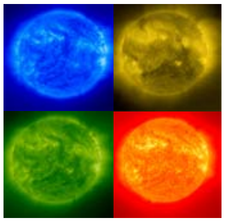
A Method of Identifying Solar Features in EUV Images using Intensity Thresholds

Anna L. Nuckolls and Margit Habbereiter

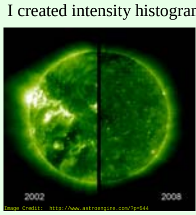
Laboratory for Atmospheric and Space Physics, 1234 Innovation Drive, Boulder CO 80303

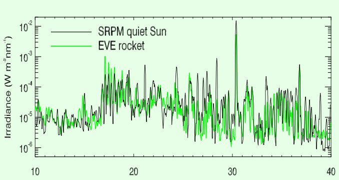
New Mexico School of Mining and Technology, 801 Leroy Place, Socorro NM 87801

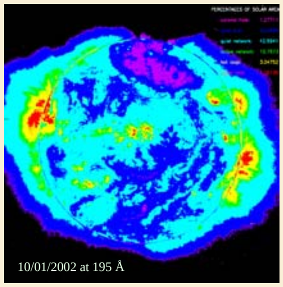


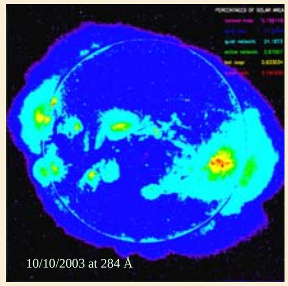
Abstract

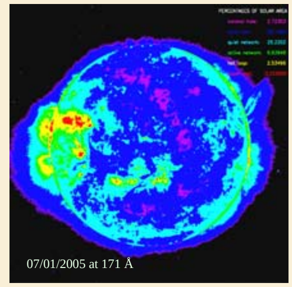
I present a method of determining the fractional areas on the sun's surface covered by different features using images taken with the Extreme-Ultraviolet Imaging Telescope (EIT) onboard the SOHO satellite. Scientists at the Laboratory of Atmospheric and Space Physics (LASP) developed a spectral solar irradiance model called the Solar Radiation Physical Model (SRPM) which will be used to model the solar spectrum at all stages of the solar cycle. This model calculates the spectrum for six distinct solar features in the corona: coronal holes, quiet sun, quiet network, active network, hot loops, and super-hot features. In order to predict the spectral irradiance of the sun, SRPM requires the input of the solar area covered by each of these six features in each of the EIT image wavelengths (171 Å, 195 Å, 284 Å, and 304 Å). To determine the thresholds, I created intensity histograms of the EIT images that show distinct variations corresponding to the different features visible on the solar surface. Using these histograms, I created a system of intensity thresholds with which to identify each solar feature. The background pixels were then removed from the SOHO images and the thresholds were applied to calculate the area covered by each coronal phenomenon. This method was applied to images from July 2002 through November 2006 in order to observe variations throughout the solar cycle. The resulting thresholds for the 171 Å, 195 Å and 304 Å images turned out to be practically time-independent and thus valid throughout the entire solar cycle. However, the 284 Å images show a distinctly different behavior, i.e. the thresholds for each feature are a function of solar activity. This result poses a challenge for irradiance reconstructions since the time-independent synthetic spectra require thresholds that are not a function of solar activity.

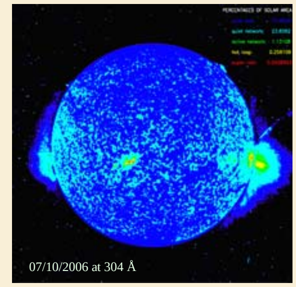




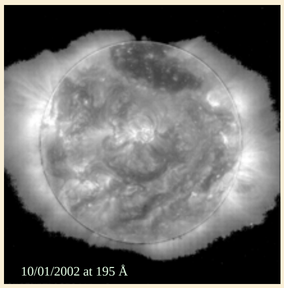


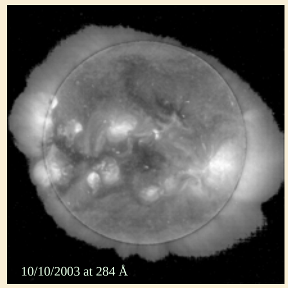


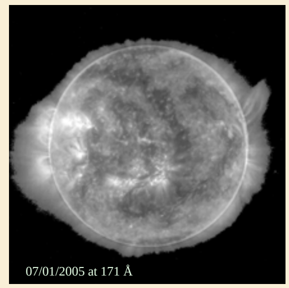


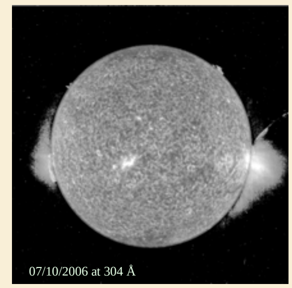


Solar Maps: These images were created using intensity thresholds to identify each of the solar features. Pixel counts were then used to calculate area percentages.





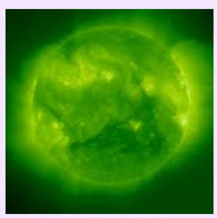




EIT Images: These images were taken by the EIT instrument aboard the SOHO satellite. They demonstrate the same physical features as the solar maps above.

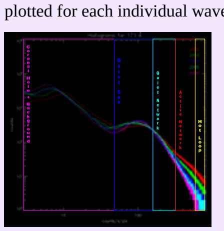
Data Processing

In order to prepare the images for threshold analysis, several tasks had to be performed. First, the solar disk was identified using SolarSoft's find_limb2.pro. The resulting disk parameters were then adjusted and improved manually to fit the image. All pixels within the solar disk were considered valid data and were not altered. In order to differentiate extended coronal pixels from unwanted background pixels, a gradient function was applied to weight a pixel's brightness and distance from the solar disk against a set intensity threshold. All gradient values which fell below this value were eliminated as background. This gradient function was adjusted manually until the resulting data fit the visible corona.



In order to ensure that features were identified properly in the optically-thin extended corona, a second gradient was then applied to pixels outside of the solar disk. This function artificially altered the intensities of the pixels in the extended corona, weighting each based on their individual intensity and their distance from the solar disk. Outer pixels were given artificially brighter values to account for the increased transparency of the corona.

Finally, histograms for images from 2002 to 2006 were plotted for each individual wavelength. In order to validate the assumption that the intensities of solar features were largely time-independent, the five years were compared for consistency. Intensity features in the histogram were then compared to visible features on the solar disk. Once a correlation was found, an intensity threshold would be assigned to that feature to uniquely identify it in all EUV images of a specific wavelength. Feature maps were then generated and compared the SOHO images to ensure that the thresholds properly represented each feature.

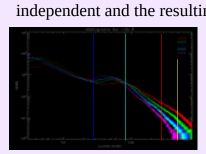


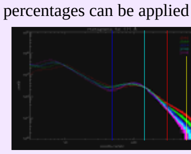
Results for 171 Å, 195 Å, and 304 Å Images

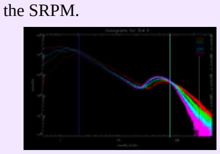
The histograms for the 171 Å images and the 195 Å images showed very clear, distinct features. Local maxima and minima, intersections, and inflection points were used to identify coronal holes, quiet sun, quiet network, active network, and hot loops. The histograms could not resolve the extremely high-intensity super-hot features and so these thresholds were identified by comparing solar feature maps to the original images. The resultant intensity threshold was chosen based on how well it defined bright features, particularly features on the limb.

The 304 Å images behaved similarly. However, since this wavelength primarily images the transition region and the chromosphere, the histogram showed no coronal hole feature. For the solar maps in this wavelength, I removed the coronal hole feature entirely.

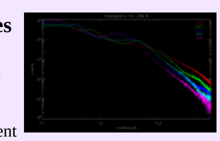
All three of these wavelengths showed very minor variations in feature intensity throughout the solar cycle. Thus, the intensity thresholds can be considered time-independent and the resulting percentages can be applied to the SRPM.



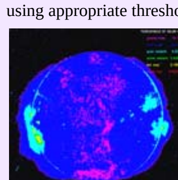


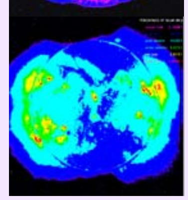


Results for 284 Å Images



In contrast to the other three EUV wavelengths, 284 Å demonstrates an entirely different behavior. The histogram shows a definite shift in the intensity of each feature throughout the solar cycle. This shift makes time-independent threshold definition difficult, if not impossible. The solar feature maps were generated using appropriate threshold values for 2003. As a result, the maps for 2006 show a striking shift towards lower-intensity features which are not necessarily visible in the original EIT images.





Additionally, the histogram demonstrates several features at higher intensities which do not appear in the other three wavelengths. Several inflection points occur in the high-intensity range whose exact feature identification is also time-dependant and requires further study. It turns out to be a challenge to accurately define time-independent intensity thresholds for this wavelength. Therefore, the resulting percentages require further study and consideration before they can be applied to SRPM.