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STUDY OF OZONEHOLEPHENOMENAAND METEOROLOGICAL PARAMETERSATSCHIRMACHER OASISNTARCTICADURING 18th INDIAN ANTARCTIC EXPEDITION 1998-2000

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Abstract

India Meteorological Department has an ongoing meteorological programme in the Antarctic Expeditions. During the XVIII Indian Scientific Antarctic Expedition installation of Brewer Spectrophotometer, for measurement of Total atmospheric Ozone, Sulphur dioxide and Nitrogen dioxide, Damaging Ultraviolet radiation, to supplement the ozonesonde programme for the study of Ozone hole phenomena was undertaken in the year 1999. In addition to total Ozone, DUV, S02, NO2 measurements using Brewer Spectrophotometer, Atmospheric Ozone profile by Ozonesonde, Meteorological and Climatological features observed during the year 1999 has been discussed in this report.

Introduction

The India Meteorological Department has been continuously participating in all Indian Scientific Antarctic Expeditions from the beginning. This is an ongoing Programme of recording and analysing the meteorological data. New members continue to collect and record the different meteorological data during their stay at Indian Antarctic Station Maitri located in Schirmacher Oasis Antarctica. During the 18th expedition a new Programme was included i.e. the installation of Brewer Spectrophotometer for measuring Total Atmospheric Ozone, Sulphur dioxide, Nitrogen dioxide and Damaging Ultraviolet-B Radiation. This Programme will be continued in future with the other meteorological parameter. Standard equipment and techniques approved as of world standard by World Meteorological Organization (WMO) is being used for the data collection. The synoptic weather data generated is also transmitted over global telecommunication network (GTN) on real time basis for the use of weather forecasting world over.

Scientific Objectives

1. Scientific objectives for the meteorological Programme during XVIII IAE was study of Atmospheric Ozone profile, its distribution and annual variation at different levels and total atmospheric ozone using Brewer Spectrophotometer and Antarctic meteorology in general. During the year 1999 following studies were carried out to fulfil above objectives,

a) Daily seasonal and annual variation of atmospheric pressure, surface wind, surface air temperature, surface ozone, snowfall, and clouds.

b) The atmospheric changes with reference to specific synoptic weather systems.

c) The radiation budget studies including Total Global Solar radiation and Diffused solar radiation.

d) Monitoring and archival of information through weather satellites and HF radio sets regarding weather system affecting the Antarctic continent.

e) Atmospheric turbidity measurement using Sunphotometer with 500nm filter.

f) Balloon borne measurements of ozone for its vertical profile over Maitri for the study of occurrence of Ozone hole phenomena over Antarctica during austral- spring months.

g) Installation of Brewer Spectrophotometer and its operation during all fair weather days for study of daily, seasonal and diurnal variation of total Ozone, DUV, SO_2 and NO_2.

Execution of the Programme

During onward cruise by ship, MV Polar Bird, observations were taken eight times a day at three hourly intervals at synoptic hours from the day of departure from Goa. At every six hours i.e. at 0000, 0600, 1200 and 1800 hrs UTC they were transmitted to IMD NEW DELHI for onward transmission to GTN.

2. Surface observational Programme is divided into the following types:

a) Surface observations of all weather parameters recorded at synoptic hours on all days and Four observations out of eight were transmitted to 1 M D office New Delhi. India over telex for real time use and for global exchange.

b) Atmospheric pressure, temperature, wind speed, and direction, surface ozone, snowfall, global and diffused solar radiation are continuously recorded.

c) Sun-photometer observations were taken on all clear weather days for analysis of atmospheric turbidity.

3. For the study of the Antarctic ozone hole phenomenon 52 Ozonesonde ascents were taken using Indian Electro-chemical ozonesonde. For study of Radiation balance 18 Numbers of Radiometersonde ascents were taken. From the month of June Ozone ascents started terminating at much lower height due to premature burst of balloons. Even balloons treated with the mixture of ATF and water were found terminating at lower levels. The treatment procedure was modified and treatment of balloons was attempted using ATF only. This new arrangement worked very good and about 20 ozone sonde ascents taken from the month of September to December reached more than 30 Km till the end of calibration of pressure sensor.

4. Weather forecasting in Antarctica is a great challenging job with limited resources such as weather charts and network of observatories. Automatic Picture Transmission receiving equipment was lying unserviceable since last one year at the time of takeover. The equipment was made operational at the earliest possible time for the reception of cloud imageries. Reception of weather charts transmitted from the Pretoria stopped from the first week of September. Despite of above limitations a very good weather forecast was provided to the team for convoys and field activities through out the year including flying operation during summer period of the 18^{th} and 19^{th} IAE.

5. Installation of Brewer Spectrophotometer was completed in the month of July and observations started just after the end of polar nights. Focussed sun and DUV observation started with effect from 14^{th} August and direct sun observations started from 16^{th} September. The equipment developed snag in Zenith drive system, Mercury lamp system, main power supply, and Micrometer No # 1. All above defects were rectified in shortest possible period and defective parts were replaced. All mode of operation was tested for this system including moon light observation for the measurement of total atmospheric ozone during polar night and other days when direct sun and focussed sun observation is not possible.

Results & discussion

1. Meteorological and Climatological studies:

For the study of climatology of Schirmacher Oasis daily synoptic data was used for computation of daily and monthly mean of temperature, wind, pressure and clouding. The daily mean values were plotted and represented in a graphical form for comparative study. A representative analysis for the month of September 1999 is shown in Figure-0.1 to 0.4. For computation of short period normal the monthly mean values from the year 1990 to 1999 were used and they are shown in Figure-1(a) to 1(c).

1.1) Surface temperature

For measurement of Surface Air Temperature, Maximum Temperature, and Minimum temperature a standard Stevenson screen is installed in the field and well-calibrated thermometers are installed therein. For round the clock recording of surface air temperature a thermolinear therm ister is installed in the same S. Screen at the height of Dry Bulb thermometer and temperature output is displayed and recorded in IMD LAB in the main station. Temperature value from the autographic record is computed manually. The lowest temperature of-35.2 degree Celsius was recorded on 08"' July and the highest temperature of +08.5 degree Celsius was recorded on 16th'January during the year 1999. Variation of monthly mean air temperature is shown in the Figure- 1(a). This year all the months were colder than short period normal except the winter months excluding July. June was exceptionally warmer and mean daily temperature reached -4.6 degree C on 25th June. Similarly August and September were warmer due to frequent storms.

1.2) Wind

For continuous recording of wind speed and direction a DIWE is installed on the roof of Maitri station and comprises of one CGA and Selsyn Windvane. Output from this system is displayed and recorded in the IMD LAB. Wind speed and direction: recorded on the recorder is used for synoptic observation and hourly values are also tabulated from these records through out the year. The month of June was the windiest month of this year. Average wind speed for this month was 28.4 Knots and was followed by the months May and August with average wind speed of 25.8 and 23.4 Knots respectively. The maximum wind speed of 94 Knots gusting to more than 110 Knots was recorded on 10th September during the strongest blizzard of the year. The month of December was calm month of this year and monthly average wind during this month was 13.4 knots. Variation of monthly average wind speed along with short period normal wind is shown in the Figure- 1(b).

1.3) Surface pressure

The station level pressure is recorded using Precision Aneroid Barometer, which is calibrated with reference to regional standard kept at the office of the D O O M (SI) Pune and converted to Mean Sea Level pressure using height and temperature correction table specially prepared for this station. Belfort Marine weekly Barograph is used for continuous recording of station level pressure. Hourly values are tabulated from the barogram. The highest M S L pressure of 1019.8 hPa was recorded on 16th June and lowest M S L pressure of 945.7 hPa was recorded on 31st August during this year. This was the lowest Mean Sea Level recorded at this station since 1990. Variation of monthly mean M S L pressure and its comparison with short period normal is shown in the Figure-1(c).

1.4) Snowfall

First time snow gauge was installed at Maitri in the year 1998 for measuring snowfall during snowfall and blizzard days. With this instrument we can measure the collected snow equivalent to water. The measuring of the snow at Antarctica is very important because of the alarm of global warming. Snowfall was observed almost in all the months. Figure- 1(d) shows the monthly total snowfall recorded during this year and last year. The snowfall was negligible in the month of January, June and November. The maximum snowfall was recorded in the month of August followed by September and October during this year. Maximum snowfall was recorded in the month of June and August during the year 1998.Threre were 80 snowfall days during the year and month of August recorded 14 snowfall days followed by 10 days in September and December. Quantitatively August give the maximum snowfall about 45% of annual precipitation followed by September (31%) and October (14%). These three months accounted for 91% of this year snowfall.

1.5) Blizzards

Weather in Antarctica is subject to frequent and sudden changes. Strong winds and blizzards dominate Antarctic weather. When wind speed exceeds 23 knots with drifting/blowing snow reducing the surface visibility to less than one kilometer then the weather phenomenon was defined as Blizzard for our study purposes. Total 34 blizzards affected the station for 60 days during the year

1999. The month of May, August, and September each was affected by six blizzards with maximum number of days in August (15 blizzard days) followed by September (10 days) and May (9).

2.Atmospheric Ozone and Ozone Hole Studies

2.1) Surface ozone

Surface is the main sink for ozone and since the mean concentration of ozone at different levels of atmosphere remains substantially same, the rate of production of ozone at higher levels must be equal to the rate of destruction near surface. Therefore continuous monitoring of ozone was done and its hourly values are computed manually from the autograph charts and the results are under process.

2.2) Vertical Distribution of Atmospheric Ozone

For the study of monthly and interannual variation of atmospheric ozone from surface to stratosphere 52 Ozonesonde ascends were attempted during this year. Out of these ascends 20 ozonesonde reached higher than lOh Pa (31 Km) height during springtime ozone depletion and recovery period.

Following preliminary results can be concluded from these ascends.

(i) Ozone Partial Pressure is generally found to be steadily decreasing with height till the tropopause level thereafter the profile shows increasing tendency with height. First maxima is observed around 150-170 hPa layer then partial pressure of Ozone increases to its maximum value of the profile between 60 to 80 hPa layer except during the depletion period.

(ii) January to June the change in the ozone partial pressure profile is not significant. Although the depletion of atmospheric ozone starts gradually with the onset of polar winter the sharp depletion takes place in the month of September and October. Thereafter recovery of atmospheric ozone starts from the middle of the month of November and normal value of ozone partial pressure was recovered by the last week of December.

(iii) During the depletion period atmospheric ozone was found completely depleted at some levels between the levels 150 to 20 hPa The representative depletion of atmospheric ozone is shown in Figure-2. The ozone profile of 23rd- April 1999 and 14th October 1999 is compared in the figure and results are self-explanatory.

(iv) Two maximas were observed during depletion period separated by the depletion zone. First maxima during the depletion were found around 140-170 hPa and second maxima around 15-20 hPa. Ozone recovery started from the higher levels and them descended down below gradually to lower levels.

3. Brewer Spectrophotometer Observations

3.1) Brewer Spectrophotometer System

BREWER SPECTROPHOTOMETER

The Brewer MK.IV Spectrophotometer is a scientific instrument, which measures atmospheric ozone and sulphur dioxide by examining the absorption of specific ultraviolet wavelengths from the solar spectrum. The instrument can be switched to visible wavelengths and measure nitrogen dioxide.

Though the Dobson instrument has served its purpose well since the 1930s, the Brewer Ozone Spectrophotometer is today becoming the instrument of choice for researchers measuring ozone and sulphur dioxide. About 100 Brewer instruments have already been incorporated in the World Ozone Network and measurements are currently being taken at research establishments in over thirty different countries. In Antarctica three Brewer Instruments are being operated apart from fourth made operational by India from 16th July 1999.

The Brewer Spectrophotometer is the core component of a complete Brewer System, which comprises the following items:

* Brewer Spectrophotometer
* IBM PC or compatible microcomputer
* Printer-dot matrix printer- Centronics compatible parallel interface
* Control software

The Brewer Spectrophotometer is normally supplied with automated iris & filterwheel controls, azimuth & zenith trackers, and a UVB monitor. The IBM BASIC control software controls all aspects of data collection and analysis. The PC is programmed to interact with an operator to control the Brewer either a manual, a semi-automated or fully automated mode of operation. At Maitri Antarctica the Brewer is being operated in semi-automated mode.

In both manual and semi-automated modes the operator initiates a specific observation or instrument test by typing an instruction 'command code' on the PC keyboard. Raw data is automatically recorded on a hard disk drive and real time ozone results can be printed on paper (hard copy).

The Brewer is an optical instrument designed to measure ground-level intensities of the attenuated incident solar ultraviolet (UV) radiation at five specific wavelengths in the spectra of ozone and sulphur dioxide. The MKIV version allows switching to nitrogen dioxide operation at 430-450nm (second order). The Brewer contains a modified Ebert f/6 spectrometer with a 1200 line/mm holographic diffraction grating operated in the third order for O_3/SO_2 and second order for NO_2.

Sunlight enters the foreoptic system through the quartz inclined window adjacent to the zenith-adjustment knob. The incoming light is directed through the foreoptics by a director prism, which may be rotated to select light from the zenith sky, the direct sun, or one of the two calibration lamps. A mercury lamp provides a line source for wavelength calibration of the spectrometer; a halogen lamp provides a well-regulated light source so that the relative spectral response of the spectrometer may be monitored. The elements in the foreoptics provide adjustment for field-of-view, neutral-density attenuation, and ground quartz diffusion, and selection of a film polarizer for zenith sky measurements.

A modified Ebert grating spectrometer disperses ultraviolet light onto a focal plane. Six slits are positioned along the focal plane at the operating wavelengths; 303.2nm (302.1nm for mercury-wavelength calibration), 306.3nm, 310.1nm, 313.5nm, 316.8nm in ozone mode with 0.6nm resolution. 426.4nm, 431.4nm, 437.3nm, 442.8nm, 448.1nm, 453.2nm in NO_2 mode with 0.85nm resolution. Wavelength is adjusted by rotating the grating with a stepper motor, which drives micrometer acting on a lever arm.

The exit-slit plane is shielded by a cylindrical mask, which exposes only one wavelength slit at a time. The mask is positioned by a stepper motor, which cycles through all five operating wavelengths approximately once per second.

The light passing through the exit slits is collected on the cathode of a low-noise EMI 9789QB05 photomultiplier. The photon pulses are amplified, discriminated. and divided before being transmitted to a counter. The resulting photon count is registered in one of six wavelength channels.

ULTRAVIOLET-B MONITOR

The Ultraviolet-B monitor is an optical assembly, which enables the Brewer to measure UV-B irradiance using a thin disc of Teflon (cosine response) as a transmitting diffuser. The disc is mounted on the top of the instrument under a 5-cm diameter quartz dome, and is thus exposed to the horizontal UV irradiance. Beneath the disc is a fixed reflecting prism, which is located so that the disc is in the spectrometer field-of-view when the zenith prism is set for a zenith angle of-90.

The UV measurement software routine supplied scans from 290 to 325nm on slit 1 in 0.5nm increments and then scans back to 290nm. The irradiance at each wavelength is integrated to produce a damaging UV value (DUV) weighted to the DIFFEY action spectrum.

3.2) Installation and operation

Brewer Spectrophotometer equipment and accessories arrived at the station Maitri in the second week of the month of May 1999. By the time equipment was shifted to the installation area the polar night was at the footstep. After the end of polar night the Brewer System was installed in the month of July and operational tests carried out. Azimuth alignment of the equipment could be completed in the last week of July when sun disc reached above horizon.

Due to low solar elevation total ozone measurements in focussed sun mode could be started only from 17^{th} August 1999 whereas first Damaging Ultra Violet radiation observation using Brewer Spectrophotometer was taken on 4^{th} August 1999. Direct Sun mode observations started from 14^{th} September when solar elevation reached mu=3 or less. From August to December 99 the Brewer system was operated for 90 days and total ozone measurements were taken on 85 days. The Brewer data for the above period has been processed and brief results regarding Total Ozone, DUV, S02, and N02 measurements are presented here.

3.3) Direct Sun Total Ozone Measurements

The total ozone measurement in Direct Sun measurement mode was taken on maximum number of days except on the days with blizzard, snowfall, gale force wind and thick overcast sky. The measurements were taken for all possible duration of sunlight to find out diurnal variation in total ozone amount. The total ozone values depicted a diurnal variation with Maxima during morning and evening and Minima near local noontime. There were occasional shooting up of Total Ozone value due to intense solar activity and arrival of ozone rich sub-tropical air with the passage of extra tropical storms. Sharp decrease on some days was also observed when the polar air was inducted in the area. The days with abrupt rise in total ozone value were also associated with auroral activity. Daily mean total ozone values recorded during the year 1999 are shown in the Figure-3].

As evident from mean daily Total Ozone value shown in figure Ozone depletion started from 09th September (Julian day 242) and reached to its minimum value on 28th October (Julian day 301). The period of intense depletion was for about 20 days. Ozone depletion period was between Julian days 260 to 320 with daily mean total ozone values between 135 and 160 Dobson Units. Maximum depletion was observed from the last week of October to the Second week of November.

Total Ozone recovery started from 20th November (Julian Day 324) and by 19th December (Julian day 351) mean daily total ozone value reached to its normal values. Above features were also confirmed with Ozone sonde profile and surface ozone records.

3.4) Focussed Sun Observations

Total Ozone observations in focussed Sun observation mode were taken for the period when solar zenith angle was above 73 till the mu value reached equal or above 8. Since these observations were made near the ozone maxima period the values were found higher than mean daily total ozone value measured in DS mode. The difference was about 10 DU during the normal total ozone value and about 20 DU during the depletion period.

3.5) Focussed Moon Observations

In the month of September focussed moon mode of operation for the measurement of Total Ozone was attempted when lunar mu was less than 3 and more than 2/3 of the lunar disc was visible. The total ozone measured in this mode was found very close to the daily mean total ozone measured in direct sun mode but the values were towards higher side by 5 DU. The method can be used for total ozone measurements during the polar nights and period of low solar elevation.

3.6) Zenith Sky Observations

The Brewer was operated in Zenith Sky mode of operation for measurement of total ozone, S02, and N02. The value obtained in this mode was not compatible with the values observed in DS mode. Main reason for this error is non-availability of Zenith Sky Map for this location. After completion of one year of operation Zenith Sky Map for this location will be prepared and the system could be used effectively for all measurements. However the values measured during high solar elevation were found to be in agreement with DS mode of measurements.

3.7) Damaging Ultra Violet Radiation measurements

DUV measurement was done on maximum number of days from dawn to dusk till the middle of the month of October. When solar days became longer, on every 10^{th} day DUV measurements were taken round the clock. On other days the observation was restricted for mu values less than 8.

DUV values measured in mW/m2 shows diurnal and seasonal variation. Daily DUV values shows a maxima near the local noon and its value changes according to solar zenith angle. It was found to reach zero after one hour of sunset and starts rising from zero value before one hour of sunrise. Diurnal variation of DUV for the 10^{th} November 99 (JD 314) is shown in the Figure-3 (a). On this day lowest total ozone value of 86.1 DU was measured at 1145 UTC. The highest DUV of 233.522 mW/m^2 was measured at 1103 UTC for zenith angle 53.67 on this day.

As discussed earlier in the UV measurement mode the diffused sunlight is scanned from 290 to 325nm in 0.5nm increments and then scanned back to 290nm. The irradiance of each wavelength for one such scan taken around noon period on 25^{th} September is shown in Figure-3(b). From the figure it is evident that major contribution of irradiance comes from the wavelengths 310nm to 325nm with maxima around 317nm. Daily variation of DUV maxima measured around noon during the year 1999 is shown in Figure-3(c).

3.8) SO_2 and NO_2 observation

SO_2 measurement was done in direct sun measurement mode as a sub-routine of Ozone mode whereas NO_2 measurements are done by a separate independent measurement mode. The daily mean values of SO_2 and NO_2 measured in DS mode are shown in Figure-3 (d). The system also measures and calculates the stratospheric and tropospheric amount of NO_2 in m-atm-cm or Dobson units for each morning and evening twilight periods if series of ZS measurements are available between angles of 84.5 and 96.5. Detailed study of role of SO_2 and NO_2 in creation of Ozone Hole and depletion recovery will be done separately.

4. Radiation Balance Studies

4.1) Total Global Solar Radiation Measurement

Total global solar radiation was continuously recorded at the Maitri station using thermo-elecric pyranometer installed on the roof of the station. Radiation measurements were taken throughout the year. The total global solar radiation was found maximum in the month of November and December during the year 1999 due to long period of cloud free sky, insolation, and high solar elevation. As the solar elevation and duration of sunshine started reducing Total global solar radiation also reduced to zero by the end of the month of May. Solar radiation again started from the last week of July and reached to the highest value by the beginning of polar day.

4.2) Diffused Solar Radiation Measurement

During the year 1997 Diffused Solar Radiation recorder was installed in the observatory enclosure at Maitri on a raised platform for the study of effect of scattering by surface features and clouds on the total global solar radiation. For recording of diffused solar radiation thermo-electric pyranometer is installed with a difference that a shading ring blocks incoming direct solar radiation. Due to daily significant variation in the solar zenith angle it was not possible to use fixed shading ring. An improvised and modified shading ring has been used at Maitri to cater above need.

Radiation recorder installed at Maitri was not sensitive enough and also shading was not proper during the first two weeks of January 99. New radiation recorder was installed and shading procedure was modified for better results. For two months very good data was recorded. Recorder developed defect beyond local repair in the first week of April 99. The data for the days when shading was not proper and with broken records has been omitted. It has been observed that on cloudy days Diffused solar radiation increases significantly and major part of Total global solar radiation on these days is contributed by diffused solar radiation.

Conclusion

During the year 1999 Ozone hole phenomena was observed as usual and there was no significant change in the quantity of depletion. Ozone sonde profile and Total Ozone measurement by Brewer Spectrophotometer were complimentary to each other and detailed study is required to understand different processes and role of UV radiation and quantitative changes observed in the S02 and N02 measurements. Spectral analysis of UV radiation is required to study its influence on ozone depletion and viceversa. Climatological features were found as usual except the fact that the year 1999 was colder and windier than normal and extreme wind speed and atmospheric pressure recorded during the year.

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TABLE-1.1: CLIMATOLOGY OF MAITRI ANTARCTICA FOR THE YEAR 1999

Months	Temperature (C) Daily Mean	Mean Max	Mean Min	Tmax	Tmin	Wind (Knots) Mean Speed	Max/Gust Speed	MSL Pressure (hPa) Mean Pr	Maximum Pr	Minimum Pr	Clouding Octa	Snowfall mm	Days with Snow	Blizzard	Aurora
JAN	0.9	3.3	-01.9	8.5	-06.0	19.6	40/64	0986.5	1002.0	0977.2	5.6	tr	2	0	0
FEB	-03.3	-00.6	-06.1	3.2	-10.0	15.1	40/52	0990.2	1001.7	0977.6	4.7	01.9	5	0	0
MAR	-07.6	-05.2	-10.6	2.5	-18.4	18.7	45/50	0987.4	1004.6	0974.8	5.1	02.9	8	7	1
APR	-13.4	-10.6	-16.7	-05.1	-22.5	19.6	55/77	0981.2	0994.8	0965.0	3.6	12.5	9	5	2
MAY	-14.0	-11.1	-17.5	-06.0	-25.8	25.8	66/72	0980.9	0997.7	0965.0	3.6	01.0	5	9	4
JUN	-11.3	-09.1	-13.9	-00.1	-21.5	28.4	65/74	0993.2	1019.8	0969.3	4.9	00.2	6	5	0
JUL	-18.4	-15.3	-22.2	-03.8	-32.5	17.0	78/100	0987.4	1007.2	0963.0	3.6	01.7	3	2	1
AUG	-16.0	-12.8	-19.3	-06.1	-31.5	23.4	80/96	0984.2	1010.5	0945.7	5.8	123.3	14	15	5
SEP	-15.6	-12.9	-19.0	-03.0	-27.4	21.5	94/110	0987.2	0999.2	0956.7	5.2	86.4	10	10	7
OCT	-12.9	-09.8	-17.1	-03.0	-25.4	17.7	66/82	0975.4	0993.1	0951.1	3.7	39.1	6	5	2
NOV	-05.4	-02.9	-08.7	4.0	-24.3	17.8	58/72	0981.4	0994.6	0962.9	3.4	tr	2	0	0
DEC	-02.6	0.0	-06.0	4.5	-11.6	13.4	54/62	0980.0	0993.7	0963.0	4.8	04.7	10	2	0
ANNUAL	-10.0	-07.3	-13.3	8.5	-32.5	19.8	94/110	0984.6	1019.8	0945.7	4.5	273.7	80	60	22

Table-1.2 : Brief summary of blizzards recorded at: Maitri during the year 1999.

S.No.	Time/Dato		Extreme values				
	Commenc.	Cassation	MSL Pressure		Temperature		Wind
			MAX.	Min.	Max.	Min.	Max. (kt)
			MARCH 1999				
1.	12/0930	15/0200	970,0	966.7	-06.0	-09.2	46
			14/1200	13/1300	14/1730	13/0230	13/0930
2.	19/0300	19/1630	978.4	976.2	-OS.7	-08.0	43
			19/1630	19/0500	19/1430	19/0340	19/0830
3.	20/2130	21/1700	981.7	978.0	-11.5	-15.7	46
			20/2130	21/1700	21/1430	21/0400	21/1100
4.	23/0130	23/1530	970.0	968.4	-12.5	-16.0	48
			23/0130	23/1530	23/1140	23/0350	23/1030
			APRIL 1999				
1.	19/0530	19/1510	981.1	978.4	-08.7	-10.3	72
			19/0600	19/1200	19/1500	19/0900	19/1400
2.	25/1400	27/0530	986.3	965.2	-05.8	-12.0	77
			26/0800	27/0300	27/0400	25/1500	26/2130
3.	30/0030	30/0930	974.1	968.0	-12.0	-12.3	40
			30/0930	30/0030	30/0100	30/0900	30/0830
			MAY 1999				
1.	10/0815	11/0530	976.4	975.0	-10.6	-11.4	40
			10/2100	10/1200	10/1130	10/0900	10/0840
2.	13/0100	13/0700	974.9	974.4	-19.3	-20.3	33
			13/0700	13/0100	13/0300	13/0600	13/0630
3.	14/0030	14/0630	984.8	982.8	-14.3	-15.0	36
			14/0630	14/0030	14/0600	14/0100	14/0500
4.	15/1900	16/1000	980.0	970.9	-14.0	-20.0	56
			15/1900	16/1000	16/0930	15/1900	16/0700
. 5.	20/0320	21/0530	983.2	977.2	-10.2	-15.6	56
			20/2100	20/0320	20/1130	21/0400	21/0100
6.	24/0600	24/1200	982.0	977.1	-07.0	-09.0	60
			24/1200	24/0600	24/1140	24/0900	24/1000
			JUNE 1999				
1.	10/0000	10/0200	997.9	997.2	-09.7	-10.0	47
			10/0200	10/0000	10/0200	10/0000	10/0100
2.	18/2200	18/2300	1007.0	1006.0	-10.5	-11.0	44
			18/2200	18/2300	18/2300	18/2200	13/2200
3.	20/1930	20/2200	992.3	991.8	-04.7	-05.2	68
			20/2200	20/1930	20/2200	20/2100	20/2200
4.	25/2000	26/0200	973.4	970.7	-00.1	-04.6	56
			25/2000	26/0200	25/2000	26/0200	25/2300

S.No.	Time/Date		Extreme values				
	Commenc.	Cossation	MSLPressure		Temperature		Wind
			Max.	Min.	Max.	Min.	Max. (kt)
			JULY 1999				
1.	22/2000	23/0100	975.7	968.7	-07.3	-08.3	9g
			22/2000	23/0100	23/0100	22/2100	22/2000
2.	23/2130	23/2330	980.0	968.8	-09.0	-12.0	100
			23/2330	23/2130	23/2130	23/2330	23/2225
			AUGUST 1999				
1.	05/2150	08/1830	1002.3	982.4	-08.4	-21.8	66
			05/2400	08/0300	07/1850	06/0130	06/0540
2.	13/0500	14/2230	990.7	948.3	-06.6	-13.8	85
			13/0600	14/1700	14/0230	13/0500	14/0155
3.	15/0530	16/1745	980.0	961.3	-13.0	-16.5	50
			16/0900	15/0600	15/1100	16/0900	15/1110
4.	22/1000	24/2315	991.7	984.4	-10.8	-20.0	70
			22/2400	24/0600	24/2300	22/1000	24/0410
5.	28/2130	30/2300	978.4	952.4	-07.4	-16.1	96
			28/2400	30/2100	30/1130	29/0900	30/1045
6.	31/0500	31/1900	974.8	945.7	-07.2	-12.3	86
			31/1900	31/0610	31/0500	31/1900	31/0530
			SEPTEMBER 1999				
1.	04/0500	04/2300	961.0	956.7	-13.5	-16.1	80
			04/0500	04/1200	04/0530	04/2110	04/1600
2.	06/0625	07/0400	997.2	993.2	-13.1	-18.0	50
			07/0400	06/0625	07/0400	06/0625	06/1900
3.	10/0330	11/1345	984.5	959.8	-13.8	-16.4	>110
			10/0330	10/1850	11/0300	10/0450	10/1720
4.	12/0630	12/1130	998.5	997.1	-13.8	-15.1	38
			12/1130	12/0630	12/1130	12/0630	12/0900
5.	13/0020	13/1130	997.9	993.3	-12.4	-14.0	40
			13/0020	13/1130	13/1130	13/0100	13/0300
6.	13/2200	14/1150	993.8	991.1	-13.4	-18.8	55
			14/0900	13/2200	13/2200	14/1150	14/0600
			OCTOBER 1999				
1.	01/1905	02/0500	966.2	956.8	-12.8	-15.8	82
			01/1905	02/0400	02/0500	02/0010	02/0010
2.	18/1800	20/2340	987.9	973.9	-06.9	-11.0	75
			18/2100	20/1200	18/1800	20/0500	19/1135
			DECEMBER 1999				
1.	20/0430	21/0100	982.7	976.3	-02.2	-05.2	65
			21/0100	20/0800	20/0900	20/0510	20/0610

No blizzard in the month of January, February and November.

Table-4.1 : Daily sum of Total Global Solar Radiation measured in MJ/m^2 received at Maitri Antarctica during the year 1999.

DATE	JAN	FEB	MAR	APR	MAY	JUL	AUG	SEP	OCT	NOV	DEC
01	21.26	28.47	14.01	08.05	1.12	--	0.00	01.70	10.05	15.89	37.76
02	33.25	29.27	15.36	04.45	0.46	--	0.21	01.90	11.08	26.08	36.05
03	22.89	24.75	11.28	01.97	0.90	--	0.17	02.16	13.41	11.62	29.44
04	23.35	21.00	13.83	06.75	0.54	---	0.22	01.47	16.21	11.67	36.03
05	34.44	09.01	11.08	05.57	0.29	--	0.34	03.36	11.28	13.12	34.99
06	33.38	16.87	06.08	06.18	0.09	--	0.15	01.76	15.25	17.73	29.05
07	35.76	11.25	15.45	05.81	0.32	--	0.21	03.80	15.88	12.87	30.72
08	21.92	13.27	07.31	05.19	0.65	--	0.45	02.47	16.86	12.29	19.40
09	24.47	16.14	05.33	05.37	0.36	--	0.74	03.57	17.19	28.22	27.44
10	15.94	24.00	06.24	05.29	0.09	--	0.35	01.14	16.56	23.17	29.40
11	12.87	22.88	13.40	02.52	0.09	--	0.27	02.55	17.35	30.68	15.53
12	35.29	24.99	03.79	04.58	0.22	--	0.18	04.58	18.02	30.99	29.61
13	28.82.	24.78	03.08	04.63	0.21	--	0.45	04.35	17.61	29.69	29.72
14	09-42	23.18	04.98	03.57	0.00	--	0.25	06.39	18.59	30.73	34.25
15	10.23	24.51	09.75	03.67	0.03	--	0.39	07.62	16.96	26.53	35.64
16	29.10	19.11	07.25	03.59	0.00	--	0.61	08.74	19.78	32.12	29.28
17	35.34	19.9O	11.52	03.24	--	--	1.32	07.10	18.00	32.66	35.68
18	37.48	18.28	13.08	01.60	--	--	1.91	03.33	08.79	28.78	15.97
19	33.73	12.40	04.79	00.99	--	--	1.42	08.97	06.28	33.01	28.27
20	34.13	07.74	11.09	02.55	--	--	1.47	09.50	10.03	33.62	09.69
21	13.99	18.13	12.05	01.04	--	--	1.48	09.62	20.62	33.75	15.26
22	13.43	07.36	09.36	02.14	--	--	0.88	08.32	21.14	33.83	31.67
23	27.75	10.84	08.66	02.75	--	--	0.47	10.61	16.80	35.01	38.68
24	32.43	18.88	08.53	02.43	--	--	0.45	02.78	10.96	34.63	38.54
25	31.65	20.86	07.57	05.55	--	--	1.29	08.79	15.10	34.85	37.79
26	27.37	19.44	05.09	00.49	--	--	1.82	11.40	23.89	34.67	35.56
27	14.09	09.19	08.12	01.01	--	--	3.05	12.46	24.47	34.13	28.85
28	23.22	15.73	08.72	00.78	--	--	1.34	12.38	25.14	34.21	29.45
29.	15.88		07.47	01.17	--	0.11	0.93	10.00	24.95	37.14	28.21
30	18.85		05.58	00.68	--	0.21	0.83	13.06	17.65	36.66	37.54
31	16.95		06.39	--	--	0.10	0.55	--	21.63	--	37.09

Table-4.2 : Daily Sum of Diiffused Solar Radiation measured in MJ/m^2 received at Maitri, Antarctica during the year 1999.

DATE	JAN	FEB	MAR	APRIL
01	—	4.48	8.16	2.5
02	—	4.2	8.71	1.44
03	—	11.81	6.61	1.97
04	—	4.66	3.7	1.59
05	—	8.82	5.32	2.34
06	—	14.71	5.16	—
07	—	9.97	3.45	—
08	—	12.09	6.96	—
09	—	10.66	4.13	'—
10	—	8.4	4.94	—
11	10.33	9.33	2.11	—
12	9.75	3.6	3.22	—
13	13.11	3.83	2.26	—
14	7.43	6.47	4.06	--
15	8.33	3.43	4.45	—
16	—	3.4	5.23	--
17	8.69	6.28	4.57	—
18	4.56	12.42	2.38	—
19	4.73	4.99	3.7	—
20	4.59	7,23	1.99	—
21	12,03	4.58	2.08	—
22	—	6.57	3.47	—
23	—	6.94	2.52	—
24	5.3	3.2	2.06	--
25	4.05	2.63	3.9	—
26	4.59	3.94	4.41	—
27	4.63	8.0	3.02	__
28	3.9	7.92	1.5	—
29	2,9	—	2.2	—
30	—	—	3.19	—
31	15.25	—	2.76	—

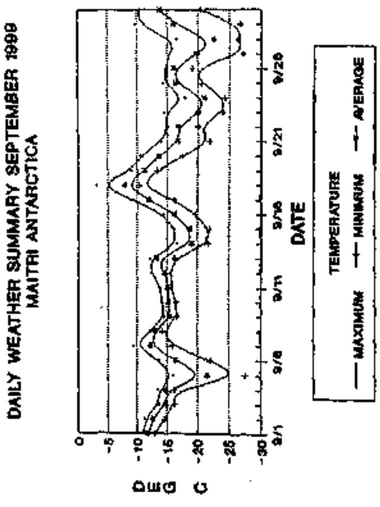


Figure-0.1 Daily Temperature variation

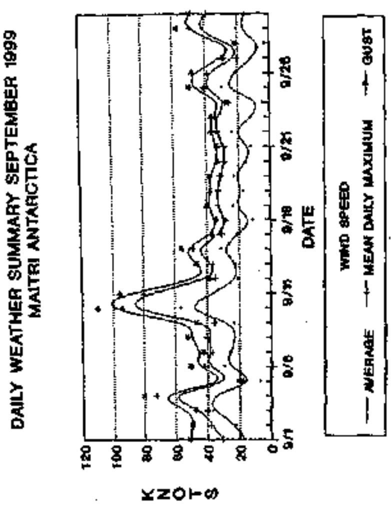


Figure-0.2 Daily wind speed variation

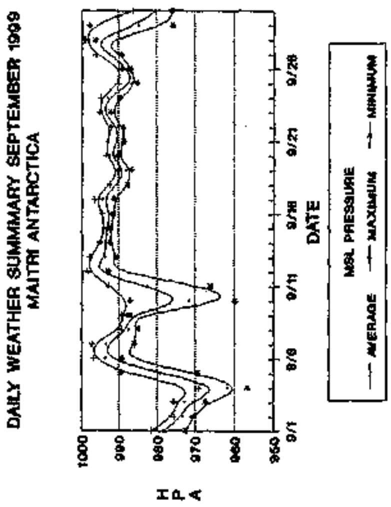


Figure-0.3 Daily Pressure variation

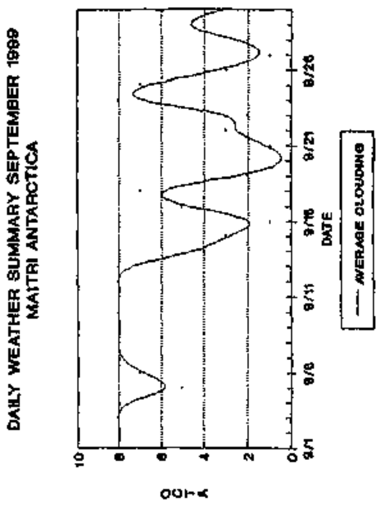
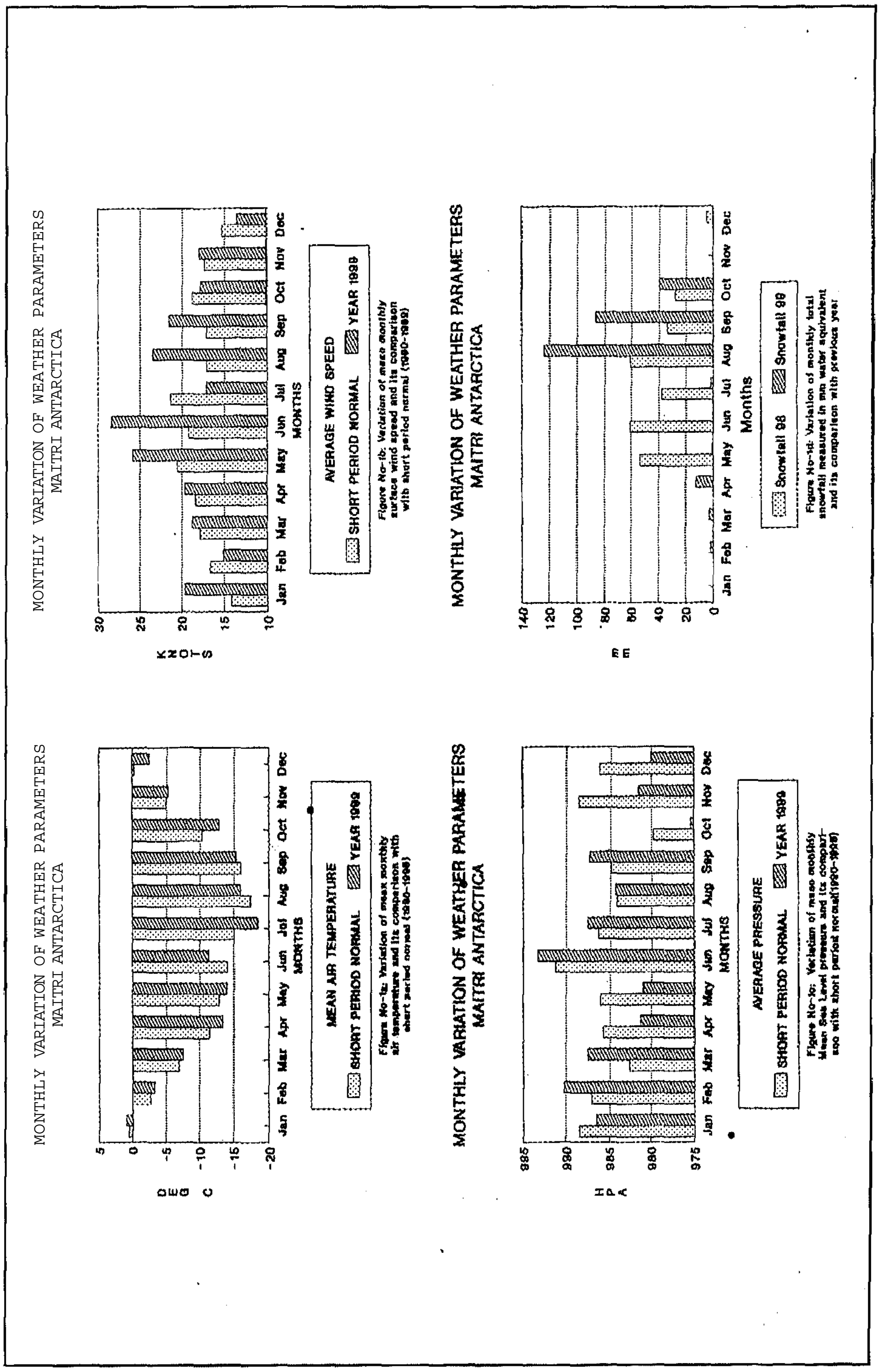


FIG: 0.4 Daily variation of average clouding


MONTHLY VARIATION OF WEATHER PARAMETERS
MAITRI ANTARCTICA
DEG C
MONTHS
MEAN AIR TEMPERATURE
SHORT PERIOD NORMAL
YEAR 1999
MONTHLY VARIATION OF WEATHER PARAMETERS
MAITRI ANTARCTICA
KNOTS
MONTHS
AVERAGE WIND SPEED
SHORT PERIOD NORMAL
YEAR 1999
MONTHLY VARIATION OF WEATHER PARAMETERS
MAITRI ANTARCTICA
HPA
MONTHS
AVERAGE PRESSURE
SHORT PERIOD NORMAL
YEAR 1999
MONTHLY VARIATION OF WEATHER PARAMETERS
MAITRI ANTARCTICA
mm
Months
Snowfall 98
Snowfall 99
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

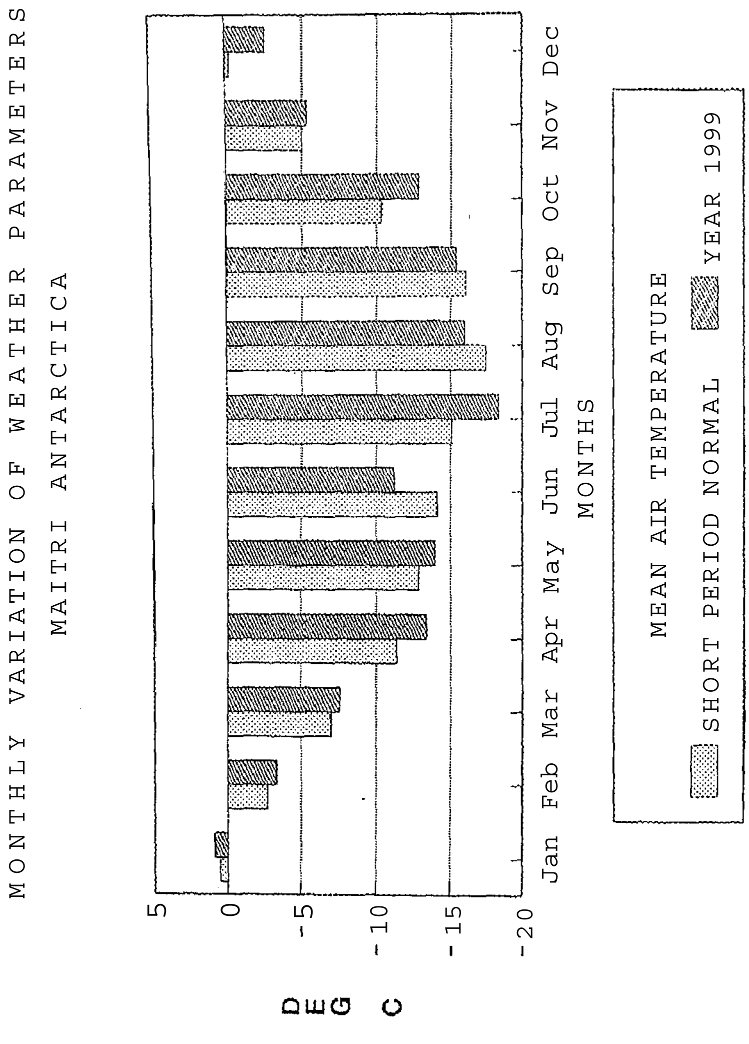


Figure No-1a: Variation of mean monthly air temperature and its comparison with short period normal (1990-1999)

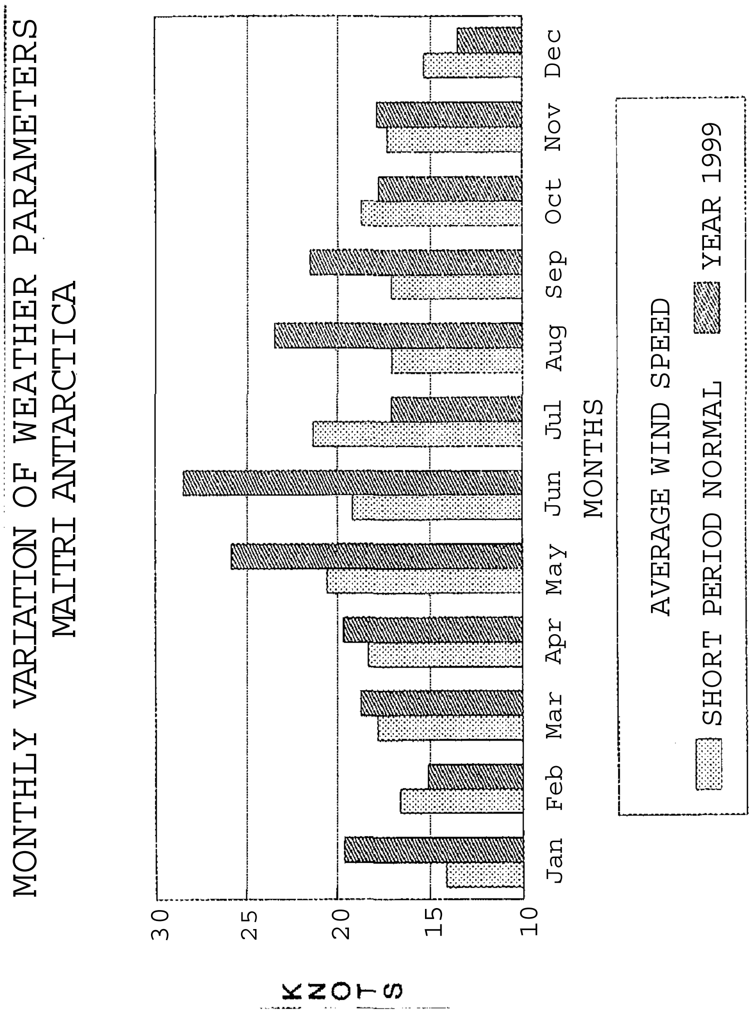


Figure No-1b: Variation of mean monthly surface wind speed and its comparison with short period normal (1990-1999)

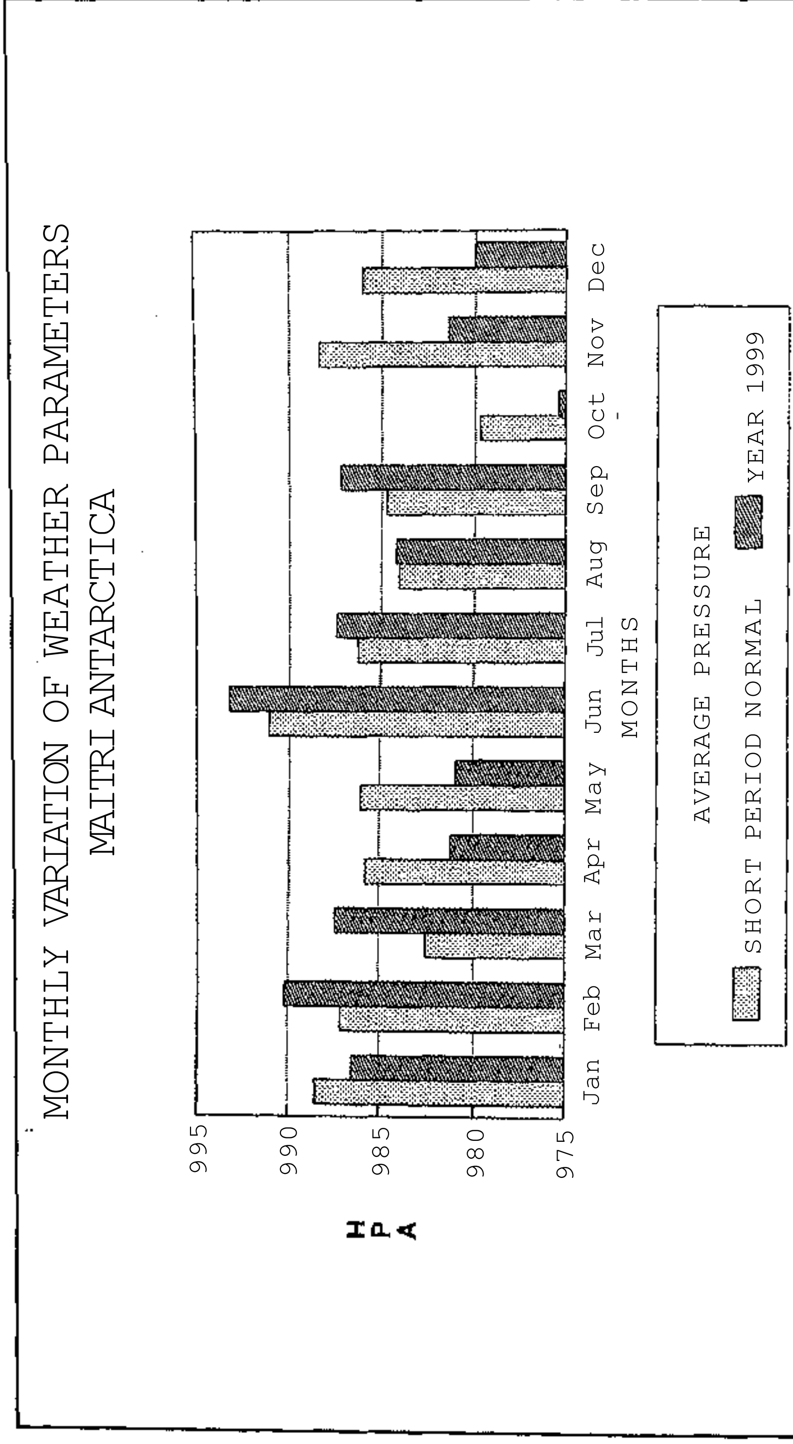


Figure No-1c: Variation of mean monthly Mean Sea Level pressure and its comparison with short period normal(1990-1999)

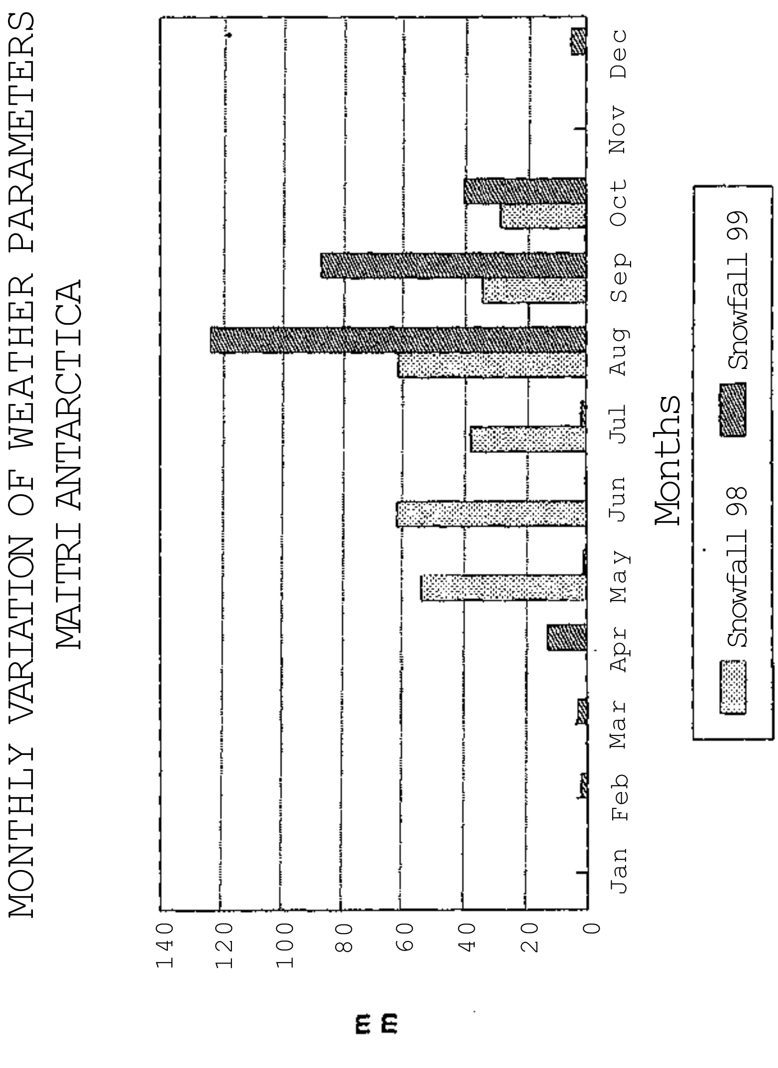


Figure No-1d: Variation of monthly total snowfall measured in mm water equivalent and its comparison with previous year

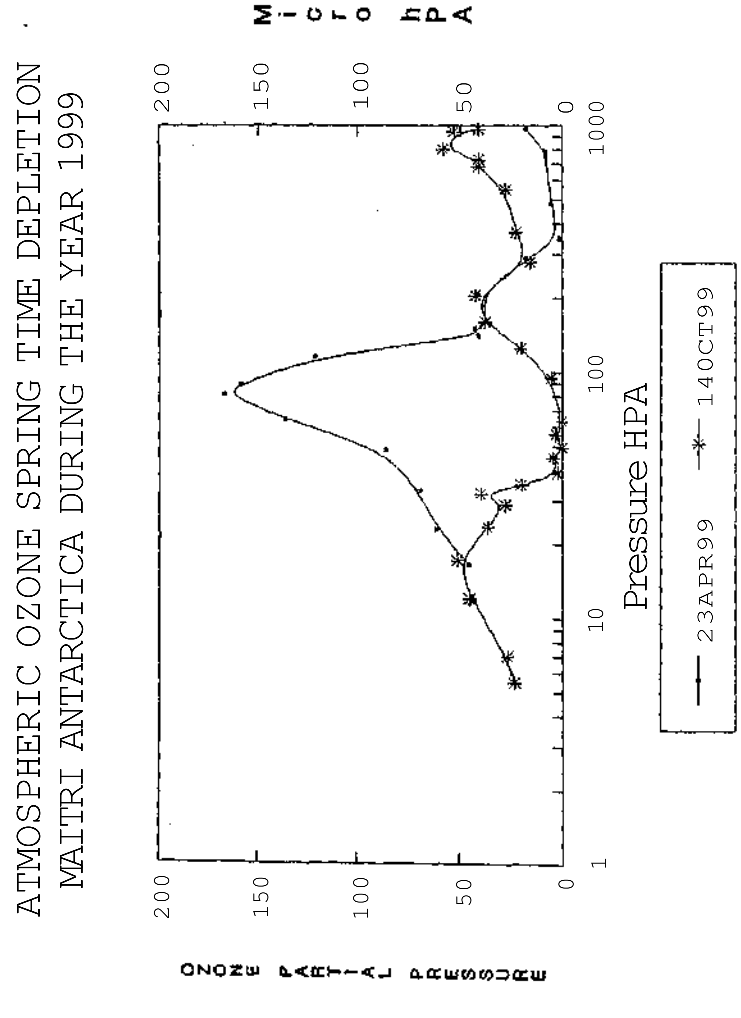


Fig No-2: Ozonogramme for date 23 APR 99 and 14 OCT 99. Ozone Partial Pressure in Micro hPA using Indian E.C. Ozone Sonde

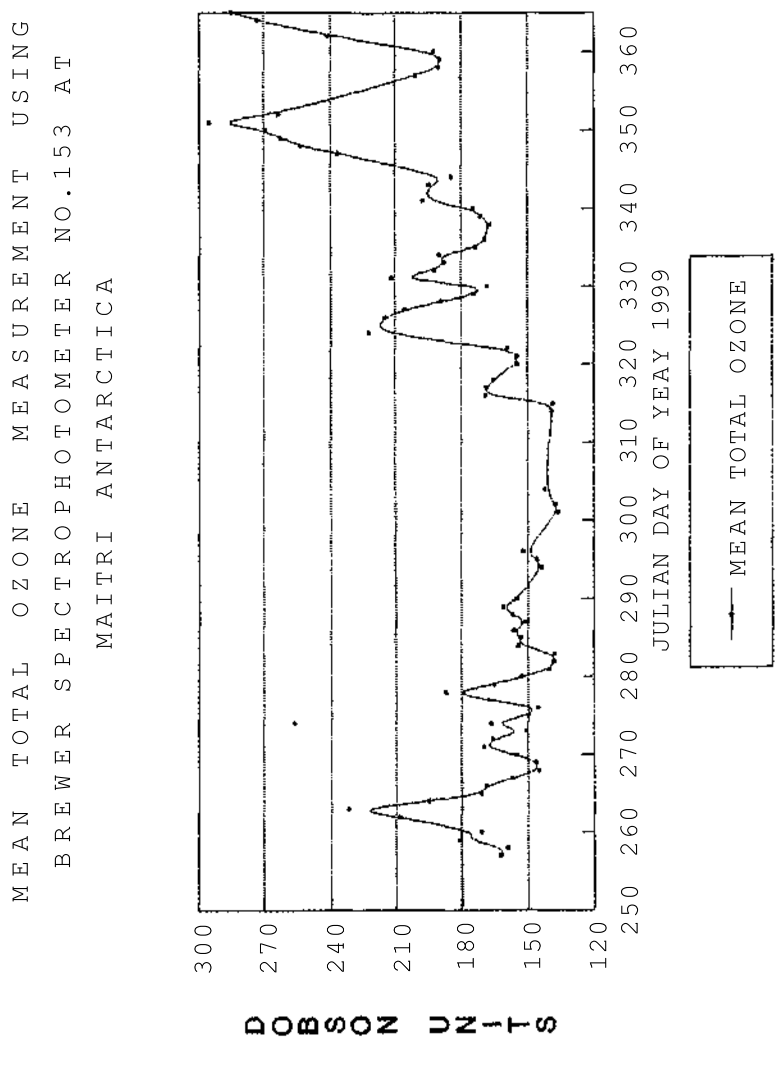
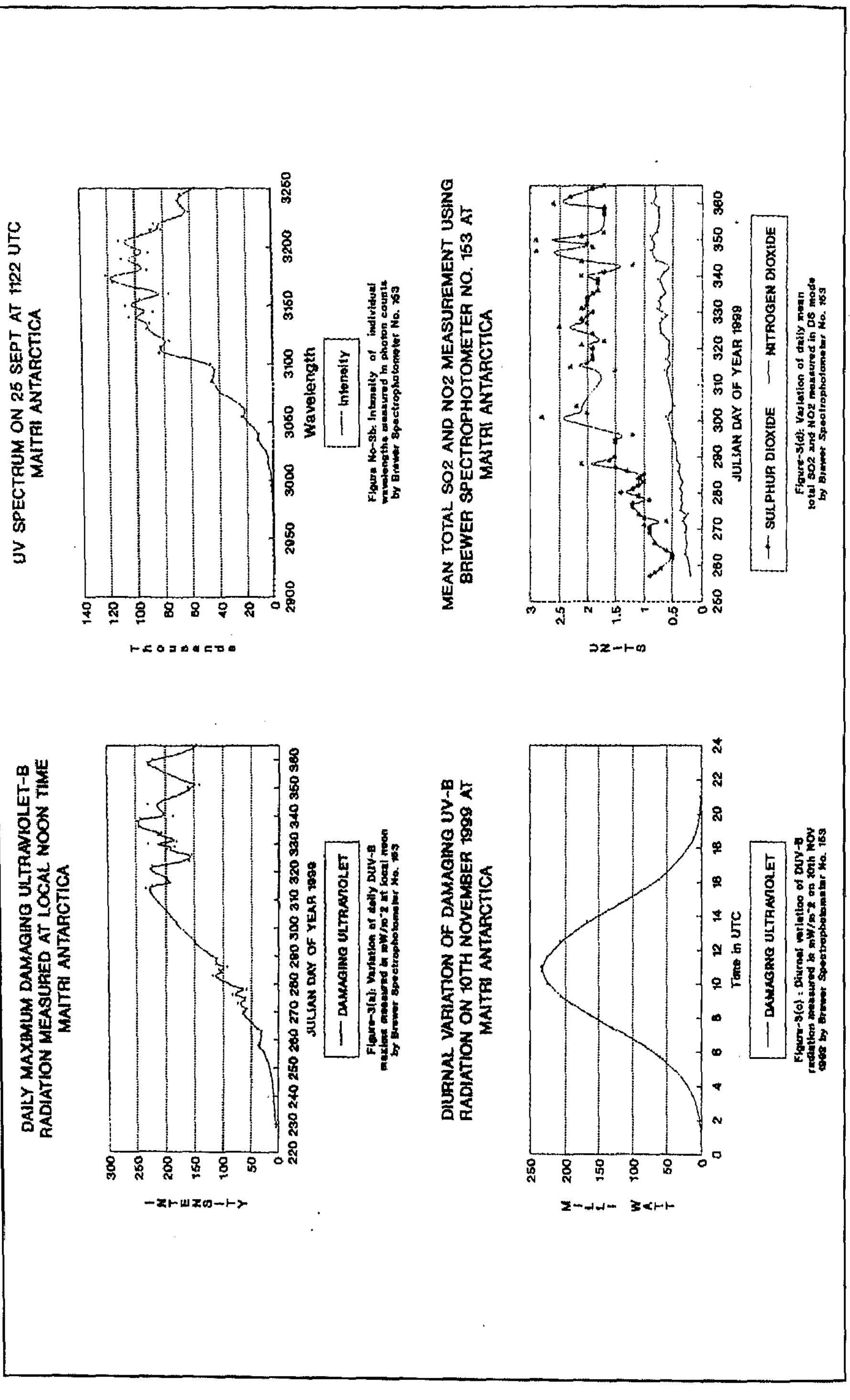


Figure-3 : Variation of daily mean total ozone measured in Direct Sun Observation mode by Brewer Spectrophotometer No.153


DAILY MAXIMUM DAMAGING ULTRAVIOLET-B RADIATION MEASURED AT LOCAL NOON TIME MAITRI ANTARCTICA
INTENSITY
JULIAN DAY OF YEAR 1999
DAMAGING ULTRAVIOLET
Figure-3(a): Variation of daily DUV-B maximum measured in mW/m^2 at local noon by Brewer Spectrophotometer No. 153
UV SPECTRUM ON 25 SEPT AT 1122 UTC MAITRI ANTARCTICA
THOUSANDS
Wavelength
Intensity
Figure No-3b: Intensity of individual wavelengths measured in photon counts by Brewer Spectrophotometer No. 153
DIURNAL VARIATION OF DAMAGING UV-B RADIATION ON 10TH NOVEMBER 1999 AT MAITRI ANTARCTICA
MILLI WATT
Time in UTC
DAMAGING ULTRAVIOLET
Figure-3(c): Diurnal variation of DUV-B radiation measured in mW/m^2 on 10th NOV 1999 by Brewer Spectrophotometer No. 153
MEAN TOTAL SO2 AND NO2 MEASUREMENT USING BREWER SPECTROPHOTOMETER NO. 153 AT MAITRI ANTARCTICA
UNITS
JULIAN DAY OF YEAR 1999
SULPHUR DIOXIDE
NITROGEN DIOXIDE
Figure-3(d): Variation of daily mean total SO2 and NO2 measured in DS mode by Brewer Spectrophotometer No. 153

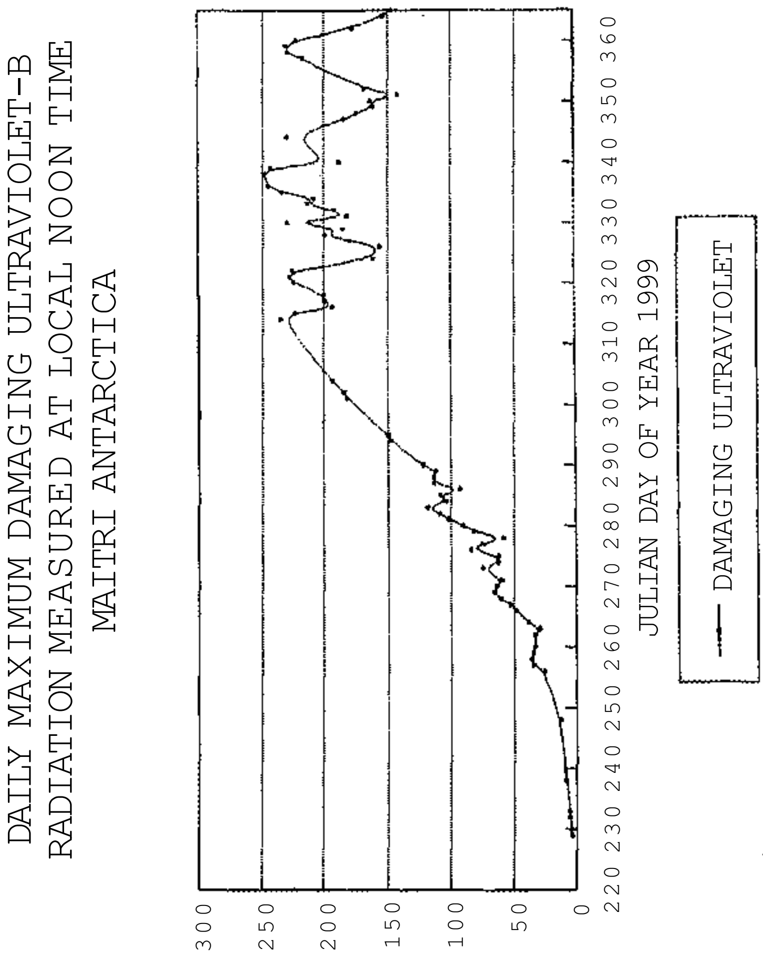


Figure-3(a): Variation of daily DUV-B maxima measured in mW/m^2 at local noon by Brewer Spectrophotometer No. 153

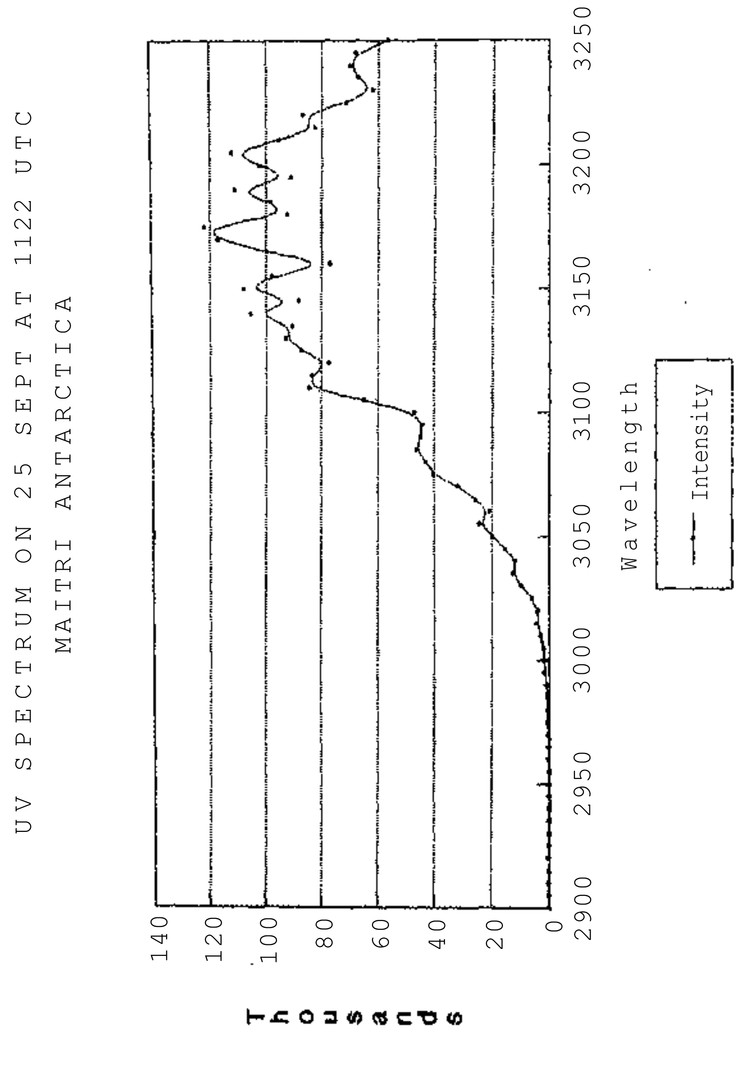


Figure No-3b: Intensity of individual wavelengths measured in photon counts by Brewer Spectrophotometer No. 153

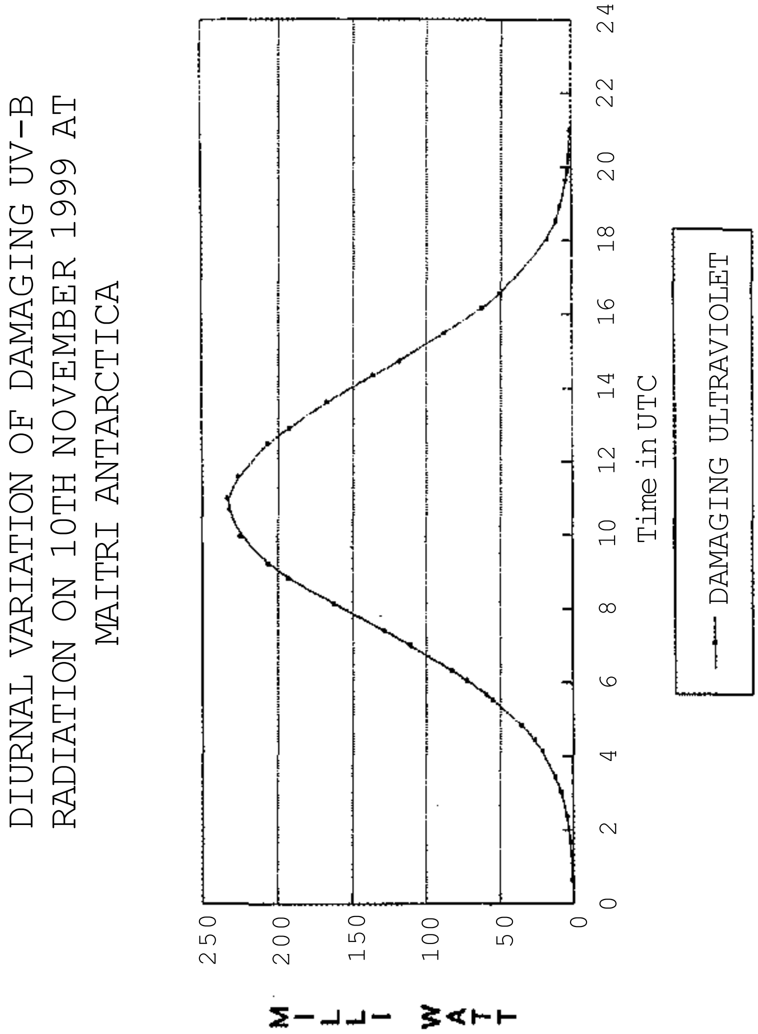


Figure-3(c) : Diurnal variation of DUV-B radiation measured in mW/m^2 on 10th NOV 1999 by Brewer Spectrophotometer No. 153

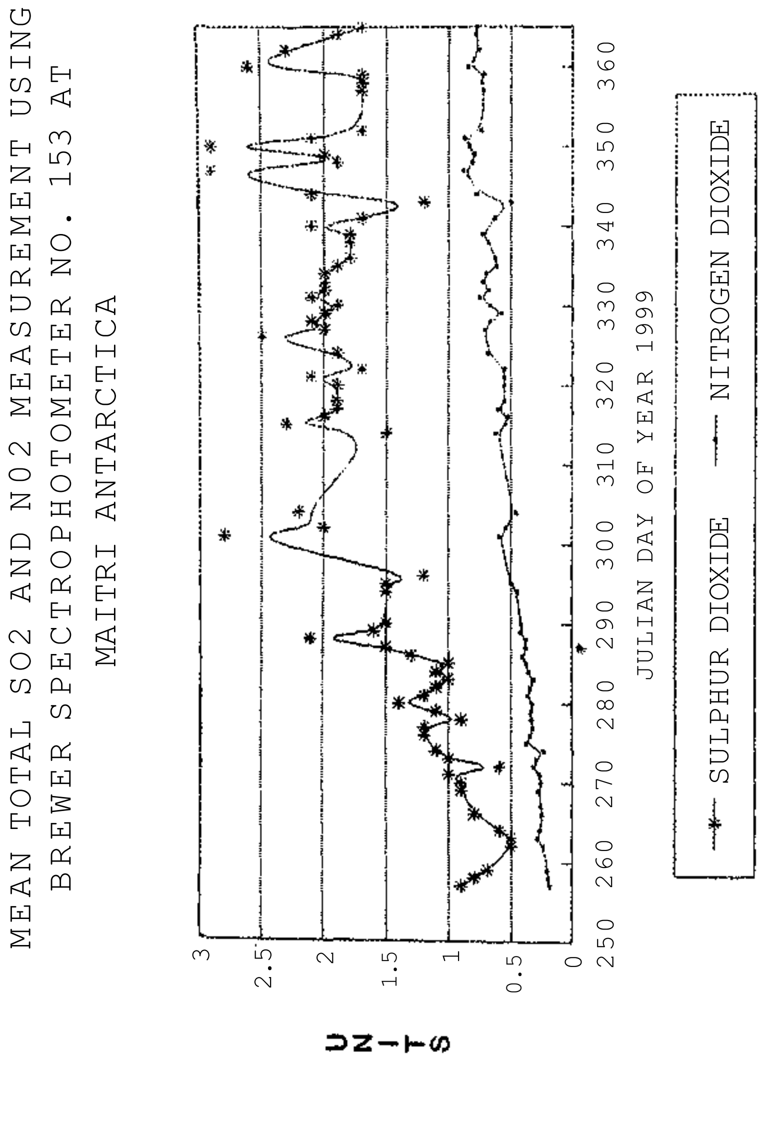


Figure-3(d): Variation of daily mean total SO_2 and NO_2 measured in DS mode by Brewer Spectrophotometer No. 153

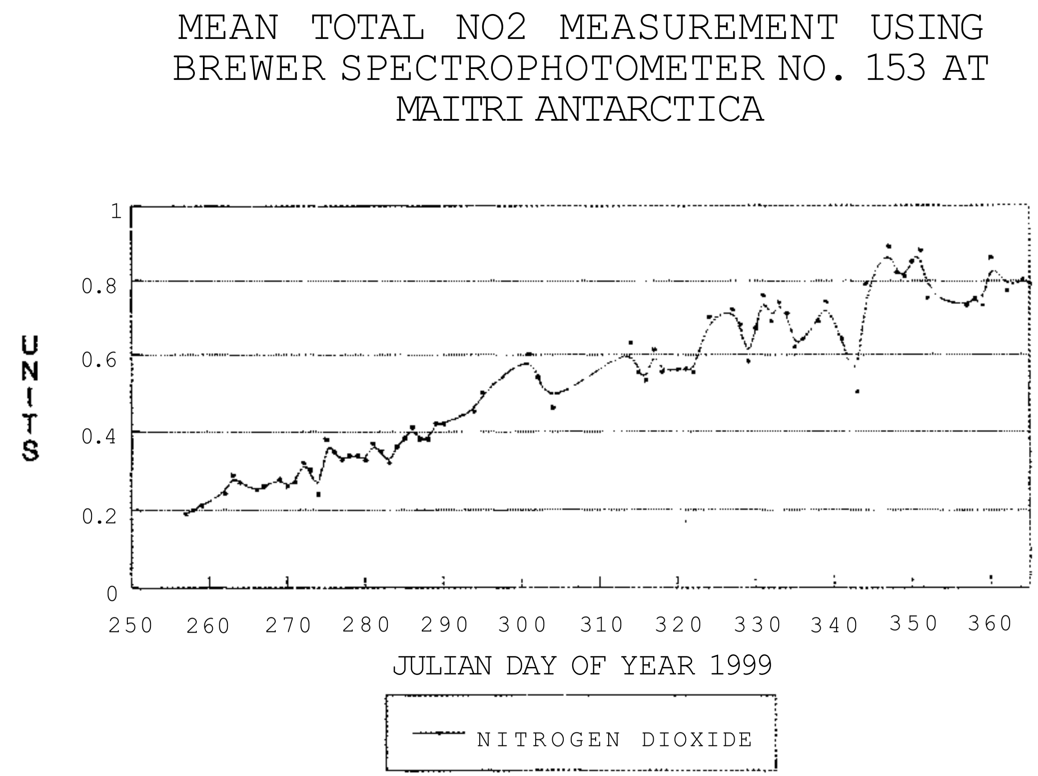


Figure : Variation of daily mean total NO2 measured in DS mode by Brewer Spectrophotometer No. 153

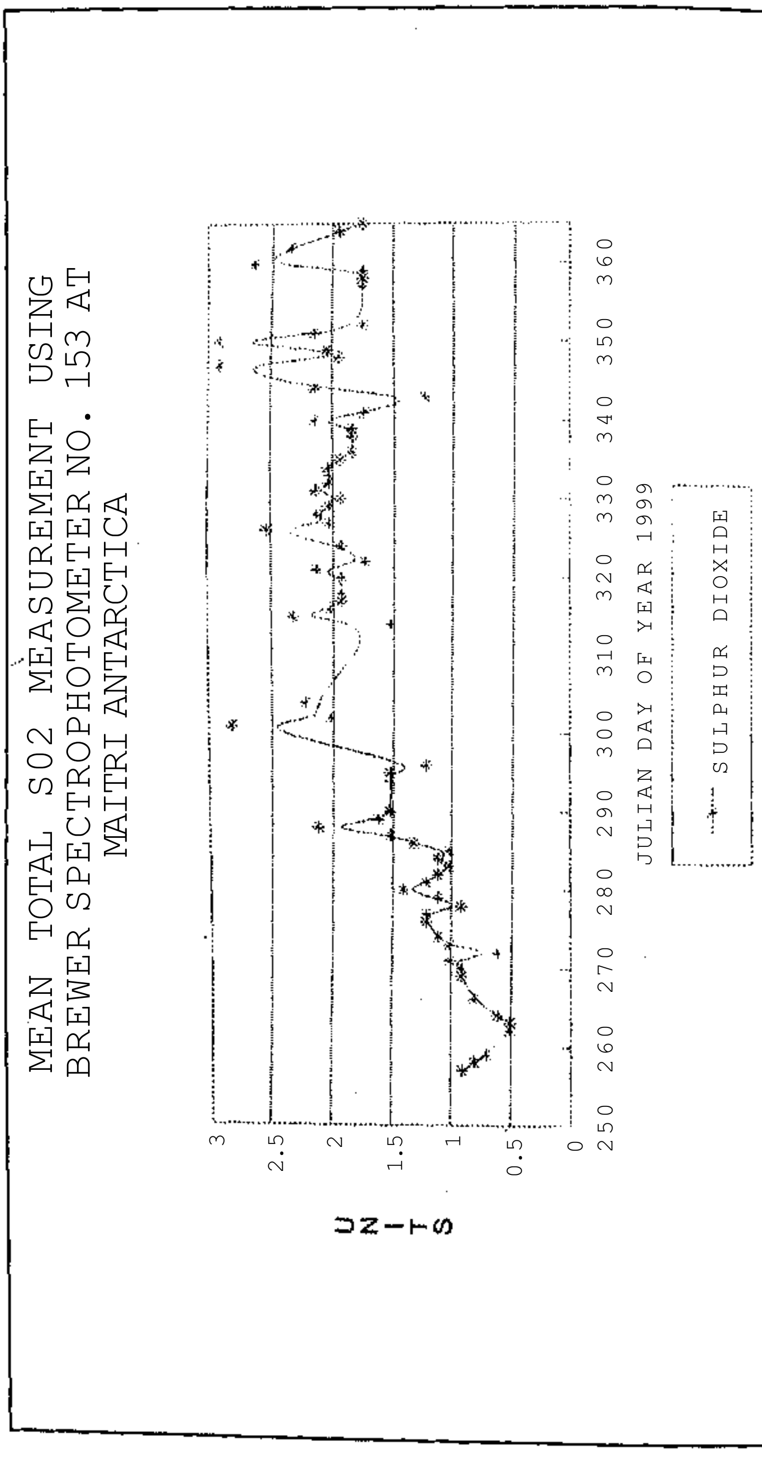


Figure : Variation of daily mean total SO2 measured in DS mode by Brewer Spectrophotometer No. 153