TIMED Solar EUV Experiment: Phase E Annual Report for 2005

Submitted for NASA Grant NAG5-11408
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SEE Science Team

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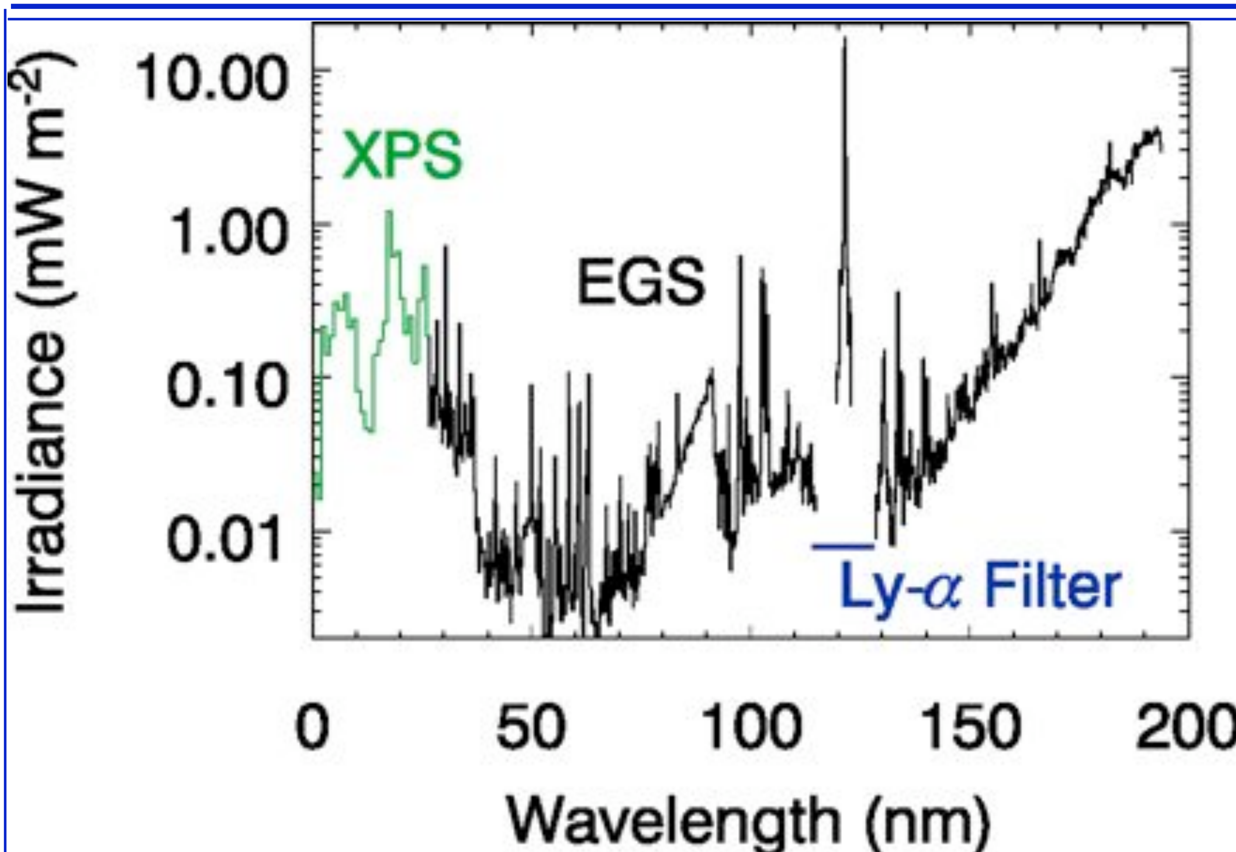
Report Outline

- SEE Instrument Operations and Instrument Status
- SEE Data Products
- SEE Science Overview
- Summary of SEE Results
  - Solar variability, atmospheric modeling, and solar irradiance modeling
- Summary of SEE Related Talks and Papers
- Summary of SEE Solar Observations
- Future Plans for SEE Team

Overview of Operations and Data Processing

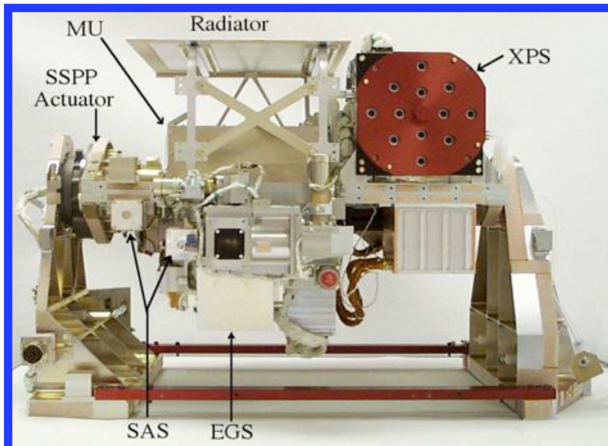
SEE Measures the Solar VUV Irradiance



XUV	EUV	FUV

EGS 27-194 nm with Δλ=0.4 nm

XPS 0.1-34 nm with Δλ=7-10 nm
and Ly-α (121.6 nm) with Δλ=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 November 14, 2005)
  - Number of normal solar experiments = 19,637
- Actual Experiments (through November 14, 2005)
  - Number of normal solar experiments = 19,353 (98.6%)
- Special SEE Operations in 2005
  - None
- SEE calibration rockets have been successful
  - 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
  - Next calibration flight is planned for October 2006

List of SEE Data 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)

Status of SEE Instruments

No recent changes for SEE

- **EUV Grating Spectrograph (EGS) - fully functional**
  - The EUV ($\lambda < 115$ 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 recovery that is corrected using UARS and XPS comparisons, but it is not fully understood at the longer wavelengths
    - need more UARS/SORCE data and next SEE rocket calibration (Aug 12, 2003)
- **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
  - SORCE, with almost identical XPS, launched on Jan. 25, 2003
    - SORCE XPS data are incorporated into SEE version 7 (and later) Level 3 data products in the 0.1-27 nm range
- **Microprocessor Unit (MU) - fully functional**
- **SEE Solar Pointing Platform (SSPP) - fully functional**

SEE Version 8 Data Products

- SEE Version 8 data products - released June 2005
  - SEE Level 2, 2A, 3, and 3A data products are available on public FTP site and are updated daily
  - EGS improvements
    - Improved flat-field corrections, wavelength scale algorithm, and field of view correction
    - Incorporate first three rocket calibration results
  - XPS improvements
    - Incorporate first three rocket calibration results
    - Improved solar irradiance model for the Level 3 and 3A data products using SORCE XPS data
  - New SEE space weather data product - Level 2A SpWx
    - Producing observation averaged solar UV irradiances for select wavelengths that are useful proxies for space weather operations used by NOAA Space Environment Center (SEC)
      - XPS: 0.1-7 nm
      - EGS: He II 30.4 nm, Fe XVI 33.5 nm, Mg IX 36.8 nm, H I 121.6 nm, C II 133.5 nm
      - EGS broadbands: 27-34 nm, 145-165 nm

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

Improved web site released July 2005

Future Plans for SEE Data Products

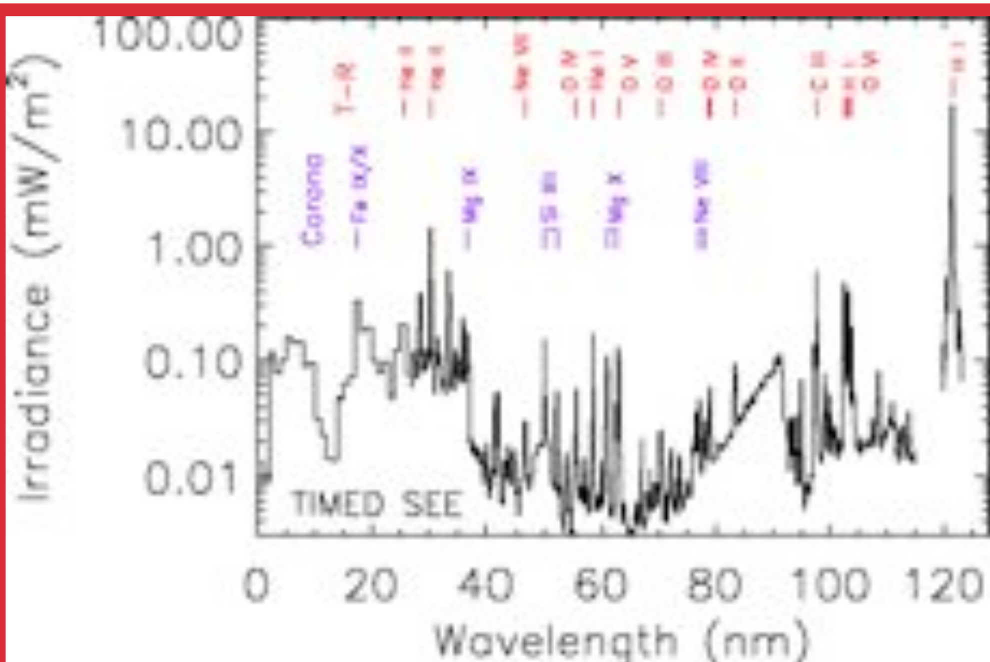
- Plans for SEE Version 9 data products - release to be in late 2005 or early 2006
  - EGS revisions
    - Improved flagging of data affected by energetic particles (in polar regions)
  - XPS revisions
    - None
  - **New SEE occultation data product**
    - Produce atmospheric transmission / density from EGS occultation measurements (100-500 km range)
      - New product will be called EGS L2occ

- **LASP Interactive Solar IRradiance Datacenter (LISIRD)**
  - New (preliminary) 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/

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

Solomon, Roble,
Bailey, Eparvier

Study Earth's Response

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

Obj. #3

Obj. #5

Lean, Tobiska,
Chamberlin, Woods

Modeling Solar Variation

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

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

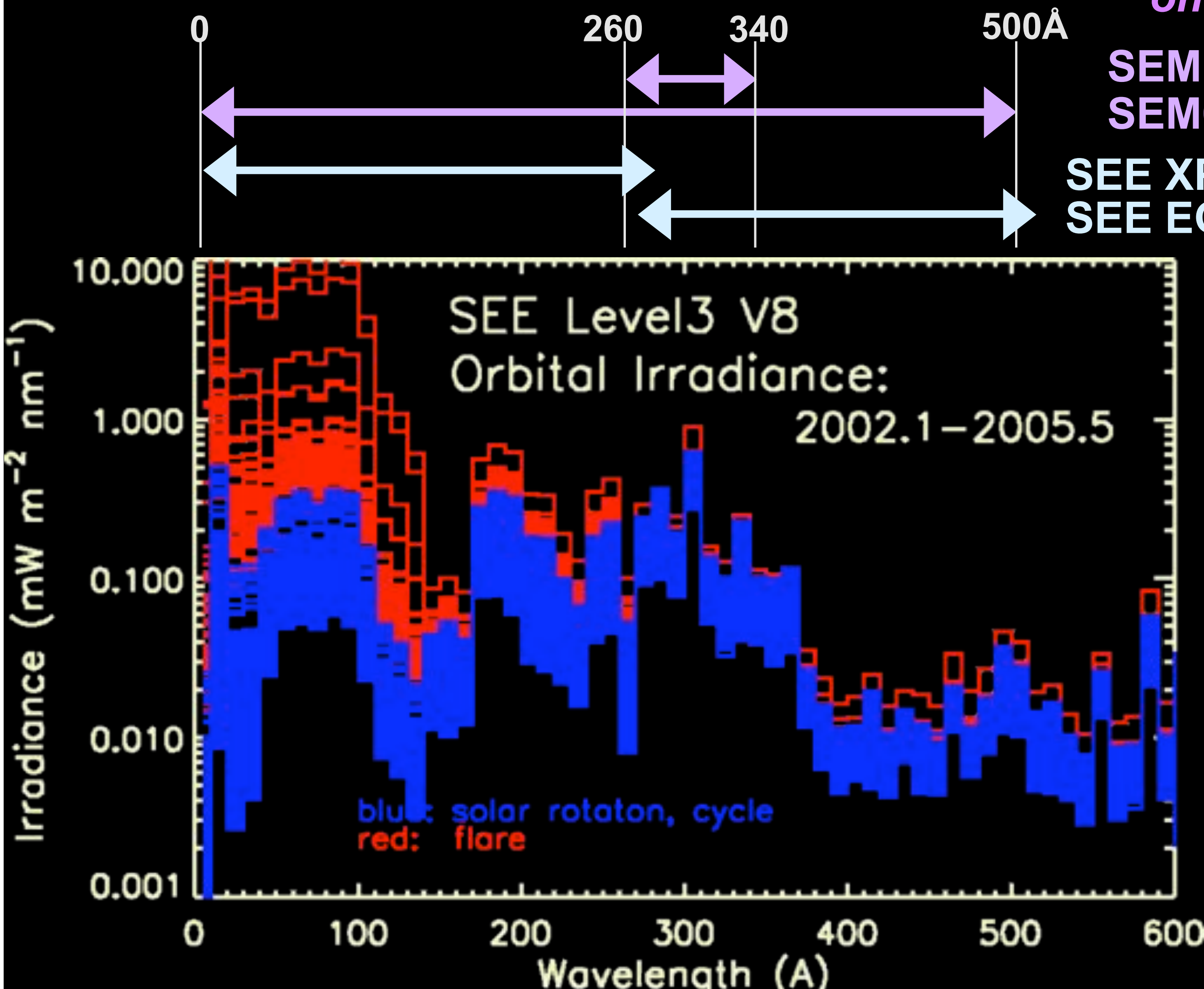
Summary of SEE Results

- **Objective 1: solar VUV spectral irradiance measurements**
  - Daily measurements since Jan. 22, 2002 with very few gaps
  - Validation effort verifies 10-20% accuracy and 2-4% precision for SEE results
- **Objective 2: solar variability**
  - New results on solar rotation and solar cycle variations
  - New results on flare variability as SEE has observed 400 flares
- **Objective 3: model solar response in Earth's atmosphere**
  - Use of *glow* model with SEE solar data and photoelectron data (FAST, GUVI)
  - Use of HAO TIME-GCM for atmospheric response to SEE's solar input
  - Definition of wavelength binning of solar irradiance to improve atmospheric modeling
  - Comparison of GUVI Q_{EUV} and SEE solar irradiance measurements
- **Objective 4: solar irradiance modeling**
  - SOLAR2000 model improvements
  - NRLEUV model improvements
  - New Flare Irradiance Spectral Model (FISM) developed at LASP
  - New flare modeling at UAF
- **Objective 5: atmospheric density from solar occultations**
  - SEE version 9 data products will include results from solar occultations

Validations

SEE and SOHO SEM Comparison
SEE and GOES XRS Comparison

SEE & SOHO-SEM Spectral Ranges



SEM: Solar EUV Monitor on SOHO (D. Judge, PI)

SEM1 first order
SEM0 zero order

SEE XPS broad band diodes
SEE EGS spectrometer

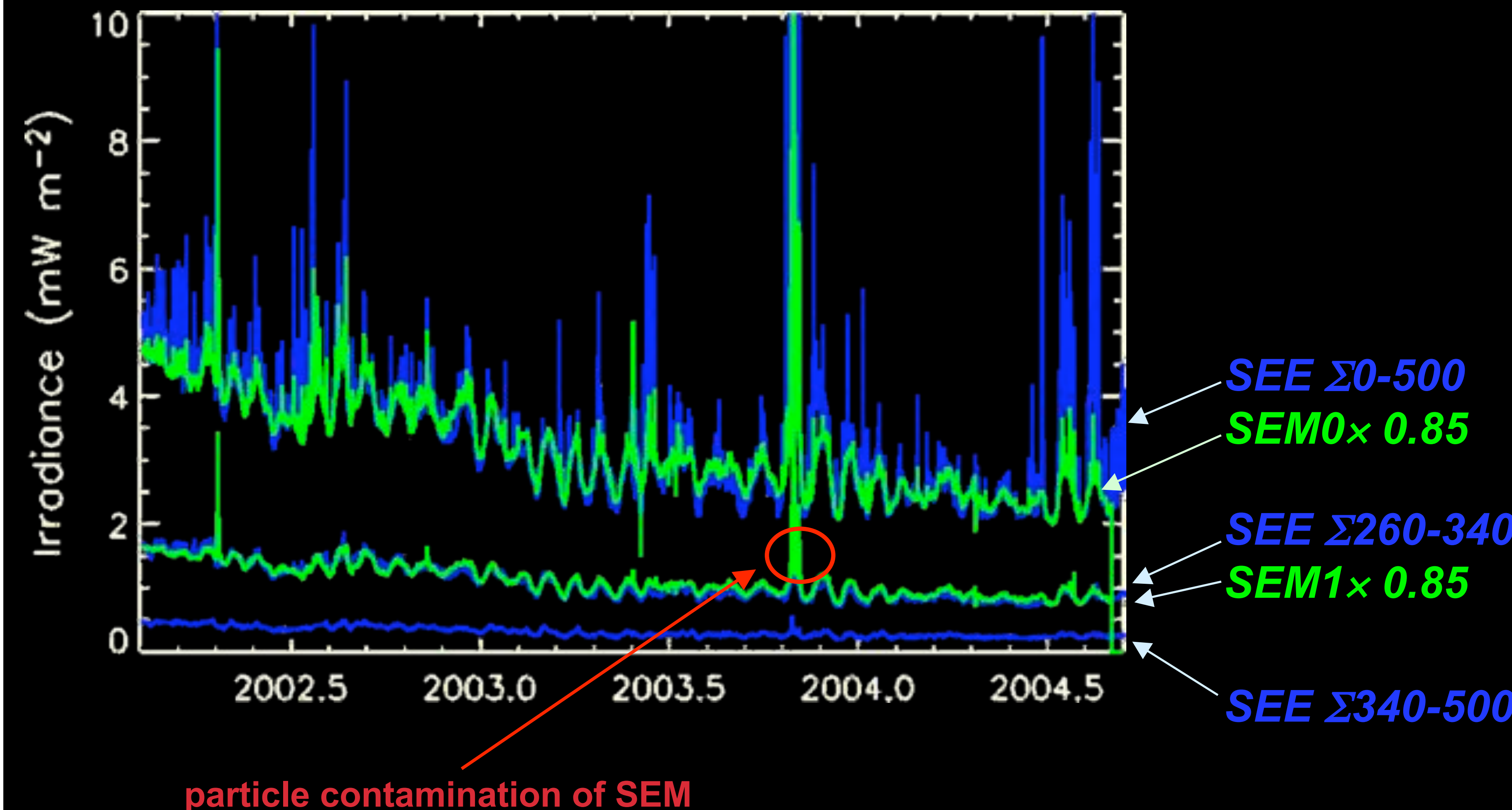
APPROACH:

- *scale SEM0 to SEE Σ 0-500*
- *scale SEM1 to SEE Σ 260-340*
- *SEMshort= SEM0-SEM1- SEE Σ 340-500*
- *Compare SEMshort and SEE Σ 0-260*

[Slide from J. Lean]

SEE and SEM Comparison - Solar Cycle

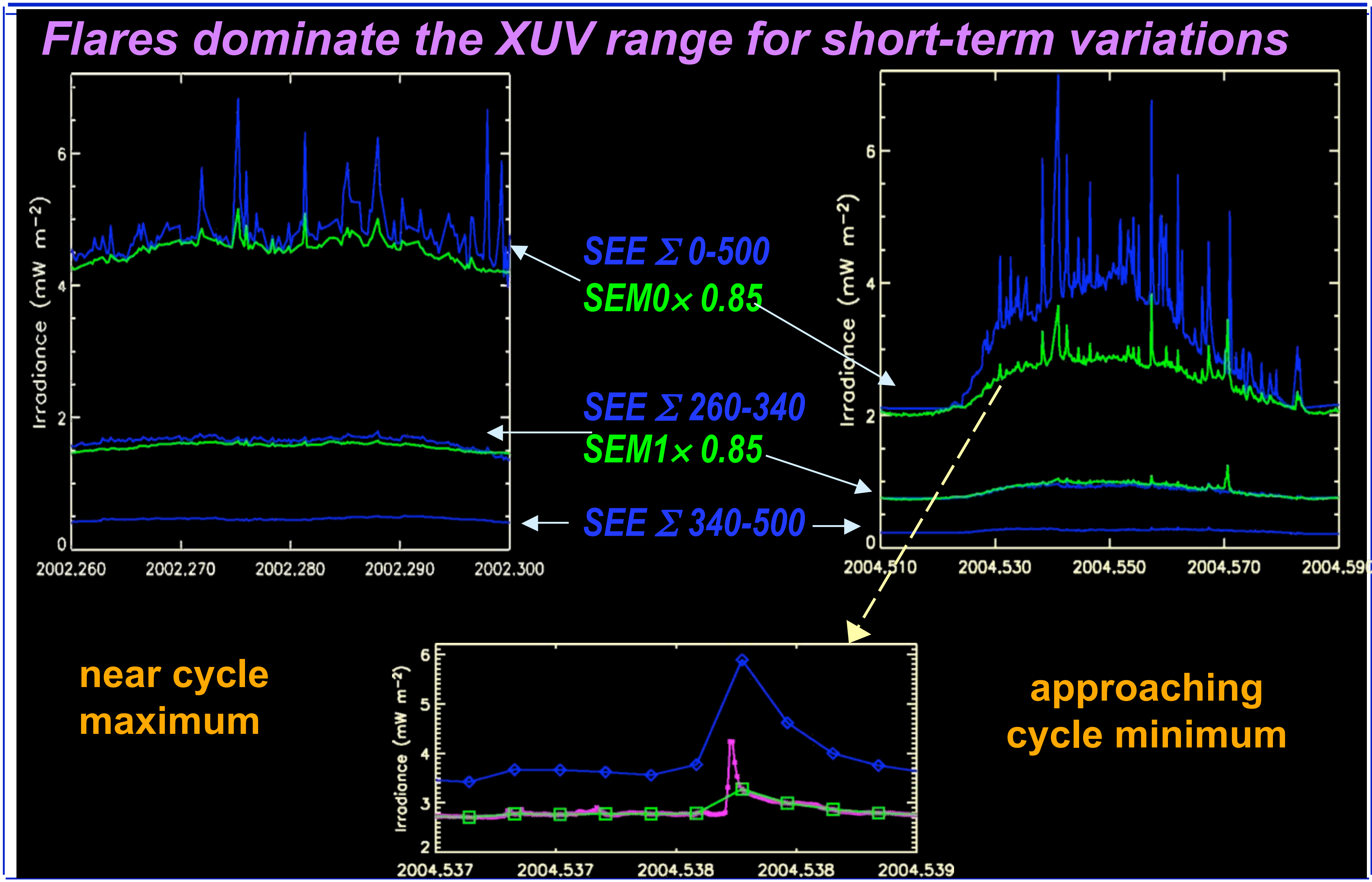
SEM irradiance values are ~15% higher than SEE values



SEM 5-min average observations are interpolated onto SEE time grid

[Slide from J. Lean]

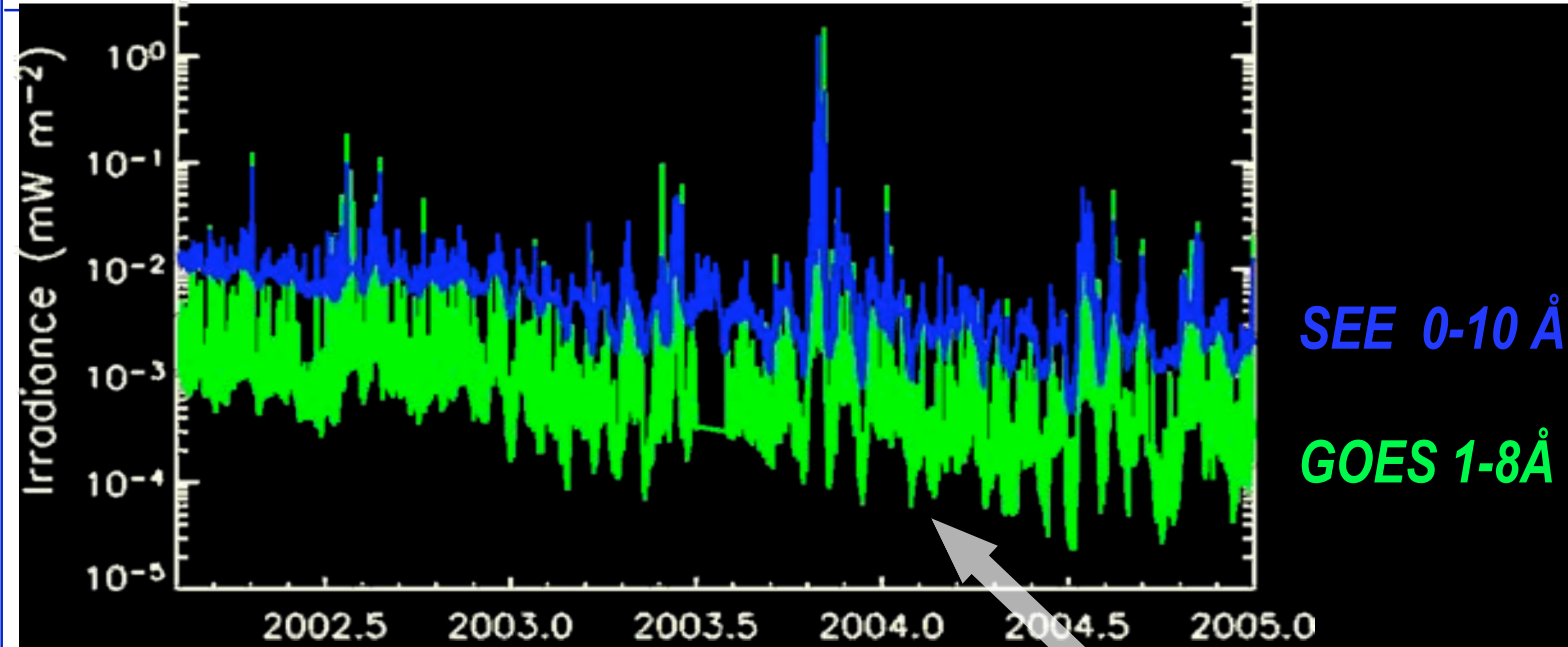
SEE and SEM Comparison - Solar Rotation

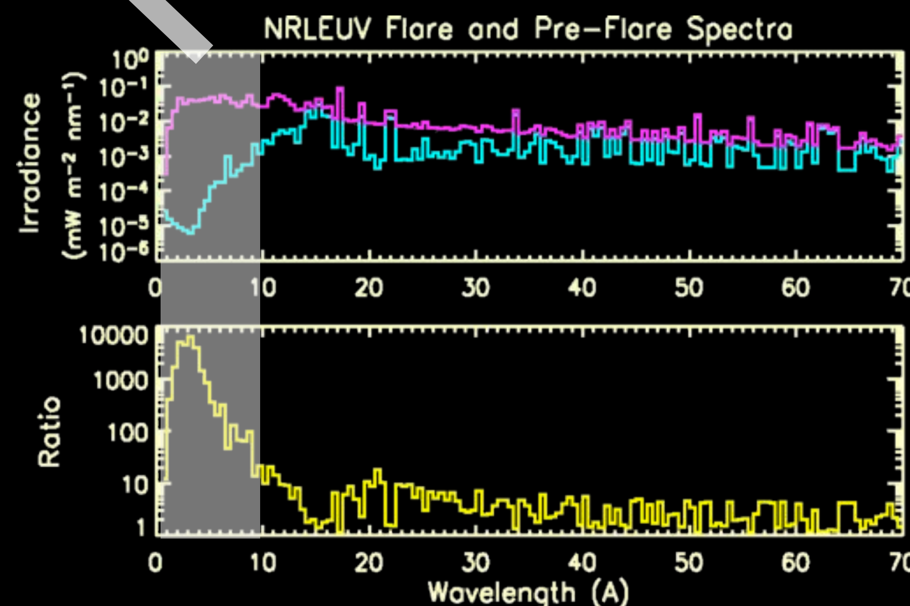


TIMED SEE

[Slide from J. Lean]

SEE and GOES X-Ray Comparison





NRLEUV: (H. Warren)

	pre-flare	flare	
0-10Å	0.0068	0.66	mW m^{-2}
1-8 Å	0.0023	0.52	
SEE/ GOES	3	1.29	

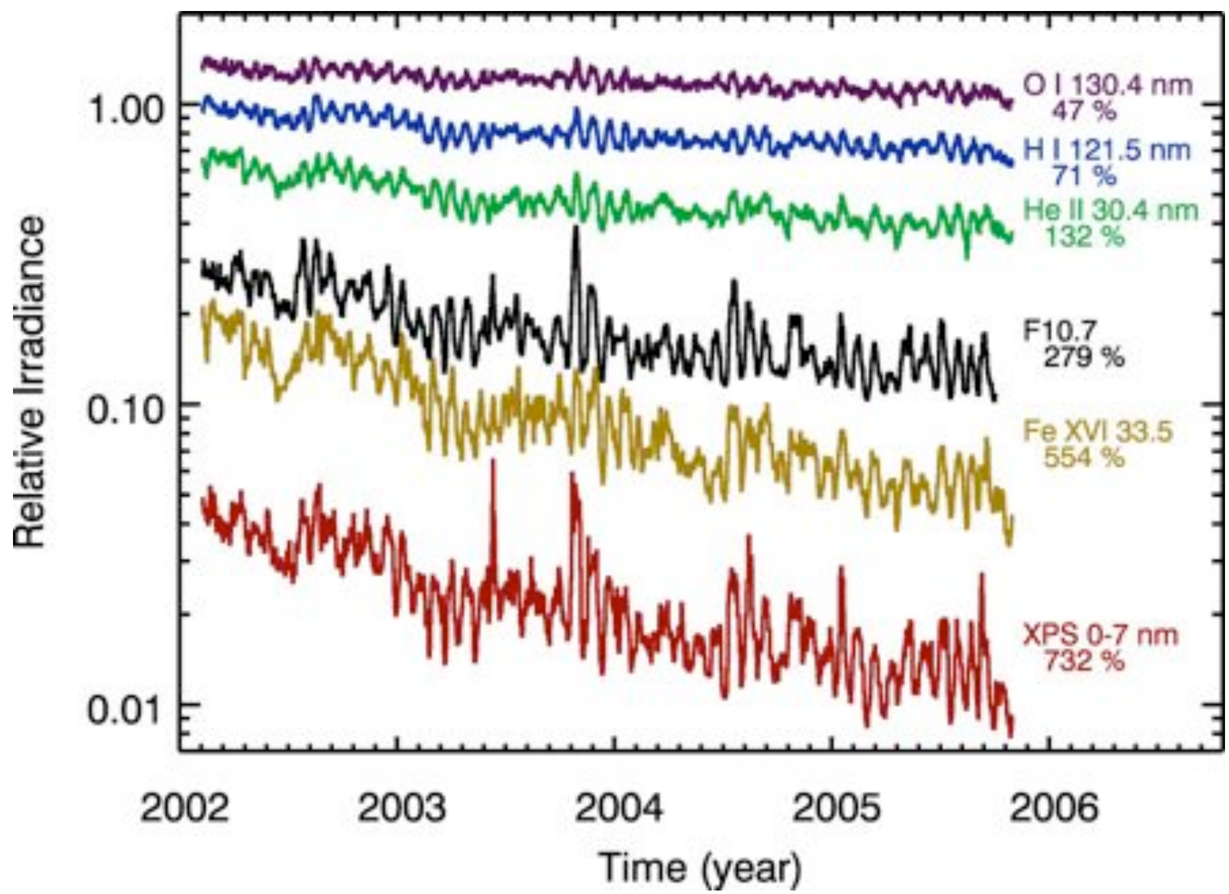
[Slide from J. Lean]

Solar Variability Results

Variability Overview
Solar Cycle Variability
Solar Rotation Variability
Solar Flares

SEE is Providing New, Accurate Solar EUV Irradiances

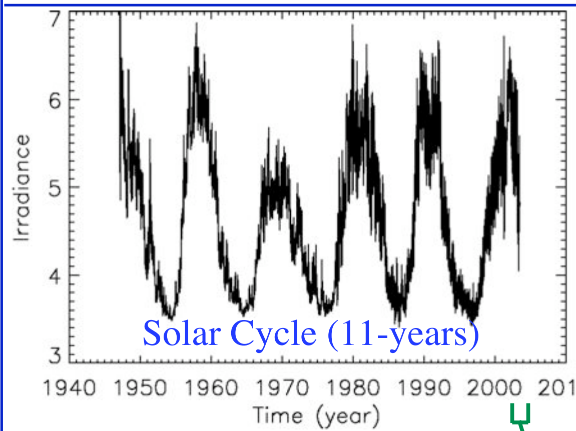
- SEE measures the solar irradiance from 0.1 to 194 nm
  - Daily measurements since Jan. 22, 2002
- Annual rocket underflight calibrations enable long-term accuracy for the SEE measurements



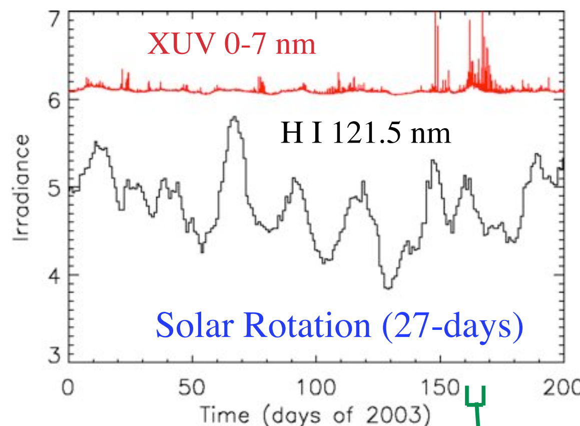
Chromosphere

Corona

Examples of Solar Variations from SEE

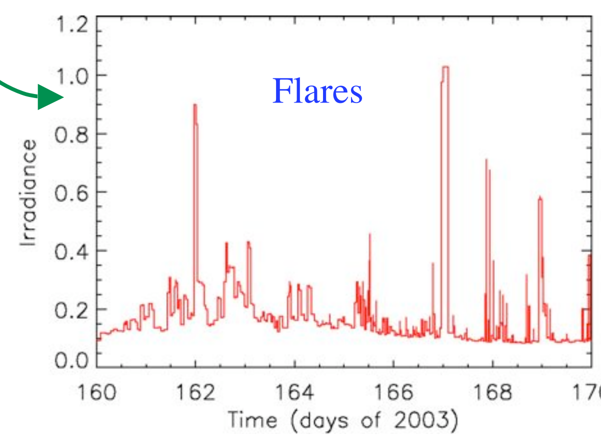


- **Solar Cycle - months to years**
  - Evolution of solar dynamo with 22-year magnetic cycle, 11-year intensity (sunspot) cycle
  - Long-term H I Lyman-α time series has been extended with TIMED SEE measurements



SEE is providing new information on solar VUV variability

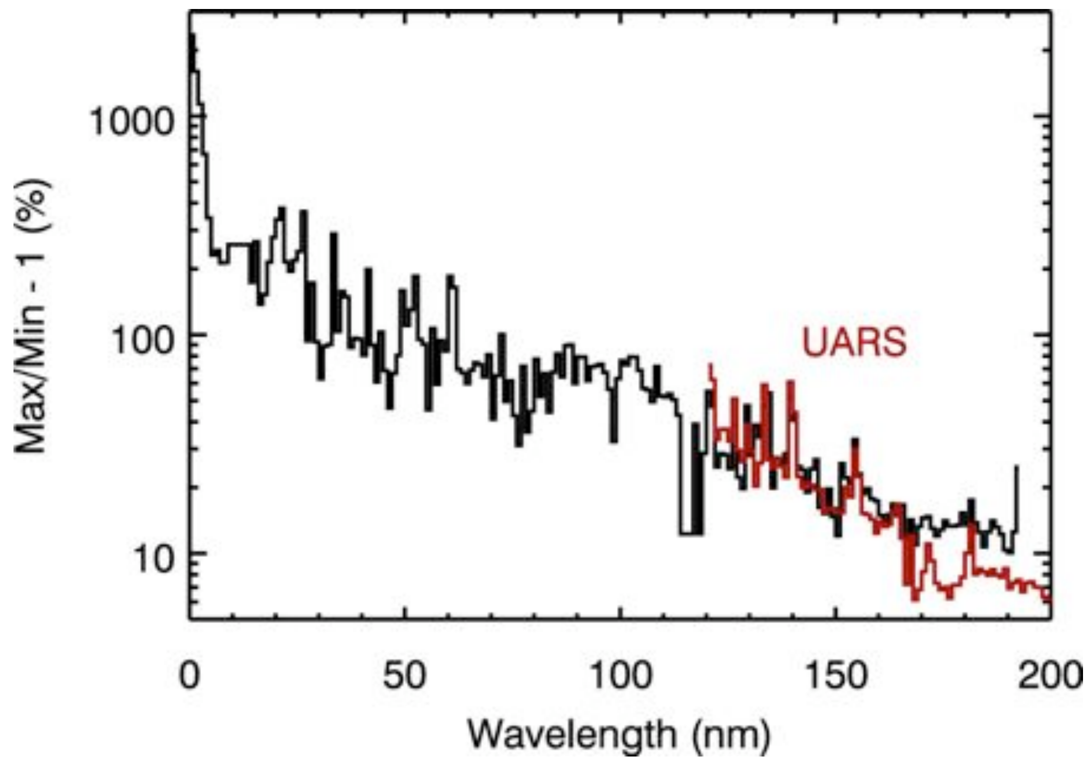
- **Solar Rotation - days to months**
  - Beacon effect of active regions rotating with the Sun (27-days)



- **Flares - seconds to hours**
  - Related to solar storms (such as CMEs) due to the interaction of magnetic fields on Sun

New Results for Solar Cycle Variability

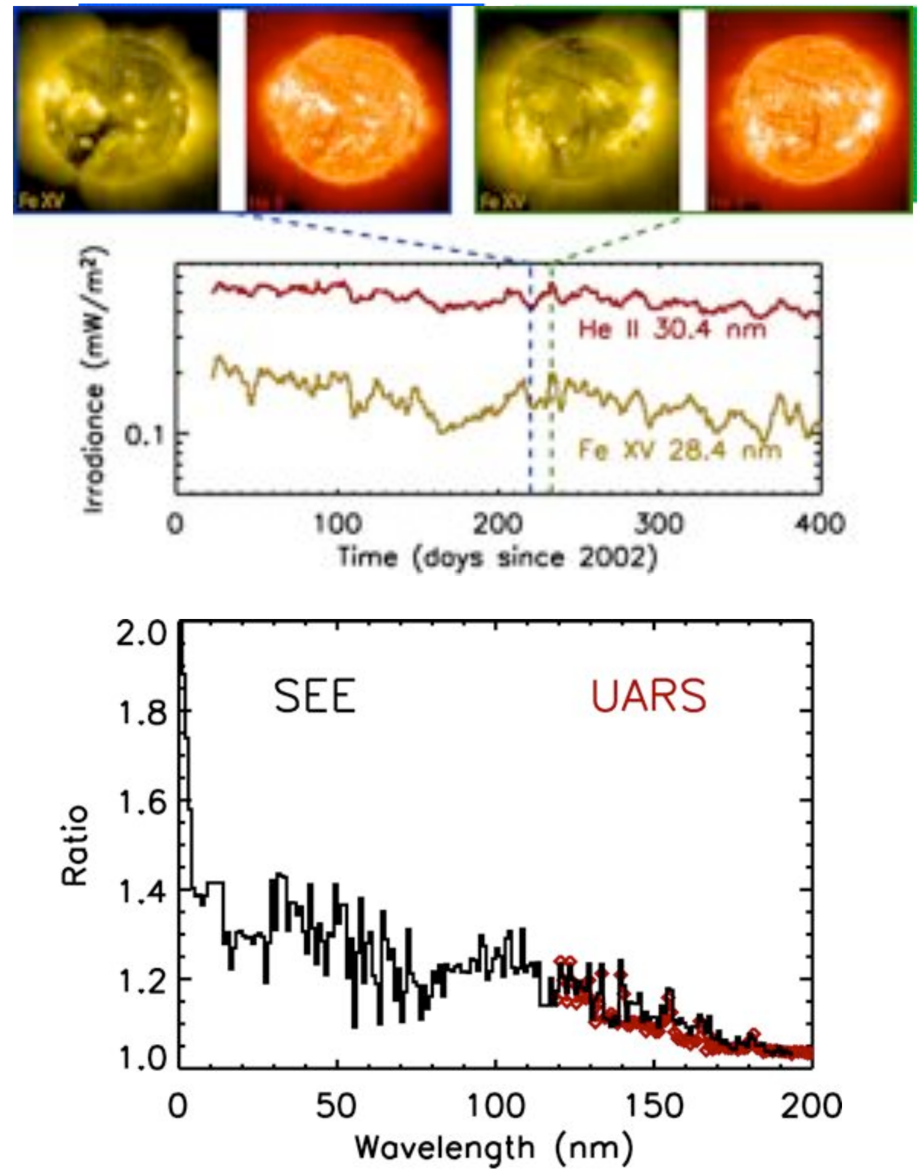
- TIMED mission started with solar cycle maximum conditions
- Recent measurements are during low solar activity, but solar cycle minimum is not expected until late 2006 or 2007
- Ratio of solar irradiance in Aug 2002 to Oct 2005 provides reasonable indication of solar cycle variation
    - Note that this variation could also be related to instrument degradation as last SEE rocket calibration was Oct. 2004



UARS = UARS SOLSTICE solar cycle results [Woods and Rottman, 2002]

New Results for Solar Rotation Variability

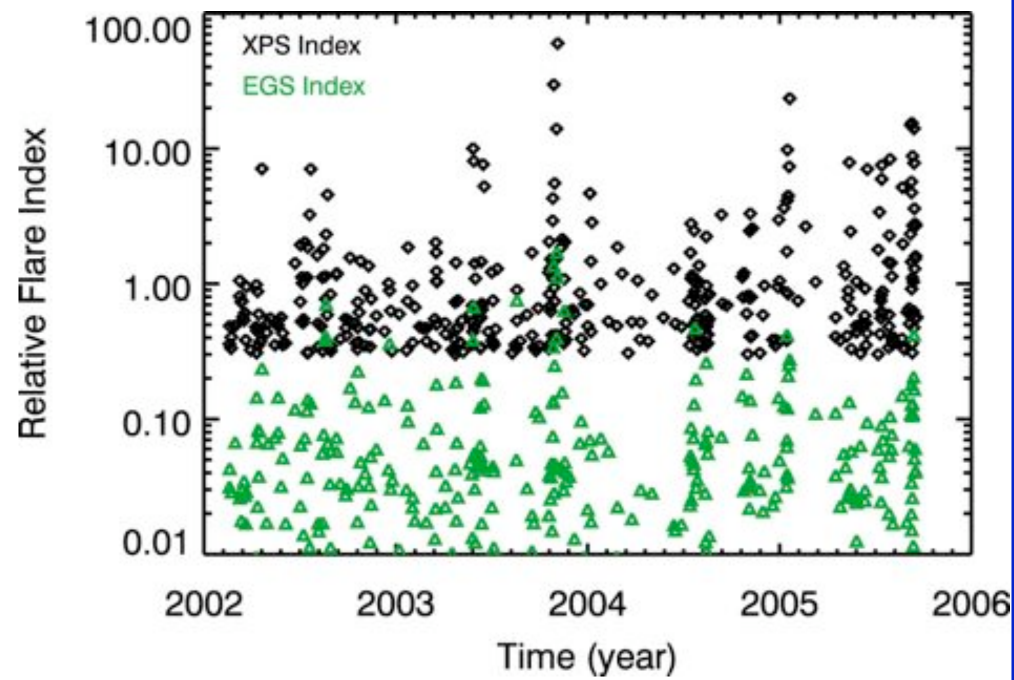
- One of the larger solar rotation variations during the TIMED mission is during August 2002
- The SEE solar rotation variations, shown for August 2002, are new results for the EUV range and are consistent with the UARS measurements in the FUV



Several Solar Storms During the TIMED Mission

- 7 Interesting Solar Storm Periods with Many Large Flares
  - April 2002
    - Woods *et al.*, *Space Weather*, 2003
  - July 2002
  - June 2003
  - October-November 2003
    - Woods *et al.*, *GRL*, 2004
  - July 2004
  - January 2005
  - September 2005
- SEE has observed 400 flares
  - Woods *et al.*, *JGR*, 2005

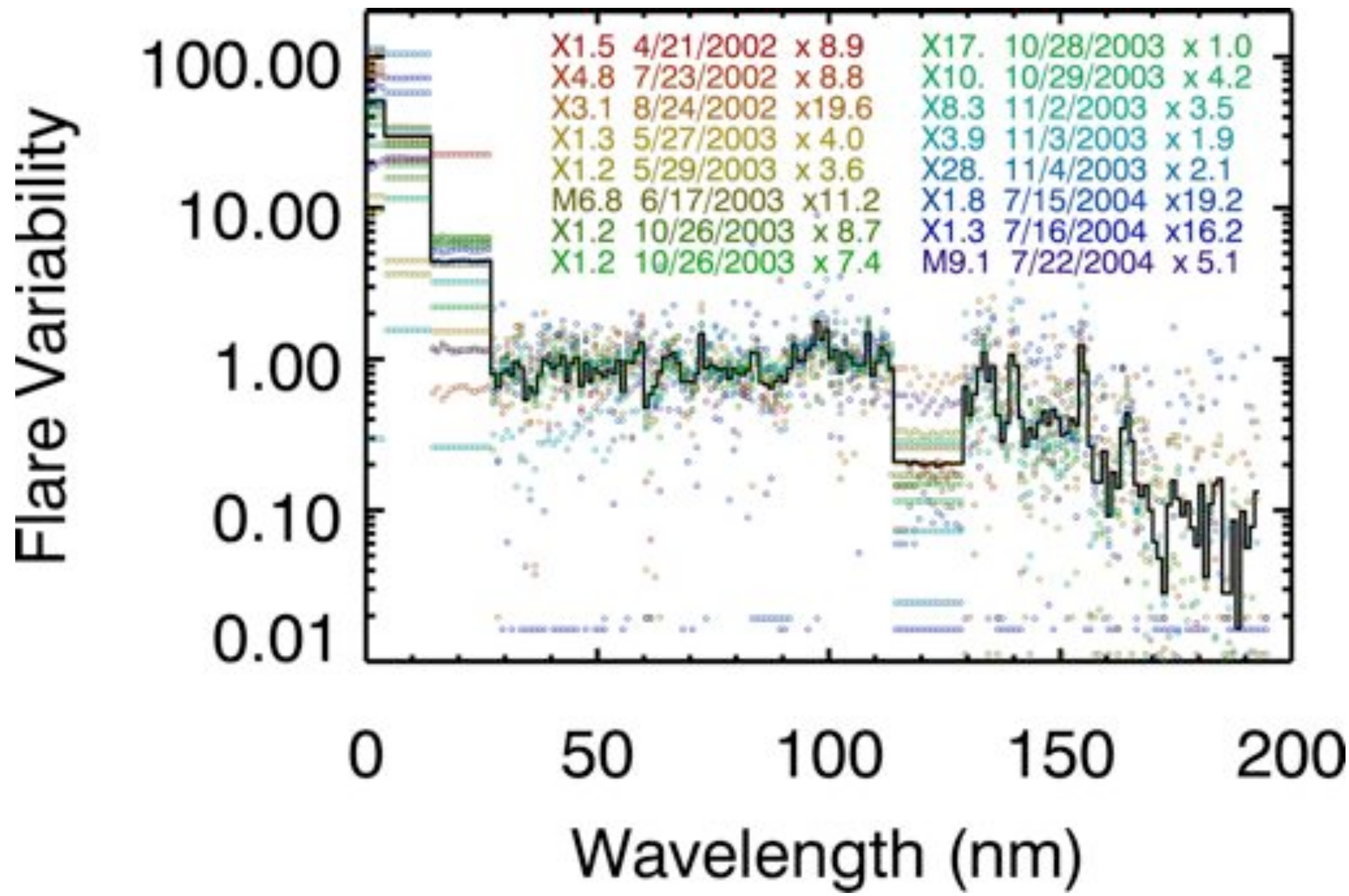
400 Flares Detected in SEE Time Series



Relative Flare Index = flare irradiance (near peak) divided by pre-flare irradiance

New Results for Solar Flare Variability

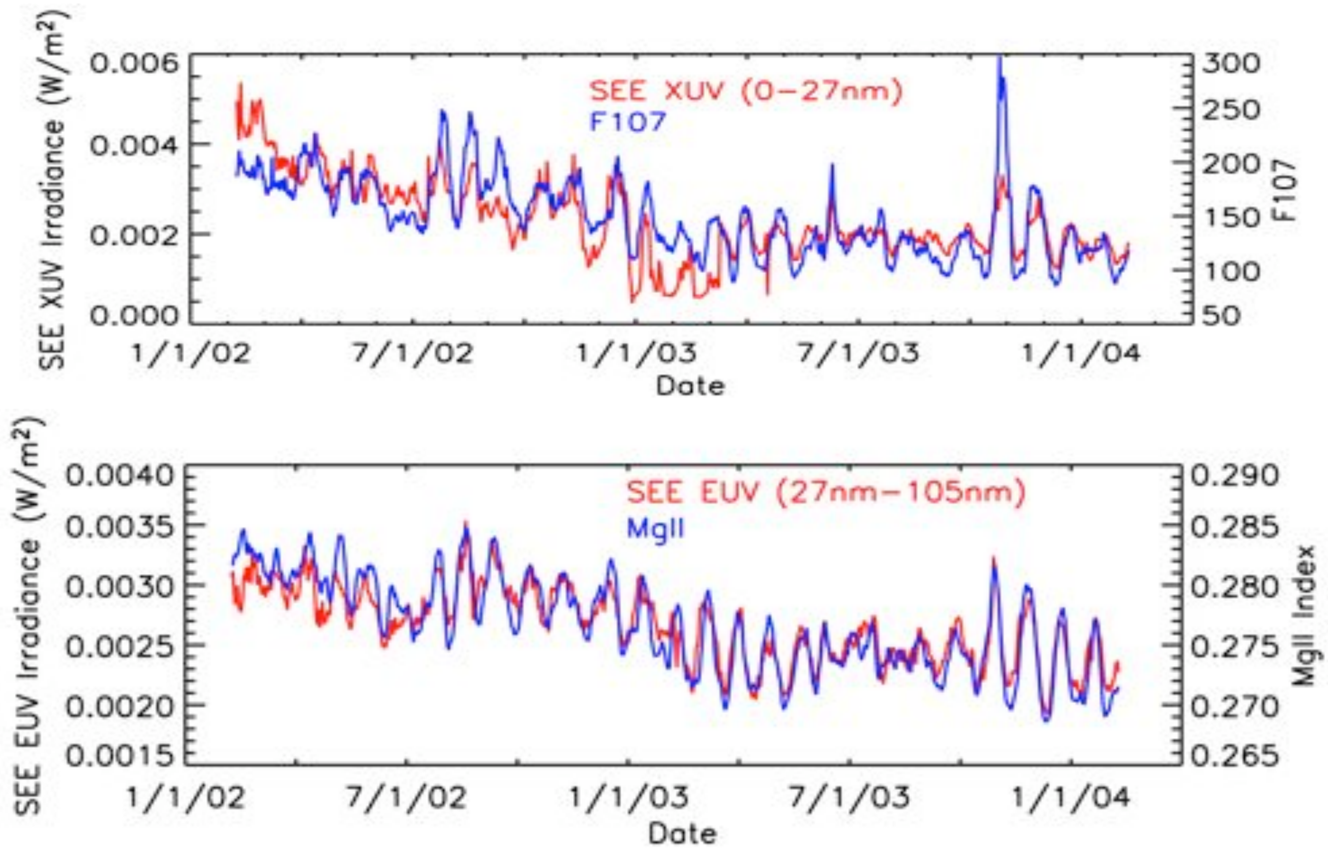
- Variation of a large flare is as much as solar cycle variations



Atmospheric Response to Solar Variations

Neutral Temperature Response (TIE-GCM result)
Satellite Drag
Atmospheric NO Response
Ionospheric Response
FUV Airglow (GUVI)

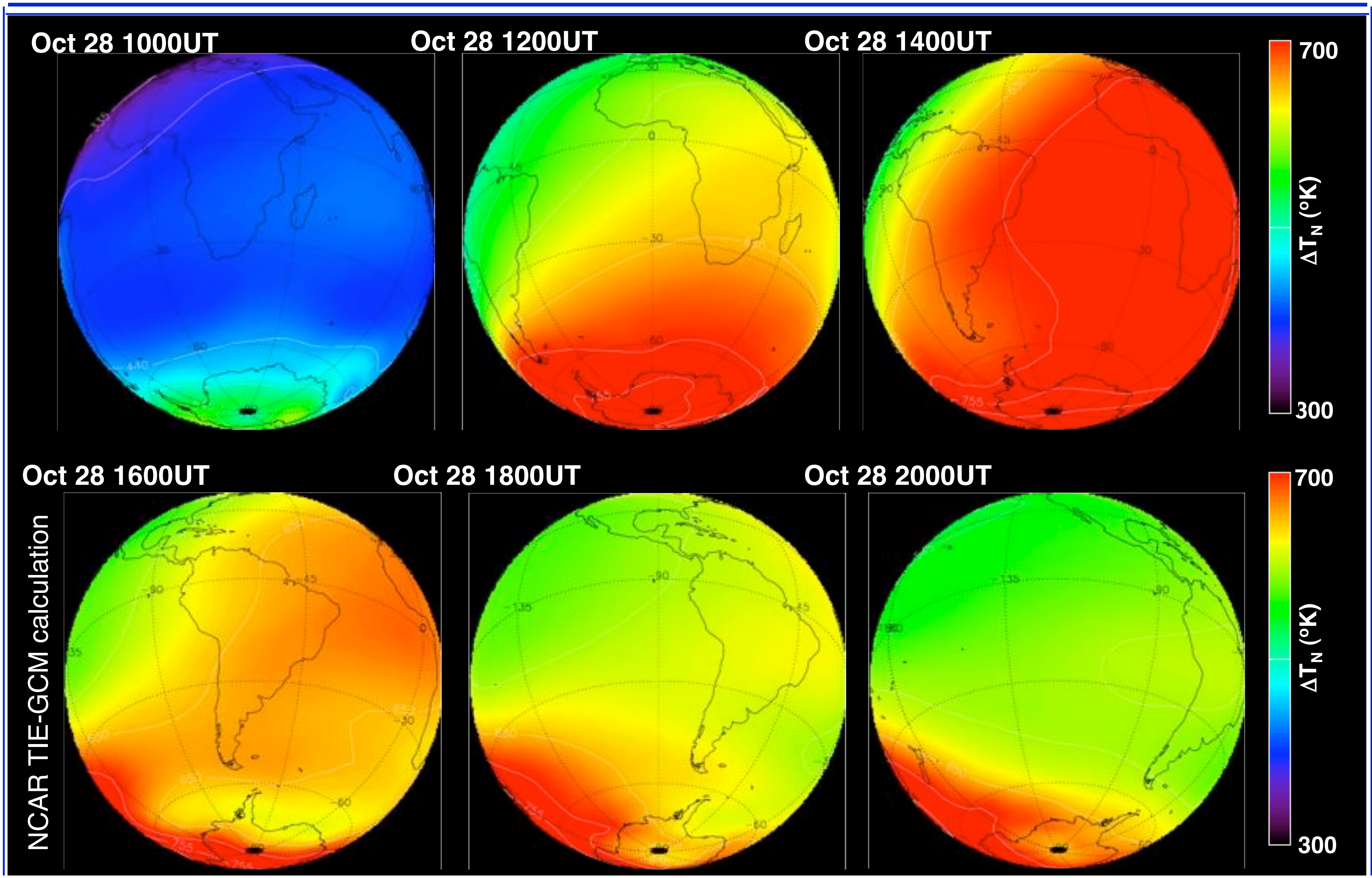
SEE Data Used in NCAR TIE-GCM Atmospheric Model



SEE measurements are employed as direct input to the NCAR TIE-GCM. Shown is comparison of SEE measurements to proxies that are used in empirical solar irradiance models such as the EUVAC model.

[Slide from S. C. Solomon]

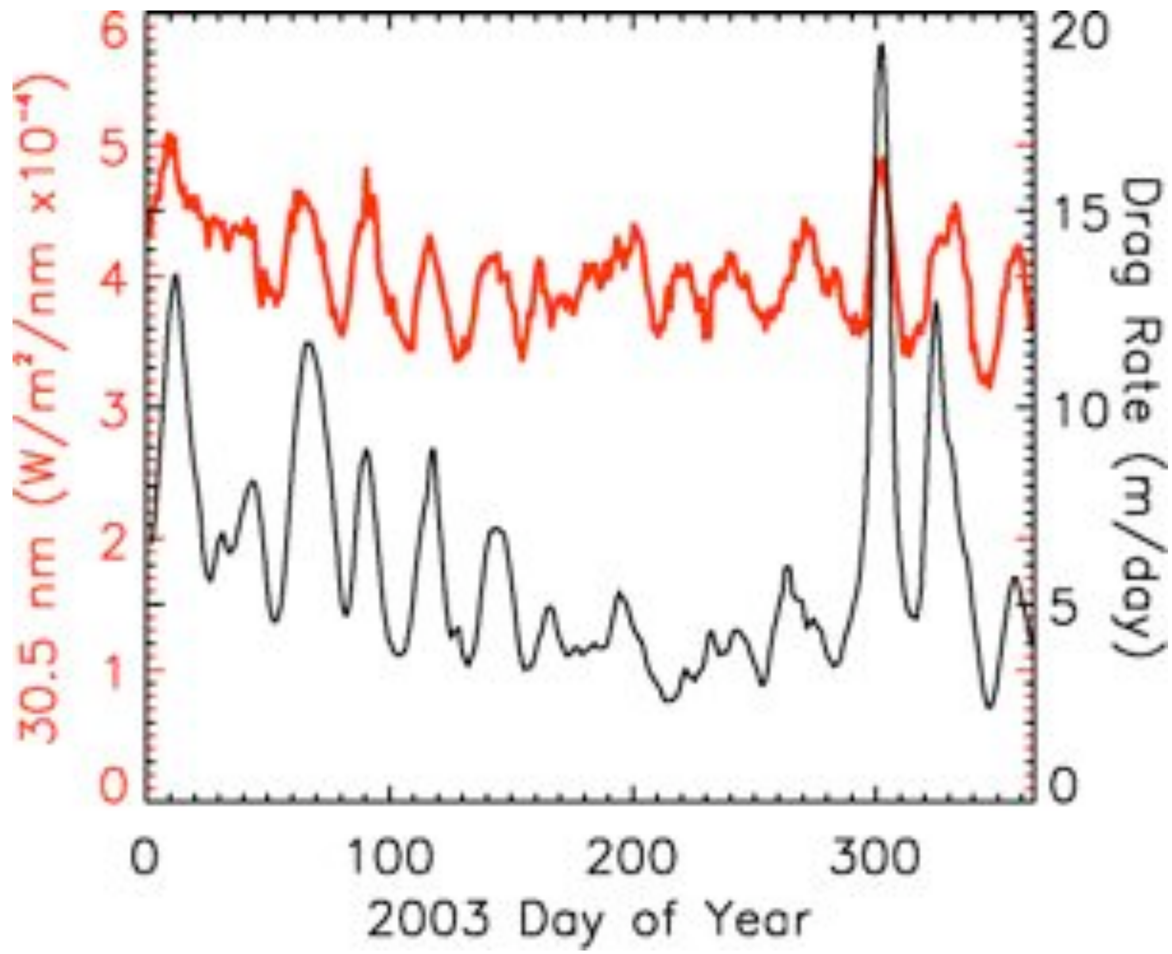
Neutral Temperature at 450 km Responds to Large Flare



[Slide from G. Lu and S. C. Solomon]

Solar Changes Affect Satellite Drag

Solar UV changes cause thermospheric density changes, which in turn directly affects satellite drag.

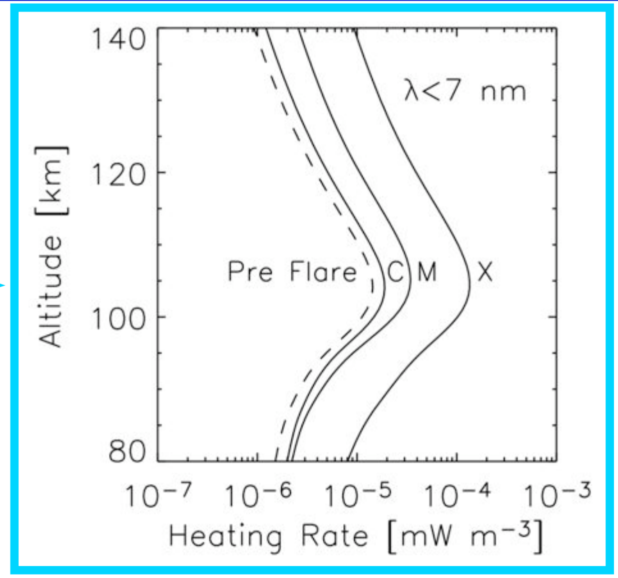


The black line is the orbit decay (drag rate) for the TIMED spacecraft. The red line is the SEE 30.5 nm irradiance time series. The period near day 300 is Oct-Nov 2003 when the solar XUV irradiance was significantly enhanced and included several large flares.

Solar Flares Impact Atmospheric Nitric Oxide (NO)

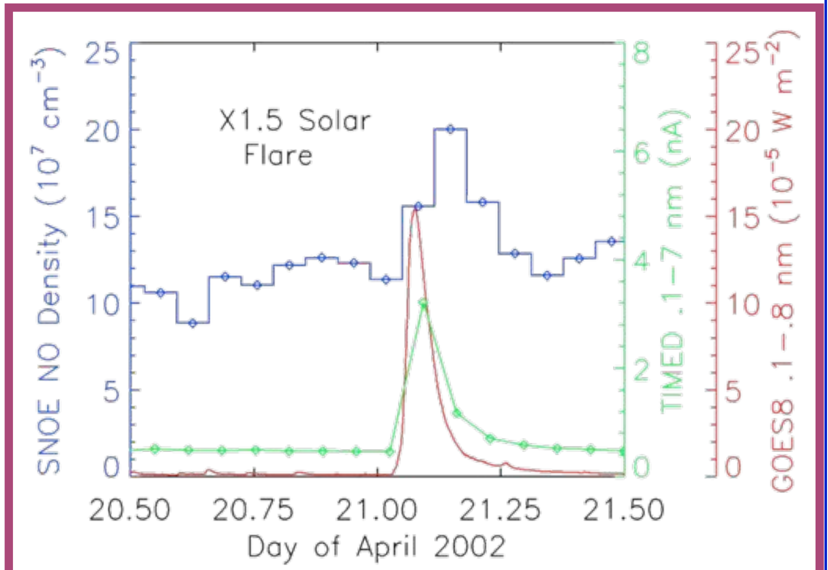
Solar Flare Energy Deposition

- Retrieved solar flare spectra are used to determine the soft X-ray energy input to Earth's thermosphere during a flare.
- The April 21, 2002 X1.5 flare provides 10 times more energy at 105 km than during pre-flare conditions.
- Enhanced soft X-ray irradiance at 105 km is important to the production of NO.

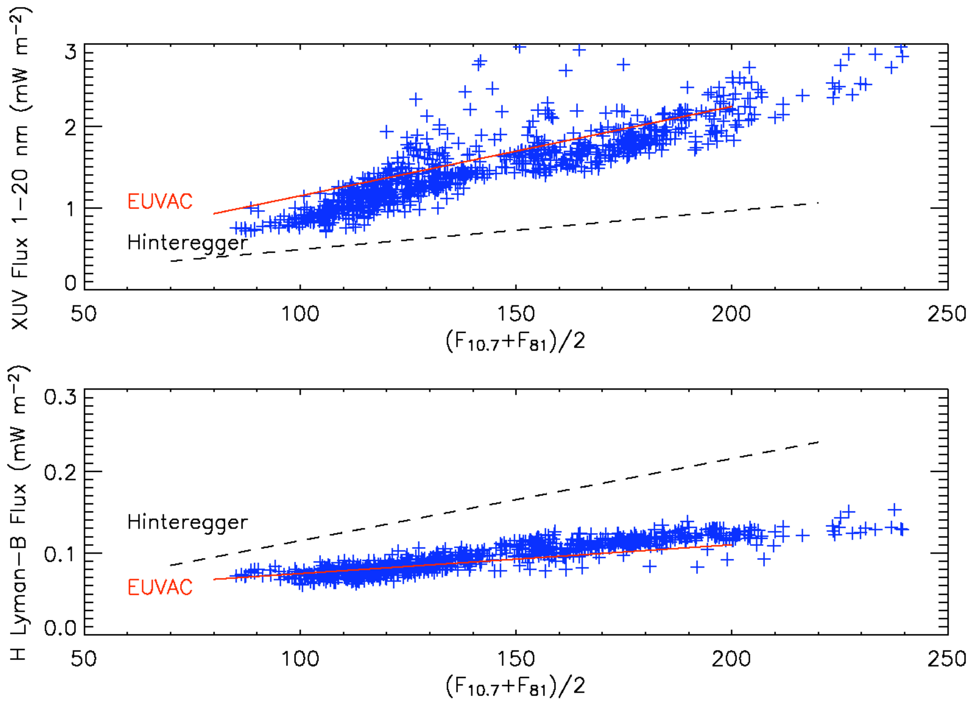


NO response to Solar Flares

- Retrieved solar flare spectra are input to *glow* - NO_x model.
- Model results are compared to SNOE observations of NO and FAST observations of photoelectron fluxes.
- Significant NO enhancements are observed in response to flares in the equatorial lower thermospheric chemistry.



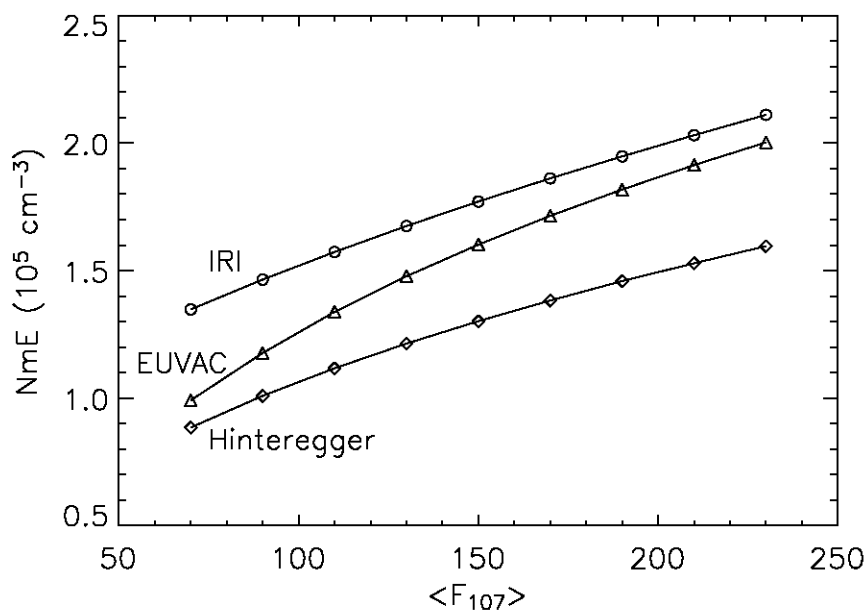
Electron Densities in the E-region Varies with Solar Activity



SEE measurements show greater XUV irradiance but lower H Lyman-β irradiance than the AE-based Hinteregger empirical model. However, the reanalysis of these data by Richards et al. (EUVAC) shows reasonable agreement to the SEE measurements.

These wavelengths control the peak E-region electron density; calculations using the GLOW model show better agreement with IRI when EUVAC is employed than using the Hinteregger model, although still lower at solar minimum conditions.

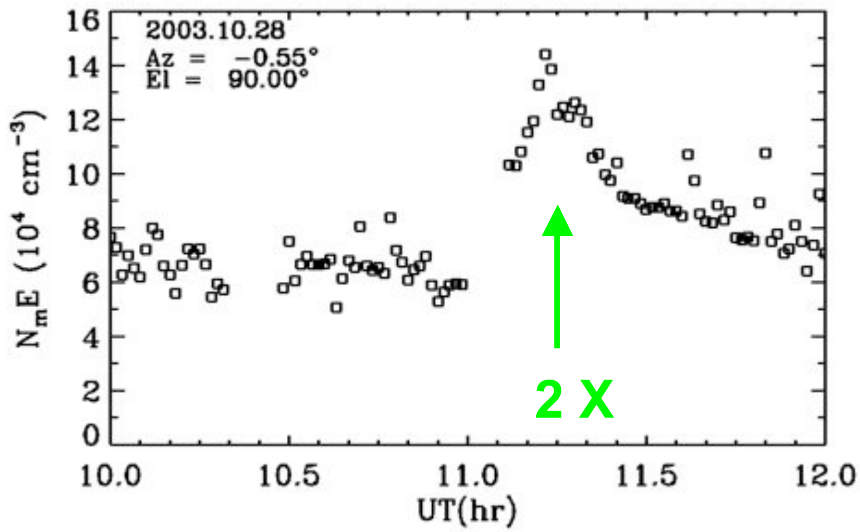
[S. C. Solomon, *ASR*, in press, 2005].



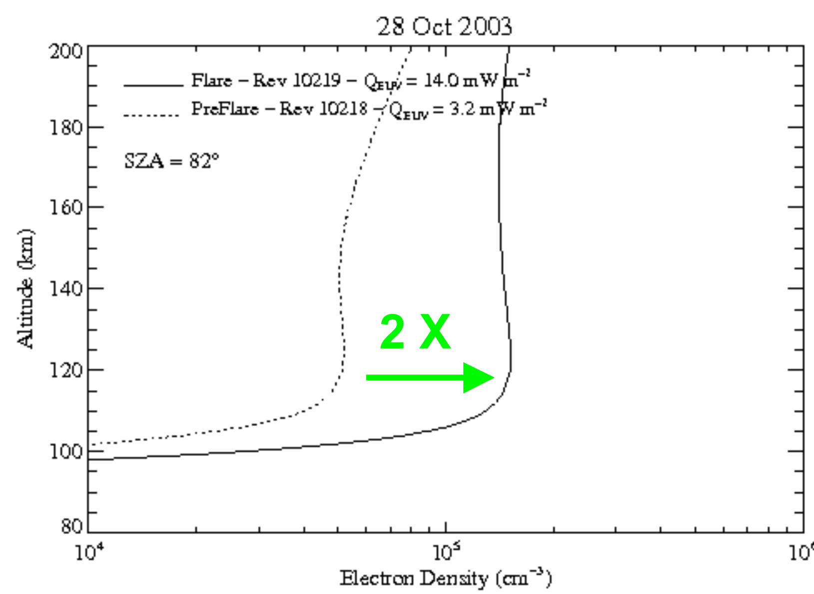
[Slide from S. C. Solomon]

E-region Responded to 28 Oct 2003 Flare

- Electron density at Tromsø increased by ~ factor of 2 during the X17 flare on 28 Oct 2003
- $N_e \propto$ square root of photoionization rate



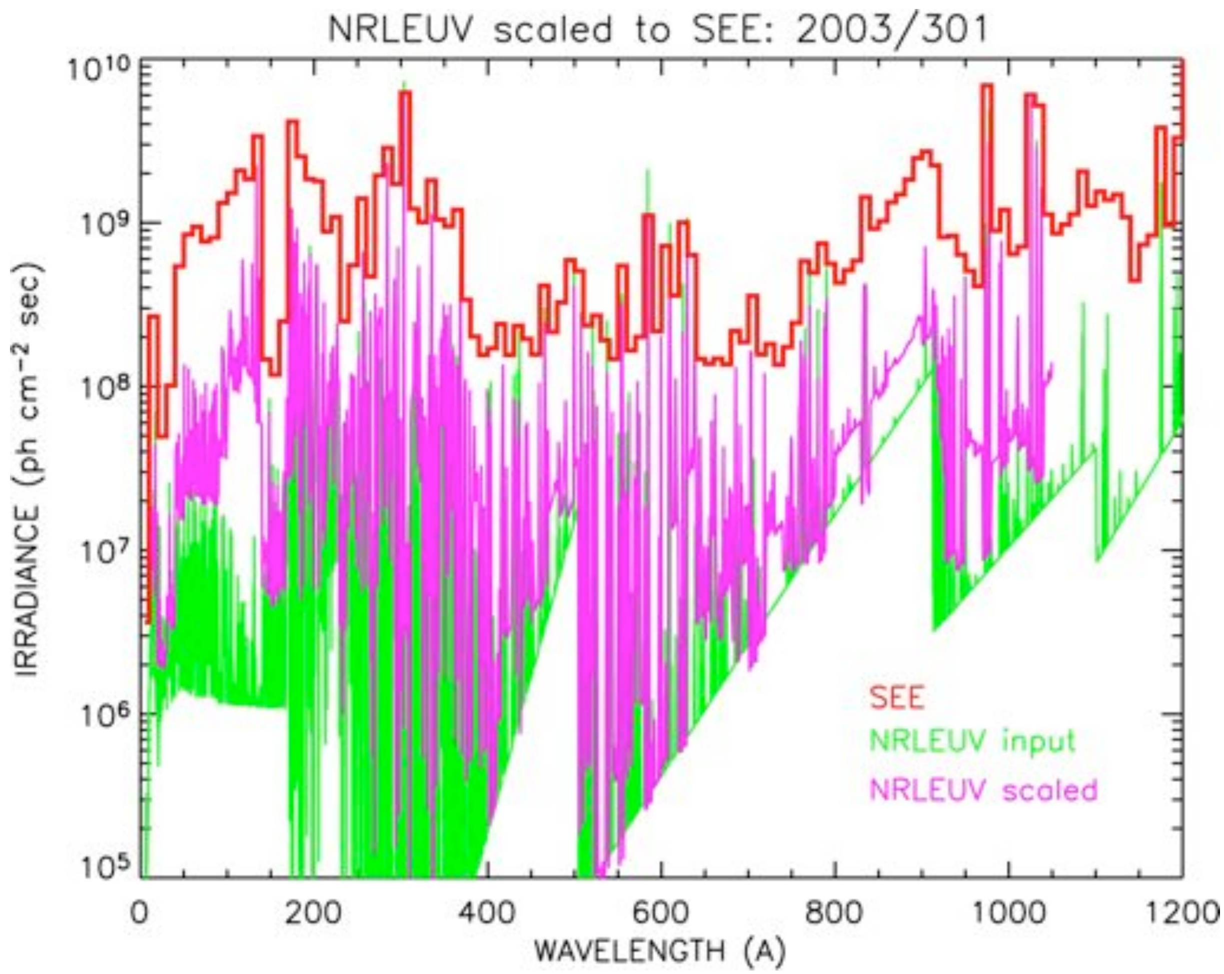
- AURIC code (Strickland) reproduces magnitude and % increase of N_e using GUVI Q_{euv}
- N_e increases by factor of 4 using SEE Q_{euv}



SEE Spectra Used in GUVI Limb Inversion Algorithm

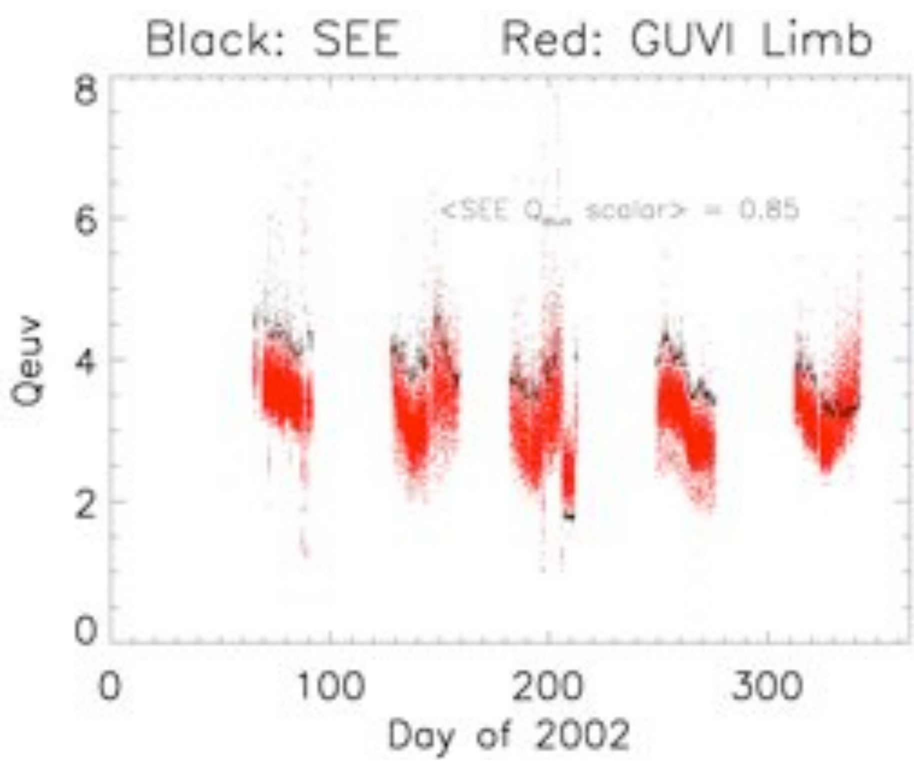
GUVI limb inversion algorithm uses the SEE data in 1 nm bands

- use NRLEUV for spectral distribution within 1 nm band
- maintain SEE energy flux within band



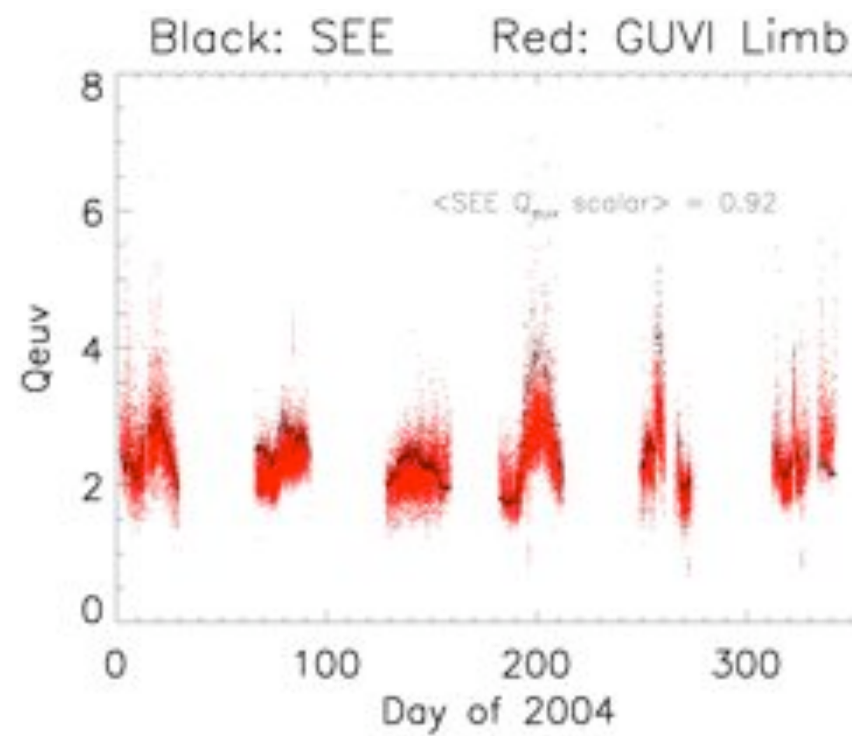
[Slide from J. Lean]

SEE and GUVI Limb Q_{euv} Comparison



On average, GUVI 15% lower than SEE for 2002

GUVI 8 % lower than SEE for 2004



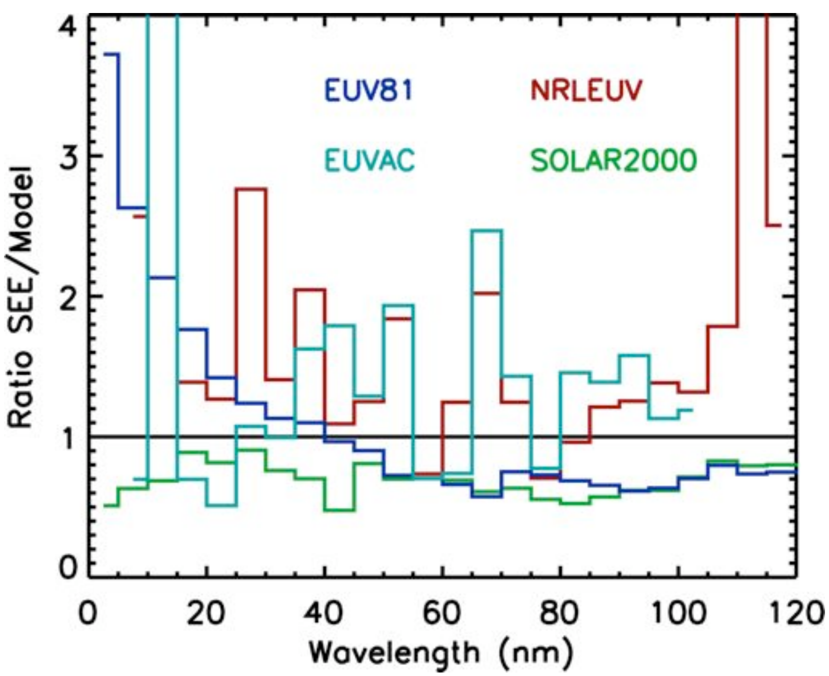
Solar activity higher in 2002 than 2004

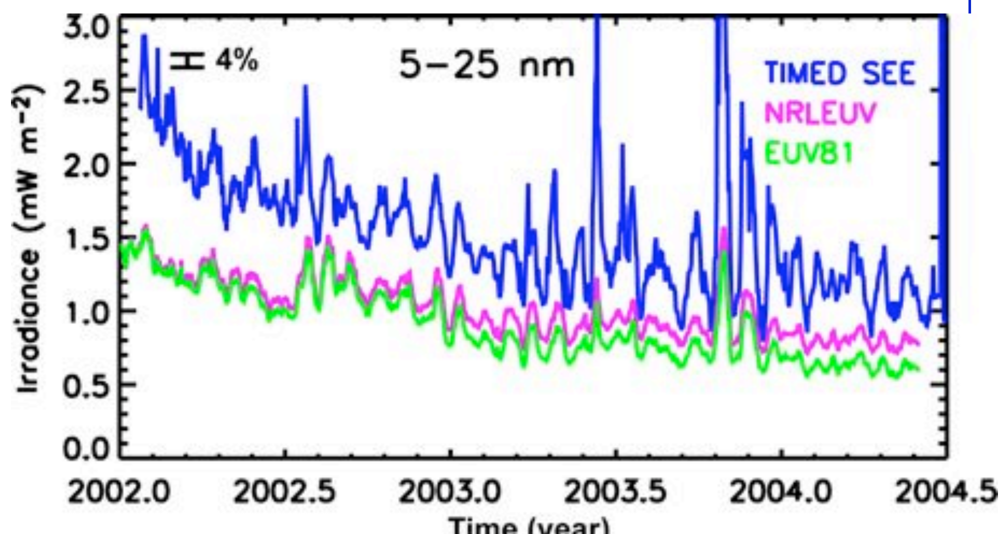
Solar Irradiance Modeling

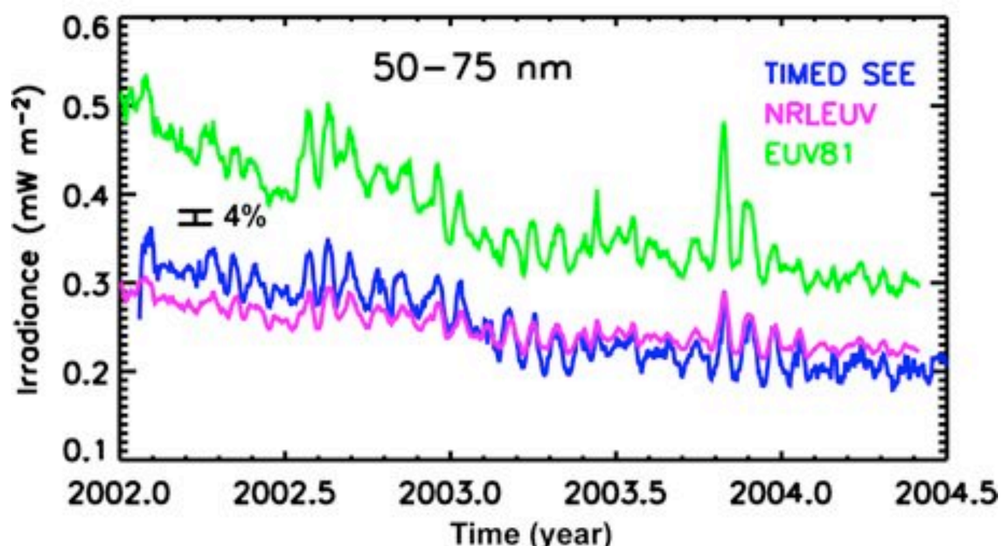
Improvements to Existing Models
New Empirical Flare Model - FISM
New Modeling of Flare Spectra

Solar Models Can Be Improved With SEE Results

- Differences between models of the solar EUV irradiance and SEE are as large as factor of 4 at some wavelengths
- Variability from models also differ with SEE results
  - SEE measures more XUV variability than the models







New Modeling of Flare Spectra Using SEE Data

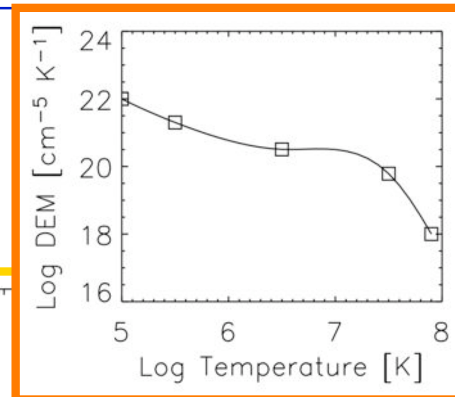
Solar Flare Spectra

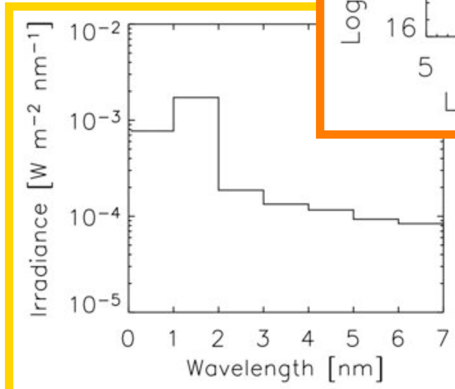
- XPS measurements are used to identify solar flares by extracting flare signals from observed signals.
- Flare spectra are determined by interpreting XPS observations with a model [Warren et al., 1998] that calculates theoretical spectra for differential emission measures (DEM).
- The DEMs are iterated until the resulting spectrum reproduces the XPS observations.

Reproduced XPS Observations

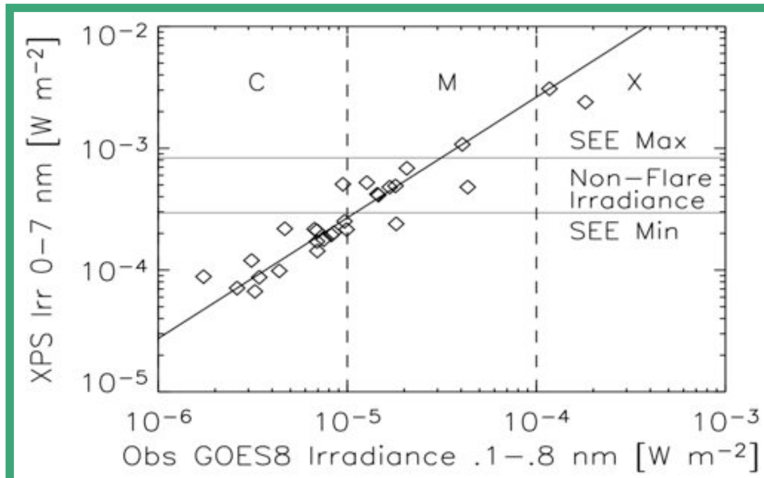
- Agreement between XPS (.1-.8 nm) and GOES (.1-.8 nm) results is good, especially for larger M-class and X-class flares.
- M-class flare produces a 0-7 nm irradiance approximately equal in magnitude to the non-flare irradiance.
- X-class flare produces at least 4 times the non-flare irradiance.

Retrieved DEM for April 21, 2002 X1.5 solar flare.

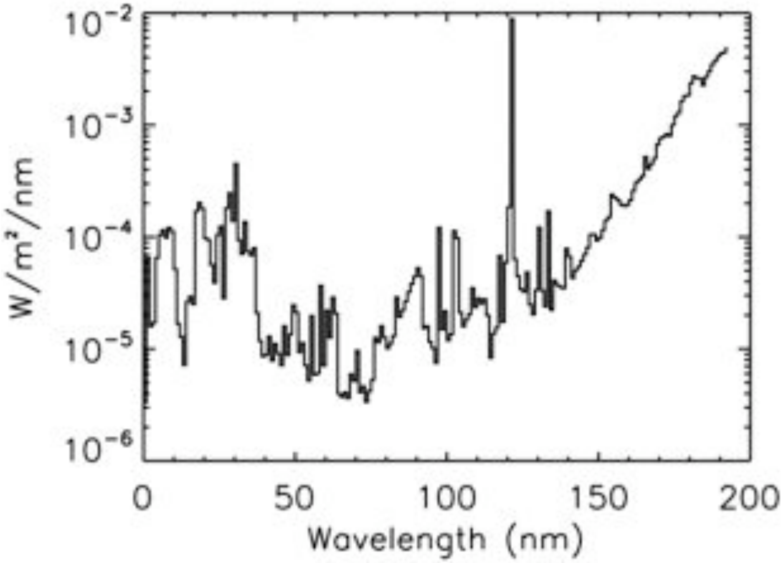


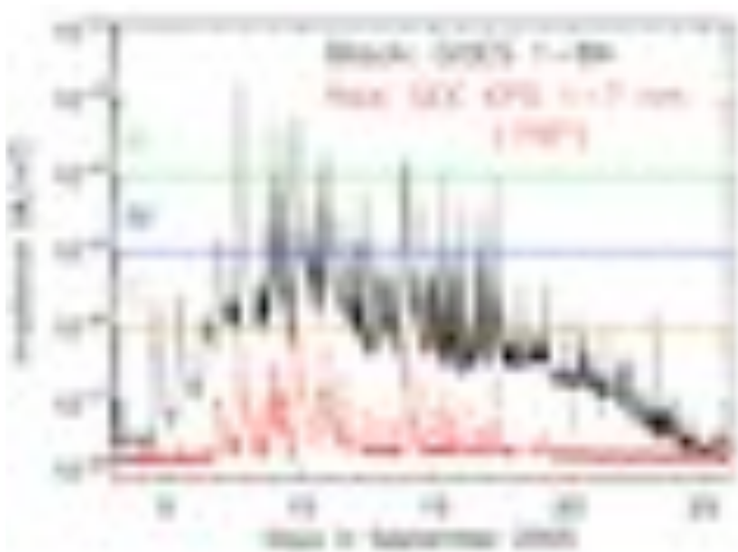


Retrieved spectrum for April 21, 2002 X1.5 solar flare.



FISM - a new flare model





- Flare Irradiance Spectral Model (FISM) is a new empirical model of the solar VUV irradiance (0.1-190 nm) at 60 second temporal resolution.
- Uses traditional proxies (MgII c/w, F10.7, and Lyα) as well as new proxies (0-4 nm, 36.5 nm, and 30.5 nm) to model the daily component.
- Uses the GOES 0.1-0.8 nm irradiance as the proxy to model flare variations.
- FISM is the first flare model that can be used for near real-time space weather operations.
- FISM developed by LASP/CU graduate student Phil Chamberlin (completed PhD in November 2005).

FISM Algorithm Overview

Irradiance (E) = **minimum irradiance** + **daily components** + **flare components**

$$E(t_{UTC}) = E_{min} + \boxed{\Delta E_{SC}(t_d) + \Delta E_{SR}(t_d)} + \boxed{\Delta E_{GP}(t_{UTC}) + \Delta E_{IP}(t_{UTC})}$$

E_{min}: Solar minimum reference spectrum, FISMref, (Constant)

Daily Component Variations (Modeled on a daily basis):

- Solar Cycle (SC)
- Solar Rotation (SR)

Flare Component Variations (Modeled on a 60 seconds basis):

- Gradual Phase (GP)
- Impulsive Phase (IP)

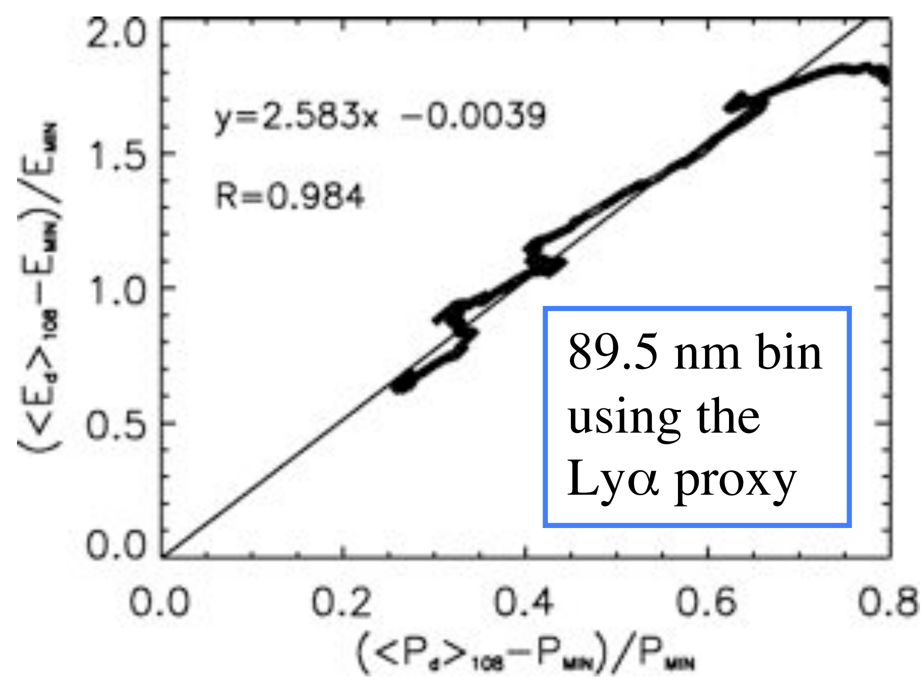
FISM Solar Cycle - ΔE_{SC}

$$E(t_{UTC}) = E_{min} + \boxed{\Delta E_{SC}(t_d)} + \Delta E_{SR}(t_d) + \Delta E_{GP}(t_{UTC}) + \Delta E_{IP}(t_{UTC})$$

$$\Delta E_{SC}(\lambda, t_d) = E_{min}(\lambda) \bullet C_{SC}(\lambda) \left[\frac{< P_d(t_d) >_{108} - P_{min}}{P_{min}} \right]$$

where

$$\Delta E_{SC}(\lambda, t_d) = < E(\lambda, t_d) >_{108} - E_{min}(\lambda)$$



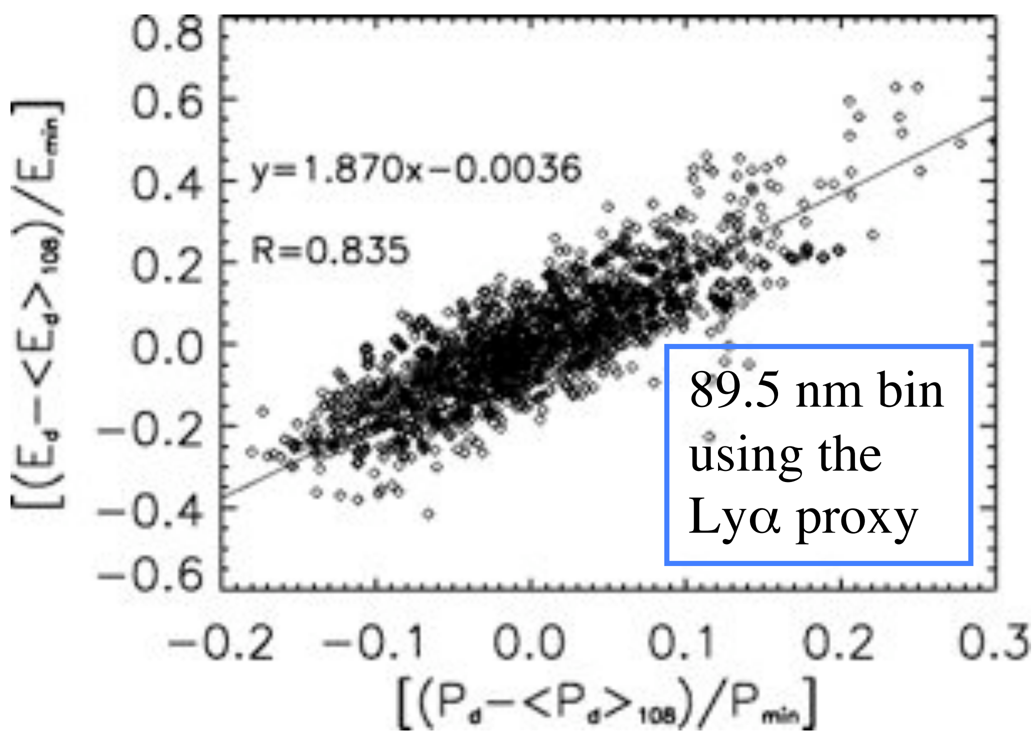
FISM Solar Rotation - ΔE_{SR}

$$E(t_{UTC}) = E_{min} + \Delta E_{SC}(t_d) + \boxed{\Delta E_{SR}(t_d)} + \Delta E_{GP}(t_{UTC}) + \Delta E_{IP}(t_{UTC})$$

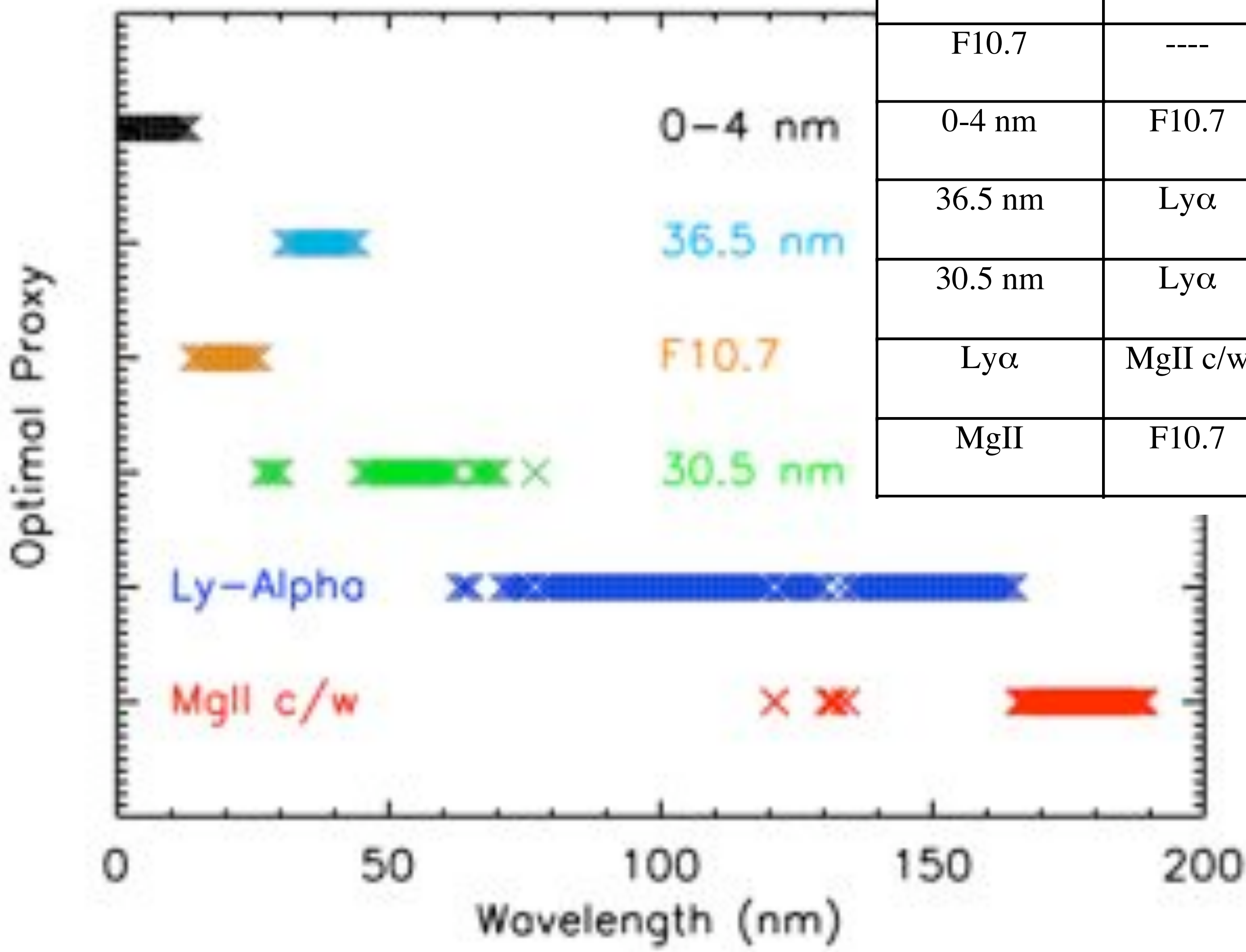
$$\Delta E_{SR}(\lambda, t_d) = E_{min}(\lambda) \bullet C_{SR}(\lambda) \left[\frac{P_d(t_d) - < P_d(t_d) >_{108}}{P_{min}} \right]$$

where

$$\Delta E_{SR}(\lambda, t_d) = E(\lambda, t_d) - < E(\lambda, t_d) >_{108}$$



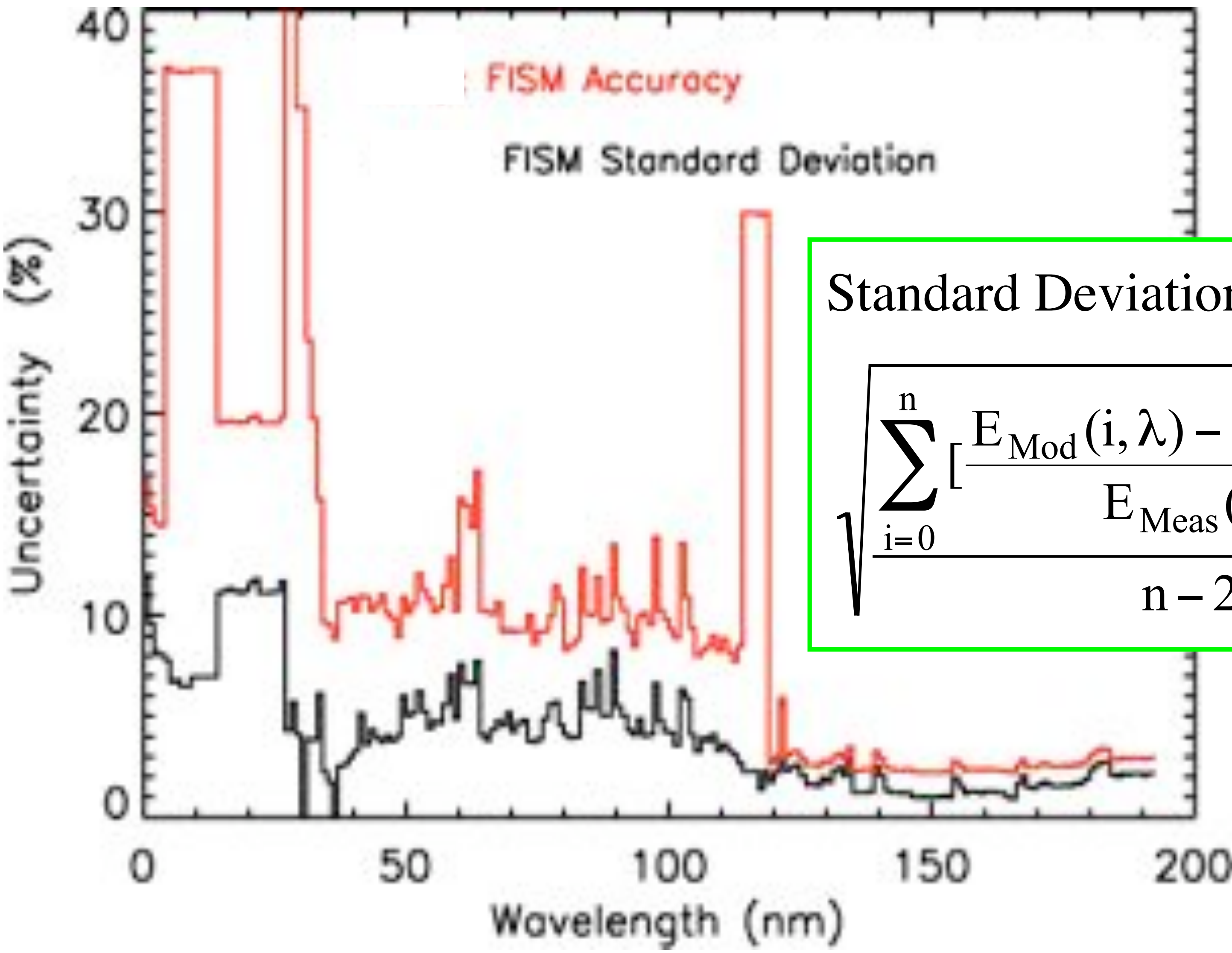
FISM Optimal Daily Proxies



Optimal Proxy	1st Backup	2nd Backup	3rd Backup
F10.7	----	----	----
0-4 nm	F10.7	----	----
36.5 nm	Lyα	MgII c/w	F10.7
30.5 nm	Lyα	MgII c/w	F10.7
Lyα	MgII c/w	F10.7	----
MgII	F10.7	----	----

[Slide from P. Chamberlin]

FISM Daily Component Uncertainty



Standard Deviation Algorithm:

$$\sqrt{\frac{\sum_{i=0}^{n}\left[\frac{E_{Mod}(i,\lambda)-E_{Meas}(i,\lambda)}{E_{Meas}(i,\lambda)}\right]^2}{n-2}}$$

FISM Flare Gradual Phase - ΔE_{GP}

$$E(t_{UTC}) = E_{min} + \Delta E_{SC}(t_d) + \Delta E_{SR}(t_d) + \boxed{\Delta E_{GP}(t_{UTC})} + \Delta E_{IP}(t_{UTC})$$

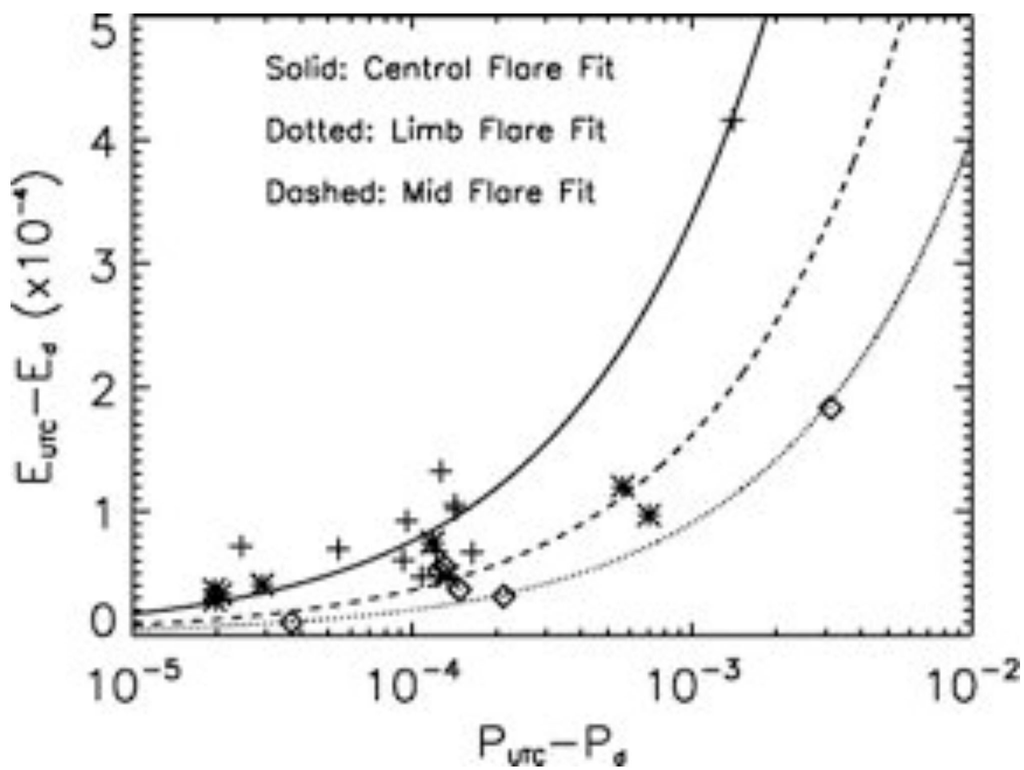
$$\Delta E_{GP}(\lambda, t_{UTC}) = 1.06 \bullet C_{GP,C}(\lambda) \bullet f(\mu, \lambda)[P(t_{UTC}) - P_d(t_d)]^{N_{GP}(\lambda)}$$

where

$$\Delta E_{GP}(\lambda, t_{UTC}) = E(\lambda, t_{UTC}) - E_d(\lambda, t_d)$$

and

$$f(\mu, \lambda) = CLV_{rat}(\lambda) + \mu\left[1 - CLV_{rat}(\lambda)\right]$$



FISM Flare Impulsive Phase - ΔE_{IP}

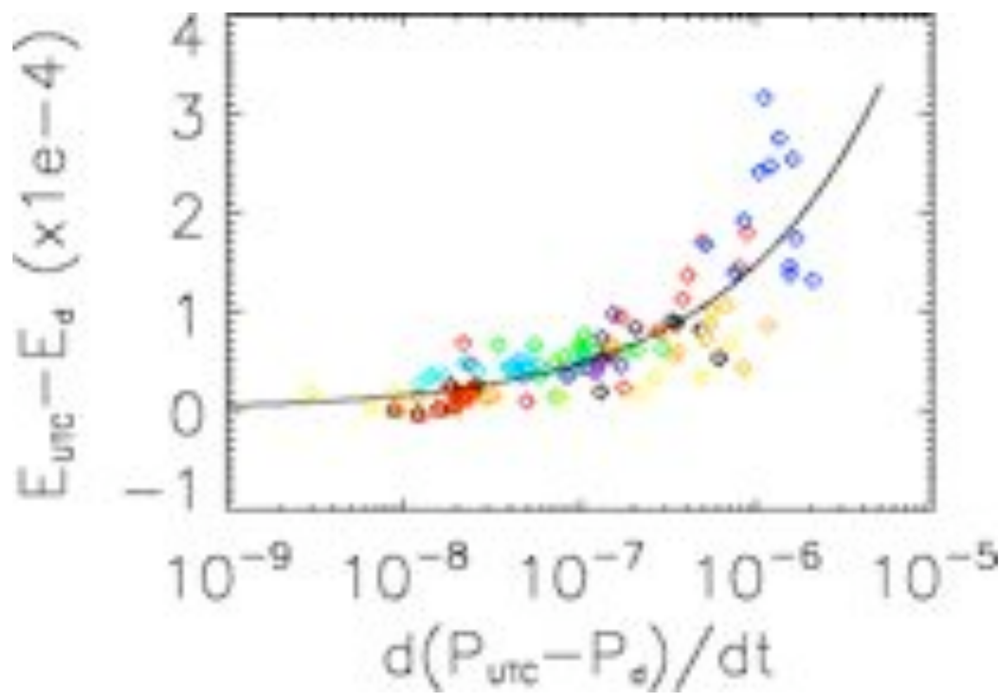
$$E(t_{UTC}) = E_{min} + \Delta E_{SC}(t_d) + \Delta E_{SR}(t_d) + \Delta E_{GP}(t_{UTC}) + \boxed{\Delta E_{IP}(t_{UTC})}$$

$$\Delta E_{IP}(\lambda, t_{UTC}) = f(\mu, \lambda) \bullet C_{IP}(\lambda)\left[\frac{d}{dt}\left(P(t_{UTC}) - P_d(t_d)\right) > 5x10^{-10}\right]^{N_{IP}(\lambda)}$$

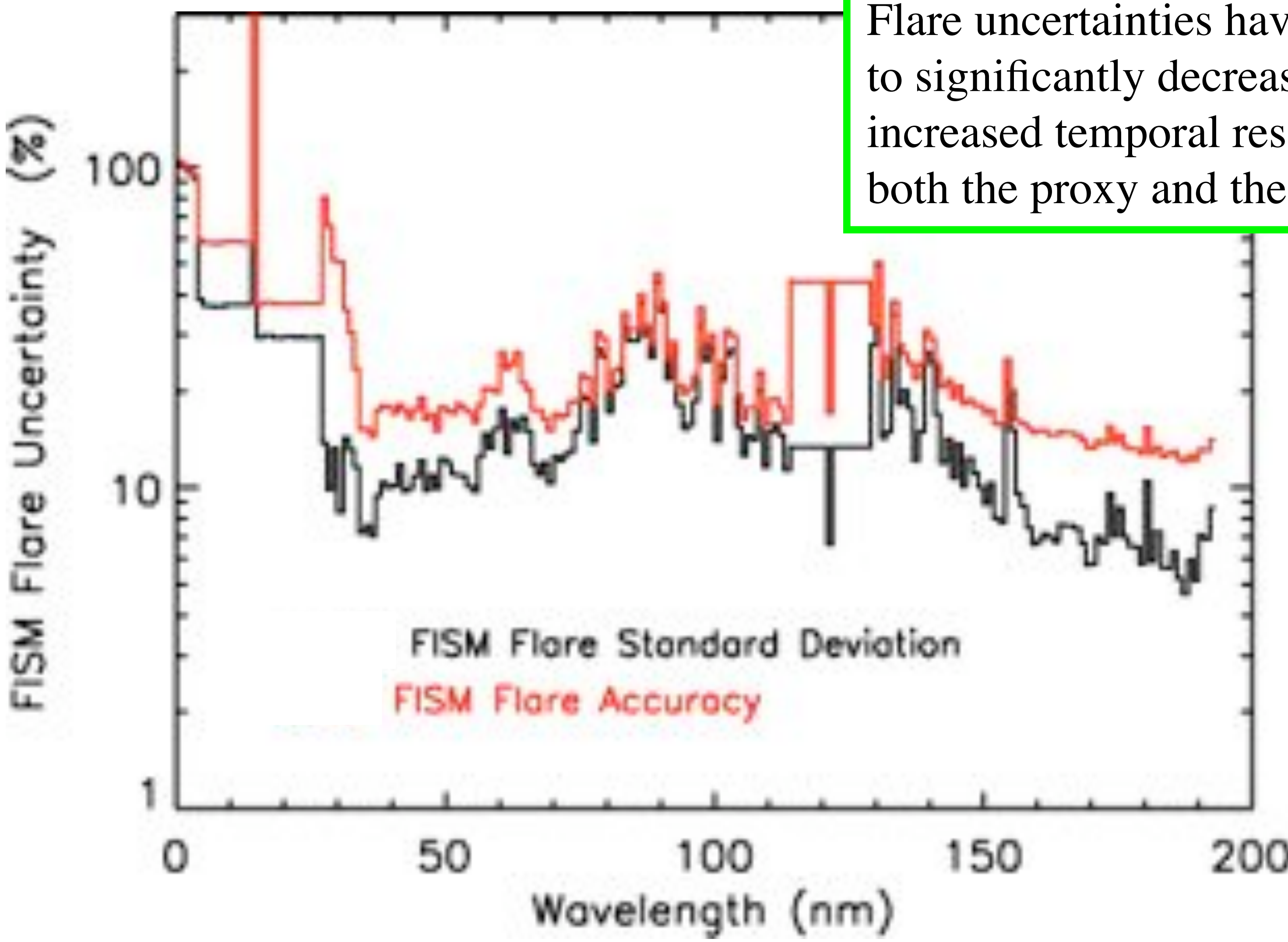
where

$$\Delta E_{IP}(\lambda, t_{UTC}) = E(\lambda, t_{UTC}) - E_d(\lambda, t_d)$$

Note: when determining IP parameters, the predicted GP component needs to be subtracted from measured data



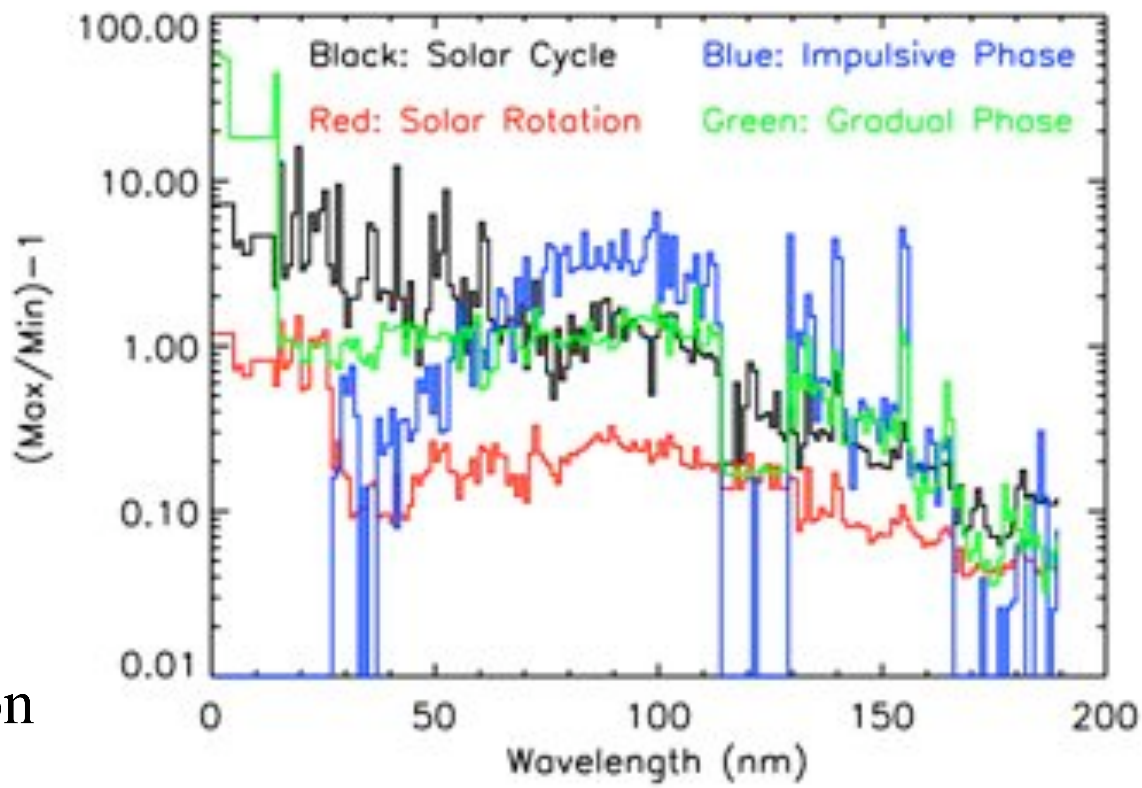
FISM Flare Uncertainties



Flare uncertainties have been shown to significantly decrease with increased temporal resolution of both the proxy and the FISM output

New Results of Solar Variability from FISM

- Characterization of the VUV irradiance changes during a solar flare
- Large energy deposited in the transition region during the impulsive phase
- VUV emissions reach their solar cycle minimum values at different times
- Proxies with representative CLV functions need to be used to accurately model the solar rotation



Improvements Provided by FISM

- Higher temporal resolution (60 sec, may be improved to 3 sec)
  - Provides spectral variations for flare events
- Near real-time processing for space weather operations
  - Provides flare variations for the VUV spectrum for use in ionospheric and thermospheric models
- Use of new, more optimal daily proxies (36.5 nm, 30.5 nm, 0-4 nm)
  - Provides most accurate solar cycle and solar rotation irradiance variations and more accurate CLV modeling
- Flexibility to use the best available daily proxy from 1947-present
- Use of most accurately available data sets and proxies
  - Most accurate data (TIMED SEE) leads to lowest uncertainties
  - Upcoming missions could provide even better data (SDO EVE, GOES-N, SOL-ACES, Space Solar Patrol)

[Slide from P. Chamberlin]

SEE Related Workshops, Meetings, Talks, and Papers

SEE Related Talks in 2005

- TIMED Science Team Meeting: Apr. 2005, 4 talks
- AGU Spring Meeting: May 2005, 8 talks / posters
- SORCE Science Workshop: Sept. 2005, 2 talks / posters
- GUVI Science Workshop: Oct. 2005, 2 talks
- EVE Science Workshop: Nov. 2005, 3 talks / posters
- AGU Fall Meeting: Dec. 2005, 7 talks / posters
- Public Seminars
  - J. Lean: Mar. 2005, AAS Goddard Symposium, GSFC
  - J. Lean: Oct. 2005, Lunch Seminar, NAS Koshland Science Museum
  - T. Woods: June 2005, Summer Colloquium on Space Weather, NCAR
  - T. Woods: May 2005, ASP Seminar, HAO/NCAR

SEE Related Papers in 2005 - 1

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- Smithro, C. G., and J. J. Sojka, A new global average model of the coupled thermosphere and ionoshpere, *J. Geophys. Res.*, *100*, A08305, doi: 10.1029/2004JA010781, 2005.
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SEE Related Papers in 2005 - 2

- Storz, M. F., B. R. Bowman, J. I. Branson, S. J. Casali and W. K. Tobiska, High accuracy satellite drag model (HASDM), *Adv. Space Research*, doi: 10.1016/j.asr.2004.02.020, 2005.
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- Tobiska, W.K. and S.D. Bouwer, New developments in SOLAR2000 for space research and operations, *Adv. Space Research*, doi: 10.1016/j.asr.2005.08.015, 2005.
- Tsurutani, B. T., D. L. Judge, F. L. Guarnieri, P. Gangopadhyay, A. R. Jones, J. Nuttall, G. A. Zambon, L. Didkovsky, A. J. Mannucci, B. Iijima, R. R. Meier, T. J. Immel, T. N. Woods, S. Prasad, J. Huba, S. C. Solomon, P. Straus, and R. Viereck, The October 28, 2003 extreme EUV solar flare and resultant extreme ionspheric effects: Comparison to other Halloween events and the Bastille Day event, *Geophys. Res. Lett.*, ***32***, L03S09, doi: 10.1029/2004GL021475, 2005.
- Wang, X., R. Eastes, S. Weichecki Vergara, S. Bailey, C. Valladares, and T. Woods, On the short term relationship between solar soft X-ray flux and equatorial Total Electron Content (TEC), *J. Geophys. Res.*, submitted, 2005.
- Warren, H. P., A solar minimum irradiance spectrum for wavelengths below 1200 Å, *Ap. J. Suppl.*, *157*, 147-173, 2005.
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SEE Related Papers in 2005 - 3

- Woods, T. N., G. Rottman, and R. Vest, XUV Photometer System (XPS): Overview and calibrations, *Solar Physics*, *230*, 345-374, 2005.
- Woods, T. N., and G. Rottman, XUV Photometer System (XPS): Solar variations during the SORCE mission, *Solar Physics*, *230*, 375-387, 2005.
- Woods, T. N., G. Kopp, and P. C. Chamberlin, Contributions of the solar ultraviolet irradiance to the total solar irradiance during large flares, *J. Geophys. Res.*, submitted, 2005.

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 400 flares have been observed by SEE
  - Extreme flare periods are April 2002, July 2002, May-June 2003, Oct.-Nov. 2003, July 2004, Jan. 2005, and Sept. 2005
  - Large flares vary as much as 11-year solar cycle variations
  - New flare models have been developed with SEE observations
- More than 50 solar rotations have been observed by SEE
  - Variability of 5-70% observed (wavelength dependent)
- TIMED mission has observed solar maximum and low solar activity during solar cycle 23
  - Extended TIMED mission should observe solar cycle minimum conditions that are predicted in the 2006-2008 timeframe

SEE Plans for 2006

- Daily mission operations and data processing for SEE
  - A new data product of the atmospheric density from the EGS occultation experiments is being developed for SEE Version 9 data processing
- Additional underflight calibration (last flight to be funded by TIMED)
  - Next underflight rocket calibration planned for October 2006
    - Includes engineering model of SEE XPS and the new engineering model of SDO EUV Variability Experiment (EVE) which will provide 0.1 nm spectral resolution in the 5-105 nm range
- Provide SEE data and model products for space weather operations
  - Working towards have more frequent updates of the SEE Space Weather data product for use by NOAA and Air Force for space weather operations
    - Currently produce SEE data products 2-4 days after observation
    - Updating SEE processing software for updates after each TIMED downlink
  - Phil Chamberlin plans to make FISM output available near real-time for space weather operations using 1-min cadence GOES X-ray measurements
- Detailed modeling of Earth's response to solar irradiance changes
  - Composition, dynamics, temperature using TIME-GCM
  - Comparison to FAST photoelectron measurements to estimated photoelectron flux from the *glow* model that uses SEE solar measurements
- Occultation data analysis