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Vitamin D Synthesis Measured with a Multiband Filter Radiometer in Río Gallegos, Argentina

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Abstract. Vitamin D plays an important role in human health. Vitamin D production from the sun is affected by UVB solar radiation. This paper presents a simple method for retrieving vitamin D-weighted UV by using a multiband filter radiometer GUV-541 installed at the Atmospheric Observatory of Southern Patagonia (OAPA) (51 º 33' S, 69 º 19' W), Río Gallegos. The methodology used combines irradiance measurements from a multiband filter radiometer with spectral irradiance modeled by the SOS radiative transfer code (developed by Lille University of Science and Technology (USTL)). The spectrum modeled is weighted with vitamin D action spectra published by the International Commission on Illumination (CIE), which describes the relative effectiveness of different wavelengths in the generation of this particular biological response. This method is validated using the vitamin D-weighted UV derived from a Brewer MKIII spectrophotometer (SN 124) belonging to the National Institute for Spatial Research (INPE), Brazil, which is able to measure solar spectra between 290 and 325nm. The method presents a good correlation between the two independent instruments. This procedure increases the instrumental capabilities of the multiband filter radiometer. Moreover, it evaluates the annual variation of vitamin D-weighted UV doses from exposure to ultraviolet radiation. These values are likely to be lower than suitable levels of vitamin D during winter and part of spring and autumn at these latitudes.

Keywords: UV radiation, Vitamin D-weighted UV.
PACS: 61.80.Ba

INTRODUCTION

As we know, UV radiation (UVR) from the sun has a number of both harmful and beneficial effects on human health. The direct relation between UVR and skin cancer has been well established in numerous studies [1]. In addition, a strong indirect relation has been found between UVR and the risk of incidence of some types of internal cancers (breast, colon) through the action of vitamin D [2, 3], while the relation to other cancers (prostate) is under discussion [4].

Some diseases such as type 1 diabetes, multiple sclerosis, high blood pressure and infectious diseases, among others, may be related to less than optimal levels of vitamin D [5]. Obtaining vitamin D production from the sun is thus extremely important. This parameter can be retrieved by ascertaining the sun spectrum and the vitamin D action spectrum [6] (action spectra to conversion of 7-dehydrocholesterol to previtamin D3). An action spectrum describes the relative effectiveness of different wavelengths in the generation of a particular biological response. A high-wavelength-resolution spectrophotometer can provide the sun spectrum necessary to obtain the vitamin D-weighted UV (UV_{VitD} [W/m^2]). However, these instruments are very expensive and have elevated maintenance costs. Robust multiband filter radiometers (MBFR) have been widely used to obtain data on biologically effective UV dose rates such as erythemally weighted UV and vitamin D-weighted UV, among others.

The main aim of this report is to present a simple method for retrieving UV_{VitD} by using a MBFR based on the Dahlback method [7]. The MBFR installed at the OAPA is a GUV-541 manufactured by Biospherical Instruments. This instrument has five channels in the UVA and UVB regions. The center wavelengths of these channels are approximately 305, 313, 320, 340 and 380 nm, and the bandwidth is approximately 10nm FWHM. It provides one

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integrated measurement per minute. The method combines the radiative transfer model and GUV-541 measurements to retrieve vitamin D-weighted UV. UV_{VitD} is affected principally by UVB radiation. Therefore, it is strongly affected by the amount of stratospheric ozone and the solar zenith angle (SZA). The method is validated using a Brewer MKIII spectrophotometer (#124) belonging to the National Institute for Spatial Research (INPE), Brazil, with a good agreement being achieved between both instruments.

In addition, we perform an annual variation analysis of the UV_{VitD} dose (time-integrated UV_{VitD}) retrieved by the MBFR GUV-541, from which we can see that people living in Río Gallegos do not reach the suitable level of vitamin D from the sun, as is shown in other studies[8, 9] for similar latitudes.

METHODOLOGY

Dahlback [7] proposed a method for retrieving biologically effective UV dose rates through a linear combination of irradiances measured with MBFR instruments. The main goal is to determine a unique set of coefficients so as to combine the irradiance measurements from the MBFR channels to obtain the desired biologically effective UV dose rate for all atmospheric conditions. To that end, it is necessary to solve an equation system such as equation (1). The left side of the equation is the biologically effective dose rate retrieved from the MBFR instrument, while the right side is the reference dose rate. The biological response studied here is UV_{VitD}. Therefore, A_λ is the vitamin D action spectrum, F_λ is the solar spectral irradiance modeled and $\Delta\lambda$ is the spectral resolution of F_λ. a_i's are the M coefficients to determine.

$$\sum_{i=1}^{M} a_i V_i = \sum_{\lambda=0}^{\infty} A_\lambda F_\lambda \Delta\lambda \qquad (1)$$

The method proposed here for obtaining the best set of coefficients is based on the Dahlback method but using the voltage values measured by the MBFR GUV-541 in clear sky conditions. We do not use the irradiance modeled for each channel through the filter responses. Therefore, the constants related to the filter response will be absorbed in the coefficients a_i's.

The solar spectral irradiance F_λ is calculated by the SOS radiative transfer code [10] for the same conditions of ozone amount (OMI data, NASA) and SZA as the GUV-541 voltage measurements in equation (1) (other input atmospheric parameters in the SOS code were taken as typical atmospheric conditions). Since the wavelength cut of the vitamin D action spectrum is 330nm [6], only the MBFR channels centered in 305, 313 and 320nm will be involved in the linear combination (M=3). Hence, a set of coefficients can be obtained with three MBFR voltage measurements and three spectrum F_λ modeled for clear sky conditions. However, taking three pairs of measurement-models as equation (1) to solve the equation system and find the set of coefficients does not ensure an appropriate set. Therefore, the methodology used here is to select a group of measurements from GUV-541 in clear sky conditions (110 measurements in our case) and model the sun spectrum to generate the right side of the equations (1) (therefore 110 equations in our case). Then, the system is solved by taking groups of three equations for all possible combinations. Each equation system generates a group of three coefficients for the channels involved (305, 313 and 320nm). The best set of coefficients is then selected. The selection method consists in comparing the vitamin D-weighted UV retrieved from the GUV and modeled in clear sky conditions through the scatter plot and linear fit (figure 1) by using the sets of coefficients obtained. The coefficient set that achieves the slope with the closest fit to one is chosen.

The method was validated using a Brewer MKIII spectrophotometer (#124) installed at the OAPA. This instrument takes about three minutes to make a spectrum. Since the GUV-541 instrument takes a measurement every minute, these measurements are averaged within the time taken by the spectrophotometer to make a spectrum for the comparison. The wavelength range of the Brewer spectrophotometer is 290-325nm. Therefore, in this comparison we take the action spectrum in that range. The difference in UV_{VitD} with respect to take the whole vitamin D action spectrum is less than 3%.

RESULTS

The correlation between UV_{VitD} modeled and retrieved by the MBFR GUV-541 for clear sky conditions is shown in figure 1. The UV_{VitD} was retrieved from the multiband instrument using the coefficient selected by the method described in the previous section. A good correlation can be observed between both GUV-541 and the model with a slope of one and correlation coefficient of R=0.9949.

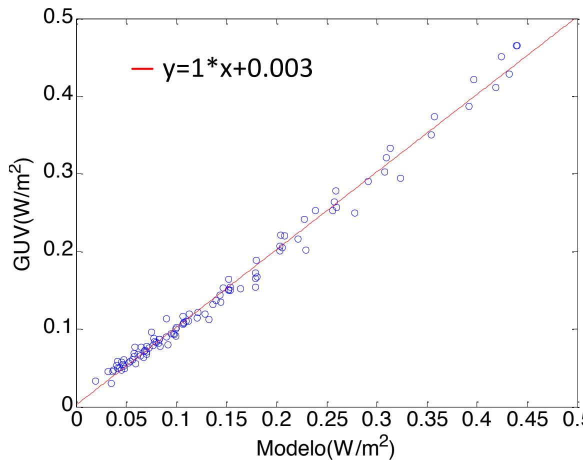

FIGURE 1. Correlation of UV_{VitD} obtained by GUV and modeled in clear sky conditions.

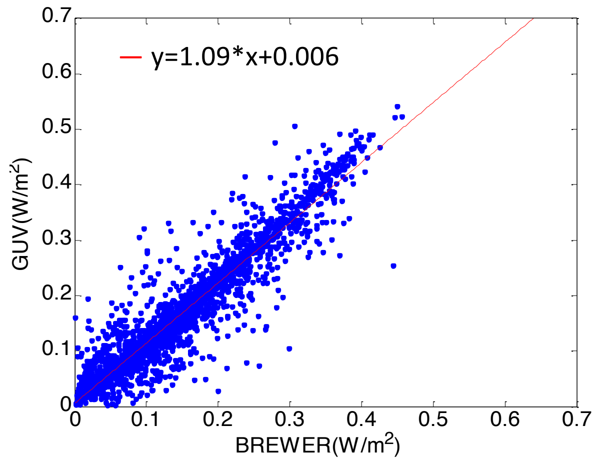

FIGURE 2. Validation. GUV and Brewer spectrophotometer correlation of UV_{VitD} in all sky conditions between October 2008 and December 2009.

Figure 2 depicts the validation of the method for all sky conditions. It shows the scatter plot between the UV_{VitD} retrieved from independent instruments: MBFR GUV-541 and Brewer spectrophotometer. The period taken for the comparison was October 2008 – December 2009. The correlation between both instruments is very good (R=0.96) with a slope of 1.09. The linear fit differs by about 10% from unity.

Figure 3 shows the annual variation of the daily average UV_{VitD} dose between 2005 and 2011 in Río Gallegos taken during an integrated period of two hours near noon. The blue line indicates the suitable vitamin D level for humans with skin type II when exposing the head (0.321 KJ/day [8, 11]). We can observe that people living in Río Gallegos do not achieve a suitable level of vitamin D from the sun for about four months of the year. The period may be longer for higher skin types. Furthermore, people do not usually manage to spend two hours outdoors in winter.

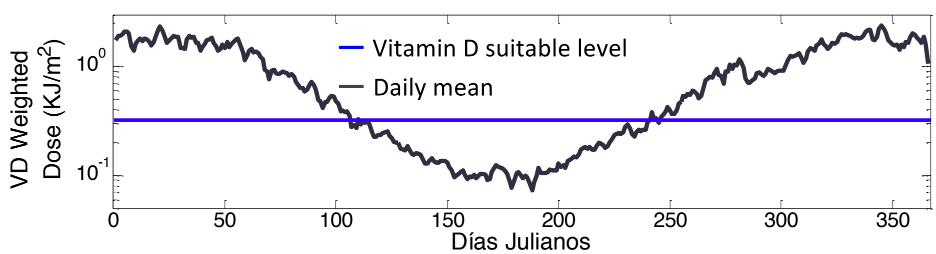

FIGURE 3. Annual variation of daily average dose of Vitamin D.

DISCUSSION

The main aim of this study is to present a simple method for selecting an appropriate set of coefficients to retrieve vitamin D-weighted UV from the GUV-541 instrument. This method was validated using a spectrophotometer for all sky conditions between October 2008 and December 2009. The UV_{VitD} retrieved from the GUV shows a good agreement with the UV_{VitD} retrieved from the spectrophotometer. The farthest points from the line in the scatter plot (figure 2) could be due to the difference in the time each instrument takes to carry out the measurements. The difference might be bigger when broken cloud affects the direct irradiance at the moment when the Brewer spectrophotometer is taking one spectra. The selection criteria for the coefficient set could make it possible to obtain a good set of coefficients for retrieving UV_{VitD} from the MBFR without another instrument.

The vitamin D-weighted UV from the GUV-541 MBFR was used to calculate the UV_{VitD} dose integrated during two hours around noon. The annual variation of the daily average indicates that vitamin production from the sun is below the suitable level, as is shown in others studies [8].

Note that the wavelength range action spectrum used here was 290-325 nm. The difference in UV_{VitD} with respect to the whole range proposed by CIE (up to 330nm) is less than 3%. Some studies use this action spectrum up to 315 nm. If we take this cut at 315 nm, only two GUV-541 channels (305 and 313nm) will be included in the calculation. The action spectrum will therefore be represented by only two coefficients and may affect the accuracy of the method.

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REFERENCES

1. J. F. Bornman, N. Paul and X. Tang, *Photochem. Photobiol. Sci.* **10**(2), 174 (2011).
2. C. F. Garland, E. D. Gorham, S. B. Mohr and F. C. Garland, **19**(7), 468–83 (2009).
3. J. A. Moan, C. Porojnicu, T. E. Robsahm, A. Dahlback, A. Juzeniene, S. Tretli and W. Grant, *J. Photochem. Photobiol. B* **78**, 189–193 (2005).
4. W. B. Grant, *Anticancer Res.* **30**, 189–199 (2010).
5. S. B. Mohr, C. F. Garland, E. D. Gorham and F. C. Garland, *Diabetologia* **51**(8), 1391–1398 (2008).
6. R. Bouillon, J. Eisman, M. Garabedian, M. Holick, J. Kleinschmidt, T. Suda, I. Terenetskaya and A. Webb. UDC: 612.014.481-06, 2006, CIE, Vienna.
7. A. Dahlback, *Appl. Opt.* **35**, 6514-6521 (1996).
8. S. Diaz et al., *Photochem Photobiol Sci.* **10**(12):1854-67 (2011).
9. R. L. McKenzie, J. B. Liley and L. O. Bjorn, *Photochem. and Photobiol.* **85**,1, 88–98 (2009).
10. J. Lenoble, M. Herman, J. L. Deuzé, B. Lafrance, R. Santer and D. Tanré, *Journal of Quantitative Spectroscopy & Radiative Transfer* **107**, 3, 479-507 (2007).
11. V. E. Fioletov, L. J. B. McArthur, T. W. Mathews and L. Marrett, *J. Photochem. Photobiol. B* **100**, 57–66 (2010).