CHAPTER 4

Southern high latitude O_3 depletion, its variation with solar flux and hazards on nature

4.1 Introduction

In chapter "two" the analysis has been performed directly between Antarctic O_3 depletion and gross solar U.V. flux. In chapter "three" the analysis has been made by dividing solar U.V. flux in their two components to study the impact of solar activity on Antarctic O_3 concentration. But both the studies were confined with in the available satellite data of solar U.V. flux (six years data set of Nimbus 7). In this chapter for further verification of the results, an attempt has been made to analyse for at least eleven years, for better understanding of the solar cycle variation impact.

In absence of long period solar U.V. data, a proxy data for eleven years has been choosen in addition with six years solar U.V. data. Solar 10.7 cm radio flux data are used as the proxy data of solar U.V. flux data. Though solar radio flux is not chemically responsible for creation or destruction of atmospheric ozone, but the significance of choosing the 10.7 cm radio flux as the proxy of U.V. flux has been analysed and found both the solar data are well correlated, calculated correlation coefficinet between solar U.V. flux and solar 10.7 cm. radio flux is positive and very high (0.95).

The purpose of this chapter is to investigate the covariation of southern high latitude O_3 concentration at Halleybay (73.5°S, 26.7°W) and McMurdo (78°S, 166°E) with the components of solar radio flux and solar U.V. flux respectively, at the same time to assess the possible hazards on nature.

Ozone resides in three regions of atmosphere - troposphere (roughly 10% of total ozone content), Stratosphere (roughly 90% of total ozone content), Mesosphere (very small quantity of ozone). The ozone in a column along these three regions of atmosphere is known as column ozone and is measured in Dobson units. One Dobson unit (D.U.) is defined to be 0.01 mm. thickness at S.T.P. The thickness of the atmospheric ozone layer reduced to S.T.P. is very small and varying from 1.5 mm. to 4.5 mm., averaging 2.5 mm. This thin ozone layer acts as an atmospheric protective shield, which protects the abiotic and biotic environments of the earth from the deleterious effects of solar U.V. radiation in the 200 nm. to 320 nm. wavelength region, and maintain the ecological balance.

It is already established that the stratospheric ozone is created by the photo dissociation of 'O_2' by the solar U.V. radiation (wavelength <242 nm.) at an altitude between about 25 km, and 100 km. Absorption of solar U.V. radiation upto about 320 nm. converts the 'O_3' back to 'O_2' and 'O' (Chapman, 1930). So the U.V. radiation is responsible for creation as well as destruction of atmospheric ozone. The resultant concentration of ozone depends, at any time, on the rate of production and the rate of loss or destruction.

In the troposphere ozone is created by interaction of U.V. radiation with automobile and other exhaust fumes; ozone also occurs in some industrial emissions. In the troposphere ozone is a toxic constituent of photochemical smong (Last, 1993).

The global ozone assessment has shown that ozone is declining everywhere throughout the world (WMO report no. 25, 1991 and WMO bull. no. 41, 1992). 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. 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), human and animals (Toylor 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 can influence tropospheric climate (Bates, J.R. 1981).

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

Atmospheric ozone changes can affect tropospheric climate in many ways - viz.

Decrease in stratospheric O_3, reduced solar absorption, more solar energy reaching the earth's surface, resulting in tropospheric warming etc.

Increase in tropospheric O_3 will result in an increased greenhouse trapping of long wave radiation resulting in tropospheric warming (Mackay et. al., 1997), which may produce global warming and is expected to influence the ocean current. This may alter the distribution of rainfall; cause weather disturbances such as hurricanes might become more severe. The other effect of this global warming is the rise in sea level caused by melting of ice and thermal expansion of sea water mass, which may submerge many coastal areas and disturb their ecosystems. Due to global warming, the temperature of the cities will rise, which may increase the heat related illness (Last, 1993).

It is established that large decrease of O_3 concentration occurs during southern winter to spring [Farman et.al. (1985), Hofmann et.al. (1994), Ghosh and Midya (1994)]. Several studies of the effect of various parameters representing solar activity upon O_3 depletion at polar region were made from time to time by different investigators.

Positive correlation between solar U.V. radiation and ozone concentration had been found by Summers et. al. (1990), Hood et. al. (1991), Hood and Mc cormack (1992), Reinsel et. al. (1994). The correlation between global total ozone and sunspot number found to be good by Angell (1989). Study of Nimbus 4 BUV O_3 data for 6 years indicates a high correlation between Global O_3 and 10.7 cm. radio flux (Heath, et.al. 1977).

In this chapter an attempt has been made to study the effect of solar activity on Antarctic O_3 concentration by dividing the solar U.V. flux and solar radio flux data in two components, as the variable component represents the solar activity.

Solar U.V. data are used with the O_3 data of McMurdo for the period 1979 to 1984 and solar 10.7 cm. radio flux data are used as the proxy data of solar U.V. flux with the O_3 data of Halleybay for the period 1979 to 1989 in absence of long period solar U.V. data.

The monthly mean values of O_3 concentration for McMurdo and Halleybay in Antarctica are obtained from Komhyr et. al. (1986), and from the internet website http://Jwocky. gsfc.nasa.gov respectively. The solar U.V. data are the observed data of Nimbus 7 satellite and the solar 10.7 cm. radio flux data are the measured data of radio observatory at ottawa and Algonquin. Both the solar flux data are published in the solar Geophysical data book, NOAA, USA, tabulated in chapter 1, page 25, 26 & 32 to 40, 46 to56.

4.2 Analysis, Discussion and Conclussions

4.2.1. Analysis

A linear regression relation between the daily value of the solar U.V. flux as well as 10.7 cm. radio flux and daily relative sunspot number on least square principle shows two components of both the solar flux for a month - one is variable component (UV_v) or (F_v)

directly proportional to the ralative sunspot number and the other called basic component (UV_b) or (F_b) independent of the relative sunspot number. Each of the two components of the solar U.V. or 10.7 cm. radio flux are computed for every month for the year 1979 to 1984 and 1979 to 1989 respectively using the equations - 3.2.1.1. and 3.2.1.2.

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

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

Where "x" is the daily value of relative sunspot number, "y" is the daily value of solar U.V. or radio flux, "N" is the number of days for which the values of relative sunspot number and values of soalr flux are available in a month. Both the solar data are obtained from the Solar Geophysical Data book, NOAA, U.S.A. Published by Department of Commerce, U.S.A.

Correlations between each of the two components of both the solar flux and ozone concentration have been calculated seasonwise by using the equation 2.2.1.1.

4.2.2. Correlation Between Each of Two Components of Solar U.V. Fulx and O3 Concentration of Antarctica Survey Station McMurdo.

The monthly mean values (variable and basic component) of solar U.V. flux are computed by using the equations (3.2.1.1.) and (3.2.1.2.). The calculated correlation coefficients between each of two components of solar U.V. flux and O_3 concentration at McMurdo for different seasons during the period 1979 to 1984 are given in Table - 4.3.1. Variations of monthly mean O_3 concentration at McMurdo with monthly mean variable and basic components of solar U.V. flux with year for the months of July, August, October, November during the period 1979 to 1984 are shown in Fig. 4.3.1.

It is found from the correlation table (Table - 4.3.1) that the correlation coefficients between each of the two components of solar U.V. flux and O_3 concentration are mainly controlled by their winter to spring values.

Correlation coefficeints are calculated between monthly mean values of O_3 concentration and yearly mean value of O_3 concentration for the seasons of Antarctic winter

(May, June, July, August), spring (September, October), Summer (November, December, January) and autumn (February, March, April). It is found from the correlation table that the correlation coefficient becomes maximum (0.68) for the spring, also high (0.62) for the winter.

The correlation coefficient calculated between monthly mean values of O_3 concentration and monthly mean values of variable component of solar U.V. flux is maximum (0.59) for the spring, in the case of basic component of the solar U.V. flux is maximum (0.18) during winter. Also the correlation coefficient of monthly mean O_3 concentration with yearly mean variable component and basic component of solar U.V. flux (0.54 and 0.64) are maximum during winter. Most of the calculated correlation co-efficients during winter and spring are significant at 5% level. Thus it may be stated that O_3 concentration and variable and basic components of solar U.V. flux are mainly controlled by their winter and spring values. However Hoffman et.al. (1994) found that O_3 depletion is quite noticeable in late winter and early spring in Antarctica.

4.2.3. Correlation Between Each of Two Components of 10.7 cm. Solar Radio Flux and Ozone Concentration of Antarctica Survey Station Halley Bay.

The monthly mean values (variable and basic component) of 10.7 cm. solar radio flux are computed by using the equations (3.2.1.1.) and (3.2.1.2.) to find the correlation coefficient between each of two components of solar radio flux and ozone concentration at Halleybay for different seasons during the period 1979 to 1989. The calculated correlation coefficients are given in Table - 4.3.2. Variations of Antarctic O_3 concentration at Halley Bay and variable and basic components of 10.7 cm. solar flux with year for the months of August, September, October and November during the period 1979 to 1989 are shown in Fig. 4.3.2.

From the correlation table (Table - 4.3.2) it is clear that the correlation coefficients between each of two components of 10.7 cm. solar flux and ozone concentration are mainly controlled by their late winter to spring values.

Correlation coefficients are calculated between monthly mean value of O_3 concentration and yearly mean value O_3 concentration for the seasons of Antarctic late winter (August), spring (September, October), summer (November, December, January) and autumn (February, March, April). It is found from the correlation Table - 4. 3. 2 that the correlation coefficient becomes maximim (0.89) for late winter. It is also very high (0.85) in spring. Also the correlation between monthly mean value of O_3 concentration and the monthly mean value of variable component of solar radio flux is maximum (0.57) during late winter. But the correlation between monthly mean O_3 and monthly mean basic component of solar radio flux is found to be maximum (0.40) during spring. The correlation coefficient between monthly mean O_3 concentration and yearly mean variable component of radio flux is maximum (0.53) during late winter. Other correlation coefficients are also maximum during late winter and most of the correlation coefficients during late winter to spring are significant at 5% level. Thus it may be stated that O_3 concentration and variable and basic components of 10.7 cm. solar radio flux are mainly controlled by their late winter to spring values.

4.2.4. **Discussion**

After creation of atmospheric O_3 mainly at equatorial region by the photodissociation of molecular oxygen, solar ultraviolet radiation produces many reactions with the pollutants (CFC_s, NO_x, etc) which destroy atmospheric ozone. The resultant ozone which depends upon the rate of production and the rate of destruction are carried by the stratospheric winds mainly 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 Himalya 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. 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 starts 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.

The 10.7 cm. solar radio flux, through the terrestrial atmosphere, reaches the ground. Its daily value is measured at Ottawa and Alogonquin radio observatory of the National Research Counncil 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 the solar radiation, though it is not chemically responsible for ozone destruction or formation, it is well correlated with the value of solar UV 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 UV data are available for a short period i,e, Nov. 1978 to Oct. 1984. (Nimbus 7 satellite data) so in this chapter it has also been used the 10.7cm. solar radio flux data as the proxy data for the period 1979 to 1989, so that the analysis can be made for at least one solar cycle.

The ozone observations in Antarctica reveal the following; There is 100% decrease over a large region of the lower stratosphere and also about 60 - 70% decrease in column ozone (Hofmann et.al. 1994). If this trend continues the risk of cataract in the eye, malignant melanoma and non melanoma skin cancer may increase (UNEP, 1991).

4.2.5. Conclusions

It is seen from the correlation Table - 4.3.1, the values of correlation coefficients between monthly mean ozone concentration and basic and variable components of solar U.V. radiation are positive being maximum for Antarctic winter to spring.

Further it is seen from the correlation Table - 4.3.2 the values of correlation coefficients between monthly mean O_3 concentration with monthly mean variable component or monthly mean basic component of solar 10.7 cm. radio flux are positive being maximum for late winter and spring respectively. Also the correlation coefficient between monthly mean O_3 concentration with yarly mean variable component or yearly mean basic component of solar 10.7 cm. radio flux are positive being maximum for Antarctic late winter. Even the correlation coefficient between monthly mean O_3 concentration with yearly mean O_3 concentration is positive being maximum for late winter.

Thus with increase of variable and basic components of solar U.V flux or solar 10.7 cm. radio flux, the ozone concentration need increase and vice versa. However Hofmann et.al. (1994) found that the dramatic decrease of ozone concentration occurs during southern late winter to spring. Components of solar radiations which are associated respectively with solar activity and steady background, may have been responsible for this declining trend of winter to spring values of ozone concentration in Antarctica and then the correlation coefficients between O_3 concentration and components of solar radiations should have been high negetive during winter to spring. But result shows that most of the correlation coefficients between O_3 concentration and components of solar radiations are highly positive and significant at 5% level, during winter to spring in Antarctica.

Thus it may be concluded that the variable and basic components of solar radiations which are associated respectively with solar activity and steady background solar radiation are not responsible for the southern high latitude O_3 depletion, though solar U.V. radiation is responsible for production as well as destruction of atmospheric O_3 concentration. The pollutants (CFCs, NOx etc.) might be responsible for this O_3 depletion. If this present trend of O_3 depletion continues, it may create so many hazards on nature.

To control ozône depletion, restriction should be imposed on the use of the pollutants, mainly chloroflurocarbon and oxides of nitrogen and ultimately the production of these pollutants should be stopped step by step and new substitute should be invented, which will be economic and environment friendly, such that it will not deplete ozone or it will not pollute environment in other forms. Moreover it should have properties to destroy the molecules of pollutants which are already in atmosphere.

The montreal protocol, 1987 which amended and adjusted on 1992 (Copenhagen) should be implemented immediately, for the recovery of the ozone layer (WMO report 34, 1994). Finally the population growth should be controlled, as rise in population leads to increased demand for food, accomodation and other necessities leading to more industrial activities and generation of pollutants, resulting in greater damage to the natural ecological system of our planet.

Table - 4.3.1

Correlation Coefficient between different 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 UV_v (1979 - 1984)	0.36	0.59	0.49	*
2. Monthly mean O_3 & monthly mean UV_b (1979 - 1984)	0.18	- 0.07	0.13	*
3. Monthly mean O_3 & Yearly mean UV_v (1979 - 1984)	0.54	0.21	0.51	*
4. Monthly mean O_3 & Yearly mean UV_b (1979 - 1984)	0.64	0.55	0.42	*
5. Monthly mean O_3 & Yearly mean O_3 (1979 - 1984)	0.62	0.68	0.59	*

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

Table - 4.3.2

Correlation coefficient between different parameters for different seasons

Halley Bay (73.5°S, 26.7°W)

Correlation coefficient between	Late Winter Aug.	Spring Sept., Oct.	Summer Nov., Dec., Jan.	Autumn Feb., Mar., April
1. Monthly mean O_3 & monthly mean F_v (1979 - 1989)	0.57	0.30	0.47	0.39
2. Monthly mean O_3 & monthly mean F_b (1979 - 1989)	- 0.11	0.40	- 0.009	0.29
3. Monthly mean O_3 & Yearly mean F_v (1979 - 1989)	0.53	0.47	0.32	0.45
4. Monthly mean O_3 & Yearly mean F_b (1979 - 1989)	0.42	0.30	0.34	0.27
5. Monthly mean O_3 & Yearly mean O_3 (1979 - 1989)	0.89	0.85	0.60	0.52

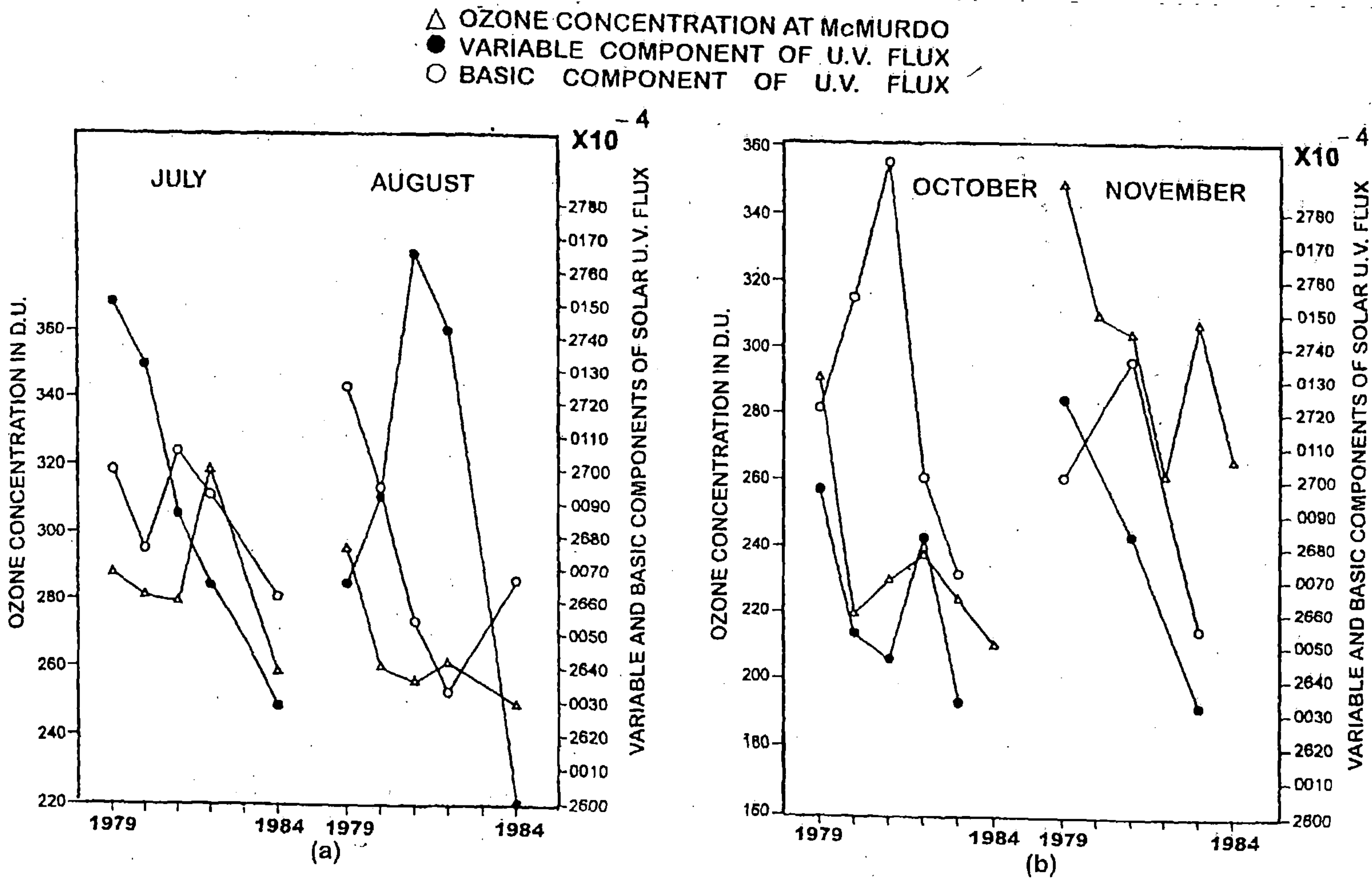
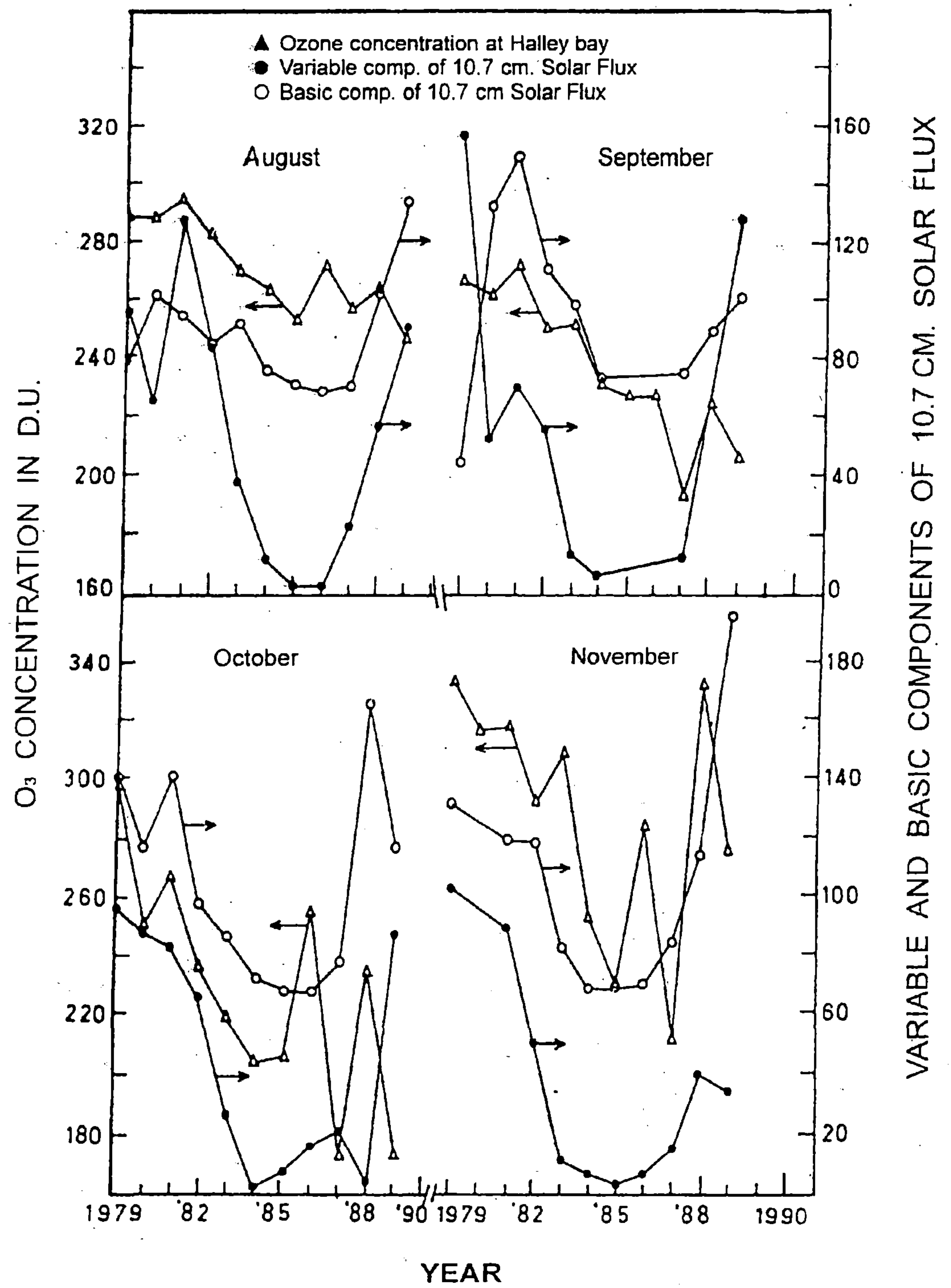


FIG - 4.3.1

Variations of monthly mean O_3 concentration at McMurdo with monthly mean variable and basic components of solar U.V. flux with year for the months of July, August, October and November during the period 1979 to 1984.



Variations of monthly mean O_3 concentration at Halley bay with monthly mean variable and basic components of 10.7 cm. radio flux with year for the months of August, September, October and November during the period 1979 to 1989

FIG. - 4.3.2

4.3.1. References

1. Angell, J.K. (1989), "On the relation between atmospheric ozone and sunspot number." Journal of climate, Vol 2 PP 1404 - 1416.
2. Bakers, K.S. and Smith, R.C. (1982). "The role of solar U.V. radiation in marine ecosystems", Newyork, Plenum, PP 233-246.
3. Bates, J.R., (1981). "A dynamical mechanism through which variations in solar ultra-violet radiation can influence tropospheric climate." Solar Physics. Vol 74(2), PP 399-415.
4. Chapman, S. (1930). "A theory of upper atmospheric ozone". Mem. Roy. Meteorol. Soc. Vol.3, PP 103-125.
5. Farman, J.C., Gardiner, B.G. and Shanklin, J.D. (1985). "Large losses of total ozone in Antarctica reveal seasonal CLO_x / NO_x interaction". Nature, Vol 315, PP 207-210.
6. Ghosh, S.N. and Midya, S.K. (1994) "Atmospheric ozone sink, its depletion and Antarctic ozone hole." IJP. Vol 68B(6) PP 473-493.
7. Heath, D.F., Krueger, A.J., crutzen, P.J. (1977) "Solar proton event : Influence on stratospheric ozone". Science. Vol 197. P 886.
8. Hofmann, D. J., Oltman, S.J., Lathrop, J.A., Harris, J.M. and vomel, H (1994) "Record law ozone at the south pole in the spring of 1993" Geophys. Res. Lett 21 PP 421-424.
9. Hood, L.L., Huang, Z, and Bougher, S.W (1991) "Mesospheric effects of solar U.V. variation. Further analysis of SME IR ozone and Nimbus 7 SAMS temperature data". J. Geophys. Res Vol 96. PP 12989 - 13002.
10. Hood, L.L., Mc Cormack, J.P (1992). "component of inter annal ozone change based on Nimbus 7 Toms data." Geophys. Res. Lett 19. PP 2309-2312.
11. Last, J.M. (1993). "Global change : Ozone depletion, greenhouse warming and public health". Annual Review of Public health., Vol 14, PP 115-136.
12. Ley, R.D., Applegate, L.A., Padilla, R.S. and Stuart, T.D. (1989) "Ultraviolet radiation-induced melanoma." Photochem. Photobiol., Vol 50, PP 1-5.
13. Logan, J.A. (1994). "Trend in the vertical distribution of ozone : An analysis of ozone sonde data." J. Geophys. Res. Lett., Vol 99, PP 25553-25585.

14. Mackay, R.M., Malcom, K.W. Ko., Run-lie Shia and Yajaing Yang. (1997). "An estimation of the climatic effects of stratospheric ozone losses during the 1980s". Journal of Climate, U.S.A., Vol 10, PP 774-788.

15. Mc Cormick, M.P., Vegia, R.E., and Chu, W.P. (1992). "Stratospheric ozone Profile and total ozone derived from the SAGE I and SAGE II data." Geophysics Res. Lett. 19, PP 269-272.

16. Nikula, K.J, Benjamin, S.A., Angleton, G.M., Saunders, W.J. and Lee, A.C. (1992). "Ultraviolet Radiation, solar Dermatosis, and cutaneous Neoplasia in Beagle Dogs." Radiat. Res. Vol 129, PP 11-18.

17. Reinsel, G.C., Tam, W. K. and Ying, L.M. (1994) "comparison of trend analysis for Umkher data using and previous inverson algorithms." Geophys. Res. lett. 21 PP 1007-1010.

18. Smith, R.C., Baker, K.S., Holm-Hanson, O. and Olson, R. (1980). "Photoinhibition of photosysnthesis in natural waters". Photochem. Photobiol., Vol 31, PP 585-592.

19. Smith, R.C. (1989). "Ozone middle ultraviolet radiation and the aquatic environment." Photochem Photobiol. Vol 50, PP 459-468.

20. Stolarski, R.S., Bloomfied, P., McPeters, R.D. and Herman, J.R. (1991). "Total ozone trends deduced from NIMBUS 7 TOMS data." Geophysics Res. Lett. 21, PP 421-424.

21. Summers, M.E., Strobel, D.F., Bevilacqua, R.M., Xunzhu., Deland,. M.T., Allen, M and keating G.M. (1990) "A model study of response of mesospheric ozone to short term solar ultraviolet flux variations." J. Geophys. Res. Vol 95. PP 22523-22538.

22. Taylor, H.R. (1989). "The biological effects of U.V. - B on the eye". Photochem. Photobio., Vol 50, PP 489-492.

23. Tevini, M. and Teramura, A.H. (1989). "U.V. - B effects on terrestrial plants". Photochem. Photobiol., Vol 50, PP 479-487.

24. United Nations Environment programme (1991) "Environmental effects of ozone depletion update." Nairobi, UNEP.

25. Vanderleun, J.C. and De Gruijl, F.R. (1993). "Influence of ozone depletion on human and animal health. Chapter 4 in U.V. - B radiation and ozone depletion : Effects on humans, animals, micro-organisms, and materials." Lewis Publishers, U.S.A., PP 95-123.

26. World Meteorological Organisation Scientific assesment of ozone depletion (1991). Global Ozone Research and Monitoring project report 25, WMO Ozone Secretariat, Geneva, Switzerland.

27. World Meteorological Organisation (1992), Changes in Polar ozone, Global Ozone Reserch and Monitoring Project, Bull. 41. PP 171-180.

28. World Meteorological Organisation (1994), Scientific Assesment of ozone depletion. Executive Summary. WMO Global Ozone Research and Monitoring Preject. Report No. 37.

29. Worrest, R.C. (1986). "The effect of solar U.V. - B radiation on aquatic systems : an overview effects of changes in stratospheric ozone and global climate". Vol. 1, ed. J.G. Titus (Washington, D.C. : US Environmental Protection Agency and United Nations Environmental Program), PP 175-191.

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Dated 15.6.2000

Professor S.N. Maitra,
Shantineketan,
SUHRID LANE,
JALPAIGURI-735101
WEST BENGAL.

Dear Professor Maitra,

Kindly refer to your letter dated 12.6.2000 which I have received today. Earlier I have also received your letter dated 15.3.2000 along with the manuscript of your paper for publication in Journal of Environmental Research.

I am glad to inform you that your following papers have been accepted for publication in the journal.

1. Southern high altitude--------- on nature.
2. Analytically derived---------- at Gorakhpur.

The journal is in the process of publication which will be published before the Conference. I will be thankful if you very kindly send me Rs. 3125.00(25 pages) towards reprint charges/publication.

I will suggest you to be Life member of the Academy so that you can be considered for Fellowship award. The necessary form is enclosed herewith for doing the needful in this regard.

I hope to ar soon from you.

Thanking you,

Sincerely yours,

V. K. Srivastava

(Prof. V.K.Srivastava)

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Southern high latitude O_3 depletion, its variation with solar flux and hazards on nature

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Abstract

The purpose of this paper is to investigate the covariation of southern high latitude O_3 concentration with the components of solar ultraviolet and 10.7 c.m. radio flux, at the same time to assess the possible hazards on nature. The critical analysis shows the following interesting results :- The seasonal correlation coefficients of O_3 concentration (Stations McMurdo and Halleybay) with each of two components of solar flux during winter to spring are maximum. The southern high latitude O_3 depletion is independent of solar parameters. It is concluded that due to O_3 depletion, increased dosage of harmful U.V. radiation can create so many hazards on nature.

Introduction

Ozone resides in three regions of atmosphere - troposphere (roughly 10% of total ozone content), stratosphere (roughly 90% of total ozone content), mesosphere (very small quantity of ozone). The ozone in a column covering an area 10 deg. X 5 deg. along these three regions of atmosphere is known as column ozone and is measured in Dobson units. One Dobson unit (D.U.) is defined to be 0.01 mm. thickness at S.T.P. The thickness of the atmoshperic ozone layer reduced to S.T.P. is very small varying from 1.5 mm. to 4.5 mm., averaging 2.5 mm. This thin ozone layer acts as an atmospheric protective shield, which protects the abiotic and biotic environments of the earth from the deleterious effects of solar U. V. radiation in the 200 nm. to 320 nm. wavelength region and maintains the ecological balance.

It is already established that the stratospheric ozone is created by the photo dissociation of 'O_2' by the solar U. V. radiation (wavelength < 242 nm.) at an altitude between about 25 km. and 100 km. Absorption of solar U. V. radiation upto about 320 nm. converts the 'O_3' back to 'O_2' and 'O' (Chapman, 1930). So the U.V. radiation is responsible for creation as well as destruction of atmospheric ozone. The resultant concentration of ozone depends, at any time, on the rate of production and the rate of loss or destruction.

In the troposhere, ozone is created by interaction of UV radiation with automobile and other exhaust fumes; ozone also occurs in some industrial emissions. In the troposphere, ozone is a toxic constituent of photochemical smog (Last, 1993).

The global ozone assessment has shown that ozone is decliniing everywhere throughout the world (WMO report no. 25, 1991 and WMO bull. no. 41, 1992). 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 farmful to the biosphere as well as ecosystem. 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 (Toylor 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 can influence tropospheric climate (Bates, J.R. 1981).

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

Atmospheric ozone changes can affect tropospheric climate in many ways :

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

Increase in tropospheric O_3 will result in an increased greenhouse trapping of long wave radiation resulting in tropospheric warming (Mackay et. al., 1997), which may produce global warming and is expected to influence the ocean current. This may alter the distribution of rainful; weather distrubances, such as hurricanes might become more severe. The other effect of this global warming is rise in sea level caused by melting of ice and thermal expansion of sea water mass, which may submerge many coastal areas and disturb their ecosystems. Due to global warming, the temperature of the cities will rise, which may increase the heat related illness (Last, 1993).

It is well accepted that dramatic decrease of O_3 concentration occurs during southern winter to spring [Farman et.al. (1985), Hofmann et. al. (1994), Ghosh and Midya (1994)]. Several studies of the effect of various parameters representing solar activity upon O_3 depletion at polar region were made from time to time by different investigators throughout the world.

Positive correlation between solar U. V. radiation and ozone concentration had been found by Summers et. al. (1990), Hood et. al. (1991), Hood and Mc Cormack (1992), Reinsel et. al. (1994). The correlation between global total ozone and sunspot number found good by Angell (1989). Study of Nimbus 4 BUV O_3 data for 6 years indicates a high correlation between Global O_3 and 10.7 cm. radio flux (Heath, et. al. 1977).

In this paper an attempt has been made to study the effect of solar activity on Antarctic O_3 concentration by dividing the solar U.V. flux and solar radio flux data in two components, as the variable component represents the solar activity.

Solar U. V. data are used with the O_3 data of McMurdo for the period 1979 to 1984 and solar 10.7 cm. radio flux data are used as the proxy data of solar U.V. flux with the O_3 data of Halleybay for the period 1979 to 1989 in absence of long period solar U.V. data.

The monthly mean values of O_3 concentration for McMurdo and Halleybay in Antarctica are obtained from Komhyr et. al. (1986), and from the internet website http://Jwocky.gsfc.nasa.gov respectively. The solar U. V. data are the observed data of Nimbus 7 satellite and the solar 10.7 cm. radio flux data are the measured data of radio observatory at Ottawa and Algonquin. Both the solar flux data are published in the solar Geophysical data book, NOAA, USA.

Analysis

A linear regression relation between the daily value of the solar U.V. flux as well as 10.7 cm. radio flux and daily relative sunspot number on least square principle shows two components of both the solar flux for a month - one is variable component (UV_v or (F_v) directly proportional to the relative sunspot number and the other called basic component (UV_b) of (F_b) independent of the relative sunspot number. Each of the two components of the solar U.V. or 10.7 cm. radio flux are computed for every month for the year 1979 to 1984 or 1979 to 1989 respectively using the equations-

$$\text{Basic component of solar flux } (UV_b \text{ or } F_b) = \frac{(\Sigma xy)(\Sigma x) - (\Sigma x^2)(\Sigma y)}{(\Sigma x)^2 - N(\Sigma x^2)} \quad \text{.....(i)}$$

$$\text{Variable component solar flux } (UV_v \text{ or } F_v) = \frac{\Sigma y}{N} - UV_b \quad \text{...........(ii)}$$

Where "x" is the daily value of relative sunspot number, "y" is the daily value of solar U.V. or radio flux, "N" is the number of days for which the values of relative sunspot number and value of solar flux are available in a month. Both the solar data are obtained from the Solar Geophysical Data book, NOAA, U.S.A. Published by Department of Commerce, U.S.A.

Correlations between each of the two components of both the solar flux and ozone concentration have been calculated seasonwise. (Table 1 & Table 2)

Table 1 : Correlation Coefficient between different 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 UV_v (1979-1984)	0.36	0.59	0.49	*
2. Monthly mean O_3 & monthly mean UV_b (1979-1984)	0.18	-0.07	0.13	*
3. Monthly mean O_3 & Yearly mean UV_v (1979-1984)	0.54	0.21	0.51	*
4. Monthly mean O_3 & Yearly mean UV_b (1979-1984)	0.64	0.55	0.42	*
5. Monthly mean O_3 & Yearly mean O_3 (1979-1984)	0.62	0.68	0.59	*

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

Table 2 : Correlation Coefficient between different parameters for different seasons.

Halley Bay (76°S, 27°W)

Correlation coefficient between	Late Winter Aug.	Spring Sept., Oct.	Summer Nov., Dec., Jan.	Autumn Feb., Mar., April
1. Monthly mean O_3 & monthly mean F_v (1979-1989)	0.57	0.30	0.47	0.39
2. Monthly mean O_3 & monthly mean F_b (1979-1989)	-0.11	0.40	- 0.009	0.29
3. Monthly mean O_3 & Yearly mean F_v (1979-1989)	0.53	0.47	0.32	0.45
4. Monthly mean O_3 & Yearly mean F_b (1979-1989)	0.42	0.30	0.34	0.27
5. Monthly mean O_3 & Yearly mean O_3 (1979-1989)	0.89	0.85	0.60	0.52

Correlation Between Each of Two Components of Solar U.V. Flux and O_3 Concentration of Antarcatica Survey Station McMurdo

The monthly mean values (variable or basic component) of solar U.V. flux are computed by using the equations (i) and (ii). The calculated correlation coefficients between each of two components of solar U.V. flux and O_3 concentration at McMurdo for different seasons during the period 1979 to 1984 are given in Table-1 variations of monthly mean O_3 concentration at McMurdo with monthly mean variable and basic components of solar U.V. flux with year for the months of July, August, October, November during the period 1979 to 1984 are shown in Fig. 1.

It is found from the correlation table (Table-1) that the correlation coefficients between each of the two components of solar U.V. flux and O_3 concentration are mainly controlled by their winter to spring values.

Correlation coefficients are calculated between monthly mean values of O_3 concentration and yearly mean value of O_3 concentration for the seasons of Antarcatic winter (May, June, July, August), spring (September, October), Summer (November, December, January) and autumn (February, March, April). It is found from the correlation table that the correlation coefficient becomes maximum (0.68) for the spring, also high (0.62) for the winter.

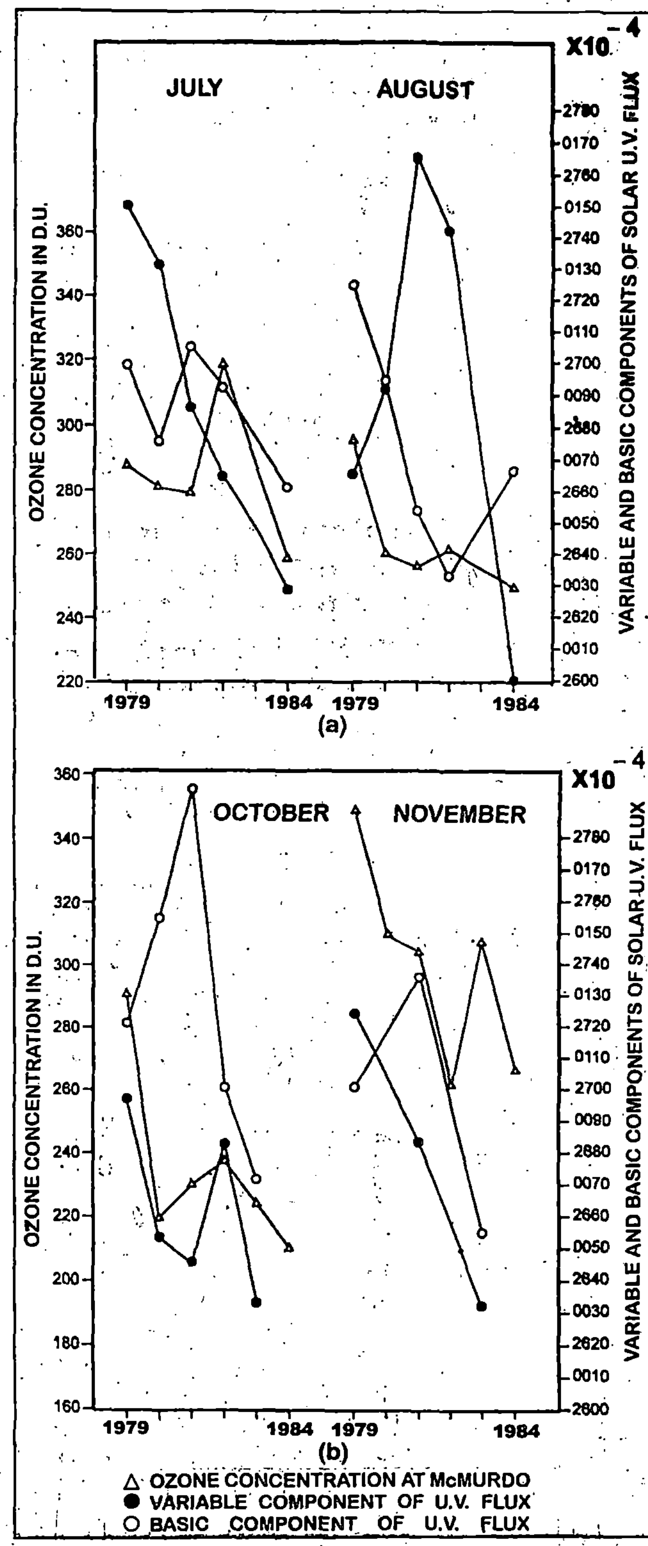

FIG - 1

Variations of monthly mean O3 concentration at McMurdo with monthly mean variable and basic components of Solar U.V. flux with year for the months of July, August, October and November during the period 1979 to 1984.

The correlation coefficients calculated between montly mean values of O_3 concentration and monthly mean values of variable component of solar U.V. flux is maximum (0.59) for the spring, in the case of basic component of solar U.V. flux is maximum (0.18) during winter. Also the correlation coefficient of monthly mean O_3 concentration with yearly mean variable component and basic component of solar U.V. flux (0.54 and 0.64) are maximum during winter. Thus we may infer that O_3 concentration and variable and basic components of solar U.V. flux are mainly controlled by their winter and spring values. However Hoffman et.al. (1994) found that O_3 depletion is quite noticeable in late winter and early spring in Antarctica.

Correlation Between Each of Two Components of 10.7 cm. Solar Radio Flux and Ozone Concentration of Antarctica Survey Station Halley Bay.

The monthly mean values (variable or basic component) of 10.7 cm. solar radio flux are computed by using the equations (i) and (ii) to find the correlation coefficient between each of two components of solar radio flux and ozone concentration at Halley Bay for different seasons during the period 1979 to 1989. The calculated correlation coefficients are given in Table - 2. Variations of Antarctica O_3 concentration at Halley Bay and variable and basic components of 10.7 cm. solar flux with year for the months of August, September, October and November during the period 1979 to 1989 are shown in Fig. 2.

From the correlation table (Table-2) it is clear that the correlation coefficients between each of two components of 10.7 cm. solar flux and ozone concentration are mainly controlled by their late winter to spring values.

Correlation coefficients are calculated between monthly mean value of O_3 concentration and yearly mean value O_3 concentration for the seasons of Antarctica 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 (0.89) for late winter. It is also very high (0.85) in spring. Also the correlation between monthly mean value of O_3 concentration and the monthly mean value of variable component of solar radio flux is maximum (0.57) during late winter. But the correlation between monthly mean O_3 and monthly mean basic component of solar radio flux is found to be maximum (0.40) during spring. The correlation coefficient between monthly mean O_3 concentration and yearly mean variable component of radio flux is

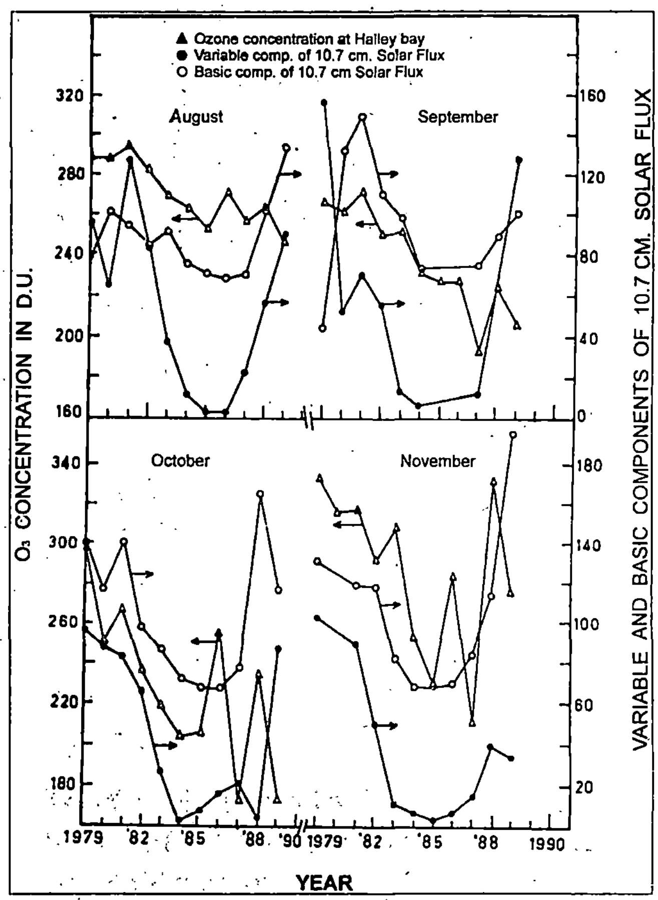

FIG - 2

Variations of monthly mean O3 concentration at Halley Bay with monthly mean variable and basic components of 10.7 cm. radio flux with year for the months of August, September, October and November during the period 1979 to 1989

maximum (0.53) during late winter. Other correlation coefficients are also maximum during late winter. Thus we may infer that O_3 concentration and variable and basic components of 10.7 cm. solar radio flux are mainly controlled by their late winter to spring values.

Discussion

After creation of atmospheric O_3 mainly at equatorial region by the photodissociation of molecular oxygen, solar ultraviolet radiation produces many reactions with the pollutants (CFC_S, NO_X, etc.) which destroy atmospheric ozone. The resultant ozone which depends upon the rate of production and the rate of destruction are carried by the stratospheric winds mainly 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 Himalyas right to the north pole. In the southern hemisphere the winds circulate to about 60^0s for much of the year especially during southern winter. During southern spring the polar vortex consisting of cold air starts to break down allowing ozone rich air from lower latitudes in to the Antarctic region. Thus during Antarctic spring, stratospheric ozone concentration over Antarctica starts to rise.

The 10.7 cm. solar radio flux, through the terrestrial atmoshere, reaches the ground. Its daily value is measured 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 the solar radiation. Though it is not chemically responsible for ozone destruction or formation, it is well correlated with the value of solar UV 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 UV data are available for a short period i.e. Nov. 1978 to Oct. 1984. (Nimbus 7 satellite data) so in this paper we have also used the 10.7 cm. solar radio flux data as the proxy data for the period 1979 to 1989, so that the analysis can be made for at least one solar cycle.

The possible impacts of O_3 depletion on earths environment has been assessed in our previous papers on Arctica (Maitra et.al. 2000) and sub Himalayan region at Jalpaiguri (Maitra et. al. 2000). It is seen that atmospheric O_3 depletion may affect : growth of plants and crops, aquatic life, human and animal health, climatic condition of earth. At Jalpaiguri there are possibilities to have more warm climate, the winter may be shorter, the rainfall distribution pattern may change, which may result water logging, flood etc. Maitra et. al. (1999) also found that O_3 concentration at tropical DumDum (India) is declining and a 5.04% loss has been recorded during the period 1979 to 1996. On the other hand ozone observations in Antarctica reveal the following; A 100% decrease occurs over a large region of the lower stratosphere and about 60-70% decrease in column ozone (Hofmann et.al. 1994). If this trend continues the risk of cataract in the eye, malignant melanoma and non melanoma skin cancer may increase (UNEP, 1991).

Conclussions

It is seen from the correlation Table-1, that the values of correlation coefficients between monthly mean ozone concentration and basic and variable components of solar U.V. radiation are positive being maximum for Antarctic winter to spring.

Further it is seen from the correlation Table-2, that the values of correlation coefficients between monthly mean O_3 concentration with monthly mean variable component or monthly mean basic component of solar 10.7 cm. radio flux are positive being maximum for late winter and spring respectively, also the correlation coefficient between monthly mean O_3 concentration with yearly mean variable component or yearly mean basic component of solar 10.7 cm. radio flux are positive being maximum for Antarctic late winter. Even the correlation coefficient between monthly mean O_3 concentration with yearly mean O_3 concentration is positive being maximum for late winter.

Thus with increase of variable and basic components of solar U.V. flux or solar 10.7 cm. radio flux, the ozone concentration should increase and vice versa. However Hofmann et. al. (1994) found that the dramatic decrease of ozone concentration occurs during southern late winter to spring.

Thus we may conclude that the variable and basic components of solar radiations which are associated respectively with solar activity and steady back ground solar radiation are not responsible for the southern high latitude O_3 depletion, though solar U.V. radiation is responsible for production as well as destruction of atmospheric O_3 concentration. The pollutants (CFC_S, NO_X etc.) may be responsible for this O_3 depletion. If this present trend of O_3 depletion continues, it may create so many hazards on nature.

To control ozone depletion, restriction should be imposed on the use of the pollutants, mainly choroflurocarbon and oxides of nitrogen and ultimately the production of these pollutants should be stopped step by step and new substitute should be invented, which will be economic and environment friendly. These will not deplete ozone or it will not pollute environment in other form. Moreover it should have properties to destroy the molecules of pollutants which are already in atmosphere.

The Montreal protocol, 1987 which was amended and adjusted in 1992 (Copenhagen) should be implimented immediately, for the recovery of the ozone layer (WMO report 34, 1994). Finally the population growth should be controlled, as rise in population leads to increased demand for food, accommodation and other necessities leading to more industrial activities and deforestation resulting in greater damage to the natural ecological system on our planet.

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References

1. **Angell, J.K. (1989)**, "On the relation between atmospheric ozone and sunspot number." Journal of climate, Vol. 2 PP 1404-1416.

2. **Bakers, K.S. and Smith, R.C. (1982).** "The role of solar U.V. radiation in marine ecosystems", Newyork, Plenum, PP 233-246.

3. **Bates, J.R., (1981).** "A dynamical mechanism through which variations in solar ultra-violet radiation can influence troposheric climate." Solar Physics. Vol. 74 (2), PP 399-415.

4. **Chapman, S. (1930).** "A theory of upper atmospheric ozone". Mem. Roy. Meteorol. Soc. Vol. 3, PP 103-125.

5. **Farman, J.C., Gardiner, B.G. and Shnklin, J.D. (1985).** "Large losses of total ozone in Antarctica reveal seasonal CLO_x/NO_x interaction". Nature, Vol. 315, PP 207-210.

6. **Ghosh, S. N. and Midya, S.K. (1994).** "Atmoshperic ozone sink, its depletion and Antarctic ozone hole". IJP. Vol. 68B (6) PP 473-493.

7. **Heath, D.F., Krueger, A.J., crutzen, P.J. (1977).** "Solar proton event : Influence on stratospheric ozone". Science. Vol. 197 P 886.

8. **Hofmann, D. J., Oltman, S.J., Lathrop, J.A., Harris, J.M. and Vomel, H. (1994).** "Record low ozone at the south pole in the spring of 1993". Geophys. Res. Lett. 21 PP 421-424.

9. **Hood, L.L., Huang, Z. and Bougher, S.W. (1991).** "Mesopheric effects of solar U.V. variation. Further analysis of SME IR ozone and Nimbus 7 SAMS temperature data". J. Geophys. Res. Vol. 96 PP 12989-13002.

10. **Hood, L.L., Mc Cormack, J.P. (1992).** "Component of inter annal ozone change based on Nimbus 7 Toms data". Geophys. Res. Lett 19. PP 2309-2312.

11. **Last, J.M. (1993).** "Global change : Ozone depletion, greenhouse warming and public health". Annual Review of Public health. Vol. 14, PP 115-136.

12. **Ley, R.D., Applegate, L.A., Padilla, R.S. and Stuart, T.D. (1989).** "Ultraviolet radiation induced melanoma." Photochem. Photobiol. Vol. 50, PP 1-5.

13. **Logan, J.A. (1994).** "Trend in the vertical distribution of ozone : An analysis of ozone sonde data". J. Geophys. Res. Lett., Vol. 99, PP 25553-25585.

14. **Mackay, R.M., Malcom, K.W. Ko., Run-lie Shia and Yajaing Yang. (1997).** "An estimation of the climatic effects of stratospheric ozone losses during the 1980s". Journal of Climate, U.S.A., Vol. 10, PP 774-788.

15. **Maitra, S. N. Bhattacharjee, B. and Tarafdar, G. (1999).** "Tropical O_3 deficit at DumDum (India), its correlation with solar U.V. radiation and possible effects on biosphere". Civil Engg. Today. A Journal of American Society of Civil Engrs. - IS, Vol. XIII No. 6, PP 3-7.

16. **Maitra, S. N. Bhattacharjee, B. and Chatterjee, S.S. (2000-Inpress).** "The subhimalayan column ozone covariation with Meteorological parameters and its possible impact on Environment at Jalpaiguri. Environment and Ecology.

17. **Maitra, S. N. Bhattacharjee, B. and Chatterjee, S. S. *(2000-Inpress)*.** "Arctic O_3 Destruction, Cause Investigation and related hazards on Earth's Environment". Civil Engineering Today. A Journal of American Society of Civil Engrs. - IS.

18. **Mc Cormick, M.P., Vegia, R.E., and Chu, W.P. (1992).** "Stratospheric ozone Profile and total ozone derived from the SAGE I and SAGE II data." Geophysics Res. Lett. 19, PP 269-272.

19. **Nikula, K.J., Benjamin, S.A., Angleton, G.M., Saunders, W.J. and Lee, A.C. (1992).** "Ultraviolet Radiation, solar Dermatosis and cutaneous Neoplasia in Beagle Dogs." Radiat. Res. Vol. 129, PP 11-18

20. **Reinsel, G.C., Tam, W.K. and Ying, L.M. (1994).** "Comparison of trend analysis for Umkher data using and previous inverson algorithms." Geophys. Res. lett. 21 PP 1007-1010.

21. **Smith, R.C., Baker, K.S., Holm-Hanson, O. and Olson, R. (1980).** "Photoinhibition of photosysnthesis in natural waters". Photochem. Photobiol., Vol. 31, PP 585-592.

22. **Smith, R.C. (1989).** "Ozone middle ultraviolet radiation and the aquatic environment". Photochem Photobiol. Vol. 50, PP 459-468.

23. **Stolarski, R.S., Bloomfied, P., McPeters, R.D. and Herman, J.R. (1991).** "Total ozone trends deduced from NIMBUS 7 TOMS data". Geophysics Res. Lett. 21, PP 421-424.

24. **Summers, M.E., Strobel, D.F., Bevilacqua, R.M., Xunzhu, Deland, M.T., Allen, M. and Keating, G.M. (1990).** "A model study of response of mesopheric ozone to short term solar ultraviolet flux variations". J. Geophys. Res. Vol. 95, PP 22523-22538.

25. **Taylor, H.R. (1989).** "The biological effects of U.V. - B on the eye". Photochem. Photobio., Vol. 50, PP 489-492.

26. **Tevini, M. and Teramura, A.H. (1989).** "U.V.-B effects on terrestrial plants". Photochem. Photobiol., Vol. 50, PP 479-487.

27. **United Nations Environment Programme (1991).** "Environmental effects of ozone depletion update." Nairobi, UNEP.

28. **Vanderleun, J.C. and De Gruijl, F.R. (1993).** "Influence of ozone depletion on human and animal health, micro-organisms, and materials". Lewis Publishers, U.S.A., PP 95-123.

29. **World Meteorological Organisation Scientific assesment of ozone depletion (1991).** Global Ozone Research and Monitoring project report 25, WMO Ozone Secretariat, Geneva, Switzerland.

30. **World Meteorological Organisation (1992),** Changes in Polar ozone, Global Ozone Research and Monitoring Project, Bull. 41, PP 171-180.

31. **World Meteorological Organisation (1994),** Scientific Assesment of ozone depletion. Executive Summary, WMO Global Ozone Reasearch and Monitoring Project Report No. 37.

32. **Worrest, R.C. (1986).** "The effect of solar U.V. - B radiation on aquatic systems : an overview effects of changes in stratospheric ozone and global climate". Vol. 1, ed. J.G. Titus (Washington, D.C. : US Environmental Protection Agency and United Nations Environmental Program), PP 175-191.