CHAPTER - 5

Antarctic Ozone sink, its covariation with solar Parameter and possible effects on environment

5.1 Introduction

The experimental observations show that the loss of atmospheric ozone concentration in Antarctica over a large area is about 60 to 70% of total column ozone, which has been termed as "ozone hole". The possible consequences of ozone hole on the environment are known. Decrease in atmospheric ozone concentration allows enhanced solar U.V. radiation (mainly UV - B, wavelength range 280 nm. to 320 nm.) which is very much harmful to the biosphere as well as ecosystem. High dosage of this U.V. - B can affect severely - plants and crops, aquatic life, micro organism, human and animals. The atmospheric ozone depletion may influence the climatic condition of the earth.

In previous three chapters, the analysis has been performed between ozone concentration of three antarctic stations in different locations with the solar gross U.V. flux, components of solar U.V. flux and with the eleven years data of solar 10.7 cm. radio flux to study the effects of solar radiation, solar activity and eleven years solar cycle variation on atmospheric ozone depletion.

In this chapter for more critical analysis of previous observations, a twelve years solar radio flux data (1974 to 1985) has been considered with the twelve years ozone concentration data of Antarctic Station McMurdo (78°S, 166°E). To have the more confirmative observations of the effect of solar cycle variation with the proxy data of solar U.V. radiation on ozone concentration at McMurdo, the present analysis has been made.

Studies have been made about the man-made pollutants, natural phenomena and transportation of ozone by stratospheric wind to investigate their role in atmospheric ozone depletion. The effect of ozone depletion on abiotic and biotic environments are scrutinised from the available published standard results.

Sydney Chapman (1930) postulated chemical reactions with ozone and U.V. light. It shows destruction as well as formation of atmospheric ozone. The resultant concentration of ozone depend at any time, on the rate of production and the rate of loss or destruction. It is also being destroyed by pollutants (Crutzen 1970, Johnston 1971, Rowland & Molina 1974). Though 10.7 cm. solar flux is not chemically responsible for ozone destruction or ozone

formation, yet it is well correlated with the value of solar U.V. flux. The calculated correlation cofficient between solar radio flux and solar U.V. flux is possitive and very high (0.95). Which is definitely significant at 5% level. Thus with increase of solar radio flux, the U.V. flux should increase and vice versa.

The ozonosphere acts as an atmospheric filter screen, which protects the biotic and abiotic environments of the earth from the deleterious effects of solar U.V. radiation and maintain the ecological balance. But the global ozone assessment has shown that atmospheric ozone is declining everywhere throughout the world (WMO report no. 25, 19991 and WMO bull no. 41, 1992), ozone level sink allows enhanced solar U.V. radiation on the earth. This harmful U.V. radiation can affect severely : Plants and crops (Tevini and Teramura, 1989), aquatic life (smith et.al. 1980, Bakers and smith 1982, Worrest 1986, Smith 1989), humans and animals (Taylor 1989, Vanderleun et.al 1993, Ley et.al. 1989, Nikula et.al. 1992).

It can also affect the climatic condition of the earth. The variation in solar U.V. radiation due to ozone level sink can influence tropospheric climate in many ways (Bates 1981, Mackay et.al. 1997).

Many work has been reported on atmospheric ozone variation (Stolarski et.al. 1991, Mc cormick et.al. 1992, Logan 1994).

Some investigators also worked on relation between ozone level sink and solar radiation (Heath et.al. 1977, summers et.al. 1990, Hood et.al. 1991 & 1992, Reinsel et.al. 1994, Midya et.al. 1996, Heath et.al. (1977) and found high correlation between atmospheric ozone concentration and 10.7 cm. solar radio flux.

In this chapter an attempt has been made to investigate some of the causes of ozone level sink and its possible effects on environment. The solar 10.7 cm. radio flux data are obtained from the solar geophysical Data book, NOAA Published by Department of commerce, USA, the monthlymean values of ozone concentration for McMurdo (78° S, 166° E) in Antarctica are obtained from Komhyr et.al. (1986), also tabulated in chapter - 1 of page 25 & 41 to 52.

5.2. Analysis, Discussion and Conclusions

5.2.1. Analysis

A linear regression relation between the daily value of 10.7 cm. solar radio flux and daily relative sunspot number on least square principle shows two components of the 10.7 cm

solar radio flux index for a month - one variable component (F_v) directly proportional to the relative sunspot number and the other called basic component (F_b) independent of the relative sunspot number. Each of the two components of 10.7 cm. solar flux is calculated for each month for the period 1974 to 1985 using the equation 3.2.1.1. and 3.2.1.2.

$$\text{Basic component of 10.7 cm. radio flux } (F_b) = \frac{(\Sigma xy)(\Sigma x) - (\Sigma x^2)(\Sigma y)}{(\Sigma x)^2 - N(\Sigma x^2)}$$

$$\text{Variable component of 10.7 cm. radio flux } (F_v) = \frac{\Sigma y}{N} - F_b$$

Where "x" is the daily value of relative sunspot number, "y" is the daily value of solar radio flux, "N" is the number of days for which the values of relative sunspot number and values of 10.7 cm. solar radio flux data are available in a month.

Correlation coefficients between each of two components of the solar radio flux and ozone concentration have been calculated by using the equation 2.2.1.1.

5.2.2. Correlation between each of two components of 10.7 cm. solar radio flux and O_3 concentration of Antarctica Survey station McMurdo.

The monthly mean values (variable and basic component) of 10.7 cm. solar radio flux are computed by using the equation 3.2.1.1 and 3.2.1.2 to find the correlation coeffiecient between each of two components of solar radio flux and ozone concentration for the different seasons during the period 1974 to 1985. The calculated correlation coefficients are given in Table 5.3.1.

From the correlation Table 5.3.1 it is clear that the correlation coefficients between each of two components of 10.7 cm. solar radio flux and ozone concentration are mainly controlled by their late winter to spring values.

Correlation coefficient are calculated between monthly mean values of O_3 concentration and yearly mean values of O_3 concentration for the seasons of winter (May, June, July, August), late winter (August), spring (September, October), summer (November, December, January) and autumn (February, March, April). It is found from the correlation table - 2 that the correlation coefficient becomes maximum (0.88) during spring. Again the

correlation coefficients between monthly mean value and the yearly mean value of the variable component of the solar radio flux is found to be maximu (0.96) during late winter and spring. Also the correlation between monthly mean value of O_3 concentration and monthly mean value of variable component of solar radio flux is maximum (0.39) during late winter. The correlation coefficients between monthly mean values of O_3 concentration and yearly mean variable component of solar radio flux is high (0.40) during late winter and (0.44) during winter. Other correlation coefficients are also maximum during the late winter and spring. Only the correlation coefficient between the monthly mean O_3 concentration and monthly mean basic component shows (0.47) in autumn; as the variable component is the representative of solar activity, so we are to consider the covariation of ozone concentration with variable component of solar U.V. flux in order to find the effects of solar activity on ozone concentration. Most of the correlation coefficients between O_3 concentration and components of 10.7 cm. solar radio flux during late winter to spring are significant at 5% level. Thus it may be concluded that O_3 concentration and variable component of 10.7 cm. solar radio flux are mainly controlled by their late winter to spring values. Variations of Antarctic O_3 concentration at McMurdo and variable and basic component of 10.7cm. solar flux with year for the months of July, August, October, November of every year during the period 1974 to 1985 are shown in Fig. 5.3.1.

5.2.3. Effects of Pollutants on atmospheric O_3 concentration

The effects of man made pollutants on atmospheric ozone concentration are scrutinised from the available published data.

In the polar region the height of stratosphere starts from the altitude 8 km from the surface of the earth and stratospheric ozone occurs maximum at an altitude between 15 km. to 20 km. The polar night starts in Antarctica from the month of May and continues up to August which is the winter season here. The temperature of stratosphere drops to –80° C during winter. The man made non reacting chemicals (aerosols or pollutants) can stay in the high atmosphere for 100 years. At the very low temperature during the polar winters these pollutants form " polar stratospheric cloud" (PSC). Another special atmospheric condition termed as "Polar vortex" which do not allow the warmer mid latitude air to mix with the air above the pole, in this crucial condition the pollutants moves upward in the stratosphere and the sunlight appears in the Antarctica in late August- early September then by the interaction

of U.V. radiation the pollutants produce active chlorine compounds (CL and CLO) which have the potential to destroy ozone molecules.

According to Masters (1991) the stratospheric ozone can be destroyed by catalytic reactions involving nitrogen, chlorine, bromine or hydrogen oxides by the following reaction -

$$X + O_3 \rightarrow XO + O_2$$
$$XO + O \rightarrow X + O_2$$
$$\overline{O + O_3 \rightarrow O_2 + O_2}$$

Where "X" may be Cl, Br, OH or NO

Ferman et.al. (1985) proposed the following reaction

$$ClO + NO \rightarrow Cl + NO_2$$
$$Cl + O_3 \rightarrow ClO + O_2$$

Soloman et.al. (1986) suggested.

$$OH + O_3 \rightarrow HO_2 + O_2$$
$$Cl + O_3 \rightarrow ClO + O_2$$
$$HO_2 + ClO \rightarrow HOCl + O_2$$
$$HOCl + hv \rightarrow OH + Cl$$
$$\overline{2O_3 \rightarrow 3O_2}$$

According to WMO (1994), the largest ozone loss in Antarctica during 1992 - 1993, with drop to less than 100 D.U. is due to the volcanic eruption of mountain pina tubo. The sulfate acrosols of Mt. Pinatubo acted in addition with the bromine and chlorine which may further deplete atmospheric ozone.

Further during southern winter the strong polar vortex does not allow ozone rich air from the lower latitudes to enter in the region, which may also be a reason of low ozone.

However the chloroflurocarbons(CFCs) are the industrial compounds used in refrigeration, air-conditioning etc., which are one of the chief agent of atmospheric ozone destruction. CFCs remained undistubed and inert in the lower atmosphere for decades and do rise several kilometers up to stratosphere, at altitude of 25km. to 30 km. they release chlorine atoms in the presence of solar U.V. radiation. These chlorine atoms react with ozone and form "ClO" and "O_2". The "ClO" becomes part of a chain reaction. As a result of this chain

reaction, a single chlorine atom can destroy 100000 molecules of ozone (Rowland and Molina, 1974).

The nitrogen oxides are the other important agent of stratospheric ozone destruction. The sources are the supersonic aircraft emission in the stratosphere, uses of nitrogenous fertilizers for agricultural work etc. These oxides of nitrogen can destroy stratospheric ozone (Crutzen, 1970, Johnston, 1971).

Another ozone destructing agent is water vapor, which occurs naturally in the stratosphere. In presence of solar U.V. rays, water molecules are split apart gives a collection of hydrogen atoms (H), hydroxyl radicals (HO) and hydroperoxyl redicals (HOO) and collectively they are known as HO_x. This can destroy ozone (John R. Holum : Wiley - Interscience Publication, USA).

5.2.4 Conclusions

The solar radio flux of 10.7 cm. Wavelength (frequency = 2800 MHz) is transparent to the earth atmosphere and reaches the ground. Its daily values is measured from 1947 at Ottawa and Algonquin Radio Observatory of the National Research Council of Canada. The values of 10.7 cm. solar radio flux adjusted to 1 AU eliminating variations due to the eccentricity of the earth's orbit around the sun are used as an index of solar radiation. Though it is not chemically responsible for ozone destruction or ozone formation, it is well correlated with the value of solar U.V. flux. The correlation coefficient between the solar radio flux and solar U.V. flux is calculated and it is very high (95%). As the solar U.V. data are available for a very short period i.e., November 1978 to October 1984 (NIMBUS 7 Satelite, published in solar Geophysical Data book, NOAA, U.S.A.,) the solar radio flux data have been used in place of solar U.V. data.

It is seen from the correlation Table 5.3.1 the value of correlation coefficients between monthly mean O_3 concentration and monthly mean variable components of solar radio flux are positive being maximum for late winter. Also the correlation coefficients between - monthly mean O_3 concentration and yearly mean variable component or yearly mean basic component of solar radio flux are positive being maximum for Antarctic late winter. Even the correlation coefficient between monthly mean ozone concentration and yearly mean ozone concentration is positive and maximum for Antarctica spring. Thus with increase of solar radio flux value, 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 were falling during successive years from 1957 to 1984 and Hofmann. et.al. (1994) found that stratospheric O_3 depletion is quite noticeable particularly in the late winter and early spring. Variable and basic components of solar radiation, which are associated respectively with solar activity and steady background, if responsible for this declining trend of ozone concentration at McMurdo during late winter to spring, then the correlation coefficients between components of solar flux and O_3 concentration should have been high negative during late winter to spring at McMurdo. But results show on the contrary that most of the correlation coefficients between O_3 concentration and components of solar radiation are high positive and significant at 5% level, during late winter to spring at McMurdo.

Thus It may be concluded that the 10.7 cm. Solar radio flux data which has been used in lieu of solar U.V. data are not responsible for O_3 depletion at McMurdo in Antarctica. Midya. et.al (1996) also found that dramatic decrease of ozone concentration in Antarctica is independent of solar U.V. radiation and correlation coefficients are mainly controlled by their spring values. Therefore, the ozone depletion in Antarctica mainly may be due to the man made pollutants as found by Rowland & Molina (1974), Crutzen (1970), Johnston (1971), WMO (1994), Solomon etal. (1996). Realising the dreaded consequences of atmospheric ozone depletion the Governments, NGO, Scientists, Engineers and the common people of the developed and developing countries should take proper measures to get rid of this global problem.

To control ozone depletion; restriction should be imposed strictly on the use of pollutants mainly chloroflurocarbons and oxides of nitrogen and ultimately the production of these pollutants should be stopped step by step and new substitutes need be invented, which will be economic and environment friendly, i,e. it will not deplete ozone or it will not pollute environment. It will be advantageous if they have properties to destroy the pollutants which are already in atmosphere.

Table - 5.3.1

Correlation coefficients between various parameters for different seasons

McMurdo (78°S, 166°E)

Correlation coefficient between	Winter May, June, July, Aug.	Spring Sept., Oct.	Summer Nov., Dec., Jan.	Autumn Feb., Mar., April
1. Monthly mean O_3 & monthly mean F_v (1974 - 1985)	0.37 (0.39)	0.11	0.08	-0.02
2. Monthly mean O_3 & monthly mean F_b (1974 - 1985)	0.13 (0.26)	0.21	0.04	0.47
3. Monthly mean O_3 & Yearly mean F_v (1974 - 1985)	0.44 (0.40)	0.02	-0.01	0.10
4. Monthly mean O_3 & Yearly mean F_b (1974 - 1985)	0.41 (0.38)	0.06	0.03	0.16
5. Monthly mean O_3 & Yearly mean O_3 (1974 - 1985)	0.64 (0.62)	0.88	0.68	0.08
6. Monthly mean F_v & Yearly mean F_v (1974 - 1985)	0.87 (0.96)	0.96	0.90	0.84
7. Monthly mean F_b & Yearly mean F_b (1974 - 1985)	0.58 (0.82)	0.92	0.80	0.20

Within ( ) shows the late winter values.

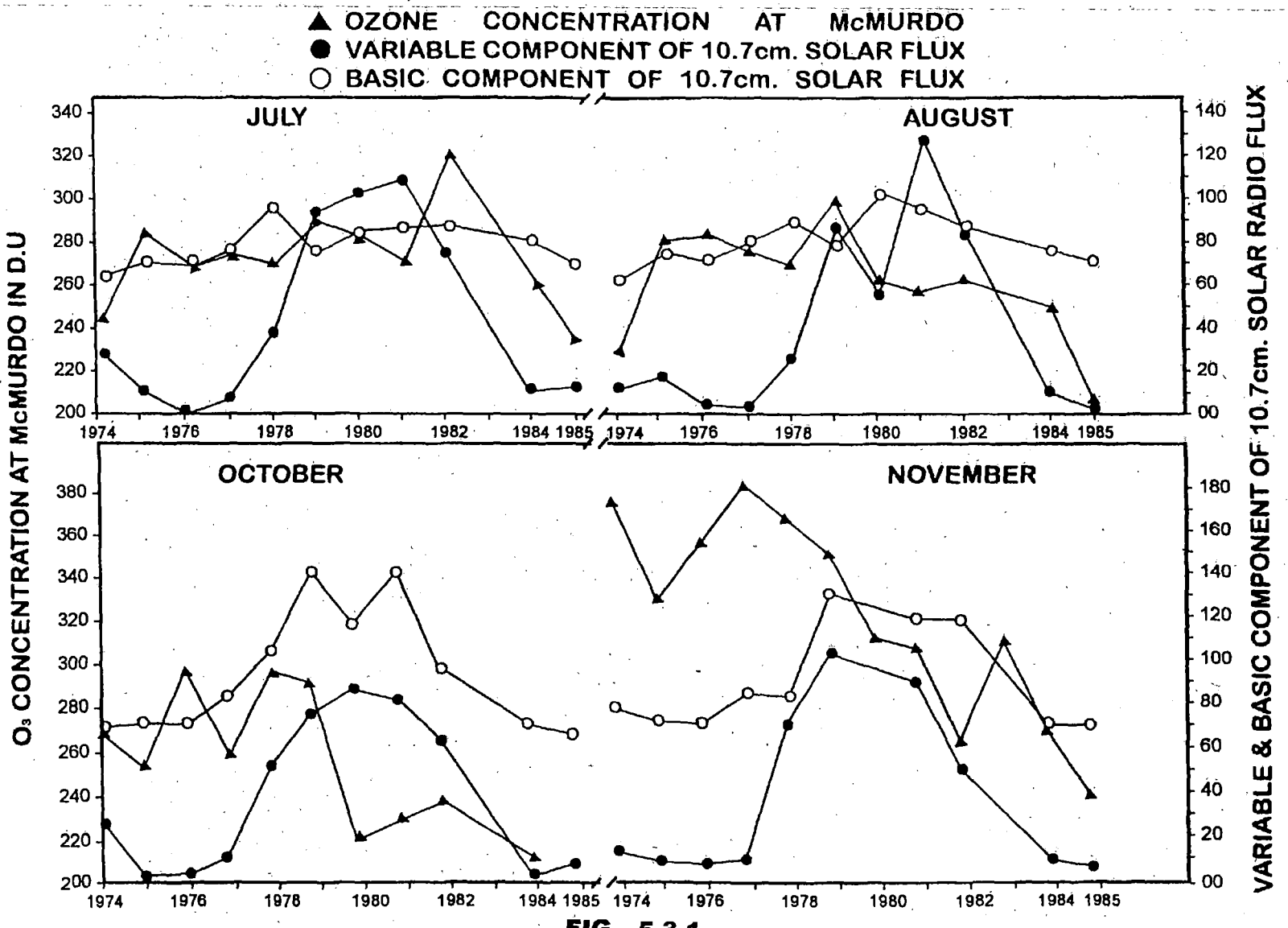
▲ OZONE CONCENTRATION AT McMURDO
● VARIABLE COMPONENT OF 10.7cm. SOLAR FLUX
○ BASIC COMPONENT OF 10.7cm. SOLAR FLUX
JULY
AUGUST
OCTOBER
NOVEMBER
O₃ CONCENTRATION AT McMURDO IN D.U
VARIABLE & BASIC COMPONENT OF 10.7cm. SOLAR RADIO FLUX
1974 1976 1978 1980 1982 1984 1985

FIG - 5.3.1

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