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Estimation of Solar UV-B Radiation at Visakhapatnam and its Variability with Columnar Ozone

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Abstract: ***Measurements of solar UV-B radiation in the biological band (280 nm – 320 nm) with the help of ground based UV-B Photometer at VISAKHAPATNAM (17.7^0 N, 83.3^0 E) have been used to develop a simple regression model. The model was developed with measured values of incoming UV-B radiation obtained by UV-B photometer deployed in the Department of Physics, Andhra University (1989-1993) and satellite measured column ozone as inputs. The model is useful to find unknown values by providing known inputs. Hence satellite measured values of columnar ozone for the period 2005-2013 were provided as one input, solar zenith angle as another input and incoming UV-B radiation for this period was estimated. With the estimated values of incoming solar UV- B radiation an attempt was made to analyze the dependence of incoming solar UV-B radiation on columnar ozone and also its dependence on solar zenith angle and wavelength***.

Keywords: UV-B, Columnar Ozone, Solar Zenith Angle, Regression Model

1. Introduction

Reduction of stratospheric ozone and enhancement in the ground reaching solar UV-B radiation in the biological band (280-320 nm) has gained wide importance due to its adverse impact on the human beings, animals and plants. In the late 70's it has been reported that a reduction of stratospheric ozone by 1% would lead to 2% increase in UV-B radiation (Cutchis, 1974). This may vary depending on specific wavelength, season and solar zenith angle of the sun (Bias et. al 1994). The effect of increased exposure to UV-B radiation by a human body depends on the physical properties of this radiation. The UV-B radiation does not penetrate far into the body as it is absorbed in the superficial tissue layers of 0.1 mm depth (Longstreth et al., 1998). However it affects skin and eyes. It causes effects like erythema, sunburn and tanning which is due to 0.5 % of the incident radiation. The dependence of these effects on wavelength is given by Everett et al.(1966). It also has effect on the immune system, aging of the skin, eyes and cause skin cancer. Previous studies indicate that these effects do not increase with an increase of incoming UV-B radiation. It is estimated that the number of excess skin cancers (1980 to 2100) due to this radiation increases from 100 to 500 million per year (Longstreth. et al., 1998). In addition to these effects of UV-B radiation on human society, it also shows significant influence on animals, agriculture, forest, plants and crops (Caldwell et al., 1998). Middleton et al., (2001) reported that amphibian declines occur due to the increase in UV-B exposure. It is reported that the physiological and developmental processes of plants are affected by UV-B radiation. Since the first reports of stratospheric ozone reduction over 20 years ago (Johnston 1971), effects of UV-B radiation on higher plants have been the subject of considerable research. Enhanced UV-B radiation can have many direct and indirect effects on plants including inhibition of photosynthesis, DNA damage, changes in morphology, phenology and biomass accumulation. UV-B radiation can alter both the time of flowering as well as the number of flowers in certain species. (Caldwell et al., 1998). In addition to these effects, UV-B radiation has its influence on air quality (Tang et al., 1998), materials (Andrady et al., 1998) and also on biogeochemical cycles (Zepp et al., 1998). To assess the significant changes in the incoming biological ultraviolet radiation with ozone depletion the values of RAF (Radiation Amplification Factor) are calculated for various effects like Erythema, DNA and Skin Cancer etc. It is a known fact that the increase in UV-B radiation strongly depends on wavelength(in addition to its dependence on solar zenith angle, ozone etc) and to assess a particular biological effect an action spectrum that gives the sensitivity of wavelength dependent UV change is to be considered.(Madronich et al., 2003). Even instruments like UV-B meters are developed which can measure some of the biological effects with high sensitivity (Maryn Moris and Daniel Berger 1993. The variation of biologically effective UV-B radiation with respect to ozone is given by RAF which is defined as the percentage increase in the incoming biological UV–B radiation for a given species that would result from a 1 % decrease in the amount of total

Columnar ozone. (Madronich et al., 1998). RAF values indicate the sensitivity of a particular biological effect to the corresponding change in ozone. Madronich et al., 1998 reported the values of RAF's for different biological effects with the help of different action spectra. They also studied the trends in biologically active radiation (Erythema) by using the action spectrum suggested by Mc Kinlay and Diffey and TOMS ozone data (1978-1992) for various latitudes and reported that for latitudes lying between 10 to 20 degrees North where the current station Visakhapatnam (17.7 ^{0} North) lies have zero % change per decade and for latitudes lying between 20 to 30 degrees North it is having 1 % change per decade.

Regular measurements of the ground reaching solar UV-B radiation were started in India during the Indian Middle Atmosphere Program (IMAP) long back at different locations and this paper reports the variation of columnar ozone at Visakhapatnam for the years 2005-2013 along with its impact of UV-B radiation for these years. The columnar ozone values for the years 2004 to 2006 are obtained from TOMS aboard Nimbus 7 and for the years 2007 to 2013 are obtained from OMI for this station from the website http://www.jwocky.gfc.nasa.com/.

2. Modeling of Data (Regression Analysis)

An attempt was made to develop a simple regression model for Visakhapatnam station in terms of incoming UV-B radiation, solar zenith angle and columnar ozone by Krishna Prasad and Niranjan ,2005. In this model the incoming UV-B radiation (U) is expressed as a function of total columnar ozone (O) and the solar zenith angle (μ). The functional relationship between the three is given by

$$\ln U = a + RAF \ln(O) + C(\mu) \quad \ldots\ldots\ldots\ldots(1)$$

Where a is the regression constant, RAF and c are the regression coefficients.
Further RAF is known as Radiation Amplification Factor which expresses the dependence of UV-B radiation on total columnar ozone and is given by

$$RAF = -\frac{d[\ln U]}{d[\ln O]} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

which gives the relative change in incoming UV-B radiation corresponding to the relative change in ozone

3. Results and Discussion

3.1 Diurnal and Seasonal variations of ozone at Visakhapatnam

Ozone is one of the main atmospheric components which depend on many factors like day, season, solar zenith angle, latitude etc. Ozone data for the years 2009 -2011 was used to study its diurnal variation in terms of year and season. (Figure 3.1.A). The graph indicates diurnal variation for the years 2009-2011 starting from January to December. From the graphs it is observed that the ozone is increasing from January and consequently decreasing by the end of December. The same trend is observed for all the four years. Also the maximum value of ozone is lying between 280 to 290 Dobson Units for year 2009 and 2010 where as the maximum value in 2011 is above 290 Dobson Units.

Figures 3.1.B, 3.1.C, 3.1.D indicate the seasonal variation of ozone for the years 2009-2011. The graphs indicate low values of ozone recorded during winter season varying between 220-270 Dobson Units and highest during summer varying between 230-290 Dobson Units and the ozone is lying between these two seasons for monsoon varying between 250-280 Dobson Units. It is also observed that summer and monsoon ozone values are almost same for this coastal urban station Visakhapatnam.

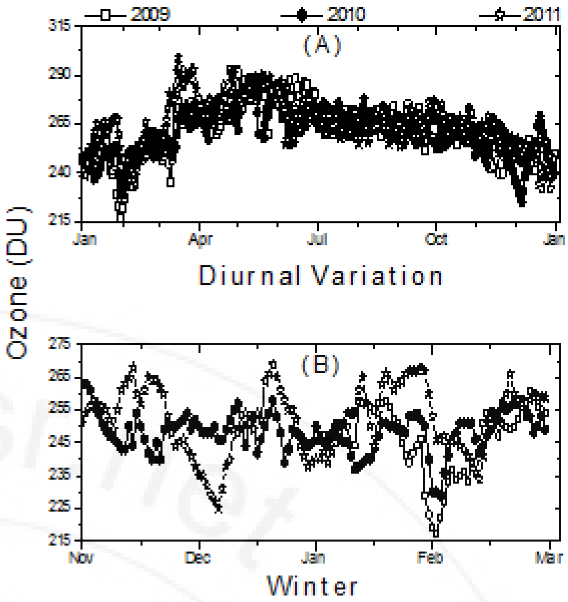

Figure 3.1:A. Diurnal Variation of ozone on monthly basis (2009 – 2011)

Figure 3.1:.B. Seasonal Variation of ozone for winter (2009 – 2011)

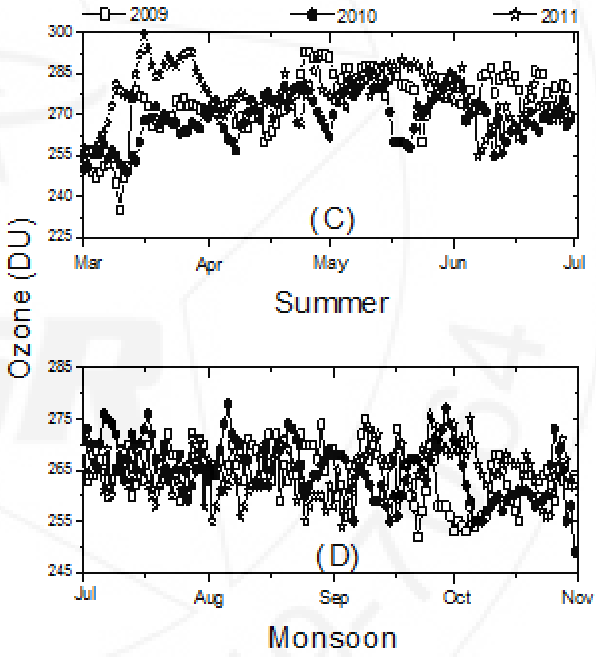

Figure 3.1: C Seasonal Variation of Ozone for summer (2009 – 2011)

Figure 3.1: D Seasonal variation of Ozone for monsoon (2009-2011)

3.2. Long term variation of estimated UV-B radiation

Figures 3.2.1 represent the long term variation of the incoming UV-B radiation for three different solar zenith angles 30^0, 40^0,50^0 for wavelength 310 nm . In this case 310 nm was considered as the biological effect is maximum for radiation near to this wavelength. With a view to monitor the long term variation of UV-B radiation the columnar ozone values for the period 2005 to 2013 are incorporated in the developed model to estimate the ground reaching UV-B radiation. The figure show the 15 point running mean of the estimated incoming UV-B radiation for Visakhapatnam station along with the columnar ozone with standard deviation. 15 point running mean is taken to remove the seasonal trends in the data. The mean value of total columnar ozone is found to be approximately 262 Dobson Units for the whole period. This mean value is less than the mean value of ozone for the period 1978-1993 which is approximately 270 Dobson Units. Also the plot does not indicate any significant increase or decrease in the incoming UV-B radiation for this station. This insignificant change in ozone may lead to analytical relations between incoming UV-B radiation, solar zenith angle and other atmospheric parameters whose values may reflect less variation than expected.

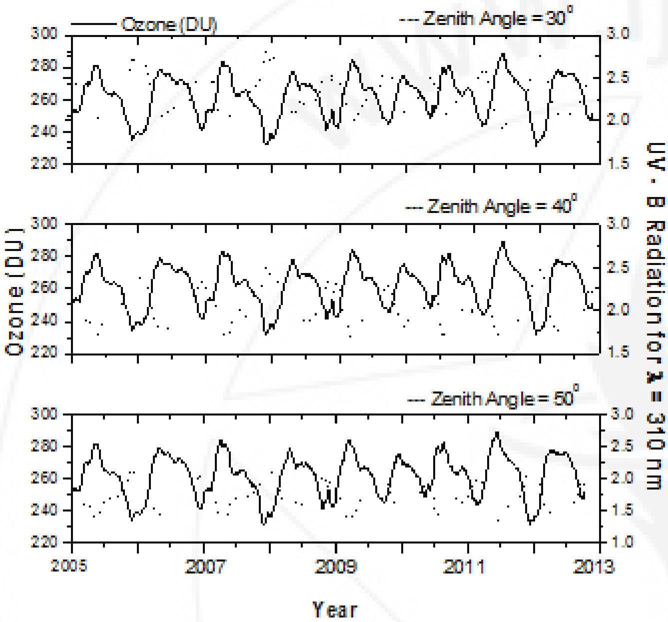

Figure 3.2.1: Long term variation of estimated UV-B radiation (310 nm) for three different solar zenith angles as a function of columnar ozone

4. Conclusions

The present paper reports some of the ozone measurements made by satellite exclusively for Visakhapatnam during the period 2005 to 2013. With the help of these measurements diurnal variation and seasonal variation of stratospheric ozone over this station for the period 2009-2011 is reported. Also these measurements are used to estimate the incoming solar UV-B radiation with the help of regression model developed for this station. An attempt was made to analyze the long term variation of estimated UV-B radiation and its dependence on columnar ozone as a function of solar zenith angle for 310 nm wavelength. These results may be helpful to further use the data in calculating various biological effects of UV-B radiation at this coastal urban station Visakhapatnam.

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