CHAPTER - 7

Mid Latitude O_3 covariation with derived solar U.V. radiation and possible environmenatal consequences

7.1 Introduction

In the preceding chapters two to six, the studies have been made for polar regions i,e. in Antarctica (south pole) and Arctica (North pole). In the present chapter an attempt has been made to investigate the mid-latitude ozone covariation in both the hemispheres with analytically extrapolated solar U.V. data. To investigate the covariation of atmospheric ozone concentration of midlatitude stations (Bucharest 44.48° N, 26.13° E and Lauder 45.03° S, 169.68° E) and solar U.V. radiation, a regression analysis has been performed between relative sunspot number and solar U.V. flux in order to derive the long period solar U.V. data. The correlation coefficient between sunspot number and solar U.V. flux is possitive and high (0.82%) which is definitely significant at the 5% level. From the scatter diagram between relative sunspot number and solar U.V. data, a straight line is obtained and a linear empirical equation using the least square principle has been obtained. From the equation, the values of U.V. flux for the period 1987 to 1997 are derived, to study the covariation with ozone concentration in the midlatitudinal stations at Bucharest and Lauder.

The thickness of the atmospheric Ozone layer reduced to S.T.P. is very small and varying from 1.5mm to 4.5mm, averaging 2.5mm. This thin Ozone layer protects the environment of our planet 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" molecular oxygen by the solar U.V. radiation (wave length <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).

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

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

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

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

where $(O_3)^*$ denotes excited state of O_3 and M represents a third body catalytic atom or molecule essential for the conservation of energy and momentum of the system.

It has been proved by laboratory experiment that Ozone is also destroyed by solar U.V. radiation according to the following reactions.

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

$$O + O_3 \Rightarrow 2O_2$$

$$O_3 + O_3 \Rightarrow 3O_2$$

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 destruction.

Besides these the atmospheric Ozone may also be destroyed by man made pollutants : Oxides of Nitrogen (source: supersonic air craft which emits nitrogen oxides, Nitrogenous fertilisers used for agricultural work etc.) may deplete atmospheric O_3 (Crutzen. 1970) following the reactions.

$$NO + O_3 \Rightarrow NO_2 + O_2$$

$$NO_2 + O_3 \Rightarrow NO_3 + O_2$$

Chlorofluro carbon (source : arerosol and refrigerant) may also deplete atmospheric O_3 (Molina and Roland, 1974) following the reactions.

$$Cl + O_3 \Rightarrow Clo + O_2$$

Moreover after creation of atmospheric O_3 mainly at the equatorial region, the stratospheric wind carry it towards the poles, which may also contribute the loss of Ozone at the regions near tropics and at the region near midlatitudes.

Further, statistical models suggest a high positive correlation between solar U.V. flux and O_3 concentration in the upper stratosphere and mesosphere (Summers et.al. 1990, Hood et.al. 1991, Hood and Mc Cormack. 1992, Reinsel et.al. 1994)

As solar U.V. radiation is responsible for creation as well as destruction of atmospheric Ozone (Chapman, 1930), so in this chapter an attempt has been made to estimate the covariation of solar U.V. radiation with the O_3 concentration at the mid latitude regions of both the hemispheres.

In absence of long period solar U.V. flux data, a mathematical regression analysis has been performed between relative sunspot number and solar U.V. data (six years data set of Nimbus 7 satellite) to derive the solar U.V. data for atleast one solar cycle, i,e, from 1987 to

1997. The observational evidence suggests that the U.V. radiation increases with the increase of relative sunspot number (Heath and Thekaekara. 1977, Gille et.al. 1984, Heath and Schlesinger. 1985). Also another statistical model suggests a high positive correlation between atmospheric O_3 and sunspot number (Angell 1989).

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 on the surface of the earth (mainly UV-B, wavelength range 280 nm. to 320nm.) 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 Williamson. 1995), Humans and animals (Taylor 1989, Vanderleun et.al. 1993, Lay et.al. 1989, Nikula et.al. 1992, Schothorst et.al.1987, Scotto et.al. 1981, Robertson 1972, Paltridge et.al. 1978, Tigel et.al. 1987). 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 tropospheric 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; viz

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 rainfall; weather disturbances 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).

Many investigators have worked on Global Ozone depletion. Antarctic Ozone depletion have been reported by number of investigators (Farman et.al. 1985, stolarski et.al. 1991, Ghosh et.al. 1994 Logan 1994, Midya et.al. 1996, Maitra et.al. 2000 and others). Ozone loss in Arctic region have been reported by various workers (Schoeberl et.al. 1990, zurek et.al. 1996, Manney et.al. 1996, Dessler et.al. 1998, Maitra et.al. 2000 and others).

Ozone deficit in tropical /equatorial region have been reported by Ilyas (1986), Maitra et.al. (2000). Few investigators have also worked on Ozone loss in Midlatitudes (DeLuisi et.al. and others).

This chapter presents the study of O_3 covariation with derived solar U.V. radiation at the midlatitude stations of both the hemisphere.

For mathematical analysis, the daily solar U.V. data of Nimbus 7 satellite are obtained from solar Geophysical Data comp. reports. October 1989 No. 542 - Part II. for the period Nov'78 to Oct'84. The Daily relative sunspot number are obtained from the internet website ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA, for the same period. The solar data are tabulated in chapter 1 page 32 to 40 & 58, 63 to 69.

The O_3 data of Bucharest (44.48°N, 26.13°E) and the O_3 data of Lauder (45.03°S, 169.68°E) are obtained from the internet website of world Ozone data centre (WODC) Canada http://www.tor.ec,gc,ca for the period 1987 to 1997, tabulated in chapter 1, page 29, 30.

7.2. Analysis, Discussion and Conclusions

7.2.1 Analysis

A statistical analysis between solar U.V. data (Nov'78 to Oct'84) and relative sunspot number presents a high positive correlation (82%). A scatter diagram (Figure - 7.3.1) between the solar U.V. data and the relative sunspot number shows an upward trend of the values of solar U.V. flux with increase of relative sunspot number. A linear empirical equation using the least square principle is obtained. The regression analysis gives the following equation :

$$\text{Solar U.V. flux} = 0.2675 + 8 \times 10^{-5} \times \text{Sunspot no.} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (7.2.1.1)$$

By using the equation (7.2.1.1) the monthly mean solar U.V. data have been computed (Table - 7.3.1) to study the correlation between O_3 concentration at midlatitude stations (Bucharest 44.48°N, 26.13°E & Lauder 45.03°S, 169.68°E) and solar U.V. flux by using the equation 2.2.1.1.

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

Where "x" is the value of solar U.V. flux "y" is the value of O_3 concentration at the midlatitude

stations. "N" is the number of data for which the values of U.V. flux and Ozone concentration are available.

7.2.2 Correlation between derived solar U.V. flux and O3 concentration of midlatitude stations: Bucharest and Lauder

The derived data of solar U.V. flux by the equation (7.2.1.1) are compared with the available NOAA 9 satellite data and the variation found below 1% to 2% only (Table - 7.3.2). And the Correlation coefficeint between derived and NOAA 9 satellite U.V. data is positive also very high (0.95) and definitely significant at 5% level.

The covariation between observed and derived U.V. flux during January' 1987 to December' 1988 are shown in fig. - 7.3.2.

The monthly mean value of O_3 concentration during the priod 1987 to 1997 for both the mid latitude stations are taken to find the correlation coefficient between solar U.V. flux and Ozone concentration for different seasons during above mentioned period. The calculated correlation coefficients are given in Table 7.3.3 and Table 7.3.4.

Correlation coefficeints are calculated (using eqn. 2.2.1.1)of monthly mean values of O_3 concentration at Bucharest, Romania (44.48°N, 26.13°E) or Lauder, Newzealand (45.03°S, 169.68°E) with yearly mean values of O_3 concentration for the seasons of winter, spring, summer and autumn. It is found from the correlation Table - 7.3.3 & Table - 7.3.4 that the correlation coefficients becomes positive and maximum (0.69) & (0.72) respectively for the spring.

The correlation coefficeints are calculated between monthly mean values of O_3 concentration of Bucharest and monthly mean values of solar U.V. flux is negative and maximum (-0.37) for spring which is not significant at 5% level. Also the correlation coefficeint between monthly mean O_3 concentration and yearly mean value of solar U.V. flux (-0.28) are negative and maximum during spring and not significant at 5% level. The other correlation coefficients are in significant.

The correlation coefficients are also calculated between monthly mean values of O_3 concentration of lauder and monthly mean value of solar U.V. flux and found to be positive and insignificant (0.06). Also the correlation coefficient between monthly mean O_3 concentration and yearly mean solar U.V. flux (0.14) are positive and maximum during spring in comparison to the correlation coefficients during other seasons. The other correlation

coefficients are insignificant. All these calculated correlation coefficients are not at all significant at 5% level.

The variations of midlatitude O_3 concentration at Lauder, Bucharest and solar U.V. flux with year for the season spring during the period 1987 to 1997 are shown in Figure - 7.3.3 & Figure -7.3.4. (For the value of U.V. flux, multiply with 10^{-3}).

7.2.3 Conclusions

It is found from the analysis that the seasonal mean Ozone concentration is maximum in spring and minimum in autumn for both the mid latitude stations. The seasonal mean O_3 during the winter of 1992 at the southern midlatitude station Lauder was 339.5 D.U. which decreases to 301 D.U. during the winter of 1997, the perecentage loss is 11.34%. At the northern midlatitude station Bucharest, the seasonal mean O_3 during the winter of 1991 found to 336 D.U. which decreases to 315 D.U. during the winter of 1995, a loss of 6.25%.

On the other hand the seasonal mean O_3 during the spring of 1988 at Lauder was 365 D.U. which decreases to 325 D.U. during the spring of 1997, the percentage loss is 11%. At Bucharest seasonal mean O_3 during the spring of 1987 found to 411 D.U. which decreases to 315 D.U. during the spring of 1995, a loss of 12.47%.

Again the seasonal mean O_3 during the summer of 1987 at Lauder was 307 D.U. which decreases to 298 D.U. during the summer of 1997, the percentage loss is 2.93%. At Bucharest seasonal mean O_3 during the summer of 1987 found to 350 D.U. which decreases to 309 D.U. in 1988 a loss of 11.71% and in 1995 it is found as 328 D.U. a loss of 6.29% with respect to 1987.

Further more the seasonal mean O_3 during the Autumn of 1987 at Lauder was 277 which decreases to 265 D.U. in 1994 a loss of 4.33% and in 1996 it is found to be 267 D.U. a loss of 3.61%. At Bucharest during Autumn of 1987, the seasonal mean O_3 was 313 D.U. which decreases to 291 D.U. in 1993 and 295 D.U. in 1995 a loss of 7% and 5.75% respectively. Therefore a significant loss of O_3 concentration in the season spring in both the midlatitude stations of Northern and Southern hemisphere are alarming, which may increase the risk of cataract, malignant and non malignant melanoma and other climatic and environmental hazards, if this trend continues.

The Scientific Assessment of O_3 depletion by world meteoroligical organisation Report No. 37, 1994 Geneva reveals the following :

The volcanic eruption of Mt. Pinatubo in 1991 has increased to sulfate aerosol in the upper atmosphere, which may decrease Ozone in the midlatitudes of both hemispheres. The

Ozone loss is larger in northern hemisphere than southern hemisphere. Also the man made pollutants (NOx, ClOx etc.) plays important role in the chemical destruction of midlatitude Ozone. Further the Ozone depleted air from polar regions has the potential to influence the Ozone loss at middle latitudes. The global total column Ozone analysis by W.M.O. found a significant loss of Ozone in all seasons at mid latitudes of both the hemispheres. The increased surface dosage of U.V. radiation at midlatitudes were observed by W.M.O.

These above mentioned fidings of WMO (1994) may be the possible reason of anticorrelation or poor correlation between the O_3 concentration and U.V. flux in the mid latitude stations of both hemispheres. However, the WMO (1998) assessment found that the declining trend of O_3 concentration in mid latitudes for both the hemispheres has slowed.

The correlation between O_3 concentration and solar U.V. flux are not high negative or high positive. If the solar ultraviolet radiation, would have been responsible for the midlatitudinal ozone depletion, then the correlation coefficients between O_3 concentration and solar U.V. radiation should have been high negative in seasons when ozone concentration is minimum for each of the mid latitude stations in both the hemispheres, i,e in Autumn. But it is found that the calculated correlation coefficients are not at all significant at 5% level, thus we may conclude that the O_3 depletion in midlatitudes of both the hemispheres are independent of solar U.V. radiation with severe environmental consequences. Therefore the Ozone depletion in midlatitudes of both the hemisphere mostly may be due to the natural phenomena (example : Volcanic eruption, stratospheric wind circulation pattern, etc.) and some may be due to the man made pollutants.We can not control natural phenomena but we can control the man made pollutants.

So to control Ozone 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, so that they will not deplete Ozone and will not pollute environment in other form. Moreover they should have properties to destroy the molecules of pollutants which are already in atmosphere. Action on this line is suggested in "The Montreal protocol, 1987" which amended and adjusted on 1992 (Copenhagen) need be implemented immediately for the recovery of the Ozone layer (WMO report 37, 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 deforestation resulting in greater damage to the natural ecological system on our planet thus increasing the production of O_3 destroying pollutants.

Table - 7.3.1

Derived monthly mean solar ultraviolet flux during 1987 to 1997

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1987	0.2683	0.2677	0.2687	0.2707	0.2701	0.2689	0.2701	0.2706	0.2702	0.2723	0.2707	0.2697
1988	0.2722	0.2707	0.2736	0.2745	0.2723	0.2756	0.2766	0.2764	0.2771	0.2775	0.2775	0.2818
1989	0.2804	0.2807	0.2780	0.2779	0.2786	0.2832	0.2777	0.2810	0.2816	0.2803	0.2813	0.2807
1990	0.2817	0.2779	0.2787	0.2787	0.2781	0.2759	0.2795	0.2835	0.2775	0.2791	0.2780	0.2779
1991	0.2785	0.2809	0.2789	0.2787	0.2772	0.2811	0.2814	0.2816	0.2775	0.2790	0.2762	0.2791
1992	0.2795	0.2804	0.2760	0.2755	0.2734	0.2727	0.2744	0.2727	0.2726	0.2746	0.2748	0.2741
1993	0.2722	0.2748	0.2731	0.2725	0.2724	0.2715	0.2721	0.2709	0.2693	0.2720	0.2703	0.2714
1994	0.2721	0.2703	0.2700	0.2804	0.2689	0.2697	0.2703	0.2693	0.2696	0.2710	0.2689	0.2696
1995	0.2694	0.2699	0.2700	0.2686	0.2687	0.2687	0.2687	0.2686	0.2684	0.2692	0.2682	0.2683
1996	0.2684	0.2679	0.2682	0.2679	0.2679	0.2684	0.2682	0.2687	0.2676	0.2676	0.2689	0.2686
1997	0.2680	0.2681	0.2682	0.2687	0.2690	0.2685	0.2683	0.2695	0.2716	0.2693	0.2706	0.2708

Table - 7.3.2

Comparison between observed NOAA-9 satellite U.V. flux and Mathematicaly derived U.V. flux during the period January 1987 to December 1988

Month & Year	Observed U.V. flux	Derived U.V. flux	Variation
Jan 1987	0.2640	0.2683	1.63%
Feb 1987	0.2639	0.2677	1.44%
Mar 1987	0.2642	0.2687	1.70%
Apr 1987	0.2654	0.2707	2%
May 1987	0.2661	0.2701	1.5%
June 1987	0.2658	0.2689	1.16%
July 1987	0.2664	0.2701	1.39%
Aug 1987	0.2666	0.2706	1.5%
Sept 1987	0.2663	0.2702	1.47%
Oct 1987	0.2672	0.2723	1.9%
Nov 1987	0.2681	0.2707	0.97%
Dec 1987	0.2675	0.2697	0.82%
Jan 1988	0.2689	0.2722	1.23%
Feb 1988	0.2692	0.2707	0.56%
Mar 1988	0.2695	0.2736	1.5%
Apr 1988	0.2714	0.2745	1.14%
May 1988	0.2710	0.2723	0.48%
June 1988	0.2729	0.2756	0.99%
July 1988	0.2734	0.2766	1.17%
Aug 1988	0.2742	0.2764	0.8%
Sept 1988	0.2741	0.2771	1.09%
Nov 1988	0.2751	0.2775	0.87%
Dec 1988	0.2776	0.2818	1.51%

Table - 7.3.3

Correlation coefficient between O_3 concentration and solar U.V. flux during 1987 to 1997

STN : - BUCHAREST, Romania (44.48°N, 26.13°E)

Correlation coefficient between	Winter Nov, Dec, Jan, Feb	Spring Mar, Apr	Summer May, June, July	Autumn Aug, Sept, Oct
1. Monthly mean O_3 concentration and monthly mean U.V. flux	-0.06	-0.37	0.09	0.09
2. Monthly mean O_3 concentration and yearly mean U.V. flux	-0.10	-0.28	0.20	0.06
3. Monthly mean O_3 concentration and yearly mean O_3 concentration	0.29	0.69	0.38	0.47

Table - 7.3.4

Correlation coefficient between O_3 concentration and solar U.V. flux during 1987 to 1997

STN : - LAUDER, Newzealand (45.03°S, 169.68°E)

Correlation coefficient between	Winter May, Jun, July, Aug	Spring Sep, Oct	Summer Nov, Dec, Jan	Autumn Feb, Mar, Apr
1. Monthly mean O_3 concentration and monthly mean U.V. flux	0.12	0.06	-0.03	-0.12
2. Monthly mean O_3 concentration and yearly mean U.V. flux	0.07	0.14	0.04	-0.06
3. Monthly mean O_3 concentration and yearly mean O_3 concentration	0.28	0.72	0.11	-0.11

SCATTER DIAGRAM BETWEEN RELATIVE SUNSPOT NUMBER & SOLAR U.V. FLUX

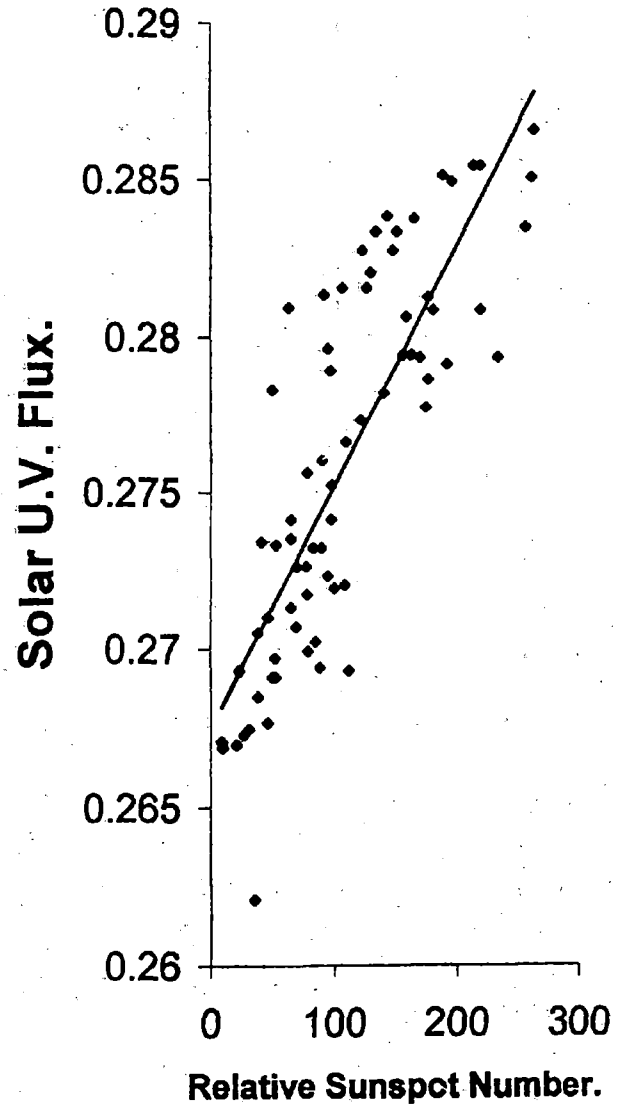

Fig. 7.3.1

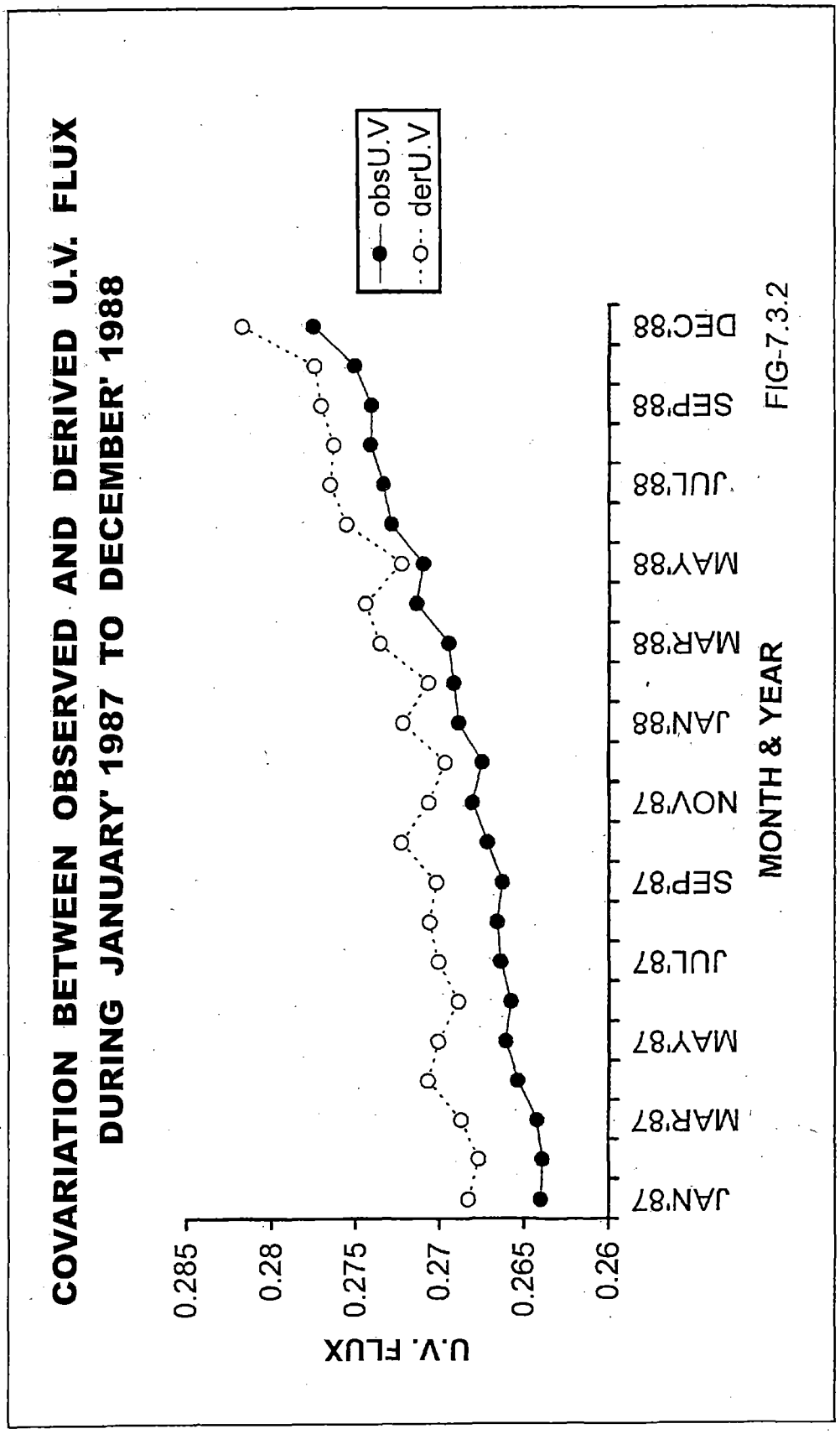
COVARIATION BETWEEN OBSERVED AND DERIVED U.V. FLUX
DURING JANUARY' 1987 TO DECEMBER' 1988
obsU.V
derU.V
U.V. FLUX
0.285
0.28
0.275
0.27
0.265
0.26
JAN'87
MAR'87
MAY'87
JUL'87
SEP'87
NOV'87
JAN'88
MAR'88
MAY'88
JUL'88
SEP'88
DEC'88
MONTH & YEAR

FIG-7.3.2

SOUTHERN MID LATITUDE O3 CO-VARIATION WITH SOLAR U.V. FLUX IN THE SEASON SPRING DURING 1987-1997

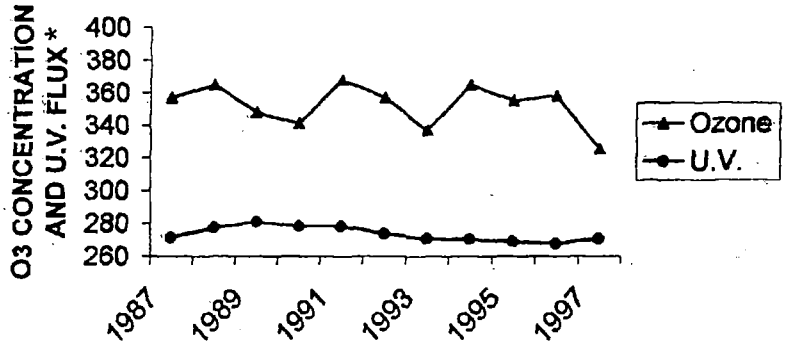

Fig. 7.3.4

(* To obtain range of values of U.V. flux multiply the "y" axis values by 10^{-3})

NORTHERN MID LATITUDE O3 CO VARIATION WITH SOLAR U.V. FLUX IN THE SEASON SPRING DURING 1987-1997

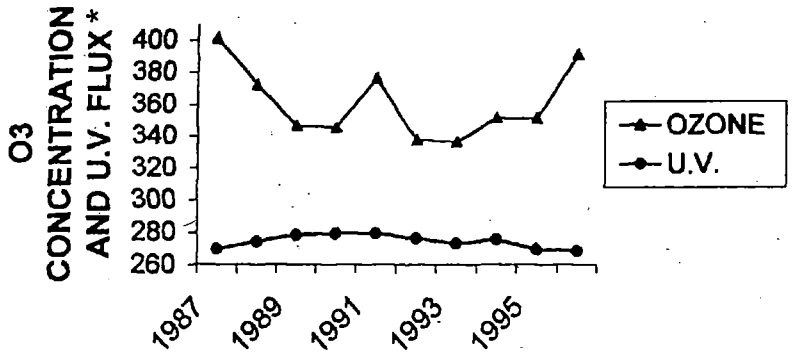

Fig. 7.3.3

(* To obtain range of values of U.V. flux multiply the "y" axis values by 10^{-3})

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