Developing a Proxy Model for Solar EUV Irradiance

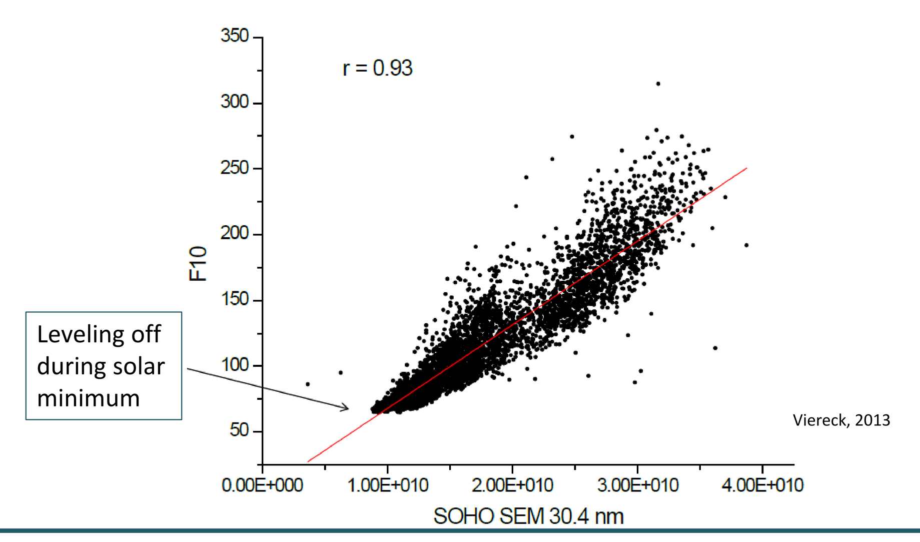
[1,2]Katherine A. Suess, [1]Rodney Viereck, [3]Janet Machol, [4]Marty Snow

[1]NOAA Space Weather Prediction Center, Boulder, CO [2]University of Colorado, Boulder, CO [3] NOAA National Geophysical Data Center, Boulder, CO [4] Laboratory for Atmospheric and Space Physics, Boulder, CO

Background and Motivation

Solar Extreme UltraViolet (EUV) irradiance is one of the major drivers of the ionosphere/ thermosphere system. EUV irradiance is highly variable and moreover, it is impossible to measure EUV from the ground and no space-based EUV measurements of all wavelengths that span decades. So for many years F10.7, a solar emission at 10.7cm, has been used as an EUV proxy. While useful, this proxy has several undesirable characteristics when used for long-term modeling and forecasting of the I/T system, such as leveling off and decreased accuracy during solar minimum.

Experimental EUV measurements are currently available through the TIMED SEE (NASA Thermosphere Ionosphere Mesosphere Energetics and Dynamics Solar EUV Experiment) and SDO EVE (Solar Dynamics Observatory EUV Variability Experiment) satellites. These are, however, scientific instruments and thus data may not be available for long-term operations. Thus, this project seeks to model the EUV flux observed by these instruments as a linear combination of other inputs from operational satellites and sources– namely, the GOES-15 EUVS instrument's A, B, and E channels, and the GOES-15 XRS instrument's A and B channels, F10.7, the magnesium core-to-wing ratio. By using real EUV data to model EUV flux, the predictive value of the proxy will be improved and the model will respond better to abnormal trends such as the most recent solar cycle.



Objectives

- For 20 5-nm bins between 5 and 105nm, determine a set of weights that will convert a linear combination of input data into the desired output data
- Use these weights as a proxy model for EUV that, because it includes EUV data, will be more accurate and dynamic then an F10.7 proxy alone
- Cater to the needs of I/T modelers
  - Create the full EUV spectrum from 5-105 nm at 5nm resolution to have similar inputs to current models
  - Put updated weights and data on the NOAA website so it is easily accessible

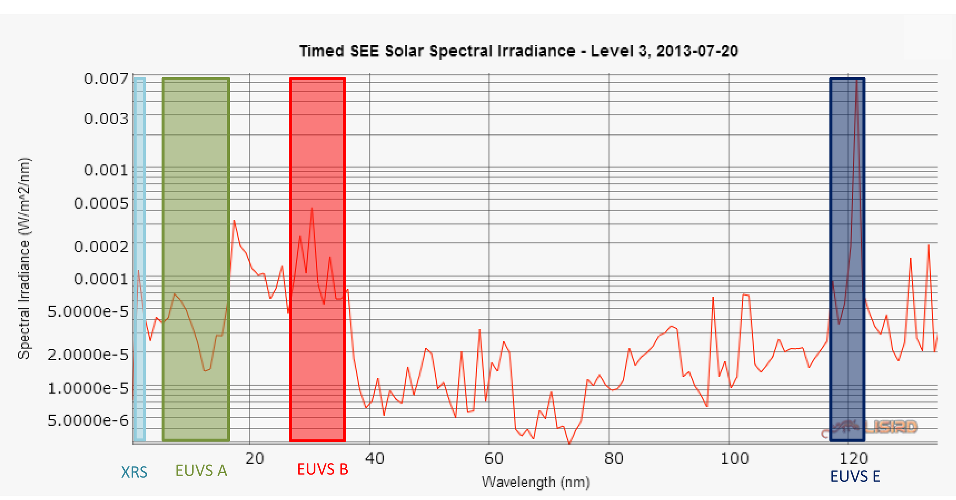
Methods and Materials

Methods

- Gather experimental data from SDO EVE and TIMED SEE to use as outputs
- Gather operational data from GOES-15 EUVS and XRS instruments as well as F10.7 and Mg II indexes
- Use the Levenberg-Marquardt least squares fitting algorithm to find the weights that will create 2012 EVE data from 2012 GOES data
- Test, refine, and make available to the public
  - Test how well 2012 weights work to predict 2013 and 2011 EVE data from 2013 and 2011 GOES data

Materials

- Output data sets: SDO EVE (5-40nm) and TIMED SEE (0.5-5nm and 40-105nm)
- Input data sets:
  - GOES-15 EUVS A, B, and E channels
  - GOES-15 XRS A and B channels
  - F10.7 index
  - Mg II index and 70-day smooth Mg II index (helps decrease variability due to Carrington rotation)
  - 1 AU correction (was not included in all data sets)



- Fitting algorithm: mpfit for IDL
  - Developed by Craig Markwardt [1], based on the Levenberg-Marquardt algorithm (damped least-squares method)

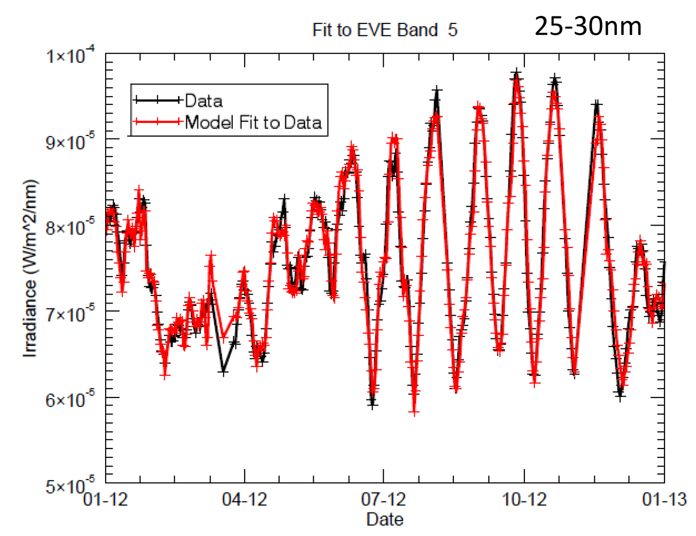
Model

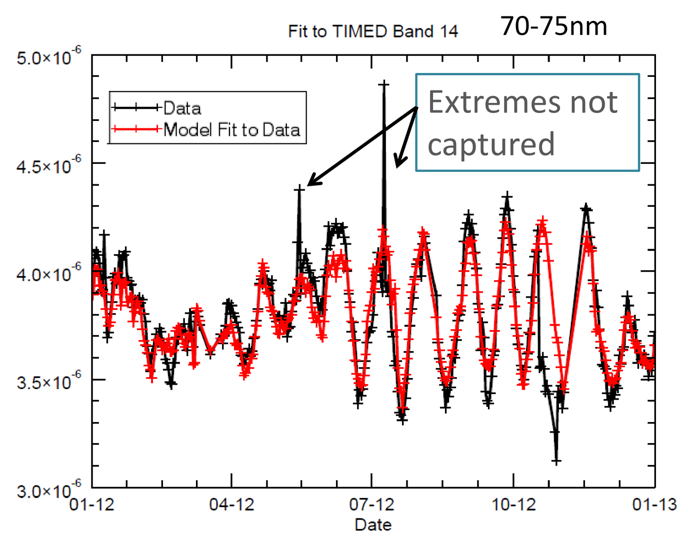
- Recreate the EUV irradiance in each bin by using least-squares analysis to fit observed irradiance to broadband GOES-15 EUVS & XRS data and current proxies
- Give fit algorithm observed irradiance and input data and it will produce weights according to: EVE or SEE irradiance in a 5nm band = weight1 (offset) + weight2*XRSA + weight3*XRSB + weight4*EUVSA + weight5*EUVSB + weight6*EUVSE + weight7*F10.7 index + weight8*Mg II index + weight9*Mg II Smooth index + weight10* 1 AU Correction (see 'Relative Contributions' for graphic results of eqn)
- Fitting algorithm returns an array of fitting weights; ten columns of weights by twenty rows of bins
- We can use these weights multiplied by today's proxy data to obtain a prediction for today's EUV flux

Results

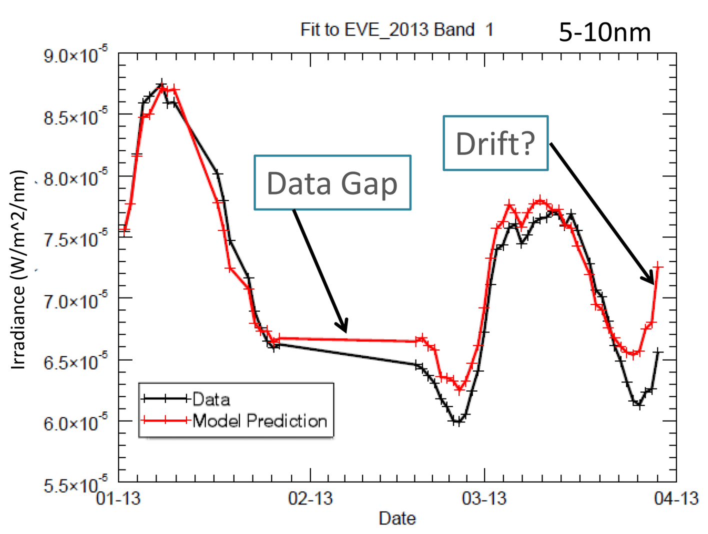
- Initially, had trouble fitting longer wavelength due to a lack of calibration in data
- To solve this, we used SDO EVE data for 5-40nm, TIMED SEE data for 40-105 nm
- This improved longer wavelengths, but best results still from 5-45 nm

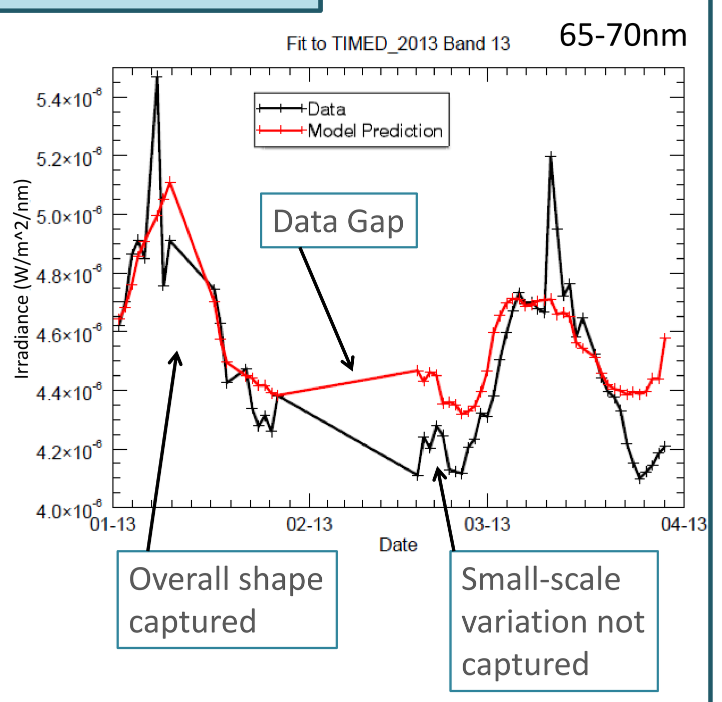
Fit



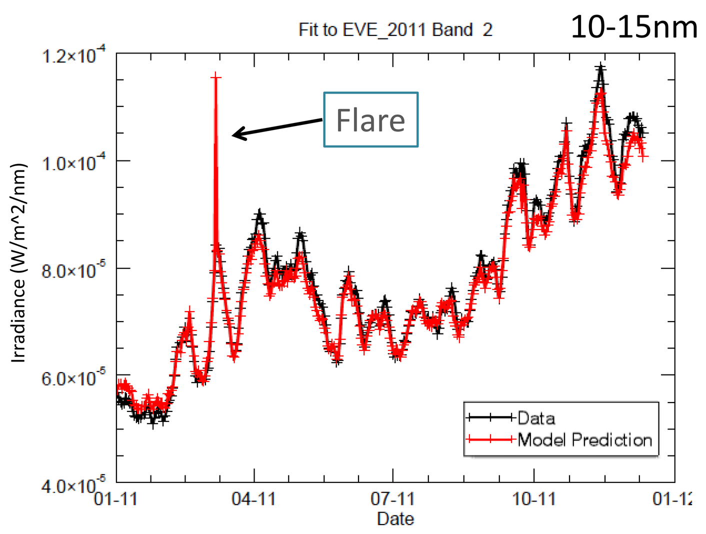


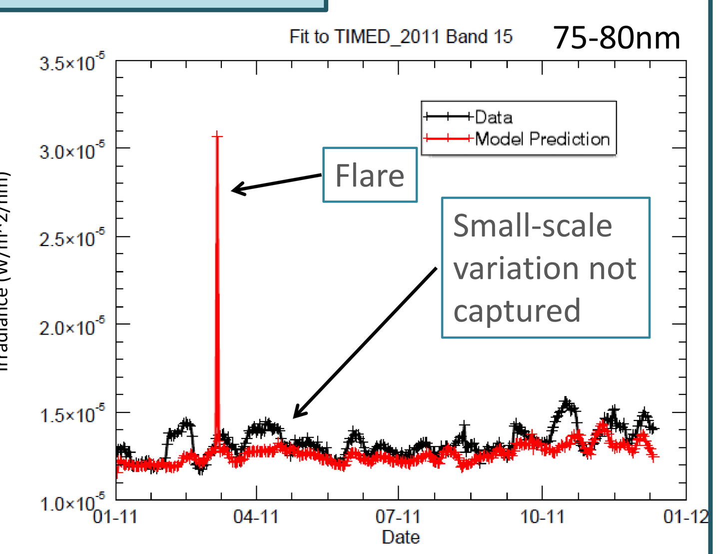
Prediction of 2013



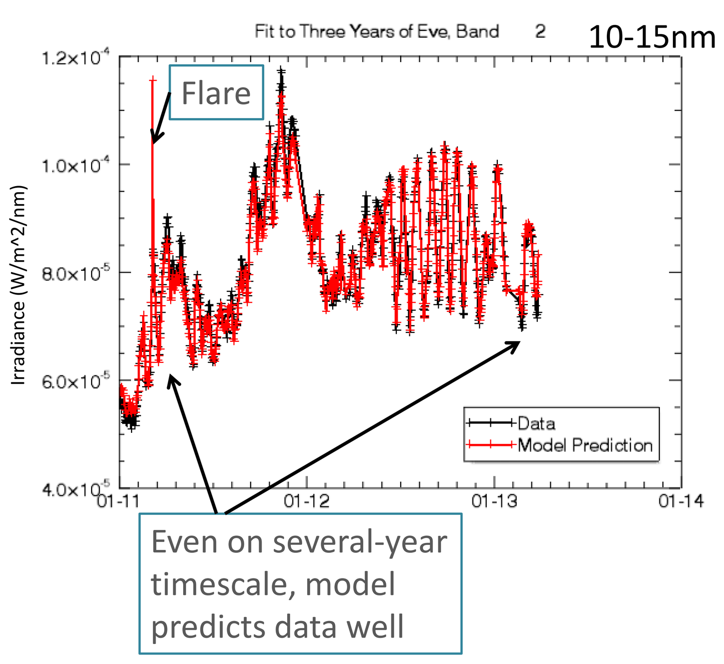


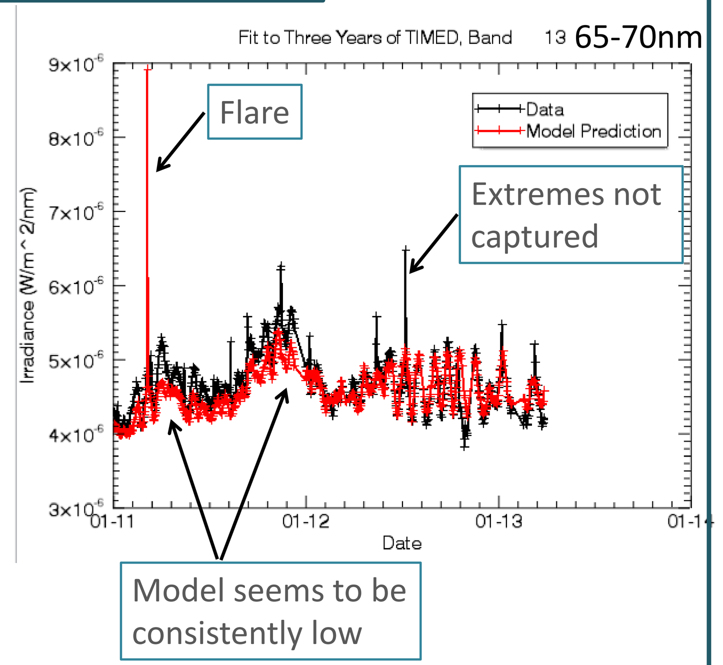
Prediction of 2011





All Three Years

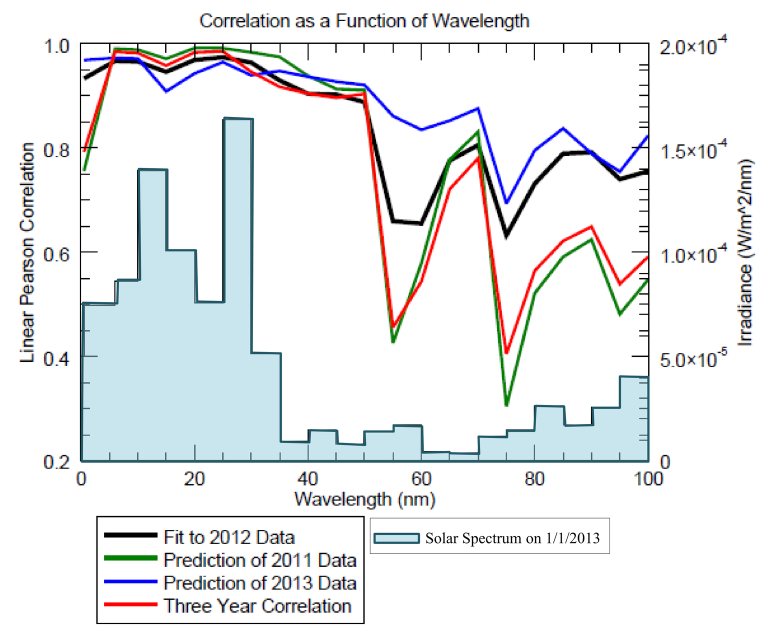




- Overall, our model's predictions seem to fit the data much better at shorter wavelengths. To confirm this, we will examine the linear Pearson correlation as a function of wavelength.

Discussion

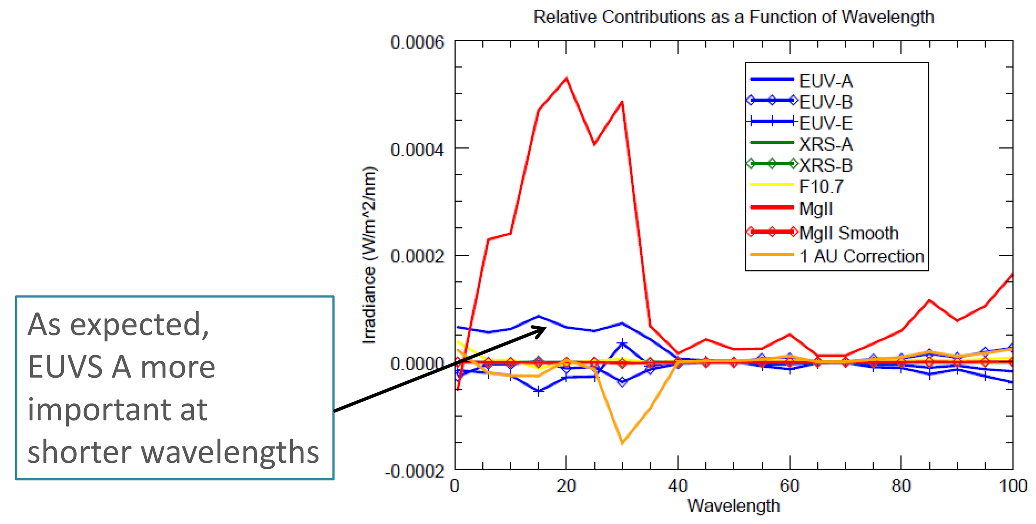
Correlation



- This explains why the predictions are less accurate at longer wavelengths– the initial correlation drops at ~45nm
- However, the irradiance as a function of wavelength (blue histogram) also drops
- This means that the 45-105nm range is not as important in the models: less energy is deposited into the I/T system from these wavelengths.
  - Also, these longer wavelengths are less variable.

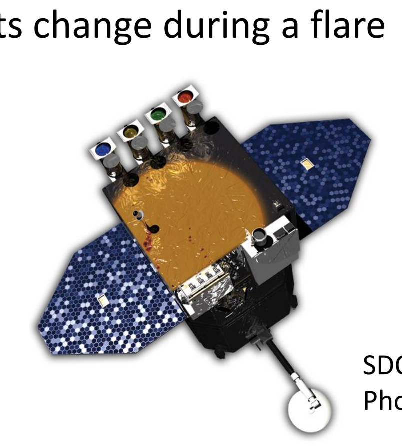
Relative Contributions

- Sanity check: want to make sure that data is more important at the wavelength ranges it is actually measuring
- Plotted wavelength versus the input data times its weighting coefficient



Future Work

- See how fit weights change during a flare



SDO satellite, designed to measure flares. Photo courtesy: LASP and NASA/GSFC

- Put results (fit weights and/or modeled spectrum) on NOAA's website for convenience, ease of use, and better implementation of the method.

Conclusions

- Using EUVS data from GOES-15 as a part of an EUV proxy model produces a model that performs very well at wavelengths from ~5-45nm
- More data is likely necessary to improve the proxy at longer wavelengths (current data does not span the range 34-118nm, so the proxy does not perform well at these wavelengths)
- Since our proxy includes EUV data, it will likely capture both long-term trends and short-term variability very well
- This model will allow us to better model the I/T system and, as a result, to better forecast space weather and its effects.

Acknowledgements

- LASP, CU, NSF, SORCE, and NOAA SWPC
- Mentors and Program Coordinators
- LASP, NOAA SWPC, NOAA NGDC, and the University of Bremen for data

Artist's conception of GOES satellite. Photo courtesy: NASA and Lockheed Martin

References

[1] Markwardt, C. B. 2009, 'Non-Linear Least Squares Fitting in IDL with MPFIT,' in proc. *Astronomical Data Analysis Software and Systems XVIII,* Quebec, Canada, ASP Conference Series, Vol. 411, eds. D. Bohlender, P. Dowler & D. Durand (Astronomical Society of the Pacific: San Fransisco), p. 251-254.