

The Flare Irradiance Spectral Model (FISM) and its Contributions to Studies of the Ionosphere and Thermosphere

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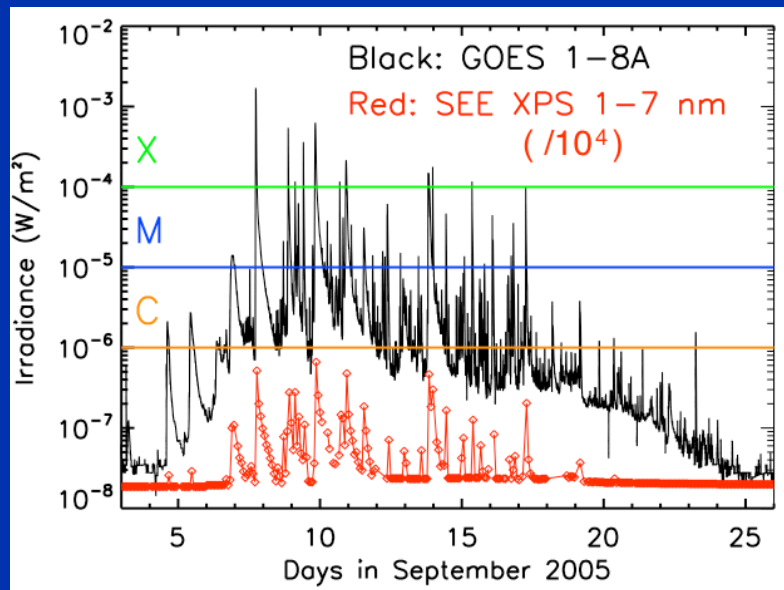
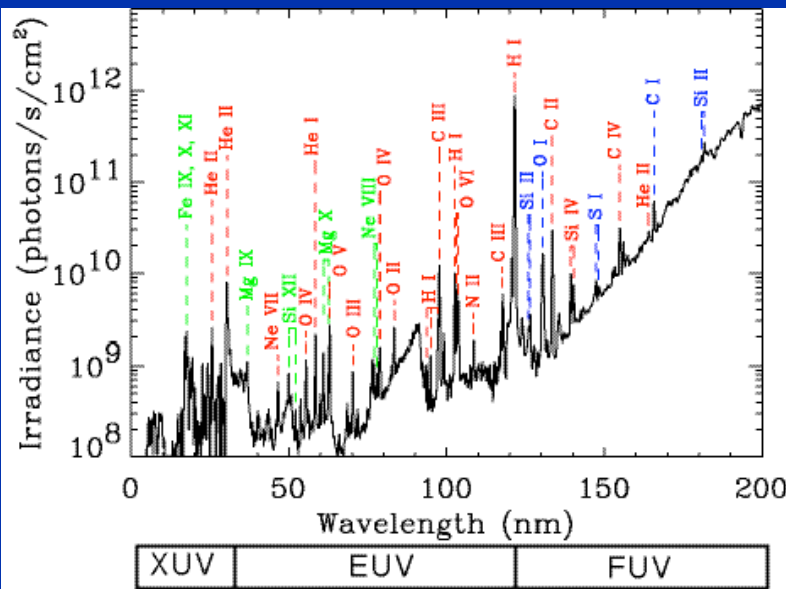


Outline

- FISM
 - Overview
 - Algorithms
 - Results
 - Data Access
- TIEGCM Results
- Gait2 Results
- Mars Ionospheric Results



The Flare Irradiance Spectral Model (FISM)



- Developed for my Ph.D. Dissertation (U. of Colorado, 2005)
- Chamberlin *et al.*, Space Weather, 2007, 2008
- FISM is an empirical model of the solar vacuum ultraviolet (VUV; 0.1-190 nm) irradiance at 60 second temporal resolution.
- Uses traditional proxies (MgII c/w, F10.7, and Ly α) as well as new proxies (0-4 nm, 36.5 nm, and 30.5 nm) to model the daily component - provide more accurate CLV.
- 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 Main Algorithm

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

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

Daily Component Variations (Modeled on a daily basis):

Solar Cycle (SC) - linear with 108-day smoothed daily proxy

Solar Rotation (SR) - linear with (daily proxy - SC proxy)

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

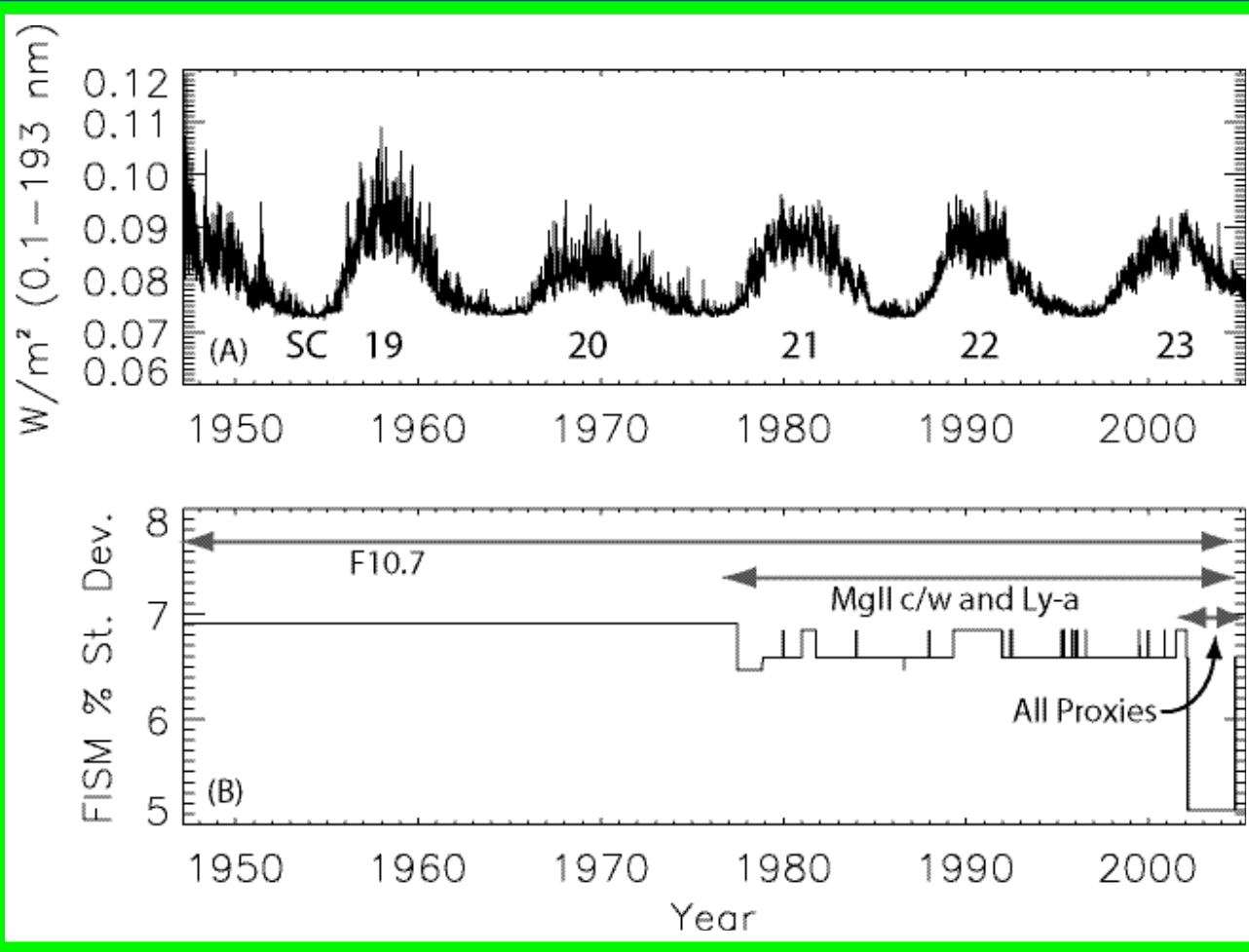
Gradual Phase (GP) - Power Law with GOES 0.1-0.8 nm

Impulsive Phase (IP) - Power Law with d/dt GOES

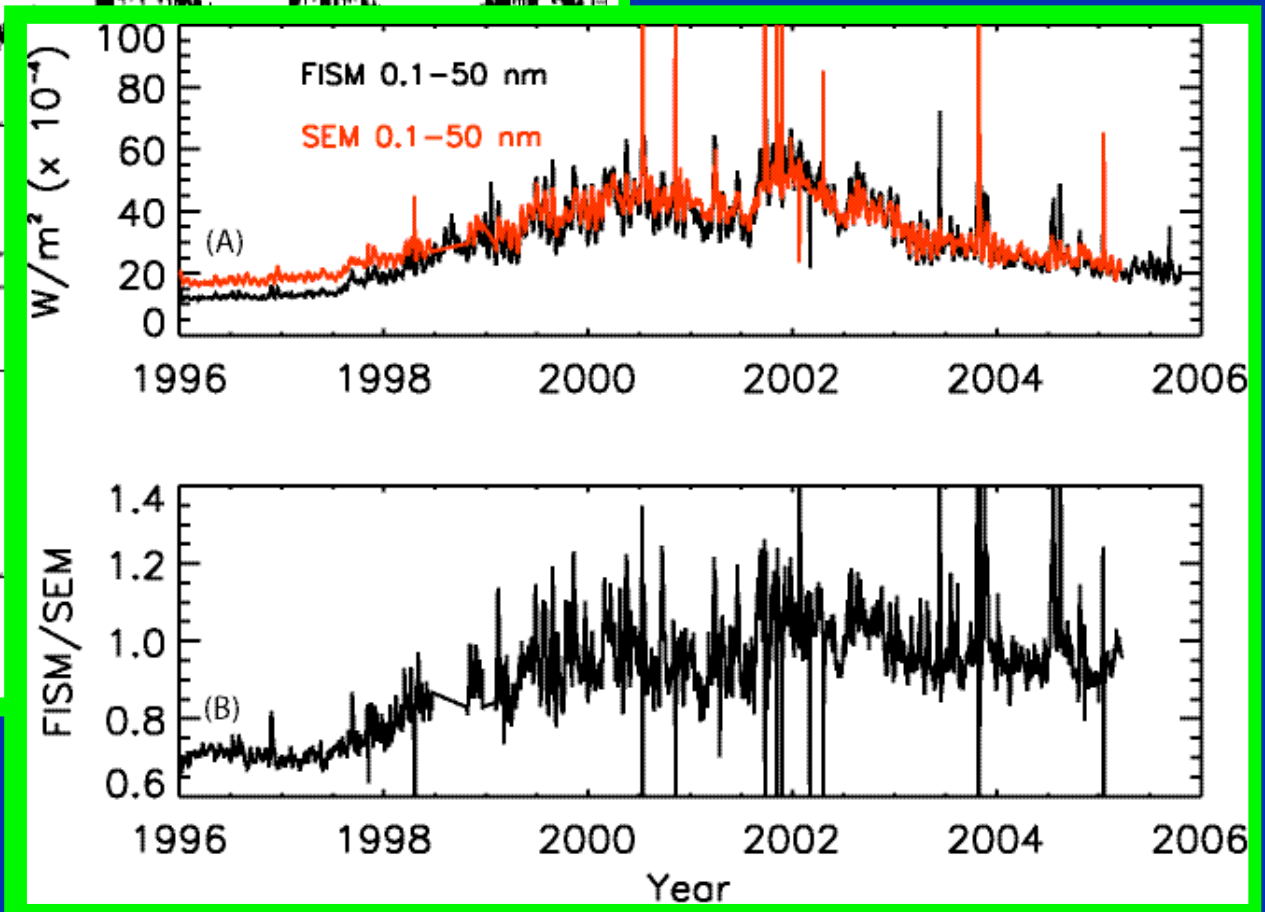
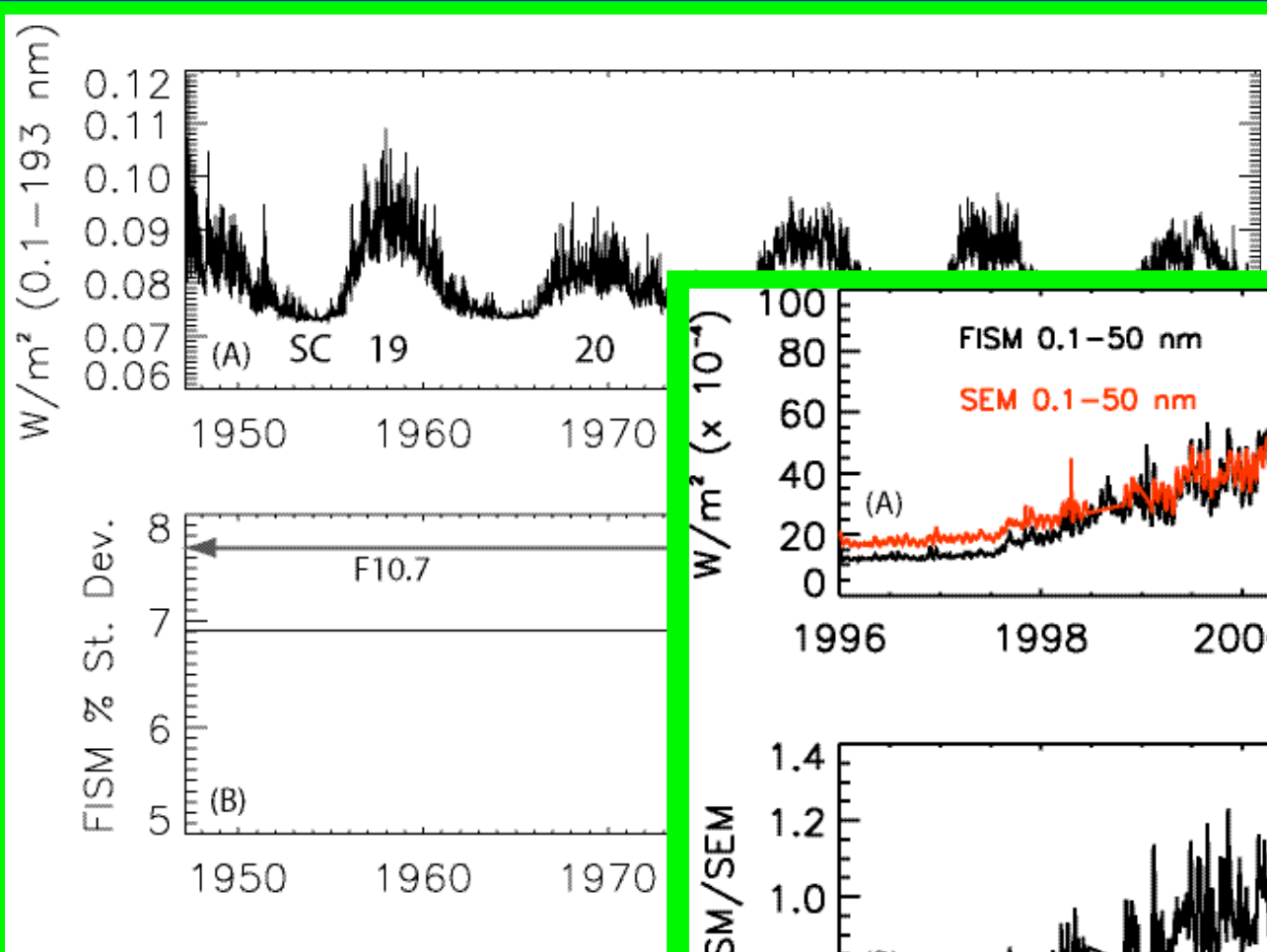
Center-to-Limb variations accounted for by representative proxies in daily component but must be corrected for in flare components



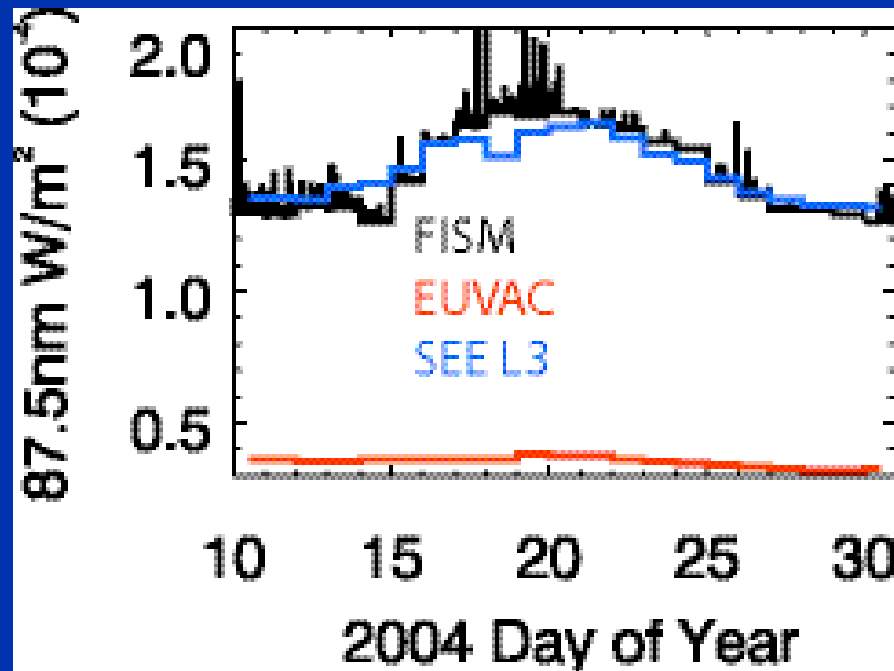
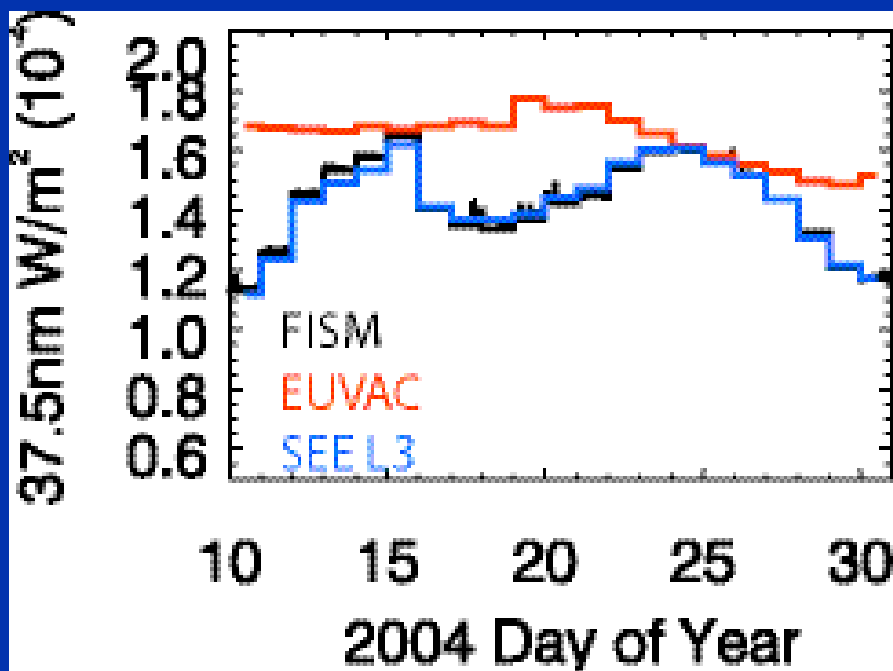
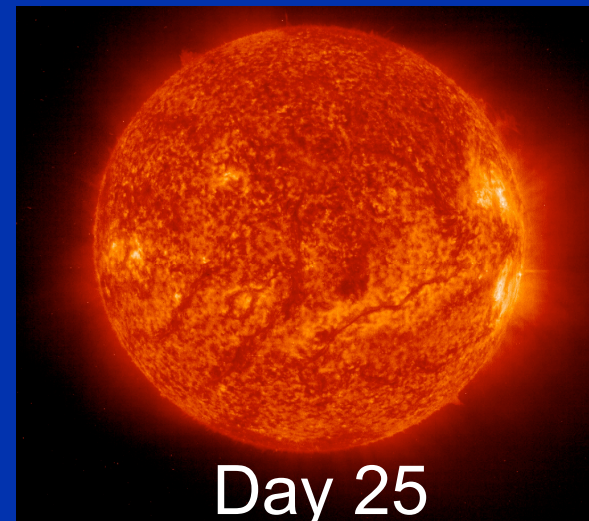
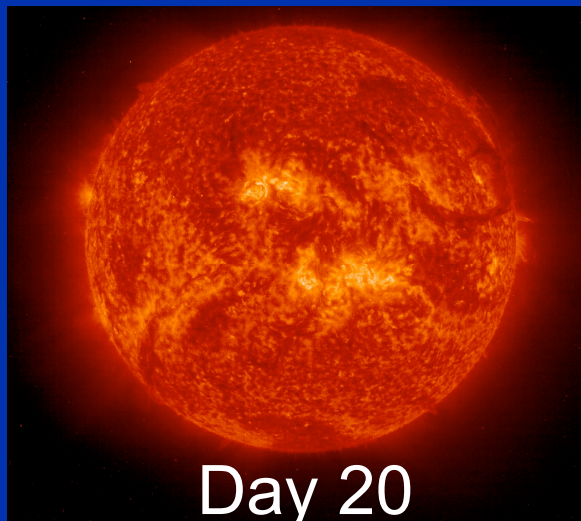
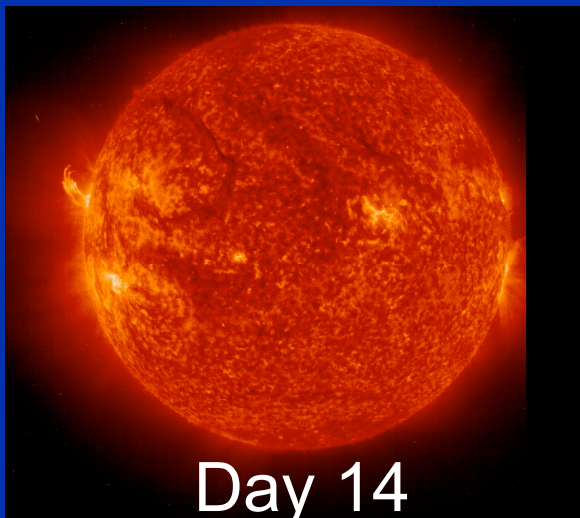
FISM Solar Cycle Variations



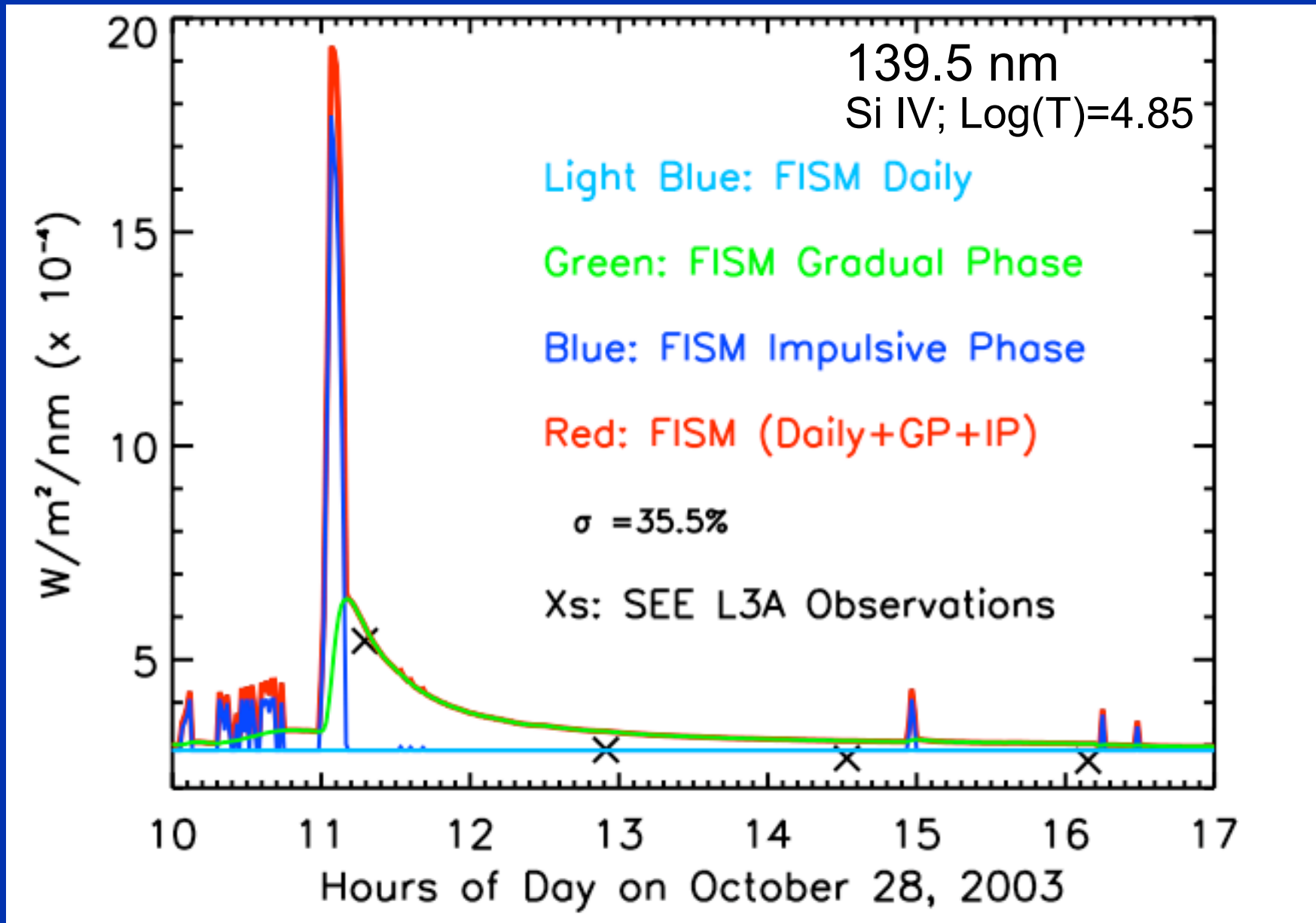
FISM Solar Cycle Variations



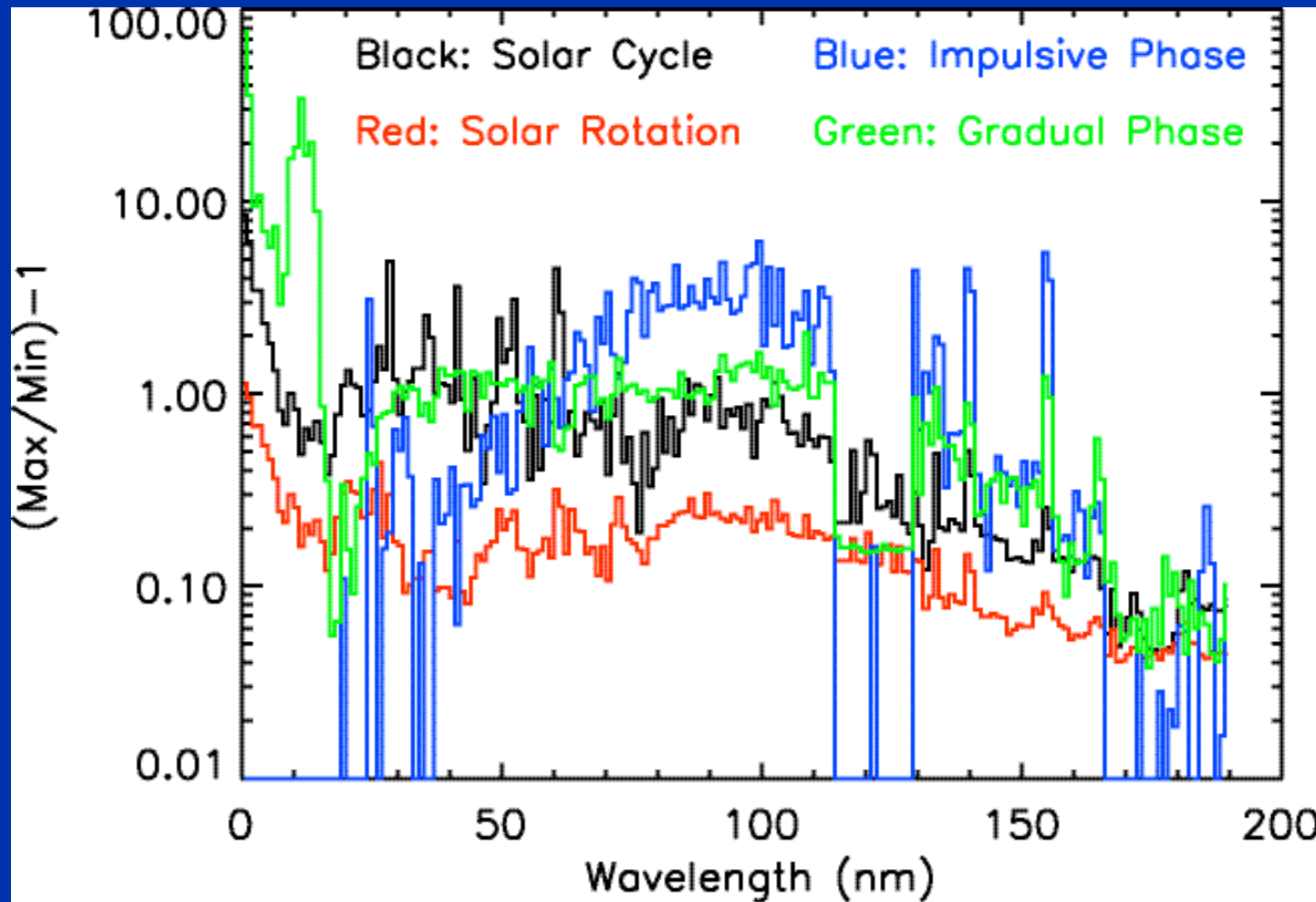
FISM Solar Rotation Estimations



X17 Flare Comparison to SEE



Solar Variation on Various Time Scales



Transition region emissions increased by up to a factor of 10 during the impulsive phase

EUV irradiance increased by a factor of 2 and XUV increases by a factor of 100 during the gradual phase

Flare Variations were as large or larger than the solar cycle variations for the Oct 28, 2003 flare



LISIRD: Lasp Interactive Solar IRradiance Datacenter

http://lasp.colorado.edu/lisird/fism.htm

FirstBank Imagekind Xpress Bill Pay Flagstar Bank - MyLoans FIA Card Ser...cess: Log In Chase Credit Card Home NASA ADS at ...act Service NSPIRES - NA...ties Online

over 6 solar cycles from 1947-Present

FISM Data

NOTE: view FISM [Readme](#) file for data interpretation

Daily Data

[Merged Data \(.sav file\)](#)

One file per day, searchable by year:

NOTE: For data prior to 1970, please use the merged data file

Flare Data

One file per day, searchable by year:

FISM Data plot utility - [launch](#)

FISM Documentation

- [FISM Readme file - \(.txt\)](#)

FISM References:

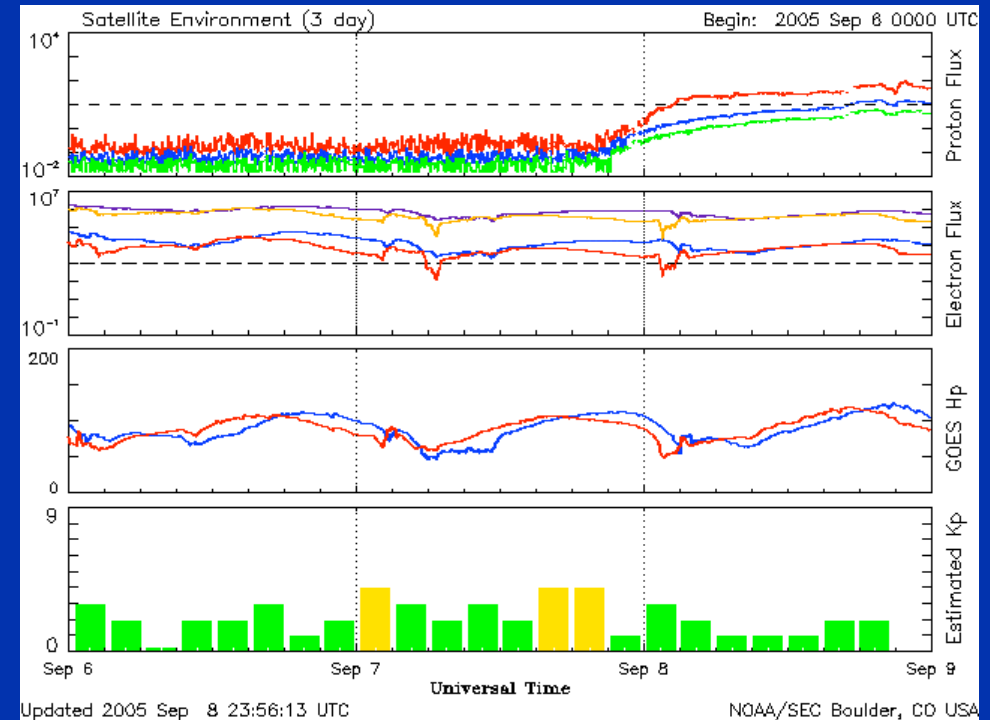
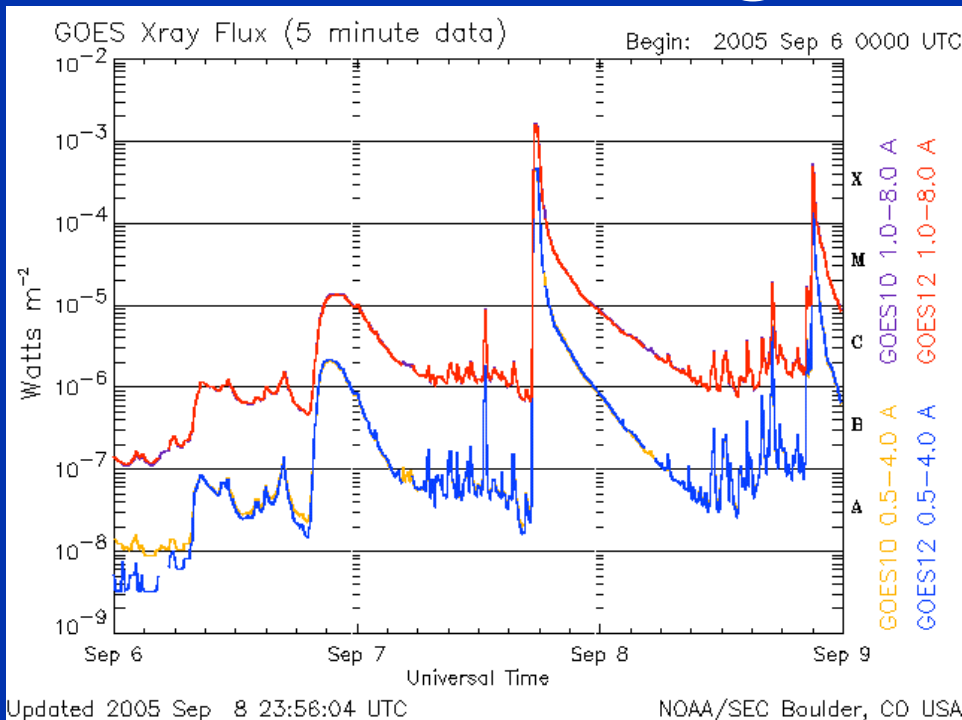
1. Chamberlin, P. C., T. N. Woods, and F. G. Eparvier, Flare Irradiance Spectral Model (FISM): Flare component algorithms and results, Space Weather, submitted, 2007.
2. Chamberlin, P. C., T. N. Woods, and F. G. Eparvier, Flare Irradiance Spectral Model (FISM): Daily component algorithms and results, Space Weather, 5, S07005, doi:10.1029/2007SW000316, 2007.

Additional FISM Papers:

1. Chamberlin, P. C., T. N. Woods, F. G. Eparvier, New flare model



TIE-GCM Model using FISM data for an X17.0 solar flare on September 7, 2005 Gang Lu, NCAR



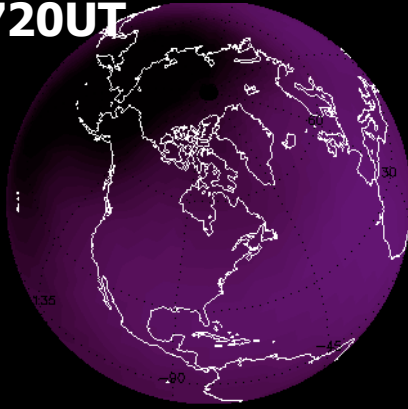
Start Time - 17:17; Peak Time - 17:40; End Time - 18:03



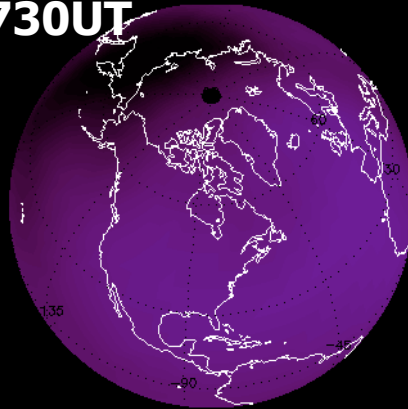
Neutral Temperature Change at ~350 km During Flare

Flare Peak

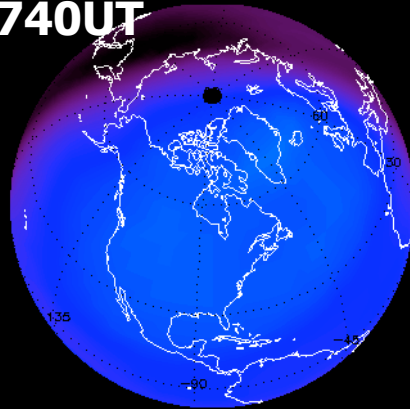
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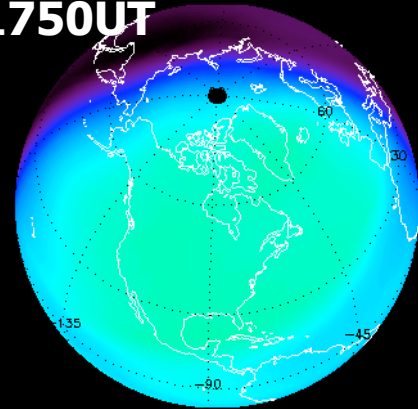
1730UT



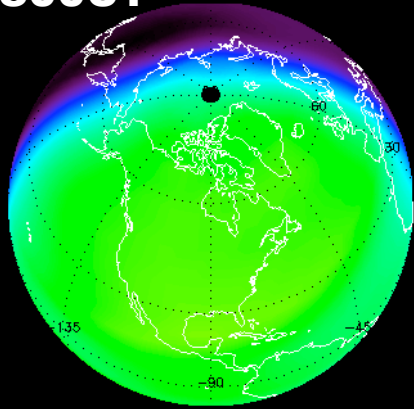
1740UT



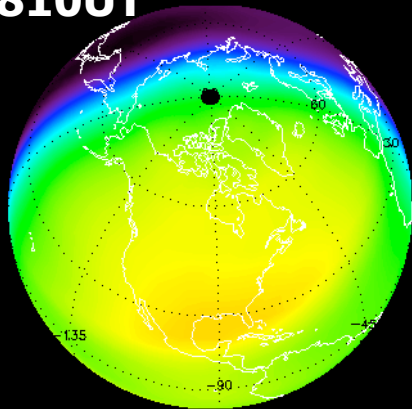
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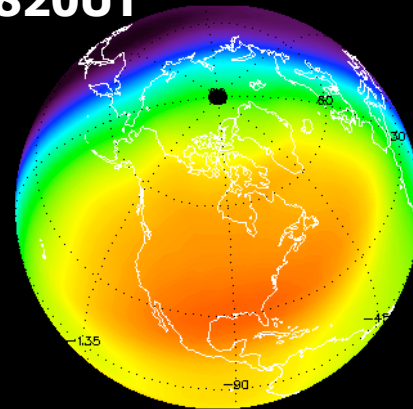
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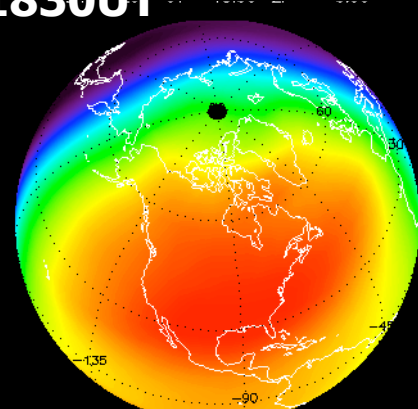
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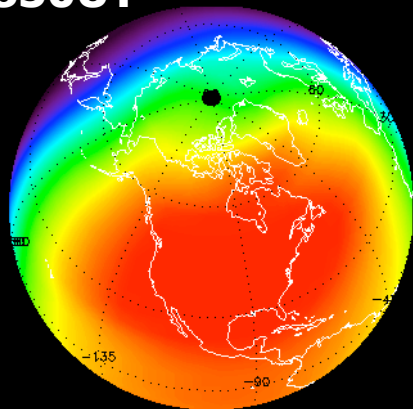
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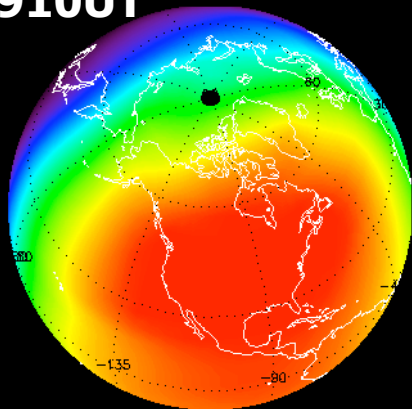
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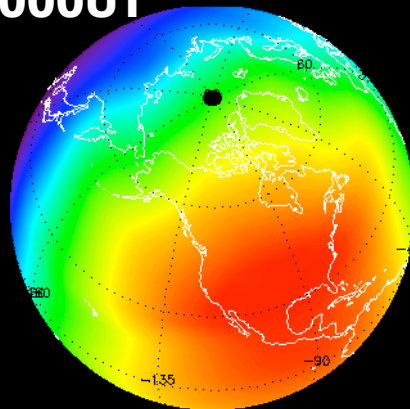
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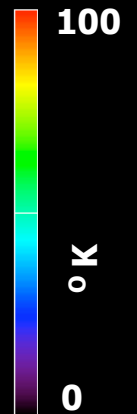
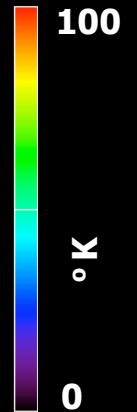
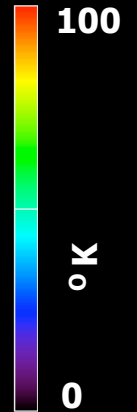
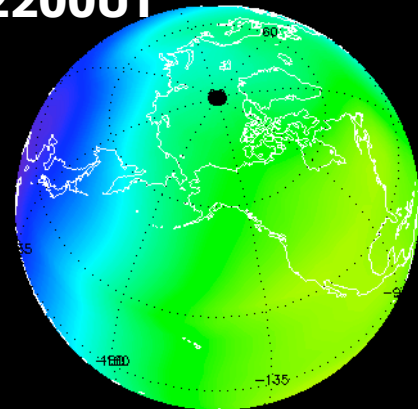
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2000UT



2200UT

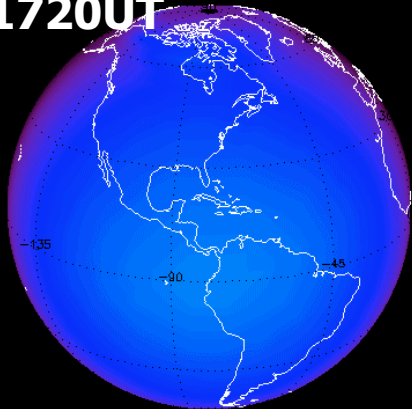


Slide Courtesy of G. Lu, NCAR

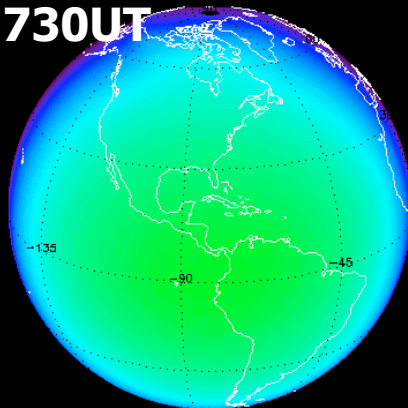
Electron Density at ~110 km During Flare on 9/7/2005

Flare Peak

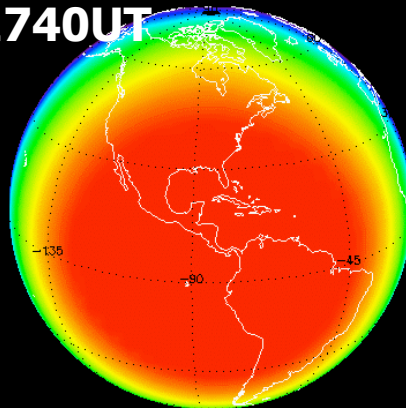
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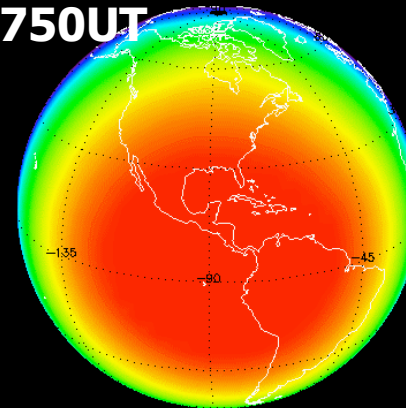
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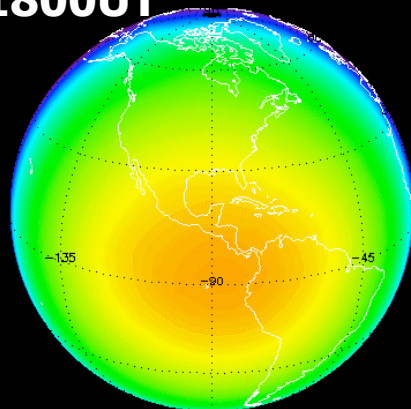
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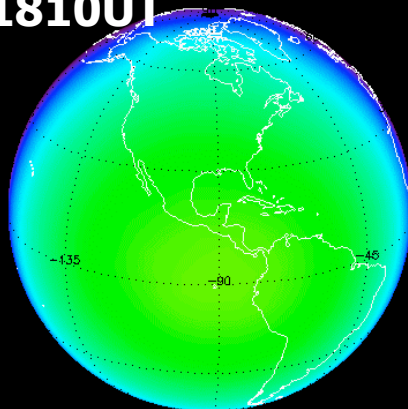
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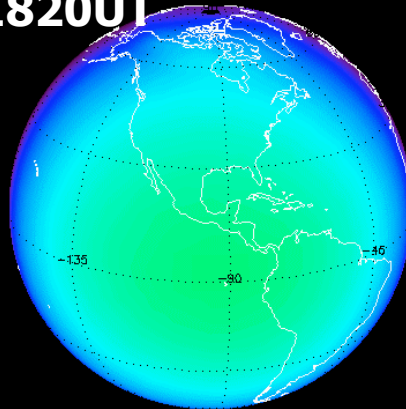
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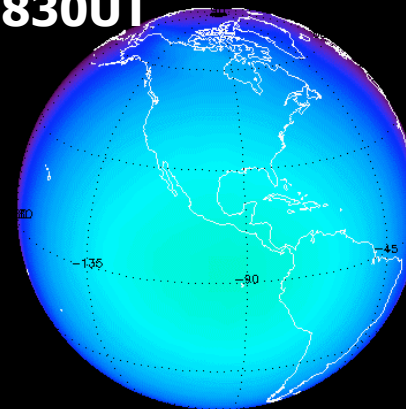
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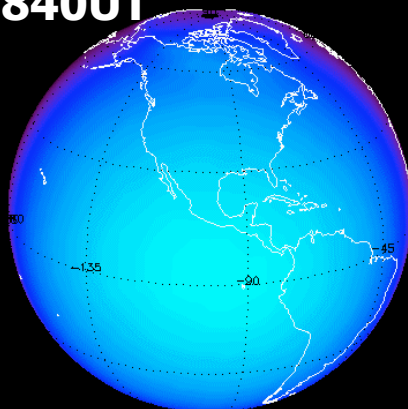
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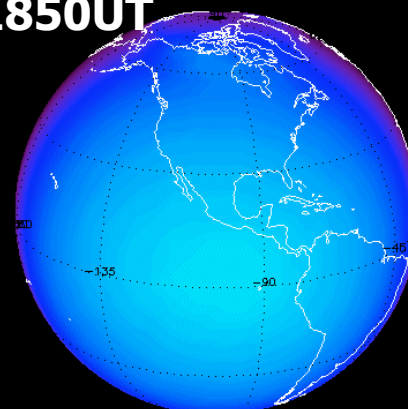
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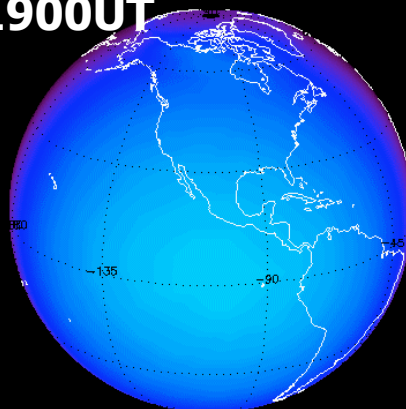
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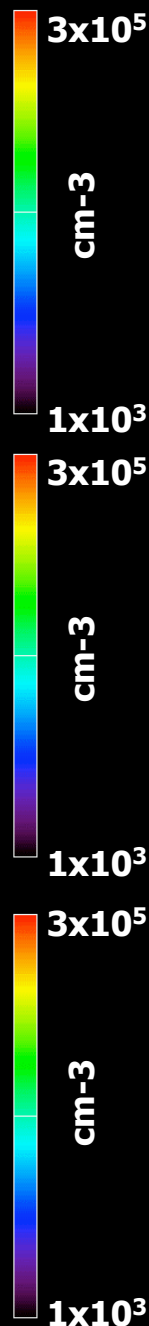
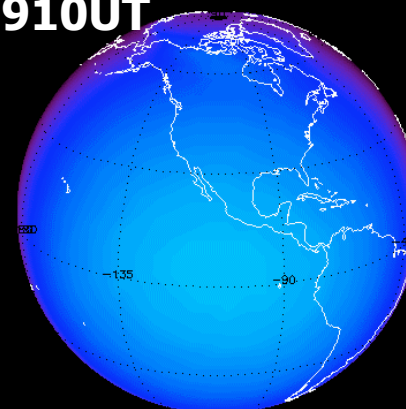
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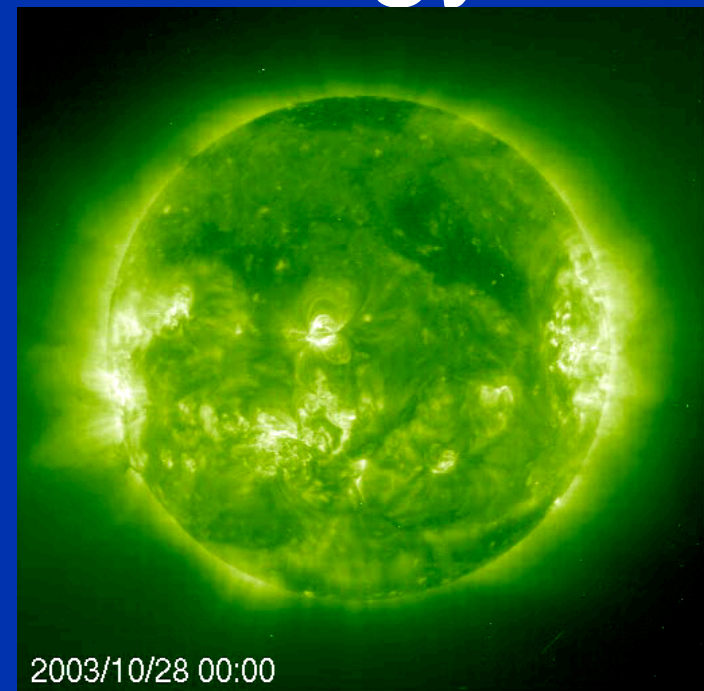
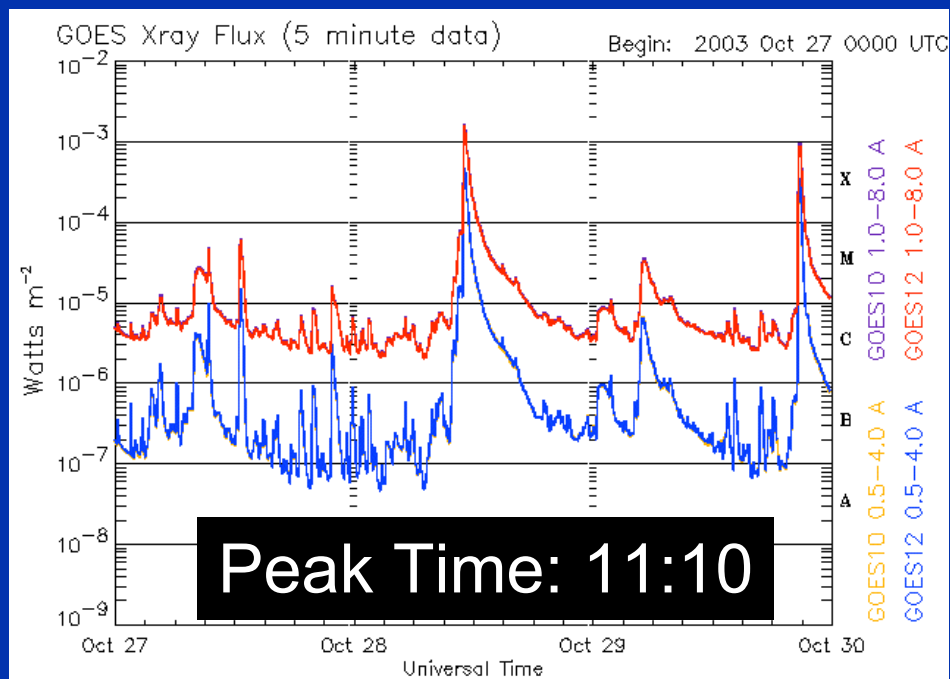


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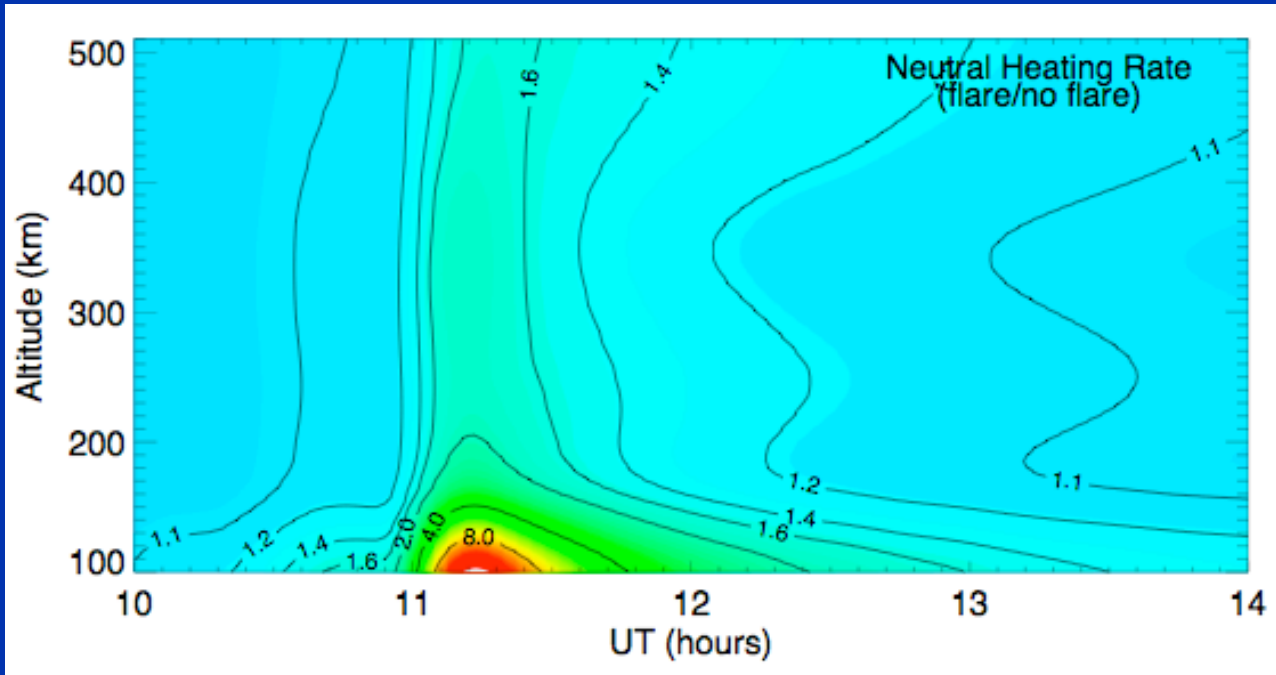


Slide Courtesy of G. Lu, NCAR

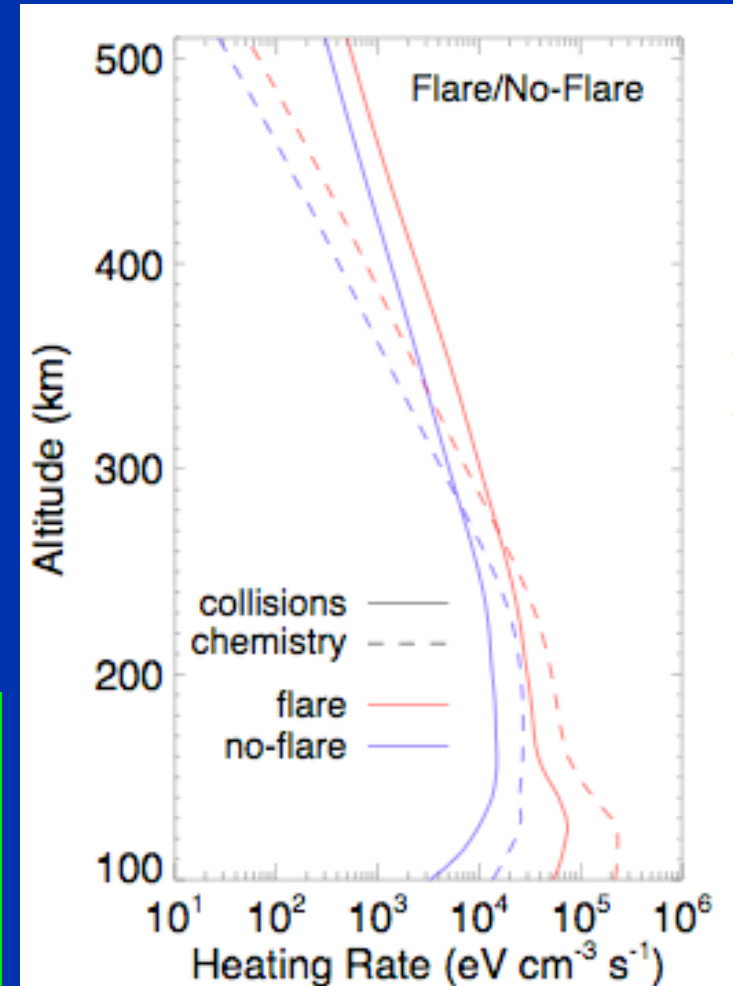
GAIT2 model run using FISM as input for the X17.2 flare on October 28, 2003 Chris Smithtro, Air Force Institute of Technology



Neutral heating rate increase due to VUV increases from flare



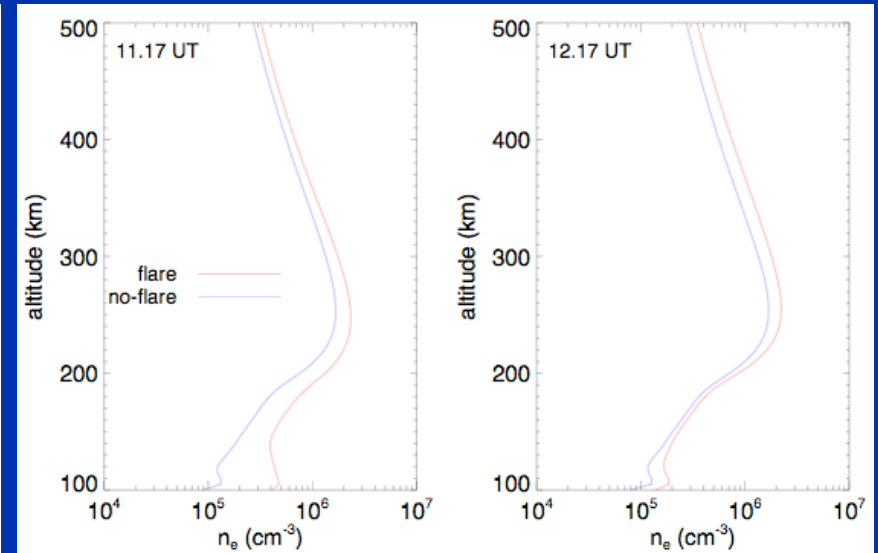
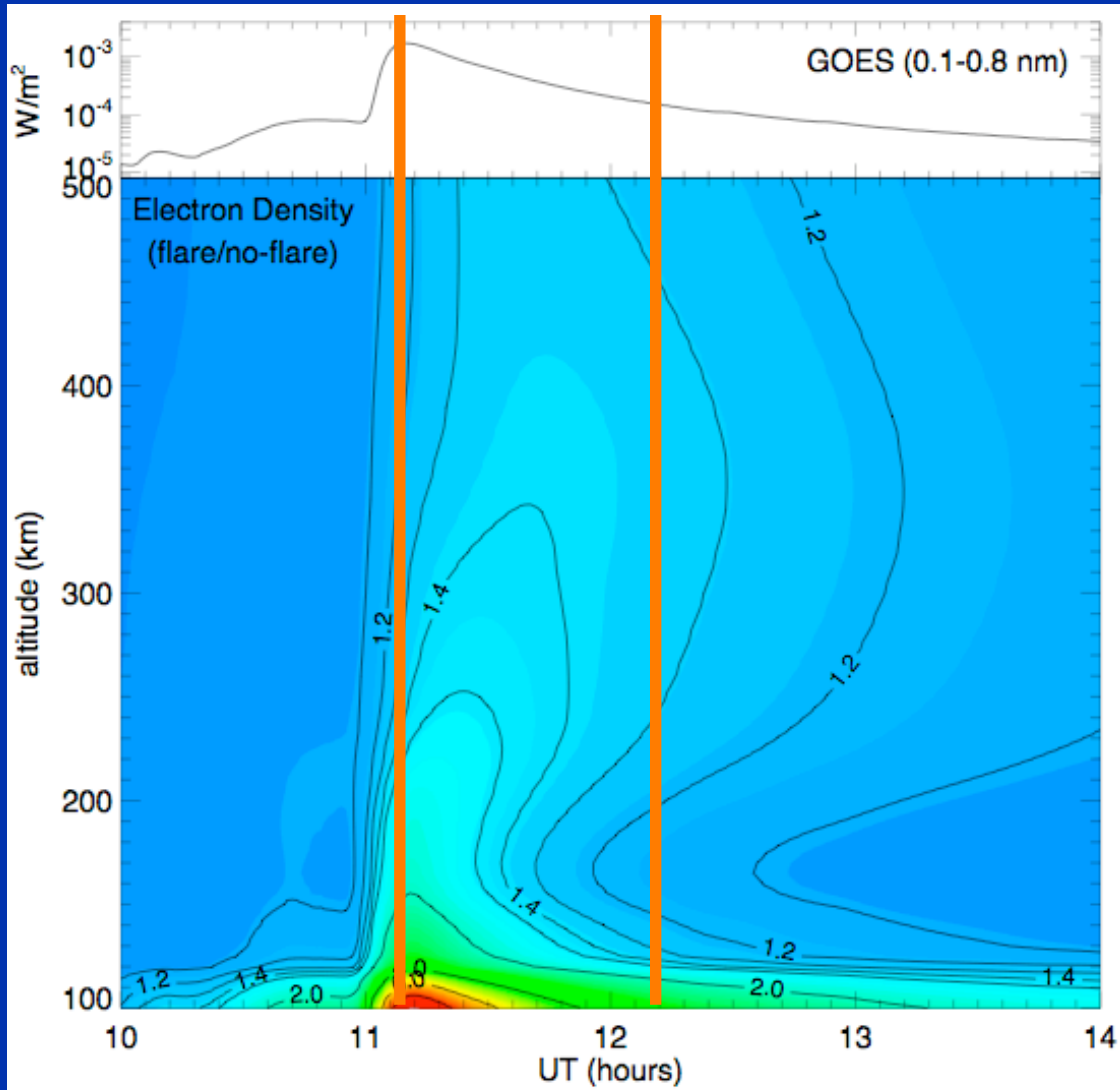
Neutral heating rate increases by almost an order of magnitude at low altitudes where the high-energy solar X-ray photons deposit their energy.



Plots Courtesy of C. Smithro, AFIT



Electron density changes due to the X17 solar flare



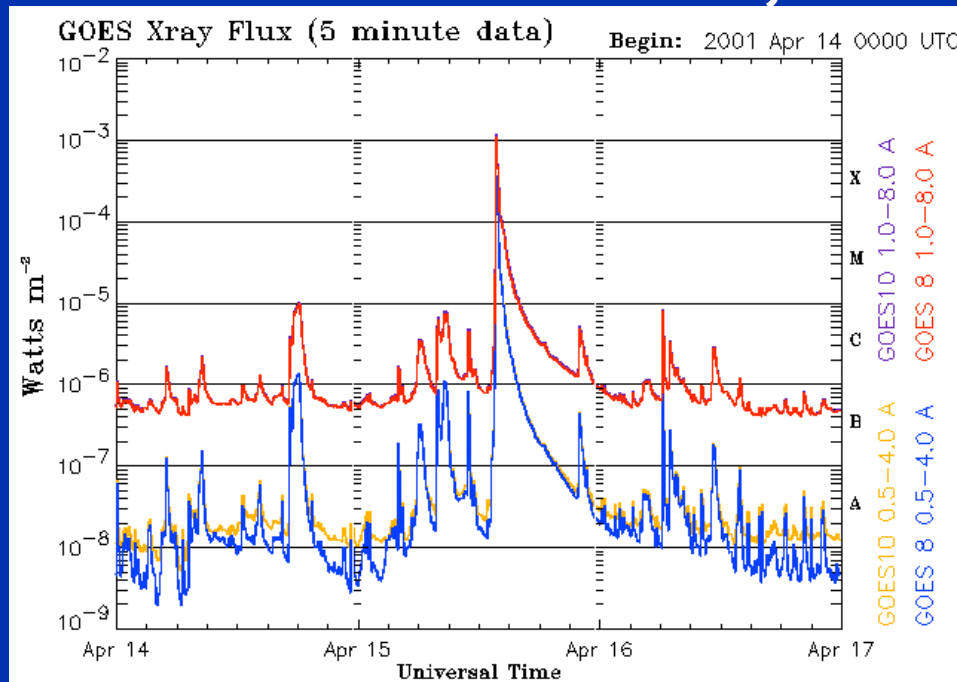
- Larger density (factor of 6) increases at low latitudes (~100 km) due to the order of magnitude increases in the solar X-rays.
- Increased electron densities persist for hours after the peak of the solar flare.

Plots Courtesy of C. Smithro, AFIT



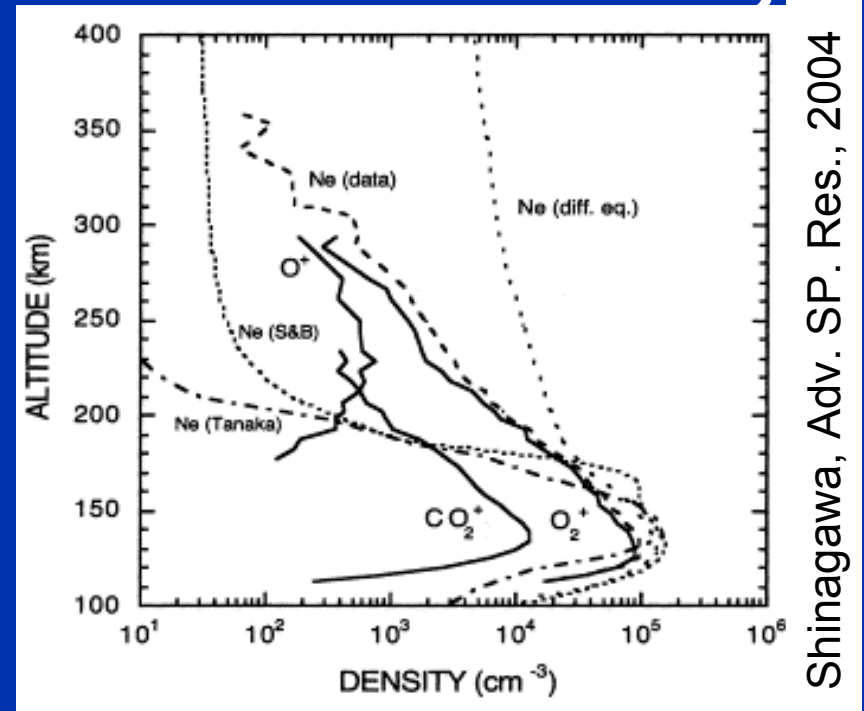
Mars Ionospheric model using FISM compared to MGS RS Measurements for a flare on April 15, 2001

Paul Withers, Boston University



Updated 2001 Apr 16 23:56:05 UTC

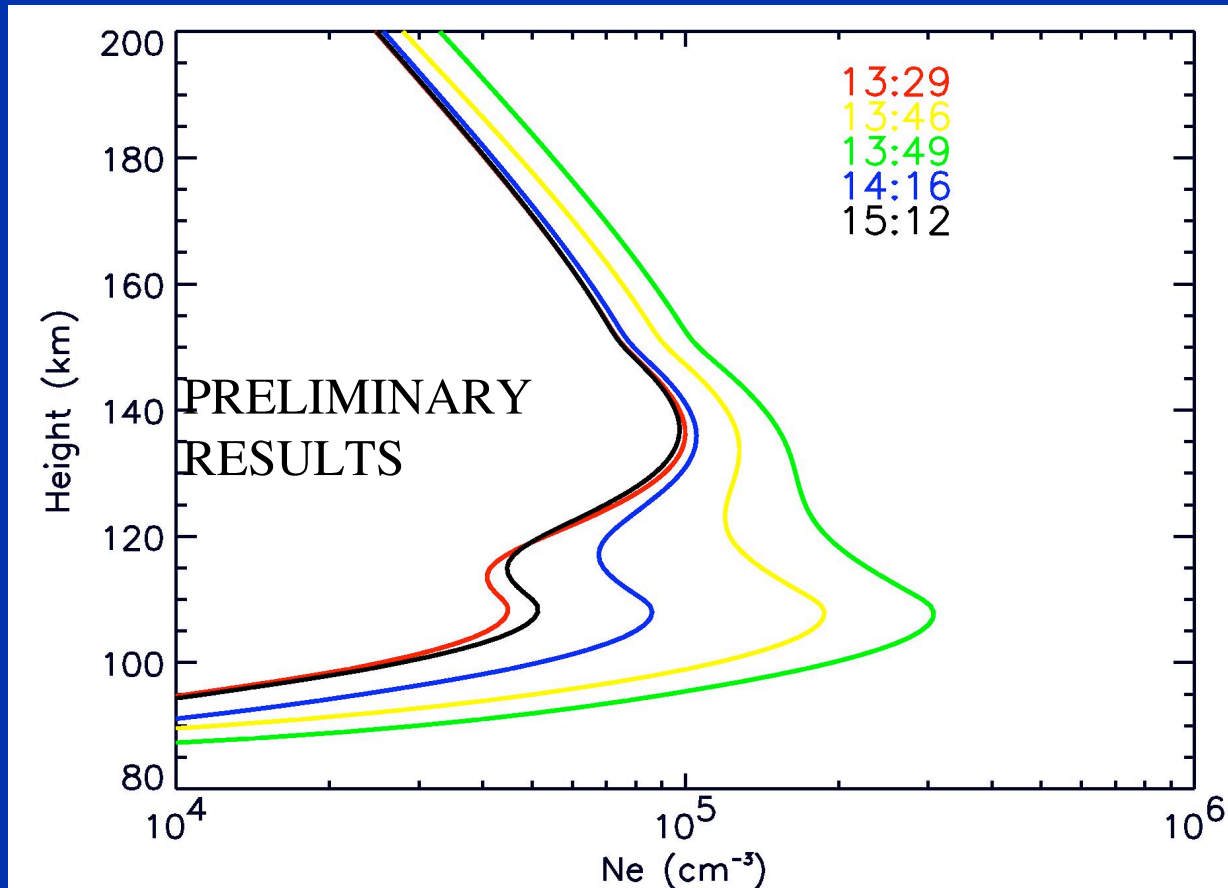
NOAA/SEC Boulder, CO USA



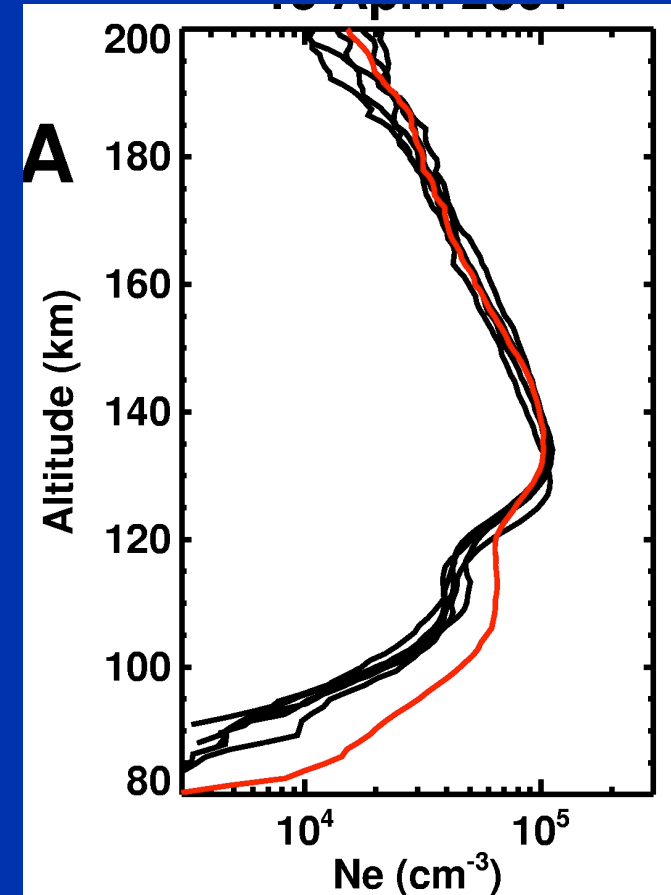
Shinagawa, Adv. SP. Res., 2004



Mars Ne Model and Observation Results



The 110 km peak (produced by X-Rays) exceeds the 140 km peak (produced by EUV) during a flare. The **red line on the right** corresponds temporally to the **blue line on the left**, both at 14:16 UT.



Mars Global Surveyor Radio Science Instrument

Plots courtesy Paul Withers, 2007



Conclusion

- FISM currently provides the most accurate, high temporal resolution estimations of the solar VUV irradiance to the I/T community.
- FISM driven I/T models are currently providing results of many responses of the I/T system to flares.
- Many planned improvements for FISM (nowcast, planetary corrections, impulsive phase timing, EVE data-1 Å)
- EVE will contribute greatly to the FISM estimation, especially for $\lambda < 27$ nm and in the number of flares that FISM is based on.



Extra Slides



June 3, 2008

Chamberlin - CAWSES, Bozeman MT

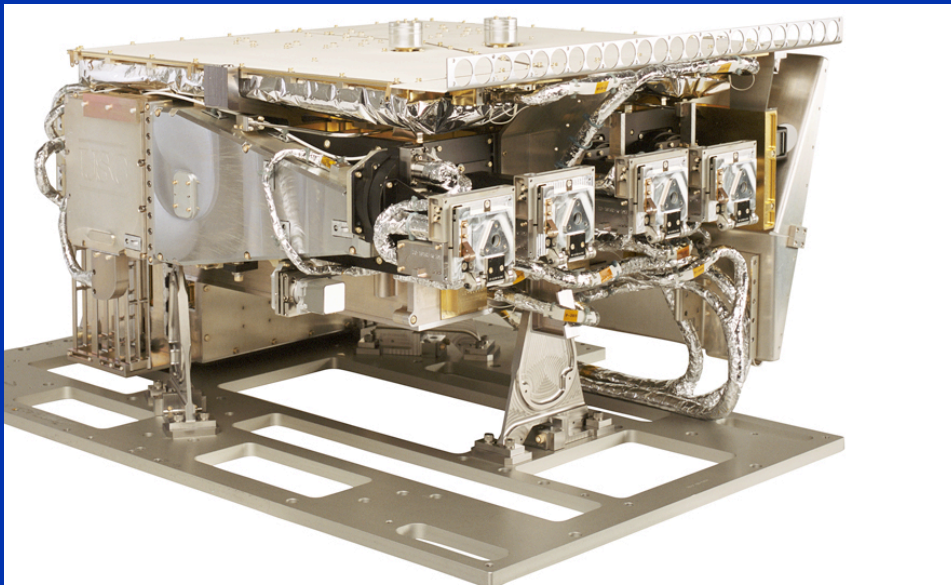
20



EUV Variability Experiment (EVE)

Launch in early 2009
onboard the Solar Dynamics
Observatory (SDO)

<http://lasp.colorado.edu/eve/>



University of Colorado / LASP

- Thomas N. Woods (PI)
- Francis G. Eparvier
- Gary J. Rottman
- Phillip C. Chamberlin

University of Southern California

- Darrell L. Judge, Donald R. McMullin

Naval Research Laboratory

- Judith L. Lean • John T. Mariska
- Harry P. Warren

MIT Lincoln Laboratory

- Gregory D. Berthiaume

University of Alaska • Scott M. Bailey

NOAA • Rodney A. Viereck

Space Environment Technologies

- W. Kent Tobiska

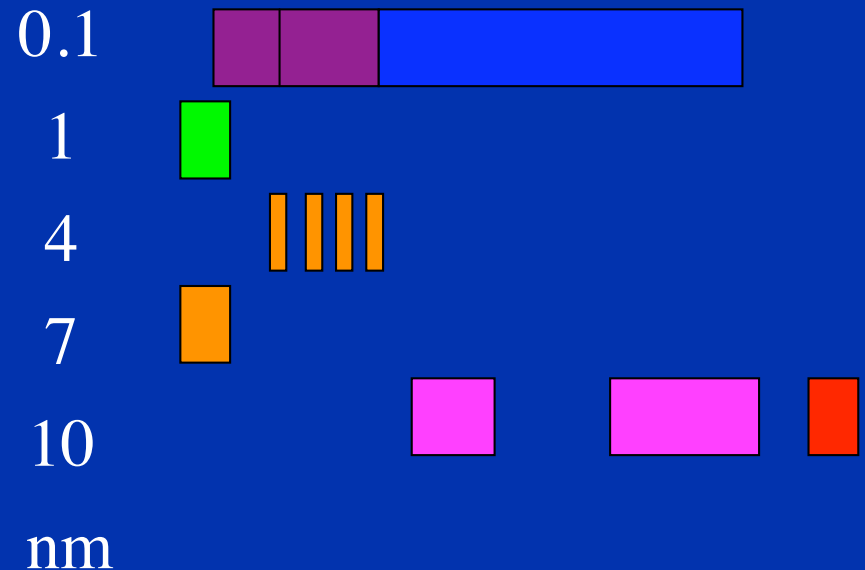
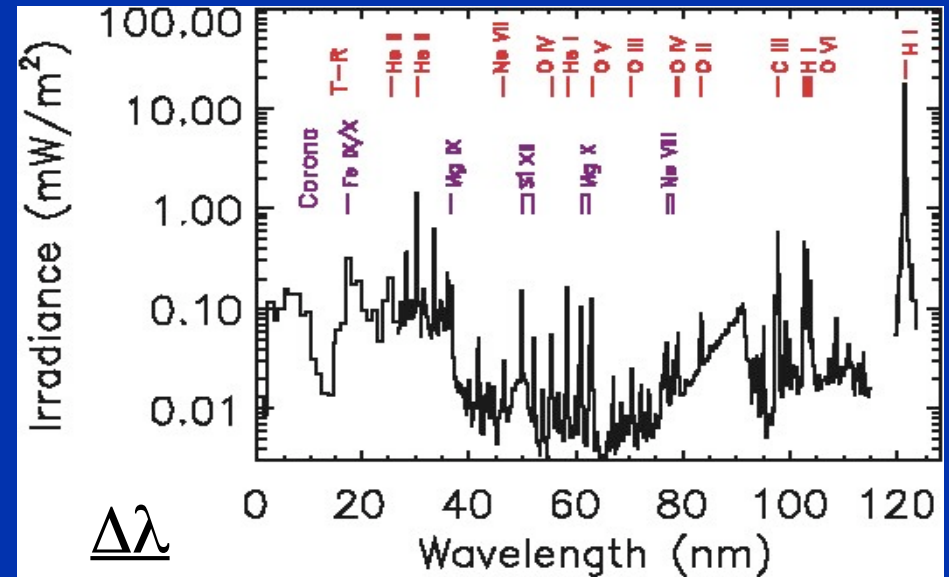
CU/CIRES/NOAA • Timothy J. Fuller-Rowell

Utah State University • Jan J. Sojka



How does EVE measure the EUV?

- Multiple EUV Grating Spectrograph (MEGS)
 - At 0.1 nm resolution
 - MEGS-A: 5-37 nm
 - MEGS-B: 35-105 nm
 - At 1 nm resolution
 - MEGS-SAM: 0-7 nm
 - At 10 nm resolution
 - MEGS-Photometers: @ 122 nm
 - Ly- α Proxy for other H I emissions at 80-102 nm and He I emissions at 45-58 nm
- EUV Spectrophotometer (ESP)
 - At 4 nm resolution
 - 17.5, 25.6, 30.4, 36 nm
 - At 7 nm resolution
 - 0-7 nm (zeroth order)
- In-flight calibrations from ESP and MEGS-P on daily basis and also annual calibration rocket flights

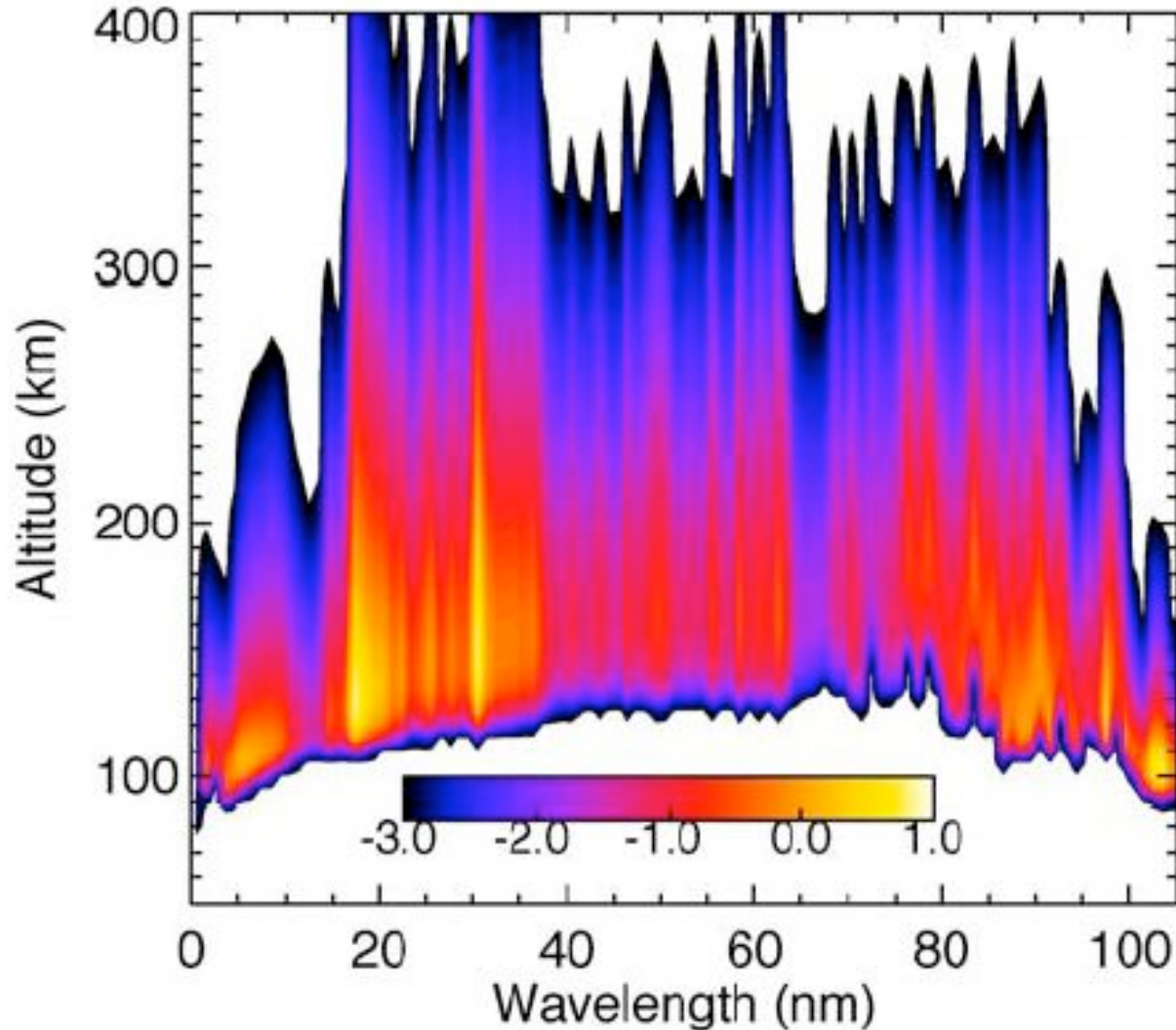


How will EVE help FISM?

- 10 sec (0.25 sec for ESP) temporal resolution, 100% duty cycle
 - EVE will measure all flares with very good temporal resolution and concurrent spectral information.
 - FISM is currently based on 11 impulsive phase observations and 29 gradual phase observations at one point during the flare from TIMED SEE.
- Extend the solar XUV and EUV irradiance measurement set with better accuracy.
- Higher spectral resolution, especially for $\lambda < 27\text{nm}$
 - EVE measurements will allow FISM to improve to 0.1 nm resolution.
- EVE will help determine the relationship between EUV and XUV flares.
 - Can there be an EUV flare with no XUV component?



Earth's Atmosphere Absorbs Solar VUV

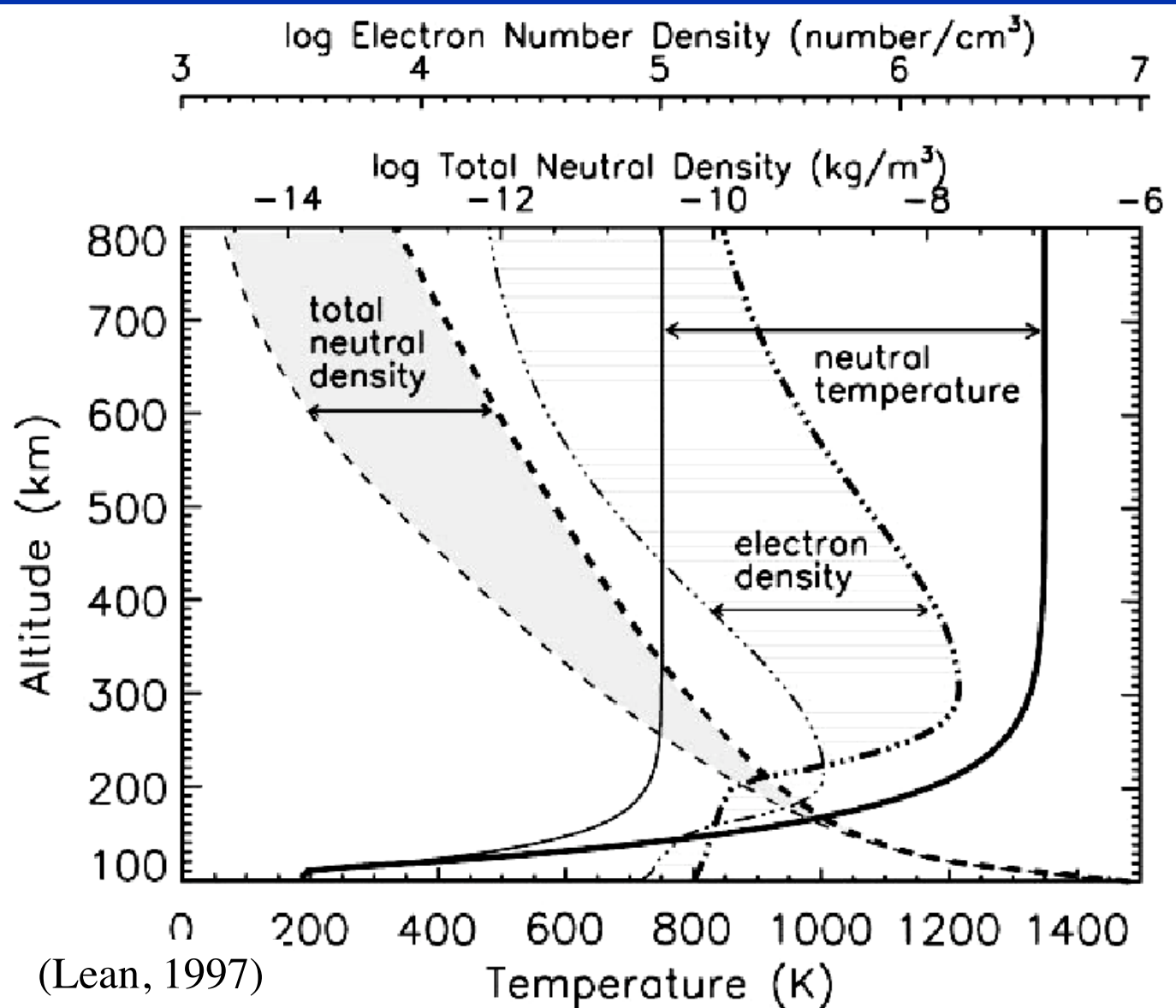


(Solomon and Qian, *JGR*, 2005)

Solar VUV irradiance is deposited in the Earth's upper atmosphere and is the primary source of energy that provides the temperature and density characteristics



Solar Cycle Effects on Earth's Atmosphere



Electron density varies by a factor of 10 over a solar cycle

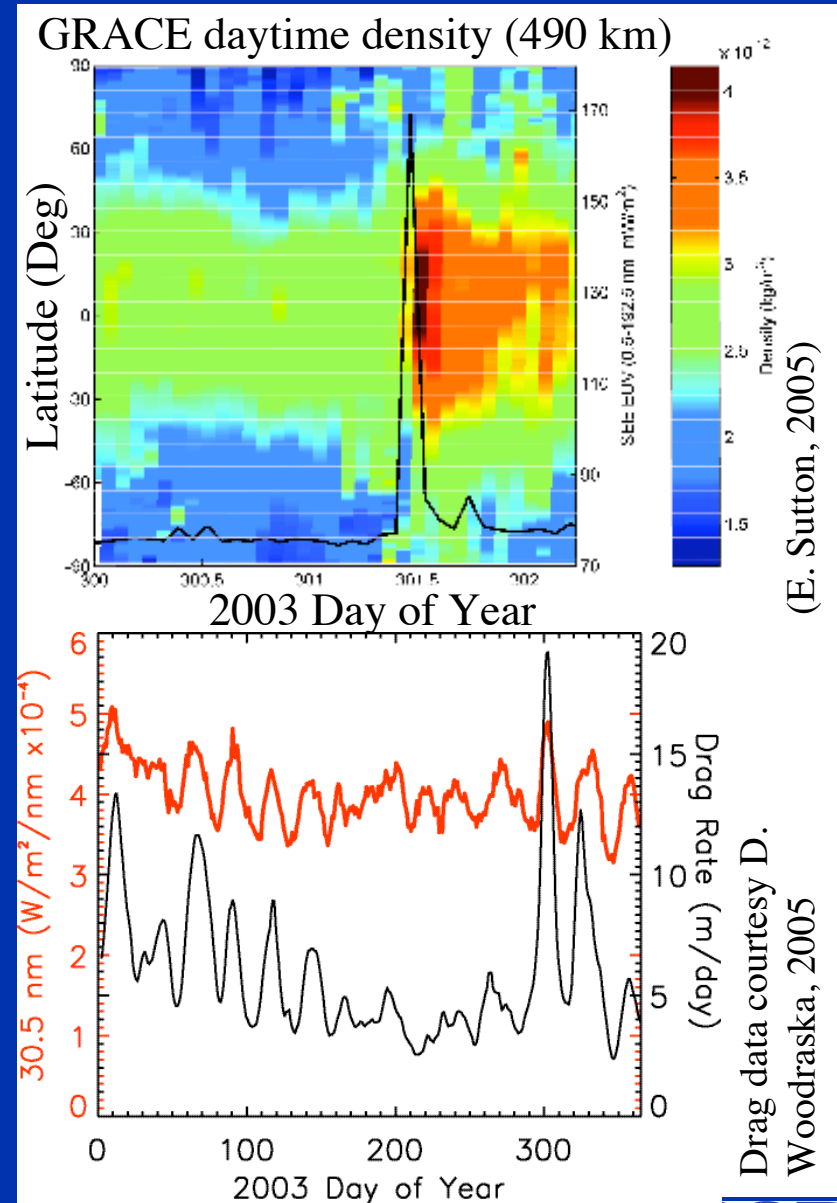
Temperature varies by a factor of 2 over a solar cycle

Neutral density varies by more than a factor of 10

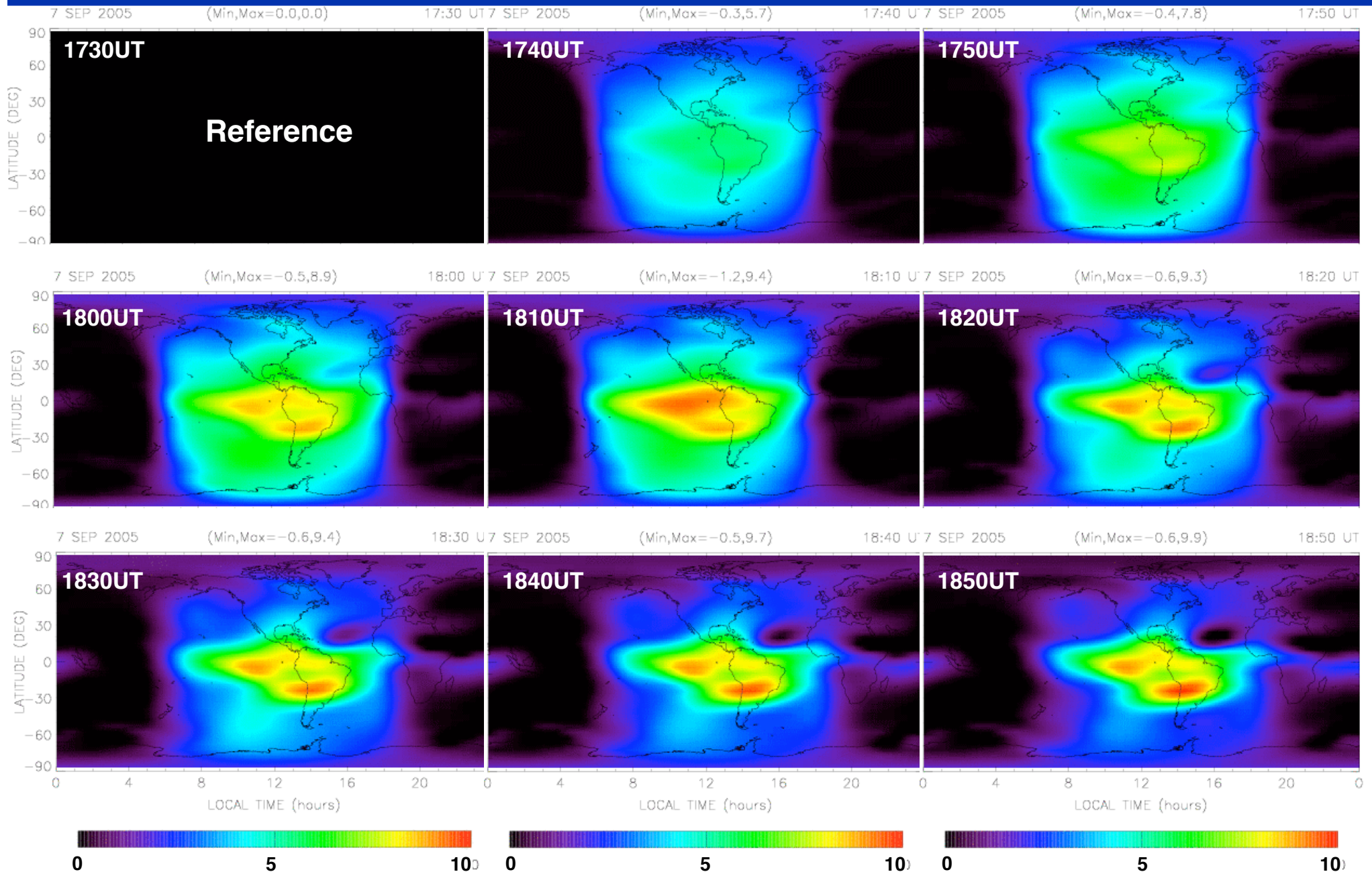


Solar Variations Cause Atmospheric Changes

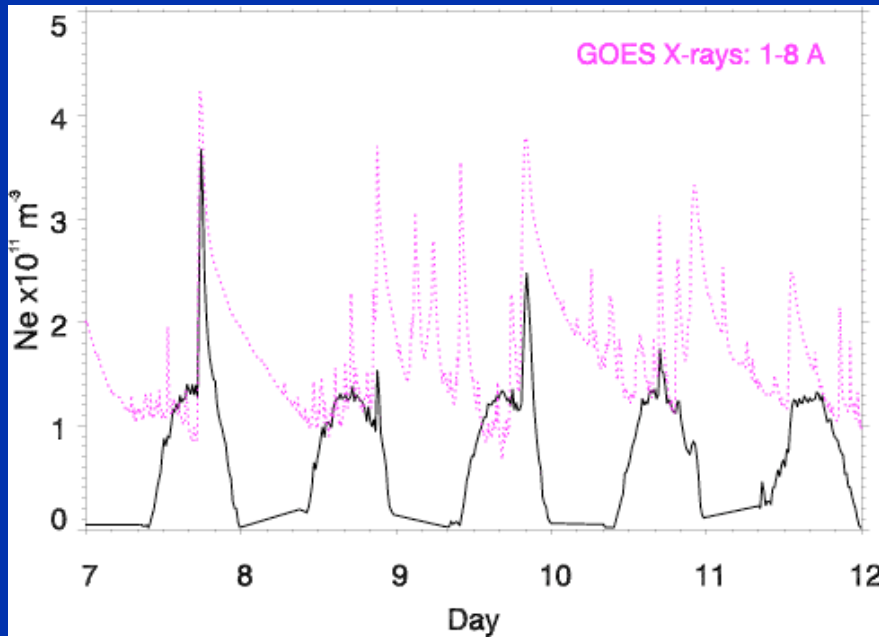
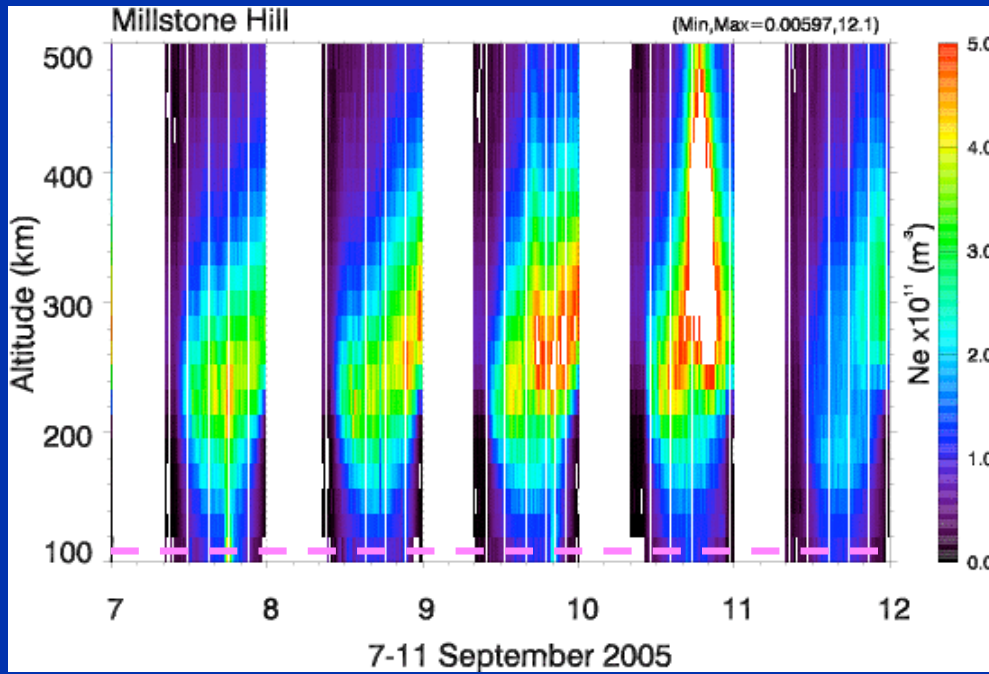
- Increased neutral particle density in low latitude regions on the dayside → Satellite Drag.
- Sudden Ionospheric Disturbances (SIDs) lead to Single Frequency Deviations (SFDs).
- Cause radio communication blackouts
- Cause increased error in GPS accuracy



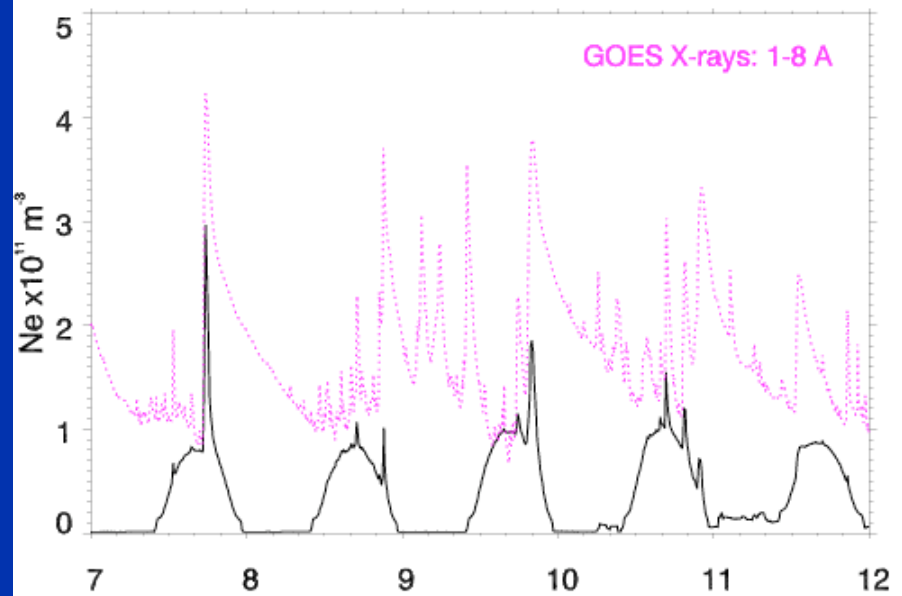
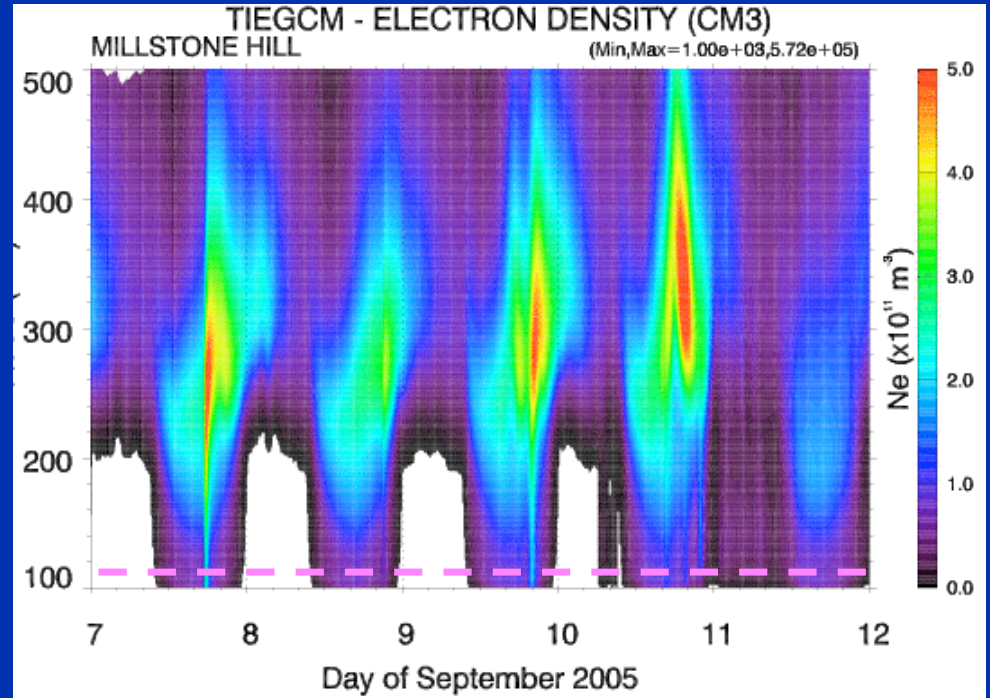
TIEGCM Difference TEC Maps During Flare



Observed N_E



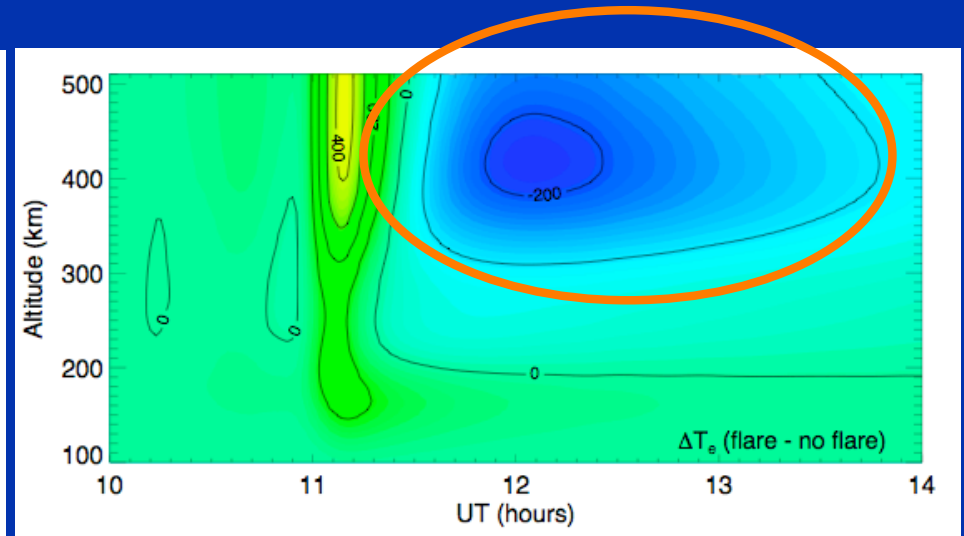
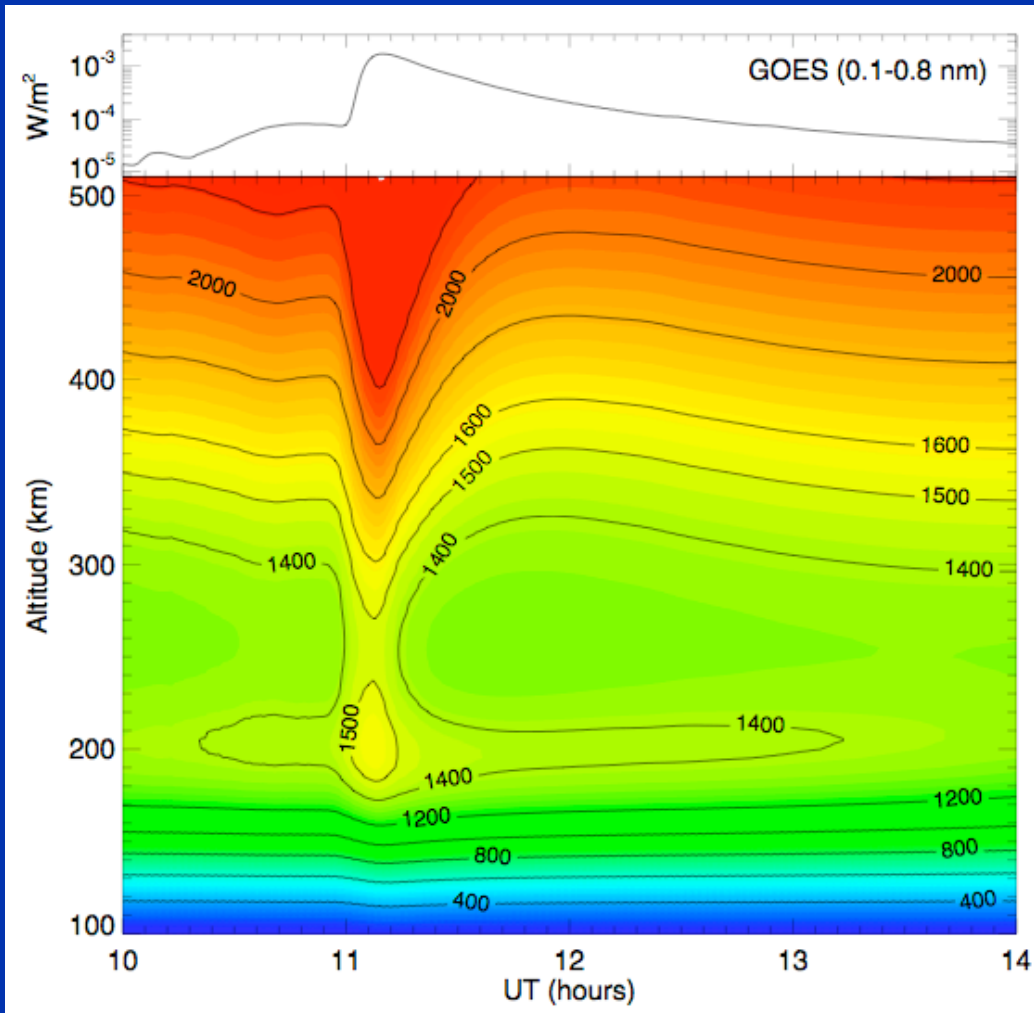
Modeled N_E



Slide Courtesy of G. Lu, NCAR



Electron temperature changes due to the X17 solar flare



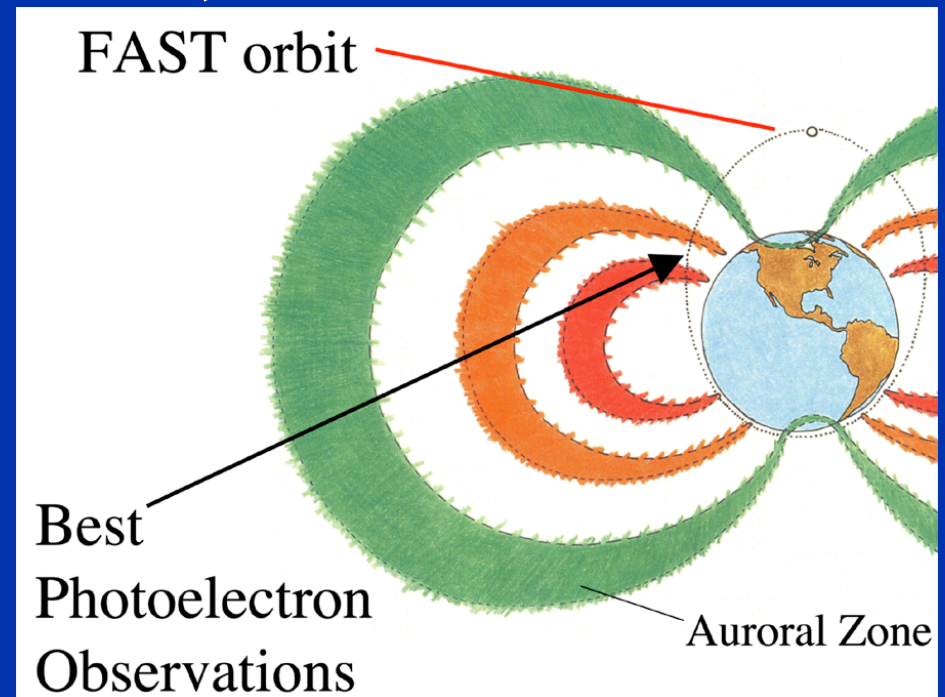
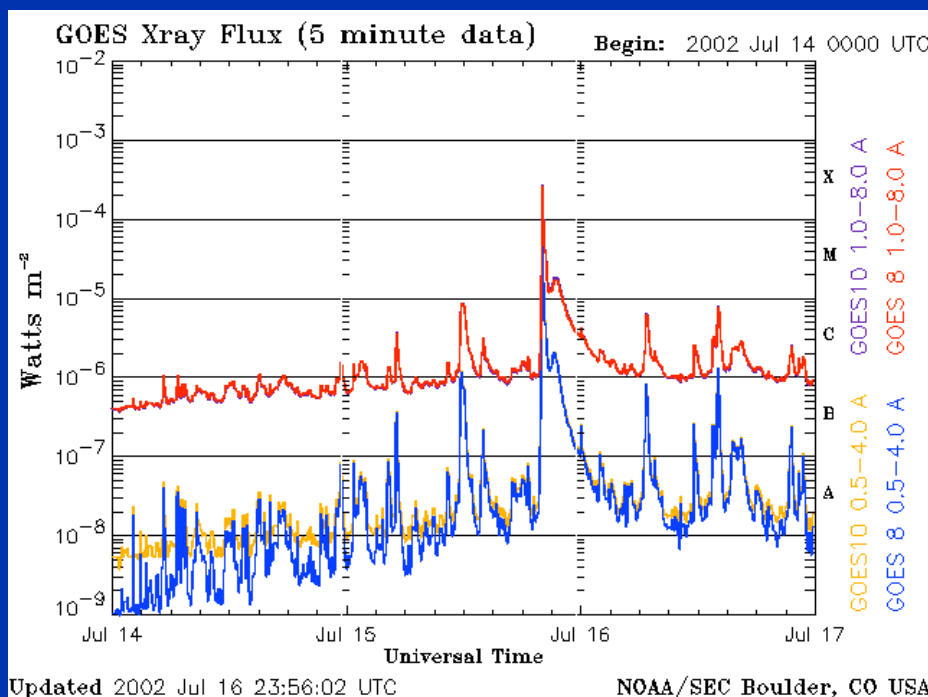
Temperature changes can be as high as 400K in the upper atmosphere around 500 km. The increased electron density at high latitudes leads to larger cooling rates that produce cooler temperatures post-flare at these latitudes

Plots Courtesy of C. Smithro, AFIT



Photoelectron production from FAST observations and FLIP simulations using FISM for the X3.0 flare on July 15, 2002

W. K. Peterson, LASP



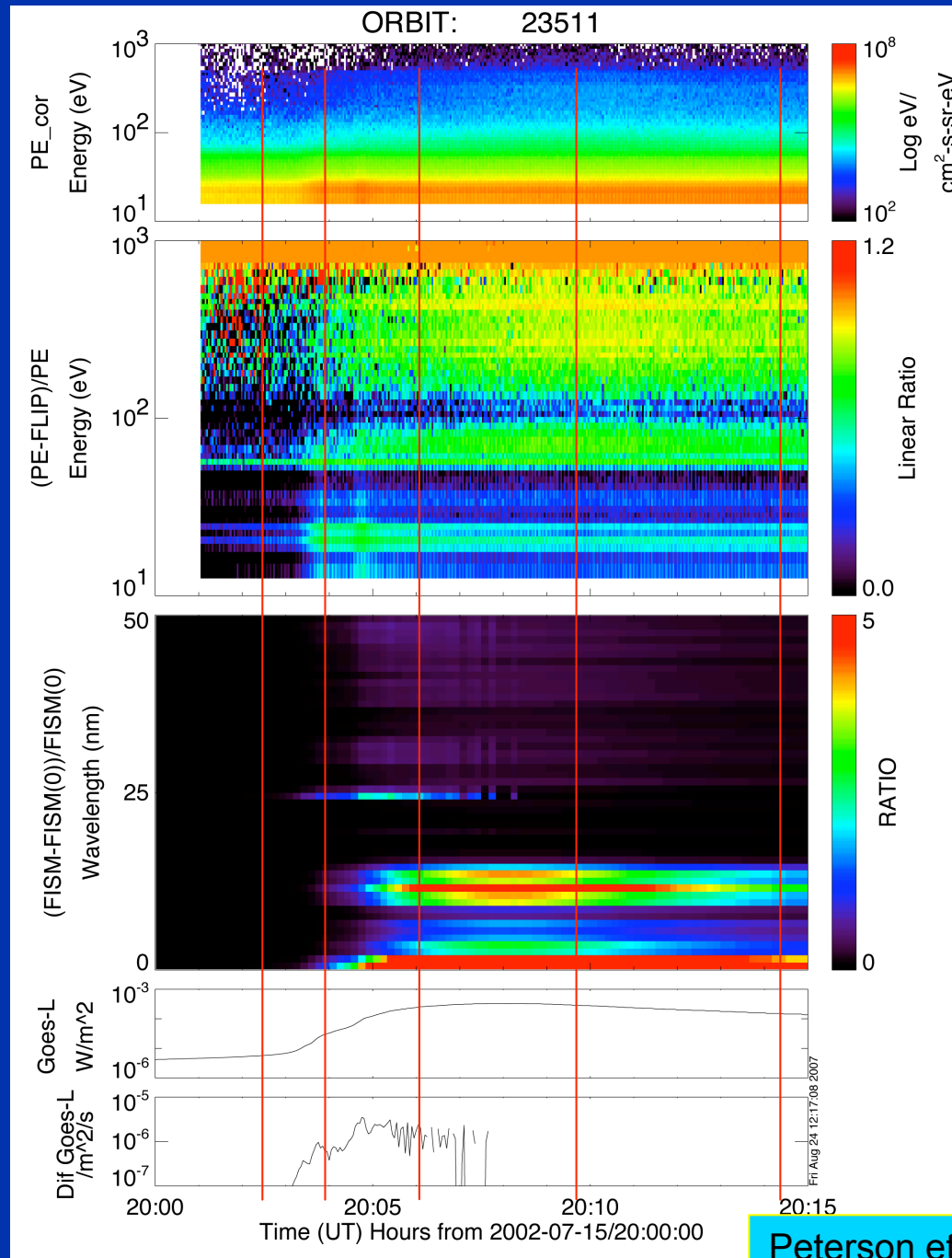
FAST PE

Temporal response of the PE spectrum relative to a static model based on the HEUVAC EUV spectrum

$$\frac{\text{FISM} - \text{FISM}(t_0)}{\text{FISM}(t_0)}$$

GOES X-ray Flux

Differential of GOES X-ray Flux

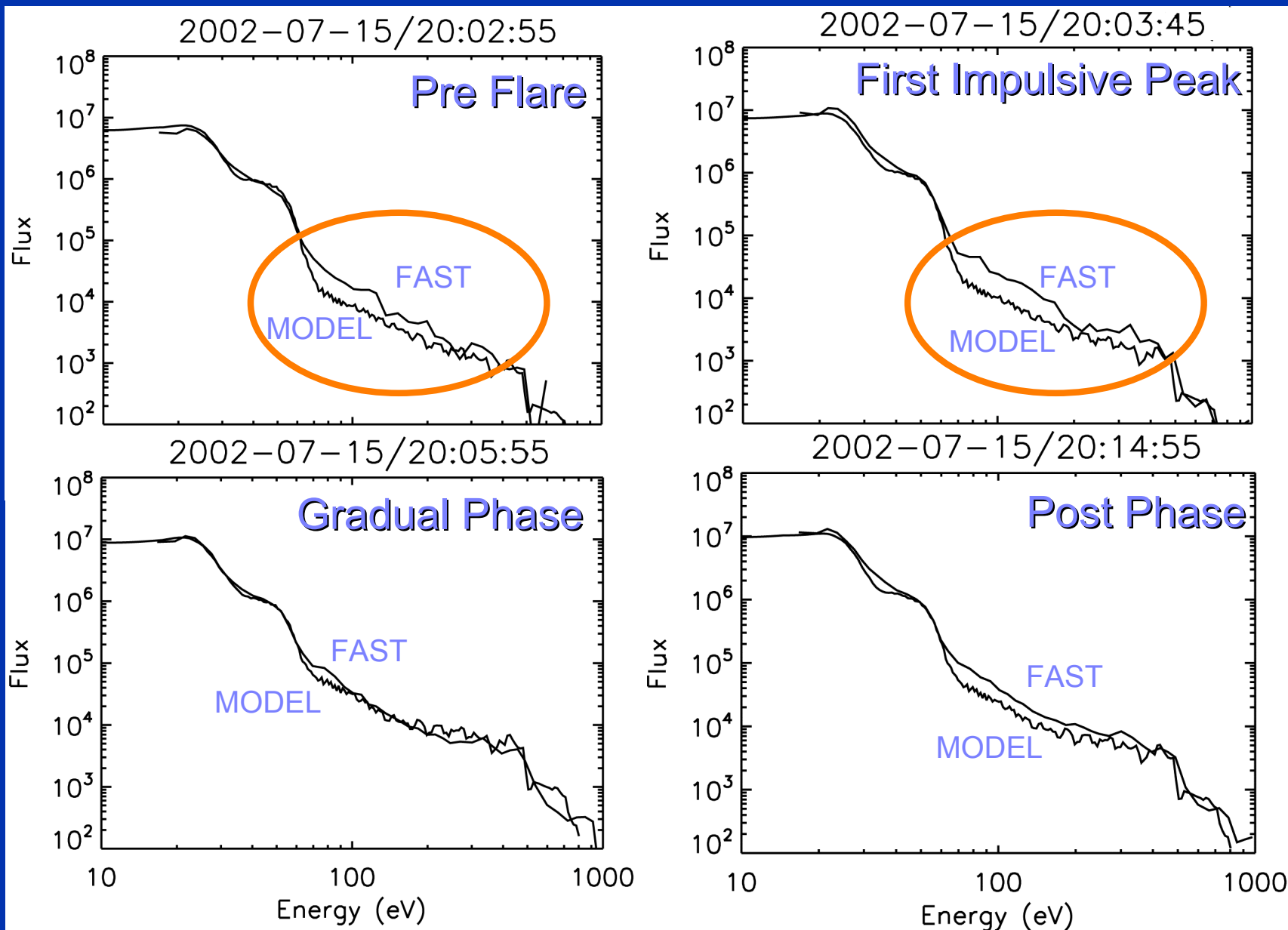


Temporal response of the FISM model EUV spectrum (1nm resolution)

Peterson et al., LWS, Boulder, 2007



FISM/FLIP and FAST Comparison



Peterson et al., LWS, Boulder, 2007

