
Solar EUV Spectral Irradiance: Measurements

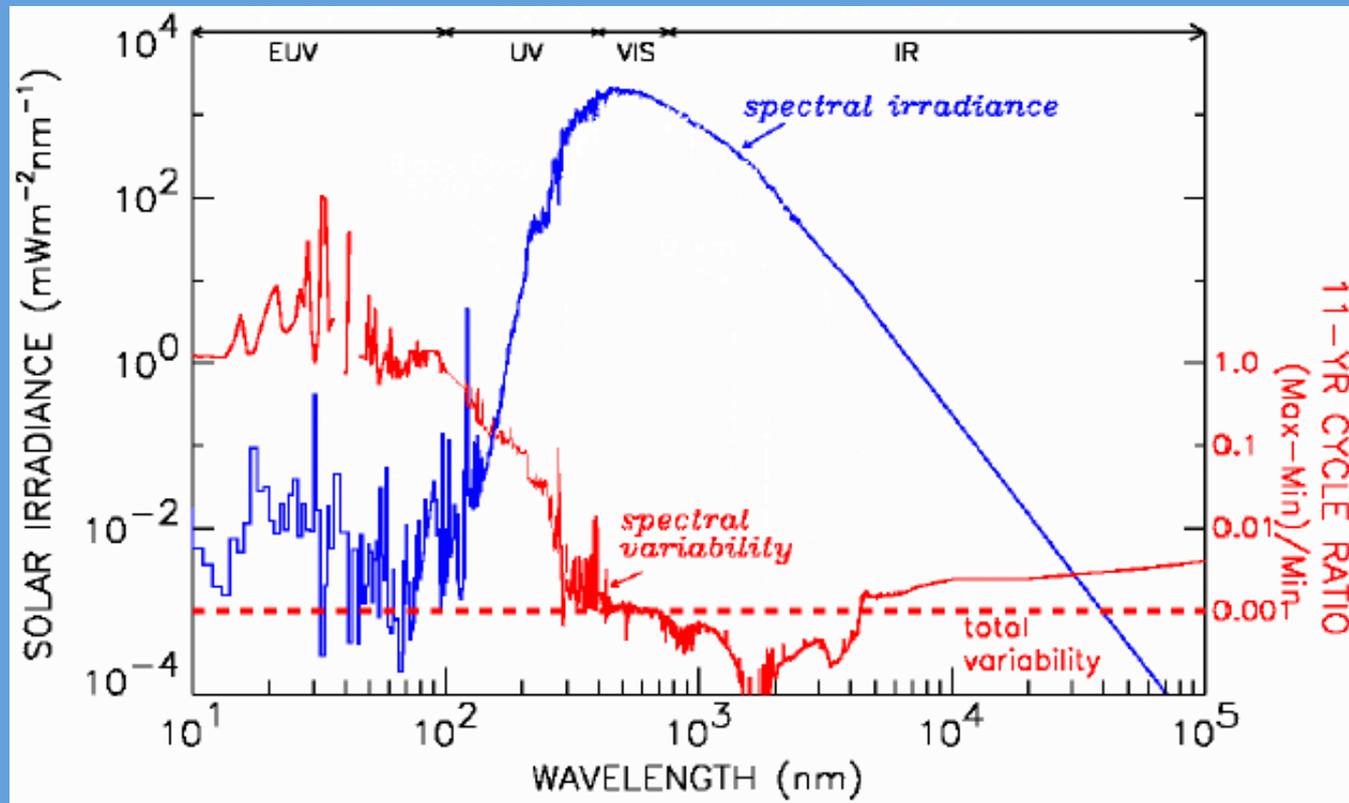
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Outline

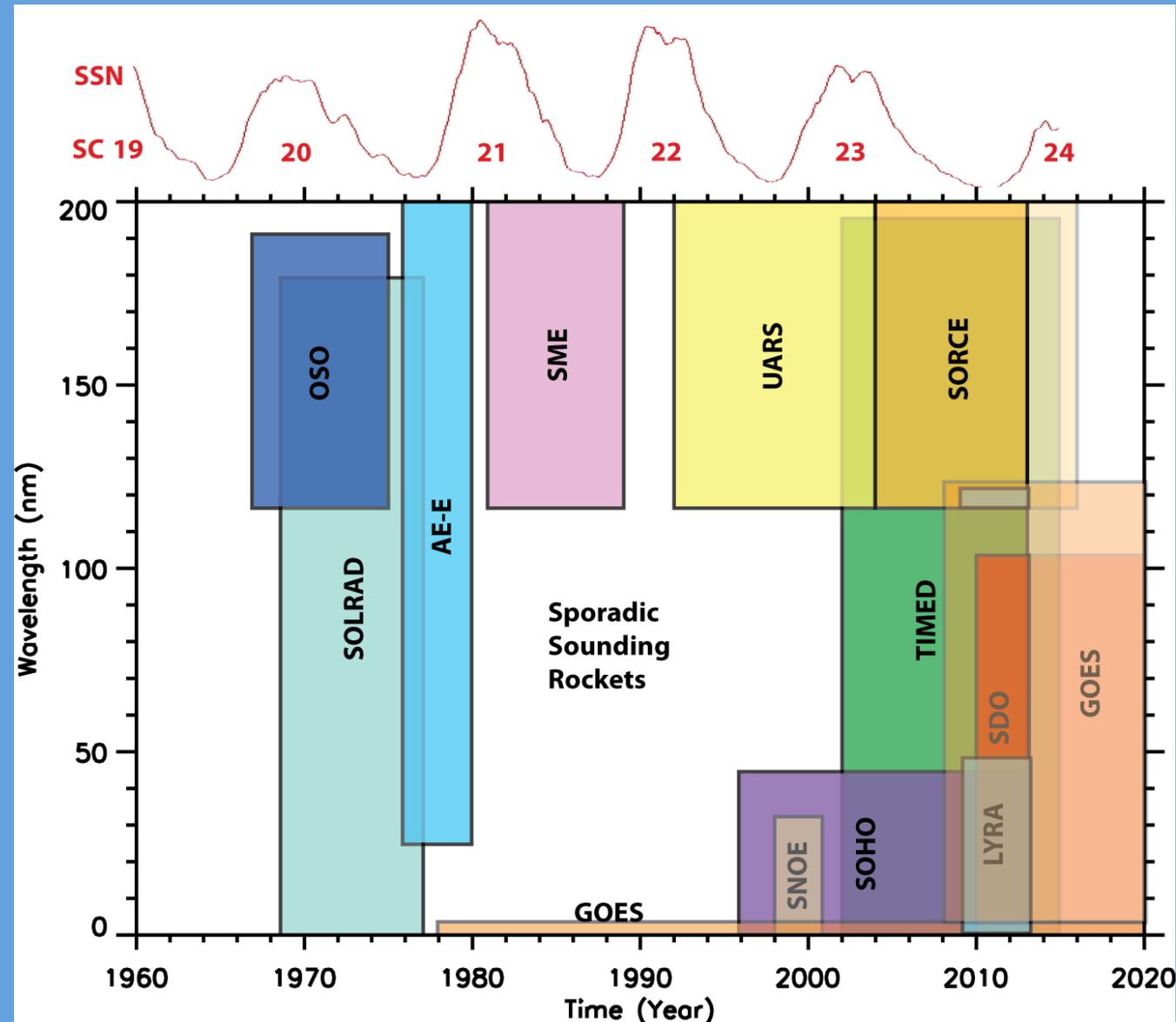
- Introduction to Solar EUV Irradiance
- TIMED-SEE and SDO-EVE
- New Insights into EUV Sun from EVE
- The Future of EUV Measurements
- Summary

The Solar Irradiance Spectrum



- Spectrum looks like blackbody ($\sim 5700\text{K}$) in visible
- TSI is integrated total ($\sim 1361 \text{ W/m}^2$)
- VUV accounts for $<0.1\%$ of TSI, yet can account for up to a third of TSI variability.

Measurements of EUV Spectral Irradiance

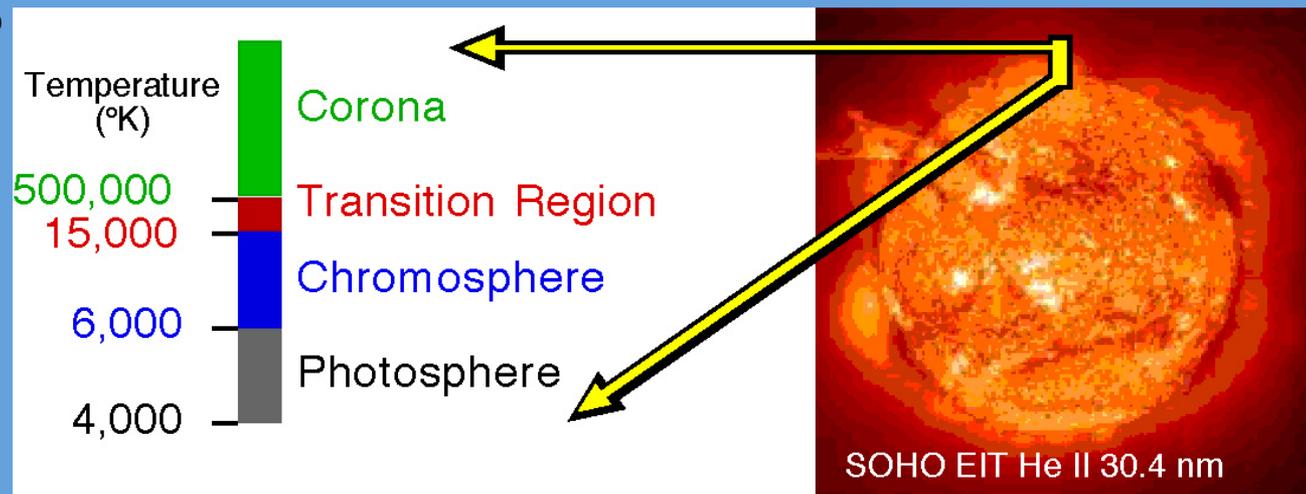
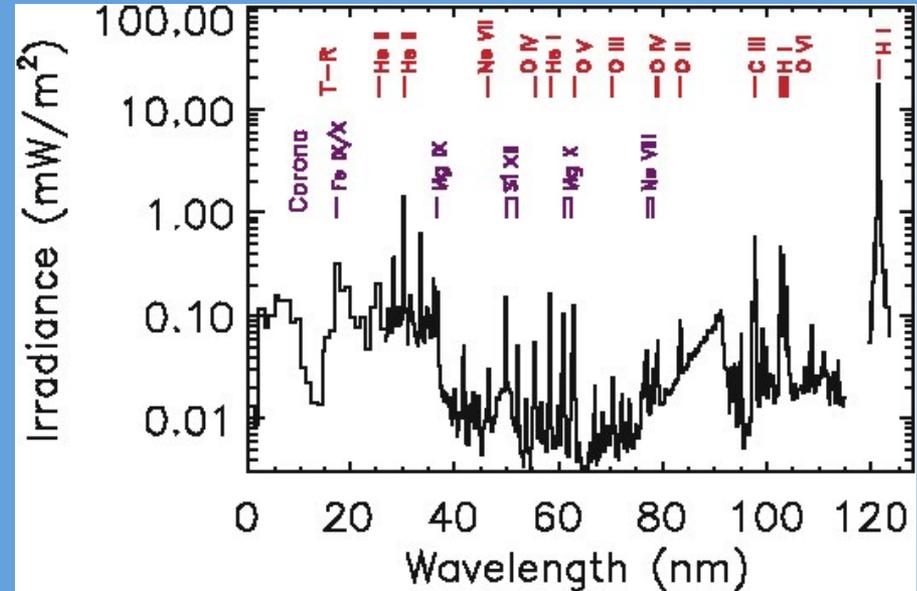


EUV irradiance measurements have been sparse.

Accuracy, precision, cadence, wavelength resolution and coverage have been less than ideal.

The Solar EUV and XUV

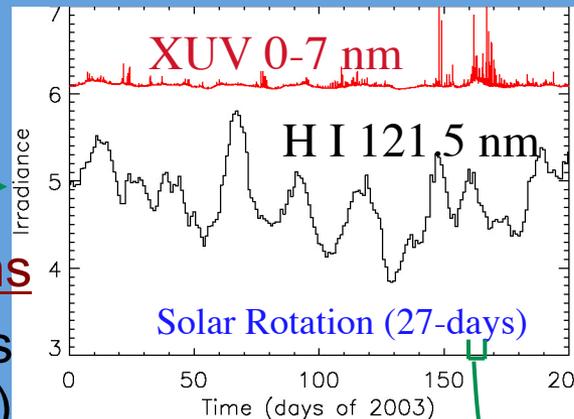
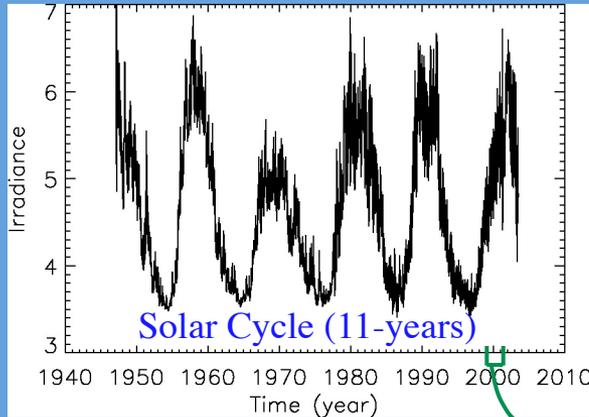
- The solar EUV and XUV radiation consists of emissions from the solar **chromosphere**, **transition region**, and **corona**
- EUV/XUV is $< 0.01\%$ of the total solar irradiance (TSI: $>99\%$ from photosphere)
 - **But** EUV/XUV variations are a factor of 2 - 100 (wavelength dependent), whereas TSI variations are typically only 0.1%



Irradiance Varies on All Timescales

Solar Cycle - months to years

Evolution of solar dynamo with 22-year magnetic cycle, 11-year intensity (sunspot) cycle

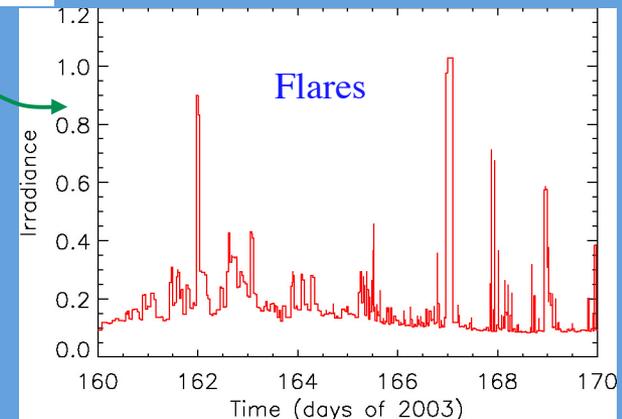


Solar Rotation - days to months

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



TIMED-SEE

- **TIMED-Solar EUV Experiment**

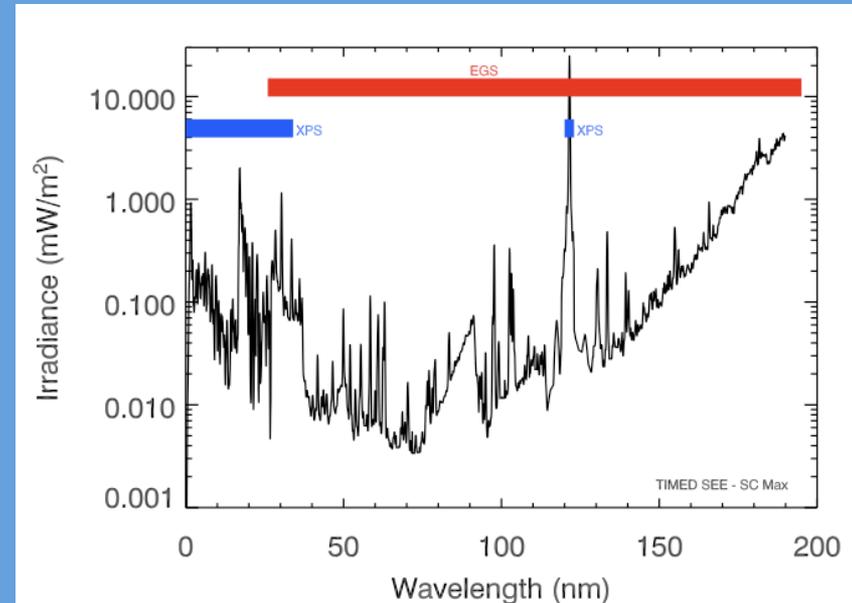
- Launched Dec 7, 2001
- Still operating (data version 11)

- **SEE Measurements:**

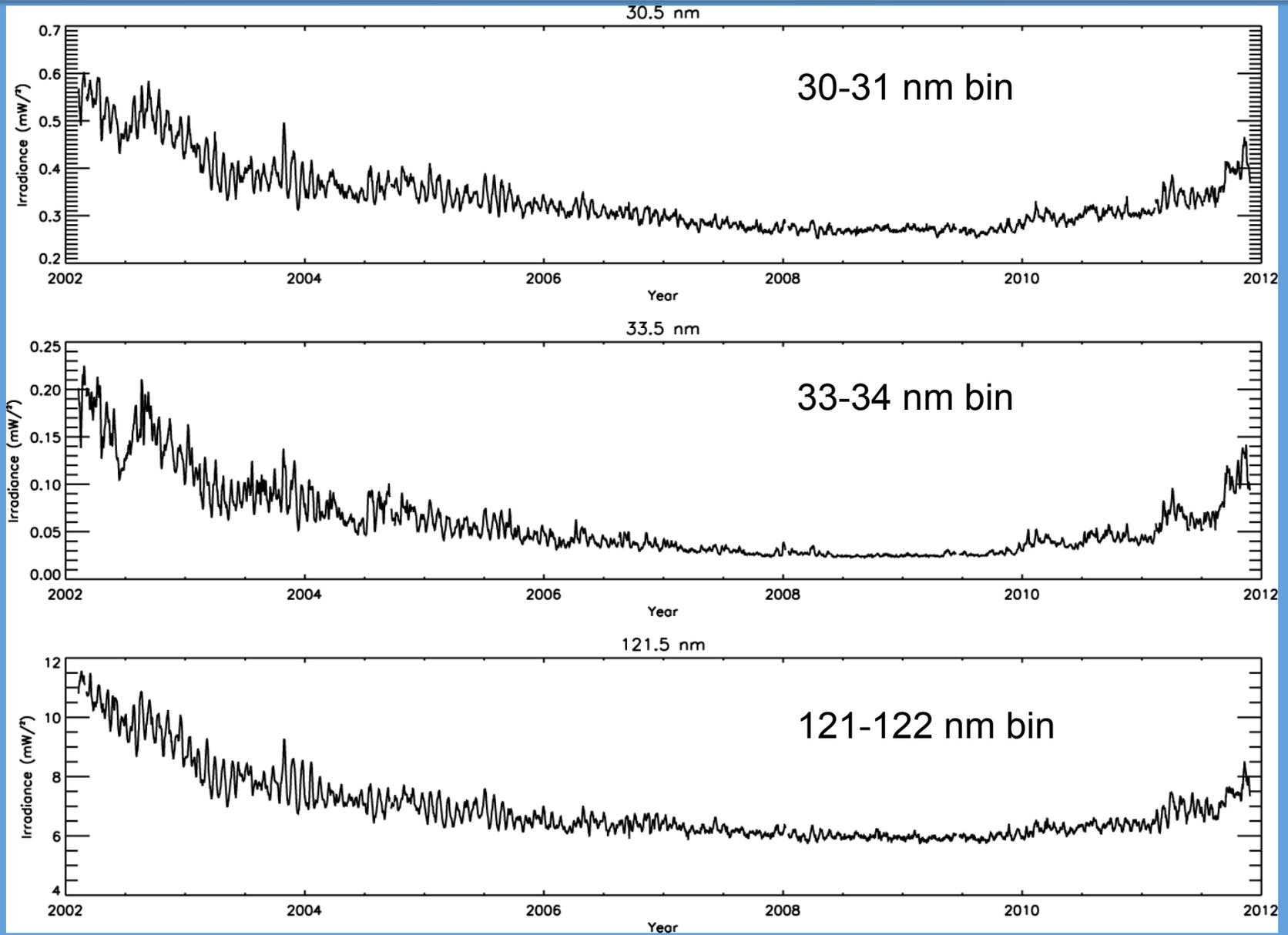
- 27-195 nm at 0.4 nm resolution (EGS)
- <27 nm broad bands (XPS)
- 3% duty cycle (3-minutes every 96 minutes)

- **SEE Data Products:**

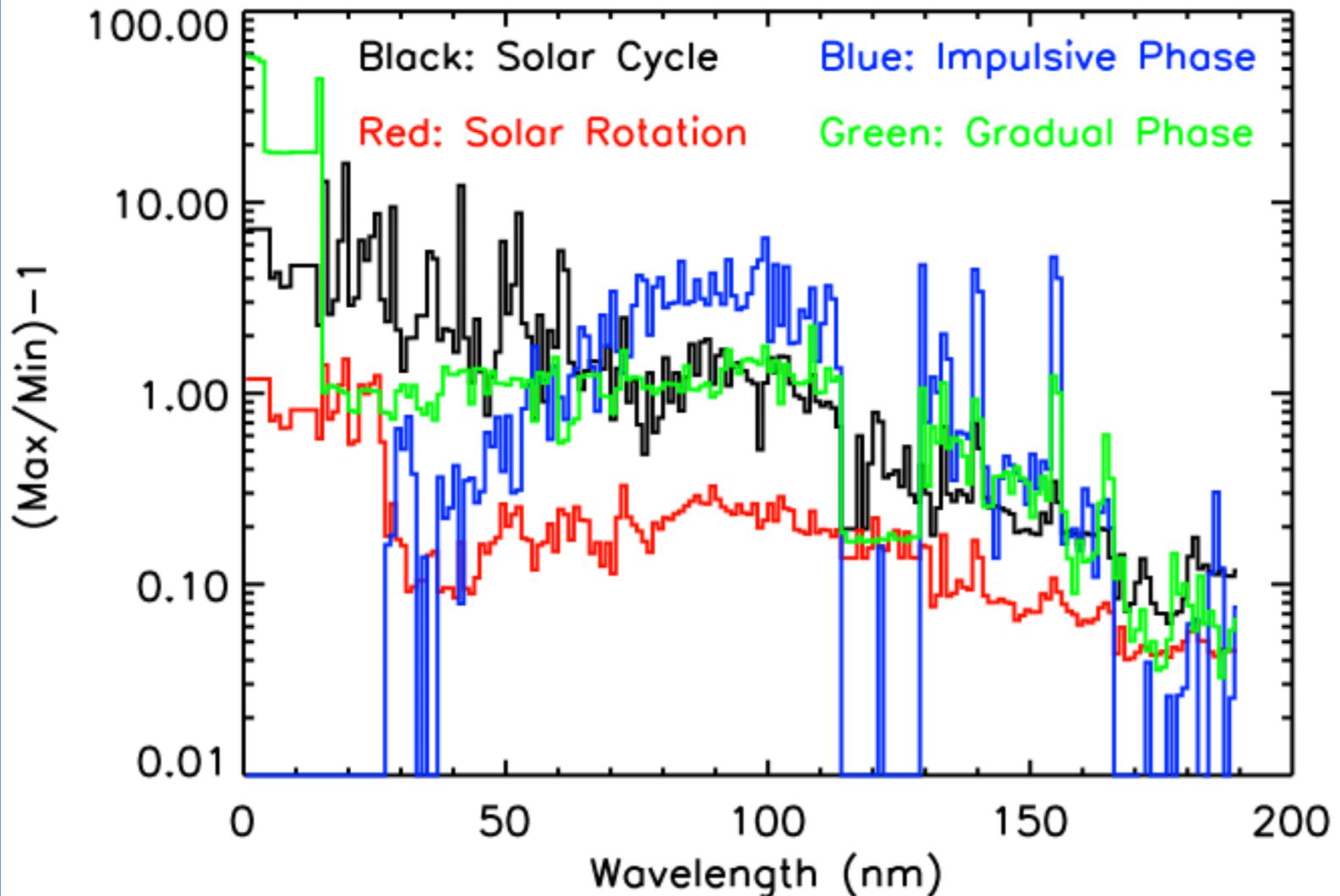
- Daily and 96-minute spectra at instrument and 1-nm resolution from Jan 22, 2002 to the present.
- Note: product shortward of 27 nm is a spectral model fit to the broadband measurements
- Data available at <http://lasp.colorado.edu/see>



SEE Gave us Dataset from Solar Max through Min



SEE Helped Understand Spectral Variability



Courtesy Phil Chamberlin

What We Don't Know From SEE

- Short Wavelength Spectral Variability & Absolute Value
 - <27 nm is from broadbands
 - Lots of ambiguity in interpreting data without spectral knowledge
- Short Timescale Variability
 - Low time cadence measurements (96-min)
 - Small sample of flares from SEE (~35 flares)

SDO-EVE

- **EUV Variability Experiment**

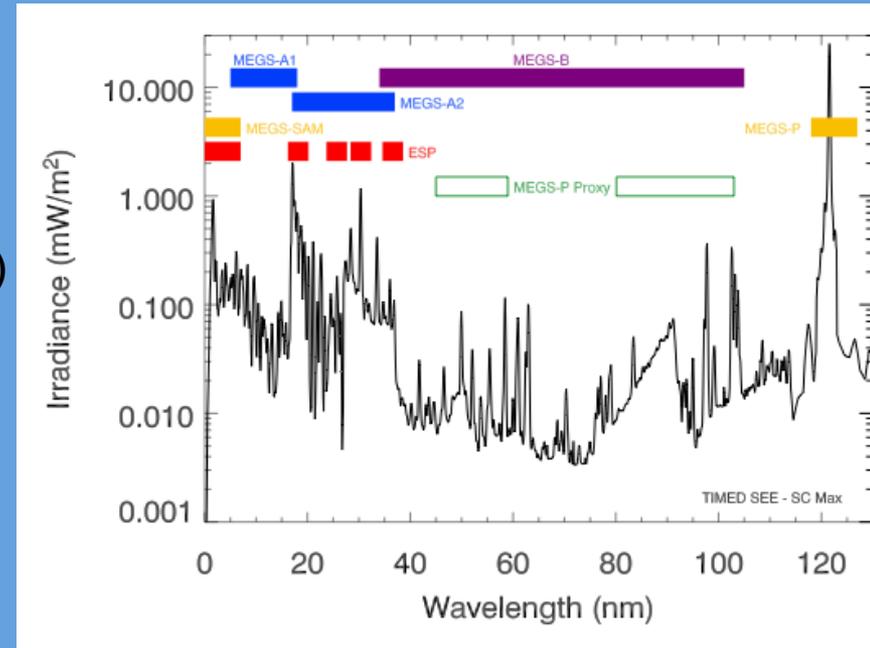
- Launched Feb 11, 2010
- Still operating

- **EVE Measurements:**

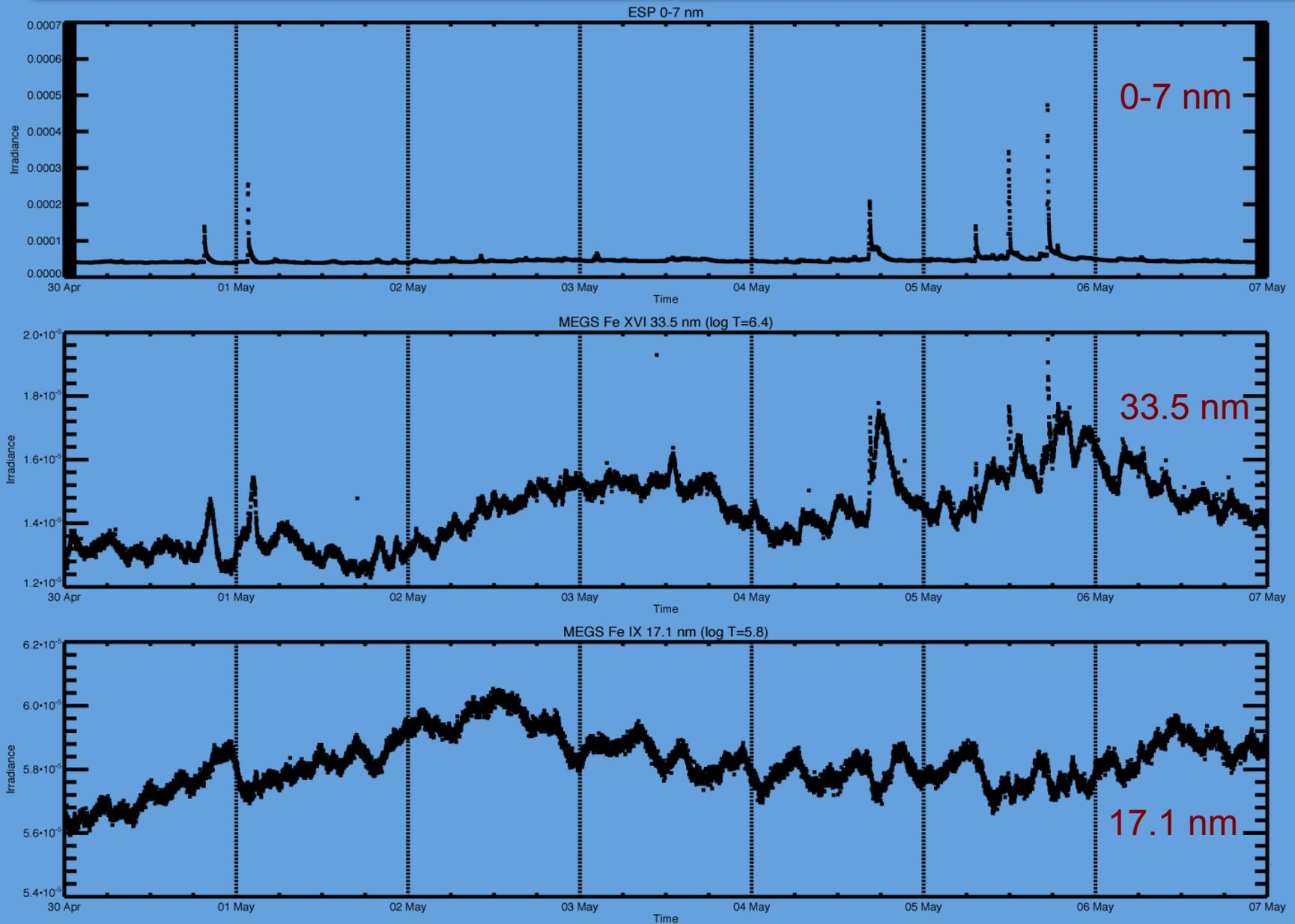
- 6-106 nm at 0.1 nm resolution (MEGS)
- Broad bands and flare location (ESP)
- 0-7 nm low-res images (SAM)
- ~100% duty cycle (10-sec for MEGS and 0.25-sec for ESP)
- Note: MEGS-B operates 5 min/hour and for campaigns

- **EVE Data Products:**

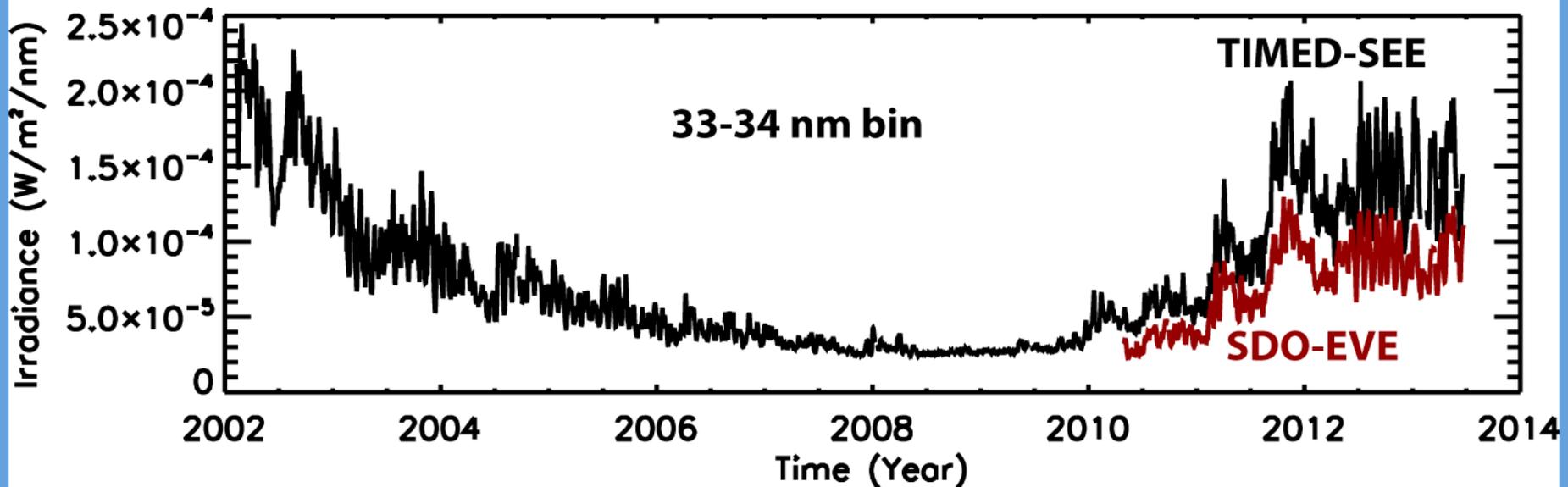
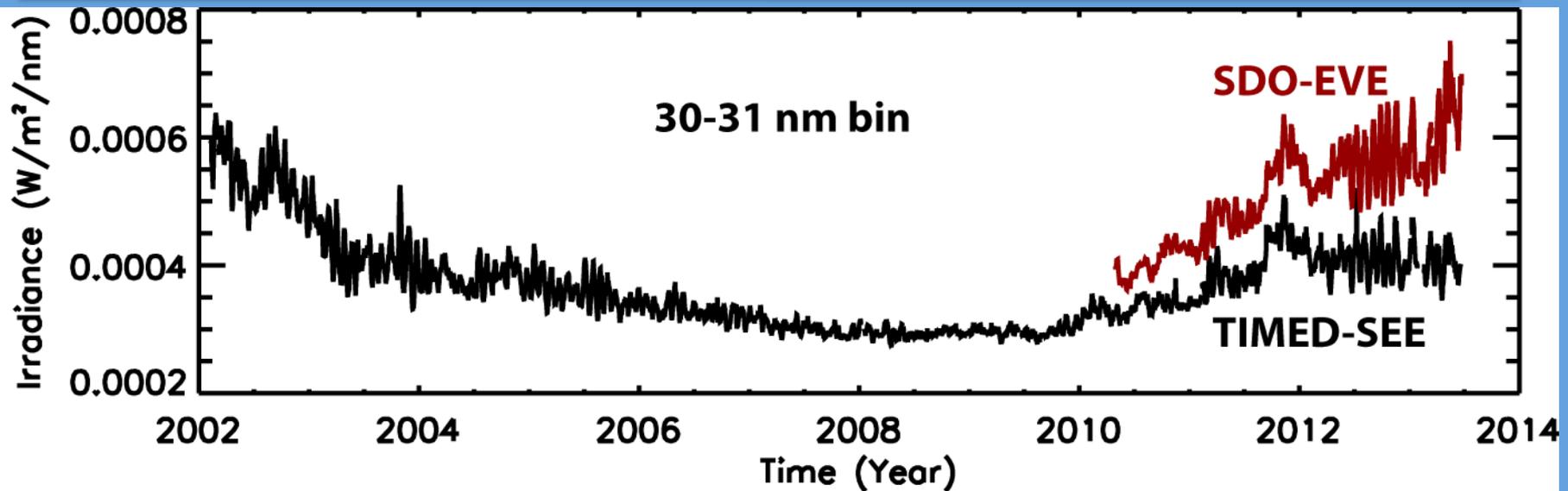
- Daily and 10-sec spectra at 0.1 and 1-nm resolution from May 1, 2010 to the present, broad bands at 0.25-sec resolution
- Space weather data products available at ~3-minute latency
- Current data Version 3 available
- Data available at <http://lasp.colorado.edu/home/eve>



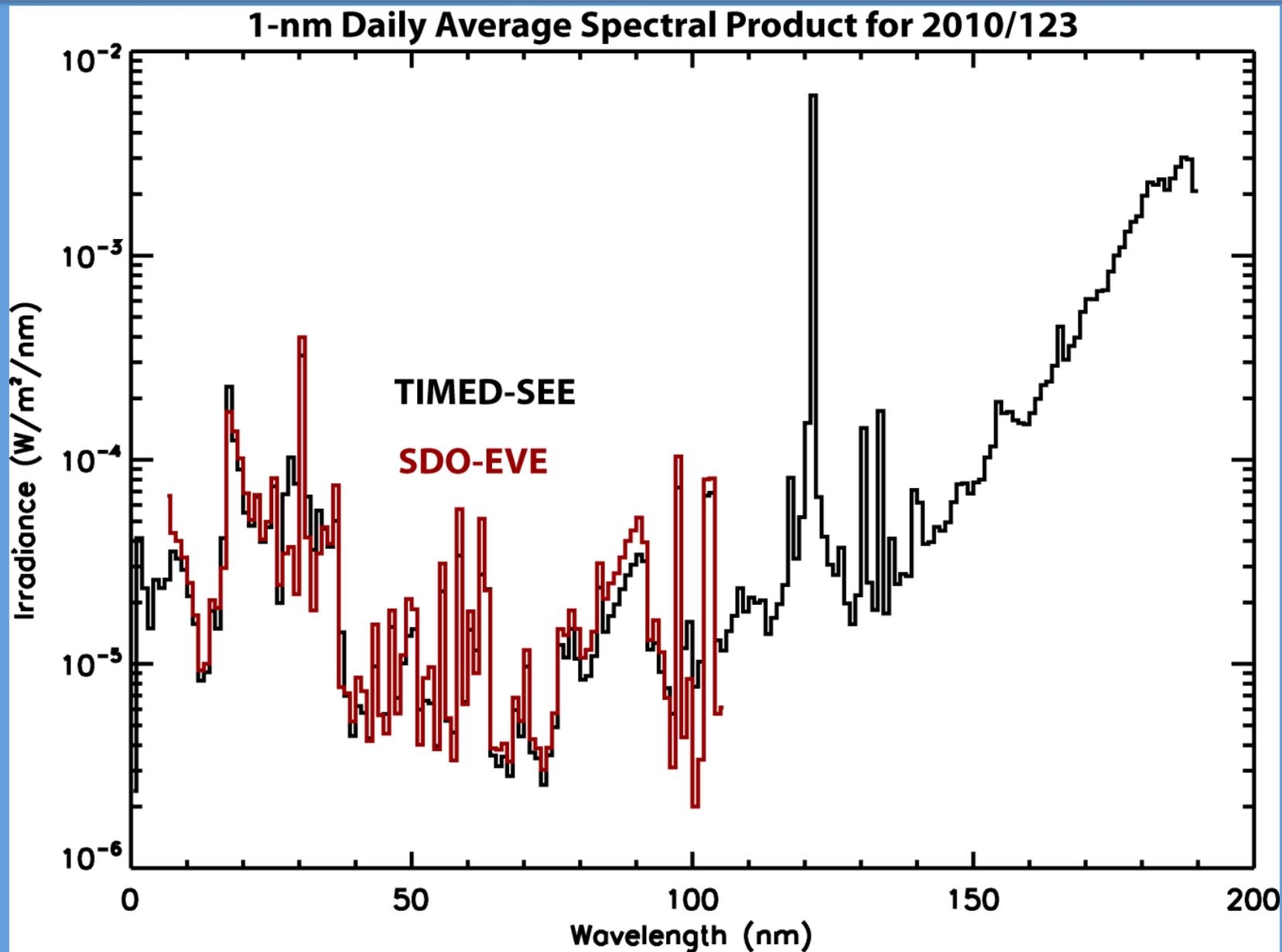
EVE Shows Quiet Sun EUV Fluctuations



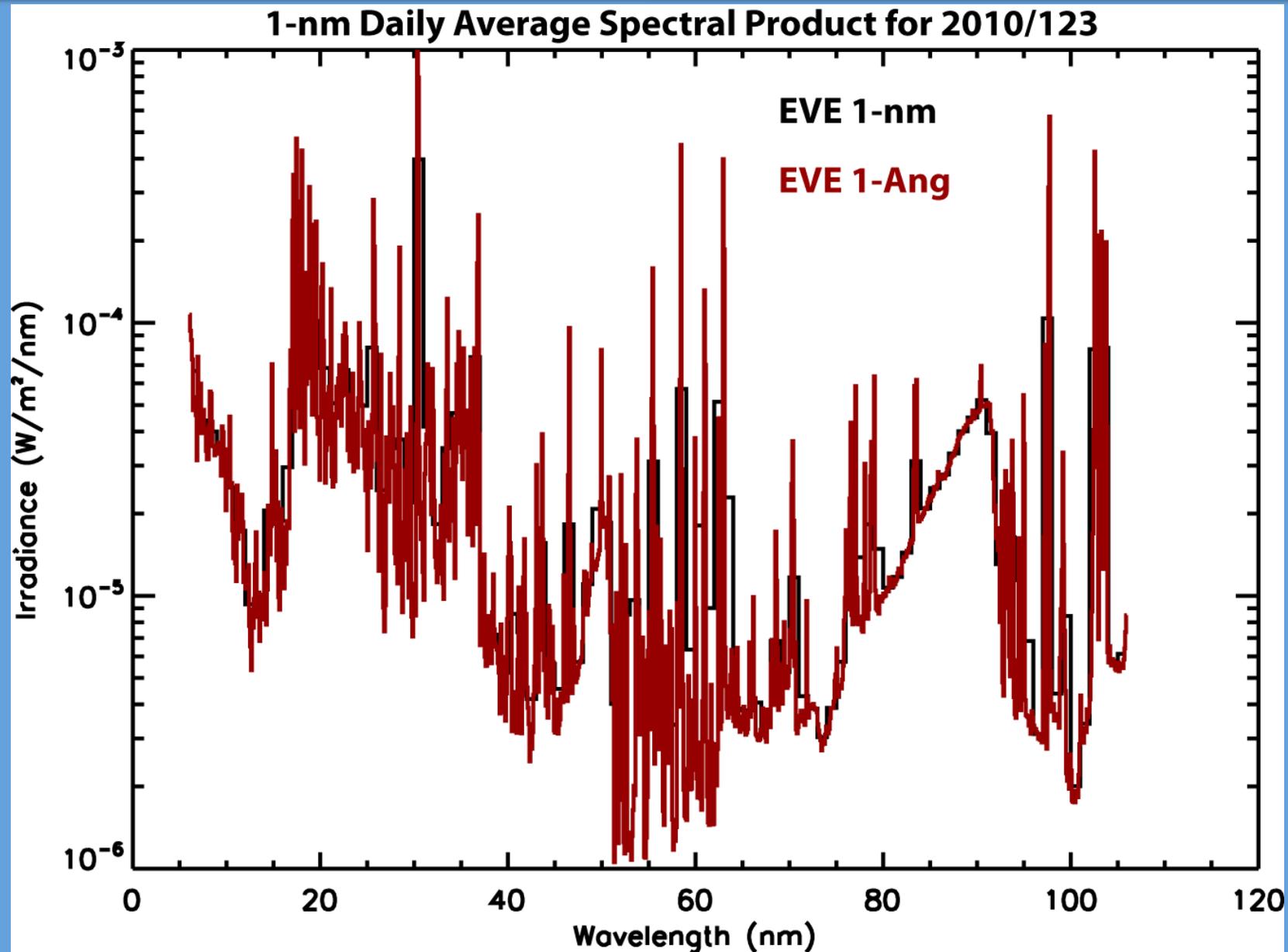
EVE continues SEE Long-term Data Series



EVE and SEE are Similar, but Different

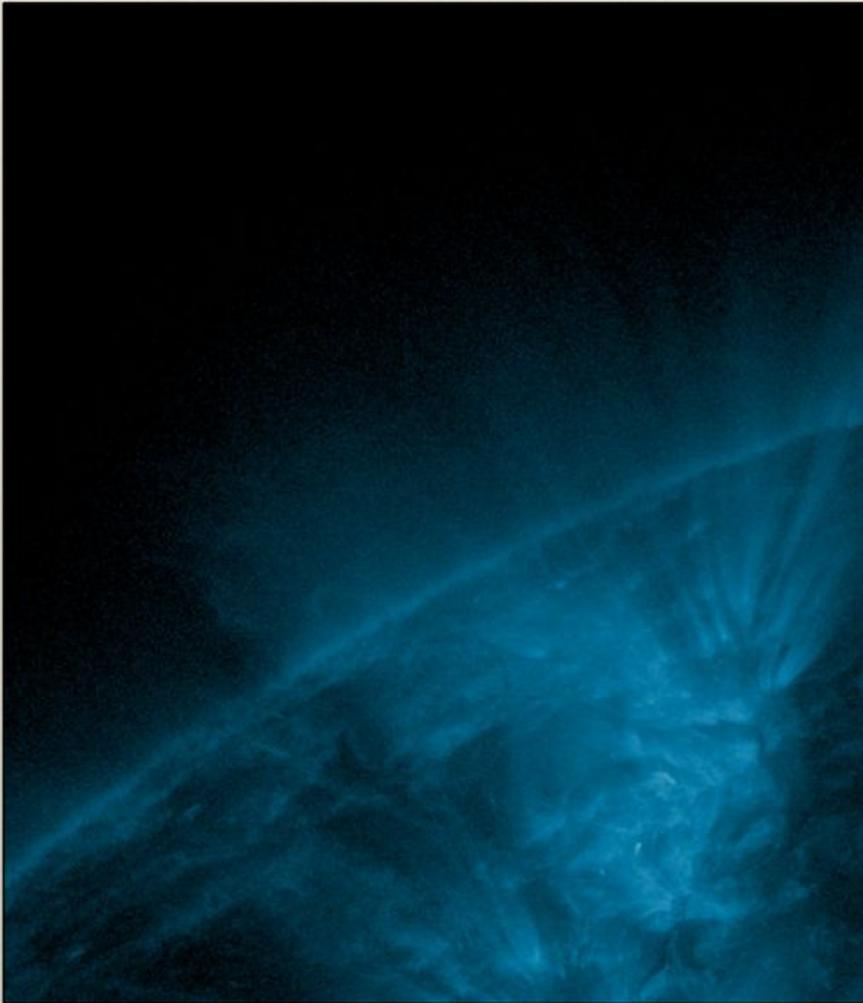


EVE has High Spectral Resolution

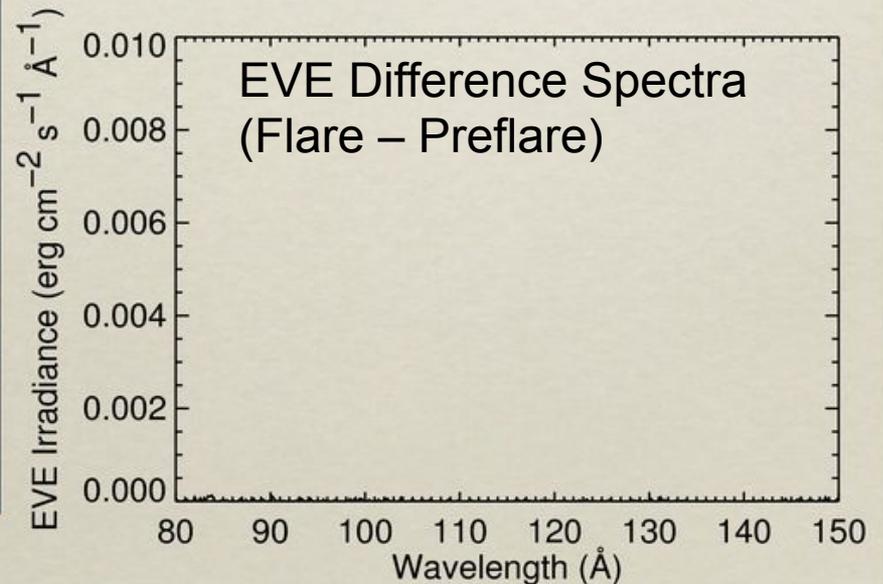
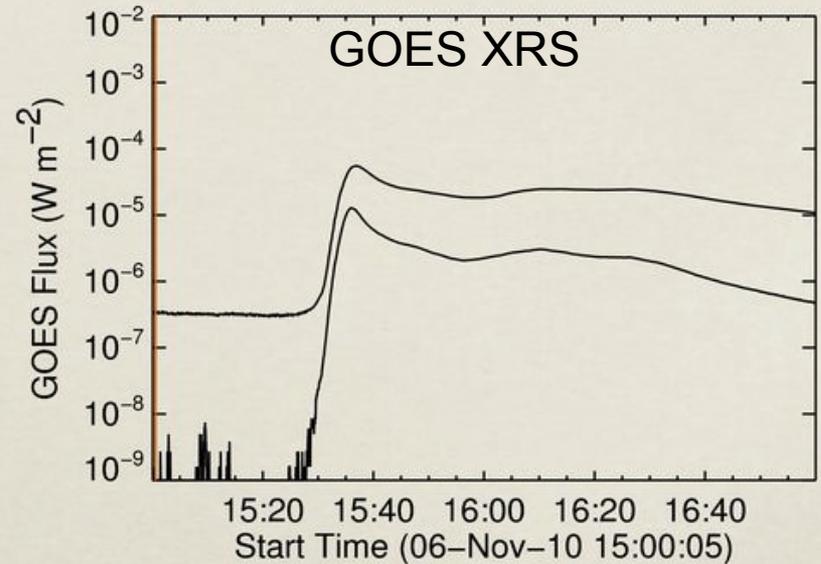


EVE Shows Flares Produce New Lines

AIA 131 06–Nov–10 15:00:09

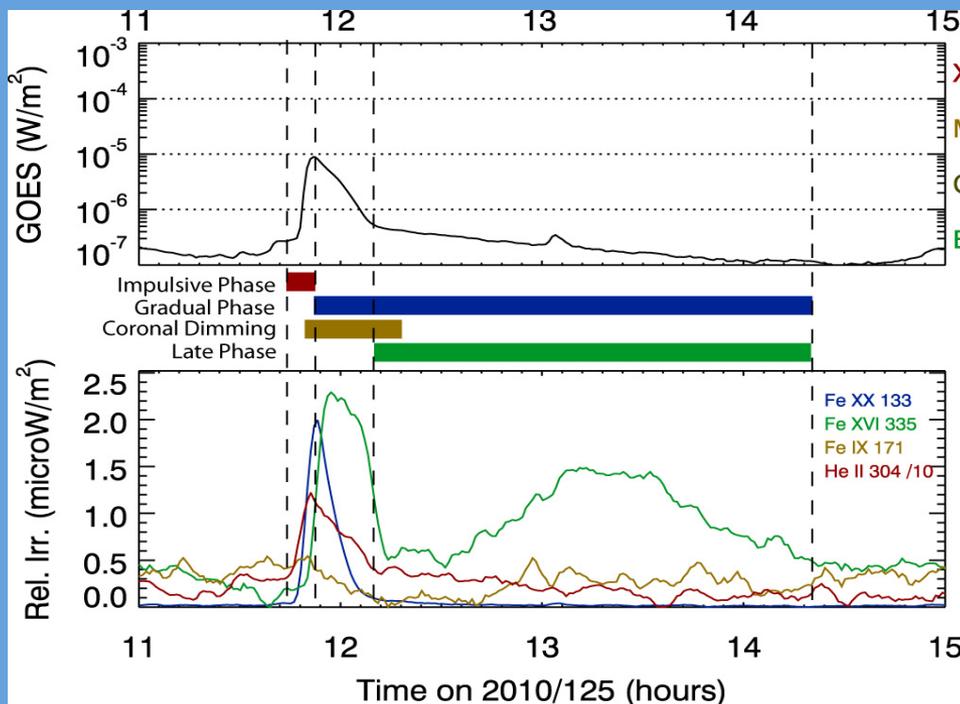
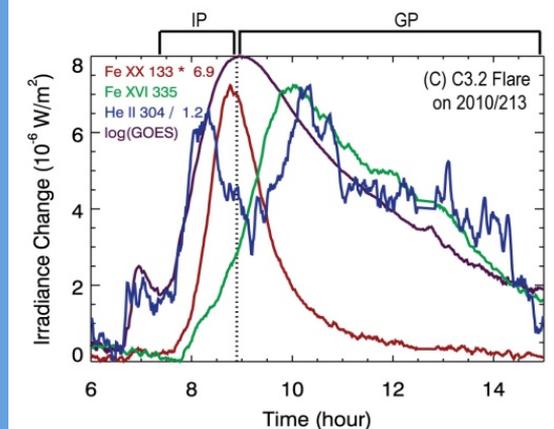
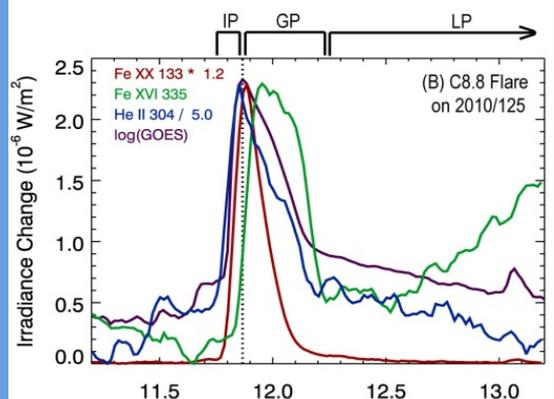
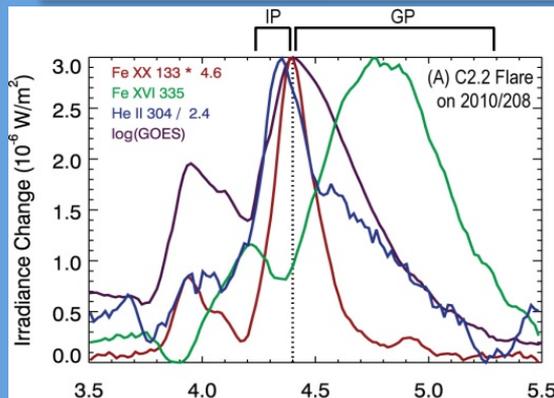


AIA 131 image (courtesy SDO/AIA)



EVE Shows Flares are Complicated

- Different types of flares behave differently in EUV
- Different emission lines peak at different times based on flare type and line temperature
- Some emission lines dim during flares (w/ CMEs)
- Some flares have EUV “late phase” up to hours after the main phase of the flare



The Future for EUV Measurements

- TIMED prime mission ended in 2004, but we're still going (with little to no money for SEE)
- SDO prime mission is until 2015, will propose for extended mission
- GOES-N,O,P have broadband EUV (broadbands since 2009)
- GOES-R,S,T,U (earliest launch 2015) will have new EUV sensors

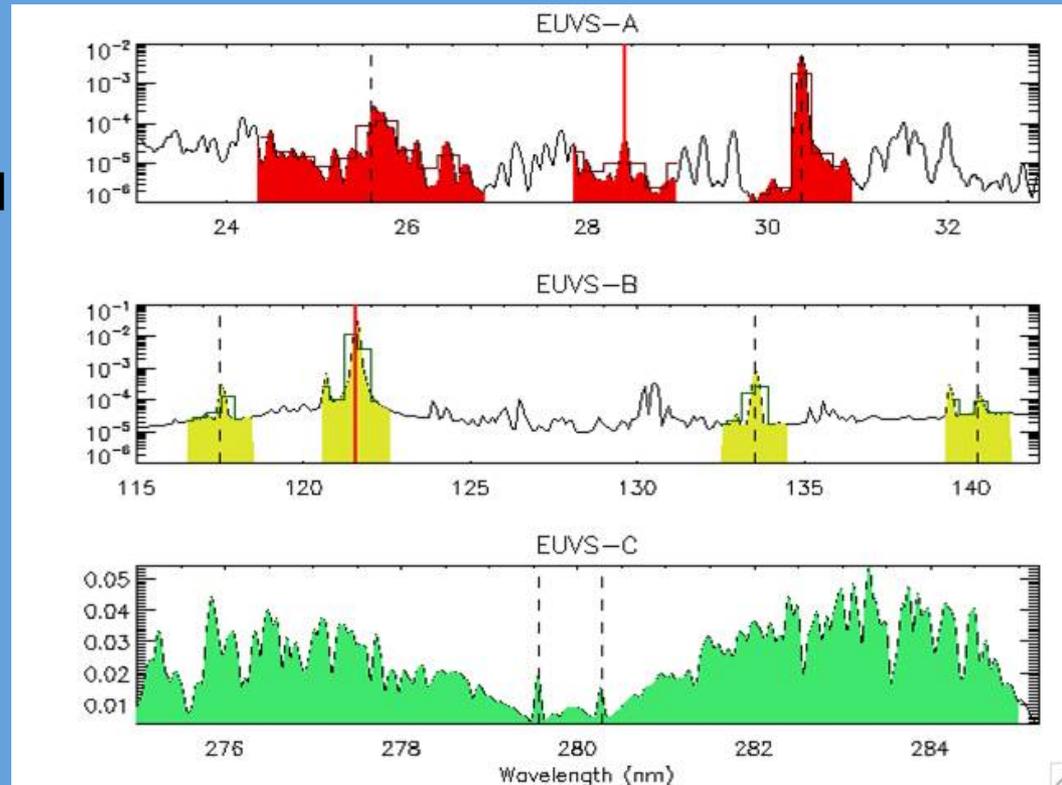
EUVS Concept for GOES-R

- Measure proxies that are used to model the full EUV range (5-125 nm)
- Three EUVS channels that provide accurate proxies for the emissions from the chromosphere (CH), transition region (TR), and corona (COR)
 - XRS provides fourth proxy for hot coronal continuum emissions during flares
- EUVS Irradiance Data Product:
 - 5-115 nm spectral irradiance in 5-nm bins + Ly α
 - 30-second cadence (measurements on 10-sec cadence)
 - <20% accuracy through mission

EUVS Measurements

Primary Measurements Used in Spectral Model:

- **Chromospheric:** MgII C/W (**EUVS-C**), CIII 117.5 nm and CII 133.5 nm (**EUVS-B**)
- **Transition Region:** Ly-alpha 121.6 nm and SiIV/OIV 140.5 nm (**EUVS-B**), HeII 30.4 nm and HeII 25.6 nm (**EUVS-A**)
- **Corona:** FeXV 28.4 nm (**EUVS-A**)
- **Hot Coronal:** 0.1-0.8 nm and 0.05-0.4 nm (**XRS**)



EUVS Proxy Model is based on TIMED-SEE and SDO-EVE and uses all measurements available from EUVS

Summary

- Solar EUV irradiance matters for atmospheric science
- EUV is complicated temporally and spectrally → a single, daily proxy index is not enough
- SDO-EVE is helping us understand solar EUV irradiance variability
- NOAA GOES will build on knowledge gleaned from past EUV measurements and will continue EUV monitoring into the future