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Regression Technique That Relate UV-B and Ozone at Visakhapatnam

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Abstract: **Atmospheric parameters that affect ground reaching UV-B irradiance include ozone, solar zenith angle, earth–sun distance, clouds, aerosols, etc. It is a known fact that total column ozone and ground reaching UV-B irradiance are inversely related The aim of this paper is to estimate the variation of the biologically effective UV-B irradiance with variation in ozone at a coastal urban location Visakhapatnam for the year 2012 with the help of a regression model that was developed with measurements made by a UV-B Photometer operated at Visakhapatnam in 1990 (Krishna et al., 2005) long back. This now reused to estimate the incoming UV-B irradiance by inputting TOMS ozone for the year 2012. An attempt was made to compare both measurements which are reported in this paper. For the analyzed period (January 2012 – December 2012), variation of estimated UV-B irradiance with ozone for different wavelengths is found for 12.5^0 solar zenith angle. These results indicate the efficiency of the regression model developed for this station.**

Keywords: **UV-B irradiance, Regression, Ozone.**

1. INTRODUCTION

Decrease in stratospheric ozone and consequent increase in the ground reaching solar UV-B irradiance in the biological band (280-320 nm) for the last couple of decades has gained large significance due to its adverse affects on the human, animal and plant species. It is reported that a 1% decrease in stratospheric ozone could cause about 2% increase in UV-B radiation (Cutchis, 1974). It may vary according to the specific wavelength, season and zenith angle of the sun. The consequences of increased exposure of the human body to UV-B radiation is characterized by the physical properties of this radiation. 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). Even though its primary effects are limited to skin and eyes, it has effects like erythema, sunburn and tanning which is due to 0.5% of the incident radiation. The relative effects of various wavelengths in producing erythema are given by Everett et al. (1966). Madronich et al. (1998) reported an annual erythemal dose of 2.35 MJ/m^2 with an increase in erythemal induction by 4±1.5% and skin cancer by 4.7±1.7% during 1979 to 1993 for subtropical latitude approximately. UV-B irradiance has also has influences 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 in UV-B irradiance. In addition to these effects of UV-B irradiance on human society, it also shows significant influence on animals, agriculture, forest, plants and crops (Caldwell et al., 1998, Teveni et al., 2008). 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 (Plants and Human), Skin Cancer, etc. It is a known fact that the increase in UV-B irradiance 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 (Micheletti et al., 2003

An attempt is made to estimate the incoming UV-B irradiance for the year 2010 at Visakhapatnam by using satellite measured column ozone, RAF and solar zenith angle as inputs. This paper reports the estimated UV-B irradiance as a function of solar zenith angle, wavelength and ozone for the year 2012 at Visakhapatnam.

2. REGRESSION TECHNIQUE

The goal of regression analysis is to determine the values of parameters for a function that cause the function to best fit a set of data observations that you provide. In linear regression, the function is a linear (straight-line) equation. For example, if we assume that a variable (UV-B irradiance) increases by a constant amount each year depending on two other variables (ozone and solar zenith angle) which are independent of each other the following linear function would predict its value as a function of the two independent variables.

For an analysis such as this we must provide a data file containing the values of the dependent and independent variables for a set of observations. In this example each observation data record would contain three parameters UV-B, Ozone and solar zenith angle for different days. The more observations you provide, the more accurate will be the estimate of the parameters.

The functional relationship between the incoming UV-B irradiance (I) as a function of total ozone (T) and the solar zenith angle (χ) is given by

$$ln\ I = a + RAF\ ln(T) + C(\chi) + u \ldots\ldots\ldots\ldots(1)$$

where a is the regression constant, RAF and c are the regression coefficients and u is the disturbance term, which has $N(O,\sigma^2)$ distribution.

Further, RAF is known as Radiation Amplification Factor which expresses the dependence of UV-B flux on total ozone and is given by

$$RAF = -\frac{d[\ln I]}{d[\ln T]} \ldots\ldots\ldots\ldots(2) \quad \text{(Dubrovsky 2000)}$$

Equation (2) can also be expressed as

$$RAF = -\frac{\left(\frac{dI}{I}\right)}{\left(\frac{dT}{T}\right)} \ldots\ldots\ldots\ldots(3)$$

which gives the relative change in effective irradiance corresponding to the relative change in ozone. Equation (1) can be written as

$$Y = \beta_1 + \beta_2 X_2 + \beta_3 X_3 + u \ldots\ldots\ldots\ldots(4)$$

where β_1 =a, β_2 = RAF, β_3 = c, Y = *ln* I, X_2 = *ln* T and $X_3 = \chi$

In deviation form (4) can be expressed as

$$y = \beta_2 x_2 + \beta_3 x_3 + (u - \bar{u}) \ldots\ldots\ldots\ldots(5)$$

Using ordinary least squares, we can obtain the estimated parameters as

$$\begin{bmatrix} \hat{\beta}_2 \\ \hat{\beta}_3 \end{bmatrix} = \begin{bmatrix} \sum x_2^2 & \sum x_2 x_3 \\ \sum x_2 x_3 & \sum x_3^2 \end{bmatrix}^{-1} \begin{bmatrix} \sum y x_2 \\ \sum y x_3 \end{bmatrix} \ldots\ldots\ldots\ldots(6)$$

where $x_{i2} = X_{i2} - \overline{X_2}$ etc. (Johnston, 1984)

Further $\hat{\beta}_1 = \bar{Y} - \hat{\beta}_2 \bar{X}_2 - \hat{\beta}_3 \bar{X}_3$

By using the known values of *ln* I, *ln* T, and χ the estimated model would be

$$\left(\hat{\ln I} \right) = \hat{a} + \left(R\hat{A}F \right) \ln T + \hat{c}\,\chi \text{ ....(7)}$$

3. RESULT

3.1 Variation of Erythemal Irradiance for different wavelengths as a function of Solar Zenith Angle:

The variation of biologically effective erythemal irradiance at Visakhapatnam for the year 2010 is plotted that indicate the variation of erythemal irradiance as a function of ozone corresponding to solar zenith angle 12.5^0. It is observed that the erythemal irradiance and ozone are inversely correlated with a range of 82 to 87% for this solar zenith angles. This solar zenith angle was considered as it gives more radiation on to the earch.

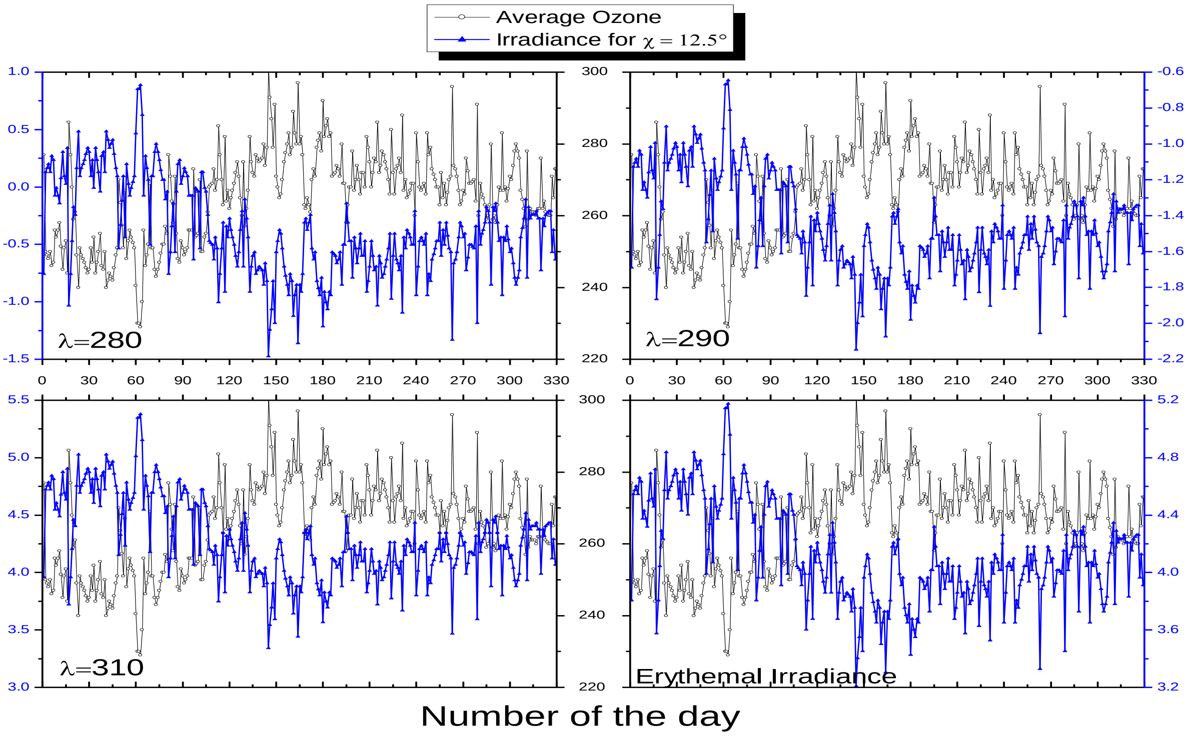

Figure 1. Variation of estimated irradiance with ozone for three wavelengths (280, 290 and 310 nm) and variation of Erythemal irradiance with ozone as a function of solar zenith angle (12.5°)

4. CONCLUSION

This paper estimates the incoming irradiance at Visakhapatnam for the year 2010 by substituting TOMS ozone as one input, fixed solar zenith angle as one input and the corresponding RAF values as other input into the regression model developed exclusively for this station. The graphs show inverse correlation between ozone and estimated UV-B irradiance up to 80%. Erythema is one of the biological effects that affect human skin and hence the analysis was mainly focused on erythema. Similarly, the graphs indicate the variation of erythemal irradiance with ozone as a function of solar zenith angle was found to be inversely correlated up to 87%. These results indicate that the regression model developed for this station long back could still be used to estimate the incoming UV-B irradiance as a function of known inputs like solar zenith angle and TOMS Ozone. However, the results need to be compared with measurements made by a ground based instrument to obtain more efficiency.

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