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Analysis of ultraviolet index, ultraviolet B insolation, and sunshine duration at Bandung in year 2017

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Abstract. Ultraviolet index, ultraviolet B insolation, and sunshine duration in 2017 have been analyzed at Bandung, Indonesia (106.6 W and 6.9 S). The daily maximum ultraviolet B insolations have been grouped in ten-daily sequence following BMKG's method in determining of dry/rainy season. Ultraviolet index classified following small modification WHO's classification. Sunshine durations are clustered in 3 levels of exposure. It is found the average of sunshine duration in range 4.1-8 hours/day has 50% occurrence in 2017, meanwhile ultraviolet index more than 10 have been recorded in 46% occurrence in 2017, even of average of maximum ultraviolet B insolation is about 1.22 W/m^2, and maximum intensity on 2017 is 2.17 W/m^2. Both of ultraviolet index and maximum ultraviolet B insolation have a similar pattern on 2017 and the minimum value is on aphelion.

Keywords : ultraviolet, sunshine duration, aphelion.

1. Introduction

As a main source of energy in the environment, solar emits energy in the radiative electromagnetic wave and known as solar radiation. Solar electromagnetic wave is a polychromatic wave which its content is very wide spectrum of wavelength i.e. ultraviolet spectrum. The wavelength of ultraviolet spectrum is 100-400 nm. This spectrum is divided to be three sub_spectrums: ultraviolet A (315-400 nm), ultraviolet B (280-315 nm), and ultraviolet C (290-400 nm). The ultraviolet B radiation is used in this paper, even of only small percentage from wide spectrum but has significant effects to environment ecosystem, human health, and some processes in atmosphere [1]. Some medical effects to human are increasing of risk of skin cancer [2,3], cataracts [4,5] and human immune system [6,7].

In the other word, global radiation is also defined as incoming solar radiation (insolation). The sum of time for which the direct solar radiation exceed 120 W/m^2 during a given period is defined as sunshine duration [8]. Sunshine duration is measured in one cycle of the length of day (hours/day) or time duration of solar at horizon. By using sunshine duration data at LPD Sumedang on period 1999-2013, it is found the distribution of sunshine duration at Sumedang is depend on the season [9], it is mostly 0-1 hour/day on DJF, 6-7 hours/day on MAM, 9 hours/day on JJA, and distributed smoothly on SON. At cloudy condition, humid, and rainy all day sunshine duration mostly very short, as a characteristic of tropical rain region.

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) in collaborative work with WHO and UNEP has recommended using of Solar Global Ultraviolet Index in order to estimate and conveying information to open public simply about ultraviolet irradiance level which can

reach earth's surface [10]. Ultraviolet index is calculated quantitatively by multiplying UVER (W/m^2) with factor 40. The calculated value is presented in integer that is very close to. Rahayu and Komala [11] reported ultraviolet index of 2008-2010 reach maximum value as 13.4 by project research at Bandung using AURA OMI satellite data, especially in September 2009. Ultraviolet index as value as 13.4 is categorized in extreme and very high risk for human life corresponded to cataract and skin cancer symptoms. Medical effects of skin burned and erythema has been reported by using ultraviolet erythemal radiation (UVER), and defined as amount of solar irradiance at surface by standard response curve adopted by Commission Internationale d l'Eclairage (CIE) in 1987 [12]. Study about medical effects of ultraviolet irradiance generally correlated to Minimum Erythemal Dose (MED) and has close relationship with type of human skin.

Incoming solar radiation is influenced widely by some environmental factors, for example stratospheric ozone and atmospheric aerosol. Change of these factors will be the main factor for variation of global ultraviolet radiation and direct-diffuse component in clear sky condition [13]. Except by water vapor, ultraviolet B spectrum also absorbed strongly by atmospheric ozone layer, with the result the persistence of ozone is very important in extinction of incoming solar ultraviolet radiation. By research of ultraviolet index at Medan by using satellite AURA data year 2005-2012, it has been reported ultraviolet index varies between 8 to 13 and has a good correlation with stratospheric ozone layer thickness [14]. Seasonal correlation of ultraviolet index shows a negative correlation with coefficient correlationbetween 0.66 to 0.92. This means increasing of stratospheric ozone concentration will decrease the ultraviolet index, and vice versa.. It is found good correlations among UVER irradiance, total ozone column, water vapor, aerosol, and solar zenith angle [15]. The aim of this paper is to analyze the ultraviolet index classification and ultraviolet insolation, and sunshine duration classification at Bandung-Indonesia in 2017.
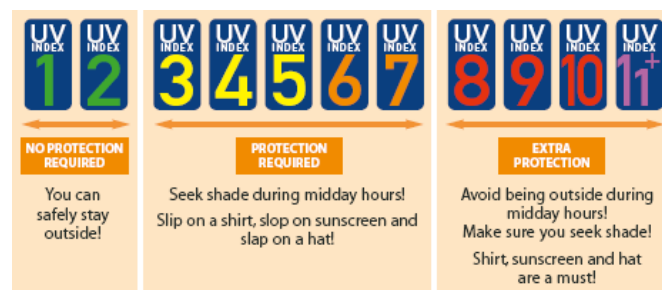

Figure 1. Ultraviolet index by WHO

2. Method

In this paper, three kinds of data have been used i.e. solar ultraviolet B insolation, ultraviolet index, and sunshine duration data. Solar ultraviolet B insolation is measured by using pyranometer MS-212W which passing solar wavelength 285-315 nm. Insolation of ultraviolet B data is recorded every 10 minutes using Data Logger Hioki LR8402-20. Sunshine duration is measured by using MS-093 sensor, recorded simultaneously by the same data logger. Both of sunshine duration sensor and pyranometer are produced by Eko Instrument Co, Japan, and installed on rooftop 4th floor of PSTA LAPAN, about 20 meters from land surface, and altitude of Bandung is 720 meters mean sea level. Measuring of ultraviolet index also using ultraviolet sensor integrated into automatic weather station (AWS), produced by Davis. The type of Davis's AWS is Vantage Pro2 Plus and records the data every 15 minutes automatically. AWS is placed at same location too.

The daily maximum ultraviolet index has been calculated for every day-data and found 365 ultraviolet indexes for Bandung in 2017. Ultraviolet index of 2017 then classified following WHO's classification modified. After re-classified, there are only 4 classes, because of ultraviolet index 3-5 and

6-7 are grouped to be one class. By reason of measured ultraviolet index has one decimal then range of classification has been revised. This revision can be seen in table 1.

Tabel 1. Ultraviolet index classification.

UV Index (1)	Categories (2)	Classifications (3)	Descriptions (4)
0-2	Low	≤ 2.5	Low risk for public.
3-5	Moderate	2.6 to 7.9	Potentially risk if not protected
6-7	High		Need protection to avoid sun burned
8-10	Very high	8 to 9.9	Avoid direct exposure, use glass and shirt
11-15	Extreme	> 10	Protect your body

The daily maximum ultraviolet B insolation has been grouped in ten daily sequence following BMKG's method in determining of dry/rainy season [16]. By using this method the daily maximum insolation grouped for every 10 days and average in 10 days have been calculated. There are 37 values of an average of 10-days daily maximum ultraviolet B insolation in year 2017. Meanwhile, the different technique has been used for calculating sunshine duration data. Sunshine durations are clustered in three levels of exposure, i.e. 0-4 hours, 4.1 – 8 hours, and 8.1 - 12 hours.

3. Result and Discussion

Data processing for ultraviolet index, ultraviolet B insolation, and sunshine duration are shown in figure 2, 3, and 4. Figure 2a shows the trend of daily maximum of ultraviolet index of Bandung in 2017 and figure 2b shows monthly ultraviolet index classification in 2017 after clustered into four classes. The high ultraviolet index on wet season DJF (December January February) correspond to the nearest distance between solar and earth, causes higher solar intensity on top of atmosphere relatively. Besides of changing of distance between solar and earth, the variability of ultraviolet index depends on atmospheric constituent also, i.e.: cloud and water vapor content, aerosol, and stratospheric ozone. Changing of cloud cover is locally component, but stratospheric ozone is generally. Ozone attenuates ultraviolet irradiance strongly in the region 280-315 nm (ultraviolet A band) and affects weakly on region 315-400 nm (ultraviolet A band). Moreover, by referring to figure 2b, it is shown that the extreme value of ultraviolet index occurred every day on January and decreased gradually in the next two months. High amount of water vapor content on DJF cannot absorb solar radiation effectively and causes ultraviolet index in extreme class persistently.
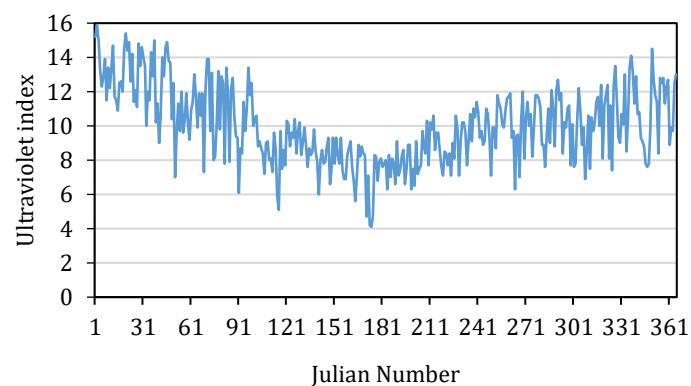

Figure 2a. Daily maximum of ultraviolet index at Bandung in 2017 has very high value especially when distance between earth and sun become short relatively (perihelion) on December, and low ultraviolet index value occurred when longest distance (August).

Figure 2b shows distribution of ultraviolet index at Bandung. In January 2017, all of the days have maximum ultraviolet index more than 10, and amount of days decreased gradually to several days in July, then increased again until December. By comparing to figure 2a, number of days with ultraviolet index less than 2.0 is not found in 2017, while in the middle of year 2017 distribution of days in both second class (3 – 7) and third class (8 – 10) are balanced. The percentage of days-event in 2017 with index $\geq$ 10 is 46%.
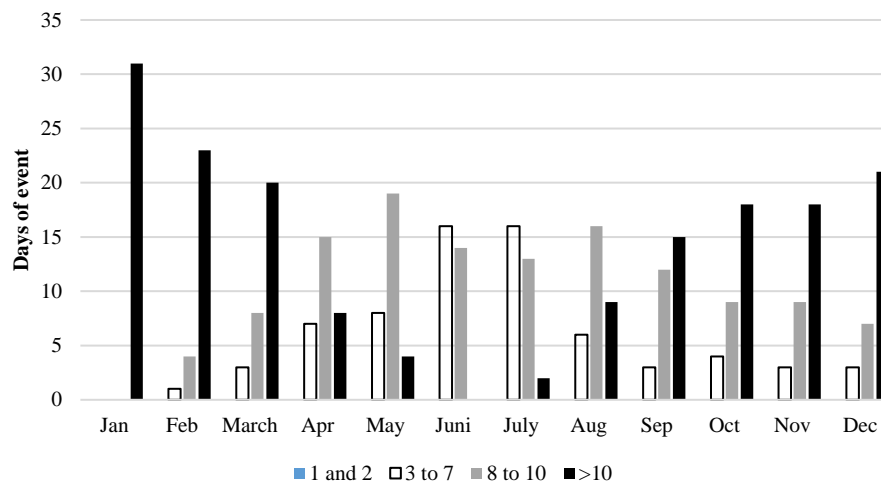

Figure 2b. Classification of monthly ultraviolet index in 2017 after grouped into four classes in Tabel 1.

10-days daily maximum ultraviolet B insolation in 2017 is shown in figure 3. By data analysis technique explained in advance the 10-days ultraviolet B maximum intensity follows trend of yearly maximum-minimum intensity, and have a higher intensity at the beginning of year correspond to perihelion, whereas has lower intensity at the mid of year. In general, the average of 10-days ultraviolet B insolation in the range 0.8-1.8 W/m^2 rated lower and can be concerned to ultraviolet B absorption by atmospheric constituents especially stratospheric ozone layer. Average of ultraviolet B insolation is 1.22 W/m^2, and clearness index is 0.3-0.7 [17], both of these have mutual relationship. The lower 10-days ultraviolet B insolation correspond to turbid atmosphere event most of the strongest absorber of solar ultraviolet B radiation is stratospheric ozone layer. Besides of ozone layer, another atmospheric constituents contribute to attenuation of incoming solar B radiation are aerosol and water vapor. The attenuation is caused by both absorption and scattering mechanisms. In addition, increasing of carbondioxide and water vapor content in stratosphere will cause infrared radiative cooling effects. However, absorption of ultraviolet B radiation by ozone layer will counteract the effects [18,19]. In correlation with absorption of aerosol, some research have found negative correlation between ultraviolet flux to aerosol optical depth (AOD) [20,21,22]. Moreover, reducing of incoming both solar UVA and UVB radiation in a big city can be correlated to loading of heavy pollutant to atmosphere [23,24].
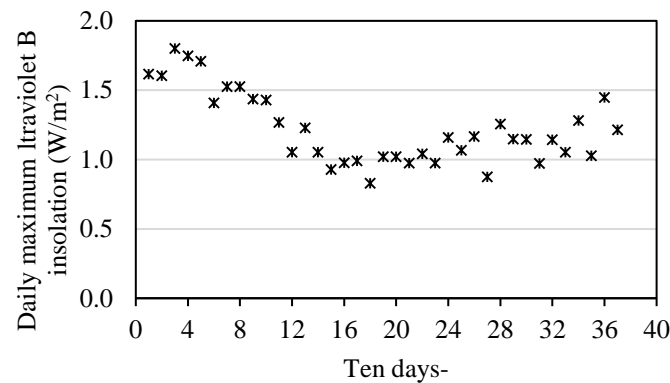
Figure 3. Average of 10-days daily maximum ultraviolet B insolation (Watt/m²). Days in 2017 are grouped by every 10 days and average value every 10 days are shown as one mark.

The statistics of sunshine duration in 2017 is shown in figure 4a and the distribution of sunshine duration event is shown in figure 4b. In figure 4a, sunshine duration is clustered to be 3 classes: short (0-4 hours), medium (4.1-8 hours), and long (8.1-12 hours). Sunshine duration in January, February and November are mostly short duration less than 4 hours/day. These correspond to weather condition which mostly rainy and cloudy. Sunshine duration in other months (March to October) mostly dominantly by medium duration (4.1-8 hours/day). Because of pseudo orbit of solar, on September 23rd and March 21st the solar will be on equator exactly, this also causes duration or length of day time and night time become similar. Location of Bandung over southern hemisphere causes longer duration of day time around beginning of October and beginning of March. In fact, sunshine duration in March and October are not dominantly by longer duration but have similarity for short and medium duration in March and medium duration in October. This can be presumed with high atmospheric water vapor content. Water vapor is a major atmospheric constituent in absorb of incoming solar radiation.
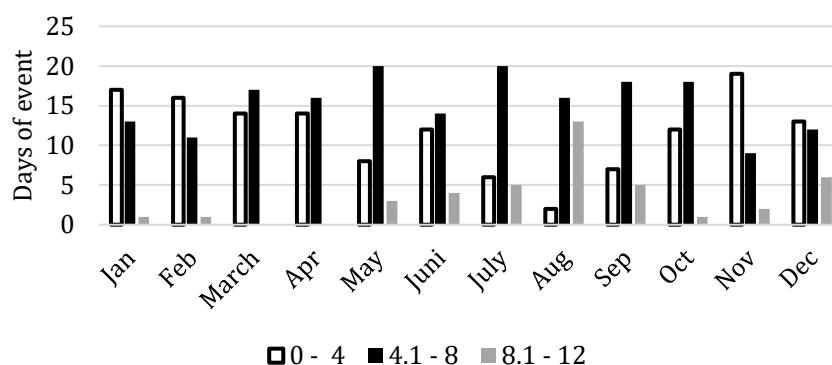

Figure 4a. Statistics of monthly sunshine duration in 2017 at Bandung after clustered to be 3 classes.

In general, sunshine duration in 2017 is mostly in medium duration class of 4.1-8 hours/day as amount 184 days-event or 50% of data, and secondly in short duration class as amount 140 days-event or 38%, and remaining in long-duration class as amount 41 days-event or 12%. Mostly duration of sunshine is 4-5 hours/day and occurred as 54 days (14.8 %) in 2017. By comparing with results found in LPD Sumedang then sunshine duration in DJF are mostly 1 hours/day, 7 hours/day in MAM, 9 hours/day in JJA, and distributed evenly in SON [9]. In that 15 years observation (1998-2013) the trend of increasing of sunshine duration from 7 hours/day to be 10 hours/day have been found. Sunshine

duration in Bandung (2017) is shorter than sunshine duration in Sumedang. Sunshine duration only explains about time accumulation of incoming solar radiation in a day, but not accumulation of energy nor intensity. Sunshine duration depends on minimum intensity of incoming solar radiation 120 W/m^2. In small solar zenith angle, sunshine duration is not affected widely by changes of atmospheric constituents, but increasing of atmospheric turbidity in large solar zenith angle contribute to decreasing of sunshine duration. Work in South Asia by using Net Downward Shortwave Radiation (NDSWR) satellite data showed the decreasing of sky clearness average -0.05 W.m^{-2}y^{-2} has been occurred in period 1979-2004 [25], and can be corresponded to solar dimming phenomena with average decrease as amount -0.54 Wm^{-2}y^{-2}. The decreasing can be correlated to increasing of optical depth caused by increasing of atmospheric aerosol content. Off course, the decreasing of sky clearness is not directly correlate to shorter sunshine duration. Only in very serious decreasing of sky clearness will affect directly to sunshine duration.
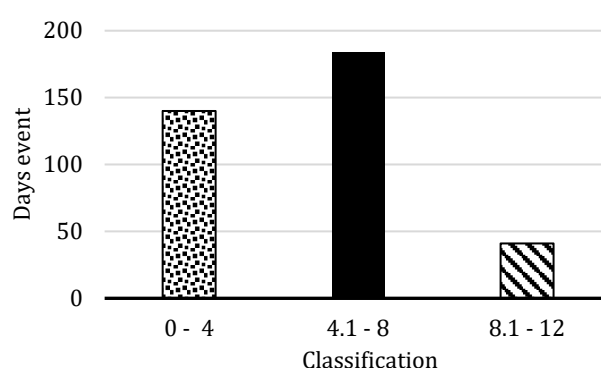

Figure 4b. Distribution of sunshine duration events in 2017 after clustered to be 3 classes.

4. Conclusion

After taking analysis of sunshine duration data, it has been found that Bandung was exposure by solar radiation as long as 4.1-8 hours /day average almost in part of 2017 and less than 10% was exposured up to 12 hours/day. Mostly duration of sunshine is 4-5 hours/day and occurred as 54 days (14.8 %) in 2017. Although daily maximum ultraviolet B insolation lower relatively (average 1.22 W/m^2) but not similar to ultraviolet index case. The ultraviolet index in 2017 at Bandung reached extreme value ($\geq$10) as amount 46%, and it was not found daily maximum ultraviolet index less than 2.

Acknowledgments

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