Developing a Continuous Record of the Data from the GOES Extreme Ultraviolet Sensor

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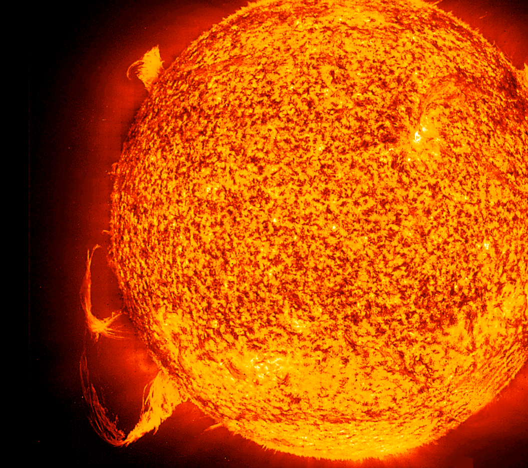


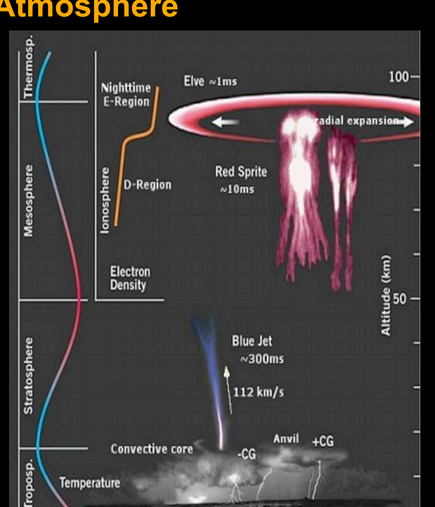
Abstract

For many years, thermosphere and ionosphere modelers, including those supporting NOAA and the Department of Defense (DOD), have been requesting solar extreme ultraviolet (EUV) irradiance data for ionospheric and thermospheric modeling because it is a key variable to these systems. Variations in EUV irradiance produce large variations in neutral and electron densities on time scales ranging from minutes to years. Currently modelers have been using F10.7 radio flux data, which is a proxy for EUV and is only available at a daily cadence. In response to these requests, the Geostationary Operational Environment Satellites (GOES) 13, 14, and 15 suites of space weather sensors included the capability to measure EUV irradiance with an instrument called the EUV Sensor (EUVS). The EUVS measures irradiance in five separate broadband channels at a cadence of 10 seconds. However, until now the data had remained unused because it had not been analyzed and made ready for public access. The focus of this project has been to create a continuous record of EUV irradiance in the A, B, and E broadband channels at a cadence of one minute dating back to July 2009 using the EUVS data from GOES 13, 14 and 15. In order to do this, we compared the data between the three different satellites during their operational time periods, specifically when those periods overlapped. We then scaled the data to one another to create a smooth, continuous record that could actually be used rather than the disjointed one that existed prior to the adjustments.

Who Cares About Solar EUV Irradiance?

- **The Solar Spectrum is Highly Variable in the Extreme Ultraviolet (EUV)**
- **EUV Radiation Heats the Upper Atmosphere**

- **There are many ways that the thermosphere and Ionosphere Can Affect Operational Systems**

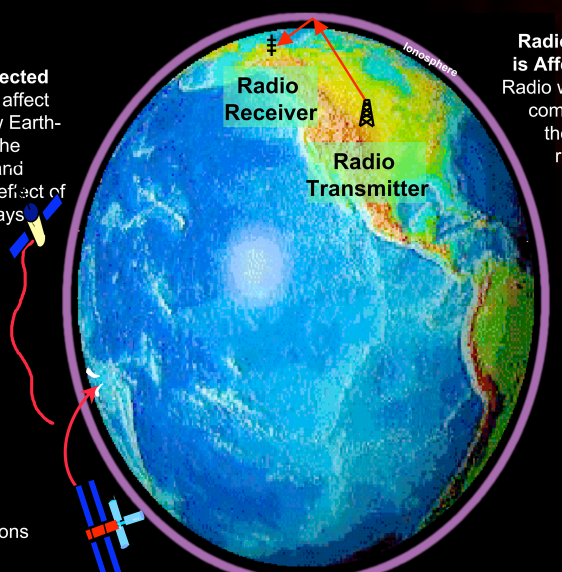


Satellite Orbits are Affected

The large density changes affect the drag on satellites in low Earth-orbit. Spacecraft such as the Hubble Space Telescope and Space Station will feel the effect of atmospheric drag in two ways.

If density is high, the fluctuations in atmospheric drag will cause satellite pointing errors.

Long periods of increased drags cause spacecraft to reenter prematurely unless expensive re-boost operations are performed.

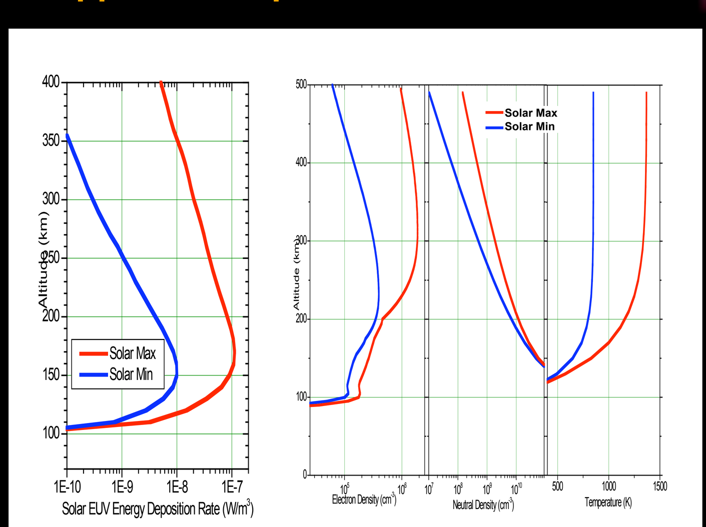


Radio Communication is Affected

Radio waves used for communication are reflected by the ionosphere so that receivers that are over the horizon can pick up the signal. Changes in the ionosphere change the frequencies of the reflected radio waves or can cause absorption of some frequencies

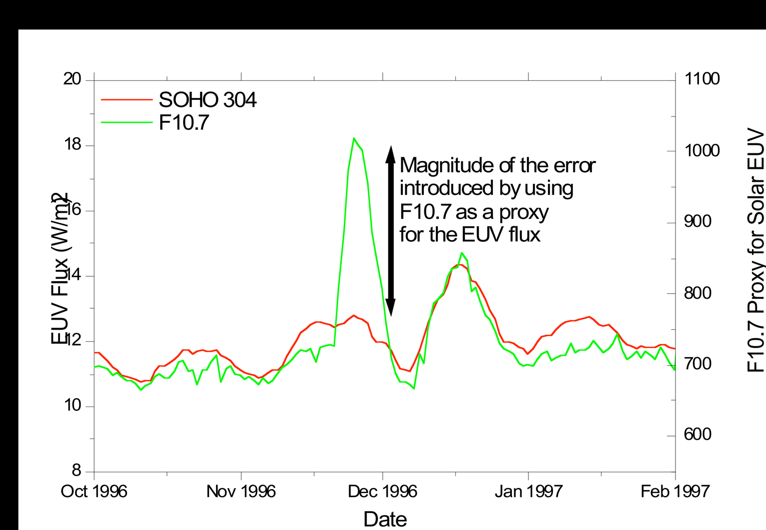
The intensity of the solar EUV emissions change by a factor of 4 from solar minimum to solar maximum. This EUV radiation is one of the primary sources of heat for the upper atmosphere.

- **Changes in the Solar EUV Flux Cause Very Large Changes in the Upper Atmosphere**



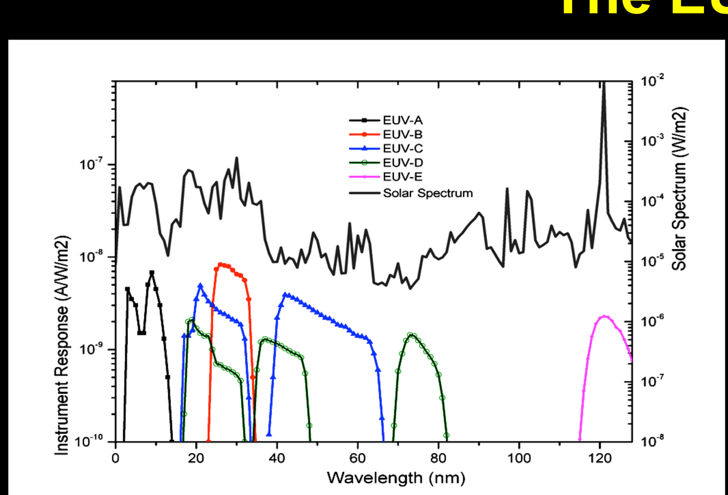
From solar minimum to solar maximum, the changes in the EUV flux produce changes density of a factor of ten and changes in temperature of a factor of two, as calculated with the MSIS model of the upper atmosphere.

- **Using Proxies Instead of the Actual EUV Flux can Introduce Large Errors Into the Models and Calculations**



The F10.7 cm radio flux is most often used as a proxy for solar EUV flux but it often does not track the EUV well. Using F10.7 cm flux in atmospheric models will introduce errors that are typically 20% and can be as large as 40%.

The EUV Sensor



This graph shows the broadband width of each of the 5 channels that the EUV Sensor (EUVS) measures solar irradiance in. For this project, we focused strictly on the A, B, and E broadband channels.

EUV-A: λ=5-17nm. Measures coronal emissions.

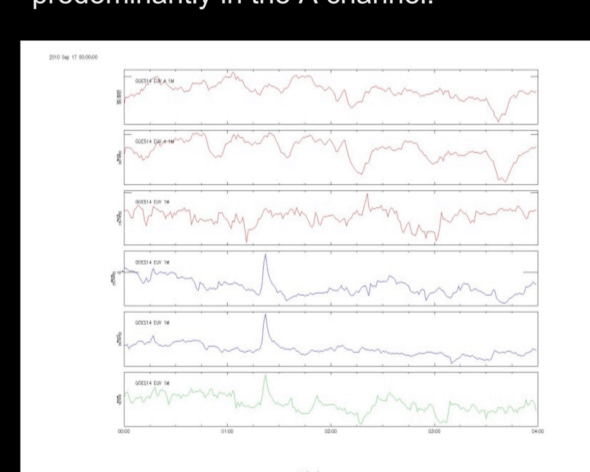
- GOES 14 has A' (Same just inverted)

EUV-B: λ= 30.4nm of the bright He chromospheric line.

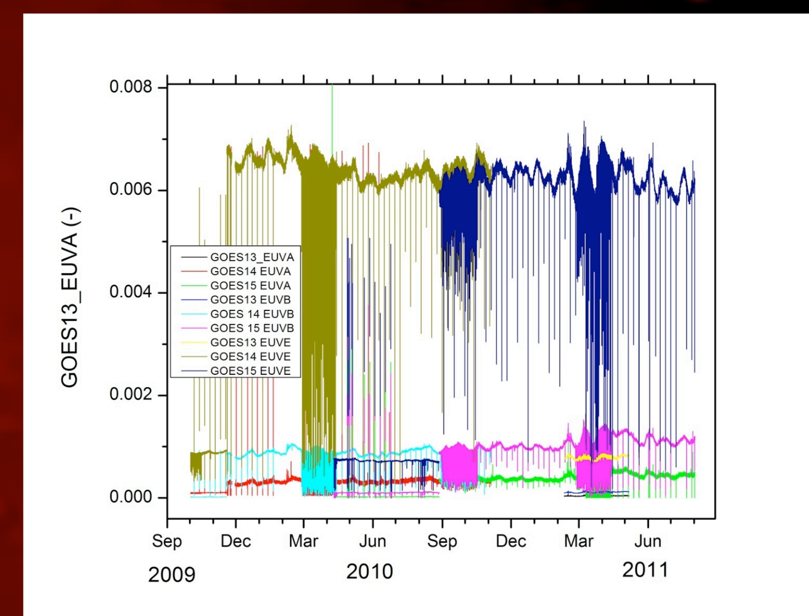
- GOES 14 has B' (Same just inverted)

EUV-E: λ=121.6nm of the very bright H Lyman Alpha line.

The graph below shows the EUV irradiance data recorded by GOES 14 during a solar flare in the corrected A, A', B, B', & E channels. Corrected A is data that has been adjusted to clean up some of the heater noise found predominantly in the A channel.



Initial Data Analysis



Key Features in the Plot

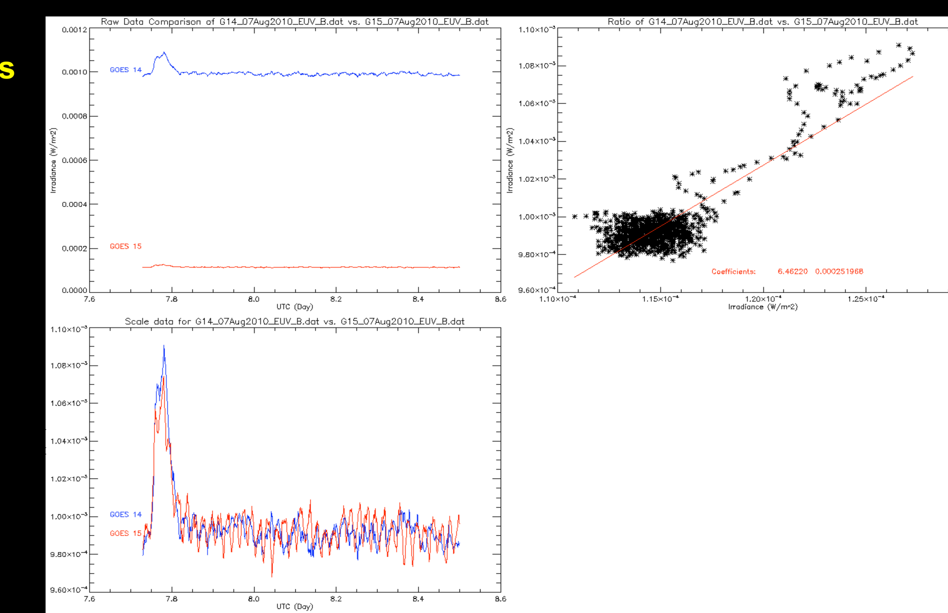
Throughout the record you will notice weekly drops in the data. These are where weekly calibrations occurred in the EUVS. Next you will notice periods where the coloring is thick and drops significantly, these are eclipse periods as the satellite traveled behind the Earth in its orbit. Lastly, but harder to point out are the daily dips that occur due to the Earth's Geocorona.

The plot above is the initial plot of the raw data from GOES 13,14, &15 in the three channels we focused on. It is easy to see the gaps between the three satellites, and even when they do agree as well. The goal was to create one continuous plot dating back to July 2009, so scaling between the three satellites to get the data sets to agree was necessary.

To begin scaling the data, we first had to find when the operational time periods for each satellite overlapped. Once the overlapping time periods were found, we then found flares within those periods to offer some variability for easier better scaling. Next, we plotted the raw data against each other and found a line of best fit to find a multiplicative and additive coefficient. We then applied those coefficients to the chosen data set to produce the scaled plot you see on the bottom.

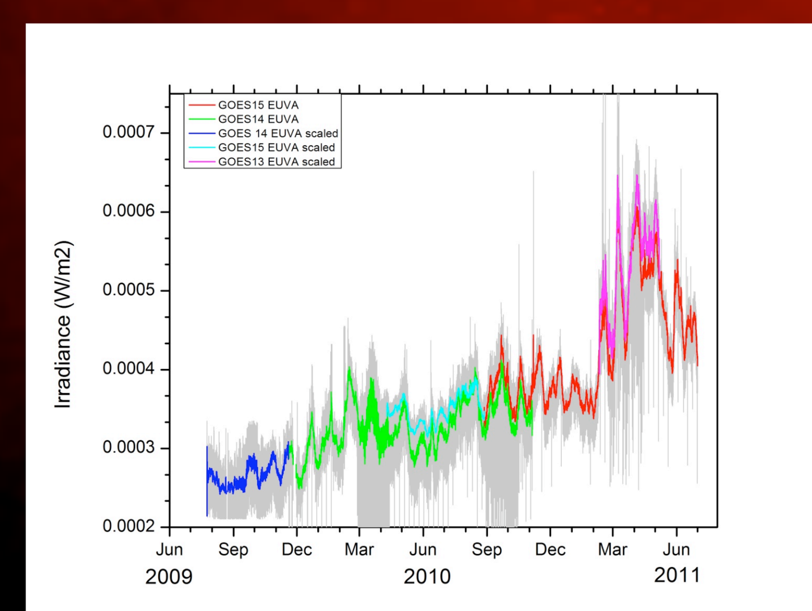
Streamlining the Process

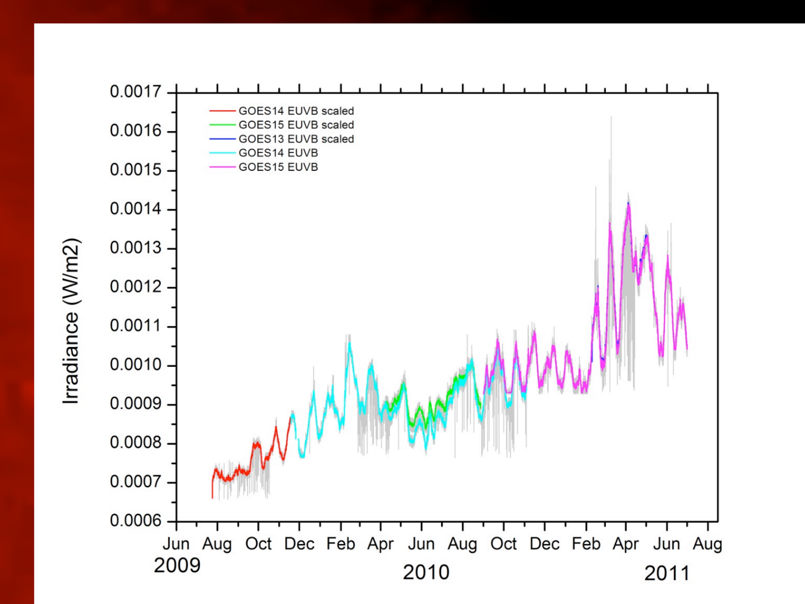
Initially we were producing each of the graphs to the right individually which was tedious and time consuming. A simple modification in the coding utilizing "!p.multi" made the process much faster.

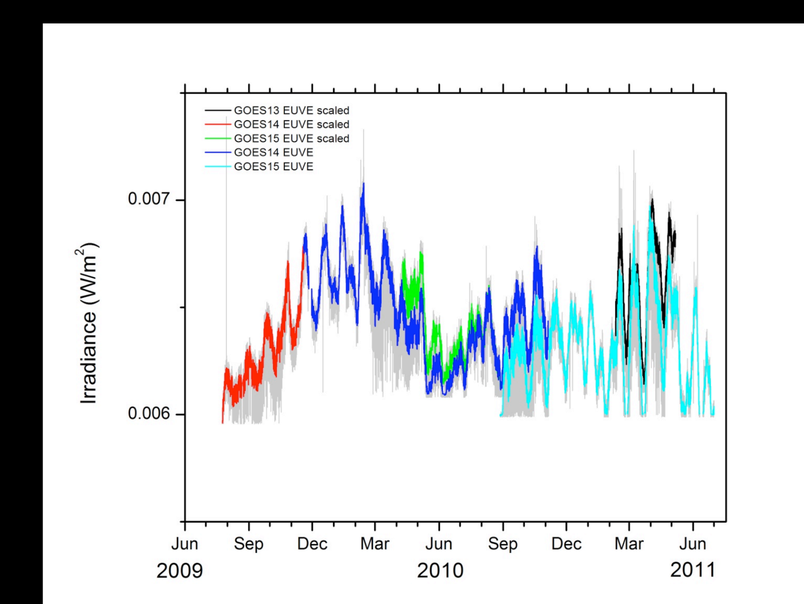


The Record of Solar EUV Irradiance from GOES EUVS

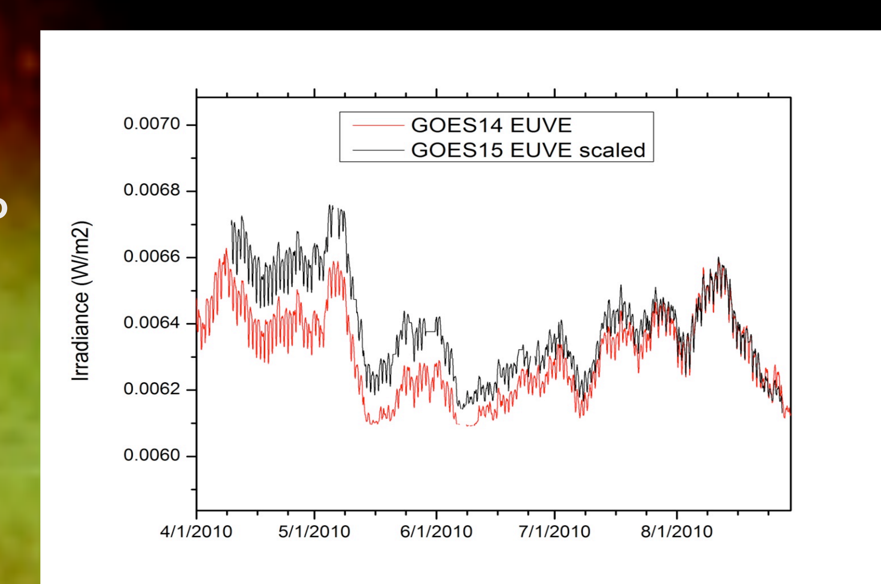
The record dates back to July 2009 and consists of EUV irradiance data from EUVS on GOES 13, 14, and 15.







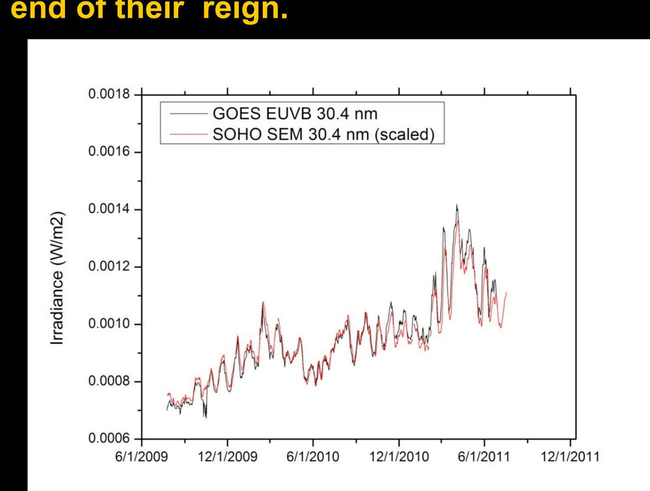
The following graphs are the final product of our work in the A, B, and E channels. In all three graphs, the gray indicates one minute data, where the colored lines are 6 hour averages of the one minute data, which helped clean up some of the noise found in the data. The A channel shows a lot of noise, much of which is believed to be caused due to a heater on board the instrument. The weekly calibrations also cause a lot of noise within the data. Lastly, you might notice the difference in trends between the A & B channels versus the E channel. The A & B plots show the gradual increase in irradiance that is to be expected as we come out of solar minimum, whereas the E channel plot doesn't show any concrete trend. We attributed this to degradation in the instrument, which we are unsure of the cause at this point.

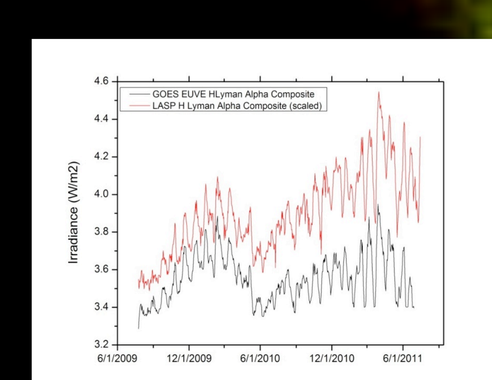


The plot to the left shows the instrumental drift between the two data sets as you go further away from the date in which we focused on to calculate the scaling coefficients.

So How does GOES Compare?

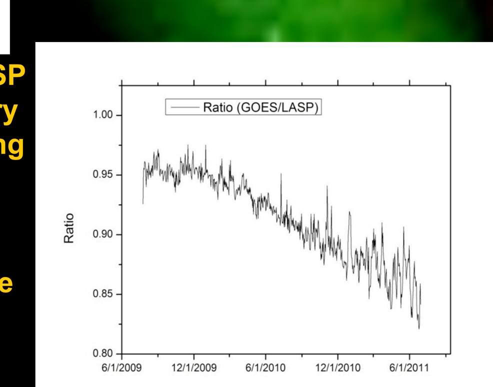
Comparing GOES data to SOHO data shows that it agrees quite well. The hope is that GOES will become the standard for EUV irradiance data as the other instruments currently in operation are approaching the end of their reign.





Left is a comparison between GOES and LASP data in the E channel. The data from GOES is a composite of the three satellites (mostly GOES 14 & 15) in the E channel.

Taking the ratio of GOES and LASP data in the E channel shows a very steady decreasing trend, indicating instrument degradation. Further investigation is needed to understand the cause of this degradation. Also in the future we hope to quantify this degradation and hopefully remove it from the data.



Summary

There is still much to be done with the EUV irradiance data from the GOES satellites. Further comparisons need to be made to SOHO, EVE, & SDO data sets. We also need to take a closer look at the instrument degradation, and other artifacts skewing the data; specifically the heater noise, weekly calibrations, and instrument degradation in the E channel. Once the data is cleaned up, absolute calibrations need to be made, as the adjustments we made were only rough, initial ones. Finally once that is complete, we would like to make the data available on a webpage in real time for the public and DOD to utilize for there models of the Ionosphere and Thermosphere. Eventually we hope that the GOES data will become the standard when it comes to investigating EUV irradiance.