

WAVELENGTH DEPENDENCE OF SOLAR IRRADIANCE VARIABILITY FROM VIRGO ONBOARD SOHO

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ABSTRACT

Total and spectral solar irradiance variability measured by the VIRGO experiment on SOHO are compared with a three component model of spectral irradiance for selected periods of solar activity in 1996. The occurrence of single active regions during the present solar minimum conditions allows to study the influence on irradiance of sunspots and faculae as they drift over the solar disk.

1. OBSERVATIONS

Since February 1996, the Variability of solar Irradiance and Gravity Oscillations (VIRGO) experiment onboard SOHO measures the total solar irradiance (TSI) with absolute radiometers and the spectral irradiance at 402, 500 and 862nm by sunphotometers (SPM) with a bandwidth of 5nm (Fröhlich et al, 1995). In this paper, we use hourly means of 1 minute cadence observations for the period from 1st of April to the end of 1996. The SPM data are detrended by cubic splines, assuming a constant quiet sun, in order to remove sensor degradation. The spline knots are determined as local minima of sunspot area and Mg-II core-to-wing ratio data. Although the absolute radiometers show much less ageing, the total irradiance was also detrended by splines through the same knots in order to get compatible timeseries.

2. IRRADIANCE MODEL

Solar spectral irradiance variations can be modelled under the assumption, that they are produced by sunspots and faculae (Solanki & Unruh, 1997) according to:

$$F(\lambda) = (1 - \alpha_s - \alpha_f) F_q(\lambda) + \alpha_s F_s(\lambda) + \alpha_f F_f(\lambda) \quad (1)$$

where $F_x(\lambda)$ are synthetic flux spectra constructed from the ones given by Kurucz (1991): $F_q(\lambda)$ for the quiet sun, F_s for sunspots and F_f for the faculae. Solanki and Unruh adjusted the temperature-height profile of a plage-model (Fontenla et al., 1993) and the area filling factors α_s and α_f to fit the relative irradiance variations over the

solar cycle in the spectral range from 170 to 400 nm compiled by Lean et al. (1997).

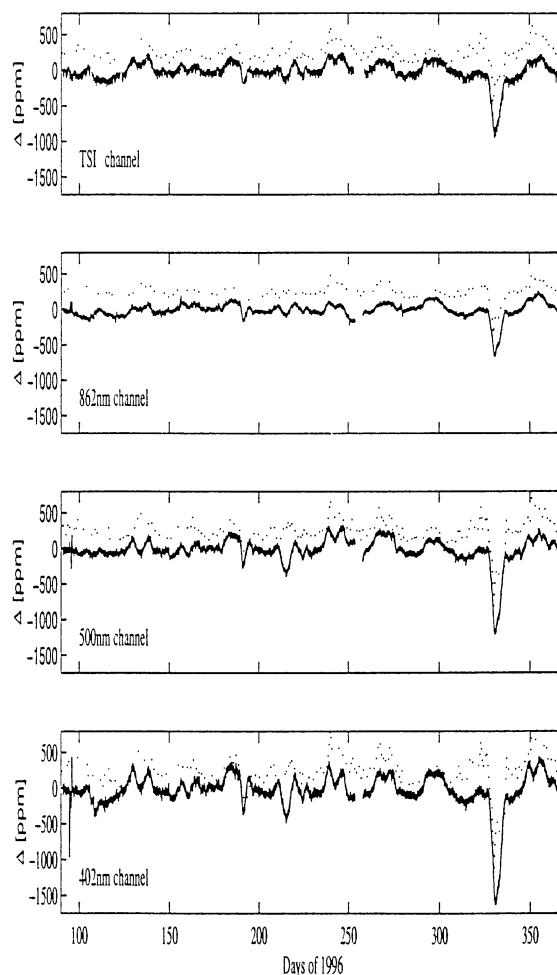


Figure 1. Irradiance variations observed by VIRGO (hourly means, solid line) and reconstructed by the model using daily values of PSI and MgII indices (dashed line, with an offset of +250 ppm to separate them from observations).

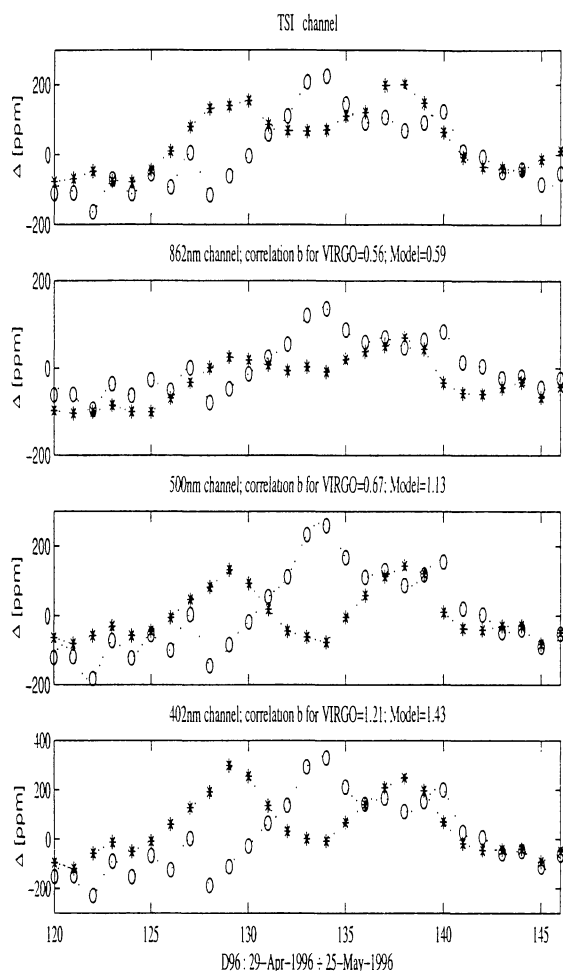


Figure 2. Observed (asterisk) and modelled (circle) irradiance variations during passage of an active region in May 1996. The slope b_λ of the linear regression (2) versus TSI is indicated for both datasets.

3. COMPARISON

In order to compare model and observations, one needs actual values of the filling factors α_s and α_r . The former is well represented by the photospheric sunspot index (PSI). An improved version of PSI , which takes the area dependence of contrast into account and calculates 'true' daily means was given by Fröhlich et al. (1994) and calculated at specific wavelengths using the center to limb variations of Neckel (1996). The latter, α_r , was obtained by fitting the Mg-II core-to-wing ratio from UARS/Susim (Floyd et al., 1997) to the VIRGO data of 1996.

Figure 1 shows, that the general agreement between model and observations is quite good although the model deviates from observations in several details. For

example, the sunspot around 30. July (day 230) is not reproduced by the model. At that time, the sunspot deficit is almost perfectly compensated by the facular brightening in the model which is obviously not represented correctly via the Mg-II index.

We examine two cases of irradiance in more detail: one in May, where the sunspot is small with respect to faculae area, the other in November where the situation is reversed. The wavelength dependence is expressed as slope b of the linear regression between a spectral and the TSI channel

$$SPM_\lambda = a_\lambda + b_\lambda * TSI. \quad (2)$$

In May an active region, NOAA 7962, drifted over the solar disk and crossed the meridian on day 133. It contained a small sunspot group that reached a maximal area of $180 \mu\text{Hemisphere}$ with a PSI value of -74 ppm. In Figure 2, the observed irradiance variations show two prominent enhancements when the active region is about ± 60 degrees from the solar meridian. The model does not reproduce these peaks: the Mg-II index and the model flux both vary as the projection of the facular area with position angle on the solar disk and do not account for any angular distribution of the emission seen as center-to-limb variation of contrast. The VIRGO observations however clearly show a facular limb brightening, most markedly in the near UV channel. The slope b_λ of the correlation Eq. (2) between spectral channels and TSI indicate further, that the model overestimates the facular enhancement at 500 nm ($b_\lambda=1.13$ versus 0.67) and less so also at 402 nm while the infrared model component relates to TSI much as the observed data does.

In late November, the active regions NOAA 7997 and 7999 moved over the disk. They included two sunspot groups with areas of 580 and $1030 \mu\text{Hemisphere}$ respectively and a combined PSI value of -778 ppm. The Mg-II index indicated a more or less constant facular excess between 250 and 300 ppm during this period. Figure 3 shows the corresponding irradiance variations observed by VIRGO and their model estimate. The agreement between observed and modelled spectral correlations b_λ is quite good, confirming the proper choice of the selected sunspot flux spectrum and PSI spectral contrasts. The dip at 402 nm is more than twice as deep as at 862 nm, with the TSI depth lying somewhere between the values at 500 and 862 nm. The observed temporal shape shows no distinct signs of facular limb enhancement as it does in May.

CONCLUSION

The Mg-II core-to-wing ratio can be used as proxy for facular area and, with wavelength dependent contrast, fitted together with PSI to the observed total and spectral irradiance variation of VIRGO in 1996. The global parameter Mg-II does not account for center-to-limb variations of facular contrast and fails to reproduce

details of irradiance variations. This is not surprising in view of the fact that the Mg-II core is formed in the chromosphere, whereas the facular contrast observed by VIRGO is almost entirely produced in the lower photosphere. Spatially resolved proxies for faculae area, like magnetograms or Ca-K images, and an extension of the current model will be needed to account for center-to-limb variations of facular contrast.

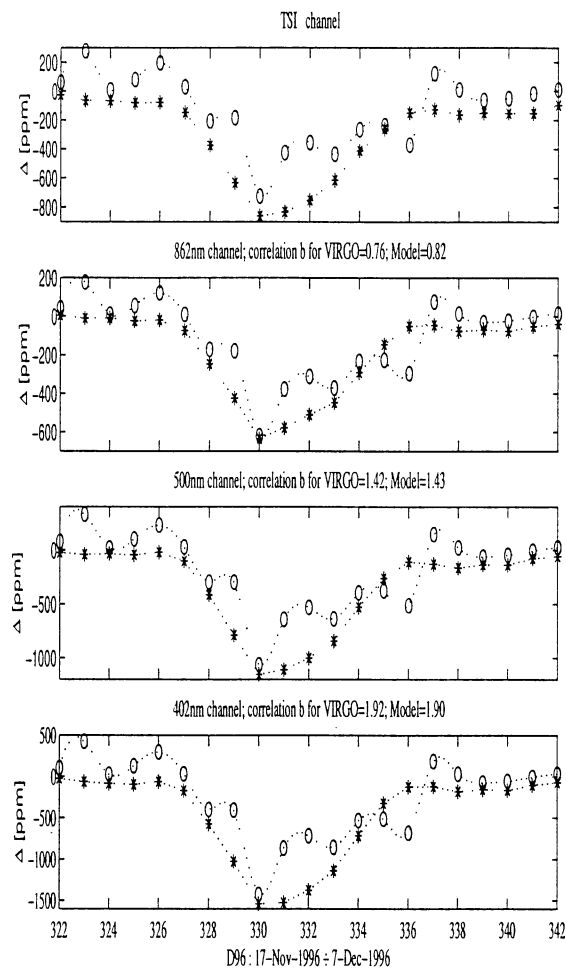


Figure 3. Same as Figure 2, but for active region in November. This case contains the largest sunspot of 1996 and little variation of the Mg-II index.

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