{54} - Mg_{\min}}{Mg_{\min}}\right)$$

$E = Irradiance \qquad Mg = MgII\ C/W\ ratio$

$C_S = Contrast\ ratio\ for\ Short-term\ (< 54\ days)$

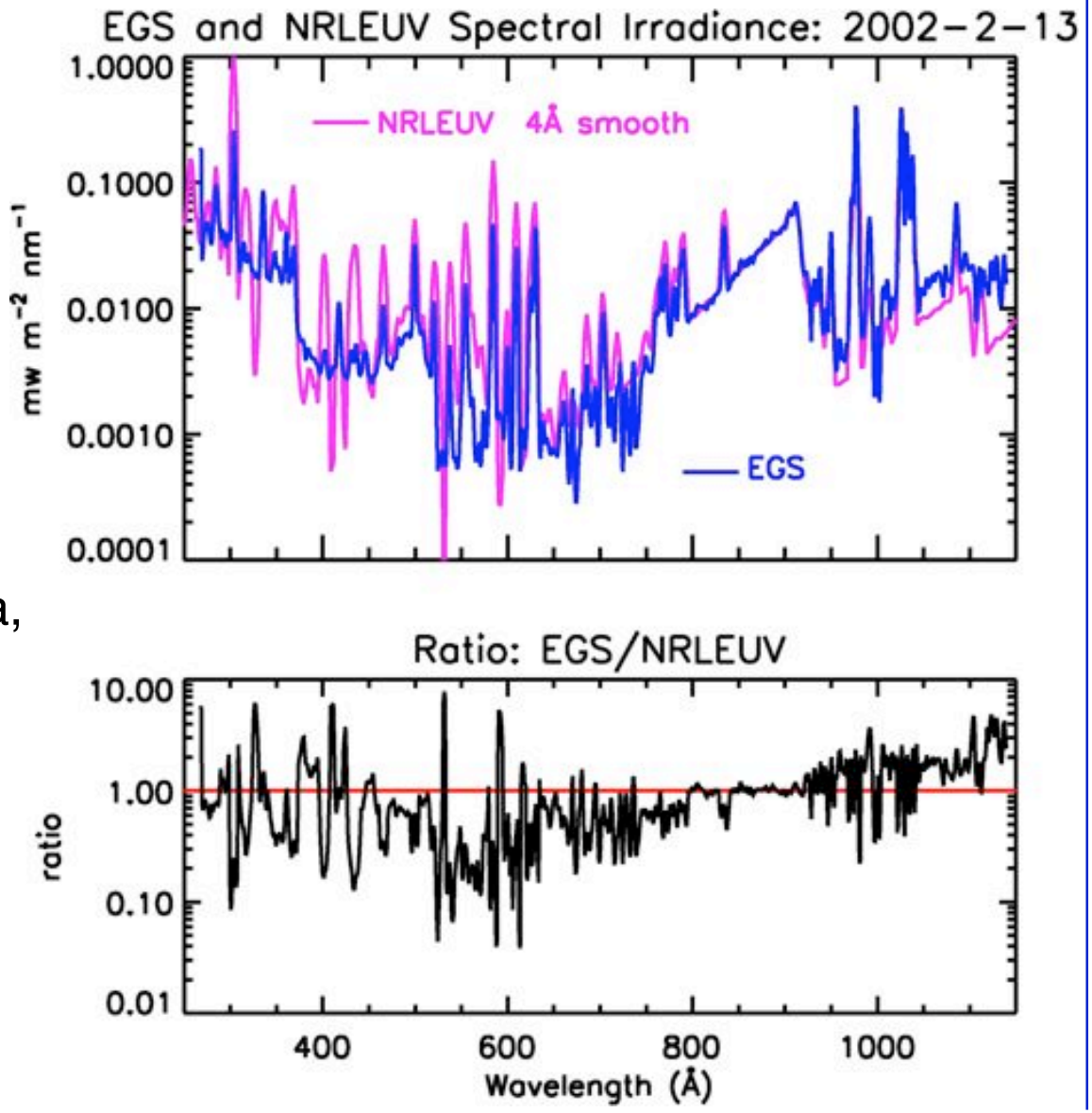
$C_L = Contrast\ ratio\ for\ Long-term\ (> 54\ days)$

$Mg_{54} = Mg\ smoothed\ 54\ days\ (prior\ to\ current\ day)$

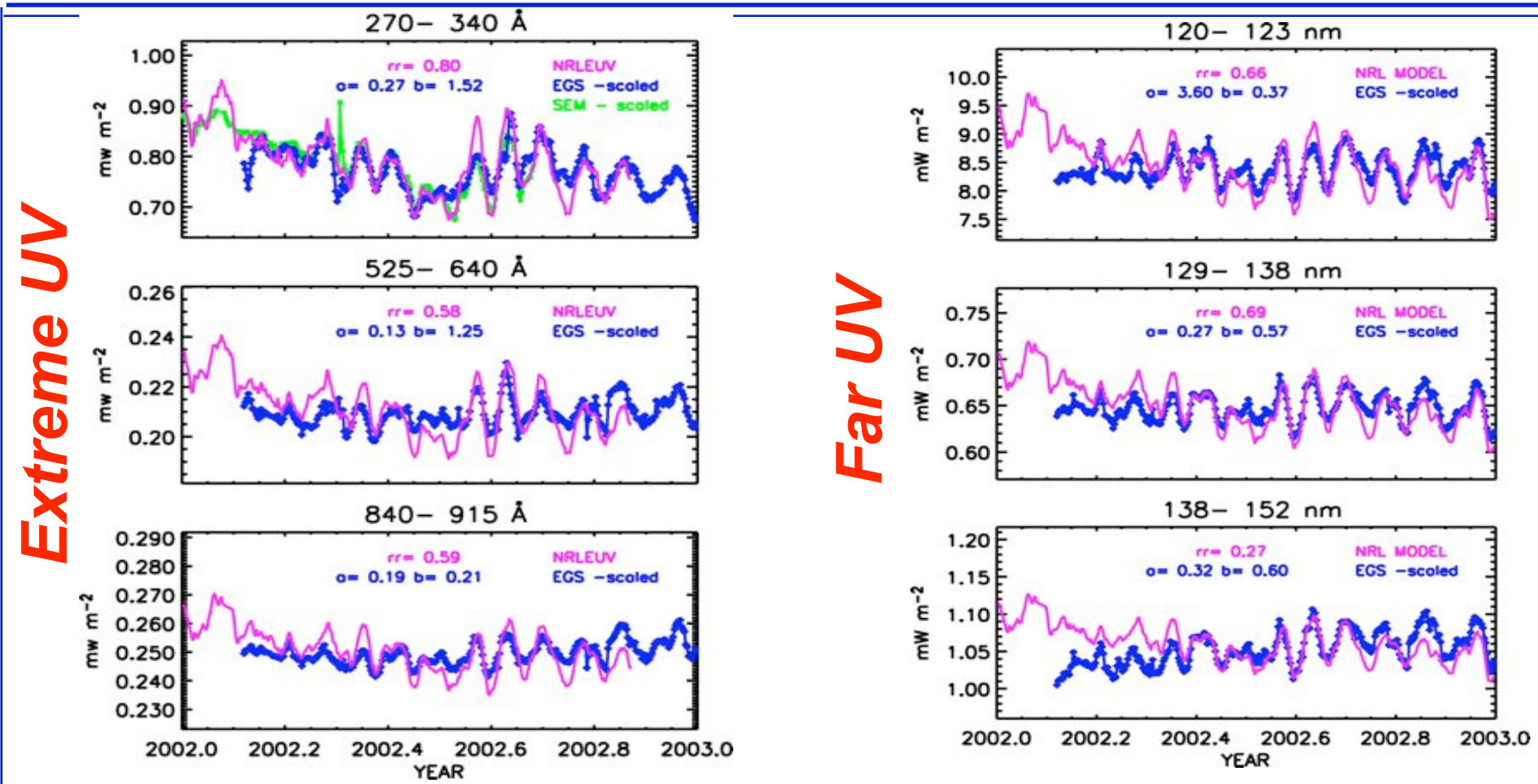
Comparison of SEE to NRLEUV Model

SEE/EGS Version 5 data and NRLEUV model have wavelength dependent differences in absolute values of the irradiance.

Some of these differences are expected to be less in the SEE EGS Version 6 data, which will include the rocket EGS calibration measurement on 2002-2-8. See page 11 for comparison of NRLEUV model to rocket EGS result.



SEE/EGS V5 and NRLEUV Modeled Variability

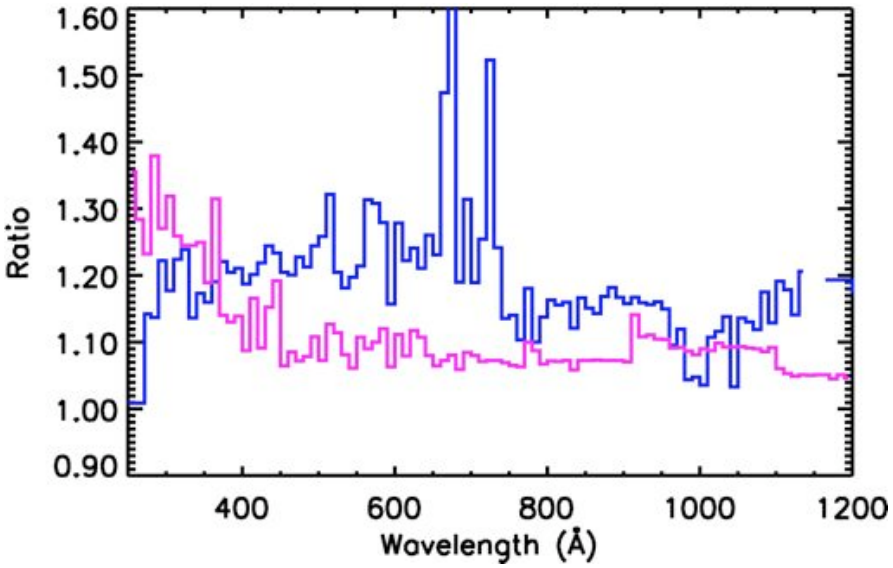


Measurements and models show similar rotational modulation when appropriately scaled
BUT…. wavelength-dependent absolute scale and long-term trend differences exist

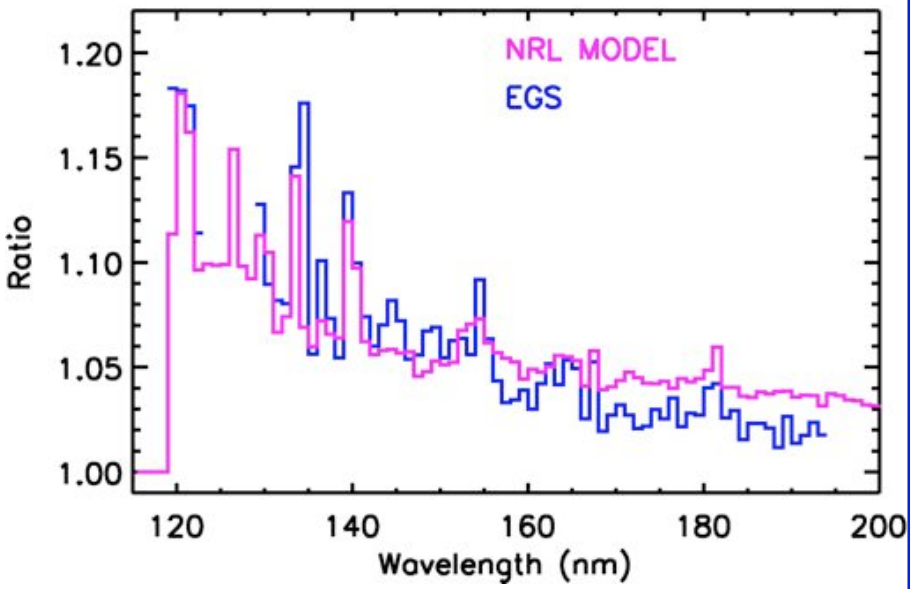
NRLEUV Model: Solar Rotation Variability

Irradiance Modulation: 2002.5-2002.75
Average Max/Min for Three Strong Rotations

Extreme UV

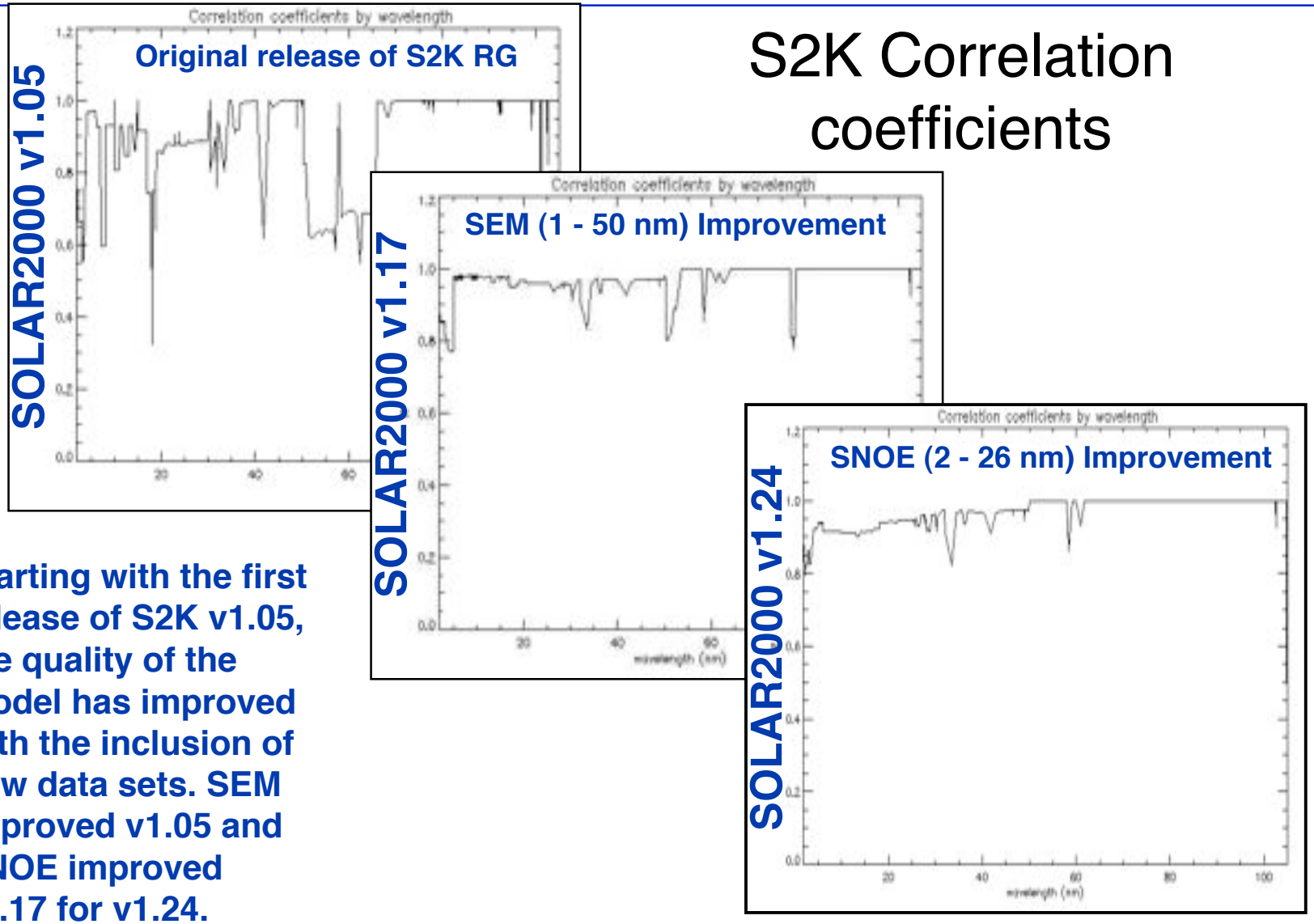


Far UV



SEE/EGS V5 observes
- ***larger mid-EUV rotational modulation than NRLEUV model***
- ***comparable FUV rotational modulation to NRL empirical model (derived from UARS)***

SOLAR2000 (S2K) Model Improvements

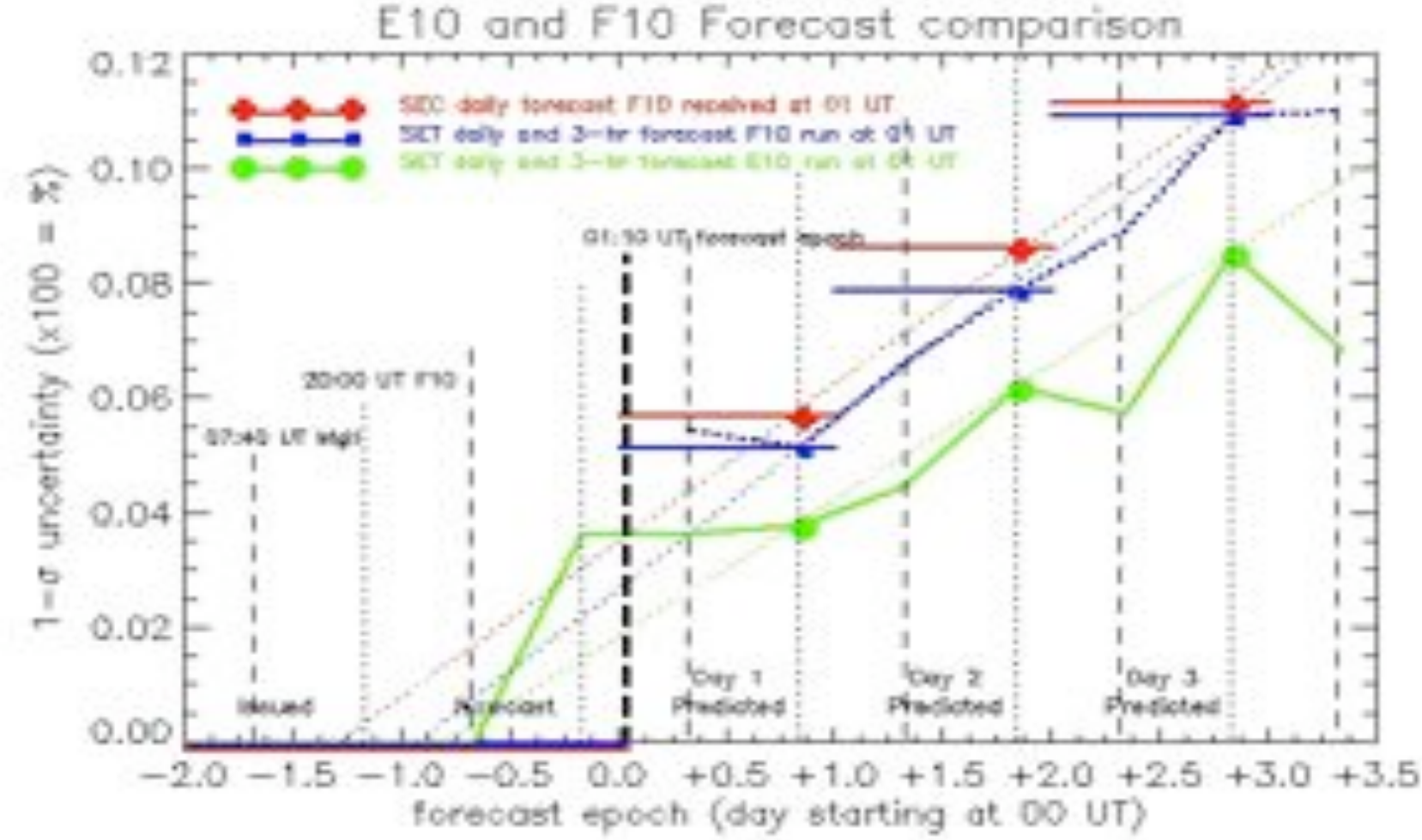


S2K Correlation coefficients

Starting with the first release of S2K v1.05, the quality of the model has improved with the inclusion of new data sets. SEM improved v1.05 and SNOE improved v1.17 for v1.24.

SOLAR2000: Forecast Tools

SET F10.7/E10.7 & SEC F10.7



SOLAR2000: Defining ISO Standard

ISO CD 21348

- **Process for determining solar irradiance**
  - This international standard specifies representations of solar irradiances. It is applicable to measurements, reference spectra, empirical models, and first-principles models.
  - Project Leads: USA and Russia (Tobiska & Nusinov)

ISO

COMMITTEE DRAFT

COMMITTEE DRAFT ISO/CD 21348	
Date: 6 August 2002	Reference number: ISO/TC 20 /SC 14 N 255
Supersedes document	

WARNING: This document is not an International Standard. It is distributed for review and comment. It is subject to change without notice and may not be referred to as an International Standard.

ISO/TC 20/**SC** 14

Title

Aircraft and space vehicles / Space systems and operations

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Circulated to P- and O-members, and to technical committees and organizations in liaison for:

☐ discussion at [venue/date of meeting]

☒ comments by 7 October 2002 [date]

☐ approval for registration as a DIS in accordance with 2.5.6 of part 1 of the ISO/IEC Directives, by

[date]

(P-members vote only: ballot form attached)

P-members of the technical committee or subcommittee concerned have an obligation to vote.

Title (English)

Space environment (natural and artificial) -- Process for determining solar irradiances

Title (French)

Environment spatial (naturel et artificiel) – Procédé de déterminatio de i'irradiance solaire

Reference language version: ☒ English ☐ French ☐ Russian

Introductory note

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SEE Related Talks in 2002

- TIMED Science Meeting: Feb 2002, 3 talks
- AGU Spring Meeting: May 2002, 4 talks
- SORCE Science Meeting: July 2002, 1 talk
- April Storm Workshop: Aug 2002, 1 talk
- COSPAR Meeting: Oct 2002, 1 talk
- NOAA Solar EUV Workshop: Oct 2002, 1 talk
- AGU Fall Meeting: Dec 2002, 4 talks
- Public Seminars: LASP/CU, NOAA, NCAR, Michigan Tech. Univ.

SEE Related Papers in 2002

- Woods, T. N., S. M. Bailey, W. K. Peterson, H. P. Warren, S. C. Solomon, F. G. Eparvier, H. Garcia, C. W. Carlson, and J. P. McFadden, Solar extreme ultraviolet variability of the X-class flare on April 21, 2002 and the terrestrial photoelectron response, GRL, submitted, 2002.
- Eparvier, F. G., T. N. Woods, D.L. Woodraska, S.M. Bailey, and S.C. Solomon, Spectral irradiance measurements from the TIMED Solar EUV Experiment, *Advances in Space Research*, submitted, 2002.
- Woods, T. N., F. G. Eparvier, S. C. Solomon, D. L. Woodraska, and S. M. Bailey, Early results from the TIMED Solar EUV Experiment, *Proceedings of* 4th *TIGER Symposium*, virtual journal at http://www.ipm.fraunhofer.de/english/meetings/workshops/tiger/, June 2002.
- Tobiska, W.K., New developments in solar irradiance proxies for operational space weather, *Proceedings of* 4th *TIGER Symposium*, virtual journal at http://www.ipm.fraunhofer.de/english/meetings/workshops/tiger/, June 2002.
- Woods, T., L. W. Acton, S. Bailey, F. Eparvier, H. Garcia, D. Judge, J. Lean, D. McMullin, G. Schmidtke, S. C. Solomon, W. K. Tobiska, and H. P. Warren, Solar extreme ultraviolet and x-ray irradiance variations, in *Solar Variability and Its Effect on Earth's Atmospheric and Climate System,* eds. J. Pap, C. Fröhlich, H. Hudson, J. Kuhn, J. McCormack, G. North, W. Sprig, and S. T. Wu, Geophys. Monograph Series, Wash. DC, in press, 2002.
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- Woods, T. and G. Rottman, Future solar irradiance observations from the NASA TIMED and SORCE satellites, in *Radiometric Inter-calibration of SOHO*, eds.M. C. E. Huber, A. Pauluhn, and R. von Steiger, Bern, Switz., 2002.
- McMullin, D., T. Woods, I. E. Dammasch, D. Judge, P. Lemaire, J. S. Newmark, W. Thompson, W. K. Tobiska, and K. Wilhelm, Irradiance working group report for the SOHO intercalibration workshop, in *Radiometric Inter-calibration of SOHO*, eds.M. C. E. Huber, A. Pauluhn, and R. von Steiger, Bern, Switz., 2002.
- Woods, T. N. and G. J. Rottman, Solar ultraviolet variability over time periods of aeronomic interest, in *Comparative Aeronomy in the Solar System,* eds. M. Mendillo, A. Nagy, and J. Hunter Waite, Jr., Geophys. Monograph Series, Wash. DC, pp. 221-234, 2002.
- Tobiska, W.K., Forecast E10.7 for improved LEO satellite operations, *J. Spacecraft Rock.,* in press, 2002.
- Tobiska, W.K., TSI variability from irradiances shortward of Lyman-α, *Adv. Space Research,* **29**, 1969, 2002.

SEE Plans for 2003

- Daily mission operations and data processing for SEE
- Additional validations
  - Validated SEE Version 6 data should be available in early 2003
  - Underflight calibration from NASA rocket 36.205 in June 2003
- Detailed solar variability studies
  - More complete analysis of the 11+ solar rotation and 30+ flare observations
  - Improve models of the solar UV irradiance
- Detailed modeling of Earth's response to solar irradiance changes
  - Composition, dynamics, temperature using TIME-GCM
  - Photoelectrons using *glow* model
- Occultation data analysis