The influence of extraterrestrial spectrum on the modeled UV irradiance

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Introduction

Solar UV radiation plays an important role in many biological processes on the earth having a special relevance on humans due to the harmful effects in excessive doses. In an attempt to make aware the population, the UV Index (UVI) was defined (Vanicek et al., 2000). Nowadays this index is used worldwide and showed by several weather meteorological services as an informative tool to take appropriate measures. Besides measuring the solar radiation with different instruments, it is also useful to make estimates and forecast implementing radiative models. These models have different inputs like the atmospheric ozone, the aerosol scattering and the extraterrestrial spectra (solar spectrum at the top of the atmosphere). The accuracy of the modeled irradiance is closely linked both the inherent characteristics of the model as well as the quantity and quality of the input data (Schwander et al., 1997). The solar irradiance at the top of the atmosphere is the basis to determine the radiation that reaches the earth surface. The radiative models allow selecting among various spectra as an input. The present work shows the influence of these extraterrestrial spectra on the modeled UV irradiance. The Sun shows a 11-year cycle associated to sunspots. Between the maximum and the minimum times, there are differences in the irradiance at the top of the atmosphere. The influence of this cycle in the modeled irradiance has been also considered.

Extraterrestrial spectra

The modeled irradiance depends on the atmospheric scattering and absorption. These processes are selective with wavelength, so it is important high accuracy of the extraterrestrial spectra. The technology available in each time differentiates two groups of spectra depending on the source of data. The oldest spectra usually were measured from telescopes pointing at the Sun and the others are taken from spectrometers locating on satellites. The advantage of the last group is that the measurement is directly to the Sun without the effect of the atmosphere (absorption bands of ozone, water vapor and other gases). In the literature there are several references to these spectra and also a synthetic one (Gueymard, 2004) that is a composition of different solar irradiance series with the aim of covering the largest spectral irradiance with the best quality.

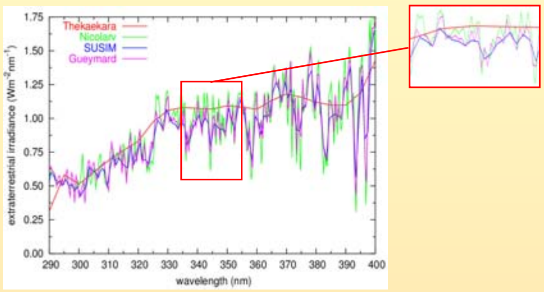

Figure 1. Extraterrestrial spectra in the UV region

Results

The radiative transfer model used in this work is SBDART 2.3, Santa Barbara DISORT Atmospheric Radiative Transfer, developed by Ricchiazzi et al. (1998). For this study, the model was implemented with a great number of common parameters for all the simulations like the total ozone column measured with a Brewer spectroradiometer, aerosol parameters (aerosol optical depth, Angström alpha and beta coefficients, single scattering albedo and asymmetry factor) from a CIMEL photometer, vertical profiles measured with radiosonde and ozonesonde. On the other hand, a different extraterrestrial spectrum was used in each modeling.

Solar altitude
Total Ozone Column
Ozone vertical profile
Atmospheric profile (T, p, U)
Tropospheric aerosols (AOD, α, g, ω_0)

→ SBDART 2.3 → Solar spectral irradiance

↑ Extraterrestrial spectra (literature)

The modeled irradiances were compared to measurements done with a spectroradiometer Bentham DM150 double monochromator with a multichannel detector system. The instrument measured spectral irradiance in UV region with a wavelength accuracy of 0.05 nm.

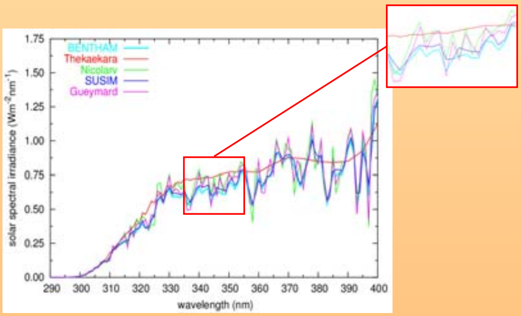

Figure 2. Solar spectral irradiance measured by a Bentham spectroradiometer and modeled with different extraterrestrial spectra

Table 1. Relative differences (%) between modeling and measurements in different ranges

	THE	LW7	NIC	AT3	SOL	SUS	GMD
UVB	12.4	11.0	7.5	9.6	5.0	1.1	4.6
UVA	11.2	5.1	6.8	3.5	4.4	2.3	4.4
UV	11.3	5.4	6.8	3.8	4.5	2.4	4.4
UVI	9.5	8.1	4.8	5.6	3.2	0.4	3.0

LEGEND
THE Thekaekara
LW7 Lowtran 7
NIC Nicolet-Aversen
AT3 Atlas 3
SOL Solstice
SUS Susim
GMD Gueymard

The highest differences in UVI are a consequence of a lowest accuracy in UVB region. Oldest spectra give results with high errors since they were measured from the earth. These errors involve up to one unit difference for high values of UVI. Spectra measured from satellite show the best result because of their resolution. It is worth mentioning the good agreement between measurements and modeling when SUSIM (SUS) or the synthetic (GMD) spectra were used.

Influence of solar cycle on UV radiation

Solar irradiance at the top of the atmosphere shows an 11-year cycle which involves a greater UV emission during periods of increasing activity. Solar irradiance variability during solar magnetic cycle depends greatly on wavelength. It ranges from 6 ± 1% at 200 nm to values lower than 0.5% at 300 nm as SUSIM data analysis shows (Figure 2).

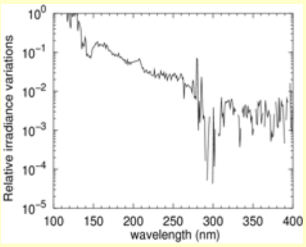

Figure 3. Relative irradiance variations at the top of the atmosphere between maximum and minimum of solar cycle

During the maximum of the solar cycle, the irradiance with wavelength less than 240 nm is about 30% higher than in the minimum period. This fact implies a greater production of ozone in the stratosphere. Using TOMS (Total Ozone Mapping Spectrometer) data, a difference of 1-2% in Barcelona was found; this value is close to the 2% in Northern Hemisphere found by Rozanov et al. (2004) using a general circulation model with interactive chemistry.
Using SBDART 2.3, modeling with differences in extraterrestrial spectra and ozone total column were prepared to show the relationship between solar cycle and solar radiation on the earth.

Table 2. Solar irradiance at two solar cycle periods determined from measurements at the top of the atmosphere (TOP) and from SBDART model simulations (SFC)

		UVB (Wm^{-2})	UVA (Wm^{-2})	UV (Wm^{-2})	I_{be} (Wm^{-2})
Measurements (SUSIM)	I_{TOP} (maximum)	18.11	80.61	98.72	6.942
	I_{TOP} (minimum)	18.08	80.40	98.48	6.939
Modeling (SBDART2.3)	I_{SFC} (maximum)	3.33	55.07	58.40	0.224
	I_{SFC} (minimum)	3.36	54.94	58.30	0.229

Results show no significant differences since a highest irradiance at the top of the atmosphere entails a highest production of ozone.

Conclusions

- The choice of different extraterrestrial spectrum in a model means relative differences of 3-10% that implies errors in UVI up to 1 unit.
- The best agreement with measurements comes from SUSIM irradiance data or the synthetic spectrum (Gueymard, 2004)
- The 11-year solar cycle has no influence on the modeled erythematic irradiance on the earth
- During the maximum of sunspots, there is an increase in stratospheric ozone production. So it is not worth to introduce these changes in modeling.

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