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Using ground-based Ca II K images as a proxy for shorter UV wavelengths

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Abstract

Solar irradiance impacts Earth's atmosphere and climate, but the effects of its variability are less-well understood. This is especially true of short wavelength ultraviolet (UV) radiation, the effects of which appear to be more significant than those of radiation at longer wavelengths. Understanding the underlying mechanisms and their effects begins with knowledge of the source and extent of this variability. To that end, we examine full-disk Ca II K images from San Fernando Observatory (SFO). Previous variability studies show that active region data obtained from these images, combined with data from the red continuum images, correlates well with satellite Total Solar Irradiance, especially SORCE/TIM (r^2 = 0.95). In addition, SFO's Ca II K correlates well with the Mg II index commonly used as a proxy for UV radiation. Here, we consider whether ground-based Ca K data can be used as a proxy for shorter UV wavelengths, with application to climate modeling.

Method

Our approach is to examine spectral irradiance from UARS/SUSIM and SORCE/SOLSTICE and SORCE/SIM combined with SFO Ca K data. Several previous studies use the 100+ year Mt. Wilson CA II K index to infer spectral information at shorter UV wavelengths. This data set is invaluable, but ends in 1985; further study, using a more recent data set, will be instructive.

The SFO K indices begin in 1988, continue to the present day, and include the most unusual solar cycle of the last 100 years and, certainly, since space-based measurements began in 1978.

A first step in this study is to examine several wavelengths for the period where UARS, SORCE, and SFO overlap.

Non-SFO Data

- **SORCE/SOLSTICE**: daily averages, single instrument

  http//lasp.colorado.edu/sorce

- **SORCE/SIM**: daily averages, single instrument

  http//lasp.colorado.edu/sorce

- **UARS/SUSIM**: daily indices

  http//disc.sci.gsfc.nasa.gov/UARS

SFO Photometric Data

CFDT1 & 2 (Walton *et al* (1998,*Sol.Phys.* **179**, 31; www.csun.edu/sfo)

- 1024 x 1024 CFDT2 images, 2.5” square pixels
- Images produced by 1024 scans of a 1024- linear diode array
- 672.3 nm (red), 10 nm bandpass
- 393.4 nm (Ca II K), 10 nm bandpass
- Single red image; Ca II K image produced from two co-added scans

SFO Image Processing

- Photometric images produced in several wavelengths: CFDT1 since 1988; CFDT2 since 1992.
- Several robust algorithms developed for producing photometric contrast images and determining relative irradiance contributions of solar surface features (sunspots, faculae, and plage) from these images. (Walton *et al* (1998 *Sol.Phys.* **179** 31))
- Several solar indices computed, including photometric sums (∑), sunspot areas and deficits, and faculae areas and excesses, for the purpose of TSI modeling. (Preminger, Walton, & Chapman 2001, *Sol.Phys.* **202** 53)

SFO Photometric Sum (∑) Index

- Photometric Sum (∑) has been one of the most successful photometric indices produced. (Preminger, Walton, & Chapman 2002, *JGR*, **107** 6)
- $\sum_r$ and $\sum_K$, used in a multi-variable linear regressions against space-based TSI, produce the best results.
- $\sum_r$ and $\sum_K$ are disk-integrated sums determined from red and Ca II K-line contrast-image pixels, respectively; each pixel is weighted by the appropriate limb-darkening.
- **$\sum_r$ and $\sum_K$ do not require feature identification**, i.e., determining whether a pixel belongs to a sunspot, facula, or network.

SFO Photometric Sum (∑), continued

- ∑
  - measures the relative change in spectral irradiance in filter passband due to all features
  - assumes image noise is symmetric around zero, causing bright and dark noise pixels to cancel, leaving only contributions from real features
- Σ_K used for this project measures variability of the upper photosphere/lower chromosphere as seen in Ca II K images

Method, continued

- SFO $\sum_r$ and $\sum_K$ have produced the best fits against SORCE/TIM TSI (R^2=.95).
- Use just $\sum_K$ to see how well it correlates with shorter wavelengths.
- 14-April-2003 to 01-August-2005: This is the overlap period for UARS/SUSIM and SORCE/SOLSTICE
- UARS/SUSIM data: mg ii (core-to-wing), lyman alpha (121.5 nm) and 393 +/- .03 nm. (closest to SFO's 393.4 nm Ca II K)
- SORCE/SOLSTICE data: 121.5 nm and 280 nm
- SORCE/SIM data: 393.36 nm

Results

Linear regressions of UARS and SORCE only gave the following:

Susim mgii v. Solstice 280nm:	619 pts	r=0.957	r^2=0.9158
Susim ly-alpha v. Solstice 121.5nm:	607 pts	r=0.7745	r^2=.5999
Susim 393.x* v. Solstice 393.39:	623 pts	r=0.494	r^2=0.244

* Susim wavelength fluctuated from day-to-day, so we used the closest to 393.4 nm.

Results

Linear regressions of SFO $\sum_K$ with each of the UARS and SORCE wavelengths gave the following:

Susim mgii v. Ca K:	417 pts	r=0.899	r^2=0.8082
Susim ly-alpha v. Ca K:	406 pts	r=0.696	r^2=0.4844
Susim 393.x* v. Ca K:	406 pts	r=0.1719	r^2=0.0295

Sorce/Solstice 280 nm v Ca K:	521 pts	r=0.9124	r2=0.8325
Sorce/Solstice 121.5 nm v Ca K:	521 pts	r=0.9026	r2=0.8147
Sorce/SIM 393.39 nm v Ca K:	523 pts	r=-0.2638	r2=0.0696

*Susim wavelength fluctuated from day-to-day, so we used the closest to 393.4 nm.

Conclusions

This is a first step but shows that information derived from ground-based Ca II K images might be useful in understanding what's going on at shorter UV wavelengths and might be used in the absence of space-based data for short intervals. It's interesting that the shorter 121nm and 280 nm wavelengths are better correlated than those close to SFO's 393.4. I'm not sure why but it bears further investigation. The next step is to expand the time series in both directions to cover the whole 1988 to present SFO data set and to consider several more wavelengths. Perhaps this will lead to a way to knit the UARS/SUSIM and the SORCE/SOLSTICE into one long data set.