CHAPTER - 8

Tropical O_3 deficit at DumDum (India), its correlation with Solar U.V. radiation and possible effects on Biosphere

8.1 Introduction

It is observed from the World Ozone data of the WOUDC, TOMS & EPTOMS for different latitudes that the atmospheric (mainly stratospheric) Ozone concentration is maximum in Arctic geographycal belt, medium value of Ozone concentration found in the Antarctic region and low value of Ozone concentration found in equatorial/tropical geographycal belt. Though Ozone is formed in the stratosphere mainly over the equator/tropics and after formation it is carried to higher latitudes by the stratospheric wind. Further the water vapour content is high in the stratosphere over the equator/tropics, which have the potential to destroy Ozone. In addition if loss due to pollutants takes place then the situation will be most deadly for this regions. Already the Ozone layer thickness is significantly small over the equatorial/tropical region for which the solar UV penetration is maximum throughout the year. The effect of this high dosage of UV radiation on the environment of this region need to be studied with greater importance and the scientists and govt. organisation of this region should be largely involved in this process. In fact this high dosage of UV radiation (mainly UV-B, wave length range 280nm to 320 nm.) may influence human health such as cataracts, viral infections, damage of natural immune system, skin cancer and many other diverse biological, environmental and climatic condition.

It is already established that the Ozonosphere acts as an atmospheric filter screen which protects life on earth against harmful UV radiation (mainly 280-320 nm wave length) from the sun. Atmospheric Ozone resides in three regions of atmosphere - troposphere (little less than 10% of its total amount), stratosphere (little less than 90% of its total amount), mesosphere (very little) and plays an important role on earth's environment to maintain the ecological balance. The Ozone is continuously being produced and destroyed in the atmosphere by the action of solar U.V. radiation, it is also destroyed by pollutants. Paul Crutzen (1970) shown that nitrogen oxides are responsible for this destruction. Harold Johnston (1971) reported that supersonic aircraft which emits nitrogen oxides seriously affect ozone layer. F. Sherwood Rowland and Mario J. Molina (1974) proposed that chlorofluorocarbons (CFCs) which are industrial compounds, used as refrigerants, solvents, propellants for spray cans, can destroy ozone; later it has been established by many investigators.

Global Ozone assessment confirmed that O_3 is declining everywhere throughout the world (WMO Bull - 1992). Decrease in stratospheric O_3 concentration allows enhanced solar UV radiation to the earth. The wavelength range 200 nm - 280 nm. known as the UV-C is lethal to man and living organism and is totaly absorbed by atmospheric ozone. Between 280 - 320 nm., called UV -B, which ozone absorbs partially, is harmful to the terrestrial biotic and abiotic environment. The ultraviolet radiation with wavelength more than 320 nm. falling in the UV - A region, is relatively harmless and ozone layer absorbs it little. The environmental scientists and Engineers are mainly concerned with UV - B radiation which is very much harmful; it affects algae, plankton, fish, larvae, human and climate : [Calkin (1976); Smith and Baker (1989); Cullen and Neale (1994), Evans.et.al (1988), Elwood .et. al(1990); IARC (1992); Cotton (1990).]

Dahlback and Moan (1990) investigated the importance of using geometric representations of the human body in calculation of UV radiation received by the Skin surface. Setlow (1974) worked with a generalised DNA damage spectrum (produce skin cancer). Robertson (1975) investigated the erythemal response of Caucasian Skin (abnormal redness of the skin).

The change of O_3 concentration can affect climatic condition of the earth's environment. Decrease in O_3 concentration means more solar radiation reaches to the earth surface resulting in global warming. Increase in tropospheric O_3 concentration will result in an increased green house trapping of long wavelength radiation, [Robert M. Mackay. et. al. (1997).]

Many investigators have worked on Ozone loss in polar regions (both south and north pole), but so far less work has been reported on equatorial ozone loss where the production of ozone from splitting of oxygen molecules by the Solar UV radiation occurs, and the stratospheric winds carry ozone over the entire earth to produce the ozone layer. Ozone depletion in Antarctica (south pole) has been reported by Farman et. al. (1985), Stolarski et. al (1991), Logan (1994), Ghosh and Midya (1994), Midya et. al. (1997). Ozone loss in Arctic region (north pole) has been reported by - Schoeberl et. al. (1990). Zurek et. al.(1996), Dessler et. al. (1998) and others.

In this chapter the Ozone data of Dum Dum (22.38° N, 88.28°E), Calcutta in India are botained from NIMBUS - 7 TOMS by Website http://jwocky.gsfc.nasa.gov and studied ozone concentration variation for the period Nov'88 to Oct'98 and found that the minimum ozone concentration in the month of Jan'80 was 229.30 D.U. and in Dec'78 it was 240.90 D.U. In Dec'96 it was found to be 217.40 D.U. and it shows that Ozone concentration is declining at Dum Dum (but not like polar regions). From the existing research work it is already known that solar UV radiation is responsible for atmospheric Ozone creation as well as Ozone destruction, some evidence suggests it is also destroyed by man made pollutants. In this part of the work to investigate the cause of Tropical (at Dum Dum) Ozone loss an attempt has been made to study whether the creator is the killer, i.e. whether the solar U.V. radiation itself is responsible for this atmospheric O_3 depletion.

For analysis the daily solar UV data are obtained from Nimbus 7 satellite data, published in Solar Geophysical Data Book, NASA, USA also available in NOAA internet Website fpt://ftp.ngdc.noaa.gov/STP/SOLAR_DATA

The ozone data and the U.V data are tabulated in Chapter 1 page 28 & 32 to 40.

8.2 Analysis, Discussion and Conclusions

8.2.1 Analysis

i) The daily average values of ozone concentration for the station Dum Dum (22.38°N, 88.28°E) in India are considered for the period Nov. 78 to Nov'98 and from the daily average values, the monthly average values are calculated to study the ozone concentration variation.

ii) The correlation coefficients are calculated season wise between monthly O_3 concentration and monthly gross value of U.V. flux (Table 8.3.1.)

iii) The correlation coefficients are calculated season wise between monthly mean O_3 concentration and analytically extra polated UV flux (obtained from table 7.3.1. of Chapter 7) and are shown in table 8.3.2.

iv) A linear regression relation between the daily value of the solar UV flux and daily relative sunspot number on least square principle shows two components of solar UV flux for a month - one is variable component (UV_v) directly proportional to the relative sunspot number and the other called basic component (UV_b) independent of the relative sunspot number. Each of the two components of the solar UV flux is calculated for every month for the period 1979 to 1984 using the equations - 3.2.1.1 & 3.2.1.2.

$$\text{Basic component of UV flux } (UV_b) = \frac{(\Sigma xy)(\Sigma x) - (\Sigma x^2)(\Sigma x)}{(\Sigma x)^2 - N(\Sigma x^2)}$$

$$\text{Variable component of UV flux } (UV_v) = \frac{\Sigma y}{N} - UV_b$$

where "x" is the daily value of relative sunspot number, "y" is the daily value of solar U.V. flux, "N" is the number of days for which the values of relative sunspot number and values of solar U.V. flux which are available in a month.

Correlations between each of the two components of solar U.V. flux and Ozone concentration have been calculated season wise (Table - 8.3.1) by using the eqn. 2.2.1.1.

8.2.2 Nature of variation of O_3 concentration at Dum Dum in India during 1979 to 1998

In 1979, the yearly average O_3 concentration was 275.71 D.U. which decreases to 260.92 D.U. in 1985; the percentage decrease is 5.36. From 1986 to 1991 it increases, the percentage increase is about 4.25; again a decreasing trend is found 1991 to 1996, the percentage decrease being 3.75, and the net percentage decrease in O_3 concentration at Dum Dum during the period 1979 to 1996 is found to be 5.04. Whereas recent ozone observations in the polar regions reveal the following. In Arctica a 3-5% decrease in lower stratospheric ozone which means 10 - 15% decrease in column ozone (Froidevaux et.al., 1994), in Antarctica a 100% decrease over a large region of the lower stratosphere and about 60 - 70% decrease in column ozone (Hofmann et.al., 1994).

Though in comparison with polar region the loss of ozone concentration at Dum Dum is much less, it is true that O_3 concentration at Dum Dum is also declining. It is also found that O_3 concentration is minimum in late autumn - early winter at Dum Dum during 1979 to 1998. The variation of O_3 concentration at Dum Dum with various solar parameters are shown in fig. 8.3.1. Variation of O_3 concentration with years at Dum Dum during 1979 to 1998 are shown in fig. 8.3.3 and variation of O_3 concentration with months at Dum Dum during 1978 to 1996 are shown in fig 8.3.4.

8.2.3. Correlation of Ozone Concentration at Indian Tropical Station DumDum from Nov'78 to Oct'84 with various solar parameters.

From the correlation table (8.3.1) the correlation coefficient between monthly mean O_3 concentration and yearly mean O_3 concentration is found to be maximum positive value (0.58) and significant at 5% level during summer.

The correlation coefficient between monthly mean value of O_3 concentration and monthly mean value of basic component of solar UV flux is highly positive (0.84) and significant at 5% level during late antumn to early winter.

Correlation coefficient between monthly mean value of gross UV flux and yearly mean value of gross UV flux is also highly positive (0.97) and significant at 5% level during late autumn to early winter.

The correlation coefficients between monthly mean value of O_3 concentration and monthly mean value of gross UV flux is highly positive (0.54) and significant at 5% level during Autumn but insignificant during late autumn to early winter.

Correlation coefficient between monthly mean value of O_3 concentration and monthly mean value of variable component of Solar UV flux is positive (0.19) but insignificant during late autumn to early winter. Other correlation coefficients are highly positive and significant at 5% level during late autumn to early winter, except the correlation coefficient between monthly mean value of O_3 concentration and yearly mean value of O_3 concentration.

From the correlation table it is seen that the correlation coefficient between the monthly mean values of Ozone concentration and variable component of Solar UV flux is found to have the largest magnitude with the negative sign during winter; during summer, autumn and late autumn - early winter its values, though positive, are not so significant. The correlation coefficient between monthly mean values of O_3 concentration and basic component of solar UV radiation is found to be maximum (0.84) during late autumn - early winter period.

It is thus seen that the covariation of O_3 concentration at the Indian tropical station Dum Dum with basic component of solar UV flux is highly controlled by their late autumn - early winter values as is the case with the values of the basic solar UV flux itself. On the other hand, the covariation of the O_3 concentration with variable component of the solar UV flux appears to be most adversely affected by their winter values. From the correlation table, the gross monthly mean values of the solar UV radiation is found to agree with its basic component as regards to its own variation and covariation with the O_3 concentration.

8.2.4. Correlation of Ozone concentration at Indian Tropical Station Dum Dum during 1987 to 1997 with analytically extrapolated solar UV flux (obtained from Table 7.3.1 Chapter 7)

From the correlation table (8.3.2) the correlation coefficient between monthly mean O_3 concentration and monthly mean solar UV flux is found to be maximum positive value (0.60) and definitely significant at 5% level during late autumn to winter.

The correlation coefficient between monthly mean value of O_3 concentration and yearly mean value of solar UV flux also found to be maximum positive value (0.53) and definitely significant at 5% level, during late autumn to winter.

Further the correlation coefficient between monthly mean value of Solar UV flux and yearly mean value of solar UV flux also have very high positive value (0.90) and definitely significant at 5% level, during late autumn to winter.

Moreover all of the correlation coeffieicnts during winter are positive and significant at 5% level.

It is thus found that the correlation coefficients of O_3 concentration at the Indian tropical station Dum Dum with analytically extrapolated UV data are highly controlled by their late autumn- early winter values during the period 1987 to 1998.

The O_3 covariation at Dum Dum with analytically extrapolated UV flux in late autumn - early winter are shown in fig. 8.3.2.

8.2.5 Conclusions

A possible explanation of the nature of covariation of the O_3 concentration at the Indian tropical Station Dum Dum with the solar UV radiation and its variable and basic components from Nov'78 to Oct'84 can be provided by noting the fact that stratospheric ozone is produced by the action of solar ultraviolet rays on the monatomic (O) and diatomic (O_2) oxygen in the equatorial region according to the following reactions.

O_2 + UV light $\Rightarrow$ O + O

O + O_2 + M $\Rightarrow$ O_3 + M

$(O_3)^*$ + O $\Rightarrow$ O_2 + O + O

O + O_2 + M $\Rightarrow$ O_3 + M

where $(O_3)^*$ denotes excited state of O_3 and M represents a third body required for conservation of energy and momentum.

Ozone is also destroyed by Solar UV radiation according to the following reactions.

O_3 + UV light $\Rightarrow$ O + O_2

O + O_3 $\Rightarrow$ $2O_2$

O_3 + O_3 $\Rightarrow$ $3O_2$

The resultant concentration of ozone depends, at any time, on the rate of production and the rate of loss or destruction. The stratospheric ozone thus produced in the equatorial region is carried by winds towards north and south poles. After late autumn and during winter in the northern hemisphere, the solar radiation falls almost at right angles on the regions between the euquator and the tropic of capricorn and obliquely on the regions between the equator and the tropic of cancer, such as Dum Dum. Hence, after the autumn and during winter, the net production of ozone by the solar UV rays is expected to be smaller than that during summer. Moreover, the transport of ozone towards the poles by stratospheric winds contributes to the loss of ozone at the regions near the tropics. This results in minimum ozone concentration during late autumn - winter period as seen from fig. 8.3.4. This may be the cause for the anticorrelation between the ozone concentration at Dum Dum and the variable component of solar UV radiation during winter.

If only solar UV radiation would have been responsible for this tropical O_3 deficit during late autumn to early winter period, then, the correlation coefficients should have been highly negative and significant during that period. But result shows that the correlation coefficients are highly positive and significant at 5% level during late autumn - early winter.

Further, if solar UV radiation were acting alone in the stratosphere, the net concentration of ozone due to the balance between production and destruction in Photochemical reactions, would vary seasonally without any loss with years, as observed in fig. 8.3.2. and 8.3.3. Besides the loss of ozone by solar U.V. rays and its transport by the winds from the equatorial to the polar regions as mentioned above, other chemical processes involving HOx, NOx, ClOx, BrOx etc. have been found to cause destruction of ozone in the stratosphere according to Crutzen (1970), Johnston (1971), Molina et. al. (1974), Farman et. al. (1985), McElroy et. al (1986), Hofmann et. al. (1991), Midya et. al. (1996), Dessler et. al (1998), WMO (1985), WMO (1988) and WMO (!991). Based on this consideration, it may be concluded that the gradual loss of ozone at the Indian tropical station Dum Dum from 1979 to 1996 may be due to the chemical processes mentioned above and solar UV radiation is not responsible for this deficit of ozone at Dum Dum.

To control ozone deficit or depletion; the production and use of the chloroflurocarbon, Nitrogenous Fertilizer, Methylbromide compounds (used as soil disinfectant) etc. should be stopped step by step and new substitutes should be invented, which will be economic and enviornment friendly, that will not deplete ozone or it will not pollute environment otherwise. Moreover it should have properties to destroy the molecules of pollutants which are already in atmosphere.

Table - 8.3.1

Correlation coefficient between various parameters for different seasons Dum Dum (22.38° N, 88.28° E)

Correlation coefficient between	Autumn (Oct., Nov.)	Winter (Dec., Jan., Feb.)	Summer (Mar., Apr., May.)	Rainy Season (June, July, Aug., Sep.)
1. Monthly mean O_3 & monthly mean value of gross U.V. flux (UV gr)	0.54 (0.12)	0.04	0.14	0.18
2. Monthly mean O_3 & monthly mean value of variable component of U.V. flux (UV_v)	- 0.02 (0.19)	- 0.51	0.17	0.12
3. Monthly mean O_3 & monthly mean value of basic component of U.V. flux (UV_b)	0.63 (0.84)	0.49	0.06	0.22
4. Monthly mean value of gross U.V. & yearly mean value of gross U.V.	0.99 (0.97)	0.93	0.94	0.93
5. Monthly mean value of UV_v & yearly mean value of UV_v	0.63 (0.97)	0.74	0.43	0.63
6. Monthly mean value of UV_b & yearly mean value of UV_b	0.91 (0.99)	0.45	0.78	0.13
7. Monthly mean O_3 & yearly mean O_3	0.34 (-0.16)	0.25	0.58	0.40

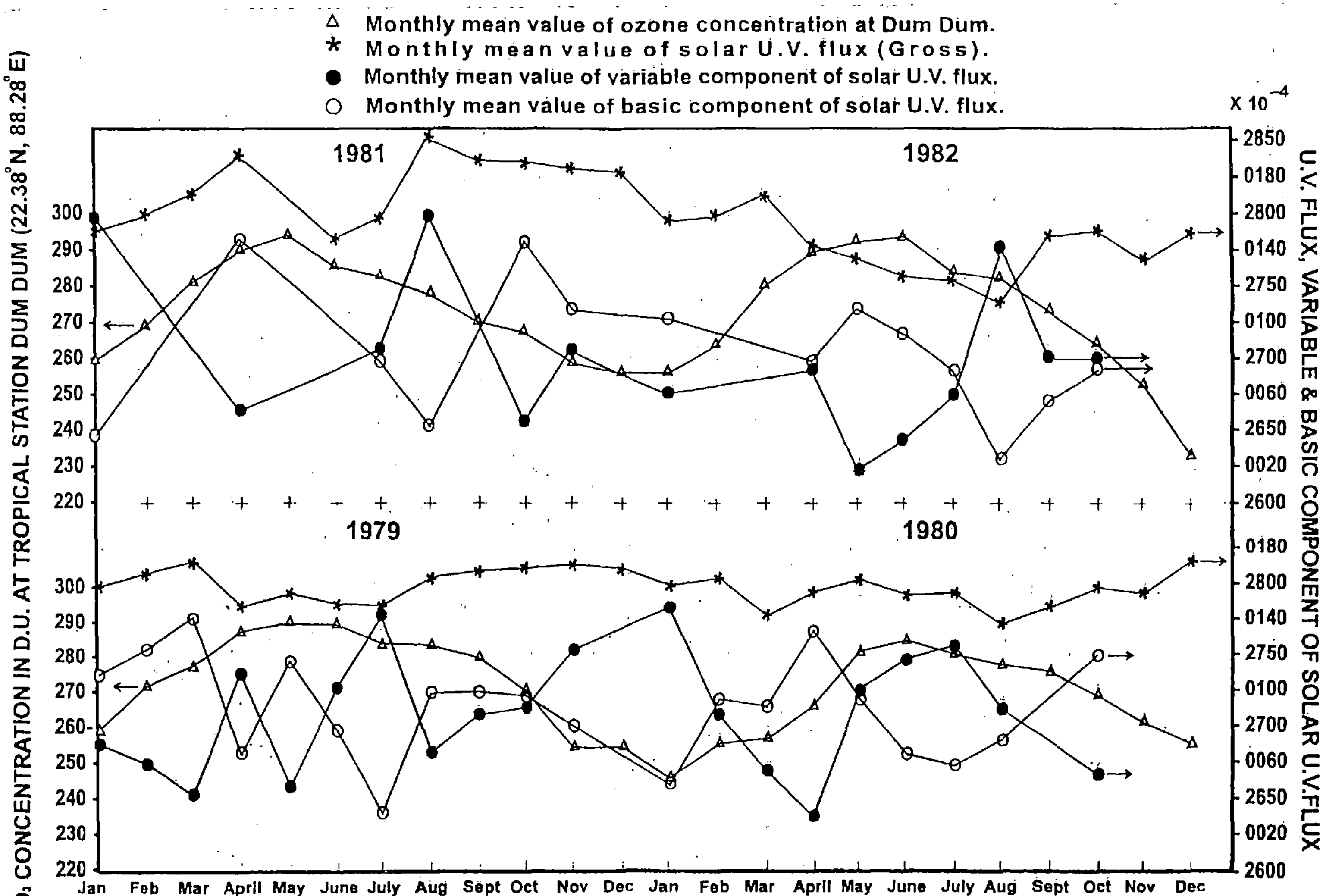
Values within ( ) shows the late autumn to early winter correlation coefficients.

Table - 8.3.2

Correlation coefficient between O_3 concentration at Dum Dum and derived U.V. flux
(obtained from Table - 7.3.1 of Chapter - 7)
Dum Dum (22.38° N, 88.28° E)

Correlation coefficient between	Autumn (Oct., Nov.)	Winter (Dec., Jan., Feb.)	Summer (Mar., Apr., May.)	Rainy Season (June, July, Aug., Sep.)
1. Monthly mean O_3 & monthly mean value of U.V. flux	0.36 (0.60)	0.40	0.07	0.47
2. Monthly mean O_3 & yearly mean value of U.V. flux	0.27 (0.53)	0.37	0.17	0.46
3. Monthly mean O_3 & yearly mean value of O_3	0.23 (0.34)	0.44	0.46	0.59
4. Monthly mean value of U.V. & yearly mean value of U.V.	0.95 (0.90)	0.88	0.85	0.93

Values within ( ) shows the late autumn to early winter correlation coefficients.



△ Monthly mean value of ozone concentration at Dum Dum.
* Monthly mean value of solar U.V. flux (Gross).
● Monthly mean value of variable component of solar U.V. flux.
○ Monthly mean value of basic component of solar U.V. flux.
X 10⁻⁴
1981
1982
1979
1980
O₃ CONCENTRATION IN D.U. AT TROPICAL STATION DUM DUM (22.38°N, 88.28°E)
U.V. FLUX, VARIABLE & BASIC COMPONENT OF SOLAR U.V.FLUX
300
290
280
270
260
250
240
230
220
2850
0180
2800
0140
2750
0100
2700
0060
2650
0020
2600
Jan Feb Mar April May June July Aug Sept Oct Nov Dec Jan Feb Mar April May June July Aug Sept Oct Nov Dec

FIG - 8.3.1

O_3 COVARIATION AT DUMDUM WITH U.V. FLUX IN LATE AUTUMN EARLY WINTER DURING 1987 TO 1997

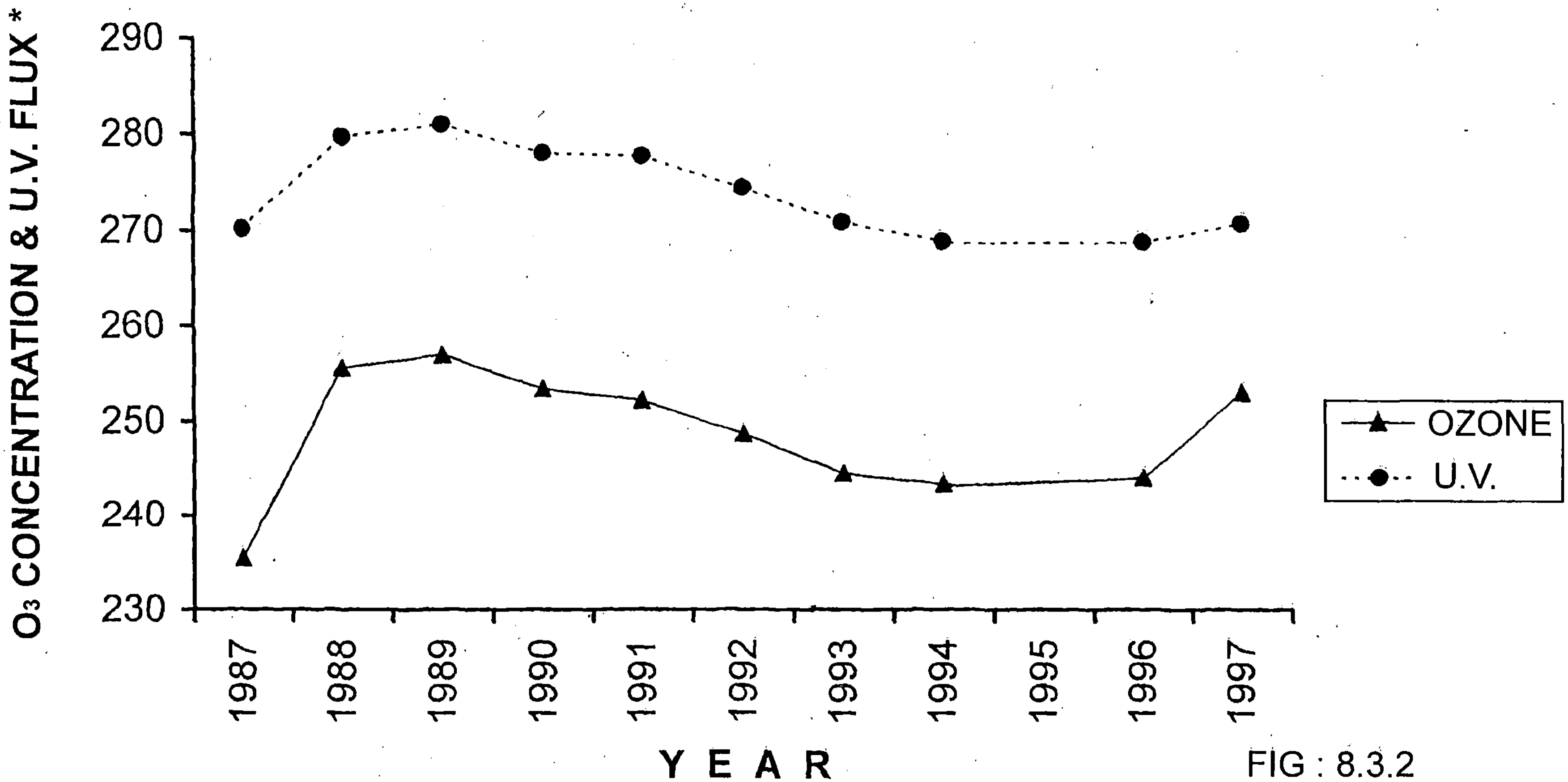


FIG : 8.3.2

* (Range of values for U.V. flux = 268.8 X 10^{-3} to 281 X 10^{-3})

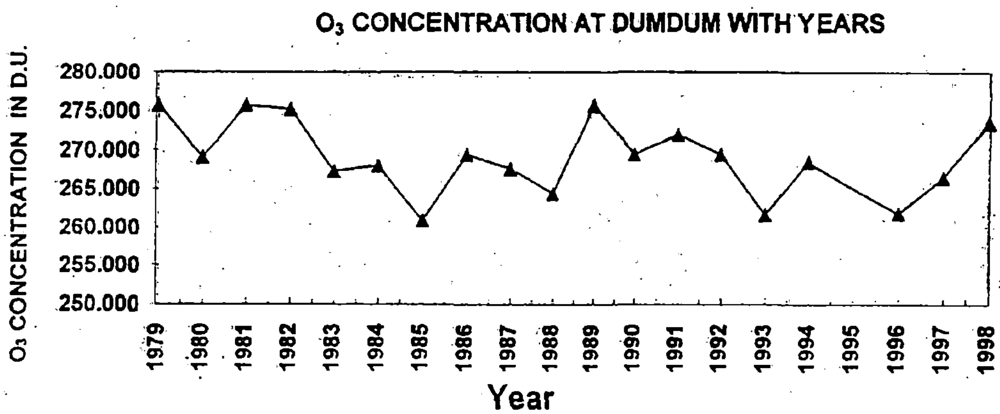


FIG - 8.3.3

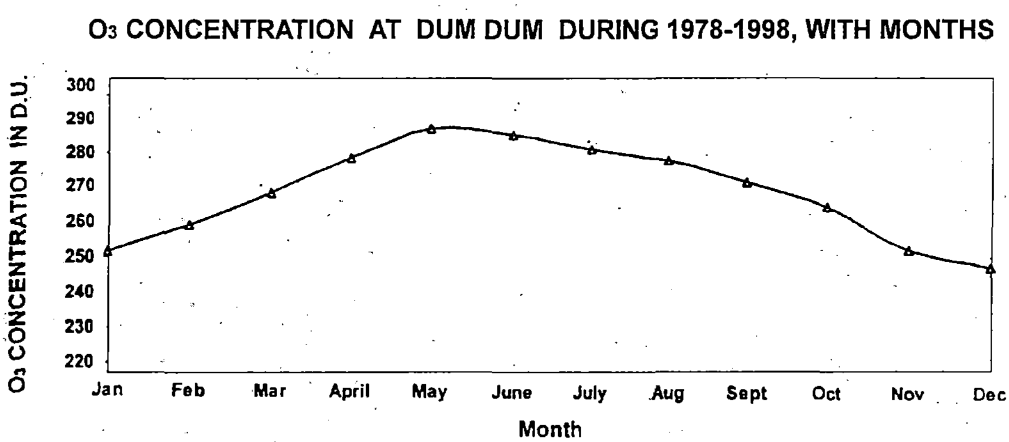


FIG - 8.3.4

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BIMONTHLY TECHNICAL JOURNAL OF AMERICAN SOCIETY OF CIVIL ENGINEERS—INDIA SECTION (ASCE-IS)

Vol. XIII | No. 6 | November-December 1999

Tropical O_3 deficit at Dum Dum (India), its correlation with Solar U.V. Radiation and possible effects on Biosphere

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ABSTRACT

It is well accepted that O_3 concentration is declining not only in polar regions but also throughout the world, which may cause severe environmental hazards, such as : D. N. A. damage, erythemal response, plant damage, algae, plankton and fish larvae damage. It can also affect the climatic condition of the biosphere. In this paper, we have tried to estimate the effect of solar U. V. radiation on O_3 concentration at Dum Dum (22.38°N, 88.28°E) in India. Season wise correlations are calculated; Graphs are plotted and the following interesting results are obtained.

Ozone concentration is found to be minimum for late autumn to early winter. The correlation coefficients between O_3 concentration and solar U. V. flux during late autumn to winter are quite significant. It is concluded that O_3 deficit at Dum Dum in India is independent of solar U.V. radiation and it may be due to some man made pollutants.

1. Introduction

The Ozonosphere acts as an atmospheric filter screen which protects life on earth against harmful U. V. radiation (mainly 280 nm. - 320 nm. wave length) from the sun. Atmospheric ozone resides in three regions of atmosphere - troposphere (roughly 10% of its total amount), stratosphere (roughly 90% of its total amount), mesosphere (very little) and plays an important role on earth's environment to maintain the ecological balance. The ozone is continuously being produced and destroyed in the atmosphere by the action of solar U. V. radiation on oxygen; it is also being destroyed by pollutants. Paul Crutzen (1970) established that nitrogen oxides are responsible for this destruction. Harold Johnston (1971) reported that supersonic aircraft which emits nitrogen oxides seriously affect ozone layer. F. Sherwood Rowland and Mario J. Molina (1974) proposed that chlorofluorocarbons (CFCs) which are industrial compounds, used as refrigerants, solvents, propellants for spray cans, can destroy ozone; later it has been established by many investigators.

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The change of O_3 concentration can affect climatic condition of the earth's environment. Decrease in O_3 concentration means more solar radiation reaches to the

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earth surface resulting in global warming. Increase in tropospheric O_3 concentration will result in an increased green house trapping of long wavelength radiation, Robert M. Mackay, et. al. (1997).

Many investigators have worked on ozone loss in polar regions (both south and north pole), but so far less work has been reported on equatorial ozone loss where the production of ozone from splitting of oxygen molecules by the solar U. V. radiation occurs, and the stratospheric winds carry ozone over the entire earth to produce the ozone layer. Ozone depletion in Antarctica (south pole) has been reported by - Farman et. al. (1985), Stolarski et. al. (1991), Logan (1994), Ghosh and Midya (1994), Midya et. al. (1997). Ozone loss in Arctic region (north pole) has been reported by - Schoeberl et. al. (1990). Zurek et. al. (1996), Manney et. all. (1996), Dessler et. al. (1998) and others.

In this paper we consider the ozone data of Dum Dum (22.38°N, 88.28°E), Calcutta in India (obtained from NIMBUS 7 TOMS by website *http://jwocky.gsfc.nasa.gov.* and studied ozone concentration variation for the period Nov '78 to Oct '98 and found that the minimum ozone concentration in the month of Jan '80 was 229.30 D.U. and in Dec '78 it was 240.90 D. U. In Dec. '96 it was found to be 217.40 D. U. So it is clear that ozone concentration is declining at Dum Dum (but not like polar regions). The correlation coefficients of O_3 concentration have been computed with solar U. V. flux, and its variable and basic components. The daily solar U. V. flux values are obtained from NIMBUS 7 Satellite data, published in Solar Geophysical Data book, NOAA, U.S.A. for the period Nov'78 to Oct '84.

2. Analysis, Discussion and Conclusions

2.1 *Analysis*

(i) The daily average values of ozone concentration for the station Dum Dum (22.38°N, 88.28°E) in India are considered for the period Nov '78 to Nov '98 and from the daily average values, the monthly average values are calculated to study the ozone concentration variation.

(ii) The correlation coefficients are calculated season wise between monthly O_3 concentration and monthly gross value of U.V. flux (Table -1).

(iii) Further a linear regression relation between the daily value of the solar U.V. flux and daily relative sunspot number on least square principle shows two components of solar U.V. flux for a month - one is variable component (UV_v) directly proportional to the relative sunspot number and the other called basic component (UV_b) independent of the relative sunspot number. Each of the two components of the solar U.V. flux is calculated for every month for the period 1979 to 1984 using the equations -

Basic component of U. V. flux (UV_b)

$$= \frac{(\Sigma xy)(\Sigma x) - (\Sigma x^2)(\Sigma y)}{(\Sigma x)^2 - N(\Sigma x^2)} \quad \text{......................... (i)}$$

Variable component of U. V. flux (UV_v)

$$= \frac{\Sigma y}{N} - UV_b \quad \text{...(ii)}$$

where "x" is the daily value of relative sunspot number, "y" is the daily value of solar U. V. flux, "N" is the number of days for which the values of relative sunspot number and values of solar U. V. flux are available in a month.

Correlations between each of the two components of solar U.V. flux and ozone concentration have been claculated season wise (Table - 1).

2.2 *Nature of variation of O_3 concentration at Dum Dum in India during 1979 to 1998*

In 1979, the yearly average O_3 concentration was 275.71 D.U. which decreases to 260.92 D. U. in 1985; the percentage decrease is about 5.36. From 1986 to 1991 it increases, the percentage increase is about 4.25; again a decreasing trend is found from 1991 to 1996, the percentage decrease being 3.75, and the net percentage decrease in O_3 concentration at Dum Dum for the period 1979 to 1996 is found to be 5.04. From 1997 it has started increasing, whereas recent zone observations in the polar regions reveal the following. In Arctica a 30-50% decrease in lower stratospheric ozone which means 10-15% decrease in column ozone (Froidevaux et. al., 1994), in Antarctica a 100% decrease over a large region of the lower stratosphere and about 60-70% decrease in column ozone (Hofmann et. al., 1994).

Though in comparison with polar region the loss of ozone concentration at Dum Dum is much less, it is true that O_3 concentration at Dum Dum is also declining. It is also found that O_3 concentration is minimum in late autumn - early winter at Dum Dum during 1979 to 1998. The variation of O_3 concentration at Dum Dum with various solar parameters are shown in fig. 1. Variation of O_3 concentration with years at Dum Dum during 1979 to 1998 are shown in fig. 2 and variation of O_3 concentration with months at Dum Dum during 1978 to 1996 are shown in fig. 3.

2.3 *Correlation of Ozone Concentration at Indian Tropical Station Dum Dum from Nov '78 to Oct '84 with various solar parameters.*

From the correlation table, the correlation coefficient between monthly mean O_3 concentration and yearly mean O_3 concentration is found to be maximum (0.58) during summer, while the correlation coefficients between the monthly and yearly mean values of the variable and basic components of solar U. V. flux are both found to be maximum during late autumn and early winter. Thus, we may infer that the values of ozone concentration, variable and basic components of solar U. V. flux are controlled by their summer and late autumn - early winter values respectively.

From the correlation table, the correlation coefficient between the monthly mean values of ozone concentration and variable component of solar U.V. flux is found to have the largest magnitude with the negative sign during winter; during summer, autumn and late autumn - early winter its values, though positive, are not so significant. The correlation coefficient between monthly mean values of O_3 concentration and basic component of solar U. V. radiation is found to be maximum (0.84) during late autumn - early winter period.

It is thus seen that the covariation of O_3 concentration at the Indian tropical station Dum Dum with basic component of solar U. V. flux is highly controlled by their late autumn - early winter values as is the case with the values of the basic solar U. V. flux itself. On the other hand, the covariation of the O3 concentration with variable component of the solar U. V. flux appears to be most adversely affected by their winter values. From the correlation table, the gross monthly mean values of the solar U. V. radiation is found to agree with its basic component as regards its own variation and covariation with the O_3 concentration.

2.4 Conclusions

A possible explanation of the nature of covariation of the O_3 concentration at the Indian tropical station Dum Dum with the solar U. V. radiation and its variable and basic components, from Nov '78 to Oct '84 can be provided by noting the fact that stratospheric ozone is produced by the action of solar ultraviolet rays on the monatomic (O) and diatomic (O_2) oxygen in the equatorial region according to the following reactions.

$$O_2 + \text{U.V. light} \Rightarrow O + O \ (\lambda < 175 \text{ nm.})$$
$$O + O_2 + M \Rightarrow O_3 + M$$
$$(O_3)^* + O \Rightarrow O_2 + O + O$$
$$O + O_2 + M \Rightarrow O_3 + M$$

where $(O_3)^*$ denotes excited state of O_3 and M represents a third body required for conservation of energy and momentum.

Ozone is also destroyed by solar U. V. radiation according to the following reations.

$$O_2 + \text{U. V. light} \Rightarrow O + O_2$$
$$O + O_3 \Rightarrow 2O_2$$
$$O_3 + O_3 \Rightarrow 3O_2$$

The resultant concentration of ozone depends, at any time, on the rate of production and the rate of loss or destruction. The stratospheric ozone thus produced in the equatorial region is carried by winds towards north and south poles. After late autumn and during winter in the northern hemisphere, the solar radiation falls almost at right angles on the regions between the equator and the tropic of capricorn and obliquely on the regions between the equator and the tropic of cancer, such as Dum Dum. Hence, after late autumn and during winter, the net production of ozone by the solar U. V. rays is expected to be smaller than that during summer. Moreover, the transport of ozone towards the poles by stratospheric winds contributes to the loss of ozone at the regions near the tropics. This results in minimum ozone concentration during late autumn - winter period as seen from fig. 3. This may be the cause for the anticorrelation between the ozone concentration at Dum Dum and the variable component of solar U. V. radition during winter.

If solar U. V. radiation were acting alone in the stratosphere, the net concentration of ozone due to the balane between production and destruction in Photochemical reactions, would vary seasonally without any loss with years, as observed in Fig. 2. Besides the loss of ozone by solar U. V. rays and its transport by the winds from the equatorial to the polar regions as mentioned above, other chemical processes involving oxides of nitrogen, chlorofluorocarbon, etc. have been found to cause destruction of ozone in the stratosphere according to Crutzen (1970), Johnston (1971), Molina et. al. (1974), Farman et. al. (1985), McElroy et. al. (1986), Hofmann et. al. (1991), Midya et. al. (1996), Dessler et. al. (1998), WMO (1985), WMO (1988) and WMO (1991). Based on this consideration, it may be concluded that the loss of ozone at the Indian tropical station Dum Dum from 1979 to 1996 may be due to the chemical processes mentioned above and solar U. V. radiation is not responsible for this deficit of ozone at Dum Dum.

To control ozone deficit or depletion; the production of the above mentioned pollutants should be stopped step by step and new subsitutes should be invented, which will be economic and environment friendly, that means it will not deplete ozone or it will not pollute environment, otherwise. Moreover it should have properties to destroy the molecules of pollutants which are already in atmosphere.

Acknowledgement :

The authors express their profound gratitude to Dr. S. K. Midya of Serampore College, Hoogly, West Bengal, India for rendering help and encouragement for the preparation of the paper.

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Legend of Figures :

Fig. 1 Monthly variations of O_3 concentration at Dum Dum, solar U. V. flux, variable and basic components of solar U. V. flux for 1979, 1980, 1981and 1982.

Range of values for solar U. V. flux and its basic component : 2600×10^{-4} to 2850×10^{-4}.

Range of values for variable component of solar U.V. flux : 0000 x 10-4 to 0180×10^{-4}.

Range of values for O_3 concentration : 220 D. U. to 300 D. U.

Fig. 2 The variation of O_3 concentration at Dum Dum with years during 1979 to 1998.

Fig. 3 The variation of O_3 concentration at Dum Dum with months during Nov '79 to Oct '98.

Table : 1

Correlation coefficient between various parameters for different seasons.

Dum Dum (22.38°N, 88.28°E)

Correlation coefficient between	Autumn (Oct., Nov.)	Winter (Dec., Jan., Feb.)	Summer (Mar, Apr., May)	Rainy Season (June, July, Aug., Sept.)
1. Monthly mean O_3 & monthly mean value of gross U. V. flux (UV_{gr})	0.54(0.12)	0.04	0.14	0.18
2. Monthly mean O_3 & monthly mean value of variable component of U. V. flux (UV_v)	−0.02(0.19)	−0.51	0.17	0.12
3. Monthly mean O_3 & monthly mean value of basic component of U. V. flux (UV_b)	0.63 (0.84)	0.49	0.06	0.22
4. Monthly mean value of gross U. V. & yearly mean value of gross U. V.	0.99(0.97)	0.93	0.94	0.93
5. Monthly mean value of UV_v & Yearly mean value of UV_v	0.63(0.97)	0.74	0.43	0.63
6. Monthly mean value of UV_b & Yearly mean value of UV_b	0.91(0.99)	0.45	0.78	0.13
7. Monthly mean O_3 & Yearly mean O_3	0.34(−0.16)	0.25	0.58	0.40

Within ( ) shows the late autumn to early winter correlation coefficients

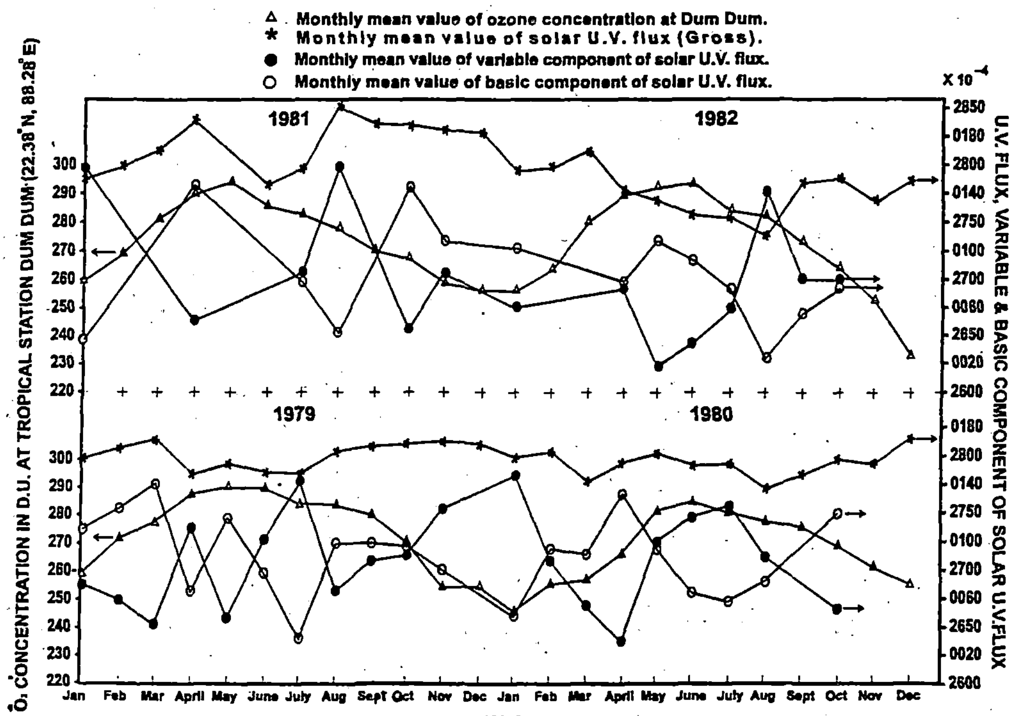

FIG - 1

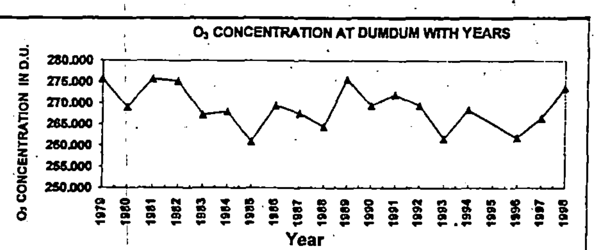

FIG - 2

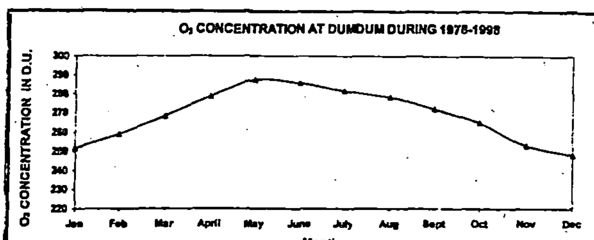

FIG - 3