LWS Workshop 2_18P

Solar Flare Soft X-ray Irradiance and its Impact on the Earth's Upper Atmosphere

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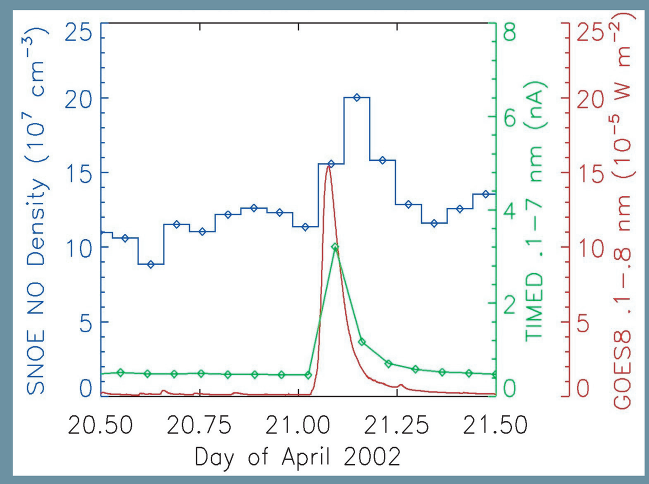
INTRODUCTION

Solar soft X-ray irradiance is extremely variable and significantly affects space weather by increasing the energy deposition to the upper atmosphere. It provides an energy source to the lower thermosphere and ionosphere for the production of photoelectrons that produce E-region ionization, dissociation of molecules, and airglow emissions. Solar flares are a dramatic source of variability. Nitric oxide (NO) is an important product of the solar energy deposition, and is key to the energetics of the lower thermosphere as it provides the primary cooling process there.

RESEARCH OVERVIEW

Data from two NASA satellite missions, Thermosphere, Ionosphere, Mesosphere, Energetics and Dynamics (TIMED) and the Student Nitric Oxide Explorer (SNOE), is being analyzed to determine how the solar soft X-ray irradiance varies during a solar flare and how this energy impacts the Earth's lower thermosphere. The TIMED - Solar EUV Experiment (SEE) makes daily measurements of the solar ultraviolet irradiance from 0.1 to 195 nm, and SNOE observed NO between 95 and 135 km.[8,9,1] TIMED-SEE observes, on average, eight solar flares of various strengths per month. SNOE observed a significant increase in thermospheric NO during times when solar flares were observed by TIMED-SEE. These overlapping observations provide a unique opportunity to study the energy outflow of solar flares and their impact on the Earth's upper atmosphere.

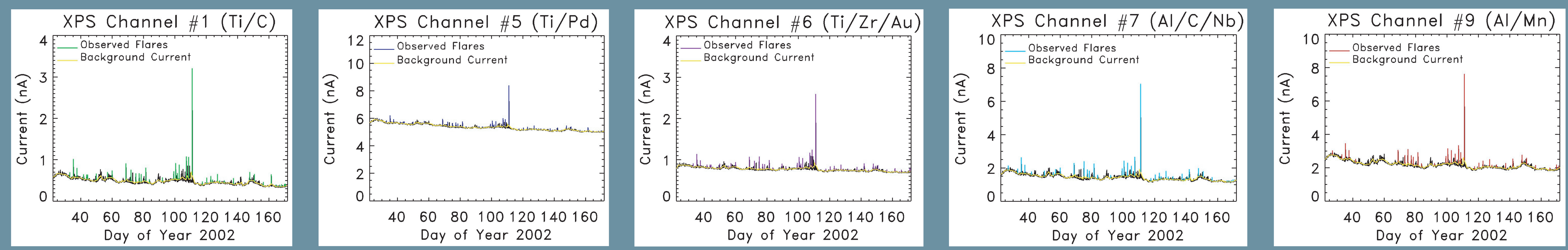


X1.5 Solar Flare April 21, 2002 - Comparison of SNOE NO density, TIMED-SEE current and GOES-8 irradiance observations of flare.

- An increase in solar soft X-ray irradiance was observed by all TIMED XUV Photometer System (XPS) photodiode detectors over the 0.1-27 nm wavelength range. The response of one XPS photodiode detector that observes the 0.1-7 nm range is plotted in green. This photodiode measured a maximum current increase of more than a factor of 5 due to the X1.5 solar flare.
- SNOE equatorial NO density at 106 km increased by a factor of 2 (blue) just after the X1.5 solar flare peak irradiance. Solar soft X-rays in the 1-10 nm range produce equatorial NO at an altitude of 106 km.[1]
- GOES-8 irradiance measurements (red) register an increase of several orders of magnitude during this X1.5 solar flare.

SOLAR FLARE SPECTRAL ANALYSIS PART I

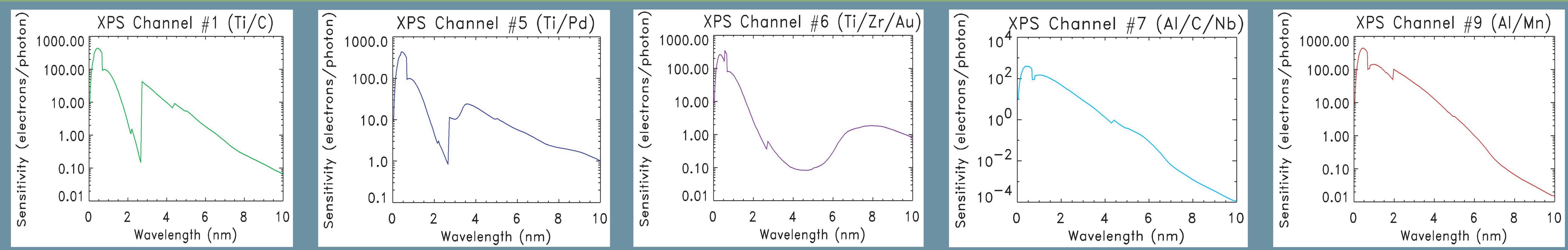
- Approximately 40 solar flares were observed over a five month period in 2002.
- A flare was defined as any signal that produces a 20% increase above the non-flare signal for that day.
- Analysis of solar flare frequency was performed on all XPS photodiodes.



Measured current (black) over a 5 month period in 2002 for five of the XPS photodiodes. Observed solar flares (colors) and background current (yellow) are plotted for each photodiode. The color for each photodiode coating corresponds to the same color of each photodiode coating in the below section.

XPS PHOTODIODES

- XPS XUV photodiodes have different thin metallic film filters deposited directly onto their surfaces.[8]
- XPS photodiodes measure solar soft X-ray irradiance from 0.1-27 nm with individual bandpasses of about 7 nm.[8,9]
- The sensitivity of each detector channel varies within each wavelength range.[8]
- These five detector channels cover the 0.1-20 nm range and the wavelengths of their peak sensitivity are different.[8]



Sensitivities of five XPS photodiodes. The color for each photodiode coating corresponds to the same color of each photodiode coating in Part II.

SOLAR FLARE SPECTRAL ANALYSIS PART II

Bremsstrahlung Radiation

- Soft X-rays are produced by thermal bremsstrahlung radiation during the gradual phase of a solar flare.[6,5]
- The emissivity of thermal bremsstrahlung radiation was determined for a plasma with a Maxwellian distribution.[7]

$$j(\nu) = 6.8\times10^{-38}\, Z^2 N_e N_Z T^{-1/2} g_{ff}(\nu,T)\, e^{-h\nu/KT} \text{ erg / cm}^3 \text{ sec Hz}$$

- The differential thermal bremsstrahlung X-ray flux is then defined as:[3]

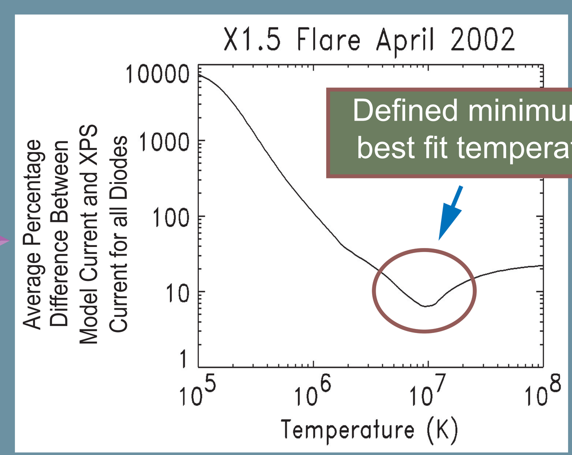
$$I(E) = 1.3\times10^{3}\, EM\, e^{-E/T} / E^{1.4}\, T^{0.1} \text{ photons / cm}^2 \text{ sec keV}$$

Find Best Fit
Calculate the average difference between model current and XPS current.

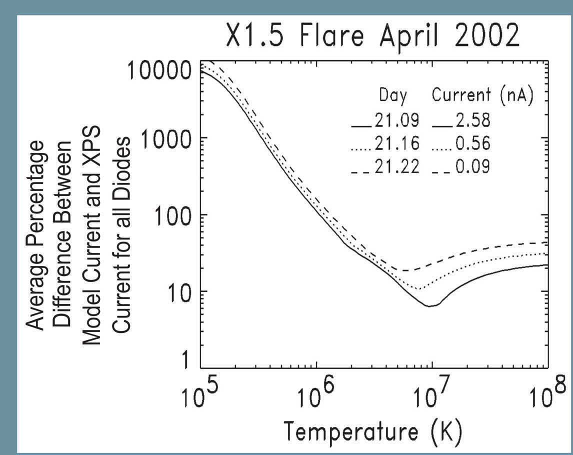
Apply Scale Factor
Scale Factor = XPS Current / Model Current

Calculate Model Current
Model Current = I(E) * Diode Calibration

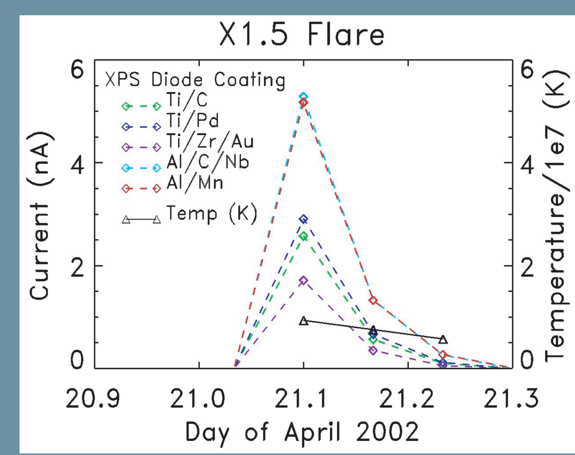
Input Temperature
Range of $10^6 < T < 10^8$ K for solar flare plasma.[2,4]



The difference between the model current and XPS current is calculated for the entire temperature range. A well defined minimum exists for a best fit temperature.



The best fit temperatures are shown for three times and their corresponding XPS currents during the solar flare. The bremsstrahlung radiation assumption produces a better fit at hotter flare plasma temperatures.



The inferred temperatures (black) from the previous figure are shown with the five XPS photodiode measured currents (colors) at corresponding times during the X1.5 solar flare. The temperature decreases as the XPS flare current decreases with time.

SUMMARY

- The described bremsstrahlung radiation assumption produces solar flare plasma temperatures that are on the order of expected flare temperatures (10^7 K) and these temperatures decrease as the XPS flare current decreases with time.
- This simple model produces a better fit at hotter temperatures because the photodiode response is more sensitive at shorter wavelengths.
- The XPS photodiodes are sensitive at longer wavelengths and a more physically realistic model is required for use in the defined procedure. This will allow the determination of the solar spectrum up to 10 nm.

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