Solar cycle and UV-B comparison for South America - South of Brazil (29°S, 53°W)

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Abstract. The solar activity effects on Earth's atmosphere and the modulation of the solar cycle on the UV-B levels play an import role on life systems, because the UV-B acts directly in organic molecules as DNA, leading normally to irreversible damages. It has a strong spectral dependency with variations of about 15% at the spectral range 175-205 nm, 4-7% at 205-250 nm and 0.5% at 250-400 nm, while total solar irradiance shows a variation about 0.1 % considering 11-years Solar Cycle. Furthermore, the Solar Cycle variations of UV radiation present a latitude and seasonal dependency. In this work, correlations between solar radio flux per frequency unit at a wavelength of 10.7cm and UV-B from Brewer spectrophotometers at the INPE's Southern Space Observatory (29°S, 53°W) - South of Brazil, from 1996 to 2007, are reported. The UV-B has presented a typical season distribution with lower averages for June $(6.8\pm0.5)\cdot10^3$ mW/m² and higher for January $(34.7\pm7.9)\cdot10^3$ mW/m². The amplitude of UV-B variation with the solar cycle has been estimated using wavelets. The differences in UV-B radiation between maximum and minimum solar cycles were estimated using yearly averages of UV-B radiation. The results with the pertinent mathematical calculations are discussed.

Keywords: UV radiation, solar activity, wavelets
PACS: 96.60.qd Sun spots, solar cycles

INTRODUCTION

The discussion about the solar impacts on climate has found its way into the issue of global warming induced by increasing atmospheric concentrations of greenhouse gases[1,2,3]. There have been claims that the recent global warming that the IPCC (2001)[4] has identified as most likely being due to the increasing atmospheric concentration of greenhouse gases might instead be attributed to changes in solar activity[5]. Thus, there are both scientific and political considerations in assessing where the field of solar activity induced climate change stands with respect to identifying viable physical mechanisms, since this helps to put solar-induced climate changes in perspective relative to other influences on the climate.

The most studied solar cycle phenomenon is the Schwabe cycle, also know 11-year solar cycle. Solar irradiance varies slightly over an 11-year cycle as the sun's magnetic activity alters its energy output. Although the total energy output of the sun varies by only 0.1% over the solar cycle[6], radiation at shorter UV wavelengths shows much larger changes. It has a strong spectral dependency, with variations of about 15% at the spectral range 175 - 205 nm, 4-7% at 205 - 250 nm and 0.5% at 250 - 400 nm[7]. This variation on direct solar ultraviolet (UV) radiation produces changes in stratospheric temperature and ozone[8], which in turn could result in large climatic effects including changes in surface UV-B radiation.

In this work, the solar activity impact on surface UV-B radiation at the INPE's Southern Space Observatory (29°S, 53°W), São Martinho da Serra, RS, in the South of Brazil were analyzed. This analysis is relevant considering that the solar activity variations of the total ozone and UV-B concentration indicate a latitude and seasonal dependencies[9,10].

METHODOLOGY

The INPE's Southern Space Observatory, (29°S, 53°W), at São Martinho da Serra, near Santa Maria, is located at about the central region of the Rio Grande do Sul State - RS, in the far South of Brazil. UV-B radiation at this site presents typical season profile with lower values in June $(6.8 \pm 0.5)\cdot10^3$ J/m² and highest in January $(34.7 \pm 7.9)\cdot10^3$ J/m². The UV-B monthly data set used in this study was obtained by Brewer spectrophotometers from 1995 to 2007.

The solar activity based in the solar radio flux data per unit frequency at a wavelength of 10.7cm was obtained from the Dominion Radio Astrophysical Observatory (Canada).

The solar activity impact on UV-B changes was found using wavelets as mathematical tool and calculated by MatLab 7.0.1. The wavelet transform is a powerful tool for non stationary signal analysis. It permits to identify the main periodicities in a time series and their evolution[11,12]. The wavelet transform of a series of discrete data is defined as the convolution between the series and a scaled and translated version of the wavelet function chosen. By varying the wavelet time scale and translating the scaled versions of the wavelet, it is possible to build a graph showing the amplitudes versus frequency (or scale) and they variations along the time.

RESULTS AND DISCUSSION

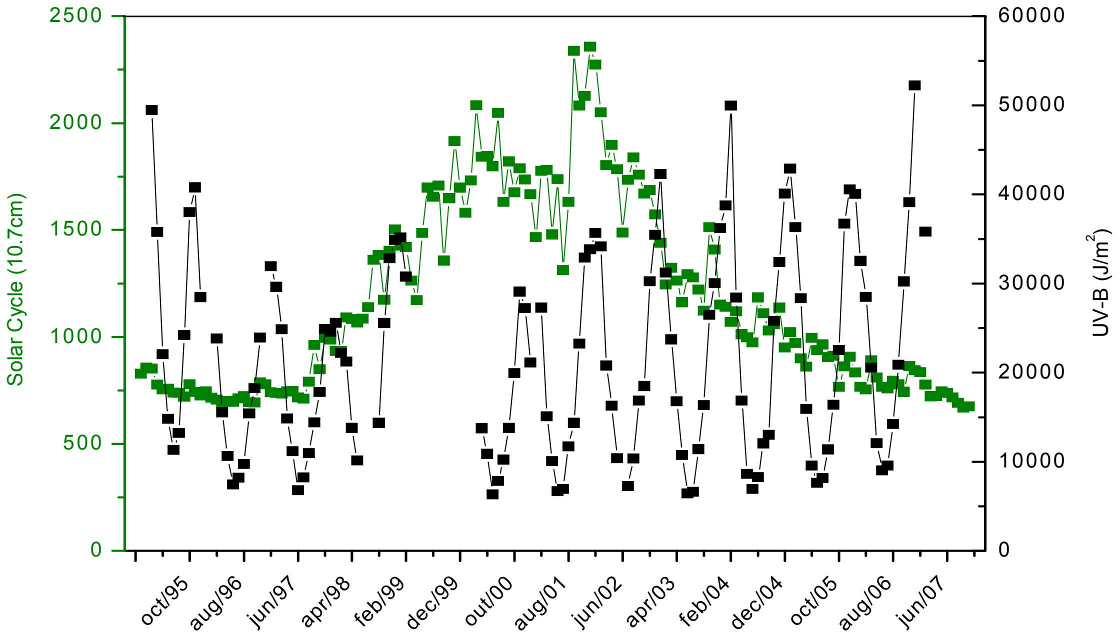

FIGURE 1: Monthly solar activity (left y axis, green point/line) and UV-B (right y axis, black point/line) measured at the INPE's Southern Space Observatory (29°S, 53°W) from 1995 to 2007.

The monthly mean of solar activity and UV-B obtained at the INPE's Southern Space Observatory (29°S, 53°W) from 1995 to 2007 are disposed in Figure 1. It is possible to see that UV-B variation presents an anti-correlation as function of the solar activity, with a minimum of UV-B around the maximum of solar activity. However the UV-B is out-of-phase with solar activity. The behavior is not regular, caused by other frequencies. The variation anti-correlated with sunspot number is very difficult to verify, as UV-B radiation is attenuated by several factors, such as clouds, aerosols, geographic variability[13]. The explanation for this observed anti-correlation is justified because the ozone modulates the surface UV radiation. Besides, it is produced by short wavelengths of the solar ultraviolet radiation and decomposed by radiation at somewhat longer wavelengths. Because the amplitude of solar cycle variability is greater in the far ultraviolet ozone production is more strongly modulated by solar activity than its destruction and this leads to a higher net production of stratospheric ozone during periods of higher solar activity[14]. In consequence to the increase of stratospheric ozone, a decrease in surface UV radiation is observed.

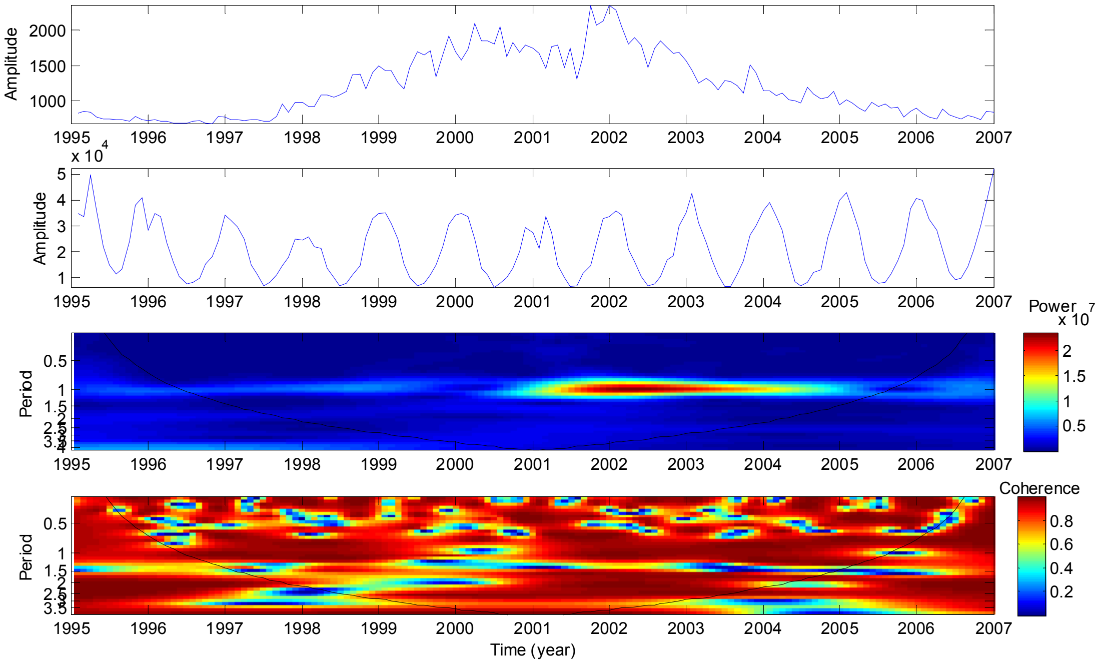

FIGURE 2: Cross wavelet power spectra (cross-correlation) for solar activity and UV-B radiation at the INPE's Southern Space Observatory (29°S, 53°W) from 1995 to 2007.

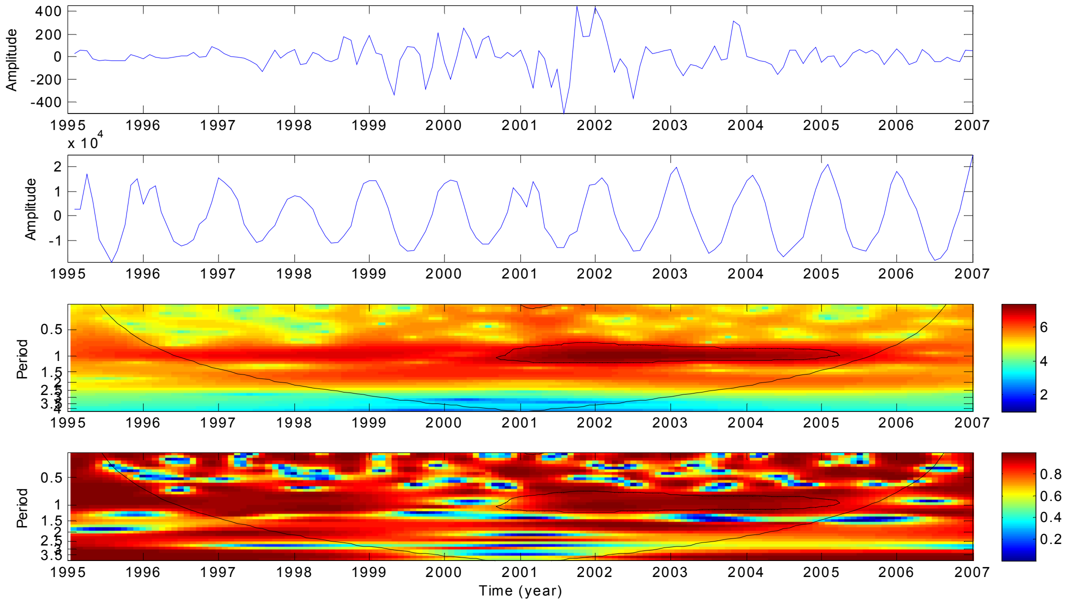

FIGURE 3: Cross wavelet power spectra (cross-correlation) for solar activity and UV-B radiation at the INPE's Southern Space Observatory (29°S, 53°W) from 1995 to 2007 with the signals between 0.5 and 5 years filtered.

For a clear visualization of the relationship between UV-B and solar activity, wavelets analysis was performed. The Figure 2 shows the cross wavelet power spectra (cross-correlation) involving UV-B and solar activity. It's observed a dominant power spectrum around one year and stable along the time. The potency increase significantly when the solar radio flux also increases, but the periodicity remains around one year. The signal's coherence is higher and above 0.7, indicating the high correlation between UV-B and solar activity.

Aiming to verify if the strong periodicity around one year could be masking other spectral frequencies, the signals between 0.5 and 5 years was filtered. These results are presented in Figure 3. A periodicity around one year remains pronounced and a secondary stable peak around 2 years is also observed. This secondary pick may be consequence of the quasi-biennial oscillation (QBO), which is modulated by solar cycle[15]. Like it's know that QBO cause variation on ozone and surface UV radiation[16], the relationship between solar activity and the interannual UV-B variability may have this explanation.

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