Indian J. Phys. **75B** (1), 15–18 (2001)

I J P B
— an international journal

A study of the variation of daily O_3 concentration at Halley Bay in Antarctica with daily solar UV flux

S K Midya*[a,c], S N Maitra[b] and G Tarafdar[b]
[a]Department of Physics, Serampore College, Serampore, Hooghly-712 201, West Bengal, India
[b]Jalpaiguri Polytechnic Institute, Danguajhar, Jalpaiguri-735 121, West Bengal, India
[c]Centre for Space Physics, 114/V/1A, Raja S C Mullick Road, Kolkata-700 047, India

Received 28 October 1999, accepted 21 December 2000

Abstract : Atmospheric ozone even being a very minor constituent, plays a central role to absorb (not all) the solar UV radiations (200 nm to 320 nm) which are lethal to man and other living organisms. The ozone concentration is slowly declining everywhere throughout the world, but dramatic decrease of O_3 concentration takes place at Antarctica during spring time. The paper reports the investigation of the correlation coefficients of daily O_3 concentration of Antarctic Survey station, Halley Bay with daily solar UV flux. Daily, monthly, yearly and seasonal correlation coefficients between O_3 concentration and UV flux are calculated from their corresponding daily, monthly, yearly and seasonal values. It is concluded that atmospheric O_3 depletion over Antarctica is independent of solar UV radiation.

Keywords : Solar UV radiation, O_3 depletion, Antarctica

PACS Nos. : 92.60.–e, 96.60.Rd

1. Introduction

Bates [1] has shown that variations in solar UV radiation can lead to changes in the mean temperature and wind distribution in the stratosphere, thus resulting in modification of O_3 photochemistry. Observations over the last two decades indicate that O_3 concentration in the lower stratosphere has decreased and the tropospheric O_3 concentration has possibly increased in some regions [2–4]. Ozone changes can affect the tropospheric system in several ways :

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

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

(3) Increase in tropospheric O_3 will result in an increased greenhouse trapping of long wave radiation resulting in tropospheric warming [5].

The solar UV–B (280 nm. – 320 nm.) radiations are not totally absorbed by the O_3 layer, its remaining part coming to the ground affects man, animal, fishes and plants. The effects are discussed in our previous papers [6,7]. Also Maitra *et al* [8] analysed the subhimalayan ozone variation with the meteorological parameters and its impact on environment at Jalpaiguri (26.32° N, 88.46° E).

Sydney Chapman [9] postulated chemical reactions with O_2 and UV light for the formation of ozone in the atmosphere. But O_3 concentration does not continue to increase, as it is also destroyed by the UV rays and by some man made pollutants [7]. The oxygen atoms released from ozone destruction combine with O_2 molecules forming again ozone molecules. The resultant concentration of O_3 depends on the rate of production and the rate of loss and destruction due to pollutants and transportation.

But the global O_3 assessment confirmed that O_3 is declining everywhere [10]. It is already accepted that the dramatic decrease of O_3 concentration occurs during Antarctic Spring [11]. Several studies on the effects of various kinds of solar activity upon O_3 depletion in Antarctica have been made from time to time by different investigators throughout

*Corresponding Author

the world Midya and Midya [12] showed that O_3 concentration varies in oscillatory manner with solar flare number during the period 1973 to 1984 Midya *et al* [13] also showed that dramatic decrease of O_3 concentration in Antarctica is independent of UV radiation by using the calibrated value of solar UV flux Maitra *et al* [7] found that O_3 depletion in Antarctica is independent of solar radiation by using the 10 7 cm solar radio flux as the proxy data of UV flux during 1974 to 1985

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

2. Analysis, discussion and conclusions

2 1 Analysis

The daily average value of the solar UV radiations for the period of November 1978 to October 1984 are obtained from Solar Geophysical Data book, NOAA, U S A. published by Department of Commerce U S A SGD comp reports October 1989 No 542 - part II and the daily average values of O_3 of Halley Bay for the same period are obtained from internet website [14] and the O_3 data for McMurdo are obtained from Komhyr *et al* [15]

Table 1. Halley Bay (76° S 27° W) during 1978 1984

Correlation coefficient between	Jan	Feb	Mar	Apr	Aug	Sept	Oct	Nov	Dec
Daily mean O_3 and daily mean solar UV flux	0.9	0.02	0.19	0.008	0.38	0.40	0.56	−0.14	0.42

Table 2. Halley Bay (76′ S 27′ W) during 1978 1984

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

*Correlation coefficients are not calculated due to insufficient data

The correlation coefficients between daily O_3 and daily UV flux have been calculated month-wise and season-wise for the period of November 1978 to October 1984, by using the statistical equation

correlation coefficient

$$\frac{N\Sigma xy - (\Sigma x)(\Sigma y)}{\left[N(\Sigma x^2) - (\Sigma x)^2\right]^{1/2}\left[N(\Sigma y^2) - (\Sigma y)^2\right]^{1/2}}$$

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

2 2 Instrument

The ozone concentration in Dobson Unit for Halley Bay was measured by "Total ozone mapping spectrometers". The same for McMurdo was measured by "Dobson spectrophotometer". The solar UV flux which is the core to wing ratio of Mg II h and k line, was measured from the "Solar back scatter ultraviolet spectral scan of Nimbus 7 satellite".

2 3 Correlation between solar UV flux and O_3 concentration of Antarctic survey stations Halley Bay and McMurdo :

The daily mean O_3 concentration values during November 1978 to October 1984 for Halley Bay in Antarctica are taken from internet system. Daily mean solar UV flux values are taken from Solar Geophysical Data book, NOAA, U.S.A. to find the correlation coefficient between solar UV flux and O_3 concentration for different months and for the different seasons during the period 1978 to 1984. The calculated correlation coefficients are given in Tables 1 and 2.

Correlation coefficient between daily mean value of O_3 concentration and daily mean values of UV flux are calculated for different months. It is found from the correlation table (Table 1) that the correlation coefficient becomes positive and maximum (0.56) for October.

The correlation coefficients between monthly mean values of O_3 concentration and yearly mean values of O_3 concentration in Antarctica are calculated for the seasons : Winter (May, June, July, August), Spring (September, October), Summer (November, December, January) and Autumn (February, March, April) and for Halley Bay it is found from the correlation table (Table 2) that the correlation coefficient becomes positive and maximum (0.72) for spring. The correlation coefficient between monthly mean value and the yearly mean value of the solar UV radiation is found to be positive and maximum (0.98) during Spring. Also the correlation between the monthly mean value of O_3 concentration and the monthly mean value of solar UV flux is positive and maximum (0.69) during Spring. Similar is the case of correlation coefficient between daily mean O_3 concentration and daily mean solar UV flux, which is positive and maximum (0.48) during Spring; for other seasons it is poor.

Again, it is found from the correlation table (Table 3) that the correlation coefficient between monthly mean value of O_3 and the monthly mean value of solar UV flux is positive and maximum (0.58) during Spring, correlation coefficient between monthly mean value of O_3 concentration and the yearly mean value of UV flux is positive and high (0.55) during Spring, also the correlation coefficient between monthly mean value of O_3 concentration and the yearly mean value of O_3 concentration is positive and maximum (0.68) during Spring.

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

The variation of the correlation coefficient between daily mean O_3 concentration and the daily mean solar UV flux as well as the variation of the correlation coefficient between the monthly mean O_3 concentration and monthly mean solar UV flux with the seasons for Antarctica are illustrated in Figure 1.

Thus, we may infer that O_3 concentration and solar UV flux are mainly controlled by their Spring values. This is

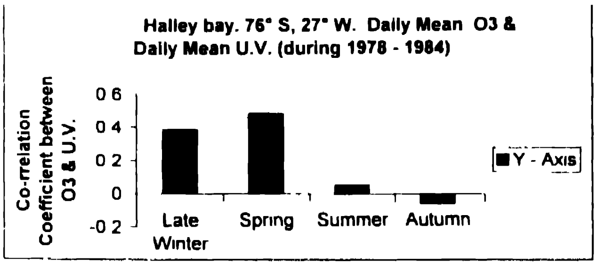

Figure 1(a). The variation of correlation coefficient between daily mean O_3 concentration at Halley Bay and daily mean solar UV flux with seasons

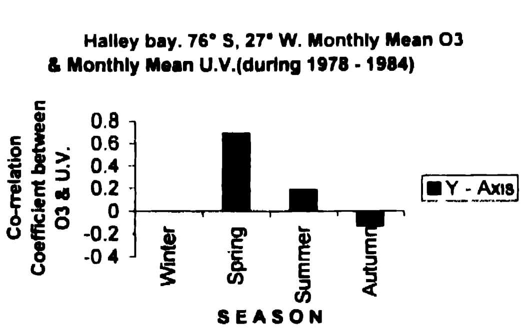

Figure 1(b). The variation of correlation coefficient between monthly mean O_3 concentration at Halley Bay and monthly mean solar UV flux with seasons (The Winter value is not computed due to insufficient data)

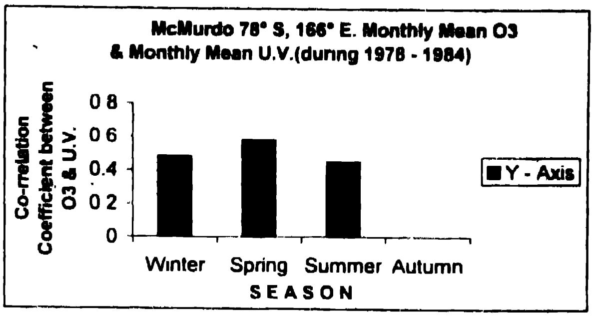

Figure 1(c). The variation of correlation coefficient between monthly mean O_3 concentration at McMurdo and monthly mean solar UV flux with seasons (The Autumn value is not computed due to insufficient data).

corroborated by Midya *et al* [13] who found the O_3 concentration and UV radiation to be mainly controlled by their October values.

2.4 Conclusions .

It is established that atmospheric ozone is produced in the stratosphere over the equatorial region from monoatomic (O) and diatomic (O_2) oxygen by the action of solar UV radiation with wavelengths less than 243 nm. Stratospheric winds carry ozone from the equatorial region towards the north and south poles. In the northern hemisphere, the circulation of winds is facilitated by the large mountain ranges like the Rockies and the Himalayas right to the north pole. In the southern hemisphere, the winds circulate to about 60° S for much of the year especially during southern Winter *i.e.* May, June, July and August. Further during southern Winter a special condition developes in the high atmosphere of polar region, when the stratospheric temperature may drop below 80° C, the man-made chemicals (mainly chlorine and bromine species) can stay in the atmosphere for 100 years. At this very low temperature during the polar nights, these pollutants form "Polar stratospheric cloud" (PSC) and become more active when sunlight appears in the Antarctica in late August and early September. By the interaction of UV radiation, rapid chemical reactions start which may destroy significant amount of atmospheric 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, PSC's 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.

It is seen from the correlation tables [(Tables (1–3)], the values of correlation coefficient between the daily mean O_3 concentration and daily mean solar UV flux are positive, being maximum for October. Also, the correlation coefficients between monthly mean O_3 concentration with monthly mean solar UV flux, or with yearly mean UV flux, or with yearly

Table 3. McMurdo (78° S, 166° E) during 1978–1984

Correlation coefficient between	Winter (May, June, July, August)	Spring (Sept., Oct.)	Summer (Nov., Dec., Jan.)	Autumn (Feb., Mar., Apr.)
Monthly mean O_3 and monthly mean solar UV flux	0 48	0 58	0 45	
Monthly mean O_3 and yearly mean solar UV flux	0 60	0 55	0.38	
Monthly mean O_3 and yearly mean O_3	0 62	0.68	0 59	
Monthly mean UV flux and yearly mean UV flux	0 90	0.98	0.93	0.96

*Correlation coefficients are not calculated due to insufficient data

mean O_3 concentration, are positive being maximum for Antarctic Spring. Even the correlation coefficient between the monthly mean solar UV flux with yearly mean solar UV flux is positive, being maximum for Antarctic Spring.

Thus, with increase of solar UV radiation, the O_3 concentration over Antarctica should increase and *vice-versa*. However, Farman *et al* [16] found that the Spring values of O_3 concentration over Antarctica decrease with years from 1957 to 1984. Thus, we may conclude that the solar UV radiation is not responsible for Antarctic ozone depletion. Maitra *et al* [6,17] also found that the solar radiation is not responsible for Arctic and tropical ozone deficit at barrow and Dumdum (India) respectively.

Acknowledgments

The authors acknowledge with regards the referee for his valuable comments. The authors also thank D Midya of Western Sydney University for providing O_3 data from internet system

References

[1] J R Bates *Solar Phys* **34** 382 (1981)

[2] R S Stolarski, P Bloomfied, R D McPeters and J R Herman *Geophys Res Lett* **18** 1015 (1991)

[3] M P McCormick, R E Vegia and W P Chu *Geophys Res Lett* **19** 269 (1992)

[4] J A Logan *Geophys Res* **99** 25553 (1994)

[5] R M Mackay, M K W Ko, R Shia, Y Yang, S Zhou and G Molnar *J Climate* **10** 774 (1997)

[6] S N Maitra, B Bhattacharjee and S S Chatterjee *Civil Engg Today* (A Journal of American Society of Civil Engrs -IS) **14** 3 (2000)

[7] S N Maitra, S K Midya, G Tarafdar, B Bhattacharjee and S S Chatterjee *Asian J Microbiol Biotech Environ Sci* **1** 2 7 (2000)

[8] S N Maitra, B Bhattacharjee and S S Chatterjee *Environment and Ecology* **18** 657 (2000)

[9] S Chapman *Mem Roy Met Soc.* **3** 103 (1930)

[10] R D Bojkov *WMO Bulletin* **41** 171 (1992)

[11] S N Ghosh and S K Midya *Indian J Phys* **68B** 473 (1994)

[12] S K Midya and D Midya *Earth, Moon and Planets* **61** 175 (1993)

[13] S K Midya, S C Ganda, G Tarafdar and T K Das *Earth, Moon and Planets* **74** 115 (1996)

[14] http . // jwosky gsfc. nasa. gov

[15] W D Komhyr, R D Grass and R D Leonard *Geophys Res Lett* **13** 1248 (1986)

[16] J C Farman, B G Gardiner and J D Shanklin *Nature* **315** 207 (1985)

[17] S N Maitra, B Bhattacharjee and G Tarafdar *Civil Engg Today* (A Journal of American Society of Civil Engrs.-IS 13) 6 3 (1999)