SOLAR IRRADIANCE ESTIMATION FOR PLANETARY STUDIES

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INTRODUCTION

The spectral solar irradiance (SSI) is the main source of external energy input to the planets of the Solar System. At the Sun, this quantity mainly varies as a function of solar rotation and evolution of active regions (sunspots and faculae).

Usually, the SSI at other planets is estimated based on the extrapolation of the measurements at Earth, without taking into consideration the evolution of spots and faculae [1].

We propose a new method for calculating the SSI anywhere within the ecliptic, regardless of the measurements at Earth, and accounting for the evolution of magnetic features.

METHODS

Our method follows the Spectral And Total Irradiance REconstruction (SATIRE, [2], [3]) approach and the works by [4] and [5].

We calculate the SSI by summing up the intensity of each contributing feature: quiet Sun (q), faculae (f), and spots (s).

At a given time t, wavelength λ, and ecliptic angle ϕ, the SSI is computed as

$$\begin{aligned} E^{\phi}(t,\lambda) = \quad & \textstyle\sum_i I_{\mathrm{q}}(\lambda)\Delta\Omega_i \\ & + \textstyle\sum_i \alpha_{\mathrm{f}}^{i\phi}(t)[I_{\mathrm{f}}(\lambda) - I_{\mathrm{q}}(\lambda)]\Delta\Omega_i \\ & + \textstyle\sum_i \alpha_{\mathrm{s}}^{i\phi}(t)[I_{\mathrm{s}}(\lambda) - I_{\mathrm{q}}(\lambda)]\Delta\Omega_i, \end{aligned}$$

where α are the area coverages on the solar surface (Figure 1) and $\Delta\Omega_i$ is the observed solid angle subtended by the ith pixel.

The extrapolation method [1] uses SSI at Earth ($E_{\oplus}$) made before ($t_d - \Delta t_1$) and after ($t_d + \Delta t_2$) the visible solar disk rotates past the planet for a day t_d, in order to estimate the SSI as

$$E(t_d,\phi) = \frac{w_1\, E_{\oplus}(t_d - \Delta t_1) + w_2\, E_{\oplus}(t_d + \Delta t_2)}{r^2(t_d)},$$

where $r^2(t_d)$ is the distance between Earth and the planet on day t_d. The measurements are linearly interpolated and weighted, and the weights w_1 and w_2 are proportional to the periods Δt_1 and Δt_2.

MODEL

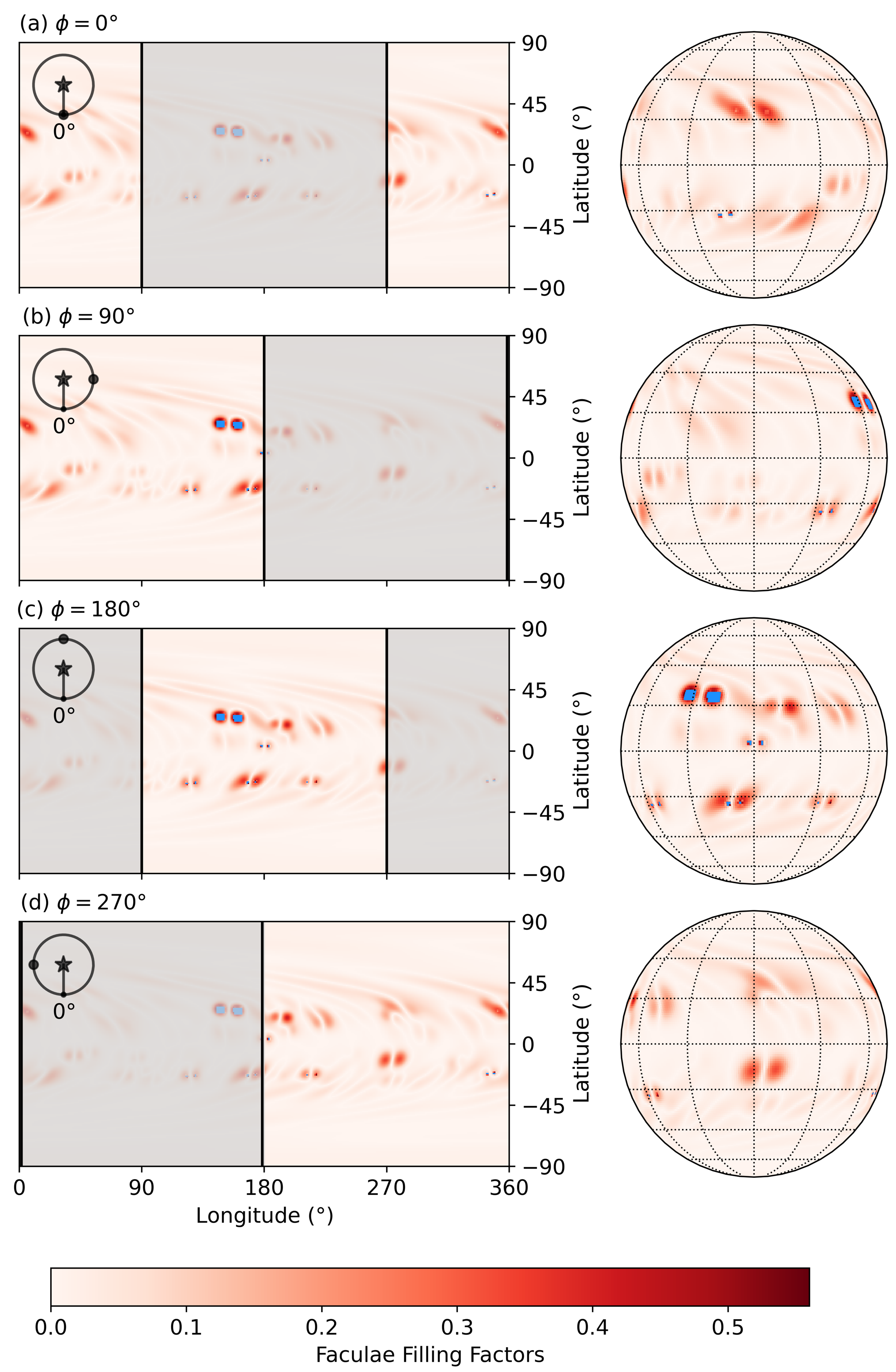

Figure 1: Synthetic distribution of faculae and sunspots, as observed from four different positions within the ecliptic plane.
Left: Full surface maps. The visible disk (unshaded area) is centered at the indicated ϕ angle.
Right: Ortographic projections of the visible disk.

RESULTS

We use the Surface Flux Transport Model [6] to produce synthetic distributions of magnetic flux for two periods of one year each: for low and high solar activity.

We calculate the SSI at $\lambda = 200.5, 501$, and 901 nm, for $\phi = 0°, 90°, 180°$, and $270°$ and compare our results to the extrapolation method.

ϕ	UV	VIS	IR
90°	0.94	0.31	0.32
180°	0.93	0.17	0.22
270°	0.93	0.23	0.29

Table 1: Correlation coefficients of the time series calculated with our method with respect to the time series extrapolated from 0° for a period of high solar activity.

ϕ	UV	VIS	IR
90°	0.94	0.46	0.59
180°	0.88	0.19	0.3
270°	0.91	0.4	0.54

Table 2: Same as Table 1, but for a period of low solar activity.

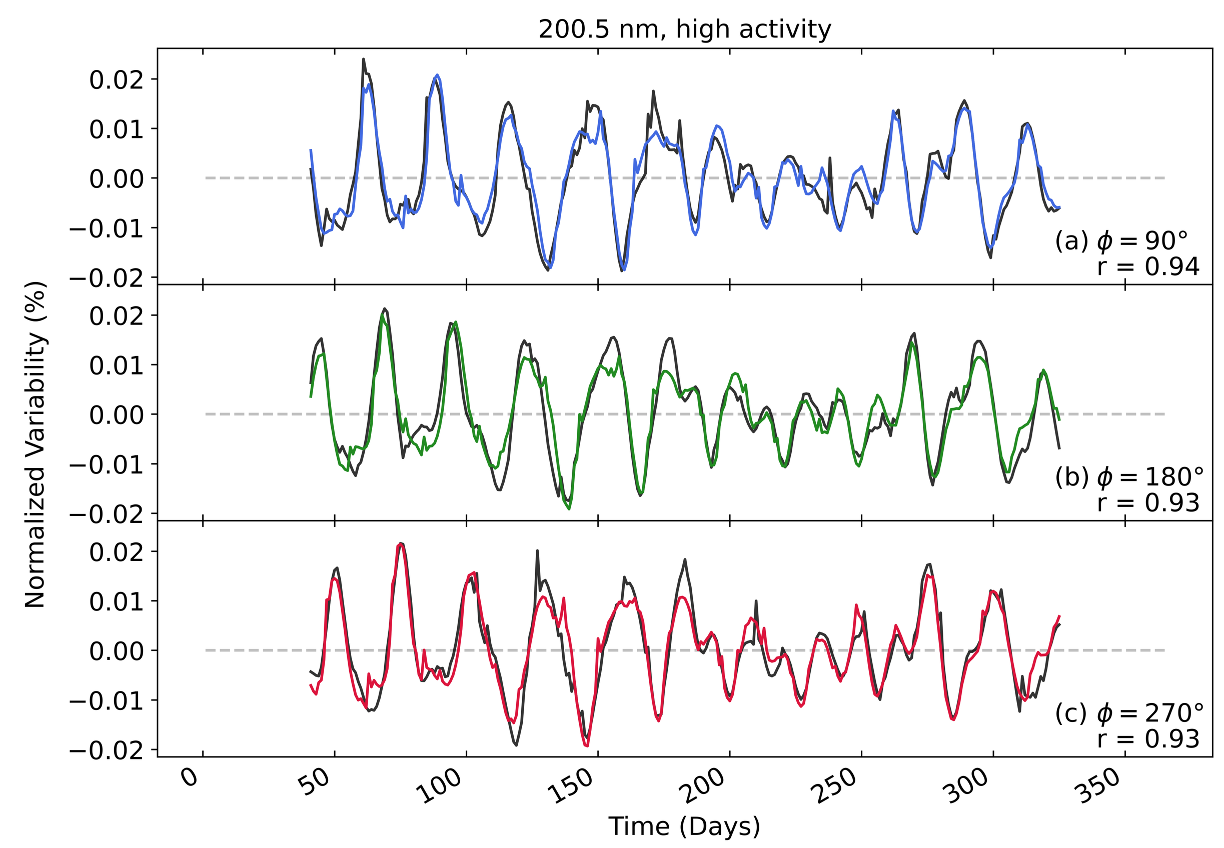

Figure 2: Time series of the 200.5 nm normalized variability for a period of high activity. Irradiance **calculated** and extrapolated to 90°, 180°, and 270°.

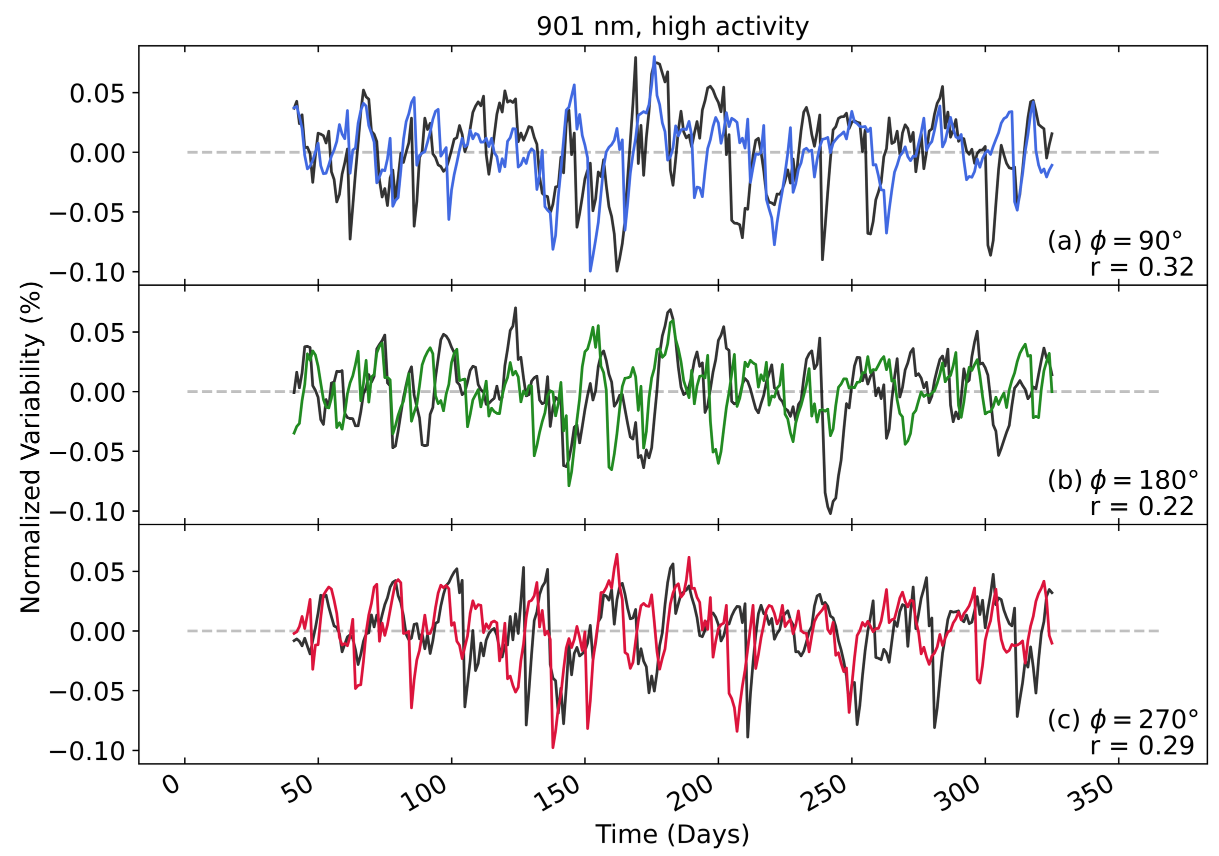

Figure 3: Same as Figure 2, but for the time series at 901 nm.

CONCLUSION

- High correlation between the methods for UV wavelengths (dominated by long-lived faculae);
- Low correlation for IR and VIS wavelengths (dominated by short-lived sunspots);
- Accounting for the evolution of active regions might improve the estimation of SSI significantly.

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