Solar Extreme Ultraviolet and X-Ray Irradiance: Impacts and Measurements

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Introduction

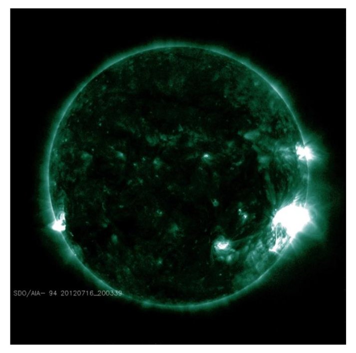


Image of the sun at 94 Å from Solar Dynamics Observer (SDO).

The first of the new NOAA GOES-R series of geostationary satellites will launch in 2016 and will carry several space weather instruments including an ultraviolet solar imager, particle sensors, and an **EXIS (Extreme Ultraviolet and X-ray Irradiance Sensors)**. Solar emissions at EXIS wavelengths impact satellite drag, communications, navigation systems, and upper atmospheric chemistry.

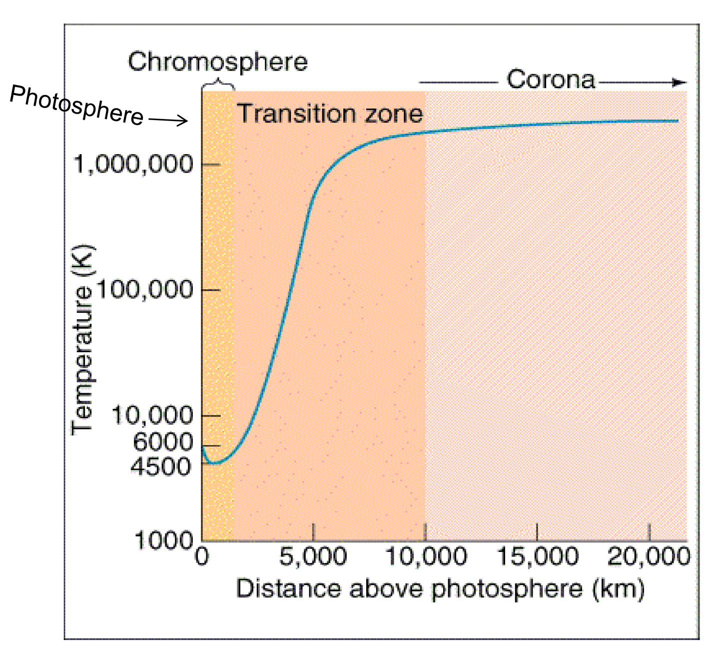
Why do we care about solar X-ray and EUV emissions?

Extreme ultraviolet (**EUV**; 30-120 nm) and X-ray ultraviolet (**XUV**; 1-30 nm) irradiance heat the thermosphere and create the ionosphere.

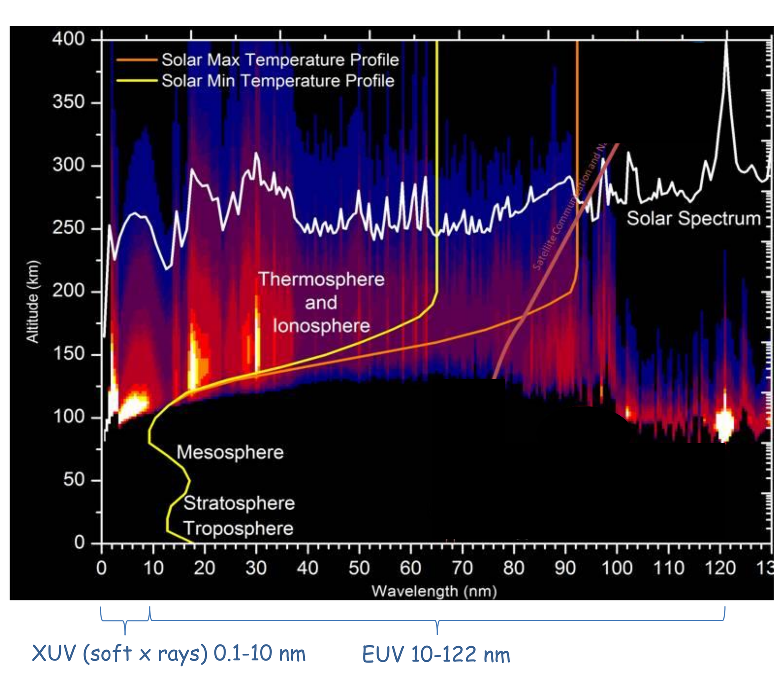
- EUV/XUV irradiance has the **highest variability**
  - EUV/XUV is <0.01% of total solar irradiance (TSI)
  - *however* TSI varies by 0.1% while EUV/XUV varies by >200%
- Variability is on many time scales.
  - secs – hrs: solar flares
  - days – months: solar rotation
  - months – years: solar cycle (dynamo)
- Since variations in the EUV flux drive the dynamics of the thermosphere and ionosphere, EUV spectra are inputs for **thermospheric/ ionospheric models**.
- X-ray measurements are needed for warnings of **radio blackouts**.

Solar X-Ray and EUV Emissions

The **solar atmospheric layers** each have different compositions, temperatures, and corresponding X-ray and EUV emissions. At Earth, different altitudes preferentially absorb different wavelengths.



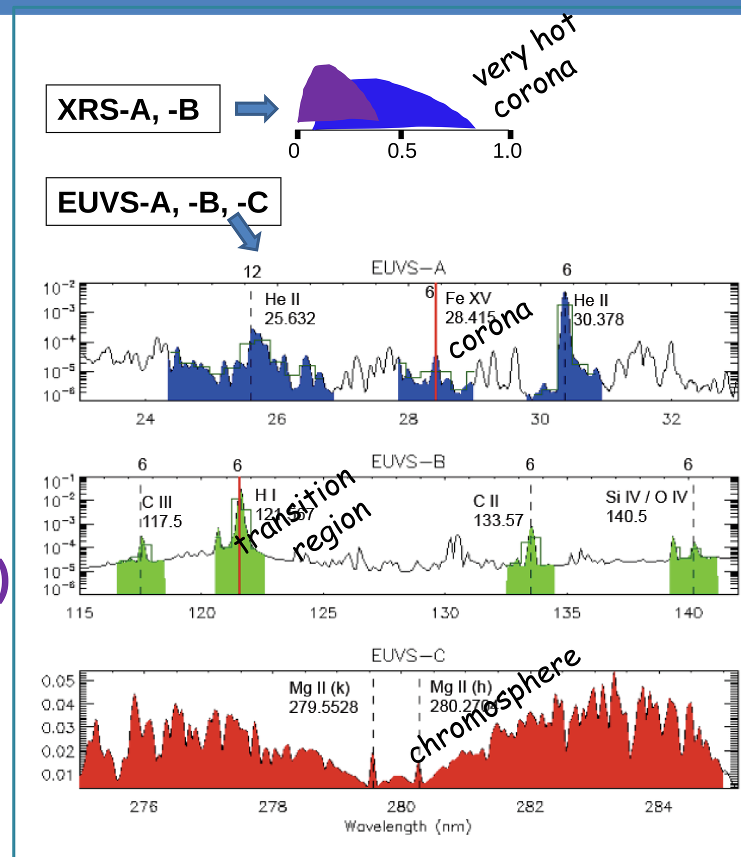
Temperatures and heights of solar atmospheric regions.



Atmospheric absorption as a function of wavelength (reds and blues). Also shown are the solar spectrum (white line on a log scale) and Earth's atmospheric temperature profiles (orange and yellow lines).

EXIS on GOES-R

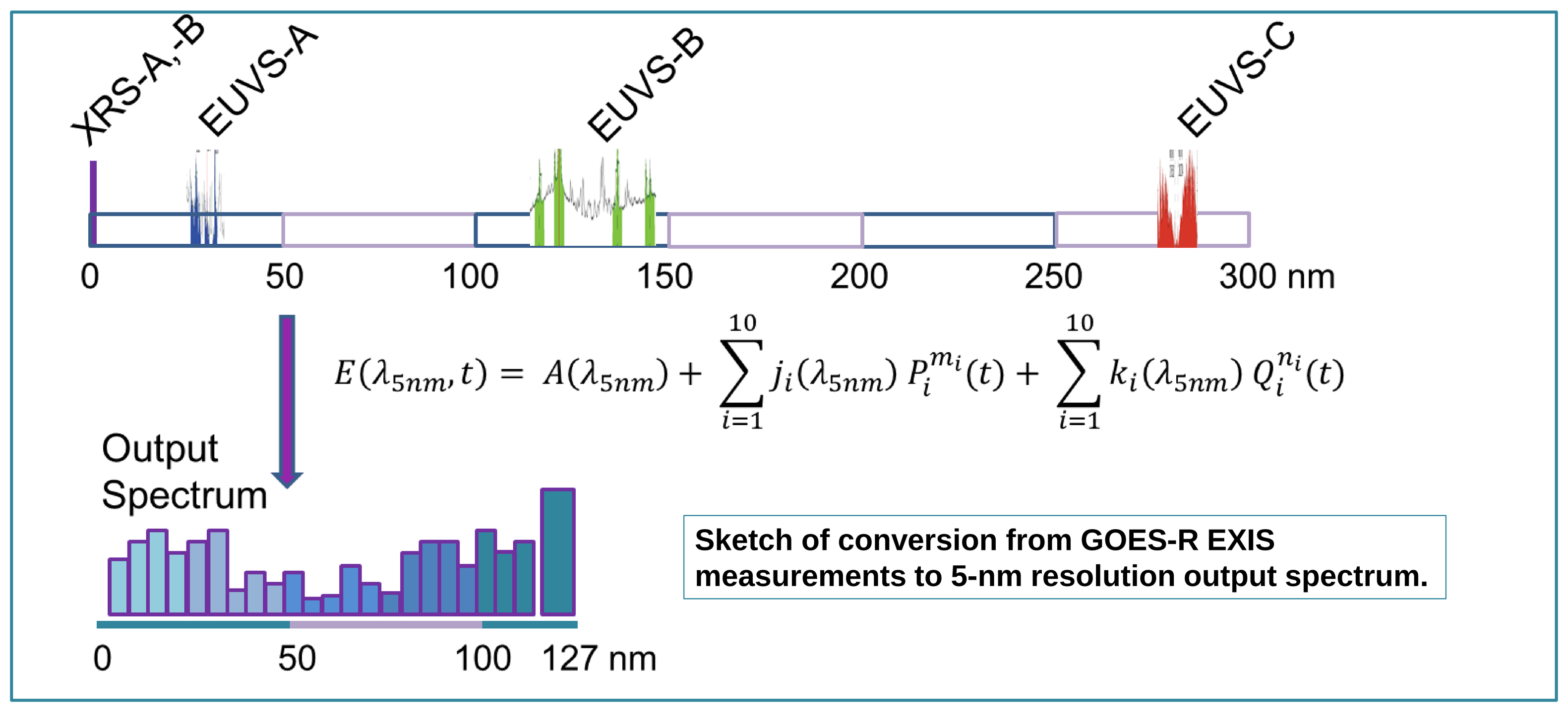
- Designed and built by the Laboratory for Atmospheric and Space Physics (LASP), University of Colorado Boulder.
- **X-Ray Sensor (XRS)**
  2-3 s resolution, 20% accuracy
- **Extreme Ultraviolet Sensors (EUVS)**
  Full EUV spectra (5-127 nm) are derived from the high-resolution measurements.
  30 s resolution, 20% accuracy,
  5-nm resolution



Wavelengths measured by EXIS.

Reconstruction of EUV Spectra

EUVS measures bands and lines which represent different layers in the solar atmosphere. The reconstruction model assumes that the EUV spectrum is a combination of components from different solar regions from the photosphere to the corona and thus that **spectral features from the same source regions vary similarly.**

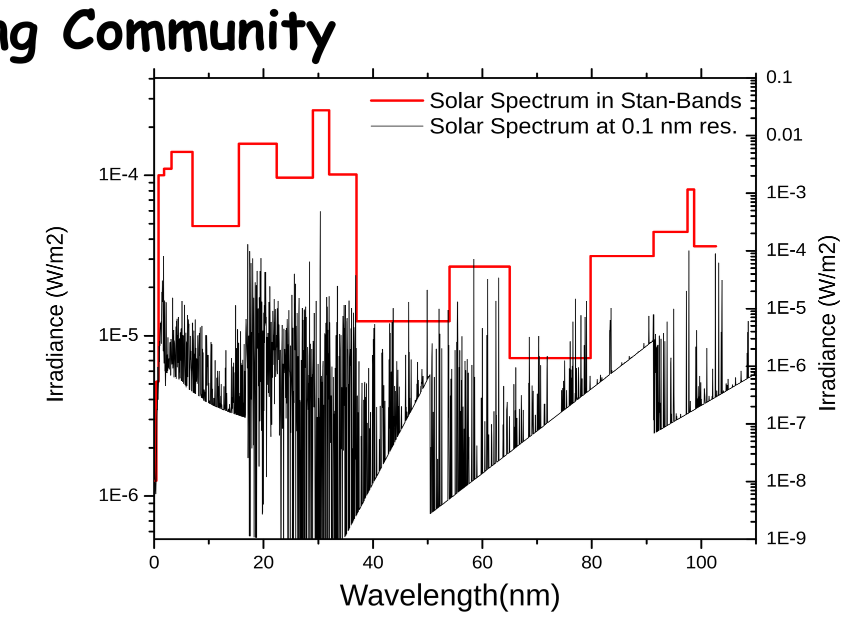


$$E(\lambda_{5nm},t) = A(\lambda_{5nm}) + \sum_{i=1}^{10} j_i(\lambda_{5nm})\, P_i^{m_i}(t) + \sum_{i=1}^{10} k_i(\lambda_{5nm})\, Q_i^{n_i}(t)$$

Sketch of conversion from GOES-R EXIS measurements to 5-nm resolution output spectrum.

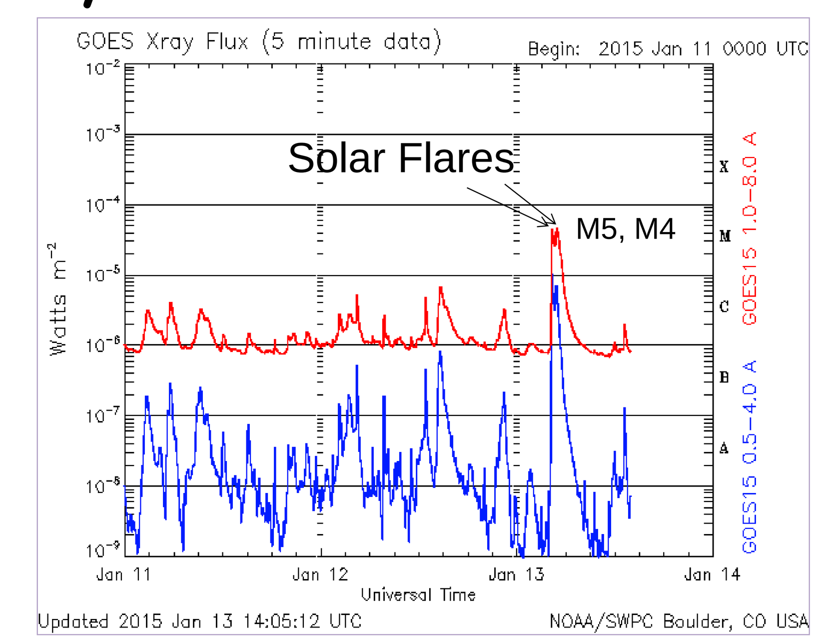
Spectral Bands for the Thermosphere/Ionosphere Modeling Community

EUV/XUV forcing is important to the atmospheric community but raw spectra cannot be readily fed into current models. So, in addition to creating spectra with 5-nm resolution, the same technique can be used to provide wavelength bands that may be more useful to modelers.



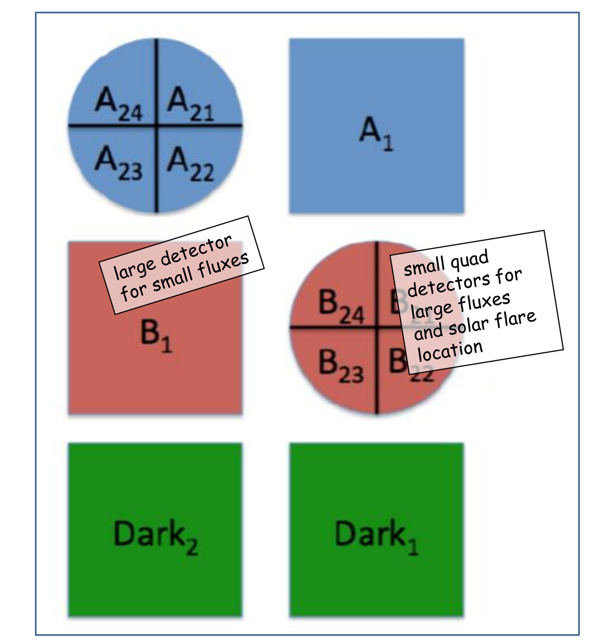
Solar X-Ray Measurements

NOAA has measured solar X-ray fluxes continuously since 1974. **XRS measures X-ray irradiance in two channels**, A (0.1-0.8 nm) and B (0.0.5-0.4 nm).



GOES XRS measurements of two M class flares.

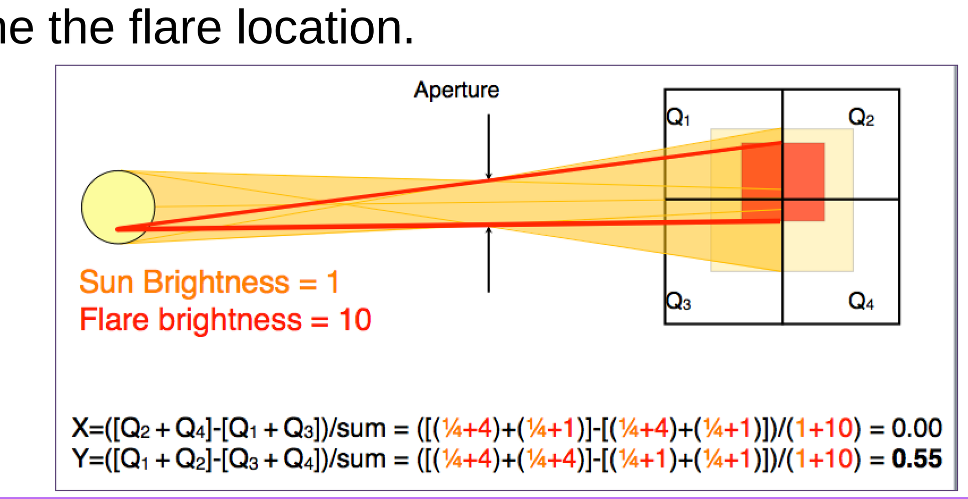
The GOES-R XRS design will be a significant change from previous GOES sensors. The new detectors will be silicon diodes instead of ionization cells. Several detectors with different apertures will be used to accommodate seven orders of magnitude of x-ray intensity. This approach expands the dynamic range to both higher and lower values than the current design.



Design of GOES-R XRS.

The high irradiance detectors have a quad-diode structure which provides estimates of flare locations. A bright spot on the Sun, such as a flare, illuminates each of the quad diodes differently. From a comparing the relative illumination on each of the quad diodes it is possible to determine the flare location.

XRS quad-diode measurements will be used to define flare locations.



$X=([Q_2+Q_4]-[Q_1+Q_3])/sum = (((¼+4)+(¼+1))-[(¼+4)+(¼+1)])/(1+10) = 0.00$
$Y=([Q_1+Q_2]-[Q_3+Q_4])/sum = (((¼+4)+(¼+4))-[(¼+1)+(¼+1)])/(1+10) = 0.55$

Summary

GOES-R satellites will carry new EUV and X-ray irradiance sensors which will be used to obtain high cadence measurements. The EUV spectra and related products will be used in thermospheric/ ionospheric models which are used to predict solar impacts on satellite drag, radio communications, and navigation. The X-ray fluxes will be used to detect solar flares and for warnings of radio blackouts.