UNIVERSIDAD PERUANA UNIÓN

FACULTAD DE INGENIERIA Y ARQUITECTURA

Escuela Profesional de Ingeniería Ambiental

Estimación del índice UV mediante la modelación TUV en el Área Metropolitana de Huancayo durante los años 2005 a 2019

Tesis para obtener el Título Profesional de Ingeniero Ambiental

Autor:

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Asesor:

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Lima, 24 de mayo del 2021

DECLARACIÓN JURADA DE AUTORÍA DE TESIS

Dr. Alex Ruben Huaman De La Cruz, de la Facultad de Ingeniería y Arquitectura, Escuela Profesional de Ingeniería Ambiental, de la Universidad Peruana Unión.

DECLARO:

Que la presente investigación titulada: **"Estimación del índice UV mediante la modelación TUV en el Área Metropolitana de Huancayo durante los años 2005 a 2019"** constituye la memoria que presenta los Bachilleres Jhumeyne Estefania De La Cruz Flores y Sandra Gutierrez Arapa, para obtener el título de Profesional de Ingeniero Ambiental, cuya tesis ha sido realizada en la Universidad Peruana Unión bajo mi dirección.

Las opiniones y declaraciones en este informe son de entera responsabilidad del autor, sin comprometer a la institución.

Y estando de acuerdo, firmo la presente declaración en la ciudad de Lima, a los 04 días del mes de junio del año 2021.

Dr. Alex Ruben Huaman De La Cruz

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ACTA DE SUSTENTACIÓN DE TESIS

En Lima, Ñaña, Villa Unión, a los **24 días** día(s) del mes de mayo del año 2021 siendo **las 8:00 horas**, se reunieron en modalidad virtual u online sincrónica, bajo la dirección del Señor Presidente del jurado: **Mg. Milda Amparo Cruz Huaranga, el secretario: Mg. Joel Hugo Fernández Rojas., y los demás miembros: Ing. Orlando Alan Poma Porras, Mg. Jackson Edgardo Pérez Carpio y el asesor: Dr. Alex Ruben Huaman de la Cruz, con el propósito de administrar el acto académico de sustentación de la tesis titulada: "**Estimación del índice UV utilizando el modelo TUV en el Área Metropolitana de Huancayo durante los años 2005 a 2019**"**

de el(los)/la(las) bachiller/es: a) **JHUMEYNE ESTEFANIA DE LA CRUZ FLORES**

……………………………b) **SANDRA GUTIERREZ ARAPA** ………………………………………………..

.conducente a la obtención del título profesional de **INGENIERO AMBIENTAL**

(Nombre del Título profesional)

con mención en……………………………………………..

El Presidente inició el acto académico de sustentación invitando al (los)/a(la)(las) candidato(a)/s hacer uso del tiempo determinado para su exposición. Concluida la exposición, el Presidente invitó a los demás miembros del jurado a efectuar las preguntas, y aclaraciones pertinentes, las cuales fueron absueltas por el(los)/la(las) candidato(a)/s. Luego, se produjo un receso para las deliberaciones y la emisión del dictamen del jurado.

Posteriormente, el jurado procedió a dejar constancia escrita sobre la evaluación en la presente acta, con el dictamen siguiente:

Candidato (a): ……… **JHUMEYNE ESTEFANIA DE LA CRUZ FLORES** ……………………………

CALIFICACIÓN	ESCALAS			Mérito
	Vigesimal	Literal	Cualitativa	
APROBADO	18	A-	Muy Bueno	Sobresaliente

Candidato (b): ……… **SANDRA GUTIERREZ ARAPA** …………………………………………

CALIFICACIÓN	ESCALAS			Mérito
	Vigesimal	Literal	Cualitativa	
APROBADO	18	A-	Muy Bueno	Sobresaliente

(*) Ver parte posterior

Finalmente, el Presidente del jurado invitó al(los)/a(la)(las) candidato(a)/s a ponerse de pie, para recibir la evaluación final y concluir el acto académico de sustentación procediéndose a registrar las firmas respectivas.

Presidente
Mg. Milda Amparo
Cruz Huaranga

Secretario
Mg. Joel Hugo
Fernández Rojas

Asesor
Dr. Alex Ruben
Huaman de la Cruz

Miembro
Ing. Orlando Alan
Poma Porras

Miembro
Mg. Jackson Edgardo
Pérez Carpio

Candidato/a (a)
Jhumeyne Estefania

Candidato/a (b)
Sandra

Estimation of UV index using the TUV modeling in the Metropolitan Area of Huancayo during years 2005 to 2019

Estimação do índice de UV usando a modelagem TUV na Área Metropolitana de Huancayo durante os anos de 2005 a 2019

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Abstract

The ultraviolet radiation (UV) Index was estimated for the years 2005 to 2019 from the Metropolitan Area of Huancayo, Junín-Peru. For these, solar ultraviolet (UV) index from Ozone Monitoring Instrument (OMI) and Tropospheric Ultraviolet and Visible (TUV) Radiation model were used to estimates UV index for 2020. Clear sky conditions were considered for measurements. The OMS categorization UV index levels were used to propose a 2020 calendar UV index. Results showed 239 days of 2020 (65,6%) with UV index levels higher than 11, which is categorized as extremely high. 95 (26.0%), 25 (6.73%), and 6 (1.80%) days for 2020 were categorized as UV index levels as very high, high, and medium, respectively. Likewise, was found that between 10:00 h and 15:00 h local time and Janeiro to April and September to December are presented higher UV index levels than 11. Thus, this information may be provided for the population in high quality enabling them to adopt suitable behaviors for health care, including skin cancer prevention.

Keywords: Extreme UV index levels; OMS categorization; Peruvian Andes

Resumo

O Índice de radiação ultravioleta (UV) foi estimado para os anos de 2005 a 2019 da Área Metropolitana de Huancayo, Junín-Peru. Para estes, o índice de ultravioleta solar (UV) do Instrumento de Monitoramento de Ozônio (OMI) e o modelo de radiação ultravioleta e visível da troposfera (TUV) foram usados para estimar o índice de UV para 2020. Condições de céu claro foram consideradas para as medições. Os níveis de índice de UV de categorização OMS foram usados para propor um índice de UV de calendário 2020. Os resultados mostraram 239 dias de 2020 (65,6%) com índices de UV superiores a 11, que é categorizado como extremamente alto. 95 (26,0%), 25 (6,73%) e 6 (1,80%) dias para 2020 foram categorizados como níveis de índice de UV como muito alto, alto e médio, respectivamente. Da mesma forma, verificou-se que entre 10:00 he 15:00 h hora local e Janeiro a abril e setembro a dezembro apresentam índices de UV superiores a 11. Assim, esta informação pode ser fornecida para a população com alta qualidade permitindo-lhes adotar comportamentos adequados para os cuidados de saúde, incluindo a prevenção do câncer de pele.

Palavras-chave: Níveis extremos de índice de UV; Categorização OMS; Andes peruanos; medição de satélite

1. Introduction

Ultraviolet (UV) radiation is a small part of the electromagnetic spectrum and covers the wavelength of 100-400 nm divided into three bands UVA (315-400 nm), UVB (280-315 nm), and UVC (100-280 nm) (WHO, 2017a). UV radiation is released naturally from the sun being that around 90% UV-B and all UV-C is absorbed by ozone, carbon dioxide, oxygen, and water vapor (Aun et al., 2019). Thus, UV radiation reaching the Earth´s surface is mainly composed of UV-A and UV-B (small quantities) radiation (Serrano et al., 2006).

The amount of UV radiation that hits the Earth´s surface depends on several factors such as latitude, altitude, cloud clover, ground reflection, and thickness of the ozone, and the sun´s height in the sky. Besides, UV radiation at a specific place depends on the day, time, cloudiness, and aerosols quantity present in its atmosphere (Diffey, 2018; Foyo-Moreno et al., 2003). The UV index is a basic indicator of the risk of exposure to solar radiation and is defined as solar erythemal irradiance (which considers the erythematic action spectrum as a weighted function of solar UV irradiance) multiplied by 40 m2/W, to have values from 0 to 20, even greater (Cede et al., 2004, 2002). However, other atmospheric variables such as aerosols, trace gases (O3, SO2, NO2), clouds, and soil reflectivity influence the behavior of solar UV radiation on the Earth's surface (McKenzie et al., 2001).

It was reported that long-term exposure to humans to UV may cause sunburn, erythema, premature aging and damage of the skin, chemical hypersensitivity, eye problems, increases the risk of skin cancers, and causes a detrimental effect on the ecosystem (Rendell et al., 2020; Sánchez-Pérez et al., 2019; Watson et al., 2016). However, UV radiation exposure stimulates vitamin D production and increases calcium and phosphorus for bone health (WHO, 2017b).

In this context, great efforts have been carried out to monitor UV radiation both from satellite- and ground-based approaches in the last years (Cadet et al., 2017; Marchetti et al., 2016). For the satellite approach, a great number of UV measuring instruments onboard various satellites were deployed to monitor UV, including the OMI, because these instruments provide uniform geographical coverage data (Janjai et al., 2014; Marchetti et al., 2016). However, they must be validated satellite UV data with ground-based measurement to guarantee the accuracy of the satellite data (Marchetti et al., 2016). Besides, many studies have focused on models for the calculation of UV index including radiative transfer models such as the tropospheric ultraviolet and visible (TUV) radiation model from the National Center for Atmospheric Research (INCAR) (Salas et al., 2017; Tie et al., 2005). TUV is a model operated under clear sky conditions. Thus, when are considered clouds, TUV requires optical parameters such as cloud optical depth and optical properties of aerosols (Salas et al., 2017)

In the southern hemisphere, Peru, Bolivia, Chile, and Argentina have higher UV levels (many times UVI values exceeded 20) (Liley and Mckenzie, 2006). Likewise, the city of Cuzco (13.5° S, 3360 m a.s.l., southern Peru) showed the highest UVI of 25 was reported (Liley and Mckenzie, 2006; Zaratti et al., 2014).

For the Metropolitan area of Huancayo, Suárez et al., (2017) reported UV index of 18.8 and 15.5 for clear sky and all-sky conditions with peaks of UVI around 28. Likewise, the SENAMHI, (2018) reported ultraviolet radiation levels to range from 9 to 18 for Huancayo, which be a high and extremely high risk for human health. For example, in 2018 were reported about 274 cases of skin cancer related to light skin, melanoma, and excessive exposure to UV (DIRESA, 2019). In this city, there is an acceptable level of awareness on sun exposure risk, however, the population does not take appropriate precautions for solar exposure (Thomas-Gavelan et al., 2011).

Thus, the present work aimed to estimate the temporal and spatial variation of UV index levels from the Metropolitan Area of Huancayo, Peru between 2005 to 2019. Thus, using this information has been proposed a calendar of UV index with the aim provides key information to reduce its impact on the population and environment.

2. Materials and methods

2.1. Site of study

The Metropolitan area of Huancayo (MAH) (12°03′54″ S; 75°12′17″ W; 3263 m.a.s.l,) is located on the Mantaro valley from Department of Junín, Perú (Figure 1). The maximum and minimum temperatures ranged from -0.3 to 6.5°C and 18.5° to 20.8°C, respectively. Minimum precipitation (4.8 mm) is observed between June-August, and maximum precipitation of 132.1 mm of January to March with February showing higher values (IGP, 2005). Maximum and minimum stratospheric ozone was observed in July (0.248 cm) and June (0.227 cm) and higher radiation values (about 1247 W/m^2) were found between June and July (Suazo et al., 2020).

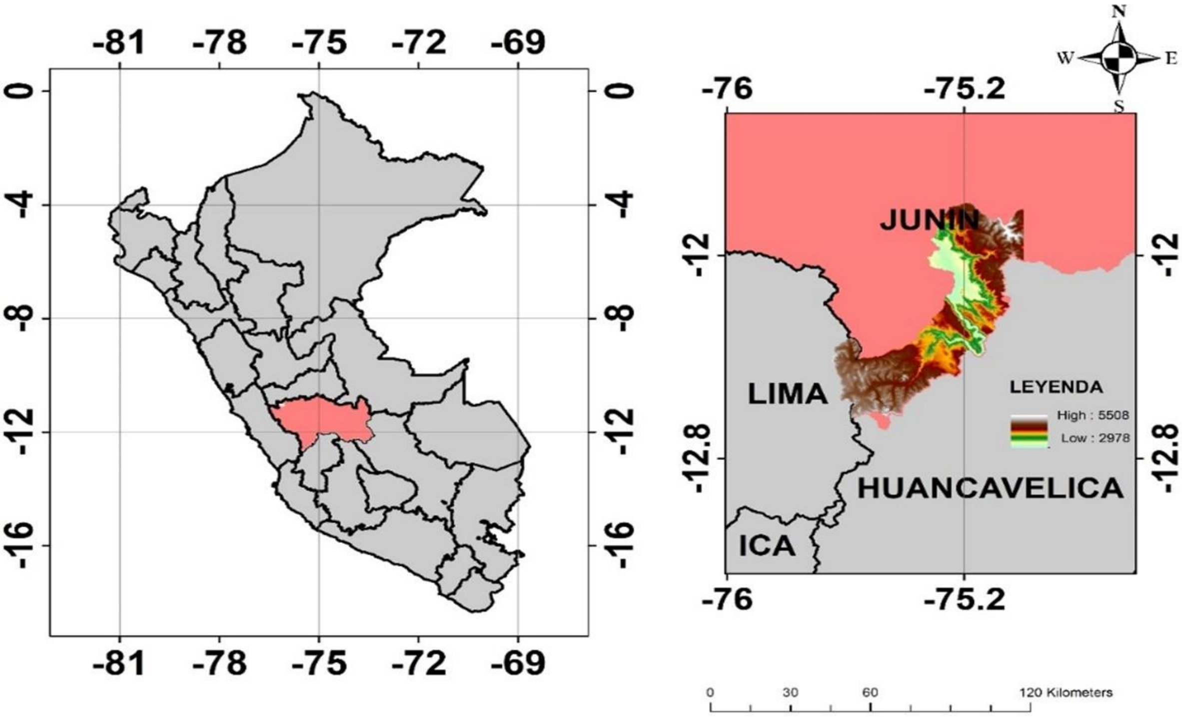


Figure 1. Map of the location of the Metropolitan area of Huancayo (MAH)

2.2. Satellite data

The Ozone Monitoring Instrument (OMI) is located onboard The NASA Earth Observing System (EOS) Aura spacecraft flying in a sun-synchronous polar orbit since 2004 (Levelt et al., 2006). This instrument is a nadir-viewing UV/Visible spectrometer with a spectral resolution of about 0.43 nm for the UV channel (307-383 nm) and about 0.63 nm for the visible channel (349-504 nm). It measures the solar radiation (SR) backscattered by the atmosphere in the range of 270-500 nm and spatial resolution of 13 km x 24 km (nadir). Data on UV spectral and solar noon spectral irradiance (1^0 x 1^0 grid) are available from October 2004 and computed from the data collected with satellite located at 1345 local solar time (Parisi et al., 2021).

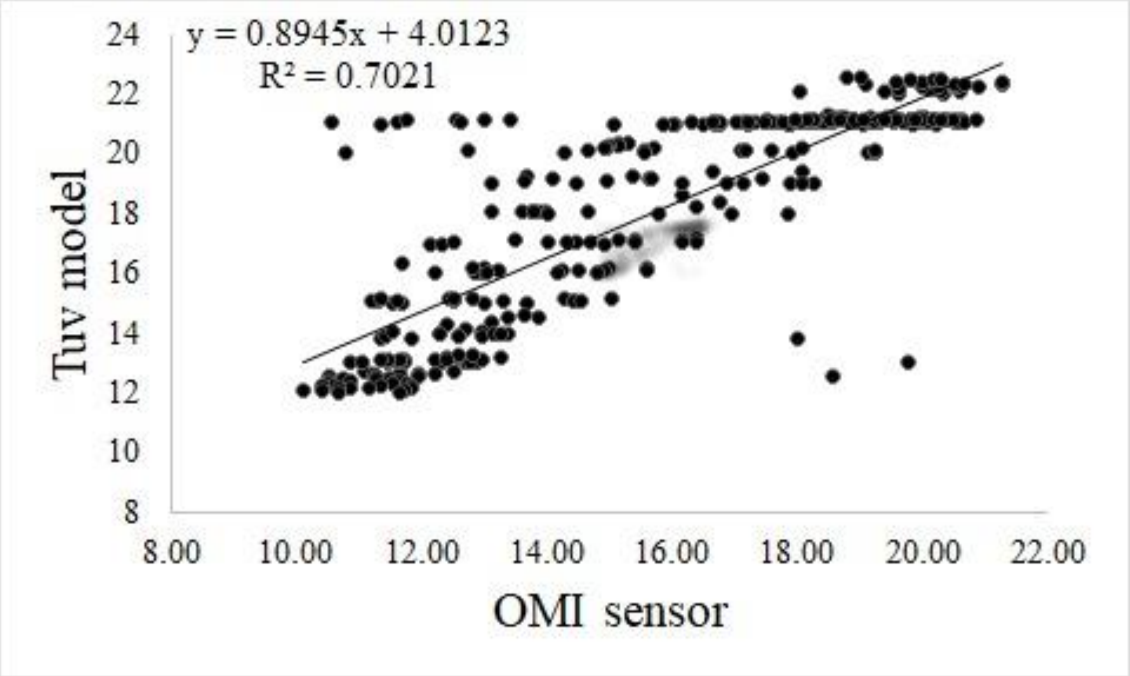
This study was used data from the OMI sensor to obtain the total ozone column from 2004 (1 January) to 2019 (31 December). Also, UV index estimates were collected from the OMI. The OMI algorithm is based on the TOMS surface UV algorithm developed by Goddard Space Flight Center NASA (Krotkov et al., 1998; Tanskanen et al., 2006).

2.3. Tropospheric Ultraviolet and Visible (TUV) Radiation model

The TUV radiative transfer model was developed by Madronich, (1993) and collaborators at the National Center for Atmospheric research (available in http://cprm.acd.ucar.edu/Models/TUV/), Version 5.3.1 was applied for the calculation of spectral irradiances and fluence rates. Aerosol and altitude profile for ozone were taken from Elterman and U.S. standard Atmosphere.

Variation in irradiance was tested based on UV index measured for 1 hour around solar noon (estimating the mean of this data set instead of the maximum absolute). Besides the radiative transfer processes were simulated through the TUV model. In this implementation, radiation was computed with a delta-Eddington code of two currents and values obtained of the sum of direct solar radiation and descending diffuse radiation. The spectral resolution of the input solar spectrum was 0.05 nm, and the model run at 0.1 nm resolution over the 280 – 420 nm. Likewise, the altitude of the atmosphere was considered at 3300 km, and surface pressure of 660 hPa (value corresponds to the annual average from Huancayo city) (SENAMHI, 2018). An albedo of 0.06 was taken into account for the underlying surface with a mixture of grass and bare soil characteristics. The total ozone columns of ozone and other trace gases (SO_2 and NO_2) were obtained from OMI. Likewise, AOD. Angstrom´s exponent and SSA were obtained from the MODIS sensor and Suazo et al., (2020).

A correlation between the UV data from the OMI and the TUV model over the data range of 1 January 2005 to 31 December 2019 is shown in Figure 2.



2.4. Data analysis

Estimates values of UV index were assessed and categorized according to the World Health organization (Table 1) (WHO, 2017c). This evaluation was carried out to propose a calendar of UV index for the Metropolitan area of Huancayo.

Table 1. WHO UV index categorization

Ratings	UV index
Low	<2
Medium	3 a 5
High	6 a 7
Very high	8 a 10
Extremely high	>11

3. Results

3.1. Temporal variation of the Total column ozone

Figure 2, is showed the Total ozone column (Dobson unit (DU)) variation estimated monthly by OMI between January 2005 to December 2019 for the Metropolitan Area of Huancayo. Figure 2 is observed higher values (higher than 255 DU) of ozone between 2010 to 2012 and 2014 to 2016 and 2019. In contrast, lower values of ozone (minor than 230 DU) were found between 2018 and 2019. Neale et al., (2021) reported minimum values of UV index at the South Pole between October and mid-November 2019. OMI estimations showed maximum values (around 260 DU) of UV index in spring (September to November), minimum values (around 230 DU) in autumn (March to May) and average values around 240 DU. Raj et al., (2004) measured the total column ozone over Pune using the multichannel Sun photometer (ozonometer) during 5 year period (1998 to 2003) and found a range of 241 -250 Dobson units. These results reported are according to our results found.

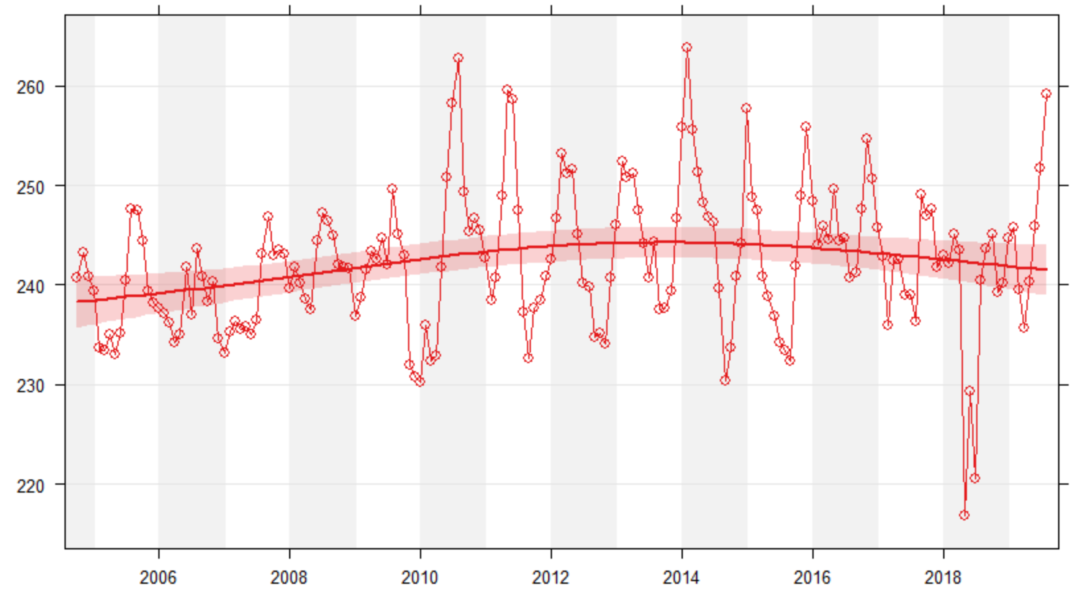


Figure 2. Temporal distribution of the total column ozone during 2005-2019 in the Metropolitan Area of Huancayo (MAH).

3.2 Variación Temporal Y Espacial De Radiación UV

The monthly variation for each year (2005 to 2019) of UV index obtained from the OMI sensor is showed in Figure 3. Figure 3, is noted a well-marked seasonal variability from 2005 to 2011, with lower values of UV index showed from March to October (about 10 to 15). In contrast, for the same moths, a higher UV index (about 20) was observed from 2012 to 2016. For the last three years (2017 to 2019) UV index was not very remarkable or accentuated for all months, showing a monthly variation between 10 to 20.

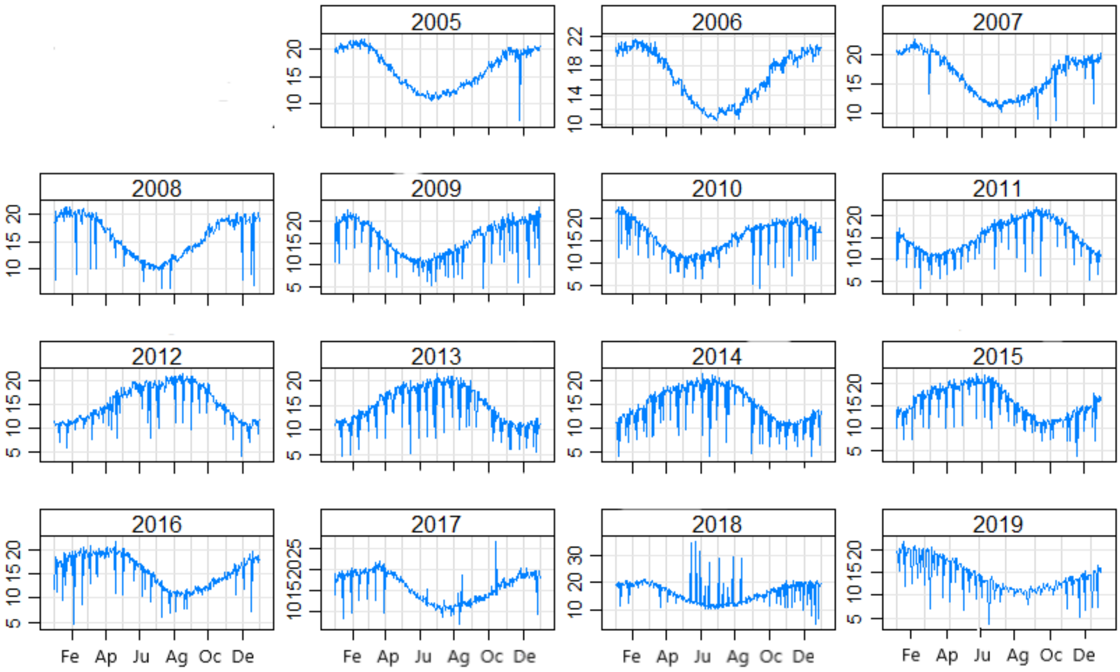


Figure 3. Monthly and annual variation of UV index during 2005 to 2019 from MAH

Using the performing Kriging spatial interpolation through the ArcGis software, version 10.5, assuming a Gaussian surface, and employing the punctual data obtained from OMI sensor for years 2005 – 2019 were estimated (Figure 4). From Figure 4, is observed inside the Metropolitan Area of Huancayo (MAH) that maximum values for UV index ranged from 15 to 20, and minimum values between 8 to 15 for Janeiro and February, respectively.

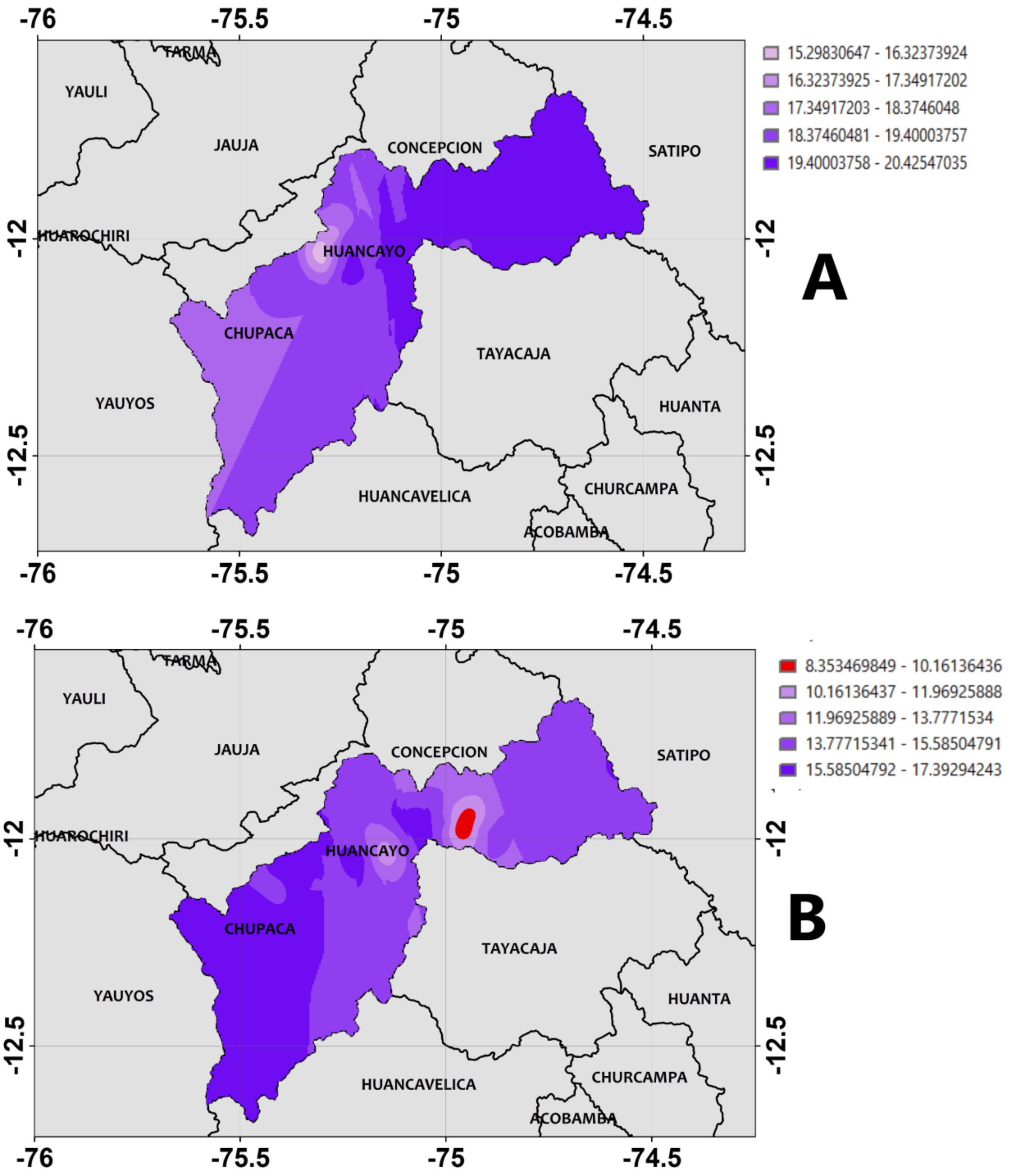


Figure 4. Spatial distribution of UV index for the MAH during January (A) and February (B) 2019.

Figure 5 shows the hourly and monthly variation of UV index estimated through the TUV Radiation model for 2005 to 2019 year from the Metropolitan Area of Huancayo. From Figure 5 is found maximum average values (UV index > 11) between 10:00 h and 15:00 h into two dates (Janeiro to April and September to December). In contrast, lower UV index values than 10 were observed for May to August, being June to July the months with lower values of UV index (between 5 to 7). Parra et al., (2019) reported similar results with UV index higher than

11 for the period from 2010 to 2014 in Quito, Ecuador. In contrast, in Chile Cabrera et al., (2012) based on OMI-derived UV index data from the period 1997 – 2003 estimated UV index average of 8.85 for October and March 2010. Based on these results our estimations are reliable and in agreement with the previously published.

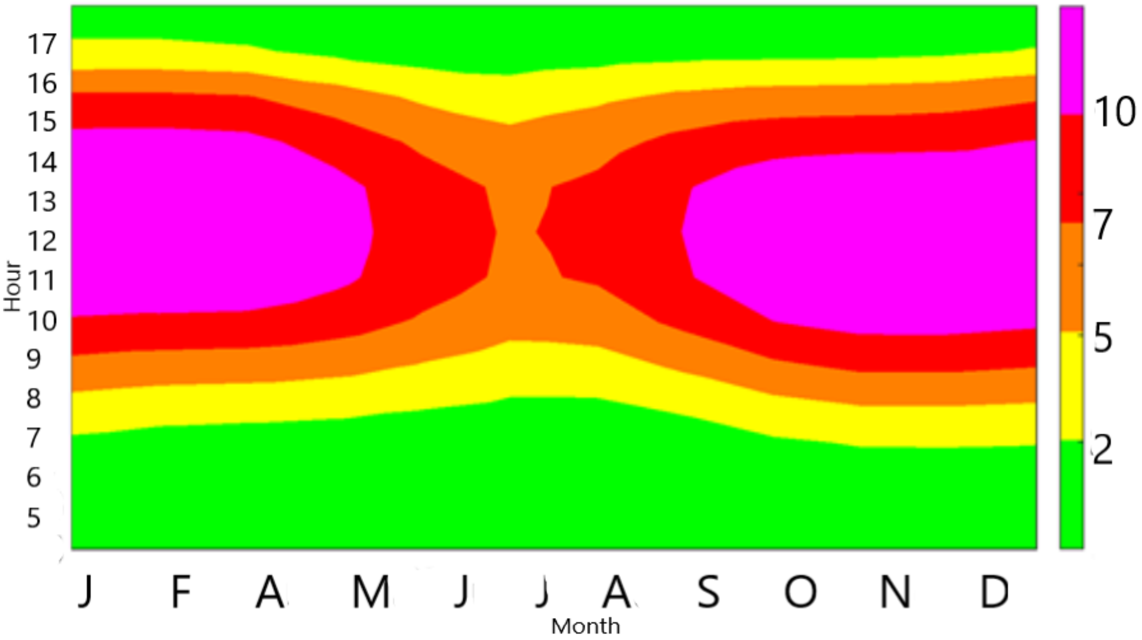


Figure 5. Monthly and hourly variation of UV index for the MAH during 2005 – 2019 using the TUV model and OMS categorization.

3.4. UV index calendar proposal for Metropolitan Area of Huancayo using the TUV Radiation model.

Figure 6 is presented the UV index calendar proposal for the Metropolitan Area of Huancayo in the function of the OMS categorization. From Figure 6 is noted that a large number of days present a frequency of UV index levels higher than 11.0 (65.6%; n = 239 days) which is categorized as extremely high according to OMS. Likewise, UV index levels between 8 to 10 are observed in 26.0% of the days (n = 95 days, categorized as very high), while 6.73% (n = 25 days) and 1.80% (n = 6 days) are presented for UV index levels between 6 to 7 (categorized as high) and 3 to 5 (categorized as medium), respectively. In contrast, no one day of the year showed UV index levels minor than 2 (n = 0 days). Higher UV index levels than 11 (40 to 76.1% days) were reported by Parra et al., (2019) in Quito, Ecuador. Maximum UV index levels occurring around 10:00 h and 15:00 h. Thus, based on this information and the self-warming system in Peru, type of skin, people will be able to know the time and dates when they need to be more careful when exposing themselves to solar radiation. This seeks to mitigate and take control measures that can prevent diseases for UV radiation exposures.

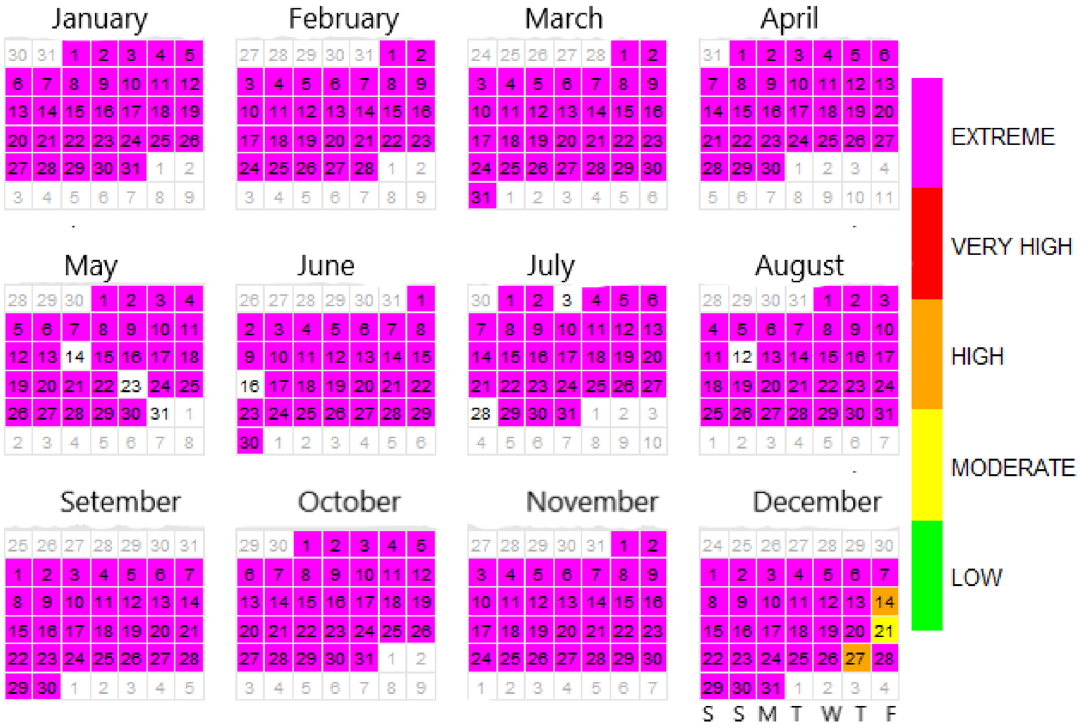


Figure 6. UV index levels calendar for the 2020 year in the MAH through the OMS categorization.

4. Conclusion

In this study, the UV index levels were estimated using the Ozone Monitoring Instrument (OMI) and Tropospheric Ultraviolet and Visible (TUV) Radiation model for the first time in the Metropolitan Area of Huancayo. Likewise, UV index estimated were categorized as extremely high (UV index levels > 11) for 239 days from total of days, with higher UV index values found between 10:00 h and 15:00 h local time for two periods: from Janeiro to April and September to December.

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