CHAPTER - 2

A Study of the Variation of Daily O_3 Concentration in Antarctica with Daily Solar U. V. Flux

2.1 Introduction

The purpose of this chapter is to investigate the variation of daily and monthly ozone concentration in Antarctica (south pole) at Halleybay (73.5° S, 26.7° W) and at McMurdo (78° S, 166° E) with daily solar U.V. flux and monthly U.V. flux respectively to find out the monthwise and seasonwise correlation between ozone concentration and U.V. flux.

Evidence shows that atmospheric (mainly in stratosphere) ozone is a very minor constituent, only few mm thick (1.5 mm to 4.5 mm) at S. T. P. but it plays an important role to absorb the solar U.V. radiations (200 nm$< \lambda <$ 320 nm) which are lethal to man and other living organism, at the same time it is also very much harmful to the abiotic environment of our planet.

A 10% decrease in atmospheric ozone has been estimated to increase the risk of eye cataract by 5% per anum, the risk of skin cancer i,e malignant melanoma may increase by 10% and the risk of nonmalignant melanoma may increase upto 26%. These estimations are based on the "United Nations Environment Programme" (UNEP - 1991).

Bates (1981) has shown that variations in solar U. V. radiation can lead to changes tropospheric climate.

Observations over the last two decades indicate that O_3 concentration in the lower stratosphere has decreased and the tropospheric O_3 concentration has possibly increased in some regions (Stolarski et.al. 1991, Mc Cormic et.al 1992, and Logan 1994).

Ozone changes can affect the troposphere system in several ways :

(1) Decrease in stratospheric O_3, reduced solar radiation absorption, more solar energy reaching to the earth's surface, resulting in tropospheric warming.

(2) Decrease in stratospheric O_3 reducing the thermal emissivity, hence less infrared radiation reaching to the troposphere, resulting in tropospheric cooling.

(3) Increase in tropospheric O_3 will result in an increased greenhouse trapping of long wave radiation resulting in tropospheric warming (Mackay et.al. 1997).

The solar UV - B (280 nm. - 320 nm.) radiations are not totally absorbed by the O_3 layer; its remaining part coming to the ground affects man, animal, fishes and plants. Tevini and Teramura, 1989 Dahlback and Moan, 1990, Nikula et.al. 1992, Smith and Baker 1989.

Sydney Chapman (1930) postulated chemical reactions with O_2 and U. V. light for the formation of ozone in the atmoshphere. But O_3 concentration does not continue to increase, as it is also destroyed by the U. V. rays and by some man made pollutants (Rowland and Molina 1974). The oxygen atoms released from ozone destruction combine with O_2 molecules forming again ozone molecules. The resultant concentration of O_3 depends, on the rate of production and the rate of loss and destruction due to pollutants and transportation.

But the global O_3 assessment confirmed that O_3 is declining everywhere (WMO 1992). It is already accepted that the dramatic decrease of O_3 concentration occurs during Antarctic spring (Farman et.al. 1985, Stolarski et.al. 1986). Several studies on the effect of various kinds of solar activity upon O_3 depletion in Antarctica made from time to time by different investigators throughout the world. Midya et.al (1993) showed that O_3 concentration varies in oscillatory manner with solar flare number during the period 1973 to 1984. Midya et al. (1996) also showed that dramatic decrease of O_3 concentration in Antarctica is independent of U. V. radiation by using the calibrated value of solar U. V. flux.

In this chapter, the solar U. V. data are taken from the NIMBUS 7 satellite, published in Solar Geophysical data book for the period 1978 to 1984 (SGD comp. reports October'89 No. 542 - part II), tabulated in chapter 1, page 32 to 40. Purpose of this chapter is to study the correlation between daily U. V. flux and daily O_3 concetration in Antarctica during the period November 1978 to October 1984. The result shows that the daily, monthly, seasonal variations of O_3 concentration for different years are independent of solar U. V. radiation.

2.2 Analysis, Discussion and Conclusions

22.1 Analysis

The daily average values of the solar U.V. radiations for the period November 1978 to October 1984 are obtained from Solar Geophysical Data book, NOAA, U.S.A. published by Department of Commerce U.S.A. SGD comp. reports October 1989 No. 542 - part II tabulated in chapter 1, page 32 to 40 and the daily average values of O_3 of Halleybay for the same period are obtained from internet website *http : //jwocky. gsfc. nasa. gov* and the O_3

data for McMurdo are obtained from komhyr et.al. Geophys. Res. lett vol 13 No 12 Pages 1246 - 1251 (1986), tabulated in chapter 1, page 19 to 25.

The correlation coefficients between daily O_3 and daily U. V. flux have been calculated months wise and season wise for the period November 1978 to October 1984, by using the statistical equation,

$$\text{correlation coefficient } r = \frac{N\Sigma xy - (\Sigma x)(\Sigma y)}{[N(\Sigma x^2) - (\Sigma x)^2]^{1/2}\,[N(\Sigma y^2) - (\Sigma y)^2]^{1/2}} \quad \ldots\ldots\ldots\ldots\ldots\ 2.2.1.1$$

Where "x" is the value of solar UV flux. "y" is the value of ozone concentration in Antarctica. "N" is the number of data for which the values of UV flux and ozone concentration are available.

2.2.2 Correlation Between Solar U. V. Flux and O_3 Concentration of Antarctica Survey Stations Halley Bay & McMurdo

The daily mean O_3 concentration values during November 1978 to October 1984 for Halley Bay in Antarctica are taken from internet system. Daily mean solar U. V. flux values are taken from Solar Geophysical Data book, NOAA, U.S.A. to find the correlation coefficient between solar U.V. flux and O_3 concentration for different months and for the different seasons during the period 1978 to 1984. The calculated correlation coefficients are given in Table - 2.3.1 and Table - 2.3.2

Correlation coefficient between daily mean value of O_3 concentration and daily mean values of U. V. flux are calculated for different months. It is found from the correlation table (Table-2.3.1) that the correlation coefficient becomes positive & maximum (0.56) for October, which is definitely significant at 5% level.

The correlation coefficients between monthly mean values of O_3 concentration and yearly mean values of O_3 concentration in Antarctica are calculated for the seasons winter(May, June, July, August), spring (Sept., Oct.), summer (Nov., Dec., Jan.), and autumn (Feb., March., April), and for Halley Bay it is found from the correlation table (Table - 2.3.2) that the correlation coefficient becomes positive & maximum (0.72) for spring, definitely significant at 5% level. The correlation coefficient between monthly mean value and the yearly mean value of the solar U. V. radiation is found to be positive & maximum (0.98) during spring. Also the correlation between the monthly mean value of O_3 concentration and the monthly mean value of solar U. V. flux is positive & maximum (0.69) during spring. Similar is the case of correlation coefficient between daily mean O_3 concentration and daily mean solar U. V. flux, which is positive & maximum (0.48) during spring; all of these correlation coefficients are definitely significant at 5% level, and for other seasons it is poor.

For McMurdo it is found from the correlation table (Table - 2.3.3) that the correlation coefficient between monthly mean value of O_3 and the monthly mean value of solar U. V. flux is positive and maximum (0.58) during spring, correlation coefficent between monthly mean value of O_3 concentration and the yearly mean value of U. V. flux is positive and high (0.55) during spring, also the correlation coefficient between monthly mean value of O_3 concentration and the yearlty mean value of O_3 concentration is positive and maximum (0.68) during spring, which are also significant at 5% level.

Due to lack of adequate data, the value of the correlation coefficient for winter at Halley Bay and for Autumn at McMurdo are not computed.

The variation of the correlation coefficient between daily mean O_3 concentration and the daily mean solar U. V. flux as well as the variation of the correlation coefficient between the monthly mean O_3 concentration and monthly mean solar U. V. flux with the seasons for Antarctica are illustrated in fig. 2.3.1.

It may be infered that O_3 concentration and solar U. V. flux are mainly controlled by their spring values. This is corroborated by Midya et.al. (1996) who found the O_3 concentration and U.V. radiation to be mainly controlled by their October values.

2.2.3 Conclusions

It is known that atmospheric ozone is produced in the stratosphere over the equatorial region from monatomic (O) and diatomic (O_2) oxygen by the action of solar U.V. radiation with wavelengths less than 243 nm. Stratospheric winds carry ozone from the equatorial region towards the north and south poles. In the northern hemisphere, the circulation of winds is facilitated by the large mountain ranges like the Rockies and the Himalayas right to the north pole. In the southern hemisphere, the winds circulate to about 60°S for much of the year especially during southern winter, i.e. May, June, July and August. Further during southern winter a special condition developes in the high atmosphere of polar region, when the stratospheric temperature may drop below – 80° C, the man-made chemicals (mainly chlorine and bromine species) can stay in the atmosphere for 100 years. At this very low temperature during the polar nights, these pollutants form "Polar stratospheric cloud" (PSC) and become more active when sunlight appears in the Antarctica in late August and early September, by the interaction of U.V. radiation rapid chemical reaction start which may destroy significant amount of atmospehric ozone. Another unique atmospheric condition known as the "Polar vortex" traps air above the pole which do not allow the warmer low latitude ozone rich air to mix with the air above the pole. By early October, ozone at 13-20 km is almost completely destroyed. However by that time stratospheric temperature starts rising, PSCs evaporate, chemical destruction ceases and ozone rich air from lower latitude helps to recover the Antarctic ozone level. Thus in September and October less ozone is found over Antarctica.

From the correlation tables (Table - 2.3.1 , Table - 2.3.2 & Table - 2.3.3), it is seen that the values of correlation coefficient between the daily mean O_3 concentration and daily mean solar U.V. flux are positive being maximum for October, also the correlation coefficients between monthly mean O_3 concentration with monthly mean solar U.V. flux, or with yearly mean U.V. flux, or with yearly mean O_3 concentration are positive being maximum for Antarctic spring. Even the correlation coefficient between the monthly mean solar U.V. flux with yearly mean solar U.V. flux is positive, being maximum for Antarctic spring.

Thus, with increase of solar U.V. radiation the O_3 concentration over Antarctica should increase and vice-versa. However, Farman et.al. (1985) found that the spring values of O_3 concentration over Antarctica decrease with years from 1957 to 1984. If solar U.V. radiation would have been responsible for this declining trend of spring values of ozone concentration, then the correlation coefficients should have been highly negative in spring. But results indicate shows that most of the correlation coefficients between ozone concentration and solar U.V. flux are high, positive and significant at 5% level during Antarctic spring. Thus it may be concluded that the solar U.V. radiation is not responsible for Antarctic ozone depletion.

Table - 2.3.1

Halley Bay (73.5°S, 26.7°W) During 1978 - 1984

Correlation Coefficient Between	Jan.	Feb.	Mar.	Apr.	Aug.	Sept.	Oct.	Nov.	Dec.
Daily mean O_3 and daily mean solar U.V. flux	-.0.9	-0.02	-0.19	-0.008	0.38	0.40	0.56	-0.14	0.42

<u>Table -2.3.2</u>

Halley Bay (73.5°S, 26.7°W) During 1978 - 1984

Correlation Coefficient Between	Late Winter (August)	Spring (Sept., Oct.)	Summer (Nov., Dec., Jan.)	Autumn (Feb., Mar., Apr.)
Daily mean O_3 and daily mean solar U.V. flux	0.38	0.48	0.047	-0.056
Monthly mean O_3 and monthly mean solar U.V. flux	*	0.69	0.18	-0.16
Monthly mean O_3 and yearly mean U.V. flux	*	0.66	0.06	-0.04
Monthly mean O_3 and yearly mean O_3	*	0.72	0.63	0.14
Monthly mean U.V. flux and yearly mean U.V. flux	0.90	0.98	0.93	0.96

** Signifies that correlation coefficients are not calculated due to insufficient data*

Table -2.3.3

Mc Murdo (78°S, 166°E) During 1978 - 1984

Correlation Coefficient Between	Winter (May, June, July, August)	Spring (Sept., Oct.)	Summer (Nov., Dec., Jan.)	Autumn (Feb., Mar., Apr.)
Monthly mean O_3 and monthly mean solar U.V. flux	0.48	0.58	0.45	*
Monthly mean O_3 and yearly mean solar U.V. flux	0.60	0.55	0.38	*
Monthly mean O_3 and yearly mean O_3	0.62	0.68	0.59	*
Monthly mean U.V. flux and yearly mean U.V. flux	0.90	0.98	0.93	0.96

* *Signifies that correlation coefficients are not calculated due to insufficient data*

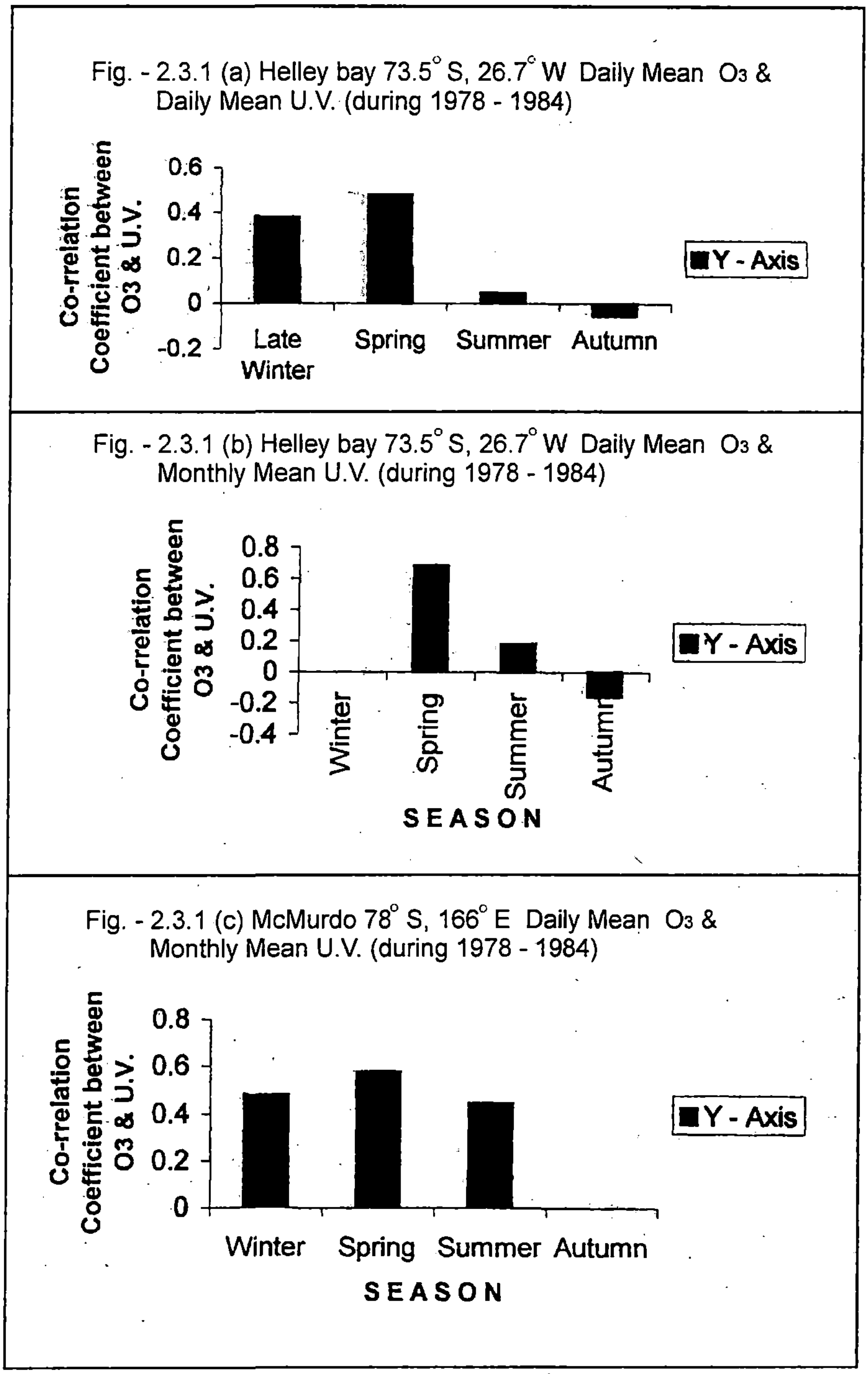
Fig. - 2.3.1 (a) Helley bay 73.5° S, 26.7° W Daily Mean O3 & Daily Mean U.V. (during 1978 - 1984)
Co-rrelation Coefficient between O3 & U.V.
0.6
0.4
0.2
0
-0.2
Late Winter
Spring
Summer
Autumn
Y - Axis
Fig. - 2.3.1 (b) Helley bay 73.5° S, 26.7° W Daily Mean O3 & Monthly Mean U.V. (during 1978 - 1984)
Co-rrelation Coefficient between O3 & U.V.
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Winter
Spring
Summer
Autumn
SEASON
Y - Axis
Fig. - 2.3.1 (c) McMurdo 78° S, 166° E Daily Mean O3 & Monthly Mean U.V. (during 1978 - 1984)
Co-rrelation Coefficient between O3 & U.V.
0.8
0.6
0.4
0.2
0
Winter
Spring
Summer
Autumn
SEASON
Y - Axis

FIG. - 2.3.1

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