GOES-R solar extreme-ultraviolet irradiance spectra: requirements, observations, and products

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Introduction

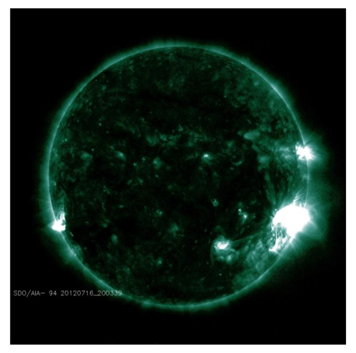
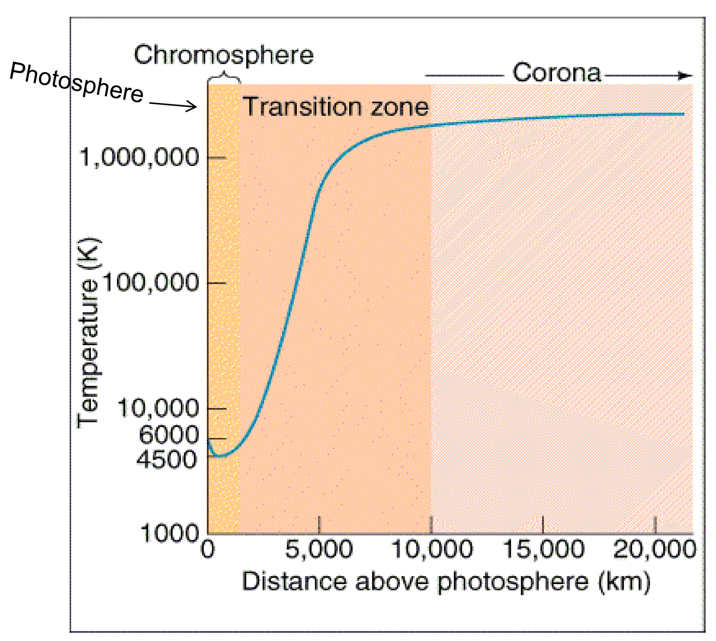


Image of the sun at 94 Å from Solar Dynamics Observer (SDO).

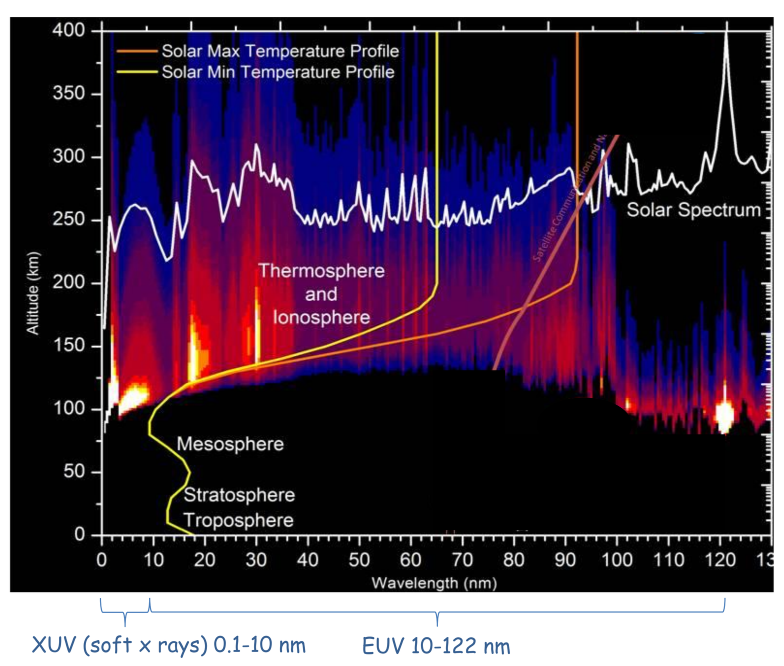
The first of the new NOAA GOES-R series of geostationary satellites will launch in 2015 and will carry several space weather instruments including an ultraviolet solar imager, particle sensors, and **EXIS** (Extreme Ultraviolet and X-ray Irradiance Sensors). EXIS measurements will be used to create extreme ultraviolet (EUV) irradiance spectra for upper atmospheric models which are used for space weather applications.

Solar X-Ray and EUV Emissions

The solar atmospheric layers each have different compositions, characteristic temperatures, and corresponding x-ray and EUV emissions. At Earth, the irradiance at various wavelengths is absorbed preferentially at various altitudes.



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).

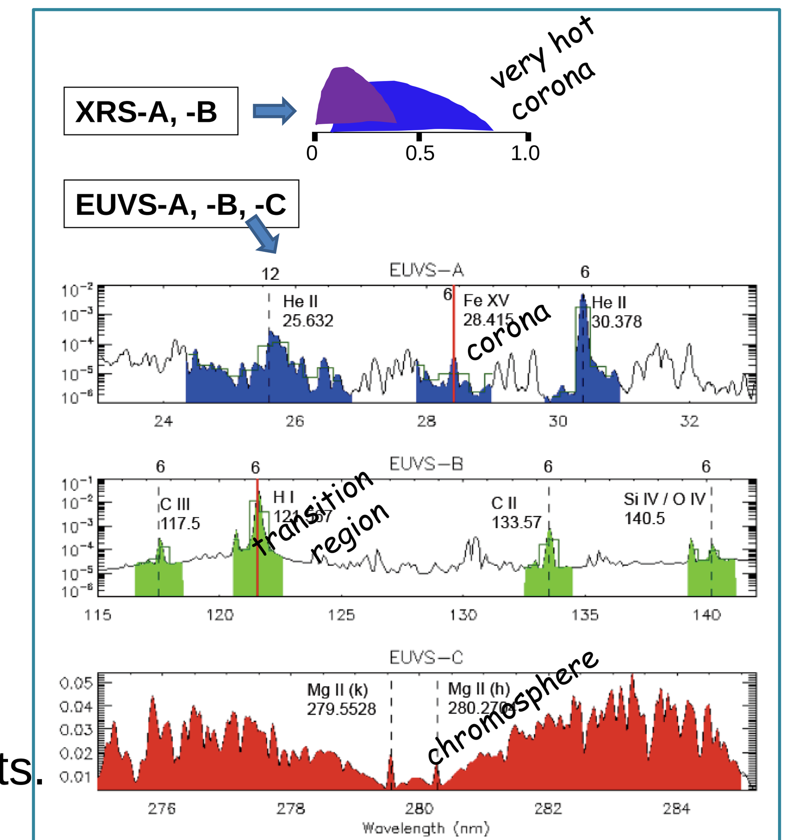
Why do we care about solar EUV and x-ray emissions?

- EUV/ XUV heat the thermosphere and create the ionosphere.
- Impacts: satellite drag, communications, navigation systems, upper atmospheric chemistry.
- EUV/XUV irradiance has high variability
  - While EUV/XUV is <0.01% of total solar irradiance (TSI) *however* TSI varies by 0.1% while EUV/XUV varies by >200%
  - The variability is on many time scales.

    secs – hrs: due to solar flares
    days – months: due to solar rotation
    months – years: due to solar cycle (dynamo)
- EUV spectra are needed as input for thermospheric/ ionospheric models.
- X-ray emissions are used for warnings of radio blackouts.

EXIS Measurements

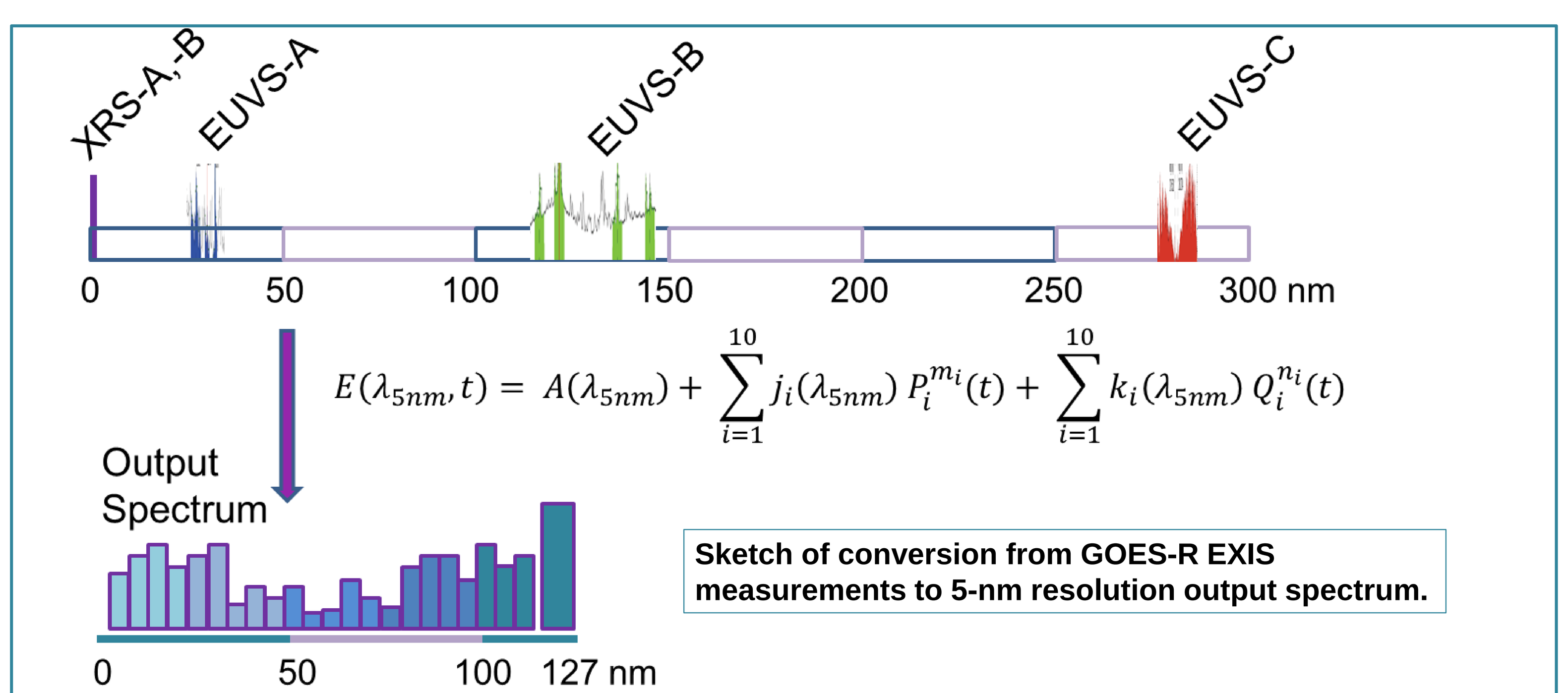
- The EXIS design is new. EXIS has 2 components:
  - EUVS Extreme Ultraviolet Sensor (-A, -B, -C)
  - XRS X-Ray **S**ensor (-A, -B)
- EXIS was designed and built by the Laboratory for Atmospheric and Space Physics (LASP), University of Colorado Boulder. LASP is also writing the algorithm to generate EUV spectra.
- EXIS measures bands and lines which represent different layers in the solar atmosphere. Full EUV spectra will be derived from these sparse high-resolution measurements.



Wavelengths measured by EXIS.

Reconstruction of EUV Spectra from EXIS Measurements

- The model to derive the EUV spectrum assumes that it is a combination of components from different solar regions from the photosphere to the corona. This assumes that spectral features from the same source regions vary similarly.
- Real time irradiance spectra with 5-nm bins, 30-s resolution will be derived from the EXIS measurements. Requirements are 20% accuracy and 2% precision.
- The equation to create the spectra will be a non-linear combination of measurements, with each wavelength having a unique set of coefficients representing the relative contribution from each layer of the solar atmosphere. The generalized equation for this model is shown below. The three terms in the fit equation represent solar minimum values, and short- and long-term variability.

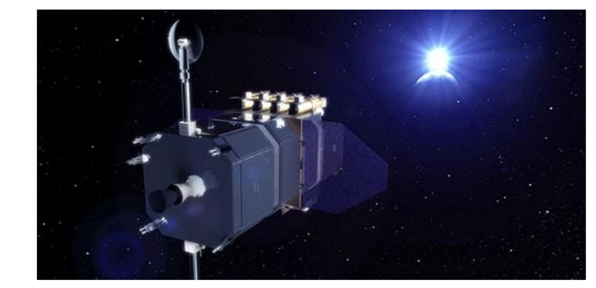


$$E(\lambda_{5nm}, t) = A(\lambda_{5nm}) + \sum_{i=1}^{10} j_i(\lambda_{5nm})\, P_i^{m_i}(t) + \sum_{i=1}^{10} k_i(\lambda_{5nm})\, Q_i^{n_i}(t)$$

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

Use of Other Measurements to Derive Spectral Model

Various EUV irradiance measurements will be used to find the coefficients of the model equation and do sensitivity studies on the spectral components. These data will be used to simulate both EXIS measurements and the output model spectra.



Drawing of Solar Dynamics Observer (SDO).

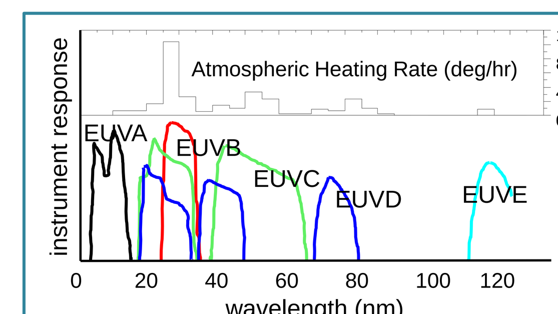
Sources of Irradiance Data

Satellite	Instrument	Wavelengths used for model derivation	Spectral resolution	Temporal resolution
GOES	XRS-A	0.05-0.4 nm	band	1 min
GOES	XRS-B	0.1-0.8 nm	band	1 min
SDO	EVE MEGS-A	6-37 nm	0.1 nm	10 s
SDO	EVE MEGS-B	37-106 nm	0.1 nm	10 s
TIMED	SEE	106-110 nm	0.4 nm	10 s
SORCE	SOLSTICE	115-127 nm	1.0 nm	daily
SORCE	SOLSTICE	~280 nm	Mg II index	7 values/day

Spectral Bands for the Thermosphere/Ionosphere Modeling Community

EUV forcing of the thermosphere/ionosphere system 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 will be used to convert the GOES-R spectra into bands that may be more useful to modelers.

Similar techniques will also be applied to create bands for modelers from current GOES-NOP series satellite data. Errors on bands derived from GOES-NOP data will be larger than those from GOES-R since GOES-NOP measurements are broadband (see figure), and cannot be fully deconvolved as a function of solar region.



Wavelength bands measured by the 5 GOES EUVS instruments (each shown in a different color). Also shown is the atmospheric heating rate as a function of wavelength.

Summary

GOES-R satellites will carry new EUV and x-ray irradiance sensors which will be used to obtain high cadence and high spectral resolution EUV spectra. The spectra and related products will be useful for thermospheric/ionospheric models which are used to predict solar impacts on satellite drag, radio communications, and navigation. We will also investigate how well the same technique can be used to generate other EUV spectral products that are tailored to work as inputs to particular atmospheric models.