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# Report on Meteorological and Climatological Studies at Maitri, Antarctica

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## Abstract

Antarctica continent influences the general circulation pattern over the globe and is supposed to provide significant forcings to the future climatic changes due to its huge ice shield covering most part of the continent. Weather over Antarctica is a real challenge to the meteorologists participating in the Indian scientific expeditions and hence a good data base is a first step to study the climate of the region in detail.

A permanently manned meteorological observatory equipped with the instruments to monitor weather systems, exist at the Indian Antarctic station "Maitri" and continuous meteorological parameters were recorded during 14th expedition from January 1995 to February 1996. Meteorological programme has been designed to include the observations of vital weather parameters e.g. Radiation, Ozone, APT etc. in addition to upper-air and synoptic observations. The meteorological observations were also recorded during the onward and return journey between Goa and Antarctica. During the voyage, the programme of ozonesonde ascents is also included to understand the latitudinal variation of ozone.

## 1. Introduction

Meteorology has been the integral part of all the scientific Expeditions to Antarctica. A manned meteorological observatory is functioning at Indian Antarctic Station Maitri round the year. The 14th Indian Antarctic Expedition left Goa from Marmugao Port on 17.12.94 by the ship MV Polar Bird (Norway) and reached Indian Barrier of Antarctica on 10.01.95. IMD team consisted of 2 members to cover both summer and winter part of the expedition. Regular meteorological observations were carried out during the voyage and were transmitted on real time basis to IMD, New Delhi.

## 2. Programme and Objectives

(i) Recording of 3 hourly synoptic observations and transmission of 6 hourly main synoptic data to IMD, New Delhi on real time basis for exchange on Global Telecommunication Network.

(ii) Investigation of ozone depletion phenomenon during the Austral Spring over Antarctica and to study its annual variation.

(iii) Measurement of surface ozone.

(iv) To measure the infra-red radiative fluxes in upper-air.

(v) Measurement of Global Solar Radiation over the surface.

(vi) Measurement of Atmospheric Turbidity using Sun-photometer with the filter of 500 nm.

(vii) Monitoring of weather systems approaching and affecting the station.

(viii) Reception of regular APT satellites pictures from Polar Orbitting Satellites NOAA and analysed weather charts from Pretoria (South Africa).

## 3(a) Meteorological Observations and Studies during the Onward Cruise

Surface observation of the meteorological parameters at 3 hourly interval e.g. surface pressure, wind speed, wind direction, visibility, air temperature, humidity, sea surface temperature, state of sea etc. and transmission of the main synoptic data to IMD, New Delhi on real time basis through Fax.

## 3(b) Meteorological Observations and Studies at Maitri Station

(i) Synoptic observations at 3 hourly intervals and transmission of main synoptic data (6 hourly) to IMD, New Delhi on real time basis.

(ii) Ozonesonde ascents one per week during the normal period and maximum number of ascents during September-November—Depletion period to study the changes in the vertical distribution of ozone during ozone-hole period. Ozonesonde data was also compared with the data of neighbouring Antarctica station Syowa (Japan) and Von Neumayer (Germany).

(iii) Radiometersonde ascents were taken to study the infra-red radiative fluxes in the upper atmosphere. The flights were generally attempted before and after the blizzards.

(iv) For planning the daily activities and maintenance of the station, weather forecast of 24 hours was also provided.

(v) Continuous recording of temperature, wind speed, pressure, global solar radiations, surface ozone was done on autographic recorder. The data was regularly tabulated and computed.

(vi) Using 500 nm wavelength filter with the Sun-photometer, measurement of atmospheric turbidity was carried out. These observations were only possible during the presence of sunlight.

(vii) APT satellite receiver was successfully recommissioned and started receiving the cloud imageries in Infra-red and Visible channels. The satellite pictures were gridded in order to pinpoint the area of interest. The pictures were very useful in order to understand the movements of weather systems.

The above pictures were also combined with the analysed weather charts received from Pretoria for better understanding.

## 4. Weather Observed Over Maitri

### A. Temperature measurement

January month's mean temperature remaining almost to 0 deg C due to 24 hour of the sunshine, the same feature was seen in the month of Dec. 95, the warmest month of the year.

A graphical presentation of minimum, maximum and average temperature of each month is shown in Fig. 1.1.

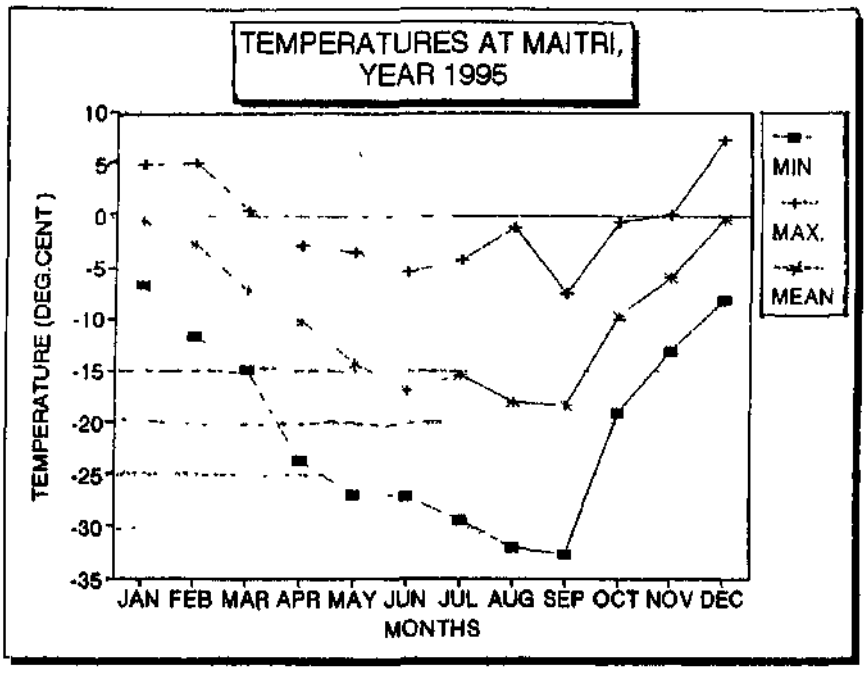


*Fig.1.1*

From the graph of monthly mean surface temperature it is evident that with the onset of winter after February the fall in the temperature is significant upto May. Between May to September though the mean temperature remained low the variations were less. In the month of My the mean temperature showing a rising tendency due to the number of low pressure systems.

The cyclonic circulations forcing in warm and moist air mass from lower latitudes into the polar regions, causing rise in the temperatures. The maximum temperature recorded in this month was -4.2 deg. C. Generally during the blizzard period, a rise in the temperature was observed due to the same reason.

The second fortnight of October remained warmer as compared to first mean cloud coverage also increased in the month. From September to October there is a steep rise in the temperatures (from -18.3 to -9.7 deg.C). The further rise in the temperature remained linear with the approach of summer over Antarctica. The lowest temperature of the year (-32.6 deg. C) was recorded on September 18,1995 on a clear day with light winds.

The highest temperature of the year was recorded on December 17, 1995 (+7.3 deg.C). The day was followed by snowfall for more than a week. Continuous recording of temperature was made with linear. Thermistors ranging between -50 to +50 deg. C.

**B. Mean sea level pressure**

A Precision Aneroid Barometer and a barograph were used for recording of station level pressure and then values were reduced to mean sea level. The highest pressure of 1012.1 mb and the lowest pressure of 957.9 mb (Fig. 1.2) were recorded in the month of June and September 1995 respectively. The average pressure curve almost symmetrical around July's average value, with two minima in the curve 981.3 mb in May and 978.1 nib in September.

From the graph it is seen that though there are not much changes in the mean pressure in the months June, July, August, however, the number of blizzards in the month of August are more. This is due to the fact that the large variation in the pressure was observed in the month of August as compared to other two months. The steep changes in the pressure from April to May and from August to September caused 13 number of blizzards out of total 22 number of blizzards of the year.

**C. Surface winds**

In Antarctica popularly known as home of blizzards winds play an important role. In the coastal areas high winds occur and it decreases inland towards the polar plateau. Planning any outdoor activity mainly depends upon

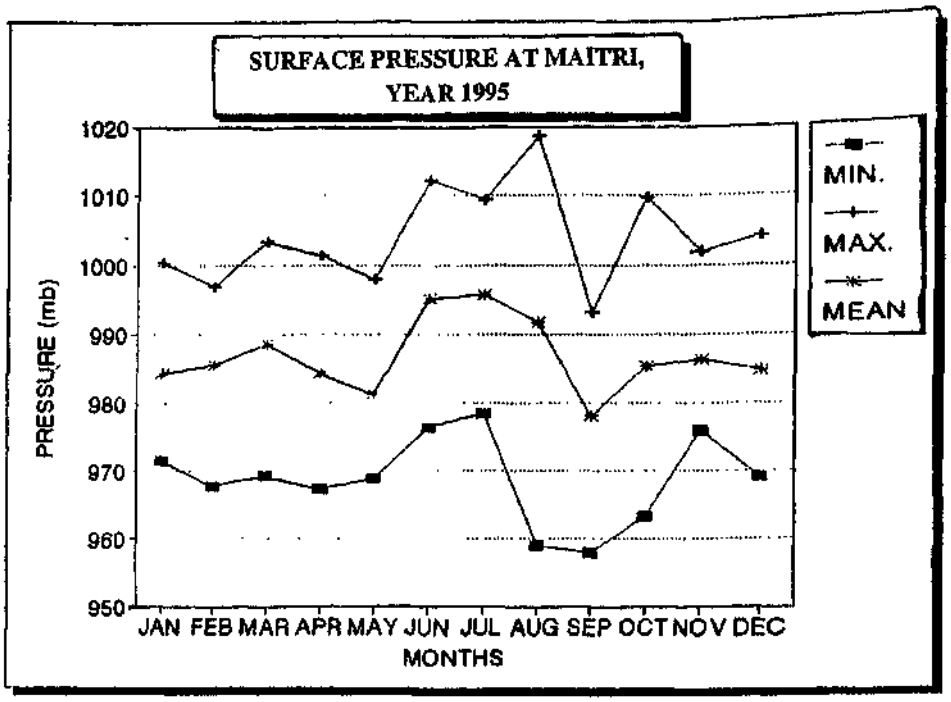


*Fig. 1.2*

the wind speed at that time. At Maitri, recording of wind speed and direction is done by electrical cup generator anemometer and synchro transducer wind vane respectively.

Monthly average winds and maximum winds are shown in Fig.1.3. The month of May being the windiest of the year with average wind speed of 23.1 kts. A highest gusting of 90 kts was recorded during the blizzard in the month of July. A Helical antenna installed on the roof of Maitri station for the reception of the signals during balloon ascents was blown off due to these strong winds. A new antenna was later installed. January with the average wind speed remaining as low as 12.4 kts was the best weather month with no blizzards, March also did not record any blizzard.

The general direction of the wind mostly remained either SE or ESE at Maitri. On number of occasions Katabatic winsads were also observed, rising suddenly from calm winds to 20-25 kts and the direction remaining Southerly. These winds are noticed only for a short period and never indicated bad weather at Maitri.

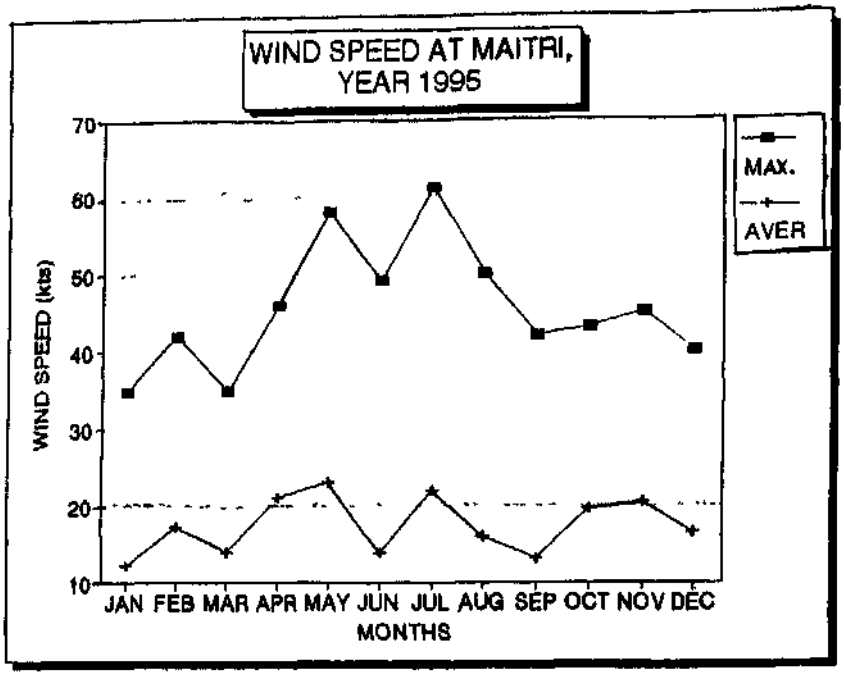


*Fig. 1.3*

### D. Clouds

Most cloud forms are variation of stratus often seen in the summer. Cirrus cloud is often wide spread and forms at much lower levels. During the blizzardic condition sky observations are difficult as it remains obscured.

Cloud types mostly observed at Maitri were stratus, altostratus, altocumulus, cirrostratus and cirrus.

The amount of cloud coverage generally associated with the approach or passing of weather systems.

### E. Precipitation

Precipitation in the form of rain or drizzle is a very rare phenomenon. In 1995 no such weather phenomenon was recorded, but in January 1996 rain was recorded for few hours. In 1995 the precipitation was only in the form of snowfall. Maitri experienced 40 days of snowfall during this period. The snowfall was either in the form of flakes or in the form of star shaped covering

the whole area around Maitri station. Snowfall was observed on maximum number of days (18) in the month of December. During the snowfall winds remained calm/light, but on some occasions when blowing of snow was also observed alongwith the snowfall, high winds prevailed. During the peak winter less snowfall was observed.

## F. Blizzards

Weather in Antarctica is subject to frequent and sudden changes. The fast deterioration of fair weather is common here. In 1995 about 22 number of blizzards were recorded at Maitri station with the maximum gusting of wind going upto 90 kts.

May recorded maximum number of blizzards followed by August. During the blizzards drifting of snow and heavy blowing of snow was observed reducing the horizontal visibility, drastically and obscuring the sky. Due to high winds, wind chill factor was high and working out during this time was very difficult. A detailed summary of all the blizzards is given in the Table 2.1.

**Table 2.1: Blizzards Recorded at Maitri during the Year-1995**

| | | | | |
|---|---|---|---|---|
| 1. | Feb.27/2115- 28/0245 | | | |
| | | Max. | Min. | Change |
| | Pressure(hPa): | 978.2 | 977.2 | 1.0(+) |
| | Temperature: | -5.2°C | -5.6°C | 0.4(+) |
| | Wind : | Average 42 kts Max. 59 kts | | |
| | Remark: | Moderate blowing of snow | | |
| 2. | Apr.11/1145 -1900 | | | |
| | | Max. | Min. | Change |
| | Pressure(hPa): | 978.2 | 977.3 | 0.9(-) |
| | Temperature: | -6.3°C | -7.5°C | 1.2(+) |
| | Wind : | Average 40 kts Max. 42 kts | | |
| | Remark : | Max. gusting of 59 kts | | |
| 3. | Apr.29/2005 - May 1/2120 | | | |
| | | Max. | Min. | Change |
| | Pressure(hPa): | 996.3 | 977.4 | 18.9(-) |
| | Temperature: | -6.7°C | -10.9°C | 4.2(+) |
| | Wind : | Average 42 kts Max. 46 kts | | |
| | Remark: Max. gusting of 70 kts and heavy drifting of snow | | | |

*(Contd.)*

**Table 2.1 —Contd.**

| | | | | |
|---|---|---|---|---|
| 4. | May 2/1420 -1940 | | | |
| | | Max. | Min. | Change |
| | Pressure(bPa): | 975.2 | 973.1 | 2.1(-) |
| | Temperature: | -6.5°C | -9.4°C | 2.9(+) |
| | Wind: | Average 39kts Max.42kts | | |
| | Remark: | Max. gusting of 59 kts and heavy drifting of snow | | |
| 5. | May 16/0640-18/0400 | | | |
| | | Max. | Min. | Change |
| | Pressure(bPa): | 985.3 | 973.1 | 12.2(+) |
| | Temperature: | -7.1°C | -19.4°C | 12.3(+) |
| | Wind : | Average 51 kts Max. 58 kts | | |
| | Remark: | Max. gusting of 88 kts and heavy blowing of snow | | |
| 6. | May 26/1000 -1510 | | | |
| | | Max. | Min. | Change |
| | Pressure(bPa): | 971.8 | 970.3 | 1.5(-) |
| | Temperature: | -13.2°C | -14.0°C | 0.8(+) |
| | Wind: | Average 40 kts Max.42kts | | |
| | Remark: | Max. gusting of 58 kts with moderate drifting of snow | | |
| 7. | May 27/2005 - 28/0242 | | | |
| | | Max. | Min. | Change |
| | Pressure(bPa): | 970.8 | 970.6 | 0.2(+) |
| | Temperature: | -10.9°C | -12.4°C | 1.5(+) |
| | Wind : | Average 39 kts Max. 42 kts | | |
| | Remark : | Max. gusting of 60 kts with heavy drifting and blowing of snow | | |
| 8. | May 30/1120 - 31/0520 | | | |
| | | Max. | Min. | Change |
| | Pressure(bPa): | 977.0 | 975.1 | 1.9(-) |
| | Temperature: | -10.5°C | -13.3°C | 2.8(+) |
| | Wind : | Average 40 kts Max. 44 kts | | |
| | Remark: | Max. gusting of 64 kts with moderate drifting of snow | | |
| 9. | Jun 26/1230 -27/0810 | | | |
| | | Max. | Min. | Change |
| | Pressure(bPa): | 986.0 | 979.6 | 6.4(+) |
| | Temperature: | -10.6°C | -15.9°C | 5.3(+) |
| | Wind : | Average 45 kts Max. 49 kts | | |

*(Contd.)*

**Table 2.1 —Contd.**

| | | | | |
|---|---|---|---|---|
| | Remark | Max gusting of 77 Kts with moderate drifting of snow | | |
| 10 | Jul 14/1600-15/0710 | | | |
| | | Max | Min | Change |
| | Pressure(bPa) | 1002 8 | 9831 | 19 7(+) |
| | Temperature | -6 2°C | -14 5°C | 8 3(+) |
| | Wind | Average 52 kts Max 61 kts | | |
| | Remark | Max gusting of 90 kts with heavy drifting of snow | | |
| 11 | Jul 16/1230 -1435 | | | |
| | | Max | Mm | Change |
| | Pressure(bPa) | 1003 5 | 1003 0 | 0 5(-) |
| | Temperature | -8 3°C | -8 8°C | 0 5(+) |
| | Wind | Average 39 kts Max 41 kts | | |
| | Remark | Sky remained overcast | | |
| 12 | Aug 01/2200-02/2300 | | | |
| | | Max | Mm | Change |
| | Pressure(bPa) | 1018 6 | 1008 9 | 9 7(+) |
| | Temperature | -8.3°C | -13 1°C | 4 8(+) |
| | Wind | Average 37 kts Max 50 kts | | |
| | Remark | Heavy blowing of snow with sky obscured | | |
| 13 | Aug 04/0230 - 04/1430 | | | |
| | | Max. | Min | Change |
| | Pressure(bPa) | 1004 0 | 1000 0 | 4 0(-) |
| | Temperature | -21°C | -3 5°C | 14(-) |
| | Wind | Average 38 kts Max 40 kts | | |
| | Remark | Heavy drifting of snow with sky obscured | | |
| 14 | Aug 13/2200 - 0620 | | | |
| | | Max | Min | Change |
| | Pressure(bPa) | 958 8 | 9791 | 6 7(-) |
| | Temperature | -11.4°C | -117°C | 0 3(+) |
| | Wind | Average 38 kts Max 43 kts | | |
| | Remark | Max gusting of 60 kts with partly cloudy sky | | |
| 15 | Aug 25/0200-26/1620 | | | |
| | | Max | Min. | Change |
| | Pressure(bPa) | 9824 | 959 0 | 33 4(-) |
| | Temperature | -14 0°C | -241°C | 10 l(-) |

*(Contd)*

**Table 2.1 — Contd.**

| | | | | |
|---|---|---|---|---|
| | Wind : | Average 37 kts Max. 46 kts | | |
| | Remark: | Heavy blowing and drifting of snow reducing visibility to 10 meters. Gusting of 68 kts | | |
| 16. | Sep 09/1140-10/0620 | | | |
| | | Max. | Min. | Change |
| | Pressure(bPa): | 982.1 | 975.9 | 6.2(-) |
| | Temperature: | -9.2°C | -13.5°C | 4.3(-) |
| | Wind : | Average 40 kts Max. 46 kts | | |
| | Remark : | Max. gusting of 64 kts with moderate drifting of snow | | |
| 17. | Sept 13/2010-14/0420 | | | |
| | | Max. | Min. | Change |
| | Pressure(bPa) : | 967.6 | 960.5 | 7.1(-) |
| | Temperature: | -12.8°C | -15.3°C | 2.5(+) |
| | Wind : Average | 39 kts Max. 43 kts | | |
| | Remark : | Max. gusting of 58 kts with moderate drifting | | |
| 18. | Oct 22/0110- 22/1800 | | | |
| | | Max. | Min. | Change |
| | Pressure(bPa): | 983.0 | 972.9 | 10.1(-) |
| | Temperature: | -4.0°C | -9.0°C | 5.0(+) |
| | Wind : | Average 38 kts Max 45 kts | | |
| | Remark : | Max. gusting of 68 kts with moderate drifting of snow followed | | |
| 19 | Oct 29/1020-1800 | | | |
| | | Max. | Min. | Change |
| | Pressure(bPa): | 983.9 | 979.9 | 4.0(-) |
| | Temperature: | -7.9°C | -8.5°C | 0.6(+) |
| | Wind: | Average 38 kts Max. 40 kts | | |
| | Remark : | Max. gusting of 65 kts with sky mostly cloudy | | |
| 20. | Nov 01/0100-0800 | | | |
| | | Max. | Min. | Change |
| | Pressure(hPa): | 980.4 | 979.7 | 0.7(+) |
| | Temperature | -8.9°C | -12.0°C | 3.1(+) |
| | Wind | Average 41 kts Max. 44 kts | | |
| | Remark : | Max. gusting of 64kts with sky overcast | | |

*(Contd)*

**Table 2.1 —Contd.**

| | | | | |
|---|---|---|---|---|
| 21. | Nov 07/2140 - 08/0220 | | | |
| | | Max. | Min. | Change |
| | Pressure(hPa): | 979.9 | 979.2 | 0.7(-) |
| | Temperature: | -4.7°C | -6.0°C | 1.3(+) |
| | Wind: | Average 39 kts Max. 40 kts | | |
| | Remark: | Max. gusting of 55 kts with sky overcast | | |
| 22. | Dec 08/1020 - 08/1800 | | | |
| | | Max. | Min. | Change |
| | Pressure(hPa): | 983.3 | 980.3 | 3.0(-) |
| | Temperature: | -1.4°C | -4.3°C | 2.9(-) |
| | Wind : | Average 39 kts Max. 40 kts | | |
| | Remark: | Max. gusting of 62 kts with heavy blowing of snow. Sky remaining obscured | | |

Climatological features observed during the year 1995 at Maitri :

| | | | |
|---|---|---|---|
| 1. | Highest maximum temperature | +07.3 deg.C | 17.12.95 |
| 2. | Lowest minimum temperature | -32.6 deg.C | 18.09.95 |
| 3. | Warmest day of the year | +03.9 deg.C | 22.12.95 |
| 4. | Coldest day of the year | -29.2 deg.C | 11.08.95 |
| 5. | Mean temperature of the year | -09.9 deg.C | |
| 6. | Warmest month of the year | -00.2 deg.C | December |
| 7. | Coldest month of the year | -18.3 deg.C | September |
| 8. | Maximum MSL pressure | 1012.1 hPa | 23.06,95 |
| 9. | Minimum MSL pressure | 957.9 hPa | 14.09.95 |
| 10. | Mean MSL of the year | 986.8 hPa | |
| 11. | Maximum wind speed | 61.0 kts. | 15.07.95 |
| 12. | Windiest day of the year | 54.4 kts. | 15.07.95 |
| 13. | Windiest month of the year | 23.1 kts. | May |
| 14. | Mean wind speed of the year | 17.5 kts. | |
| 15. | Total number of blizzards | 22 | |
| 16. | Blizzardous month | 05 | May |

Annual variation of meteorological parameters recorded at Maitri during the year 1995 is given in the Table 2.2.

**Table 2.2: Annual Variation of the Meteorological Parameters Recorded at Maitri, Antarctica during the Year 1995**

| Units | Temperature (Degree Cent) | | | Pressure (Millibar) | | | Wind speed (Knots) | | Blizzards | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1995 | Min | Max | Mean | Min | Max | Mean | Max | Mean | No | Days |
| Jan | -6.7 | 5.0 | -0.4 | 971.5 | 1000.4 | 984.3 | 35.0 | 12.4 | 0 | 0 |
| Feb | -11.6 | 5.2 | -2.7 | 967.6 | 996.9 | 985.5 | 42.0 | 17.4 | 1 | 1 |
| Mar | -14.8 | 0.6 | -7.2 | 969.3 | 1003.3 | 988.5 | 35.0 | 14.1 | 0 | 0 |
| Apr | -23.6 | -2.8 | -10.2 | 967.3 | 1001.4 | 984.4 | 46.0 | 21.2 | 2 | 3 |
| May | -26.8 | -3.4 | -14.2 | 968.9 | 997.9 | 981.3 | 58.0 | 23.1 | 5 | 10 |
| Jun | -27.0 | -5.4 | -16.9 | 976.5 | 1012.1 | 995.1 | 49.0 | 13.9 | 1 | 2 |
| Jul | -29.2 | -4.2 | -15.3 | 978.5 | 1009.2 | 995.7 | 61.0 | 22.0 | 2 | 3 |
| Aug | -31.9 | -1.0 | -18.0 | 959.0 | 1018.6 | 991.7 | 50.0 | 16.0 | 4 | 7 |
| Sep | -32.6 | -7.4 | -18.3 | 957.9 | 993.1 | 978.1 | 42.0 | 13.3 | 2 | 4 |
| Oct | -19.0 | -0.5 | -9.7 | 963.2 | 1009.6 | 985.4 | 43.0 | 19.7 | 2 | 2 |
| Nov | -13.1 | 0.2 | -5.9 | 976.0 | 1001.9 | 986.4 | 45.0 | 20.6 | 2 | 3 |
| Dec | -8.1 | 7.3 | -0.2 | 969.1 | 1004.1 | 984.8 | 40.0 | 16.6 | 1 | 1 |

## A. Upper-air observations:

Twelve radiometersonde flights and 50 ozonesonde flights were taken during the year 1995. One ozonesonde ascent per week was taken in the normal time, however, ozonesonde ascent programme was intensified during the depletion period of ozone i.e. Antarctic Spring. About 25 ozonesonde ascents were taken during August 95 to November 95 for better understanding of ozone depletion. The data was also compared with the available data of neighbouring Antarctic stations viz. Syowa (Japan), Von Neumayer (Germany), Novolazarev (Russia). The station did not have indoor facility for filling of the balloons with hydrogen gas and hence it was not possible to take the ascents during the windy day. The balloon filling and launching shed is coming up at Maitri and will be very useful to take ascents even during windy days.

From the analysis of the ascents the following conclusions regarding the variation in the upper-air temperatures can be drawn:

(a) Temperature inversions are observed between the ground level and 850 mb level from the month of April to October. Feeble inversions are also observed between 750 to 600 mb layer during this period.

(b) During the summer period, inversion layer disappears due to 24 hours of sunlight.

(c) The temperatures corresponding to isobaric levels are on the higher sides in summer as compared to the winter season. The annual mean tropopause

is at 297 mb corresponding to the temperature of -63.9 deg. C. During the summer period the height of the tropopause varies between 8-10 kms and with the onset of winter period the height varies between 12-14 kms. The tropopause was found to be warmer in summer compared to winter by 15 to 20 deg. C.

(d) During the peak winter, records do not indicate the existence of tropopause and temperatures fall steeply with increase in height, it starts reappearing during the spring season.

(e) In the first week of November sudden warming up of the stratosphere was observed. This was also reported by Syowa Station (Japan).

## 5. Ozonesonde Programme at Maitri, Antarctica

More than 60 number of ozonesonde ascents were attempted during this year and for analysis 50 successful are considered here. During the ozone-hole period the programme was intensified and maximum number of flights were attempted irrespective of the time but depending upon the wind conditions outside, as the balloon filling and launching shed was under construction. During the winds of even 20 kts. it was found very difficult to inflate the big balloon of ozonesonde (Totex 2000).

During the winter period, the normally used balloons burst at low levels, terminating the flights. Hence a special treatment for the balloons is required before the ascents. A new modified method was devised for the treatment of balloons which gave satisfactory results. In the Table 2.3, partial pressure of ozone at standard levels is given for the flights of different period. Fig. 1.4 presents the actual ozone profiles of the above said ascents.

The following preliminary results can be concluded from the flights:

i) Partial pressure of ozone is generally found to be steadily decreasing with the height till tropopause. Thereafter the profile shows increasing tendency with height and the first maxima occurs around 150-170 mb layer, and then partial pressure of ozone increases to its maximum value of the profile. Hereafter, the partial pressure of ozone decreases gradually in the higher layers.

ii) Depletion of ozone started from the last week of August 95 and maximum depletion was observed in the month of September and October. Thereafter ozone recovery starts with the approach of summer.

iii) Depletion of ozone generally occurs between 100 hPa to 30 hPa layer and at certain levels the amount of ozone going below the level of tropospheric ozone amount.

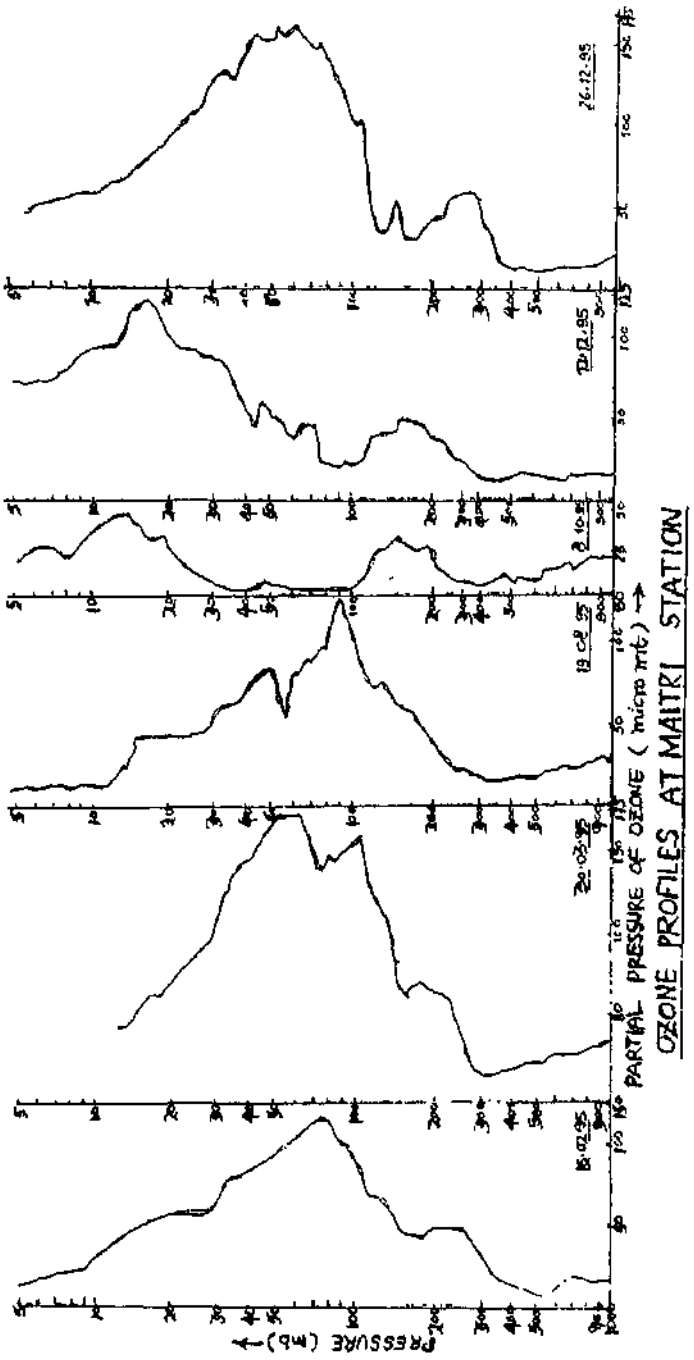
OZONE PROFILES AT MAITRI STATION
PARTIAL PRESSURE OF OZONE ( micro mb) →
PRESSURE (mb) →
26.12.95
19.12.95
2.10.95
19.09.95
20.03.95
15.02.95

*Fig. 1.4*

**Table 2.3: Partial Pressure of Ozone at Standard Atmospheric Levels**

| Levels | 28.1.95 | 30.3.95 | 19.8.95 | 8.10.95 | 12.12.95 |
|---|---|---|---|---|---|
| 950 | 13.0 | 34.0 | 30.0 | 22.0 | 15.0 |
| 900 | 12.0 | 32.0 | 29.0 | 21.0 | 14.0 |
| 850 | 12.0 | 31.0 | 27.0 | 20.0 | 14.0 |
| 700 | 14.0 | 27.0 | 23.0 | 16.0 | 12.0 |
| 600 | 9.0 | 27.0 | 22.0 | 13.0 | 11.0 |
| 500 | 5.0 | 22.0 | 16.0 | 6.0 | 14.0 |
| 400 | 10.0 | 19.0 | 17.0 | 9.0 | 11.0 |
| 300 | 32.0 | 16.0 | 18.0 | 3.0 | 13.0 |
| 250 | 46.0 | 43.0 | 22.0 | 6.0 | 23.0 |
| 200 | 44.0 | 66.0 | 40.0 | 18.0 | 38.0 |
| 150 | 47.0 | 67.0 | 62.0 | 33.0 | 46.0 |
| 100 | 98.0 | 154.0 | 106.0 | 3.0 | 20.0 |
| 70 | 110.0 | 158.0 | 90.0 | 2.0 | 46.0 |
| 50 | 88.0 | 169.0 | 86.0 | 5.0 | 52.0 |
| 30 | 62.0 | 99.0 | 55.0 | 8.0 | 86.0 |
| 20 | 55.0 | 68.0 | 45.0 | 31.0 | 102.0 |
| 15 | 46.0 | 53.0 | 43.0 | 45.0 | 120.0 |
| 10 | 27.0 | - | 13.0 | 38.0 | 94.0 |
| 7 | 17.0 | - | 7.0 | 29.0 | 76.0 |
| 5 | 11.0 | - | 6.0 | 22.0 | 74.0 |

iv) Two maximas were observed during depletion period, separated by the depleted zone. First maxima occurring at around 150-170 hPa layer and second maxima around 15-20 hPa layer.

v) Ozone recovery was observed from the month of November and the normal value of ozone was recorded in the last week of December.

vi) January to June the changes in the ozone profile are not significant. The ozone starts decreasing from the month of June slowly and sharp fall is observed in September and October i.e. Antarctic Spring time. The ozone data of few days is given at standard atmospheric levels (Table 2.3). Total ozone data at Syowa is graphically represented in the Fig. 1.5 as well as given in Table 2.4

## 6. Global Solar Radiation Measurement

Global Solar radiation was continuously recorded at Maitri station, using thermo-electric pyranometer installed on the roof of the station. Radiation measurements were carried throughout the year. Global Solar radiation for each month are given in the Table 2.5.

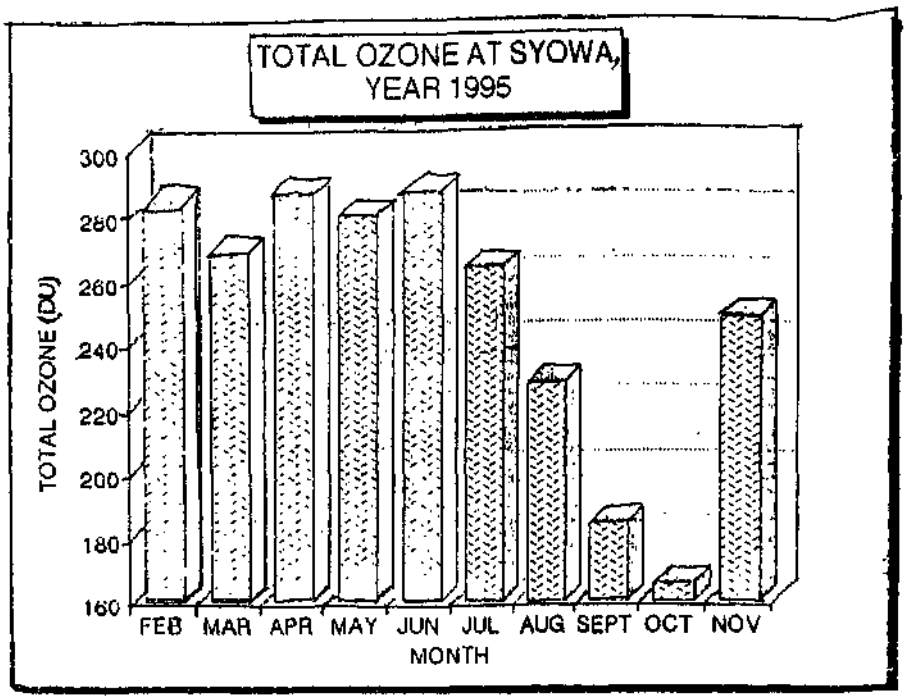


*Fig. 1.5*

The highest value of average radiation in a day is in the month of January due to longerhours of Sunshine and higher zenith angle of the Sun. In the month of February average value of radiation received in a day reduced by 43.1 % since the mean cloud cover in January was 4.9 and it increased to 5.6 in the month of February. Also on about 8 days in February snowfall occurred and a blizzard was also recorded with blowing of snow.

The maximum radiation per day was recorded on 17th December. The maximum temperature of the day was +07.3 deg. C, the highest during December 95 with clear sky and average winds of 8 kts. No significant weather was observed on this day.

A graphical representation of global solar radiation received throughout the year is also shown in Table 2.4.

## 7. Surface Ozone Measurement at Maitri

Continuous measurement of surface ozone was done at Maitri station using electrochemical surface ozone sensor. The data of January 95 is not included

**Table 2.4: Ozonesonde Data of Syowa, Japanese Antarctic Station during Year 1995**

| Month | Date | Time UTC | Terminate Press (mb) | Ozone Max. Level (mb) | Ozone Max. (nb) | Total Ozone (DU) | Correction Factor |
|---|---|---|---|---|---|---|---|
| Feb | 07 | 0700 | 7.2 | 42.6 | 140 | 265 | 0.922 |
| | 20 | 0640 | 5.4 | 60.0 | 124 | 244 | 0.892 |
| Mar | 01 | 0640 | 4.9 | 51.1 | 129 | 220 | 0.955 |
| | 06 | 0705 | 6.3 | 46.4 | 127 | 218 | 0.840 |
| | 13 | 0710 | 10.2 | 33.4 | 129 | 223 | 0.877 |
| | 21 | 0625 | 26.0 | 77.2 | 141 | 204 | 1.012 |
| | 27 | 0700 | 4.3 | 64.0 | 129 | 236 | 0.864 |
| Apr | 06 | 0645 | 5.0 | 58.3 | 144 | 293 | 0.890 |
| | 10 | 0738 | 4.1 | 60.5 | 130 | 261 | 0.832 |
| May | 01 | 0720 | 4.7 | 40.3 | 150 | 265 | - |
| | 15 | 0715 | 9.2 | 106.4 | 166 | 263 | 0.946 |
| | 19 | 0655 | 8.1 | 67.0 | 169 | 254 | 0.976 |
| Jun | 17 | 0440 | 3.7 | 107.2 | 154 | 250 | 1.038 |
| | 28 | 1750 | 4.3 | 67.1 | 168 | 271 | - |
| Jul | 16 | 0215 | 8.3 | 57.0 | 126 | 219 | - |
| | 24 | 0700 | 8.0 | 56.3 | 165 | - | - |
| Aug | 04 | 1940 | 7.0 | 48.1 | 141 | 231 | 1.058 |
| | 10 | 1910 | 5.4 | 115.6 | 143 | 218 | 1.379 |
| | 18 | 1815 | 7.2 | 54.1 | 120 | 209 | 0.985 |
| | 23 | 1350 | 6.9 | 82.6 | 106 | 191 | 0.875 |
| | 31 | 0820 | 13.9 | 89.6 | 134 | 215 | 1.198 |
| Sep | 01 | 0830 | 9.2 | 34.5 | 114 | 215 | 0.984 |
| | 06 | 0740 | 7.0 | 98.8 | 69 | 170 | 0.990 |
| | 16 | 0650 | 9.2 | 20.8 | 78 | 130 | 1.021 |
| | 21 | 0745 | 9.7 | 26.3 | 78 | 138 | 0.902 |
| | 29 | 0802 | 7.5 | 22.7 | 66 | 129 | 0.929 |
| Oct | 04 | 0755 | 12.9 | 21.9 | 69 | 97 | 1.108 |
| | 10 | 0815 | 4.9 | 21.6 | 56 | 105 | 0.845 |
| | 15 | 0800 | 6.8 | 22.5 | 68 | 133 | 0.964 |
| | 27 | 1355 | 7.1 | 25.9 | 77 | 132 | 1.079 |
| Nov | 10 | 0455 | 5.1 | 24.0 | 158 | 210 | 0.891 |
| | 16 | 1355 | 5.3 | 18.3 | 128 | 189 | 0.889 |
| | 23 | 0420 | 5.7 | 19.6 | 162 | 228 | 1.063 |
| | 28 | 1355 | 6.2 | 18.3 | 132 | 220 | 0.936 |

as instrument was under test and maintenance during this period. During the day night cycle period it was observed that maximum surface ozone values were recorded during night time and minimum were recorded generally near local noon time. Highest value was recorded in the month of June 95. During

**Table 2.5; Global Solar Radiation Received at Maitri during the Year 1995**

| Date | Ian | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 34.50 | 18.01 | 17.75 | 3.95 | 0.13 | 0.00 | 0.00 | 0.20 | 3.83 | 14.19 | 15.57 | 16.33 |
| 2 | 32.02 | 28.16 | 17.33 | 2.15 | 0.17 | 0.00 | 0.00 | 0.18 | 3,69 | 10.31 | 21.85 | 22.11 |
| 3 | 36.71 | 17.05 | 16.94 | 3.10 | 0.16 | 0.00 | 0.00 | 0.35 | 4.02 | 13.21 | 14.32 | 36.43 |
| 4 | 33.62 | 26.93 | 8.44 | 2.35 | 0.22 | 0.00 | 0.00 | 0.42 | 3.62 | 13.00 | 17.26 | 30.12 |
| 5 | 37.86 | 14.34 | 6.57 | 2.03 | 0.61 | 0.00 | 0.00 | 0.57 | 3.71 | 9.32 | 26.36 | 28.61 |
| 6 | 34.90 | 23.24 | 12.80 | 5.03 | 0.24 | 0.00 | 0.00 | 0.53 | 3.91 | 9.86 | 11.28 | 35.80 |
| 7 | 31.53 | 6.51 | 14.80 | 2.54 | 0.46 | 0.00 | 0.00 | 0.19 | 6.46 | 7,48 | 10.97 | 27.35 |
| 8 | 22.87 | 20.80 | 10.36 | 2.26 | 0.33 | 0.00 | 0.00 | 0.28 | 6.52 | 16.11 | 13.34 | 11.65 |
| 9 | 19.70 | 23.97 | - | 2.43 | 0.52 | 0.00 | 0.00 | 0.73 | 3.68 | 13.54 | 27.91 | 18.28 |
| 10 | 18.97 | 18.55 | 13.15 | 1.77 | 0.12 | 0.00 | 0.00 | 0.82 | 2.80 | 14.70 | 28.64 | 17.85 |
| 11 | 12.42 | 13.42 | 13.30 | 1.79 | 0.23 | 0.00 | 0.00 | 0.84 | 7.23 | 15.88 | 10.55 | 26.29 |
| 12 | 18.41 | 24.76 | 4.56 | 2.93 | 0.27 | 0.00 | 0.00 | 0.50 | 7.27 | 12.68 | 14.42 | 17.88 |
| 13 | 32.53 | - | 9.67 | 2.70 | 0.29 | 0.00. | 0.00 | 0.60 | 7.15 | 16.22 | 13.00 | 29.15 |
| 14 | 31.86 | - | 14.75 | 1.70 | 0.20 | 0.00 | 0.00 | 0.53 | 4.60 | 17.72 | 19.98 | 38.47 |
| 15 | 33.71 | 16.32 | 12.81 | 2.54 | 0.01 | 0.00 | 0.00 | 1.04 | 5.64 | 12.09 | 29.17 | 39.18 |
| 16 | 33.80 | 20.64 | 9.06 | 0.53 | 0.00 | 0.00 | 0.00 | 1.50 | 8.88 | 18.37 | 29.87 | 32,96 |
| 17 | 17.41 | 16.96 | 8.20 | 3.30 | 0.04 | 0.00 | 0.00 | 1.63 | 9.37 | 18.39 | 12.22 | 39.20 |
| 18 | 28.23 | 19.79 | 7.04 | 3.29 | 0.04 | 0.00 | 0.00 | 2.18 | 10.01 | 18.91 | 28.82 | 26.37 |
| 19 | 17.07 | 15.91 | 10.37 | 1.06 | 0.07 | 0.00 | 0.00 | 1.04. | 9.42 | 16.92 | 13.22 | 14.94 |
| 20 | 20.29 | 5.64 | 6.59 | 2.14 | 0.05 | 0.00 | 0.00 | 1.64 | 3.36 | 18.84 | 32.03 | 26.59 |
| 21 | 34.74 | 9.10 | 10.32 | 1.17 | 0.00 | o.oo | 0.00 | 1.19 | 3.99 | 21.56 | 32.15 | 22.12 |
| 22 | 36.23 | 8.17 | 10.21 | 1.35 | 0.00 | 0.00 | 0.00 | 2.41 | 7.06 | 15.55 | 33.26 | 29.80 |
| 23 | 26.90 | 10.02 | 6.98 | 0.97 | 0.00 | 0.00 | 0.05 | 1.53 | 10.06 | 8.64 | 24.64 | 17.58 |
| 24 | 27.00 | - | 3.59 | 1.89 | 0.00 | 0.00 | 0.12 | 1.84 | 10.95 | 7.65 | 32.50 | 13.40 |
| 25 | 23.74 | - | 8.06 | 0.21 | 0.00 | 0.00 | 0.10 | 0.71 | 12.08 | 17.79 | 30.62 | 23.11 |
| 26 | | 11.31 | 9.50 | 1.62 | 0.00 | 0.00 | 0.11 | 0.99 | 9.95 | 22.34 | 24.82 | 23.19 |
| 27 | 26.81 | 9.58 | 4.60 | 1.78 | 0.00 | 0.00 | 0.21 | 1.40 | 12.48 | 23.33 | 19.90 | 37.74 |
| 28 | 28.66 | 6.29 | 4.55 | 0.71 | 0.00 | 0.00 | 0.27 | 2.78 | 12.17 | 23,85 | 14,83 | 37.04 |
| 29 | 31.44 | - | 8.46 | - | 0.00 | 0.00 | 0.25 | 4.21 | 13.38 | 18.14 | 23.44 | 32.49 |
| 30 | 30.62 | - | 8.13 | 0.18 | 0.00 | 0.00 | 0.28 | 3.47 | 13.43 | 14.04 | 15.34 | 14.13 |
| 31 | 31.75 | - | 6.30 | - | 0.00 | - | 0.40 | 2.03 | - | 24.28 | - | 14.58 |
| Total | 846.30 | 385.47 | 295.19 | 59.47 | 4.16 | 0.00 | 1.79 | 38.33 | 220.72 | 484.91 | 642,28 | 800.74 |

the peak winter period surface ozone showing decreasing tendency and with the onset of spring rising tendency is observed. Also during toe blizzardic conditions surface ozone showing little rising tendency, this is further to be investigated and confirmed.

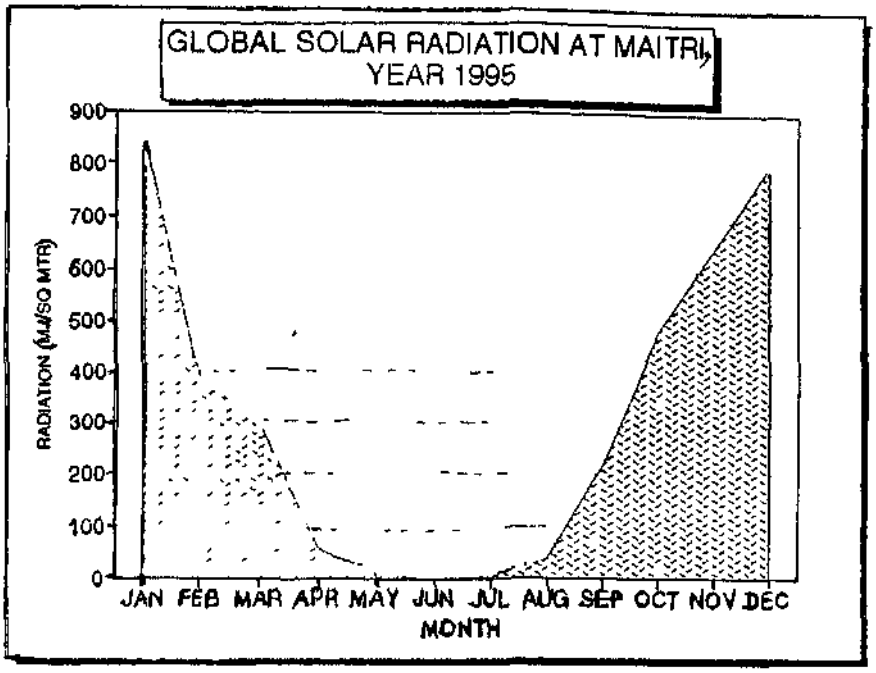


*Fig 16*

Average maximum and average minimum values of each month are given in the Table 2.6

**Table 2.6: Surface Ozone Measurements at Maitri**

| Month | Average Max | Average Min |
|---|---|---|
| Jan | - | - |
| Feb | 10 38 | 6 05 |
| Mar | 23 24 | 1451 |
| Apr | 15 46 | 10 57 |
| May | 22 68 | 15 10 |
| Jun | 26 59 | 17 40 |
| Jul | 23 37 | 14 04 |
| Aug | 17 57 | 7 84 |
| Sep | 19 37 | 8 73 |
| Oct | 22 39 | 12 67 |
| Nov | 18 12 | 13 10 |
| Dec | 2152 | 15 48 |

## 8. Studies during the Summer Part of the XV Indian Antarctic Expedition

Onboard the ship regular 3 hourly observations were carried out and main synoptic observations were transmitted to IMD office at Delhi. About 4 ozonesonde ascents were also taken onboard the ship on fair weather days. During the rough sea conditions and high winds ascents were not possible. In Antarctic water due to very low atmospheric temperatures, the KI solution used in the bubbler, the ozonezonde sensor, during the preparation period started freezing even during ground preparation because the Lab. container onboard the ship was not temperature controlled.

Expedition started from Goa on 7th December '95 at 0600 hrs and reached Antarctica (Indian Bay) on31st December '95 (69 D. 9'S, 12 D 6'E). The ship MV brinkness (Philipines was hired for the Expedition. During the voyage a regular halt at Mauritius was one of the interesting features. The Australian helicopters also joined the expedition team here. Very rough sea conditions were experienced at about 37 deg. S, causing heavy rolling and pitching of ship. Near Antarctic continent, pack ice condition was also observed and going ahead of the ship was difficult. Shifting of expedition members started from 2nd January '96 to summer camps. A brief resume about the latitudinal variations of some meteorological parameters during the voyage is given below in Table 2.7.

### Pressure

It is observed that there is not much change upto 20 deg. S and thereafter started decreasing till about 36 deg S. A good variation was observed from here onwards upto Antarctica (69.9 deg.S). The highest pressure recorded at 47 deg. S was 1023.9 hPa and the lowest pressure was recorded at 68 deg. S (985.4 hPa).

There are significant changes in the surface pressure recorded between 30 deg. S to 69 deg. S causing on few occasions bad weather. Average pressure of the period remained to 1010.0 hPa. For ar all pressure measurements Precision Aneroid Barometer was used and values were compared with ship data.

### Temperature

Psychrometer was used for measurement of dry bulb and wet bulb temperature. The temperature shows gradual fall from 23 deg. S upto 69 deg. S as expected with highest temperature recorded in the earlier part of voyage i.e. +29 deg. C at 7 deg. N and lowest was recorded -1.0 deg. C at 69 deg. S. The average temperature of the period remained to +18.2 deg. C.

**Table 2.7: Latitudinal Variations in Meteorological Parameters during the Voyage from Goa to Antarctica (Daily Av.) during 8-31 Dec.95**

| Date | Lat. | Long. | Pressure (mb) | Temp.°C | | | | Wind | Cloud |
|---|---|---|---|---|---|---|---|---|---|
| | | | | D.B. | W.B. | Dew PT. | S.W. | Dir. Speed (Kts) | Okts |
| 08 | 07.4N | 068.5E | 1013.0 | 28.6 | 23.2 | 20.7 | 29.0 | 180/05 | - |
| 09 | 03.4N | 066.5E | 1011.6 | 27.4 | 23.5 | 21.7 | 29.0 | 136/03 | 1.0 |
| 10 | 01.0S | 063.9E | 1011.0 | 28.4 | 24.1 | 22.6 | 29.1 | 157/03 | 1.5 |
| 11 | 05.8S | 061.2E | 1011.5 | 28.5 | 25.3 | 23.8 | 29.0 | 200/09 | 2.0 |
| 12 | 10.4S | 058.5E | 1013.0 | 28.1 | 25.6 | 24.6 | 28.1 | 160/08 | 3.0 |
| 13 | 16.3S | 057.9E | 1014.6 | 23.3 | 23.1 | 20.2 | 28.0 | 130/09 | 2.0 |
| 14 | 20.1S | 057.4E | 1015.0 | 26.0 | 22.5 | 20.9 | 26.5 | 130/06 | 6.4 |
| 15 | 20.1S | 057.4E | 1015.6 | 25.2 | 21.9 | 21.5 | 25.8 | 130/05 | 7.6 |
| 16 | 20.1S | 057.4E | 1016.6 | 24.9 | 19.5 | 21.1 | 25.0 | 140/04 | 3.4 |
| 17 | 20.1S | 057.4E | 1016.0 | 27.6 | 22.9 | 20.9 | 25.5 | 197/03 | 3.4 |
| 18 | 20.1S | 057.4E | 1015.3 | 26.0 | 22.7 | 21.2 | 21.7 | 132/07 | 7.6 |
| 19 | 23.2S | 055.4E | 1014.0 | 25.7 | 23.1 | 22.1 | 25.9 | 202/06 | 2.2 |
| 20 | 27.6S | 052.6E | 1012.1 | 23.2 | 20.3 | 18.5 | 24.0 | 137/10 | 6.8 |
| 21 | 32.1S | 049.0E | 1009.4 | 20.3 | 16.7 | 14.4 | 21.8 | 180/06 | 5.6 |
| 22 | 36.7S | 046.5E | 1005.4 | 17.8 | 14.3 | 11.7 | 18.1 | 180/10 | 5.6 |
| 23 | 40.1S | 048.9E | 1016.3 | 14.9 | 11.2 | 07.4 | 15.5 | 188/17 | 7.8 |
| 24 | 44.3S | 040.7E | 1012.2 | 10.5 | 08.6 | 07.2 | 08.4 | 190/17 | 8.0 |
| 25 | 48.7S | 037.0E | 1022.0 | 09.5 | 09.3 | 06.3 | 03.6 | 222/16 | 8.0 |
| 26 | 52.2S | 032.1E | 1014.8 | 07.7 | 04.5 | 01.9 | 01.3 | 240/22 | 7.8 |
| 27 | 55.6S | 027.4E | 1000.4 | 04.9 | 03.0 | 01.2 | 01.4 | 296/19 | 8.0 |
| 28 | 58.6S | 020.9E | 1003.1 | 01.3 | 00.2 | 01.6 | 01.1 | 235/22 | 3.8 |
| 29 | 63.3S | 016.0E | 1002.6 | 01.5 | -0.2 | - | 01.4 | 262/17 | 6.9 |
| 30 | 67.9S | 013.4E | 987.5 | 04.0 | 02.9 | - | 01.0 | 295/14 | 8.0 |
| 31 | 69.9S | 012.6E | 987.5 | 02.5 | -0.3 | - | 03.0 | 090/09 | 8.0 |

As the ship moved into the Antarctic water, the sudden drop in the temperatures limited the outside access.

## Winds

For measurement of wind speed and its direction, ship's instrument was used. Upto 36 deg. S, the mild winds were recorded, thereafter till 56 deg, S winds picked up and with approach of Indian Barrier (Antarctica) winds came down. The expedition team was lucky not to face very strong winds during the voyage. The average wind remained to 10.6 kts.

## Ozonesonde Ascents

As mentioned earlier about 4 number of ozonesonde ascents were attempted during the voyage. Out of this one flight was completely successful and one was partly. The flight data in brief is given below:

| Date | Time (UTC) | Max.Level (mb) | Max.Ozone level(mb) | Max.Partial pressure (micro mb) |
|---|---|---|---|---|
| 11.12.95 | 1840 | 40.6 | 53.0 | — |
| 13.12.95 | 0807 | 74.7 | — | — |
| 18.12.95 | 1124 | 06.5 | 34.3 | 117.2 |
| 12.12.95 | 1441 | — | — | — |

## Acknowledgement

We would like to place our grateful thanks to Dr N. Sen Roy, Director General of Meteorology, India Meteorological Department for giving us an opportunity to participate in this scientific expedition to Antarctica. A large number of our colleagues in the Meteorological Department worked day and night for organising and getting the equipments ready in time. We express our gratitude to each of them.

To Dr S.D. Sharma, Leader of the Expedition, we are grateful for all the help and support given to us for carrying out our meteorological programme against heavy odds. All expedition members helped us with our programme and would particularly mention the whole hearted support we received from Hav. Raju Mohan of Indian Anny. We are also thankful to M/s. Yash (Bombay) and Upper-air Lab (New Delhi) for providing the computer facility for preparation of this report.

We would also like to express our sincere gratitude to Secretary, Department of Ocean Development for his encouragement and his sustained interest in our scientific work during Expedition.