Fourteenth Indian Expedition to Antarctica, Scientific Report, 1998
Department of Ocean Development, Technical Publication No. 12, pp 1-14

Aerosol and Erythemal Observations at Maitri, Antarctica during 14th Indian Antarctic Expedition (spring/summer of 1995/96)

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Abstract

A comparative study of the aerosol content of Maitri region of Antarctica for 6th, 11 th and 14th Indian Antarctic expeditions has been undertaken using a multiwavelength sun-photometer.It was found that the aerosol contents were quite low during 1987 and 1995. compared to 1992, thereby clearly indicating the effect of Pinatubo eruption in June 1991 .Erythemal dose of UVB has also been monitored during the austral spring/summer of 1995 and the ozone hole formation has been observed through the enhanced doses of UVB received at Maitri.In the presence of a low content of aerosol, a clear anticorrelation between UVB and ozone has been observed normally not observed in the presence of higher aerosol loading of the atmosphere.

Introduction

Recently, a lot of studies are being undertaken on aerosol, UVB, ozone and their interrelationship (McKenzie *et al*, 1991 ;P.K.Bhartia *et al*, 1993 ; D. J.Hofman and S.J.Oltmans,1993). Aerosols whether anthropogenic or from the volcanic eruptions present in the troposphere had been found to cause a decrease in the UVB irradiance.In non-urban areas of Industrialized countries this decrease has been found to range from 5 to 18% since the industrial revolution.This reduction may partly or fully offset the increase of UVB caused by stratospheric ozone depletion in the Northern hemisphere (Liu *et al,* 1991).

Stratospheric aerosols caused by volcanic eruption have been found to affect stratospheric ozone seriously (R.A.Kerr, 1993) and the mechanism of this depletion has been ascribed to one or more of the following causes;direct chemical loss through heterogeneous processing, aerosol induced changes in radiative heating which affects ozone transport and higher loss rates caused by aerosol heating. Stratospheric aerosols also increase the transmission of UVB to the surface due to scattering and this enhancement increases with solar zenith angles and absorption optical depth.Under appropriate conditions of aerosol and ozone depletion,the UVB irradiance at Antarctica has been theoretically shown to exceed that of tropics (Roger Davies, 1993). UVB irradiance on ground is modified by the presence of clouds.Clouds can either increase or decrease the UV radiations.Additional radiations can be reflected onto the detector by the clouds causing the increase or the irradiance is reduced due to direct obcuration of the sun by the clouds.It has been seen that from 1979 to 1990 the amount of total ozone has decreased over most of the globe ; small (3 to 5%) losses at mid-latitudes, large (6 to 8%) losses at high latitudes and no loss near the equator (Stolarski *et al,* 1992).In a related observation , the total irradiation on average has been found to decrease by 3.7±1.3% per decade in Germany.

About 10% of the total ozone amount is found in the troposphere as confirmed by the balloon measurements (K.Henriksen *et al,* 1992). In a cloud-less atmosphere, the enhancement in UVB due to ozone depletion can be calculated (Dahlback *et al,* 1989) but the effect of precipitation and cloudiness can not be calculated quantitatively (Stamens *et al*.,1988).

The trend of ozone hole depletion in Antarctica shows that during 1995 the ozone hole period was spread over a longer period but the depletion of ozone was considerably less as compared to year 1993 or 1994.The depletion is expected to be high again in 1996. The prediction is based on the concept of quasi-biennial oscillation (QBO) related to air transport from tropics to Antarctica (D.J.Hofmann, 1996).Ozone loss rates have been greater when the winds were easterly for several months preceding the ozone hole period. Ozone loss maxima has been seen during 1987, 1989, 1991 and 1994. The periodicity was broken in 1992 due to large scale aerosol loading from Pinatubo volcanic eruption.

This paper describes the observations on aerosol, erythemal dose and daily total ozone taken at Maitri (70° 46'S; 11° 44'E) Antarctica during the austral spring and summer of the year 1995/96 and interrelation between these parameters.

Measurements

The atmospheric turbidity due to suspended particulate matter has been obtained from the spectral measurement of direct solar radiation. The measuring instrument should have an accurate bandwidth wavelengths and good linearity .The instrument is also supposed to be stable against ambient temperature changes which otherwise can introduce a major error while working in

Antarctic subzero temperatures. 'Eko' Japan make four wavelength sun-photometer has been used to record irradiance at wavelengths of 368 nm, 500 nm, 675 nm and 778 nm. The instrument is pointed at the Sun and the light after passing through the optical guide tube reaches the narrow band interference filters which are mounted on filter wheel. A selection switch is provided to adjust the amplification. Ambient temperature can also be read. Measurements were undertaken only on clear days.

UVB irradiance was measured in terms of erythemal dose using Solar Light (USA) made 501 UV-Biometer. The biometer has a characteristic similar to that of Robertson-Berger meter. The spectral response of the instrument is quite identical to the erythema action spectrum. It can indicate the effectiveness of solar radiation for the induction of sunburn, Phytoplankton mortality , skin elastosis and thymine dimers. The instrument consists of two parts: detector and recorder.

The detector measures the global UVB and was mounted on top of the building such that the solar irradiance is not obstructed by any structure. The quartz dome was regularly cleaned off dust and snow. The solar light goes through the input filter that eliminate the visible component. Then the partially filtered light containing whole UV spectrum excites the phosphor. The visible light emitted by the phosphor is detected by the Ga As diode. The diode and the phosphor are encapsulated in the metal enclosure which is thermostated by the Peltier element. The current produced by the Ga As diode is amplified and converted to frequency inside the detector. The temperature of the detector is converted to frequency also. The frequency signal from detector is transmitted to the recorder.

The recorder was kept below in the hut maintained at a constant temperature. It can keep 5248 blocks of data in memory which amounts to half hourly data for about 3.5 months. The data was periodically transferred to a computer using a communication software. The system was kept running round the clock during all-sun days. The data is measured in units of MED/Hr (5.83×10^{-6} W/cm^2). One MED/Hr would cause minimal redness of the average skin after one hour of irradiation (21 mj/cm^2).

Results and Discussion

Atmospheric turbidity is defined as the extinction of direct solar radiations by existing aerosols. The direct solar intensity ($I\lambda$) for a particular wavelength is calculated as:

$I\lambda = Io\lambda{:}e - (Tm\lambda, + To\lambda + TR\lambda)\, m$

where

$I\lambda$ — The irradiance at wavelength at the observing point

$Io\lambda$ — The irradiance on top of the atmosphere at mean Sun-earth distance

$Tm\lambda$ — The extinction coefficient due to aerosol

$To\lambda$ — The absorption coefficient of ozone

$TR\lambda$ — The Rayleigh scattering coefficient

m — The absolute airmass

The apparatus used here does not read the absolute values of I directly but a value proportional to it. $Io\lambda$, $Tm\lambda$ is the instrument calibration constant.

$Tm\lambda$ can be calculated as:

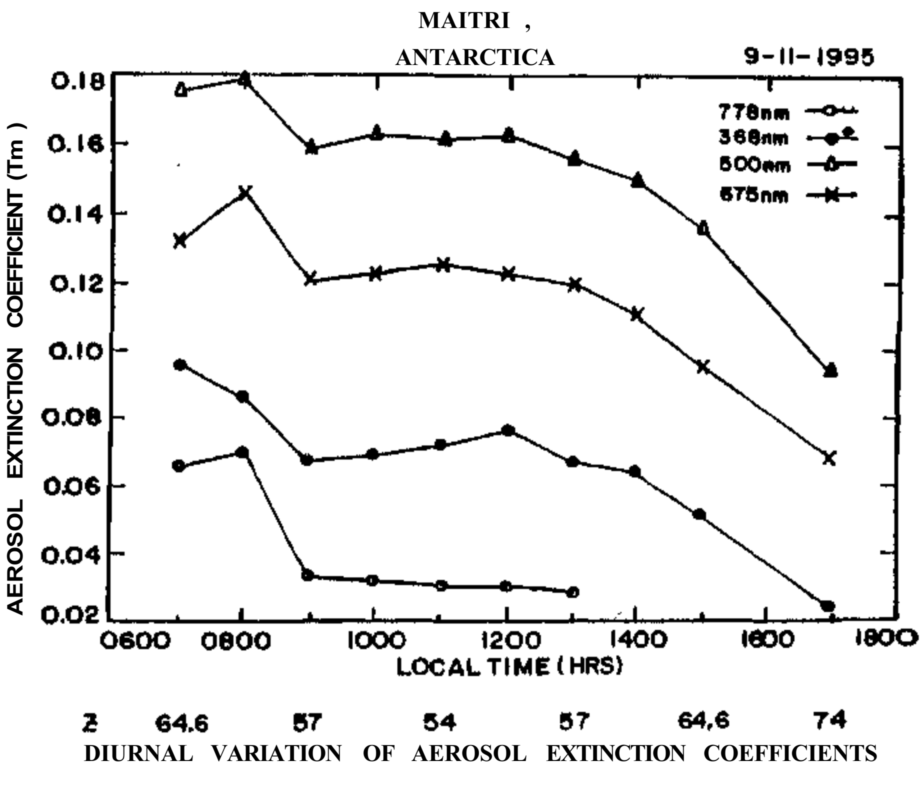


Fig.1 : Diurnal variation of aerosol extinction coefficient

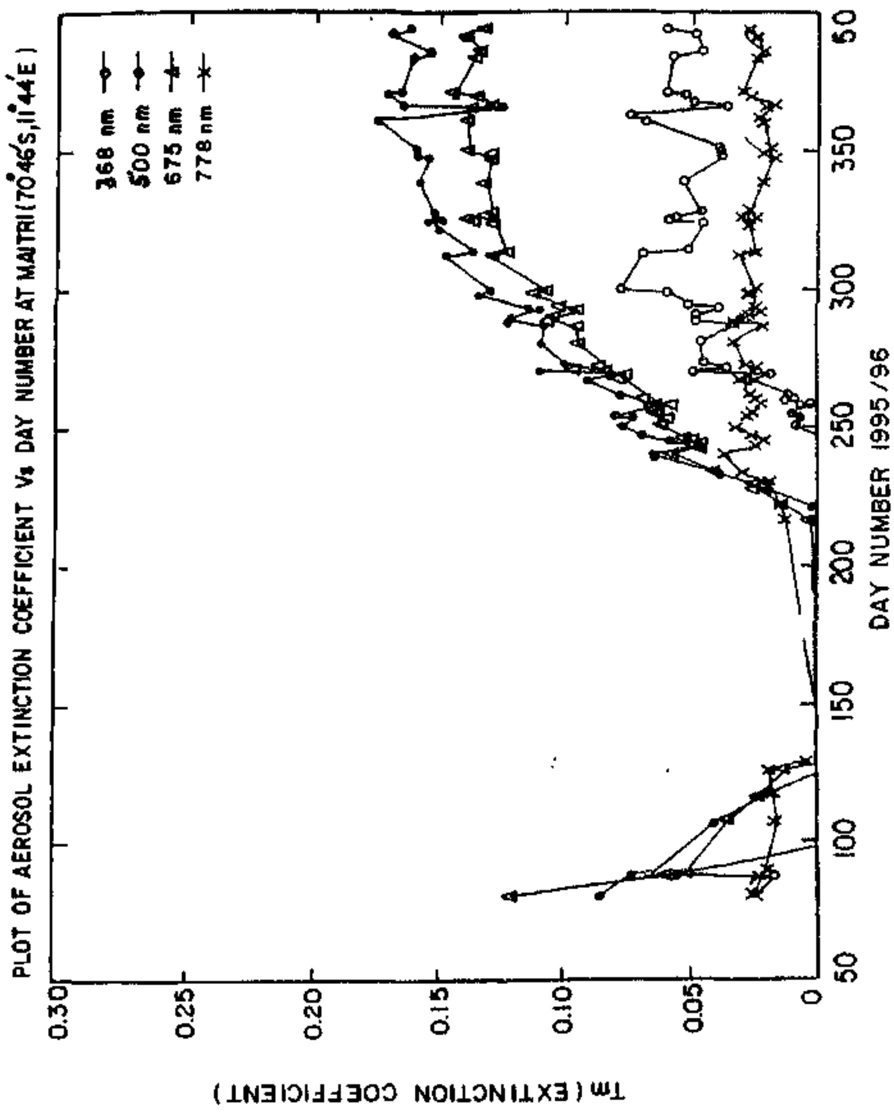


Fig.2 : Seasonal variation of aerosol extinction coefficient

$Tm\lambda = 1/m \ In \ Io\lambda . / I\lambda - (To\lambda + TR\lambda)$

"λ' has been selected so as not be absorbed by CO_2, H_2O vapours etc. The above equation can be modified for a more precise and practical application as :

$Tm\lambda = 1/m \ In \ (Eo\lambda / E\lambda S) — (P/Po \ TR\lambda + To\lambda)$

where $Eo\lambda$ is the calibration constants obtained from Langley plots drawn for each wavelength separately ; $E\lambda$ - meter reading ; S - mean Sun-earth

MAITRI, ANTARCTICA
(DIURNAL VARIATION)

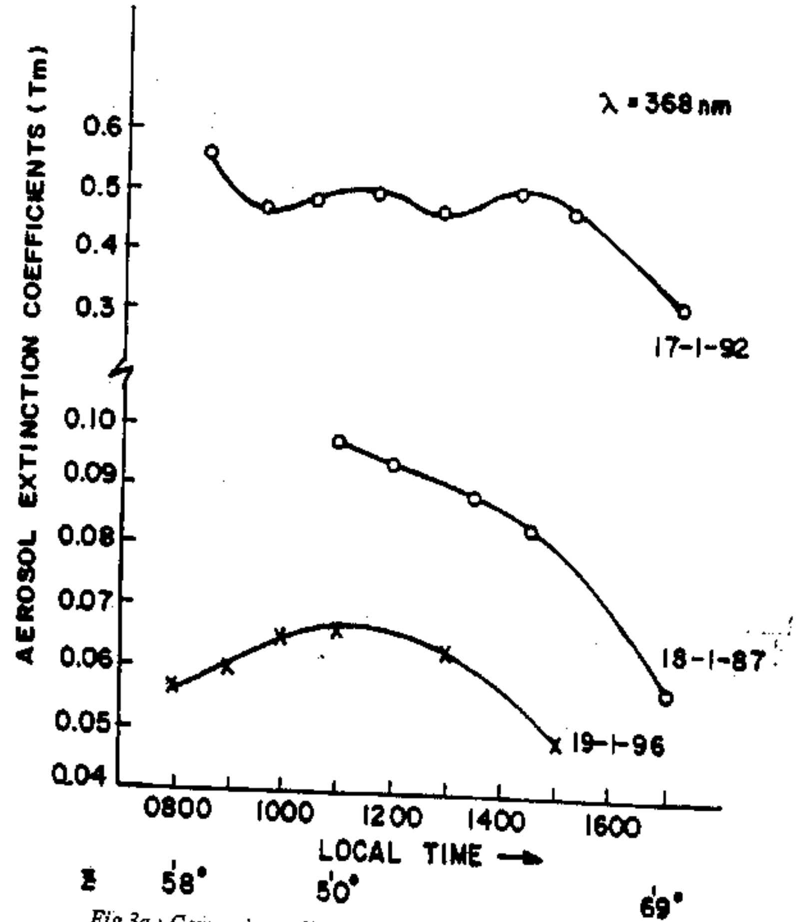


Fig.3a : Comparison of Tm values for the wavelength 368 nm distance; Po - standard pressure at sea level (1013.2 mb); P - station atmospheric pressure ; m - 1/sin h (approx.); h - solar elevation angle.

Local noon observations have been taken for all available sunny days (63) between the period March 1995 to January 1996 with the variation in temperature ranging from -32.6 °C to + 8°C. Figure 1 shows the diurnal variation of aerosol extinction coefficient (Tm).The higher values observed during early hours is due to the presence of thin clouds which were cleared after 0900 hrs.Figure 2 shows the seasonal variation of Tm .The flat part without any

MAITRI , ANTARCTICA
(DIURNAL VARIATION)

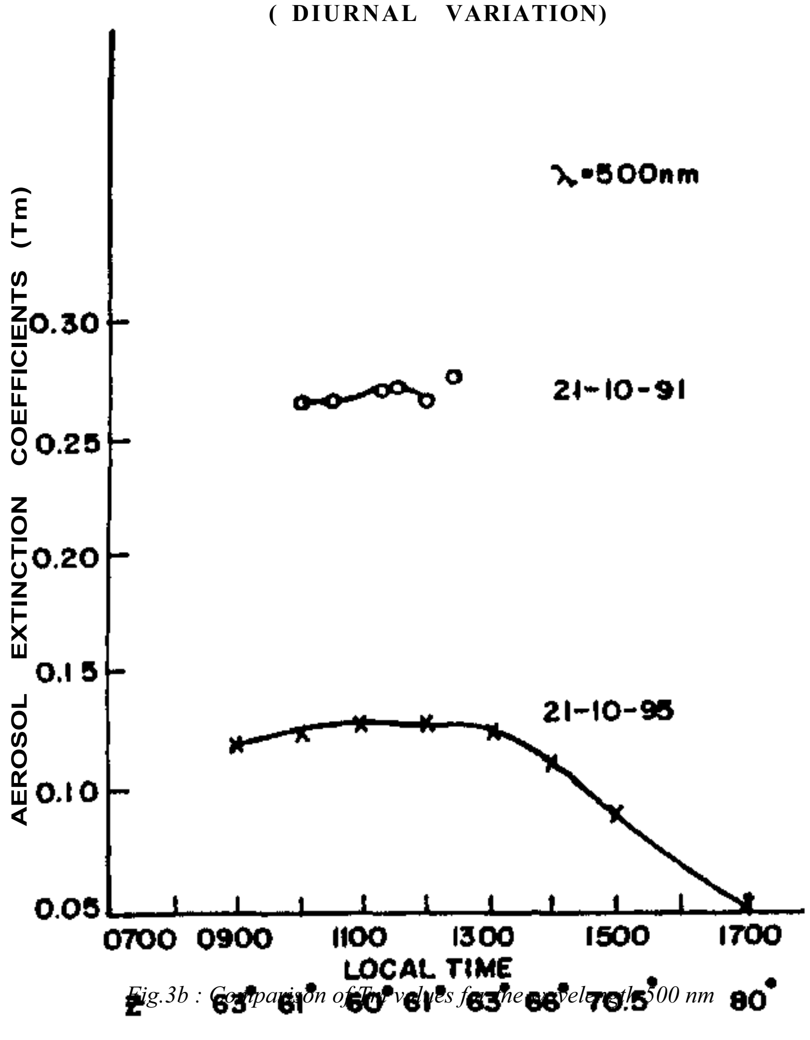


Fig.3b : Comparison of Tm values for the wavelength 500 nm observation corresponds to no-Sun or low-Sun days. It shows that the extinction coefficients have large values for middle wavelengths of 500 nm and 675 nm but smaller values for wavelengths 368 nm and 778 nm. The observations indicate that majority of aerosols present in Antarctic atmosphere were of average size and both the fine as well as coarse particulates are less common. For low solar elevation angles Tm values for 778 nm tend to be higher than for other wavelengths. Figures 3 a and 3b show a comparison of the aersol extinction coefficients observed over Maitri during different visits in 1987,1992 and 1995. It is observed that for a wavelength of 368 nm ,Tm values (extinction coefficients) for 17th January, 1992 are much higher than those of 18th Jan, 1987 and 19th Jan,1996.Since the days are almost identical the effect of zenith angle is neglected and the difference is purely due to the atmospheric aerosol content. Similarly the observations taken on 21st Oct.,1991 when compared with that of taken on 21st Oct.,95 shows that 1991values were much higher.It also shows the effect of Pinatubo which erupted in June, 1991 in Phillipines could be seen in Antarctica by October of the same year and it further increased in Jan. 1992

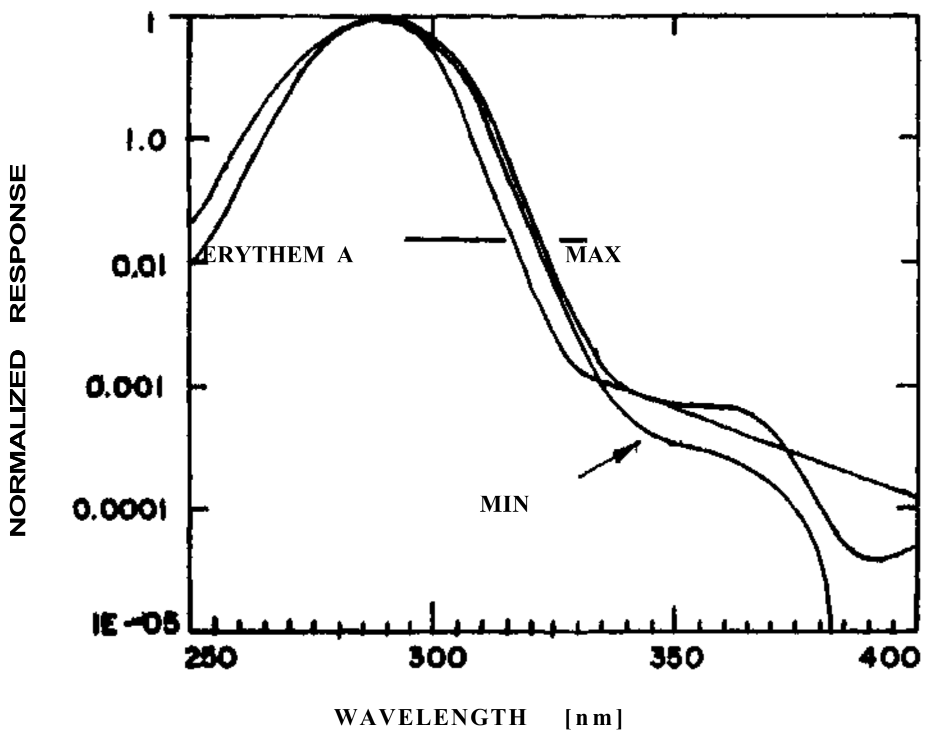


Fig.4 : Normalized spectral response of UV-Biometer

as seen in Figures 3a/3b.The curves corresponding to 1987 and 1995/96 are quite sharp compared to those of 1991/92 indicating thereby the presence of a stable background of aerosols conforming to their volcanic origin.

Figure 4, shows the normalized spectral response of 501 UV- Biometer detector and erythema action spectrum of human skin.It only shows that the sensitivity of the detector and the human skin are quite identical.In Antarctica there is a large variation in solar angle of elevation over the year.Figure 5 shows

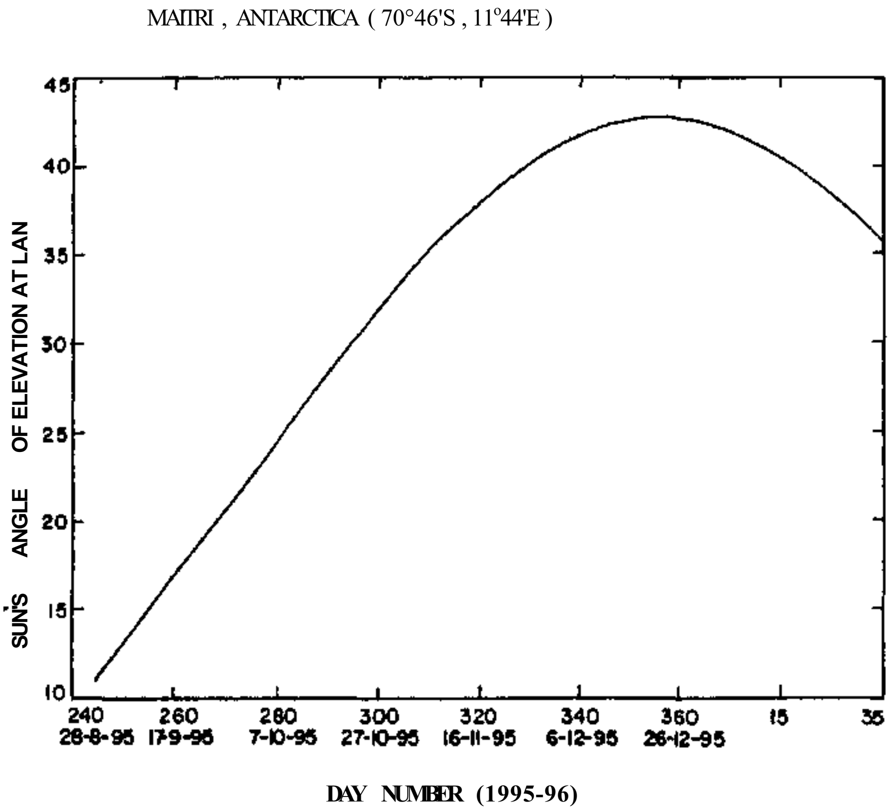
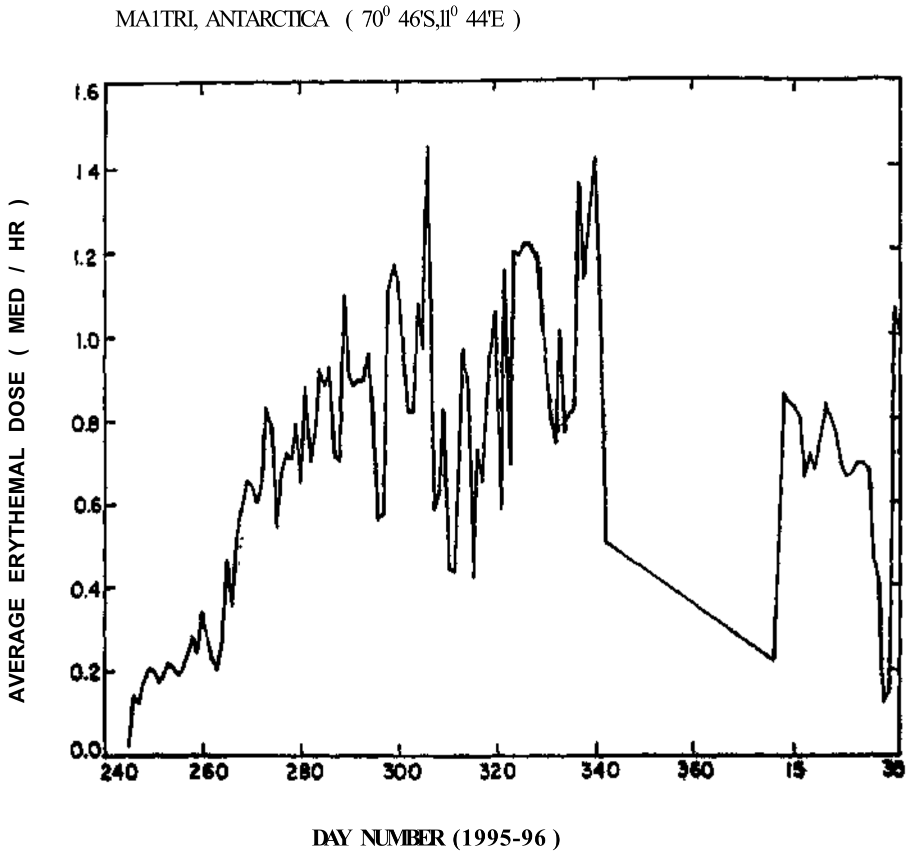


Fig.5 : Variation of Solar angle of elevation over the year

the variation in solar angle of elevation at local apparent noon (LAN) after the polar winter at Maitri site.It varies from 0 to 42.67 deg at the site of Maitri where there is no Sun from 22nd May to 21st July. Similarly the Sun does not set for about two months around 22nd December. Figure 6 shows the daily average erythemal dose against the day number. The flat portion of the curve indicates the period when the system was non-operational. The variations



Fig,6: Average erythemal dose versus day number

present in the curves are ascribed to various weather parameters like cloud, snow, aersol and ozone. Figure 7 shows the variation of total ozone over the period during the austral spring, commonly known as ozone-hole period.

Figure 8 is the normalized combination of the Figures 5,6 and 7.As the solar elevation starts increasing after the polar nights the erythemal dose is expected to rise monotonically if the other parameters like ozone remains constant.In a real situation where severe ozone depletion is observed during ozone hole period,the rise in erythemal dose is expected to be more than that caused by Solar elevation.This is clearly marked in Figure 8 as the anticorrelation between ozone and erythemal dose.Generally such an anticorrelation is

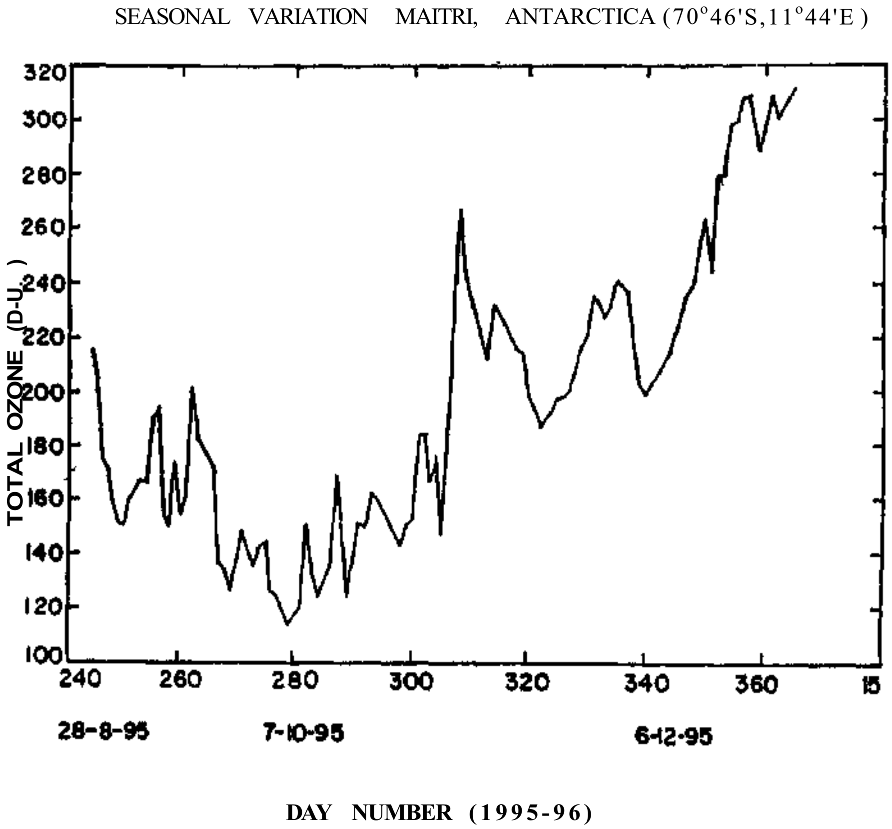


Fig.7: Variation of total ozone during austral spring/summer

masked in the presence of aerosols but in Antarctica this could be possibly observed due to a relatively clearer atmosphere.

Figure 9 shows the diurnal variations of the erythemal dose on two clear days viz. 28.9.95 and 24.11.95 for zenith angles of 69 deg and 50.3 deg respectively at local apparent noon ; the total amount of erythemal irradiance was 5.712 MED and 27.661 MED respectively.A comparison has been made between the irradiance at Delhi (28.63 deg N,77.22 deg E) and at Maitri (70.77 deg S,11.73 deg E) at local noon on 5th Dec,1995 at zenith angles of 51 deg and 48.5 deg; UVB irradiance recorded at Delhi and Maitri was 1.28 MED/hr and 3.482 MED/hr respectively.This experimental observation conforms to the theoretical calculation of Roger Davies (1993).

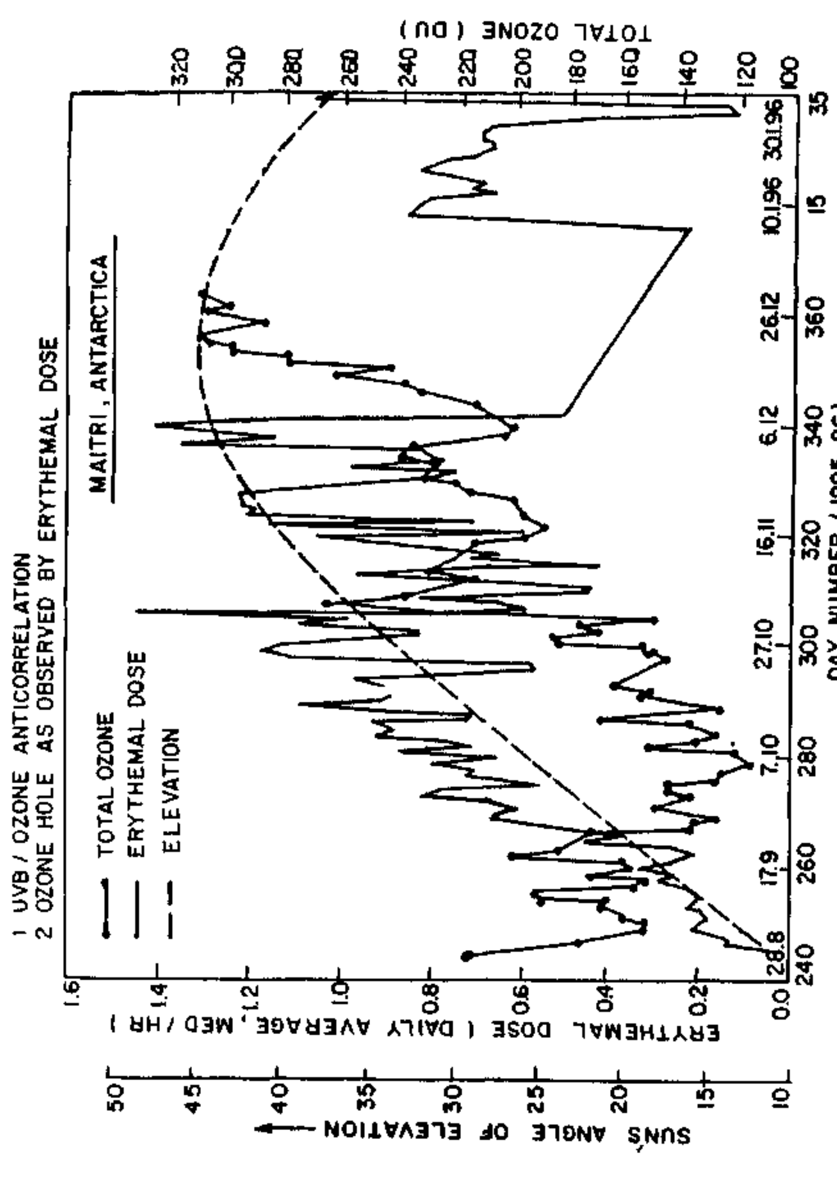


Fig.8 : Anticorrelation between ozone and erythemal UVB dose

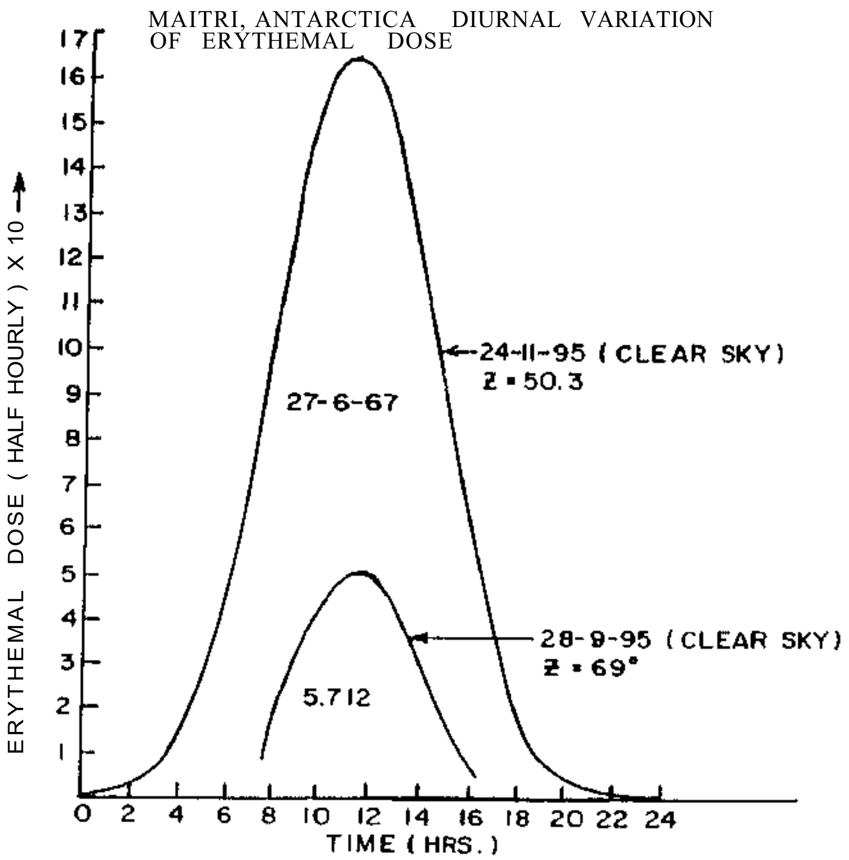


Fig.9: Diurnal variations of erythemal dose

Conclusion

Observations taken at Maitri show that the aerosol extinctions found during 1987 and 1995 are similar but much smaller than those found during 1992 indicating thereby the presence of Pinatubo aerosols in Antarctica. The presence of ozone hole during the austral spring could also be observed through enhanced doses of UV observed over and above the increase due to rising solar elevation.

Acknowledgements

One of the authors (SDS) is thankful to Dr. K.K.Mahajan, Head Radio and Atmospheric Science Division for cooperation and encouragement. But for the overall support of the secretary and the staff of DOD,thc present work could not have been undertaken efficiently

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