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# UV-B Radiation Intensity Measurements at Antarctica

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## Abstract

The UV-B radiation intensity measurements, at various wavelengths, were carried out at different time slots during the January 1987-February 1992 period. The analysis of these observations shows that, in addition to atmospheric ozone, the other factors like cloud scattering and aerosol scattering also play an important role in affecting the solar UV-B intensities. It is found that due to these additional factors, the anticorrelation factor between atmospheric ozone content and UV-B intensity is different for different atmospheric conditions over the Maitri Station of Antarctica.

## Introduction

The discovery of the remarkably large atmospheric ozone losses in Antarctica during the 1980's was an event totally unpredicted by anyone. That discovery was quickly followed by intense scientific inquiry that continues today. Qualitatively, it has been found that the ozone reduction process is dominantly chemical. The mechanism is mainly due to heterogeneous reactions on the surfaces of polar stratospheric clouds (PSC) that convert the relatively inert chlorine compounds into reactive chlorine which, after its production, catalytically attacks and consequently results in ozone reduction. The production of the critically important PSC, for ozone depletion depends on the dynamical processes of the atmosphere which control the chemical switch and decide whether the PSC will be formed or not. The existence of PSC require very cold polar temperatures that can only exist when stratospheric dynamical activity is low. So, the polar ozone depletion processes appear to depend sensitively upon the details of the interplay between chemical and dynamical processes. Furthermore, the dynamical processes are affected by radiation environment and radiation climatology of the region. Thus, the ozone depletion becomes a complex product of the senstive interplay of the chemical, dynamical and radiation environment of the region.

The initial Antarctic ozone depletion studies through UV-B radiation intensity measurements (Hanjura et al, 1988; Lubin et al.,1989; Sharma & Srivastava,1992 and Singh et al.,1992) have been done in context of direct anticorrelation between the atmospheric ozone content and the UV-B radiation intensities measured at the earth's surface. Afterwords, Lubin and Frederick (1991) have included the role of clouds in affecting the UV-B intensities reaching the earth's surface. As the measurements of the UV-B irradiance include the combined effects of its attenuation by ozone layer and its scattering by the clouds, hence both these processes are important in determining the radiation climatology of a region. The transmission of UV-B radiation associated with scattering by clouds varies overtime-scales of few hours to few days and hence the UV-B irradiance reaching the earth's surface will have the variation on the scale of few hours to few days due to the scattering effects of clouds. The present study, about UV-B intensity variation at Antarctica, is carried out to see whether the UV-B radiation intensities reaching the earth's surface have additional effects on its variation other than the variation due to atmospheric ozone content variations. For this purpose the data on UV-B intensity measurements at Indian Antarctic Station Maitri (70°46'S, 11°45'E) for the period January 1987 to February 1992 were analysed.

## Experimental Setup and Data Recordings

The ultraviolet radiation intensities were measured by two instruments. One was a single filter photometer (Srivastava and Sharma, 1979; srivastava et al.,1989) designed and developed by National Physical Laboratory, New Delhi. This instrument uses an interference filter selecting the wavelength at 310 nm, The bandwidth of the filter is 5 nm and transmission is ~30%. The ultraviolet radiation after passing through the filter falls on a photomultiplier tube which converts the radiation energy into electrical energy and the signal from the photomultiplier tube is amplified and measured either by a multimeter or a datalogger. The output in the final form is in millivolts. The second instrument used for UV-B radiation intensity measurement was a monochromator based spectroradiometer. The total system is a computer controlled instrument having a grating which can select the wavelength in the range 200-800 nm. In this instrument three diffusers can be used. The first diffuser, which is a quartz diffuser, is used in the wavelength range 200-400 nm, the second diffuser, which is tefflon diffuser, is used in the wavelength range of 250-400 nm and third diffuser (opal diffuser) is used in the wavelength range of 380-800 nm. The wavelength resolution is 1 nm. The radiation after being selected by monochromator falls through a slit on a photomultiplier tube which converts the radiation energy into electrical signal. This signal is amplified and after using the calibration factors is again converted into equivalent of radiation energy. This whole process is performed by an on-line computer. For Antarctic UV-B radiation measurements, this spectroradiometer was operated between 280-368 nm. The wavelength resolution was kept 2 nm for 280-320 nm and the intensity at 368 nm was measured separately. The 368 nm intensity was measured for normalising the radiation intensities at other wavelengths. The radiation intensity at 368 nm was taken as the unattenuated radiation by ozone layer.

## Results and Discussion

The UV-B observations by National Physical Laboratory at Antarctica started since January 1987 and continued upto February 1992. In 1987 the observations were carried out by NPL built photometer. The variation of UV-B radiation intensity from Day No. 1 to Day No. 45 for this year at 310 nm for 60° solar zenith angle are shown in Fig. 1a. It is seen that the intensity variation has two components, one day to day variation on'small time scales and the second on the larger time scale in which the UV-B intensity maximises around 25-30 January. If the straight line curve fitting is perfomed on the data during this period, the straight line is with positive gradient and if the curve fitting is performed for second degree approximation, the curve maximises in the middle having lower values on both sides of this maximum. To have an assessment of the correlation between the UV- B intensities and total atmospheric ozone values, the curve in Fig. lb is drawn between the day numbers of the similar period and the total ozone values observed by the TOMS (Niu et al.,1992). It is seen here that an anti-correlation is generally maintained between the UV-B intensities and the ozone values. The straight line fit for the ozone values for this period shows a negative gradient almost of the similar magnitude as that of the positive gradient between UV-B intensities and the identical day numbers.

To further study the magnitude of anti-correlation between UV-B radiation intensities and the total ozone values for Jan-Feb, 1989 period, the UV-B radiation intensities at 290, 300 and 310 nm for 60° solar zenith angle were plotted alongwith total ozone values for the same day numbers 20-65. The plot is shown in Fig.2. It can be seen in this figure that the anti-correlation between the UV-B intensities and the total ozone values is not very strong. This anti-correlation is sometimes so weak that for certain days the anti-correlation becomes even the direct correlation. The breakdown of this general anti-correlation is further analysed through Fig.3. In this figure the UV-B radiation intensities are plotted against the total ozone values for the day numbers 20-60, 1989. It is seen in this figure that on the average for this period the anti-correlation between the UV-B radiation intensities and the total ozone values is generally broken for all the three wavelengths. The breakdown of strong anti-correlation between the UV-B radiation intensities and the total columnar ozone content may find its explanation in the studies of Frederick et al.,1993; Davies, 1993 & Liu et al.,1991. These studies have shown that the pollutants present in the planetary boundary layer absorb the radiation quite significantly and that at relatively higher solar zenith angles the UV radiation is perturbed a lot due to a stratospheric aerosol layer present above the absorbing ozone layer. So in totality the UV radiation is affected by, in addition to ozone absorption, stratospheric aerosols, polar stratospheric clouds, cloud scattering in general and the boundary layer pollutants. Hence the anti-correlation between the UV-B radiation intensity

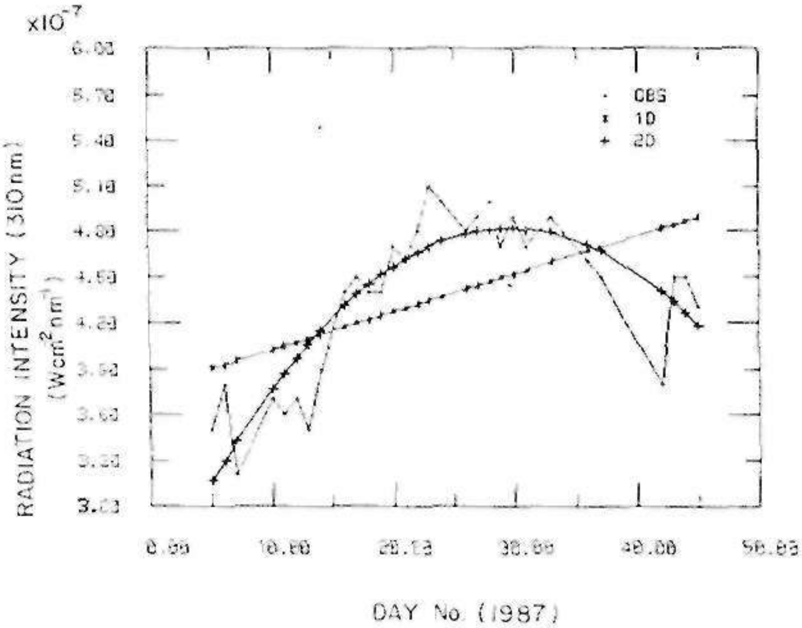



*Fig. 1a. Variation of solar intensity (310 nm) with time for the January-February period of 1987. The first degree and second degree curve fit in the observed data is also shown.*

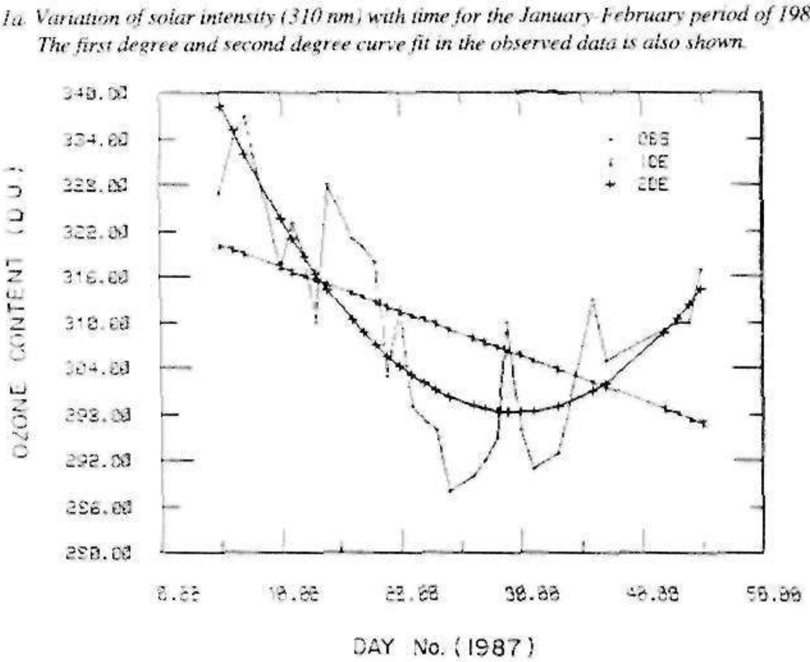



*Fig. 1b. Variation of total columnar ozone content (DU) with time for the January-February period of 1987. The first and second degree curve fit in the observed data is also shown.*

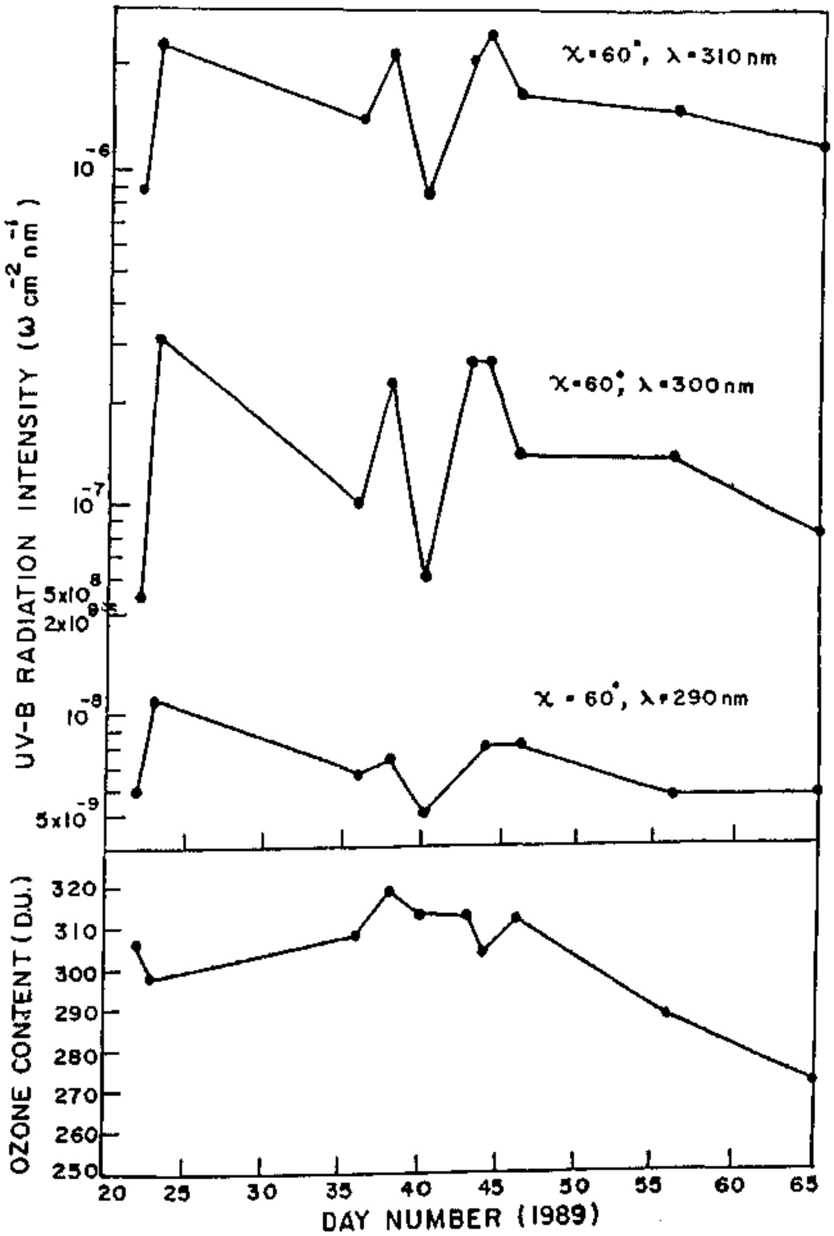
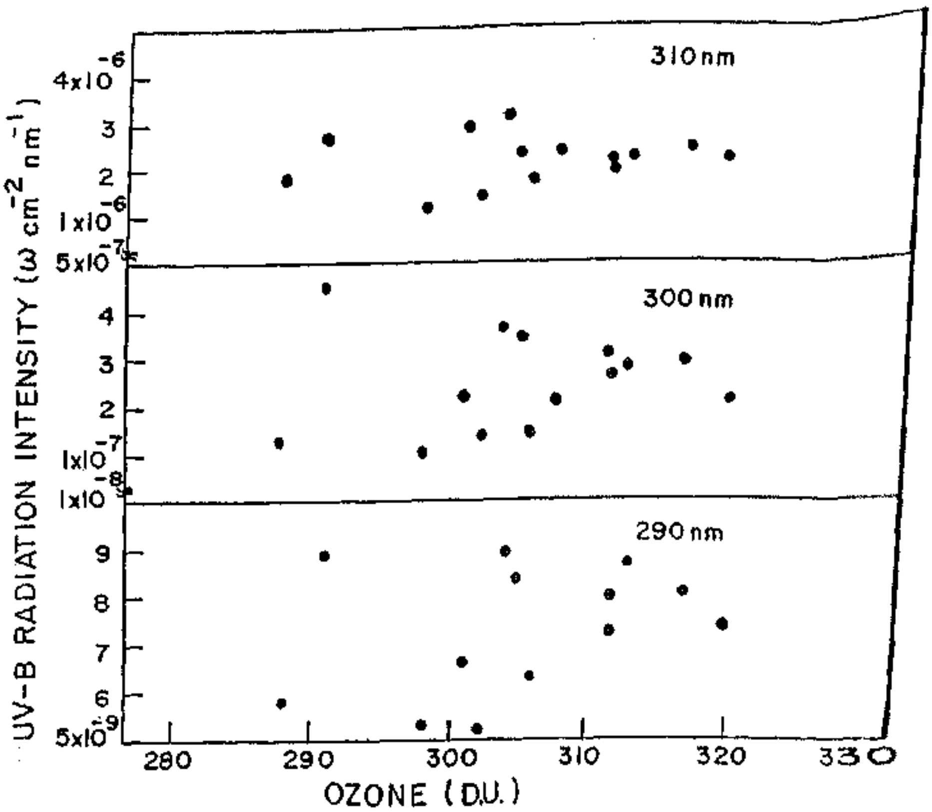



*Fig. 2. Relation of solar intensity at three wavelengths 290, 300 and 310 nm and also the variation of total columnar ozone content with time for the period 20-65 day numbers of 1989.*




*Fig, 3. Variation of UV-B intensity v/s ozone content correlation with time for the period of 20- 60 day numbers of 1989.*

and ozone content is disturbed by many other factors and these factors sometimes are quite effective not allowing this anti-correlation to remain strong.

The anti-correlation between UV-B radiation intensities and the total ozone values were further studied for the period of January- February, 1990. The UV-B radiation intensities for 310 nm at 58° solar zenith angle and total ozone values obtained by TOMS were plotted for the identical time-period. The correlation is shown in Fig.4. It can be seen from this figure that both the direct correlation and anti-correlation exist during this period. During January month there seems to be direct correlation while during the February month both the direct correlation and the anti-correlation seem to be operating. Of course, the data on UV- B intensities is not very intense but the trend can be assessed out of this scarce data also.

Further the observations on UV-B radiation intensities during the January-February months of 1990 show a rather peculiar feature. The radiation intensities for this period often show an east-west asymmetry. It is found that at many occasions the radiation intensities measured in the pre-noon times are higher than those for the after-noon time for the similar solar zenith angles. A typical example is shown in Fig.5. Fig.5a shows the 310 nm radiation intensity variation with local (GMT) time. The local noon at Indian Antarctic station Maitri is 11.12 hrs GMT. It can be seen from this figure that the forenoon values for the day number 50 of the year 1990 are higher than the afternoon values of the same day. This phenomenon is seen to be repeating on many number of days of January- February, 1990 period. This type of asymmetry is not seen in the observations pertaining to the similar period of the year 1989. The observations for the similar period of Jan.-Feb. of 1989 and 1990 were taken by the same instrument i.e. spectro-radiometer. The east-west asymmetry is further clarified in Fig.5b. In this figure the variation of UV-B radiation intensity for 310 nm is shown with solar zenith angle. Alongwith the intensity values the local time is also shown. It can be seen from this figure that the intensities of similar mangitude are available at higher solar zenith angles in the forenoon periods than the afternoon periods.

So far the correlation between the UV-B radiation intensities and the ozone values were studied for the southern summer period. This correlation is also studied for the austral spring periods. The single filter photometer and the spectroradiorneter were operated during the austral spring of 1990 and 1991 respectively. The variation of UV-B radiation intensity with solar zenith angle for different months of the year 1990 is shown in Fig.6. It can be seen from this figure that there are large fluctuations during the months of January and February when the solar zenith angles are relatively smaller. It is also seen here that the intensities have something like periodic type variations during this period. Further, the difference in intensities for the period of Jan.-Feb. on one hand and for the period of November on the other hand can be seen in this figure. The intensities for the period of November 1990 are higher than those for Jan.-Feb., 1990. This indicates that the effect of ozone hole has deeply penetrated well into the whole month of November 1990. Again, it is also observed that the radiation intensities remain almost same for solar zenith angles larger than 56° for all the months of 1990. The intensities do not change for these solar zenith angle during the months of austral spring compared to the Jan.-Feb. months of the same year.

The unchanged intensities at higher solar zenith angles for different periods of the year 1990 including the ozone hole period may find its explanation in the work of Davies (1993). In this study, it is seen that at the larger solar zenith angles the UV radiation is affected to a greater extent by the aerosol contents in the stratosphere if there is a significant absorbing layer like, ozone layer, below this stratospheric aerosol layer. If such type of conditions are operative then the ozone absorption is

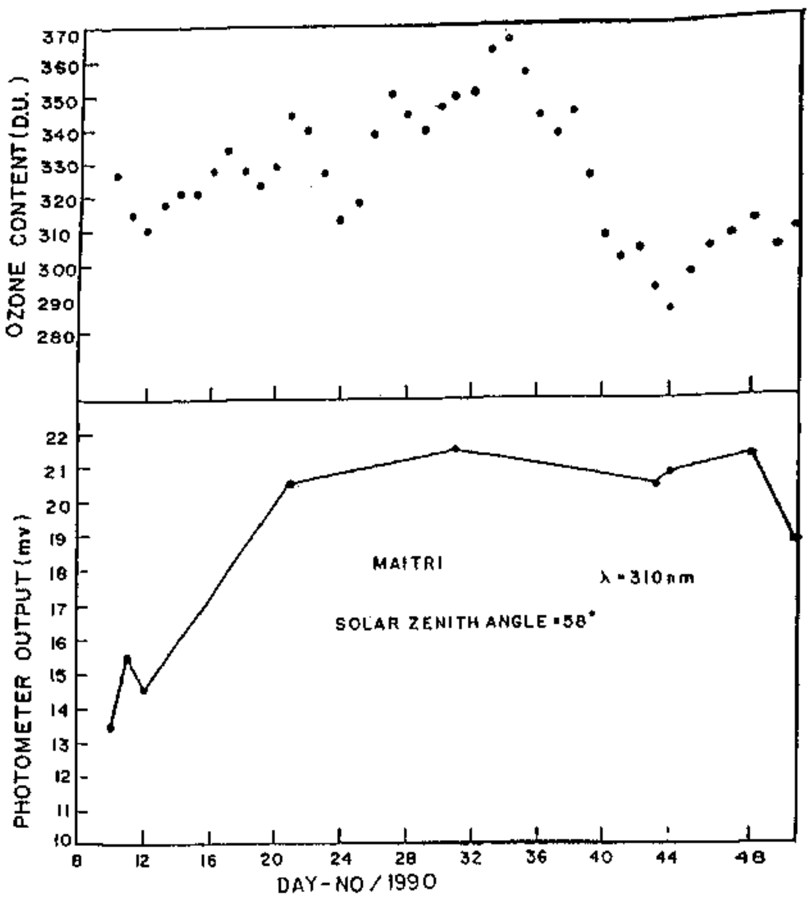



*Fig. 4. Variation of UV-B intensity and total columnar ozone content with time for the period 8.50 day numbers of 1990,*

not the only affecting parameter for UV-B radiations but also the stratospheric aerosol layer, polar stratospheric clouds and the absorption by boundary layer pollutants (Frederick & Alberts,1991 Frederick & Snell,1993;Frederick & Wealh-erhood,1992) also play important roles. Hence, the picture of variation in UV-B radiation becomes a multifactor dependent. This may give rise to an unusual type of pattern like the one given in this figure.

The behaviour of the ultraviolet radiation intensities during the austral spring for the month of November, 1991 is shown in Fig.7. The total ozone values derived by TOMS are also plotted for the same period. It may be seen from this figure that the anti- correlation is almost maintained between the UV-B intensities and the total

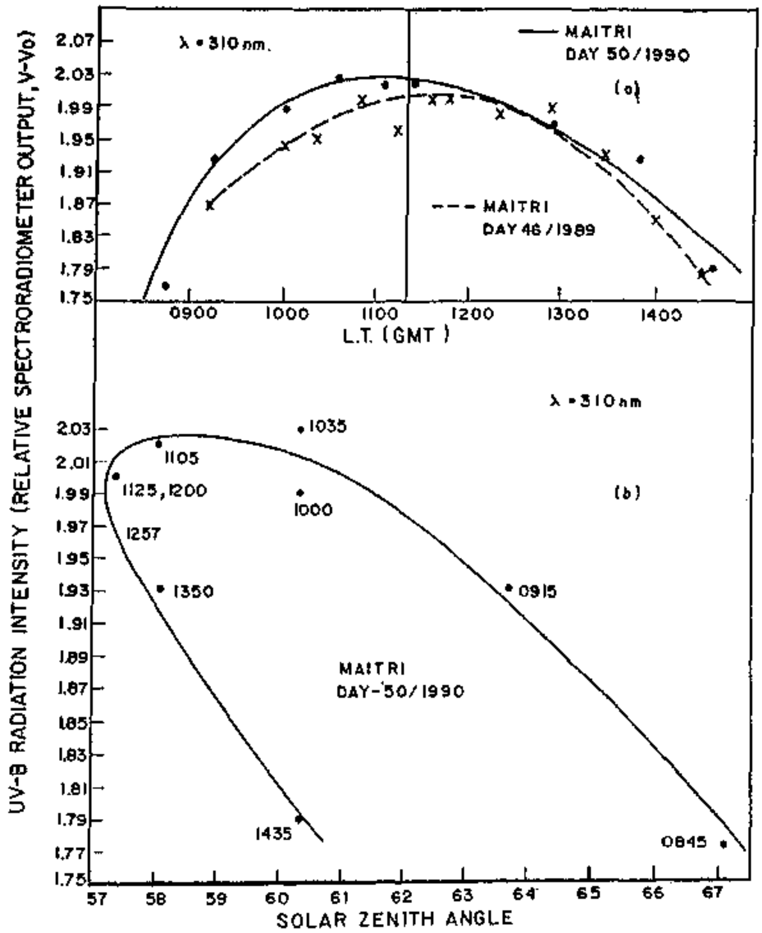



*Fig. 5, Variation of solar intensity at 310 nm with local time and also with solar zenith angle.*

ozone values. This anti-correlation is maintained on almost all the UV-B wavelengths.

The absorption co-efficient of UV-B radiation by ozone varies with radiation wavelength. Absorption co-efficient decreases with increasing wavelength in entire UV-B range being maximum at 280 nm and minimum at 320 nm. If one goes deep into the UV-A range then the absorption is still less and around 350 nm the absorption is almost negligible. The calibration of the UV-B measuring instrument has always been a problem. To overcome this problem, the ratio of the intensities at two wavelengths, one in the absorption range I and another outside the absorption range IR is calculated and then the variation of this ratio for different periods and

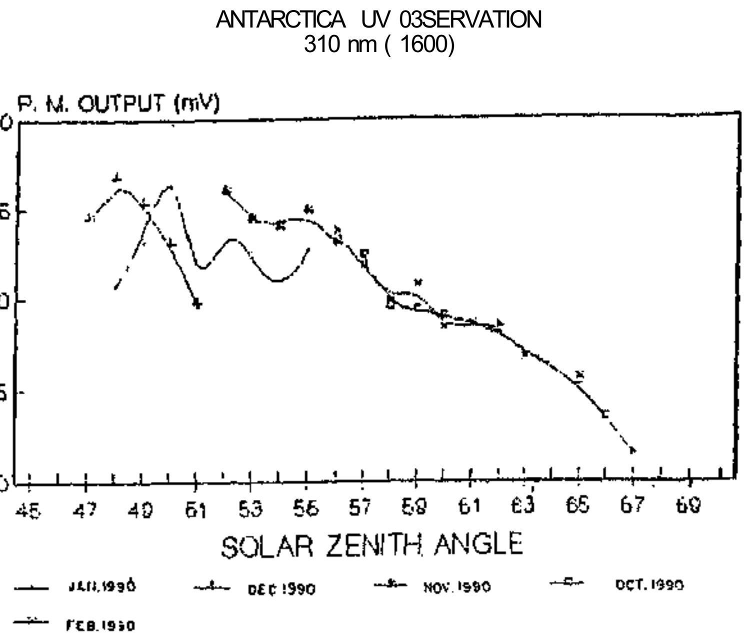



*Fig. 6. Variation of soiar intensity at 310 nm (in the form of photomultiplier tube output) with solar zenith angle for the different periods of 1990,*

different wavelengths are studied. One such typical example is shown in Fig.8. Curves 1, 2 and 3 are taken from Frederick and Alberts (1991). In this study the authors took the ratios of the radiation intensities measured at Palmer station (64.8$^{O}$ S) at Antarctica, at different wavelengths in UV-B range with the radiation intensity at 350 nm as the reference and unattenuated radiation. They found that the ratios were quite high in 1990 compared to 1988 and the Palmer values were at times higher in the month of December as compared to the October values of the same year. This shows that the ozone hole phenomenon sometimes penetrates quite deep in time after the austral spring. The authors have calculated the intensity ratios taking 368 nm wavelength as the reference (IR) wavelength outside the UV-B range. This analysis was done for the austral spring of year 1991 and 1992. The curve 4 in Fig.8 pertains to this study. It is shown that the ratio values at different wavelengths measured at Maitri station of Indian scientific expedition at Anatarctica are higher than those measured at the Palmer Antarctic station. This may again be due to the different radiation climatology and the different radiation environment of the two stations. Also the Palmer values are for the October-December period of 1990 while the Maitri values are for January as well as austral spring months of the year 1991.

The extent of the penetration of the ozone hole phenomenon beyond the austral spring in Antarctica varies from year to year, The ozone hole was not fully

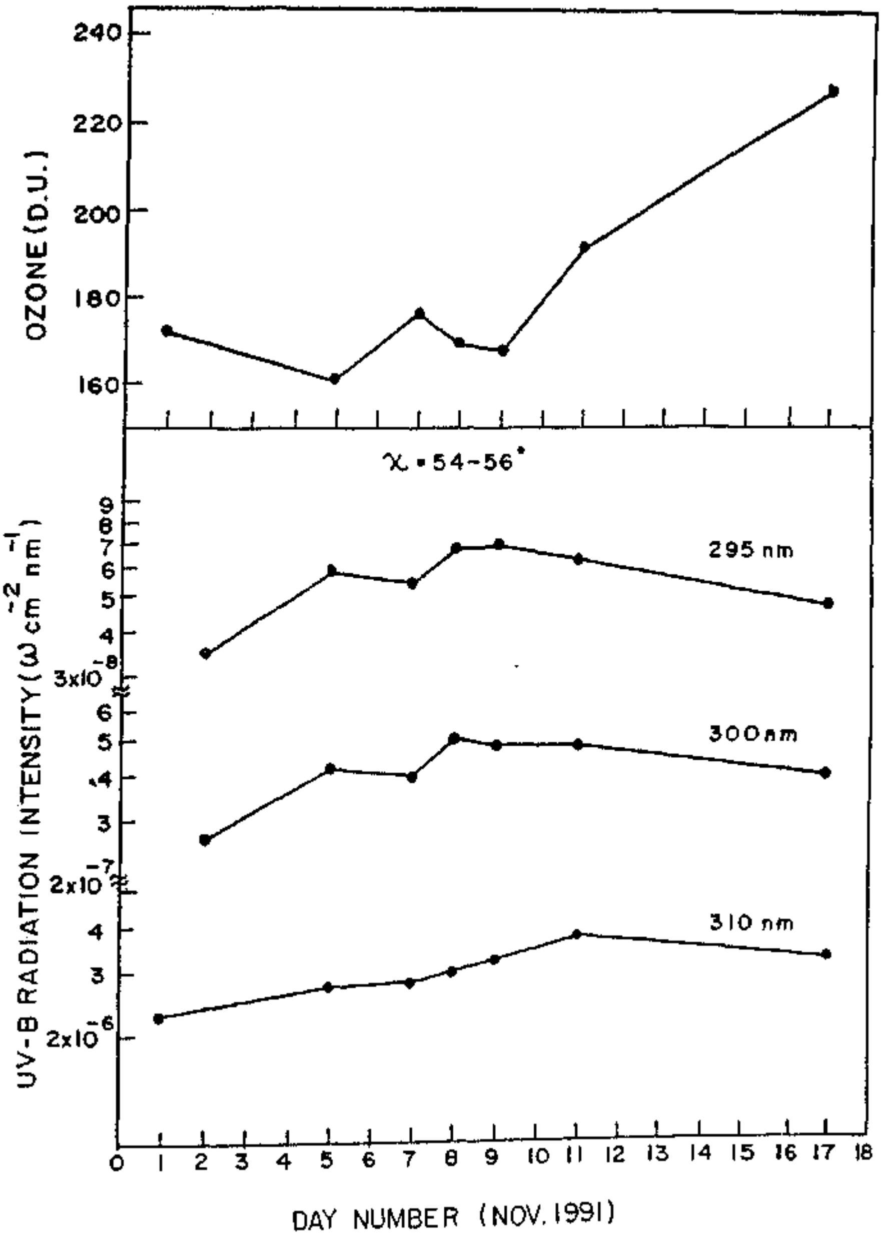



*Fig. 7, Variation of solar UV-B intensity at different wavelengths and the variation of the total columnar ozone content with time for November 1991.*

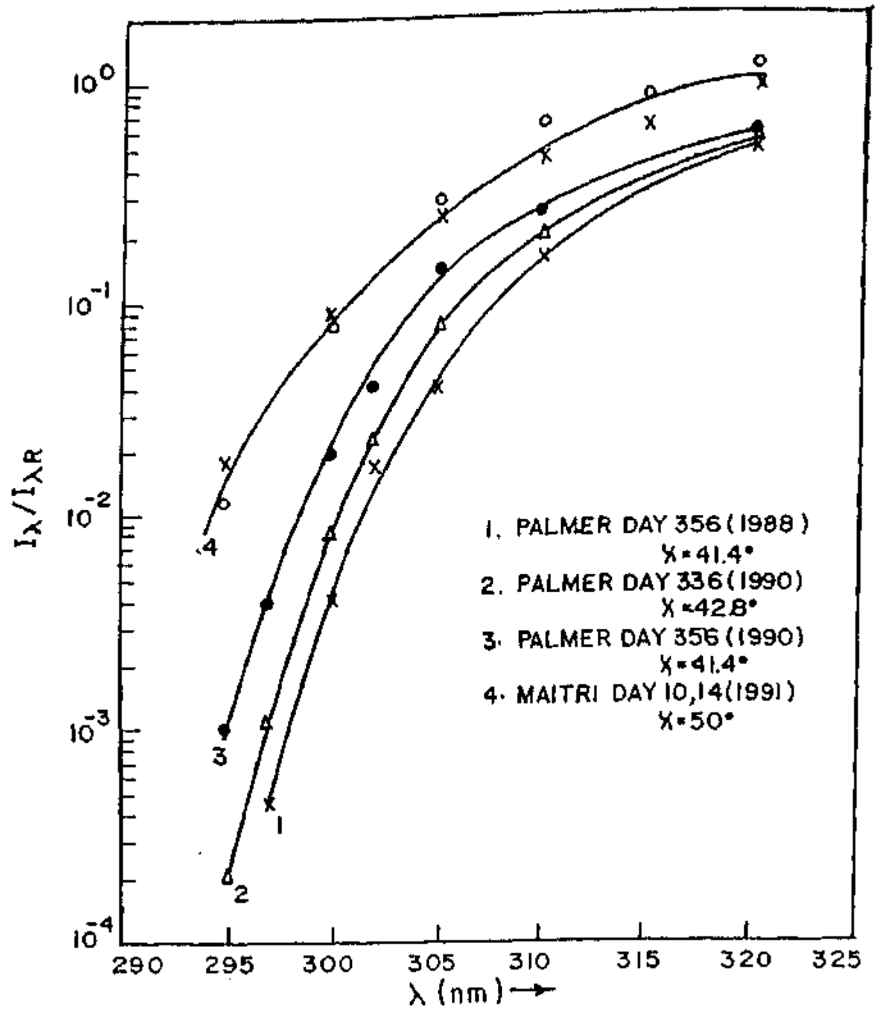



*Fig. S, Variation of $1/I_R$ ratio with wavelength in UV-B range. R is the reference wavelength and is 350 nm for Palmer and 368nm for Maitri.*

recovered by end of November in the year of 1990 as shown by Palmer observations, but it was fully recovered by 20th November in the year of 1991 as shown in Fig. 9. The ozone values are the observed values at Maitri during the 10th expedition. It can be seen from this figure that though the ozone content had substantial fluctuations during the Ozone hole period but the hole was fully recovered by 20th November and during the month of December 1991, there were no fluctuations of the magnitude as observed during ozone hole period. Again there were some fluctuations in the month of January 1992 but the magnitude was very small compared to that of the ozone hole period.

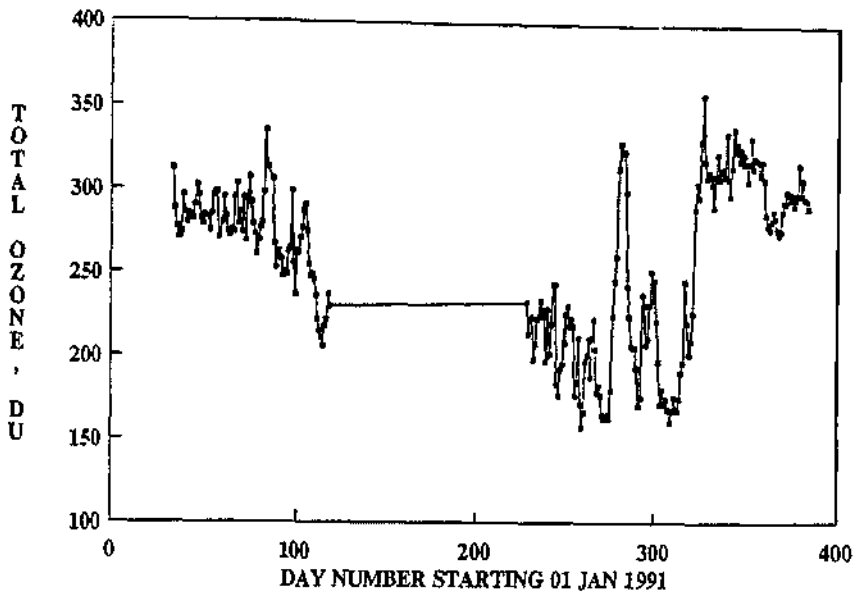



*Fig. 9. Variation of total ozone content for the period January 1991-January 1992.*

The observation of the higher UV-B intensities during 1991-92, at higher solar zenith angles, pertaining to the austral spring periods can again be explained in the light of the existence of the aerosol layer above the ozone layer. This fact is demonstrated in Figs. 10a and 10b. It is shown in these figures that the optical depth at 368 nm and 500 nm are quite high in the year 1991 and 1992 compared to the corresponding values for the years 1988 and 1990. The observations were taken by the same sunphotometer during different expeditions. It is seen from the figure that the optical depth for the year 1991-92 are higher by a factor of 2 to 3. Again it is seen that the optical depth in November 91 are higher than those of September 91 and February 92. This means that the optical depth increased substantially after September 91 and again came down around February 92. Fig. 11 shows a plot of optical depth plotted for the period March 91- February 92. The increase in optical depth can be explained in the light of transporting of volacanic ash from the eruptions of mt. Pinatubo volcano in Philipines and the Cerro Hudson volcano in southern Chile which burst in mid 1991.

The Langley plot for 22$^{nd}$ December 1991 is shown for 4 different wavelengths in Figs. 12a,b,c & d. It is seen from this figure that the variation in solar zenith angle can be obtained on a reasonably good span to have the proper aerosol size distribution studies.

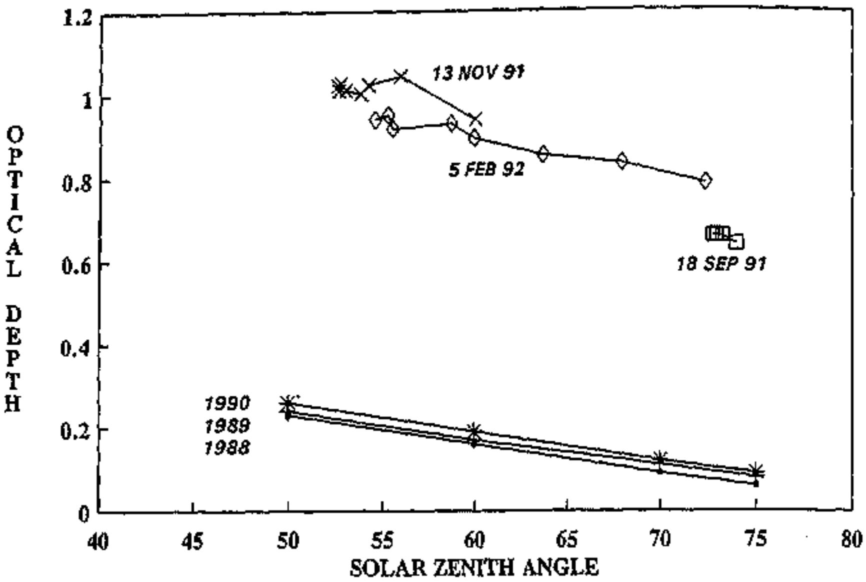



*Fig. 10a. Variation of optical depth with solar zenith angle for 368 nm.*

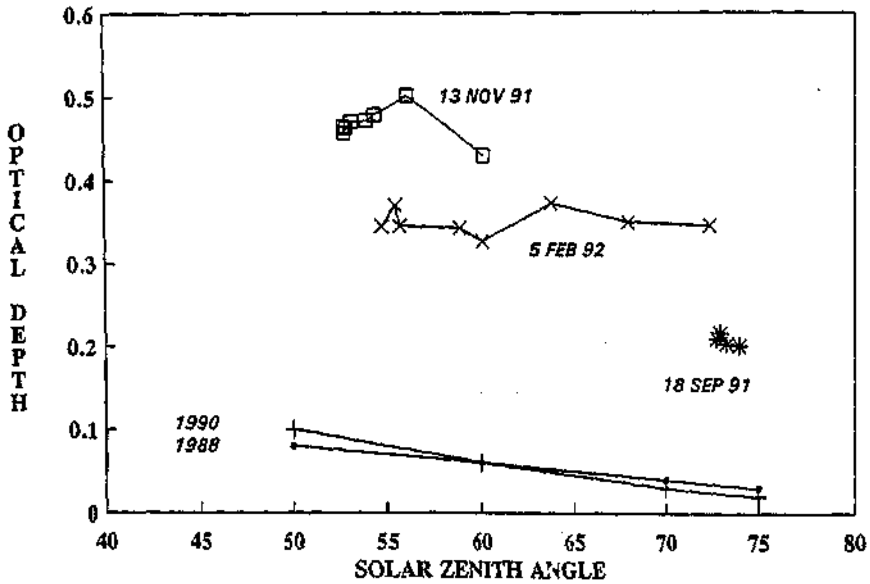



*Fig. 10b. Variation of optical depth with solar zenith angle for 500 nm.*

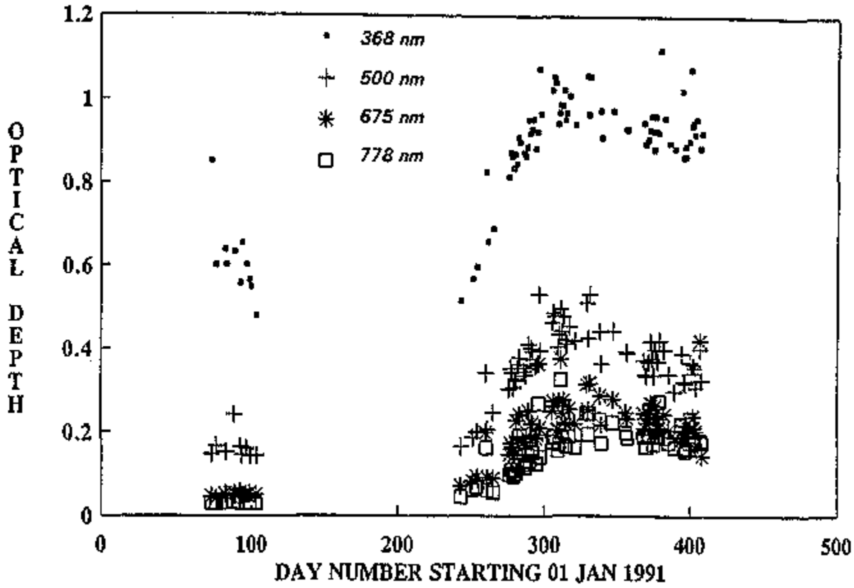



*Fig. 11. Variation of optical depth for 368, 500, 675 and 778 nm for the period March 1991 — February 1992.*

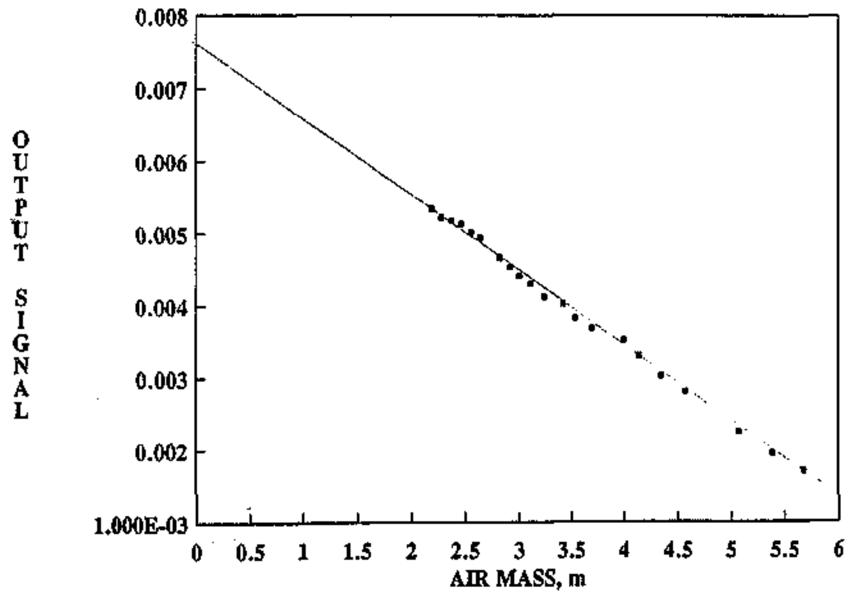



*Fig. 12a. Langley plot for 368 nm.*

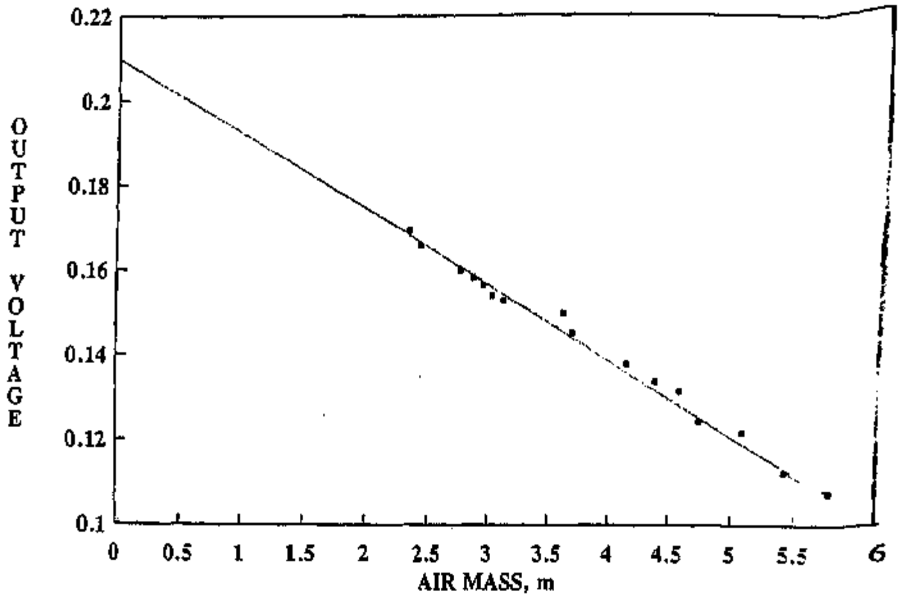



*Fig. J 2b. Langley plot for 500 nm.*

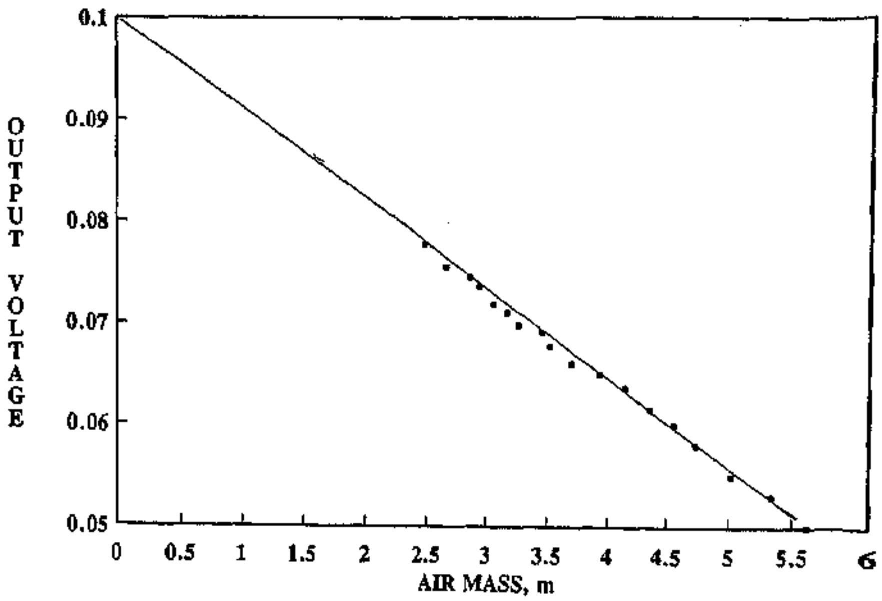



*Fig. 12c. Langley plot for 675 run.*

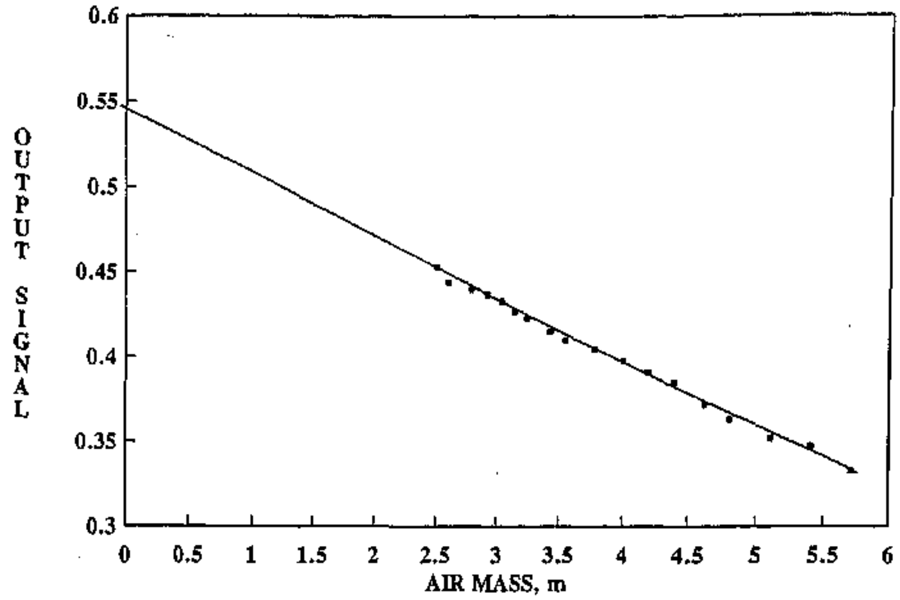



*Fig. 12d. Langley plot for 778 nm.*

## Conclusion

From the analysis of the data on UV-B radiation intensities for different time periods during 1987-1992, it has been found that the strong anti-correlation between the UV-B radiation intensities and the total columnar ozone content does not always remain strong. It is broken at many occasions. In addition to the ozone absorption of the UV-B radiation the other factors like absorption of those radiations by boundary layer pollutant, the scattering effects of the clouds and the absorption and scattering effects of stratospheric aerosols are also important and play significant role in certain conditions.

## Acknowledgements

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