Twenty First Indian Expedition to Antarctica, Scientific Report, 2007
Ministry of Earth Sciences, Technical Publication No. 19, pp 73-93

Study of Meteorological Parameters and Ozone Hole Phenomena at Schirmacher Oasis Antarctica During 21st Indian Antarctic Expedition 2002-2003

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Abstract

India Meteorological Department has an ongoing meteorological program in the Antarctic Expeditions. During the XXI Indian Scientific Antarctic Expedition operation 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. The instrument was installed in 1999 and was operational since then. In addition to total Ozone, DUV, $S0_2$, $N0_2$ measurements using Brewer Spectrophotometer, Atmospheric Ozone profile by Ozonesonde, Meteorological parameters observed during the year 2002 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 analyzing 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 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 XXI 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 2002 following studies were carried out to fulfill above objectives.

1. Daily, monthly and annual variation of atmospheric pressure, surface wind, surface air temperature, surface ozone, snowfall, and clouds.
2. The atmospheric changes with reference to specific synoptic weather systems.
3. The radiation budget studies including Total Global Solar Radiation.
4. Monitoring and archival of information through weather satellites and HF radio sets regarding weather system affecting the Antarctic continent.
5. Atmospheric turbidity measurement using Sunphotometer with 500 & 560nm filter.
6. Balloon borne measurements of ozone for its vertical profile over Maitri through out the year at regular interval for the study of occurrence of Ozone hole phenomena over Antarctica during austral- spring months.
7. Operation and maintenance of Brewer Spectrophotometer and its operation during all fair weather days for study of daily, seasonal and diurnal variation of total Ozone, DUV, $S0_2$ and $N0_2$.

Execution of the Programme

During onward cruise by ship, MV Magdalena Oldendroff, observations were taken eight times a day at three hourly intervals at synoptic hours from the day of departure from Cape Town till Antarctic coast. At every six hours i.e. at 0000, 0600, 1200 andl800 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 IMD 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 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 13 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. The treatment of balloons was attempted using ATE

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 was very irregular. 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 21st and 22nd IAE. •

5. Brewer Spectrophotometer developed snag in data cable, secondary power supply system and clock monitor card. 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

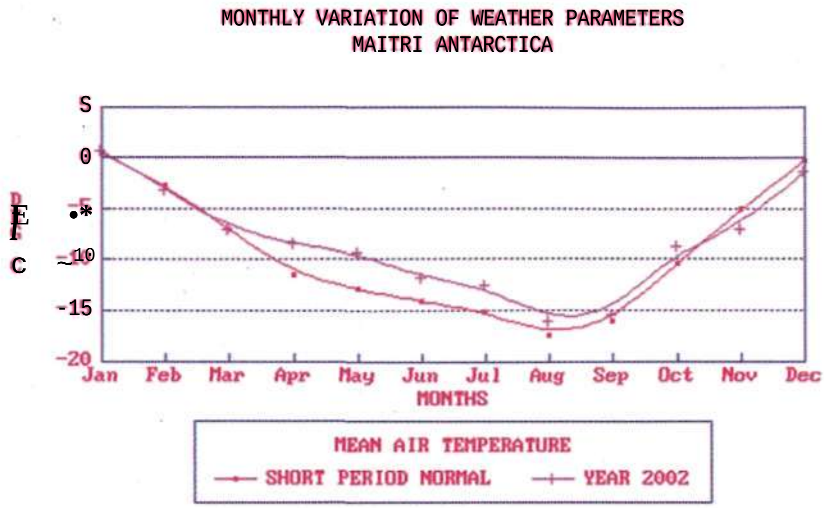

Fig. 1 (a): Variation of mean monthly air temeperature at Maitri, Antarctica

represented in a graphical form for comparative study. Annual weather summary for the year 2002 is given in the Table 1.1. 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 thermo linear thermister 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 -27.0 degree Celsius was recorded on 08th September and the highest temperature of +08.4 degree Celsius was recorded on 10th January during the year 2002. Variation of monthly mean air temperature is shown in. the Figure 1(a). This year April to October was warmer than short period normal where as November and December were colder.

1.2. Wind

- For continuous recording of wind speed and direction a DIWE, comprising of one CGA and Selsyn Windvane, is installed on the roof of

Table—1.1: Weather Summary of Maitri, Antarctica for the year 2002
(Lat 70° 45' 53"S, Long 11° 45' 03"E)

Months	Temperature (°C)					Pressure (HPA)			Wind Speed (Kt)			Number of days with							
	Daily Mean	Mean Max.	Mean Min.	T. Max. / Date	T. Min. / Date	Mean Pr.	Pr. Max. / Date	Pr. Min. / Date	Mean	Max/ Gust	AVG/Max W. Speed>23 KT	Snow Fall	Fog	Blizzard	Clear Sky	Overcast Sky	Average Cloud OCTA	Number of Blizzards	Snowfall in mm
Jan	0.7	3.4	-3.2	8.4 10/1	-9.7 30/1	986.5	1001.0 11/1	970.8 18/1	11.9	30/42	01/03	7	0	0	8	12	4.7	0	6.0
Feb	-3.2	-0.4	-6.9	3.6 24/2	-10.1 26/2	979.5	993.6 17/2	963.4 13/2	17.6	45/60	07/18	0	0	0	1	6	4.6	0	0.0
Mar	-7.0	-3.9	-10.3	0.4 16/3	-16.4 25/3	990.9	1006.8 24/3	974.1 05/3	20.2	42/59	10/23	7	0	6	9	7	3.9	3	13.5
Apr	-8.4	-5.8	-11.1	2.2 11/4	-20.1 08/4	985.1	1000.9 17/4	965.5 03/4	22.8	60/74	15/22	9	0	8	5	13	5.4	4	37.2
May	-9.3	-6.9	-12.2	-1.8 30/5	-20.7 11/5	992.5	1011.1 28/5	972.3 04/5	29.1	70/92	20/27	9	0	9	7	15	5.6	4	44.8
June	-11.8	-9.5	-14.4	-1.8 11/6	-25.0 28/6	986.7	1002.4 15/6	971.1 20/6	25.8	50/65	19/25	5	0	2	7	13	5.4	2	25.2

(Contd.)

Table—1.1: Weather Summary of Maitri, Antarctica for the year 2002 (Lat 70° 45' 53"S, Long 11° 45' 03"E) (*Contd.*)

	Temperature (°C)					Pressure (HPA)			Wind Speed (Kt)			Number of days with							
Months	Daily Mean	Mean Max.	Mean Min.	T. Max. / Date	T. Min. / Date	Mean Pr.	Pr. Max. / Date	Pr. Min. / Date	Mean	Max/ Gust	AVG/Max W. Speed>23 KT	Snow Fall	Fog	Blizzard	Clear Sky	Overcast Sky	Average Cloud OCTA	Number of Blizzards	Snowfall in mm
July	-12.6	-10.2	-15.1	-6.5 11/7	-21.0 09/7	987.3	1006.4 09/7	976.6 18/7	28.2	64/75	21/29	8	0	6	8	13	5.5	3	32.8
Aug	-16.0	-13.1	-19.1	-6.5 15/8	-24.5 04/8	984.5	1008.4 12/8	967.6 06/8	19.3	50/63	16/23	6	0	5	5	7	4.6	2	8.2
Sep	-15.4	-12.4	-18.5	-8.0 12/9	-27.0 08/9	985.3	1007.7 09/9	943.2 15/9	21.1	70/85	11/22	5	0	3	8	13	5.0	2	40.5
Oct	-8.7	-6.4	-11.2	-2.3 12/10	-15.5 01/10	993.2	1005.5 02/10	978.0 14/10	22.3	50/73	15/24	4	0	2	5	12	5.3	2	0.5
Nov	-7.0	-4.1	-10.6	0.5 29/11	-14.3 06/11	987.5	1003.9 03/11	974.9 24/11	11.3	31/42	01/09	4	0	0	16	4	2.9	0	5.4
Dec	-1.3	1.2	-4.4	7.2 23/12	-9.7 05/12	982.1	995.6 22/12	968.8 19/12	14.5	36/56	05/12	5	0	0	8	10	4.9	0	6.8
Year 2002	-8.4	-5.7	-11.4	8.4 10/1	-27.0 08/9	986.7	1011.1 28/5	943.2 15/9	20.3	70/92	141 / 237	69	0	41	87	125	4.8	21	220.9

Maitri station. 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 May was the windiest month of this year. Average wind speed for this month was 29.1 knots and was followed by the months July and June with average wind speed of 28.2 and 25.8 knots respectively. The maximum wind speed of 70 knots gusting to 92 knots was recorded on 4th May during the strongest blizzard of the year. The month of November was calm month of this year and monthly average wind during this month was 11.3 knots. Variation of monthly average wind speed along with short period normal wind is shown in the Figure 1(b). Annual average wind speed was higher than short period normal and they were higher by about 5 knots for the month from April to October.

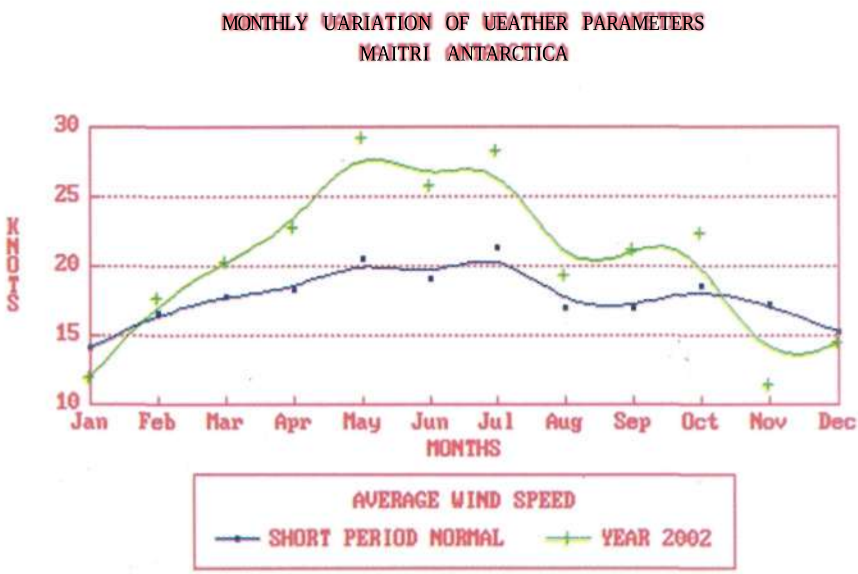

Fig. 1 (b): Variation of mean monthly surface wind speed and its comparison with short period normal (1990-1999)

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 DDGM (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 MSL pressure of 1011.1 hPa was recorded on 28th May and lowest MSL pressure of 943.2 hPa was recorded on 15th September during this year. This was the lowest Mean Sea Level recorded at this station since 1990. Variation of monthly mean MSL pressure and its comparison with short period normal is shown in the Figure 1(c).

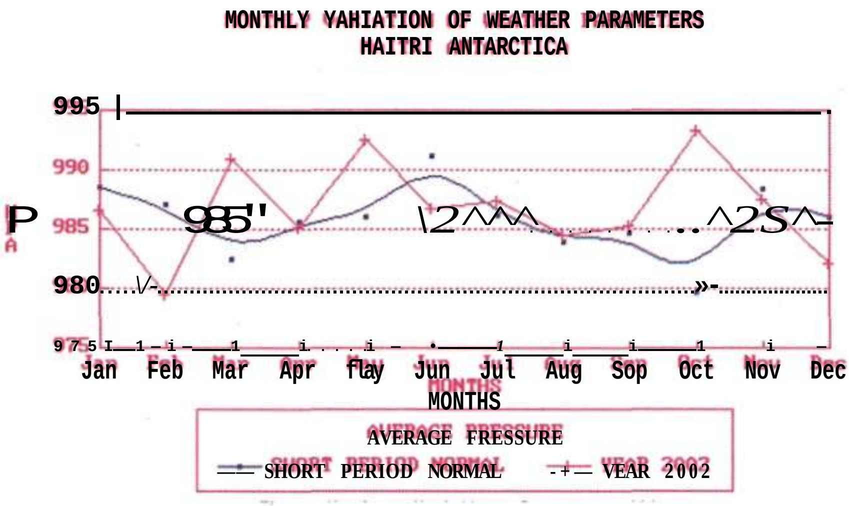

Fig. 1 (c): Variation of mean monthly Mean Sea Level pressure and its comparison with short period normal (1990-1999)

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 except February. Figure 1(d) shows the monthly total snowfall recorded during this year. The snowfall was negligible in the month of October. The maximum snowfall was recorded in the month of May followed by September and April during this year. There were 69 snowfall days during the year and month of April and May recorded 9 snowfall days followed by 8 days in July. Maximum snowfall was spread almost evenly from the month of April to September.

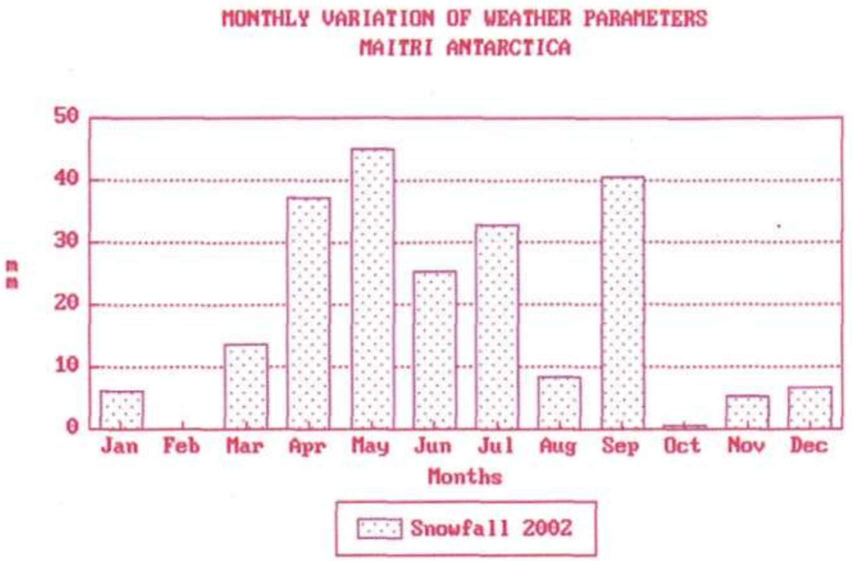

Fig. 1 (d): Variation of monthly total snowfall measured in mm water equivalent

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 21 blizzards affected the station for 41 days during the year 2002. The month of April and May were affected by 4 blizzards each with maximum number of days in May (9 blizzard days) followed by April (8). A brief summary of each blizzard is given in the Table 1.2.

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.

Table 1.2: History of Blizzards

Sl. No.	Date/Time UTC Commencement	Cessation	MSL Pressure Max. (HPA)	MSL Pressure Min. (HPA)	Temperature Max. (°C)	Temperature Min. (°C)	Wind Max. KTS
March 2002							
01.	10/1900	12/1050	0991.2 12/1050	0995.4 10/1900	-01.4 10/1900	-06.1 12/1050	50 11/0710
02.	14/1810	15/0620	0990.4 15/0620	0987.5 14/1810	-04.4 15/0600	-07.0 14/2300	50 14/2340
03.	30/0730	30/2200	0997.2 30/2100	0992.0 30/0900	-05.0 30/2200	-11.0 30/0730	59 30/1750
April 2002							
04.	10/0615	10/1330	0988.0 10/1330	0982.0 10/0615	-02.0 10/1330	-02.7 10/0615	61 10/0710
05.	14/1900	15/2000	0990.9 14/1900	0984.5 15/1300	-04.0 14/1900	-08.2 15/0630	60 15/0735
06.	21/1515	24/1400	0985.3 21/1515	0977.1 23/1200	-06.3 24/1400	-17.0 21/1515	60 23/0530
07.	30/1000	30/2200	0986.6 30/2200	0980.1 30/1200	-04.4 30/2140	-06.2 30/1000	61 30/2010
May 2002							
08.	04/2000	05/0830	0985.0 05/0830	0974.0 04/2000	-06.3 04/2000	-08.8 05/0730	51 04/2150
09.	06/1830	08/2200	1004.5 08/2200	0984.3 07/1500	-08.0 07/2130	-12.9 06/1830	92 07/2110
10.	14/1310	15/1100	0994.8 15/1100	0987.7 14/1810	-12.2 14/1310	-14.1 14/1900	66 14/2245
11.	25/0145	26/2300	1010.0 26/2250	0977.0 25/0145	-04.9 25/0145	-07.2 26/1830	82 25/0200

(Contd.)

Table 1.2: History of Blizzards *{Contd).*

SI. No.	Date/Time UTC Commence-ment	Cessation	Extreme Values (with Date/Time) MSL Pressure Max. (HPA)	MSL Pressure Min. (HPA)	Temperature Max. (°C)	Temperature Min. (°C)	Wind Max. KTS
June 2002							
12.	11/0230	11/2300	0981.3 11/2300	0977.9 11/0400	-01.8 11/2010	-06.0 11/1000	65 11/0705
13.	30/0630	07/01/ 1330	0985.9 01/1130	0976.9 30/2100	-09.8 01/1110	-12.1 30/0630	63 30/1630
July 2002							
. 14.	30/06/02 0630	01/1330	0985.9 01/1130	0976.9 30/2100	-09.8 01/1110	-12.1 30/0630	63 13/1630
15.	02/1600	04/0520	0990.9 03/1500	0987.8 02/1600	-07.9 03/0200	-12.0 02/1700	43 03/0500
16.	13/1630	14/1630	996.0 13/1630	989.2 14/0300	-10.5 14/1100	-15.2 13/1630	75 14/0510
August 2002							
17.	11/0730	12/0100	0999.2 12/0100	0983.3 11/0800	-13.2 11/2230	-17.2 11/0850	59 11/1955
18.	14/1145	16/1330	0992.2 14/1145	0972.4 16/1330	-06.5 15/0200	-11.1 16/0300	46 16/0423
September 2002							
19.	09/2300	11/0740	0991.8 09/2300	0969.6 10/1510	-11.0 10/1325	-14.6 10/0100	85 10/1042
20.	27/0030	27/0935	0991.2 27/0030	0989.8 27/0935	-16.2 27/0935	-18.2 27/0300	51 27/0630
October 2002							
21.	14/2230	15/0130	0982.4 14/2230	0981.5 14/2400	-03.6 14/2230	-04.4 14/2400	42 14/2340

No blizzard in the months of January, February, November and December 2002.

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 25 ozonesonde reached higher than 30hPa height.

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 took place in the month of September. Thereafter recovery of atmospheric ozone started quite early from the middle of the month of October and normal value of ozone partial pressure was recovered by the last week of the month. The depletion period was shorter than normal.

(iii) During the depletion period atmospheric ozone was found considerably depleted at some levels between the levels 110 hPa and above.The representative depletion of atmospheric ozone is shown in Figure 2. The ozone profile of 19th September 2002 and 26th October 2002 is compared in the figure and results are self-explanatory.

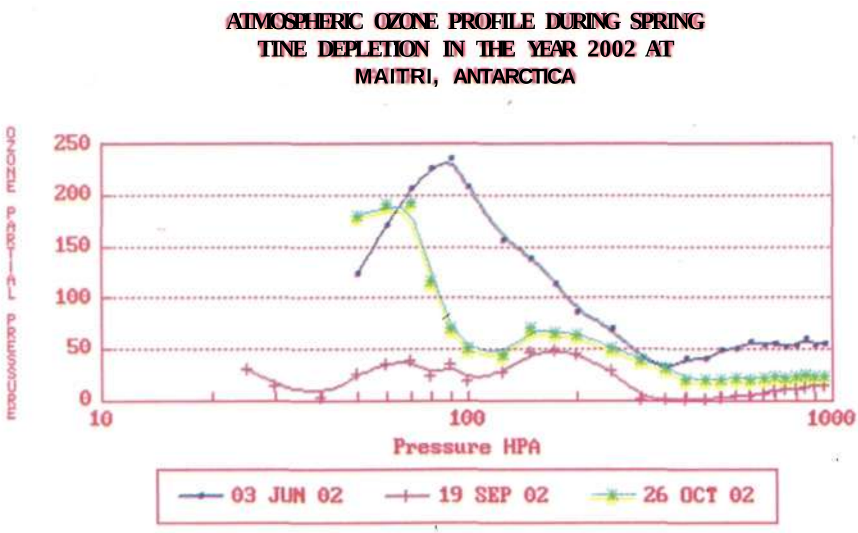

Fig. 2: Ozonogramme for 23 Jun, 19 Sep, and 26 Oct 02. Ozone Partial Pressure in Micro hPA using Indian E. C. Ozone Sonde

(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 MKIV 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.

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 $0_3/S0_2$ and second order for $N0_2$.

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.lnm for mercury-wavelength calibration), 306.3nm, 310.lnm, 313.5nm, 316.8nm in ozone mode with 0.6nm resolution. 426.4nm, 431.4nm, 437.3nm, 442.8nm, 448.lnm, 453.2nm in $N0_2$ 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 EMI9789QB05 photo-multiplier. 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. Operation and maintenance

During the year 2002 Brewer system was operated for 180 days and total ozone measurements were taken on 90 days. The Brewer data for the above period has been processed and brief results regarding Total Ozone, DUV, $S0_2$, and $N0_2$ 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 was 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 2002 are shown in the Figure 3.

As evident from mean daily Total Ozone value shown in figure Ozone depletion started from 14th September (Julian day 257) and reached to its minimum value of 173.4 DU on 24th September (Julian day 267). The period of intense depletion was for about 10 days during which average total ozone value was about 180 DU . Ozone depletion period was between Julian days 257 to 282 with daily mean total ozone values between 173 and 228 Dobson Units. Maximum depletion was observed in the third week of September.

Total Ozone recovery started from 16th October (Julian Day 289) and by 19th October (Julian day 292) mean daily total ozone value reached to its normal values. Above features were also confirmed with Ozone sonde profile and surface ozone records. The abnormal total ozone value of 400 DU was observed on 25th October 2002. During the month of October and November high ozone value was observed.

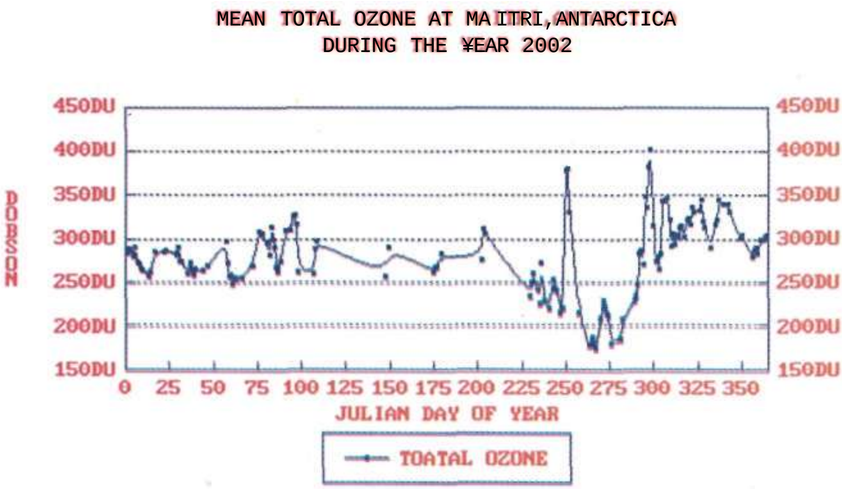

Fig. 3: Variation of daily mean Total Ozone, measured by Brewer Spectrometer No. 151

3.4. Focused sun observations

Total Ozone observations in focused 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. Focused moon observations

In the month of May, June and August focused 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, $S0_2$, and $N0_2$. The value obtained in this mode was not compatible with the values observed in DS mode in lower elevation of sun. Main reason for this error is non-availability of Zenith Sky Map for this location. 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.

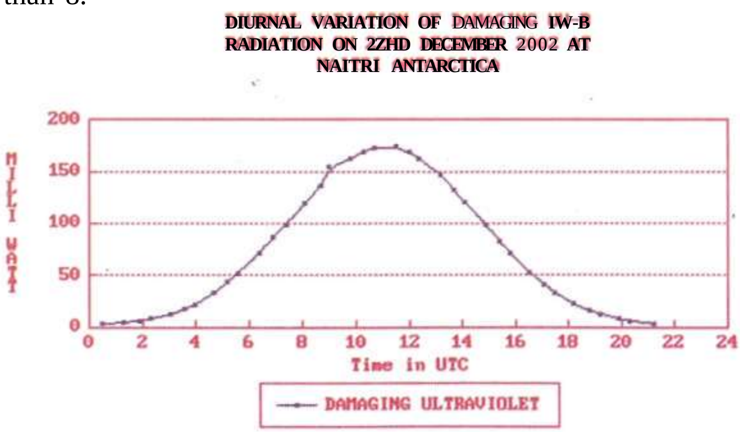

Fig. 3(a): Diurnal variation ofDUV-B radiation measured in mW/m^A2 on 22nd Dec. 2002 by Brewer Spectrophotometer No. 153

DUV values measured in mW/m^2 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* 22nd December 2002 (JD 356) is shown in the Figure 3(a). The highest DUV of 174.134 mW/m^2 was measured at 1129 UTC for zenith angle 47.38 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 24th September is shown in Figure 3(b).

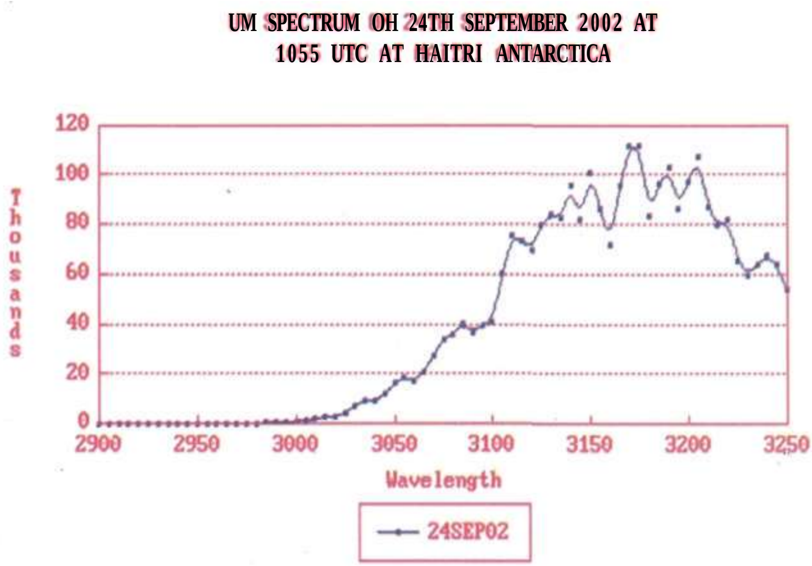

Fig. 3(b): Intensity of individual wavelengths measured in photon counts by Brewer Spectrophotometer No. 153

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 2002 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

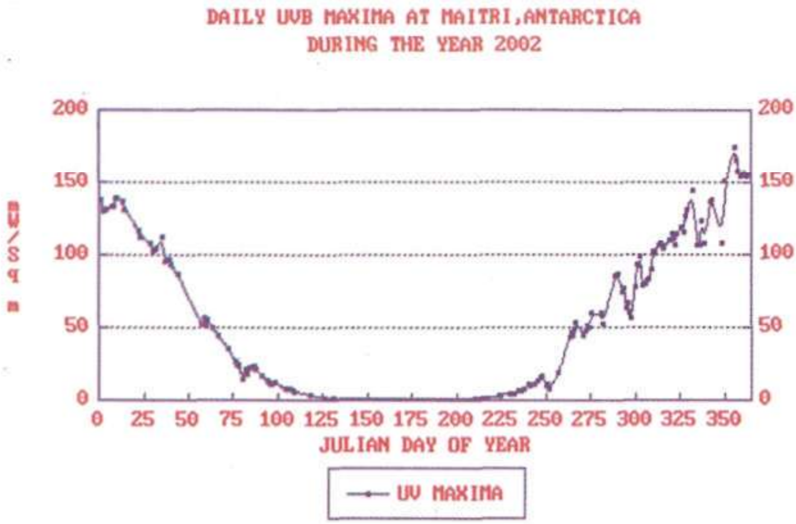

Fig. 3(c): Variation of UVB MAXIMA measured by Brewer Spectrophotometer No. 153

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.

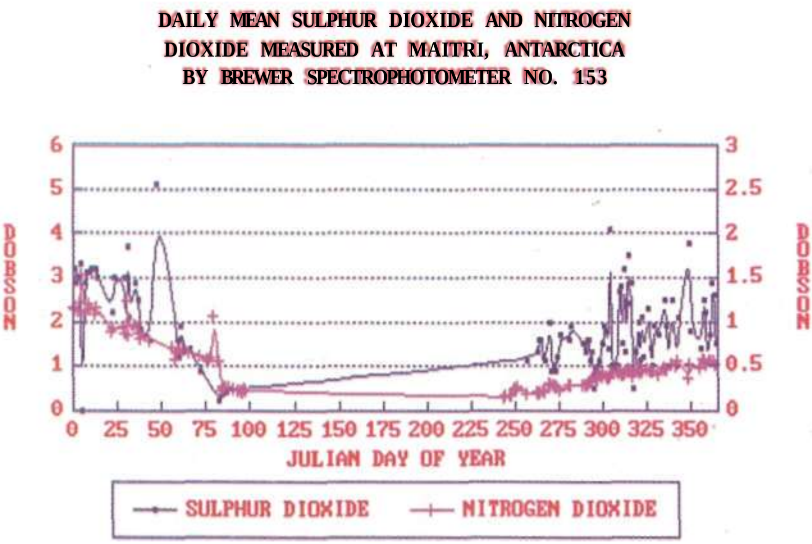

Fig. 3(d): Variation of daily sulphur dioxide and nitrogen dioxide measured by Brewer Spectrophotometer No. 153

Table 4.1: Maitri Antarctica (89514) Total Global Solar Radiation (TGSR) January 2002 – December 2002
Unit: MEGA JOULES/SQ.METER (MJ/SQ M)

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.	23.86	31.50	-	05.86	00.50	00.00	00.00	00.00	03.78	12.29	27.22	36.94
2.	41.15	21.60	19.83	02.76	00.50	00.00	00.00	00.11	04.22	07.77	27.78	38.60
3.	39.35	17.77	14.54	01.74	00.60	00.00	00.00	00.16	01.98	11.48	27.42	37.80
4.	42.23	27.60	20.67	04.80	00.30	00.00	00.00	00.00	03.44	08.13	27.67	11.26
5.	33.71	27.06	08.32	04.15	00.00	00.00	00.00	00.00	04.32	07.23	25.83	32.66
6.	37.58	25.90	07.52	04.14	00.30	00.00	00.00	00.00	03.06	02.61	28.12	32.24
7.	40.52	-	13.07	04.60	00.20	00.00	00.00	00.24	06.09	07.75	23.20	26.19
8.	39.28	27.05	07.07	02.70	00.00	00.00	00.00	00.00	04.49	14.56	19.67	38.61
9.	40.06	25.55	09.80	01.10	00.00	00.00	00.00	00.00	03.69	14.08	29.16	38.77
10.	37.34	19.24	05.81	00.90	00.30	00.00	00.00	00.37	01.77	05.58	28.99	33.14
11.	35.82	14.93	03.45	-	00.20	00.00	00.00	00.54	02.85	08.45	30.27	20.01
12.	30.53	20.94	03.77	01.90	00.10	00.00	00.00	00.72	02.33	10.38	30.92	26.96
13.	33.90	24.42	09.82	01.80	00.30	00.00	00.00	00.54	02.50	10.22	22.32	17.81
14.	36.38	-	04.82	02.00	00.00	00.00	00.00	00.16	04.88	04.32	21.59	26.18
15.	21.24	-	04.47	00.70	00.00	00.00	00.00	00.77	03.05	05.55	31.27	23.62

(Contd.)

Table 4.1: Maitri Antarctica (89514) Total Global Solar Radiation (TGSR) January 2002 – December 2002
Unit: MEGA JOULES/SQ.METER (MJ/SQ M) (*Contd.*)

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
16.	19.22	20.08	12.84	01.70	00.00	00.00	00.00	00.44	01.34	18.89	31.41	37.30
17.	35.25	05.37	10.80	02.10	00.00	00.00	00.00	00.65	04.24	21.14	32.21	11.30
18.	11.97	12.80	11.56	02.00	00.00	00.00	00.00	01.20	04.99	10.46	32.84	21.41
19.	13.63	16.21	10.96	01.80	00.00	00.00	00.00	01.09	04.94	12.00	30.07	08.99
20.	17.80	09.39	-	01.70	00.00	00.00	00.00	01.71	08.77	21.38	22.75	09.73
21.	20.51	13.64	-	01.60	00.00	00.00	00.00	00.85	10.52	20.67	32.36	19.92
22.	30.15	10.19	-	00.10	00.00	00.00	00.00	01.00	10.19	21.71	33.30	39.95
23.	27.63	20.37	09.80	00.10	00.00	00.00	00.00	01.19	10.64	21.50	35.16	38.92
24.	09.54	-	08.30	00.20	00.00	00.00	00.00	01.61	10.73	23.67	32.36	39.54
25.	07.41	18.07	07.30	00.30	00.00	00.00	00.00	01.36	07.68	18.56	36.51	33.14
26.	11.39	20.11	07.83	00.00	00.00	00.00	00.00	01.77	06.42	10.14	31.97	25.94
27.	20.81	19.24	07.36	00.00	00.00	00.00	00.00	00.53	12.68	25.86	16.43	38.85
28.	-	21.80	07.64	00.30	00.00	00.00	00.00	03.08	12.04	24.94	34.93	36.17
29.	-		06.74	00.50	00.00	00.00	00.00	02.23	12.97	26.14	28.44	39.45
30.	31.58		01.64	00.40	00.00	00.00	00.00	01.93	11.76	25.78	24.23	40.42
31.	26.95		04.25		00.00		00.00	03.55		19.32		36.16

4. Radiation Balance Studies

Total global solar radiation measurement

Total global solar radiation was continuously recorded at the Maitri station using thermo-electric pyranometer installed on the roof of the station. Radiation measurements were taken throughout the year. Daily total global solar radiation values for each month are given in Table 4.1. The total global solar radiation was found maximum in the month of November and December during the year 2002 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.

Conclusion

During the year 2002 Ozone hole phenomena was unusual and there was 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 $S0_2$ and $N0_2$ measurements. Spectral analysis of UV radiation is required to study its influence on ozone depletion and vice-versa. Meteorological features were found as usual except the fact that the year 2002 was warmer and windier than normal and extreme atmospheric pressure recorded during the year.

Acknowledgements

We express our sincere thanks to Dr R.R.Kelkar, Director General of Meteorology and Dr. S.K. Srivastava ADGM for giving us this unique opportunity to work in Antarctica. Our grateful thanks are due to all members of the 21^{st} IAE and 19^{h} Wintering over Team for their ever-available support without which we could not have been able to accomplish our programme.