Study Of UV Cloud Modification Factors In Southern Patagonia

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Abstract. The anthropogenic perturbation on ozone layer has induced change in the amount of UV radiation that reaches the Earth's surface, mainly through the Antarctic ozone hole, making the ozone and ultraviolet (UV) radiation two important issues in the study of Earth atmosphere in the scientific community. Also the clouds have been identified as the main modulator of UV amount in short time scales and produce the main source of uncertainty in the projection of surface UV level as consequence of projected ozone recovery. While clouds can decrease direct radiation, they can produce an increase in the diffuse component, and as consequence the surface UV radiation may be higher than an equivalent clear sky scenario for several minutes. In particular this situation can be important when low ozone column and partially cloud cover skies happen simultaneously. These situations happen frequently in southern Patagonia, where the CEILAP Lidar Division has established the Atmospheric Observatory of Southern Patagonia, an atmospheric remote sensing site near the city of Río Gallegos (51º55'S, 69º14'W). In this paper, the impact of clouds over the UV radiation is investigated by the use of ground based measurements from the passive remote sensing instruments operatives in this site, mainly of broad and moderate narrow band filter radiometers. For these studies, it is analyzed the UV Index obtained from a multiband filter radiometer GUV-541 (UVI) [Biospherical Inc.] installed in the Observatorio Atmosférico de la Patagonia Austral, Río Gallegos, since 2005. Cloud modification factors (CMF, ratio between the measured UV radiation in a cloudy sky and the simulated radiation under cloud-free conditions) are evaluated for the study site. The database used in this work covers the period 2005-2012 for spring and summer seasons, which is the moment when the ozone hole can affect these subpolar regions. CMF higher than 1 are found during spring and summer time, when lower total ozone columns, higher solar elevations and high cloud cover occur simultaneously, producing extreme erythemal irradiance at ground surface. Enhancements as high as 25% were registered. The maximum duration of the enhancement was around 30 minute. This produces dangerous sunbathe situations for the Río Gallegos citizen.

INTRODUCTION

Cloud cover mainly has an attenuating effect in the UV waveband which ranges between 20% and 70% for overcast skies, depending on the cloud type, optical depth, and solar elevation angle [2]. The short-term variability of the UV radiation reaching the Earth's surface is mainly controlled by changes in the cloud cover [1,2]. Thus, cloudiness variability often masks the effects of ozone changes, and it may reduce, cancel or even reverse the expected UV increase related to the reduction in ozone amount [3]. Additionally, clouds may also have an enhancement effect, manifested by increased UV irradiance at the surface compared with the equivalent cloud-free situation. The magnitude of UV enhancements is not well established, being highly variable. Thus, these enhancements can reach values of up to 30% over clear-sky values during several minutes in a row, pointing out the importance of these events [4,5] . The enhancements were found to be most pronounced for large cloud cover of 5 to 7 oktas when the solar disk is unclouded [6], being smaller in the UV band than in the visible and infrared intervals

[7]. It is well documented that these short-term enhancements in UV levels may affect the photosynthesis rate of vegetation like marine algae or phytoplankton [8]. Additionally, the quick and intense UV increase could have detrimental consequences for human skin and eyes, although the literature about the health effects of these episodes is quite scarce.

METHOD

The Atmospheric Observatory of Southern Patagonia has a set of radiometers to measure solar radiation at different spectral ranges. The different radiometers are listed in Table 1.

TABLE a). Passive sensors at Río Gallegos Site.

Instrument	Model	Spectral Range
Radiometer UV	GUV-541 – Biosp. Inst. Inc.	305, 313, 320, 340, 380 nm
Radiometer UV-A	UVA1-YES	315 nm – 400 nm
Radiometer UV-B	UVB1- YES	280 nm – 320 nm
Pyranometer	Kipp & Zonen Holland.	305 nm – 2800 nm
SAOZ	DOAS zenithal	430 µm – 450µm
Solar Photometer	CIMEL	1020, 940, 870, 670, 500, 440, 380, 340 nm
Brewer Spectraphotometer	MkIII - SN 227	280-365 nm (1nm)

We focused the attention on UV range because of the link with ozone in the stratosphere. In the present work the measurements of UV radiation were made with ground-based UV radiometers GUV-541, manufactured by Biospherical Instruments, in San Diego, California. This instrument has an irradiance collector of 2.1 cm diameter, with an external trapezoidal Teflon sheet covered with a quartz window. They have a directional response which follows closely a cosine response curve. Typical errors in measurements are 0% to -5% from 0º to 70º (considering the zero reference as the normal to the collector surface), 10% to -10% from 71º to 85º, and -10% to -30% from 86º to 89º. The GUV-541 radiometer has five different channels for UV measurement centred at 305, 313, 320, 340 and 380 nm with a mean band wide of approximately 10 nm (FWHM).

A quantity internationally recognised as a standard for determining the solar risk to UV radiation is the erythemal irradiance, directly related through the factor 40 (if it is expressed in the International System of Units) with the UV index. In this work, we use the UVI as the quantity of UV irradiance at ground. It was derived from UV irradiances measured with the GUV using the methodology of Dalbrack [9].

The ratio of experimental UV irradiance under cloudy skies (UV_m) to modeled UV irradiance for the equivalent cloud-free conditions (UV_{cl}) is usually knows as cloud modification factor (CMF):

$$CMF = \frac{UVI_m}{UVI_{cl}} \tag{1}$$

While the experimental values are measured by means of the GUV radiometer, the simulated data are derived from the following empirical expression propose by Madronich [10]:

$$UVI_{cl} = a\left(\mu_0\right)^b \left(\frac{TOC}{300}\right)^c \tag{2}$$

Here, µ is the cosine of the solar zenith angle (SZA) and TOC is the Total Ozone Column, which is taken from the OMI date base, on board of AURA satellite [https://aura.gsfc.nasa.gov/omi.html]. Because the GUV-541 instrument was installed in June 2005 in the OAPA, we can consider that the company calibration was remained during June 2005 to December 2006 and we can take it as reliable data. For this reason, that period is used to determine the coefficients a, b and c.

The model can be considered valid under cloud free, unpolluted and low surface albedo conditions. To select "cloud free" data from the GUV-541 database for applying the non-linear fitting, the COD derived from the GUV-541 is used [9]. We consider "cloud free" periods when the COD is less than 0.1 for a time longer than 20 minutes and when the start time and end time of this period is further than 10 minutes from the data with CDO≥0.1. In addition, only data with SZA less than 60° are taken into account due to the fact that the error of the parametric model increase with the solar zenith angle up to ~10% for SZA=60° [10].

RESULTS

We calculated cloud modification factor (CMF) for UV irradiances to evaluate the cloud impact. The data base analyzed expand from June 2005 to October 2012. The UVIs were measured by the GUV moderated narrow band radiometer. This instrument takes two measurements per second and registers one average data per minute. Typical measurements of daily variation of UV index are presented in Fig. 1. The red curve corresponds to model UVI taking into account the ozone column for the corresponding day. The effects of the cloud over the UV radiations are clearly identified on the UVI measurement (blue line in Fig. 1). Generally, reduction of UVIs respect of clear sky modeled UVI are observed along the day. Also, enhancements of radiation, with measured UVI higher than modeled clear sky conditions are observed in the first two days of Fig. 1, representing the typical situation of enhancements measured in Rio Gallegos. During the morning of Day 4, clear sky condition were registered, and parametric model fit very well to measured valued in that condition, validating the model calculation.

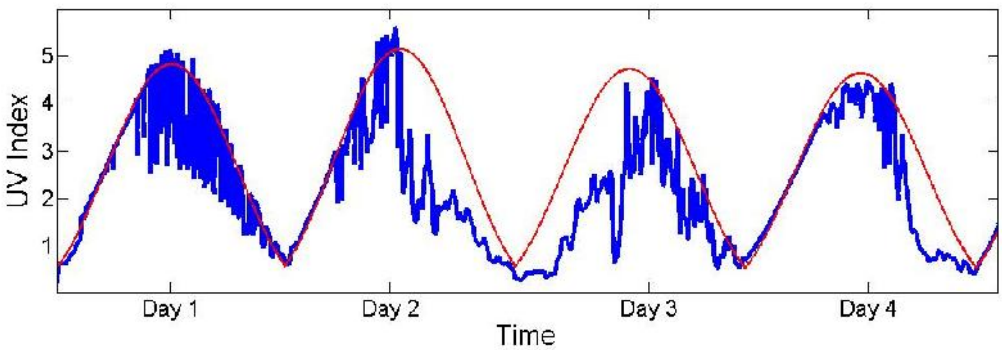

FIGURE 1. UV index measurements (blue line) and empirical model (red line) to four consecutive days

The Fig. 2 shows the occurrence frequency of enhancements in the analyzed period. The more frequent duration of UV enhancements are in the range 1-5 minutes (62% of cases), 17.5% are in the range 5-10 minutes duration, 9.6% in the range 10-15 minutes, 3.8 % in the range 15-20 minutes, 2.7% in the range 25-30 minutes and less 1% of enhancements are longer than 30 minutes.

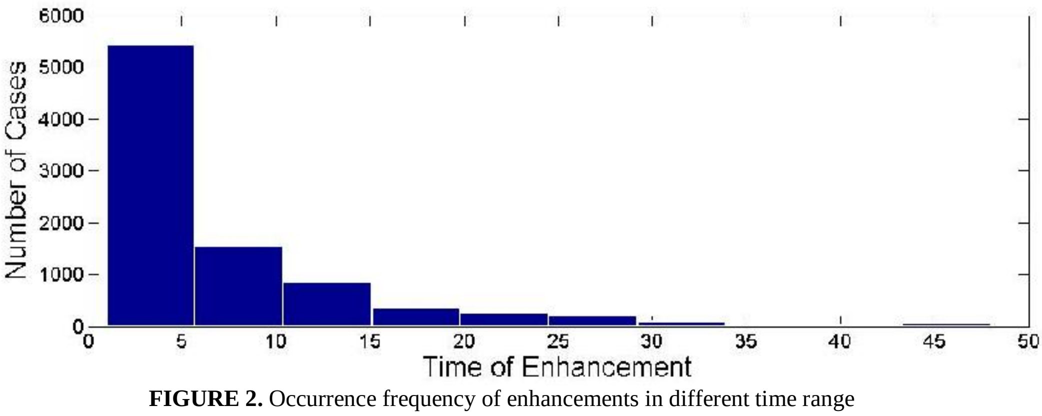

FIGURE 2. Occurrence frequency of enhancements in different time range

We filtered the data for SZA < 50º. In cloud days, the attenuation effects of cloud are present at all SZA with strong attenuation of UV irradiances up to 80% (CMF = 0.2). UV enhancements (CMF >1) are very high us 30%. (CMF = 1.30), but typically and more often situations are CMF around 1.1, that means 10% of increments. The

CMF for enhancement situations (CMF>1.05) as function solar zenith angle (SZA) shows that the bigger enhancements happen at SZA higher. That is early in the morning or late in the afternoon, and can be a consequence of the methodology involved in the calculation of CMF due the error increase of model with SZA (10) .

CONCLUSION

In this work the Cloud Modification Factors derived from UV irradiance measurements for Río Gallegos site are reported. The goal of this paper is investigate the cloud effects on UV radiation, focusing in the enhancement situation more than the attenuation effects. Cloud modification factors (CMF) were calculated for irradiance measurements recorded every minute. The studied period was the year 2005-2012.

Broken clouds are very frequent in Patagonia region, inducing that UV enhancement can occur. Enhancements as high as 25-30% were recorded. The more frequent duration of UV enhancements are in the range 1-5 minutes (62% cases), but in same times were registered enhancement as long as 45 consecutive minutes, but it only represent less than 1% of all cases detected.

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REFERENCES

1. Alados-Arboledas, L., Alados, I., Foyo-Moreno, I., Olmo, F.J., Alcántara, A.,2003. The influence of clouds on surface UV erythemal irradiance. Atmos. Res. 66, 273–290.
2. Calbó, J., Pagés, D., González, J., 2005. Empirical studies of cloud effects on UV radiation: a review. Rev. Geophys. 43, RG2002. http://dx.doi.org/10.1029/2004RG000155.
3. Crawford, J., Shetter, R.E., Lefer, B., Cantrell, C., Junkermann, W., Madronich, S., Calvert, J., 2003. Cloud impacts on UV spectral actinic flux observed during the International Photolysis Frequency Measurement and Model Intercomparison (IPMMI). J. Geophys. Res. 108, 8545.
4. Estupiñan, J.G., Raman, S., Grescenti, G.H., Streicher, J.J., Barnard, W.F., 1996. Effects of clouds and haze on UV-B radiation. J. Geophys. Res. 101, 16807–16816.6.
5. Sabburg, J., Calbó, J., 2009. Five years of cloud enhanced surface UV radiation measurements at two sites (in the Northern and Southern Hemispheres). Atmos. Res. 93, 902–912.
6. Cede, A., Blumthaler, M., Luccini, E., Piacentini, R., Nuñez, L., 2002. Effects of clouds on erythemal and total irradiance as derived from data of the Argentine network. Geophys. Res. Lett. 29 (24), 2223. http://dx.doi.org/ 10.1029/2002GL015708.
7. Pfister, G., Mckenzie, R.L., Liley, J.B., Thomas, A., 2003. Cloud coverage based on all-sky imaging and its impact on surface solar irradiance. J. Appl. Meteorol. 42, 1421–1434.
8. Gwynn-Jones, D., 2001. Short-term impacts of enhanced UV-B radiation on photo-assimilate allocation and metabolism: a possible interpretation for time-dependent inhibition of growth. Plant Ecol. 154, 67–73.
9. A. Dahlback, "Measurements of biologically effective UV doses, total ozone abundances, and cloud effects with multichannel, moderate bandwidth filter instruments", Appl. Opt., 35(33), 6514-6521, 1996.
10. Madronich, S., 2007. Analytic formula for the clear-sky UV index. Photochem. Photobiol. 83 (4), 1537–1538.