Meteorological Studies at Antarctica

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ABSTRACT

Meteorological data was collected over the seas between India and Antarctica and over Antarctica itself At Antarctica a full fledged surface observatory was set up with remote recording facilities for atmospheric temperature windspeed and direction humidity global reflected and ultraviolet radiation and temperature of ice at different depth levels

INTRODUCTION

Extensive meteorological measurements were earned out during the Second Indian Scientific Expedition both from the ship during the voyage between Goa and Antarctica and from the Antarctica continent itself

MEASUREMENTS

From the Ship

(i) Three hourly measurements of temperature,pressure, humidity, windspeed and wind direc tion at the deck level

(ii) Continuous recording of surface ozone

(iii) Upper air measurements of temperature, humidity, windspeed and wind direction using radiosondes

From Antarctica

(i) Three hourly measurements of temperature, pressure, humidity, windspeed and wind direction from the ship

(ii) Continuous recording of windspeed, wind direction, humidity, air temperature, temperature under the ice surface and incoming, reflected and ultra-violet radiation

(iii) Continuous recording of surface ozone

(iv) Upper air soundings for temperature, ozone etc

INSTRUMENTATION

The entire instrumentation for the expedition was designed and developed by the India Meteorological Department Equipment used for various measurements are listed below -

(a) Temperature	Thermistor telethermometer
(b) Humidity	Humicap - semiconductor humidity sensor

(c) Windspeed	:	Cup generator anemometer
(d) Wind direction	:	Selsyn windvane
(e) Pressure	:	Aneroid barograph/precision aneroid barometer
(f) Upper air observations	:	(i) Radiosonde (ii) Ozonesonde
(g) Incoming and reflected radiation	:	Pyranometers
(h) Ultraviolet radiation	:	UV radiometer
(i) Surface ozone	:	Surface ozone measuring system.

In addition, the ship carried a facsimile equipment for reception of weather pictures from various countries.

RESULTS

Preliminary results from the analysis of the data collected are given below

Meteorological conditions over Antarctica during January-February, 1983

Continuous recordings of temperature, pressure, humidity, windspeed and wind direction were made from the base camp situated at 69^0S lat, 12 E long from 10 Jan to 20 February 1983 Instruments were installed in the open following standard exposure practices and connected by cables to the recorders kept in the tent nearly 30 metres away from the observatory

Temperature

The air temperatures were mostly subzero during our entire stay in the continent. The lowest temperature recorded was 15 C below zero and the highest was 8 C above zero

The average temperatures over Antarctica during January and February are depicted in Fig 1. It may be seen that the average diurnal variation is of the order of 7 C and from January to February there is a gradual decrease of about 2 to 3^0C for the average temperature at any time.

Pressure

Pressure during the entire expedition was recorded by aneroid barograph and cross checked with precision aneroid barometer. Average pressure for each day has been worked out and plotted in Fig .2.

It may be seen that over the oceans on an average, the atmospheric pressure is around 1012 mb (as expected) except over the oceans within 2000 km of Antarctica where the average pressure is around 1000 mb. During a storm which crossed near the track of the ship there was an abrupt fall of pressure by nearly 60 mb (drop, from 1030 to 970 mb) in 24 hours Over the Antarctica continent itself, the average pressure was of the order of 990 mb.

The lowest pressure recorded in the continent was during the blizzard when the pressure dropped from 985 to 970 mb.

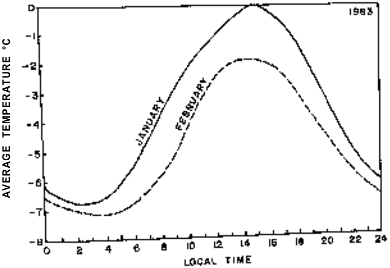

Fig.1. Average hourly temperature at Dakshin Gangotri(Base Camp)

Winds

Wind speeds and wind direction throughout the expedition were monitored using equipment installed in the ship as well as equipment installed at the base camp Average windspeed was worked out for each day and is presented in Fig 3.

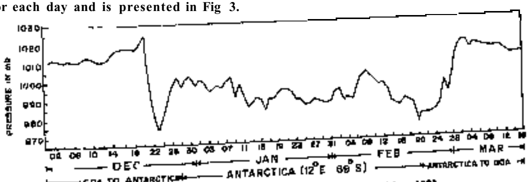

Fig 2 Average daily pressure from 1 Dec 1982 to 14 Mar 1983

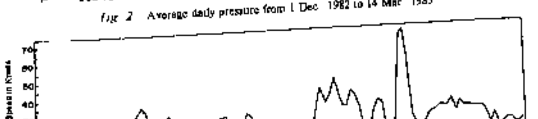

Fig 3 Daily maximum wind speed (knots) from 1 Dec 1982 to 18 Mar 1983

The salient points that emerge from the Fig 3 are (*i*) Average windspeed over oceans is about 25 kmph (*ii*). In the roaring forties the windspeeds increased to peak value of 60 kmph (*iii*). Over Antarctica the windspeeds were highly variable. Prolonged spells of light winds were interspersed with spells of high winds. During our 52 days stay in Antarctica there were 4 windy spells the peak windspeeds progressively increasing each time and touching gale speeds of 140 kmph dun ng 18 to 20 February 1983. It is also interesting to note that the highest windspeed the tents could withstand is of the order of 60 kmph. All our tents were uprooted one by one when the windspeed crossed this level. The highest windspeed we encountered was 140 kmph on 20th February 1983.

Wind directions were nearly steady throughout our stay in Antarctica and varied only between E and SE all the time.

ATMOSPHERIC SOUNDINGS

A large number of atmospheric soundings were carried out both from the ship is well is from the base camp in Antarctica for the measurement of temperature pressure humidity windspeed wind direction infra red radiative fluxes and ozone in the upper atmosphere Data is still under processing and scrutiny. Some data which has been processed is presented.

Upper air observations

Radiosonde ground equipment and omega sounding system were installed on board ship for monitoring temperature pressure humidity and winds in the upper atmosphere (upto 35 kms) and fine structure of lower layer of troposphere (upto 5 kms). Indigenous system was shifted from ship to base camp over Antarctica for carrying out atmospheric soundings.

Latitudinal variation of meteorological parameters in the troposphere. In all 29 Omegasonde ascents and 3 Radiosonde ascents were launched from the ship during the journey from Goa to Antarctica and return journey from Antarctica after staying at the continent for about 54 days. The analysed data of two typical soundings over tropic and polar region are plotted in Fig 4 for

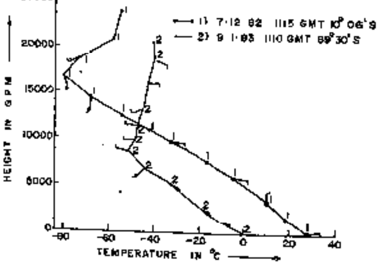

Fig. 4. Two omegasondes ascents depicting upper air winds in tropical and Antarctica region.

comparative study of the upper atmosphere at tropics and Antarctica. Some of the salient features of these soundings are as follows:

(*i*) The tropopause at Antarctica is at a much lower height (about 9 km) than the tropopause over tropical regions (about 16 km).

(*ii*) The tropopause at Antarctica is warmer (about -53^{0}C) than that over tropics (about - 80 C).

(*iii*) The temperature lapse rate in the atmosphere over tropics and Antarctica are almost equal.

(*iv*) The stratosphere at Antarctica has higher temperatures than the stratosphere over tropical regions. Also the lapse rate in stratosphere over tropics is more steep than that over Antarctica.

(*v*) No definite conclusion can be made by observing the winds in these two ascents but it is evident that no strong winds were observed in the troposphere at the time of these ascents.

(*vi*) In the Fig. 5 the heights of the freezing level at various latitudes as observed during the expedition have been plotted. The graph clearly depicts that the height of freezing level goes on decreasing from tropics to higher latitudes. Over Antarctica the temperature at the sealevel itself is subzero most of the times. This shows that along a particular level in the troposphere the atmosphere gets cooler with increasing latitude.

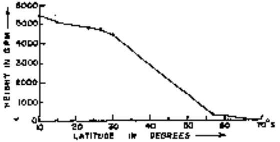

Fig 5 **Latitudinal variation of freezing level height**

Some typical characteristics of atmosphere over Antarctica : About 24 radiosonde ascents were launched from the base camp (one per day) after the prefabricated but was erected over the snow. These flights revealed data of atmosphere upto a maximum height of 31 km. Some of these flights are plotted in Fig. 6 showing height *versus* temperature distribution. Some sailent features of atmosphere over Antarctica observed from these soundings are as follow :

(*i*) Though the tropopause over Antarctica is thin compared to tropic, but it is very well pronounced.

(*ii*) Height of tropopause varied from 8 to 10 km.

(*iii*) The temperature lapse rate is almost constant in the troposphere (about 6°C/km).

(*iv*) The temperature lapse rate in the stratosphere varies

km) to a steep gradient (-5^{0}C/km).

Fine structure of lower troposphere over Antarctica: Eight low level sondes flights were launched for the study of diurnal variation of the temperature and humidity in the lower levels (upto 5 km) of

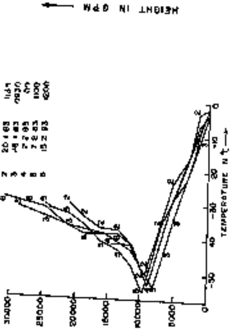

Fig 6 Radiosonde Ascents over Antarctica Base Camp

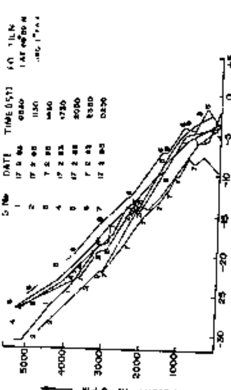

Fig 7 Low level sonde ascents over Antarctica Base Camp

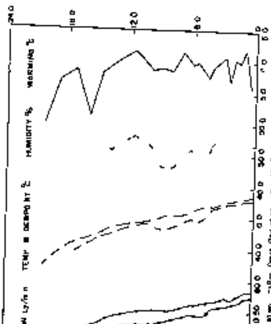

Fig 8 Antarctica 13 3 83 2045 hrs IST Clouds nil

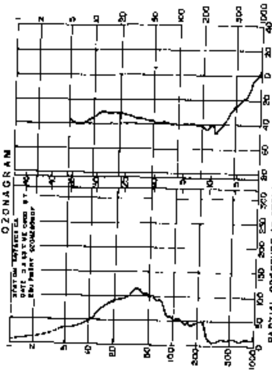

Fig 9 Ozonogram

atmosphere from the base camp at Antarctica at an interval of 3 hours. These nights have a very low rate of ascent (6 km/hr) for monitoring the fine variations in the temperature. Fig. 7 is a plot of temperature with height of 7 low level soundings. Some of the salient features of lower troposphere over Antarctica are as follow :

(*i*) Radiative inversions of about 300 m thickness were observed during the two ascents taken during night hours (2330 hrs and 0250 hrs).

(*ii*) In two flights taken around midday (1130 hrs and 1430 hrs) a thin layer of temperature in-version was observed at about 2 km above ground level.

(*iii*) In general the layer around 2 km showed variability in temperature lapse rate during the day as observed from sequential flights.

(*iv*) The temperature lapse rate had very small diurnal variation above 2.5 km.

Infra-red radiative flux over the oceans : Three soundings were taken with the IMD infra-red radiometers from the ship. The results from the soundings on 13.3.1983 are presented in Fig. 8.

Ozone measurements over Antarctica

Soundings for the vertical distribution of ozone and continuous monitoring of surface ozone were both attempted during the expedition, using standardised instruments developed in India. Interesting results have been obtained from both these measurements. The preliminary results are described below :

Vertical distribution of ozone : **Results of an ozone sounding for the vertical distribution of ozone from 70^0S, 12^0E on the Antarctic continent are depicted in Fig. 9. The profile is not adjusted for total ozone.**

Comparing with the vertical distribution of ozone over the tropics for the same period, a few features of the vertical distribution of ozone over Antarctica stand out:

(*i*) The highest ozone concentration over Antarctica is found around 20 to 22 km above ground as against the 27 to 28 km over tropics.

(*ii*) Lowest ozone concentrations in the Antarctic atmosphere occur at about 7.5 km above ground as against the 15 to 17 km over the tropics.

(*iii*) The highest ozone concentration over Antarctica is of the order of 10 g/g as against the 15 g/g over tropics.

Our experiments have proved the feasibility of launching the ozone sondes successfully from the Antarctic continent. These measurements may be attempted in a systematic way when our permanent camp in Antarctica is operational.

Surface ozone : **For the first time uninterrupted measurement of surface ozone was done over the seas and from the Antarctic continent using the IMD electrochemical surface ozone sensor. The results are depicted in Fig. 10. What is intriguing is that average level of surface ozone over the seas is about 30% less than what is reported in literature. In addition, it was observed that on approaching landmasses in the oceans like the Mauritian Islands, the ozone level increased by almost 75%above the general sea surface values. If these observations can be substantiated by further measurements, it is likely to lead to a re-estimation of the total daily ozone production over the globe.**

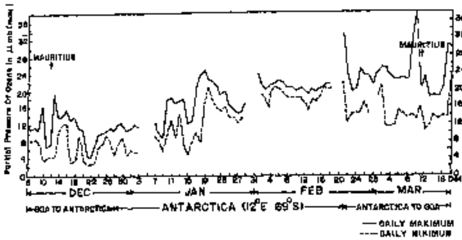

Fig. 10 **Surface ozone concentrations over oceans and over Antarctica (1982-1983)**

RADIATION

Global and reflected solar radiation were continuously recorded over the Antarctica using two separate thermo electric pyranometers installed 5 ft above the ice on two horizontal arms on a vertical support. The global ultraviolet radiation in the wavelength range 300 390 mm was also continuously recorded. The radiation measurements made during January and February are depicted in Fig 11.

Global radiation value on an average totalled 27 20 MJm ^{2} (megajoules per sq metre) in a day in January. The value reduced by 16% to 23 01 MJm ^{2} in February. The main cause of the higher value in January is the longer hours of sunshine and the higher zenith angle of the sun in January. The hourly values of global solar radiation register high in January when compared to February. The mean noon maximum is 2 36 MJm ^{2} in January. The February noon value is 2 15 MJm ^{2} being 9% less than that in January. The maximum was 35 70 MJm ^{2}, received on 12 January Even on an overcast sky with stratus cloud, the daily values in January totalled 17 26 MJm ^{2} mainly due to about 22 hours duration of the daytime.

Reflected solar radiation however, shows a different picture. With solar radiation being incident at a more oblique angle in February, the daily values are 15 95 MJm ^{2} as compared to 14 47 MJm of January, which is about 8% higher than the January value .This is due to the stronger reflection by the ice surface of the global radiation incident at a greater angle of incidence .A cloudless day of 30th January reflects 20 13 MJm ^{2} of the 28 64 MJm ^{2} of the incoming radiation giving the albedo for the whole day a value of 70%. This value is about 37% more than the mean value of1447MJm ^{2}. The overcast day of 16th January recorded 11 41MJm ^{2} which gives a value of albedo of 66%. The lowest recorded reflected radiation is 8 81 MJm ^{2} on 15th January giving an albedo value of 38°o only Although the mean value of February is higher than that of January the maximum recorded reflected radiation is 20 01 MJm on 3 February, which is 25%higher than the mean value The lowest value is however higher at 10 92 MJm ^{2} on 15th February, which is 31%lower than the mean value of 15 95 MJm.

The diurnal variation of the reflected radiation follows the global radiation pattern. The noon value recorded is 1.505 MJm ^{2} in an hour in January. The corresponding value for February was

1.474 MJm^{2}-both values having been recorded during 11-12 hours L.A.T. the change is only 3%as against the 9% difference in global radiation. This small difference can perhaps be explained to be due to the stronger reflection of the radiation from the ice due to the larger angle of incidence in February. The highest hourly value of reflected radiation is, however, 2.120 MJm^{-2} in January and 1.733 MJnr^{-2} in February. The highest hourly value in the case of global radiation is 3.041 MJm^{-2} in January and 2.791 MJm^{-2} in February.

Ultra-violet radiation

The mean value of global ultra-violet radiation is 1.99 MJm^{-2} for January. This forms 7.3%of the global radiation in the spectral range 290-400 mm. The highest value of daily ultra-violet is 2.304 MJm^{-2} on 12th January, which is 6.4% of global radiation. The ultra-violet radiation received on the clear day of 30 January is 1.883 MJm^{-2} which is 6.6% of the total global spectrum. Under an overcast sky with stratus clouds, the daily value was recorded as 1.685 MJm^{-2} which is 9.8%of global radiation. Thus these values are quite high compared to the maximum of 4% obtained at Pune.

The average hourly distribution of global ultra-violet radiation for February is depicted in Fig. 12. It is clearly seen that the ultra-violet intensity which is lower during the sunrise hours goes on increasing upto noon and then decreases following the global solar radiation pattern. The mean value around noon is 0.194 MJm^{-2} giving a value of 8.2%around 12-13 L.A.T. It is, however, 8.5% of global radiation between 11 and 12 hours L.A.T. with an absolute value of 0.197 MJm^{-2}. However, the variations are restricted and then lie between 5.4%at sunrise and sunset and 8.5% around noon. The maximum recorded value is 0.217 MJm^{-2} giving a percentage value of 8.1.

The ultra-violet radiometer was kept inverted in February to measure the reflected ultra-violet radiation which is 1.36 MJm^{-2} as compared to the reflected solar radiation of 15.95 MJm^{-2} in the total

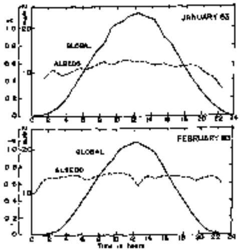

Fig. 11. **Diurnal variation of global radiation and albedo over Antarctica**

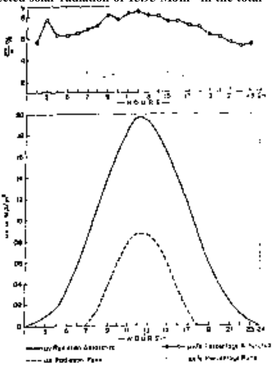

Fig 12 **Average hourly distribution of global ultra-violet radiation for February, 1983**

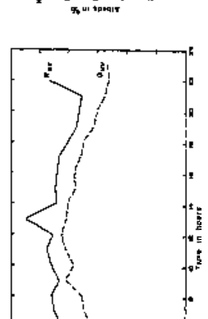

Fig 13 **Percentage variation of UV in global and reflected solar radiation**

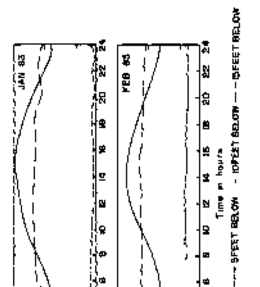

Fig 15 **Mean diurnal variation of temperature above and below ice**

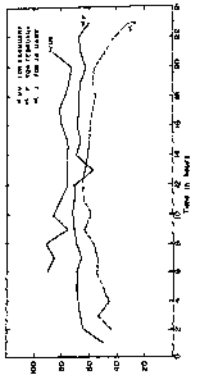

Fig 14 **Variation of mean albedo for solar radiation and UV radiation**

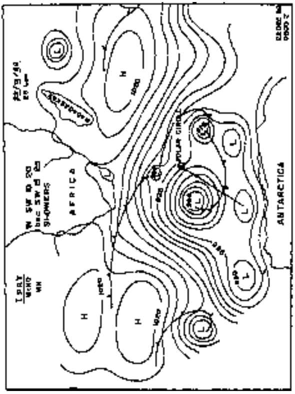

Fig 16 **Weather chart received from Pretoria on 22.12.1982**

global radiation spectrum. This gives a percentage of ultra-violet of 8.5 as against the value of 7.3 in the downward beams. The lowest total recorded is 1.02 MJm^{-2} which is 8.5% of the total reflected radiation. On the cloudless day of 16 February, the ultra-violet component was 8.1% in the total reflected radiation.

A study of hourly values reveals that like the total reflected spectrum, ultra-violet also is maximum around the noon. The mean value is 0.135 MJm^{-2}. The maximum individual value is 0.156 MJm^{-2} which is 9% of the total reflected solar radiation. The diurnal albedo variation of the ultra-violet percentage in the total reflected radiation shows a maximum around the noon (9.5%) and it is 7.1 to 7.7% at the time of sunrise and sunset (Fig. 13).

Albedo

The average value of albedo for January is 54% and it is 69% in February. The increase is to be expected as the incident beam makes more angle with the vertical in February than in January. The albedo on the clear day works out to be 70%. On an overcast sky with stratus cloud, it is only 66% With high Ci clouds, the value works out to be 35%. With higher zenith angle of the sun at any given time in February, the mean albedo has slightly increased to 73%under cloudless sky condition. Jt is 67% under overcast sky with stratus clouds. However, with 4 octas of AC cloud, the mean value slightly rises to 69%.

The diurnal variation of albedo over ice gives a completely different picture from what is observed over soil. Over the soil and even over the water surface, the albedo goes on decreasing as the angle of incidence increases. However, over the Antarctica ice surface, it was increasing with increasing solar altitude (Fig. 14). The change in the mean is about an increase of 47% from sunrise time to the noon in January. The change is, however, very much smaller in February, of the order of 10% only. This can be ascribed to the smaller variation in solar angles during the month. There is little variation in albedo under cloudless sky conditions, the hourly values lying between 67 and 72% Under overcast sky condition with stratus cloud, the value remains around 67 and 68% for most of the time of the day.

TEMPERATURE PROFILE UNDER ICE

Continuous temperature measurements were carried out with a chain of thermistor probes burried under the ice upto a depth of 15 feet below the surface for 35 days in January and February. Results are depicted in Fig. 15. It is interesting to note that at a depth of 15 feet below the surface the temperature was very nearly steady throughout the period between -11^0C to -12.5^0C.

In fact, the small temperature gradient between 10 and 15 feet disappeared during February and an isothermal layer appears to have set in from 10 to 15 feet. The sharpest gradient of about 2^0C/ft was observed between 10 and 15 feet below the surface.

FASCIMILE EQUIPMENT ON BOARD

The facsimile equipment on board the ship was of great help in monitoring the weather charts transmitted from neighbouring countries. New Delhi transmissions were received during the cruise when the ship was in the northern hemisphere. While in the southern hemisphere, Pretoria transmissions were the only ones that could be received properly. These weather charts were of great help in anticipating the weather conditions over the oceans ahead of us. A typical weather chart received from Pretoria on 22nd December 1982 is reproduced in Fig. 16.

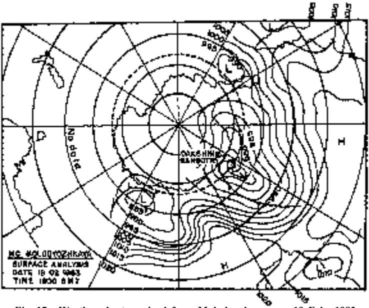

Fig 17 Weather chart received from Molodyozhnaya on 19 Feb. 1983

The position of the ship is marked in the picture. It can be clearly seen from the picture that *Polar Circle* was dangerously close to an intense storm. This and similar pictures helped us to make changes in the ship's heading and speed as and when required and thus avoid getting into a storm.

The reception of the fascimile broadcasts from Pretoria was very weak in Antarctica. However, Molodyozhnaya, the Russian station, was received on most occasions with reasonable strength. We were also able to receive the ice chart transmitted from Molodyozhnaya, on 11 December, 1982 while we were approaching Antarctica Ice charts are transmitted from Molodyozhnaya as a routine on the 1st, 11th and 21st of every month. This chart is prepared on the basis of satellite pictures received at Molodyozhnaya and gives very accurately the position and density of pack-ice in the oceans surrounding Antarctica While we were in Antarctica, the only transmissions received with reasonable strength was from Molodyozhnaya. One such typical weather chart received from Molodyozhnaya on 19 2 1983, when the base camp was hit by a blizzard with winds ranging upto 140 kmph, is reproduced in Fig 17.

The facsimile or APT is a must for every expedition to Antarctica to warn them about impending bad weather.

ACKNOWLEDGEMENTS

We would like to place on record our grateful thanks to the Director General of Meteorology for giving us an opportunity to participate in the expedition A large number of our colleagues in the Meteorological Department toiled day and night for organising the trip and getting the equipment ready in time. We express our gratitute to each one of them.

To Shri V.K. Raina Leader of the Expedition, we are grateful for all the help and support he gave us for carrying out our programme against heavy odds. Many members of the Expedition helped us with our programme. We would particularly mention the unstinted support we received from Dr Amitava Sengupta of NPL. We would also like to express our sincere gratitute to Dr S Z Qasim, Secretary to the Department of Ocean Development, for his encouragement and his sustained interest in our scientific work both during and after the expedition.